FISHING BOATS OF THE WORLD : 3

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Edited by

JAN-OLOF TRAUNG

The views expressed in this book are those
of the contributors

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Preface

ALL of us are keenly interested in the improvement, in every significant way, of the design and efficiency of small fishing vessels. Why, however, should FAO call such a meeting as the Third FAO Technical Meeting on Fishing Boats and why should so many, more than 300 men and women from 40 nations and from all quarters of the earth spend time and money in attending?

The Preamble of the Constitution of the Food and Agriculture Organization commits the Member Nations to take separate and collective actions to promote the common welfare for the purpose of:

- **raising levels of nutrition and standards of living of the peoples under their respective jurisdictions;**
- **securing improvements in the efficiency of the production and distribution of all food and agricultural products;**
- **bettering the condition of rural populations:**
- **and thus contributing toward an expanding world economy.**

These simple phrases make our duty clear. Technical information and experience data will help in our continuing and urgent duty to give technical assistance to the developing nations of the world. To such nations the seas and their resources are particularly important because they supply vital animal protein and because they are readily and easily accessible to all.

But FAO in any given field can only muster a very few experts. In addition to bringing together all of our own professional staff in this field, we had to augment their efforts with the services of other experts kindly loaned to us by other co-operating organizations.

Under these circumstances, we in FAO can act only as promotors and catalysers, as stimulators of action and a clearing house for information. The participants themselves represented by far the greatest potential for improving the design of fishing vessels. The meeting has brought forward experience and knowledge about new materials, new power plants, new instruments, new methods of designing hulls and equipment which will help all of us take a long step forward in the never-ending process of improving the tools through which we all improve our standard of living.

Through the years much attention has been given to the improvement of the design of small fishing vessels, but much remains to be done. In spite of the present emphasis on the large and highly-integrated distant water factory-type fishing vessels, 80 per cent of the world's catch of fish comes from grounds on or near the continental shelves. Such fishing grounds are readily and economically fished by small vessels based on adjacent shores. It cannot be said that there is necessarily any advantage in having to sail half-way around the world to reach a fishing ground and half-way back again to deliver the catch. This fact alone contributes greatly to the importance of the small fishing vessels.

We do not believe that we shall ever have a single set of standard designs for fishing vessels. The needs of the fisheries in different parts of the world are much too varied to make such standardization sensible. All designs, however, must be subject to continuous study and improvement in order that those living from the sea may progress as steadily as those living on the land.

To the Third FAO Technical Meeting on Fishing Boats came both Government delegates and independent naval architects, boatbuilders, etc., from many parts of the world. There was free and open discussion. In this volume there is a definite quantitative record as far as discussion presented to our one-week technical FAO meeting is concerned. The discussion and ideas are recorded and reported as they were made—even if condensations have had to be made.

The resulting book is not meant to be a text book of naval architecture. It, like its companions, *Fishing Boats of the World* and *Fishing Boats of the World: 2*, deals with that part of fishing boat design which is missing from text books on naval architecture, and it is so edited and presented that everyone

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concerned with designing and building more efficient and profitable fishing boats will find its illustrations and information of practical and economic value.

It has sometimes been the practice to limit the efficiency of individual fishing vessels in order to reduce the effectiveness of a fishing fleet and thus achieve conservation targets—for those this book is not intended. In fact, we must always remember that conservation and efficiency are not incompatible. We must not stifle technological progress in the name of conservation. Of course, the finite limits of size of all stocks of fish make it mandatory, sooner or later, that total fishing effort must be restricted. However, within these limits, it is equally mandatory that the efficiency of each fishing unit should be as high as possible. It is easier to restrict fishermen when fleets consist of efficient and profitable units than it is when the fleets are so large and inefficient that the very economic survival of the individual fisherman is at stake. Under such circumstances, it becomes politically most difficult to restrict the operations of any individual.

FAO was established 20 years ago with high purposes. These purposes are more important now and the problems hampering their achievement are more difficult, as world population increasingly outstrips the growth of food supplies. World fishing in recent years continues to be the only major source of food whose rate of gain in production is outstripping the rate of population growth. Although many national and international organizations carry out excellent fundamental work in fisheries research, conservation and development, we in FAO constitute the only truly international and world-accessible body in the field of fisheries. The most recent General Conference of FAO Member Nations, held in late 1965, decided to ensure that FAO in future years has the status of being the leading inter-governmental body in encouraging rational harvesting of food from the oceans and inland waters.

It established a high-level Committee on Fisheries selected on a world-wide basis to enable us to serve world fishery interests more capably and effectively in the future and to raise the Fisheries Division to Department status. We now hope to be able to offer more assistance to nations in carrying out their difficult tasks of increasing their harvests from the world ocean. At the same time we must help to meet the common and inescapable requirements of realistic, rational fishing and conservation of oceanic fish stocks. As we work towards these ends, we must always remember the special problems of the imbalance of food distribution which confront the developing nations as they strive to raise their standards of living and in particular their standards of adequate and proper nutrition.

Many of the nations most in need of more protein have abundant fish resources within a few miles of their own shores. What we learned and what we planned at the Boat meeting will, one day, result in more and better small fishing vessels. Those in turn can help fight hunger—our greatest problem in the years to come.

ROY I. JACKSON
Assistant Director-General (Fisheries)

Food and Agriculture Organization
Rome,
March, 1967.

Note from the Chairman

IT has only been a little over ten years since the publication of *Fishing Boats of the World* which followed the first FAO World Fishing Boat Congress. Most of us can remember the impact of that volume on technologists engaged in the operation or construction of fishing vessels. Almost overnight it became the bible of the industry and the indispensable reference work which was consulted first in the design stages of not only fishing vessels but small vessels of all kinds and types.

When its companion volume *Fishing Boats of the World: 2* appeared in 1960 reporting the papers and discussions that took place at the Second FAO World Fishing Boat Congress it took its place alongside the first volume as a major work of reference essential to all technical libraries concerned with the fishing and small vessel industry. It was no surprise, therefore, when over three hundred delegates from forty nations came from all corners of the world to attend the Third FAO World Fishing Boat Congress in Göteborg. Knowledge of the results of the two previous Congresses, and memories of the First Congress, had not prepared me, however, completely for what was to take place at this Congress.

There were four areas in which the Congress delighted me, and which I think deserve some comment.

The first area was the friendliness and courtesy to others shown by all of the delegates. In spite of the barriers of language and different customs there was true communication between the delegates. Everyone there had a common purpose which was to learn as much as they could about fishing vessels in areas other than their own and to pass on to anyone who wanted it any information they had which might be helpful to the other man.

It was communication at an international level at its very best, and the spirit was perhaps best illustrated by two young, able and educated delegates one from Pakistan, and the other from India. One evening at a reception I saw these two gentlemen come in arm in arm. With the Pakistan-Indian conflict over Kashmir hitting all the headlines of the world's presses, I said: "It doesn't appear to me that you are particularly disturbed or bothered about the actions of your respective countries". One of them replied: **"Governments make war; not individuals".**

The second thing that really amazed me was the quality of the comments, in spite of the fact that we had to cut and to limit the amount of time each individual could take. I opened the meeting and attempted to point up the need for brief and succint statements by telling the story of a native of the State of Vermont in my country. Vermont has long had a reputation, perhaps because of its northern location, rocky and forbidding terrain, and harsh winters, of breeding people who are extremely independent and very taciturn— particularly in conversation with strangers.

A group of lady tourists were travelling by car around Vermont one summer when they came to a small village which consisted primarily of a cross roads, a few scattered homes, a general store and post office on the corner. The ladies stopped their car, got out, and walked up on the porch of the country store exclaiming "How quaint!", "How charming!", etc. One of them spied an elderly man in overalls, wearing a straw hat, sitting in a chair on the corner of the porch whittling on a piece of wood with a knife. She went over to the old man and said: "Oh, you must be a native". "Tell me, have you lived here all your life?" He replied: "Not yet!"

While we didn't always get comments as brief and succint as that, we did get a large number of excellent comments and discussions condensed into very brief periods. In each day's session, which consisted of a three-hour meeting in the morning and three hours in the afternoon, we averaged throughout the conference over sixty speakers a day. Time after time the Chair had to cut off speakers who obviously had much more to say. One of the great values of this publication is that here there is room so that all of the pertinent comments of each man can be published.

The third area which was particularly evident to the man sitting in my chair was the efficient and skilful organization work that had been done by the FAO Secretariat. The months of preparation and the long hours put in by these gentlemen from FAO both before and during the meeting paid off. Only by their efforts was it possible to compress the summarization of technical papers and the comments of the delegates into five and one-half days of technical sessions.

The fourth and final area deserving specific mention was the quality of the work done by the Vice Chairmen/Rapporteurs. As Chairman, I owe these gentlemen a message of praise and thanks for their dedicated work in preparing the summary for the individual sessions and for their masterly conduct of these meetings. These men had been in close contact with the FAO Secretariat long before the meeting and received concurrently copies of the papers and the written contributions to the discussion. Of necessity they had to read and digest all of this to be able to prepare the 20 or 30 minute summary of the papers and discussion presented by people who could not attend. These summaries were all masterpieces, and only by virtue of their quality was it possible to keep the discussion on the subject at all times. It is unfortunate that, because these summaries only covered what was in the papers or written discussions, it is not practical to publish them in these proceedings. It should be remembered, however, by everyone reading the very full discussion herein that this was the result of the extremely able leadership of the Vice Chairmen/Rapporteurs.

In this book we now have the printed record of the Third FAO Fishing Boat Congress. I am confident that like its predecessors it will find an honoured position in the technical literature of the world.

G. C. NICKUM
Chairman

A. C. Hardy Memorial Lecture

Chairman of the first World Fishing Boat Congress held in Paris 1953 and duplicated in Miami in November of the same year, was Commander A. C. Hardy. He was chosen again to be Chairman of the Second Fishing Boat Congress held in Rome 1959.

On both occasions he made a profound impression on delegates by his diplomatic handling of the Congresses, his charm of manner and intense interest and enthusiasm for the improvement of fishing vessels.

Cecil Hardy

THE
A.C.HARDY
MEMORIAL
—
F.A.O
BOATS
CONGRESS

After a brief illness he died in 1961. His death was a definite loss to the fishing interests of the world because he was an outstanding enthusiast for the advancement of fishing activities in all areas as a major factor for the more efficient feeding of the world's growing populations.

Apart from his individual enthusiasm for the industry he brought high technical qualifications to the advancement of the industry. As a naval architect he was keenly interested in the better application of technical skills and scientific knowledge in the design of fishing craft.

In addition to acting as Chairman of the first two Congresses he made important technical contributions to both meetings and those are on record in the books Fishing Boats of the World: 1 and 2 covering proceedings of those Congresses.

Because of the services rendered by Commander Hardy in the initiation and successful conduct of those Congresses on fishing boats, a general desire was felt to perpetuate his memory by inaugurating a lecture on a subject of definite interest and value to the fishing industry, this to be given by a maritime journalist familiar with the problems so dear to the heart of Commander Hardy.

It was decided to ask Captain T. Rinman to deliver this lecture. He was chosen for three reasons; first he is of Swedish nationality and the third Boats Congress was held in Gothenburg with the Swedish Government as hosts; secondly he is a maritime journalist working for the journal *Swedish Shipping Gazette* (*Svensk Sjöfarts Tidning*); thirdly, he had been closely associated with Commander Hardy as an apprentice in his London office studying naval architecture.

As a memento of the occasion and a permanent tribute, a gold medal—pictured above was presented to Captain Rinman. The donors were two personal friends of the late Commander Hardy, Arthur J. Heighway, Fishing News (Books) Ltd. and Henri Kummerman of MacGregor-Comarain. In presenting the medal to Captain Rinman, Mr. Heighway recorded his appreciation of and admiration for the work done for fishing by Cecil Hardy, as he was popularly known to his friends.

While still in the engine-room, I would like to say something about rationalization and/or automation of the working procedures here. Fishermen have always been receptive to ideas that could help them to do more work with less manpower. The activity seen in the Merchant Navy during the 1960's to mechanize or automate various functions in the engine-room and at the same time ensure operational reliability have already shown good results. During the next ten years, a revolution is likely to take place in the operation of a modern commercial ship.

Perhaps to the fishing industry it does not seem a very important development that the crew of a mammoth tanker may be reduced by 70 per cent or even be eliminated, while the ship's 20,000 hp engines run unmanned in an engine-room which may be locked up for 16 hours a day. Of course this is of no immediate practical importance to a fisherman in a medium-sized boat. But what I am trying to say is that even these highly technical developments in the largest ships may provide hints or clues of possible developments which will someday be practical in the smaller fishing boats. Many items out of the wide range of fairly inexpensive monitors and supervisory instruments designed to suit the needs of the Merchant Navy could probably be used in the fishing industry for various purposes.

Hydrodynamic research and a scientific approach to ship design have led to important improvements. The encouragement given by FAO in this respect is particularly welcome. Since World War II, entirely new fishing boat hulls have been evolved in some parts of the world. In this, Great Britain is well ahead and employs computers and modern research methods. The Swedes, on the other hand, use 100 ft trawlers with underwater bodies suited for 250 to 450 hp and 7 to 9 knots, but they put 800 to 1,200 hp engines in them to gain another 3 to 5 knots. The same result could probably have been achieved with a 600 hp engine and a new underwater body which is just as seakindly and seaworthy as the old one.

Extensive research has given us faster cargo ships without increasing main engine power. We have got the bulbous bow, new rudders and new underwater lines in the Merchant Navy. We have got cheaper and more suitable hull designs.

The merchant ships of today are more efficient and less expensive than their predecessors. This means higher earning capacity. It seems rather odd that, with few exceptions, similar progress has not been made in fishing boat design. This is obviously a field where FAO has an important mission to fulfil.

There are other examples where the shipping industry and the fishing industry have similar problems and these examples are not always of a technical character. The change toward bigger ships and the increasingly keen competition has created in many parts of the world a need to introduce changes of business organization. New tax laws and the ever increasing need for capital are factors that if they do not dictate the type of business, they at least favour certain types of companies.

In conclusion, during the past dozen years more has been done in the shipping industry in some shipping nations than ever before to improve technical functions and earning capacity. I have touched on some general tendencies. More specifically, I feel that the fishing industry would also benefit from a close study of all the numerous items which cost between five and five hundred pounds which are used in engine-rooms and on deck aboard merchant vessels of different types.

Finally, I should like to stress the fact that, although I believe my general observations are relevant, in varying degree, to conditions in many parts of the world, specific examples mentioned mainly refer to the situation in this country (Sweden).

ADVERTISEMENT SECTION

AT the end of this volume appears an advertisement section. This is included because it is appreciated that practical, commercial information should be readily available for all interested parties concerning fishing vessels, fishing gear and equipment that can be procured from various sources for the betterment of fishing practices.

A list of advertisers arranged in major categories is as follows:

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PART 1

TECHNO-SOCIO-ECONOMIC BOAT PROBLEMS

The Influence of Social and Economic Factors on Technological Development in the Fishing Sector

by R. Hamlisch

Influence des facteurs sociaux et économiques sur le développement technologique de la pêche

La question se pose pour les dessinateurs et constructeurs de bateaux de pêche de savoir quel concours ils seront appelés à apporter à l'avenir. L'auteur répond à cette question en analysant la demande de bâtiments neufs ou perfectionnés, laquelle dépend elle-même des perspectives du marché pour les produits de la pêche.

Après avoir décrit, en citant quelques exemples, les circonstances ayant entraîné une expansion des pêches en divers points du globe, l'auteur étudie certains facteurs humains de production: attitude vis-à-vis du travail à bord, préférences en matière d'équipement, décisions relatives aux investissements, ainsi que l'influence des institutions et des pouvoirs publics sur le développement technologique.

Vient ensuite un exposé détaillé des conditions qui favorisent ou retardent l'évolution technologique du secteur halieutique. La dernière partie de la communication étudie principalement l'encouragement de l'expansion des pêches et la cadence du progrès technologique halieutique dans les pays en voie de développement.

La influencia de los factores económico-sociales sobre el desarrollo tecnológico en el sector pesquero

Los arquitectos y constructores navales dedicados a las embarcaciones pesqueras se interesan en las futuras necesidades para sus servicios. El autor expone esas necesidades en función de la demanda de embarcaciones nuevas y perfeccionadas, la cual depende a su vez de las perspectivas del mercado de productos pesqueros.

Partiendo de algunos ejemplos, describe las circunstancias que han conducido a la expansión de la pesca en varias partes del mundo y pasa después a exponer los factores de „insumo humano", en relación con la actitud adoptada ante el trabajo a bordo, con las preferencias por determinado equipo, las decisiones sobre inversión y los efectos de la acción de las instituciones y el Estado sobre el desarrollo tecnológico.

Sigue un examen más detallado de las condiciones favorables o retardatarias para la evolución tecnológica del sector pesquero. La última sección del trabajo se extiende en consideraciones sobre el fomento de la expansión de la pesca y el ritmo del progreso tecnológico en las pesquerías de los países en desarrollo.

The "market" for fishing boat architects and builders

TECHNOLOGICAL aspects, understandably, have occupied the foreground in the fishing boat congresses and other meetings concerned with fishing craft and gear organized under FAO auspices. Economic considerations came up in documentation or discussions usually only in context with construction costs, although one paper submitted to the First Fishing Boat Congress in 1953 also included a discussion of other factors affecting fishing vessel design (Beever, 1955).

The purpose of this paper is to look at factors other than those relating to technology and nature (i.e., fishery resources, oceanography, climate, etc.) through a wider lens. The fishing boat builder and architect have an interest in these factors, since they play an important part in determining future needs for their services.

The young man who is considering a career as fishing boat architect or builder wants to know something about the market for specialists in the profession since his earning capacity will depend not only on his professional competence but on supply and demand conditions in this market.

On the supply side, the number of competitors the prospective naval architect or boat builder has in his field will be limited by the availability of training facilities. More specifically, the number of naval architects and boat builders available for work on fishing boat design and construction will fluctuate with the oscillations in the market for fishing versus other craft.

The demand for boat builders and architects is a function of the demand for new and improved fishing craft and thus, ultimately, of the market for fishery products.

Dissemination of technological knowledge

Scientists and technologists often tend to discount the importance of demand factors. They feel that increased catches could be marketed without difficulty, as long as promotional activities are not altogether neglected. The real problem, in their estimation, is to produce enough fish to feed the rapidly expanding population of the world; the biggest obstacle is human ignorance and slowness of dissemination of technical knowledge. Lack of money and neglect of extension work is admitted to play a part (Traung, 1960).

Is this thesis valid? In 1946, some leading atomic scientists estimated that it would take the USSR a minimum of ten to fifteen years (after coming into possession of atomic secrets) to "solve technological and organizational problems" before it would be able to explode its first bomb. Other examples along this line could be cited. Scientific and technical news spread rapidly nowadays (thanks to the existence of a good technical press and the continuous expansion of mass-communication media) and the laboratory and engineer-

ing people are perhaps the world's most closely-knit group. Even administrators are not as unaware of technological development—nor as callous in considering the needs of progress—as they are made out to be by the more impatient members of the fraternity of scientists and technologists.

The danger of equating animal protein food requirements with effective demand for fishery products

It is a fallacy to believe that a worsening world food situation will translate itself automatically into increased effective demand for food or for fish, in particular. If nutritional needs were the only guiding criteria for fisheries development, many a developing country with only a small stretch of sea coast could be expected to emulate the USSR's and Japan's example in outfitting large scale factory ship operations to roam the oceans for fish. There is nothing so very secret about the technical aspects of these operations, and any country is free to participate in the exploitation of common property ocean resources. Some developing countries have shown considerable skill in obtaining finances from foreign sources for (not always strictly economic) large-scale development, and others might be similarly successful if sufficient motivation for developing fisheries existed.

Political boundaries, then, and differences between countries in regard to needs as well as resources available for production of fishery and other food products, make it impossible to project *world markets* on the basis of anticipated nutritional needs, calculated from population growth rates.

Extent and direction of development reflect specific local, physical and economic conditions. This holds also for the adoption of techniques. Similar fishing techniques are often being used, one observer notes, in areas which, until recently, lacked much contact in fishing matters, but where conditions otherwise resembled each other (Morgan, 1956).

A few examples of how major development has come about

Fishing and hunting are man's oldest occupations. As cultivation of agricultural land expanded, fishing survived mainly in areas where short summers, scarcity or poor quality of soil, and absence of communications to internal markets, gave it a comparative advantage over farming. Fisheries in these areas remained at the subsistence level until international trade opportunities enabled the fishermen of such countries as Norway, Iceland, Newfoundland, Alaska, and British Columbia to export their surplus fish (Morgan, 1956).

The advances made by some countries in fishery development in recent decades can, for the most part, be traced to specific factors in domestic or foreign markets or to changes in physical and financial resources available for fisheries operations. Similar explanations can be found for the decline of fisheries elsewhere.

Development in other sectors of the economy, under some circumstances, has stimulated development of fisheries and, under other circumstances, has made people leave the industry. The decline in the fishery of one country may contribute to the growth of a fishery in another country.

The fisheries of a country may go through cycles with marked ups and downs. Newfoundland's fisheries were its pre-eminent industry until the turn of the century when the economy began to diversify. The depression of the 1930's had a disastrous effect on fish prices. The industry was able to recover its one-time leading position during the Second World War but suffered a severe setback when Newfoundland united with Canada in 1949 and the United Kingdom market was lost. A moderate increase in the number of fishermen after 1956 was interpreted by some as a sign of reviving prosperity but, according to others, merely reflected a general lack of employment opportunities in the economy of the Province. The difficulties of the fisheries of Newfoundland have been blamed on developments in the foreign markets for its cod production and on the expansion of fishing operations of competing countries. In addition, technical retardation due to lack of financial backing and managerial enterprise are cited as causes (Copes, 1961).

Market factors played an important role in the sensational rise of Peruvian fisheries. Also, the lifting of government restrictions on the fishing of the anchoveta resources (protected until a few years ago for the sake of the guano industry) made it possible to supply fish meal to a rapidly growing feed compounding industry in North America and Western Europe.

South Africa was able to carve out for herself a good share of the fish meal market, among other reasons, because it had acquired a large part of the equipment utilized until the 1950's in the Pacific Coast pilchard industry, after the disappearance of the fish off the coast of California.

On occasion, development of a new type of fishery is at the expense of another, traditional, fishery which cannot compete on even terms, be it in respect of economic returns to the entrepreneur or in terms of attractions to the labour force. The introduction of deep sea cutters in Poland, thus, led to a geographic concentration of the sea fishery industry. The younger fishermen left the coastal fishing villages for work on the cutters where their earning prospects were considerably better (Ropelewski, 1962).

The countries with centrally planned economies favour fisheries over livestock development in their food production industries because a given quantity of annual protein can be produced from a smaller bundle of inputs. Market demand is being given growing consideration but the governments still reserve themselves the right to fix price relationships in accordance with overall policy criteria. The countries with centrally planned economies, therefore, may want to push development of large scale fishing to the point where marginal input productivity in fisheries is reduced to the level of marginal input productivity in agriculture.

In the non-socialist countries, price competition from meat and other animal protein products places limits on private investment. Development in the fishing sector of the economy, consequently, is not likely to be carried as far as in the centrally planned economies, even when public subsidies are provided by government (FAO/UN, 1965).

Developments in other sectors of the economy, which

characteristically have promoted fisheries expansion, are those related to the creation of new industries or markets. South-east Alaska and northern British Columbia benefited substantially as the result of the first great gold rush. The fishermen were no longer exclusively dependent on the canned salmon market; fresh and lightly salted products could be sold and new fisheries, such as those for halibut and herring, could be established (Bartz, 1942). Sales of dried fish for the rations of miners in the Congo Copperbelt provided much of the impetus to fishery development in the African lakes. More recently, the discovery of rich iron ore resources in Mauritania, and the construction of an ore port at Port Etienne, have had a part in stimulating interest in the establishment of a fishing port as an adjunct.

Growth in other sectors of industry will be detrimental to fisheries if it (a) creates alternative economic opportunities which are more attractive, or (b) threatens the resource and/or land base for fishing operations. Good road communications, and a consequent development of the tourist trade, for instance, were blamed for having almost killed off fisheries in many of the coastal cities of Oregon which at one time were exclusively dependent on the industry (Bartz, 1942). Industrial pollution and new uses of water for other than fishery purposes have been, for a long time already, among the greatest problems of inland fisheries. Lately, the same problems have been given growing attention also by marine biologists, as the result of off-shore oil and of atomic industry development.

Fisheries expansion has been indirectly stimulated by decline in another sector of the economy. This has been the case, for instance, in Chile, where the slump in the nitrate industry led to increased interest in the exploitation of fishery development possibilities.

FACTORS INFLUENCING DEVELOPMENT

Classification of factors

Classification of factors influencing development and technological progress has been attempted on various occasions (Netherlands Economic Institute, 1958; Traung (Ed.), 1960; Morgan, 1956). Most sources distinguish between "natural" and "human" influences, the former encompassing factors related to fishery resources, distances to grounds, climatic and nautical conditions, land features, etc.; the latter including market, labour, entrepreneurial, capital, technical, economic, institutional, and political factors. There is agreement that (1) the factors are often interdependent, e.g., the labour market influences technical change and vice-versa, and that (2) the separation between natural and human factors is to a large extent an artificial one. Provided motivation is strong enough, natural obstacles can be overcome. If market forces are sufficiently powerful, fishing centres are likely to come into being, notwithstanding unfavourable coastal conditions (Morgan, 1956). Similarly, the reaction to a worsening of fishing conditions may be a change to other fishing grounds, construction of sturdier craft, etc. If humanity is starving, farming the sea may become an economic necessity and may provide the answer to increasing depletion of marine food resources.

Discussion of "natural" factors does not come within the scope of this paper. In the following, the "human" factor will be considered both in terms of individual and collective behaviour, i.e., from the individual consumer or producer standpoint, and from the standpoint of the institutions man has created in the interest of organizing and controlling economic life. A distinction will be made between sociological, cultural, psychological, and economic elements motivating human action.

Demand factors

A wealth of literature on market research, including a certain amount of information on the general aspects of the demand for fishery products, is available. Here we want to point out only that the cultural, economic, and psychological factors influencing demand must be carefully investigated by the development planner and technologist. Income and price elasticities of demand express the response of the market to changes in type, quantity, and quality, of products offered for sale, and thus indirectly have an impact on type, number, cost, and utilization of craft and other equipment employed in fisheries. Traditional preferences for species and forms of preparation of fishery products, relative preferences (together with relative prices) of fishery versus substitute food products, religious attitudes, consumption taboos, similarly, have an impact on demand and, consequently also, on technology of production and distribution. All of these elements must be studied in relation to population trends, including changes in age, sex, and family composition, to gain a true understanding of market and technological development possibilities.

"Human" input factors

Sociological factors influencing production: Social and economic status of fishermen affects development and technology in a variety of ways, for example in respect to availability of labour, recruitment prospects for the future, attitude toward work, productivity of labour, etc.

In developing countries in all parts of the world, fishermen have the dubious distinction of ranking at the lower end of the social scale. An investigation of the causes of this phenomenon and of its impact on the labour market, development possibilities, and technological change in fisheries, could form the subject of a fascinating separate study. Poverty and economic inferiority with respect to other groups, as in India (Morgan, 1956), does not necessarily provide the explanation. The income of the Bozos and Somonos fishing the Delta of the Niger River is substantially higher than that of the farmers and cattle rangers in the area, yet they continue in a state of social inferiority, although economic improvement in recent years appears to have narrowed the gap that separates them from other tribal groups. The position of the Bozos is explained by the fact that they were pressed into quasi-serfdom by invading tribes who, because of the economic services the Bozos rendered as fishermen, did not destroy them. The Somonos, in contrast, are a lower caste of the Bambara people and take other, more lucrative, employment if the opportunity presents itself (Charbonnier and Cheminault, 1964).

Different ethnographic origin is an important factor in social discrimination. This is true whether the fishermen, as in the case of the Bozos, have been subjected by invaders or whether they themselves are the foreign element in an area, as in Hong Kong, where they are reported to differ from the rest of the population also in customs and education (Szczepanik (Ed.), 1960.)

In some cultures where, as in Burma for instance, strong religious feelings against the killing of animals exist, fishermen are despised because they take lives and are considered to be unscrupulous (Mead (Ed.) 1953). In Central Africa, fishing in Lake Chad is in some areas considered an occupation to be looked down on; conditions are so hazardous that no-one else wants to engage in fishing (La pêche au Tchad, 1965). On the other hand, willingness to accept hardships and risks spurned by old-time settlers accounts for the fact that new fisheries are often pioneered by immigrants. Development of fisheries on the Pacific Coast of North America has been credited, in a large part, to this circumstance (Bartz, 1942).

Many cultures traditionally despise manual labour. The warrior races of Africa find the discipline of industrial labour degrading (Mead (Ed.), 1953). In Korea, fisheries under the Yi Dynasty remained inactive because of the feudal tendency of despising fishermen and others engaged in manual labour (Korean Fisheries, 1962).

Cultural factors influencing producer attitudes: The individual's response to personal experience is determined in large part by the culture within which he lives. "Pain may appear as an injury, or an insult, or a challenge; one may learn to respond to rewards or punishments, or merely react with terror to unusual situations; to prefer death to dishonour or dishonour to inconvenience" (Mead (Ed.), 1953).

The most serious mistakes made by technical experts on their first contacts with producers in developing countries, result from their assumption that goal direction and reaction to stimuli are the same as those of producers in the countries from which they come. Desire for material possessions and economic independence, and other traits of the "homo economicus" are not always present, or not present in the same degree, as in developed countries (Spicer (Ed.), 1952). The fact that people do not have the same incentive to improve their standard of living affects their readiness to take on employment or to work on a steady basis. Fishermen may work solely to catch enough fish to feed the family. Money may be saved only to be "blown" on an elaborate ceremonial. If the producer has enough food or money for his immediate needs, he does not see why he has to return to his job (Mead (Ed.), 1953).

In some parts of India (and elsewhere in the Far East), where such ambitions for improvement as may exist tend to be thwarted by the quasi-serfdom position toward the middleman, fishermen are reported to "simply not care for more than three meals a day" (Szczepanik (Ed.), 1960). Fishermen in Madagascar are said to lack ambition. As long as this attitude toward work prevails, investment in fisheries must of necessity remain at a modest scale and introduction of new methods is not justified (Couvert, 1963).

In many parts of the world man adheres to the belief that his actions have no causal effect upon his future. A corollary of this fatalistic attitude is that man tries to adapt himself to what he finds rather than tries to change anything in his environment (Mead (Ed.), 1953). The feeling that "nothing can be done about it" or that "all is in the hands of God" reflects itself in curious ways. The faith he possesses, or the superstitions he adheres to, may make the fisherman accept hardships or dangers others would be inclined to shun. It may, in other cultures or other circumstances, deprive him of the incentive to extricate himself from danger. In some parts of Africa, a fisherman who is attacked by a crocodile will make no special effort to escape, nor will he be helped by his colleagues. Even in Western countries, fishermen often will not learn how to swim, or will not keep life-saving appliances aboard, if they believe, as is sometimes the case, that it is written in the stars whether they are destined to drown or not.

In Hong Kong, most of the fishermen believe that their gods or goddesses will protect them, bring them good fortune and lead them to the best fishing grounds. Instead of purchasing vessel insurance policies, they are reported to prefer "buying and burning incense to honour the gods and to worship the ancestors, and paper clothes to placate the evil spirits . . . (they believe that) they would meet disaster if they displayed any sign of lack of confidence in the protecting or destructive supernatural powers" (Szczepanik (Ed.), 1960).

Belief may influence peoples' attitude toward life at sea, the mode by which they choose to make a living. Orthodox Hindus may suffer loss of caste if they leave inshore or "green" waters for the darker waters of the deeper seas. This kind of outlook is thought to have had the effect, in past centuries, of retarding the evolution of Indian fisheries (Morgan, 1956).

In his study on the fish trade in the Northern Cameroon, Couty (1964) cites several authors who have written on the influence of religion and philosophy of life on entrepreneurship in developing countries. According to one of these sources, the fatalistic element in the Mohammedan religion, not to speak of specific commandments of the Koran, such as the prohibition against the charging of interest on loan, had held back the development of a dynamic business spirit among professors of this faith. Another authority is quoted explaining the low rate of capital formation in developing countries in terms of the business people's reliance on rapid gains from purchase and sale of merchandise and their reluctance to make long term investments for productive purposes. Couty believes that stagnation in fisheries and overcrowding in the trade sectors in Tropical Africa can, in some measure at least, be accounted for by the above factors.

Some cultures, such as the Burmese one, disparage the accumulation of capital. This, plus the tendency to spend much money for religious purposes, and the tenet that a Buddhist cannot make a valid will, prevent the creation of capital needed for industrial enterprises of major scope (Mead (Ed.), 1953).

The natural conservatism of fishermen and other primary producers is often only a reflection of the value which traditional life holds for them. This comes to the fore when attempts are made to introduce change without the assistance—or worse yet, against the will—of those in traditional authority. In many parts of Africa, thus, obedience to someone without traditional authority appears extremely difficult to enforce (Mead (Ed.), 1953). The head of the family, as among the Bozos and Somonos in the Niger Delta, attends to the needs of individual members and watches out, to the best of his ability, for the interests of the group. He pays the taxes, buys and distributes requisites and consumption goods, sells the catches, and gives guarantees to suppliers on loans for purchases of nets and sees to the repayment of these debts (Charbonnier and Cheminault, 1964).

Traditional authority sometimes has its source, as in the case of the Bozos, in long-inherited beliefs relating, for instance, to the establishment of fishing rights. In the Bozo cult, the river is thought to be the home of water spirits whose favours must be courted to ensure untroubled exploitation of the waters and a successful fishery. The Bozo tradition has it that their people have concluded an alliance with the water spirits. This authorizes them to live off the product of the fishery, provided they respect certain taboos and offer regular sacrifices. The fishery masters in the various fishing zones all take their authority from the first family head who had occupied a hitherto unfished zone and had concluded an alliance with the local water spirit (Daget, 1949).

Religion and traditional authority can be formidable obstacles to efforts to institute improvements. In some cultures, the violation of a taboo is among the worst of crimes, and the person in traditional authority decides what constitutes a violation and what not. Conversely, there is no easier way to succeed than by winning the co-operation of the family head, fishery master, or other local chieftain in the implementation of a project.

Working conditions, equipment preferences, and wage levels and the availability of labour: To compete successfully in the labour market an industry must aim "to improve safety, increase comfort, lessen human exertion, and pay better wages" (Soublin in Traung (Ed.), 1960). Technological improvement helps meeting these objectives. On the other hand, there are elements in the nature of the fisherman's profession which have a basic, essentially adverse, influence on labour supply. The work of the fisherman is hard and fatiguing. Hours of work or days off, as a rule, are not regulated. The fisherman has virtually no family life; he has limited opportunity to participate in community or political life. Accidents on board are frequent.

Irregularity and uncertainty of earnings, inadequate social security coverage of the profession, etc., are among the economic disincentives to entry into the fishing labour market. This labour market also reflects abundance or scarcity of alternative employment opportunities in the local area and density of population, in general. Distance of fishermen's settlements from port may mean additional travel and loss of already limited leisure time. It also limits opportunities for the

fishermen's sons to get to know life at the port and to acquire a liking for the fishing profession. This may be of importance for future recruitment, where a large portion of the young fishermen comes from traditional fishing families (Vanneste and Hovart, 1959).

Because of this, the attitude of parent fishermen on the professional choice of their sons must be studied. Ceylonese fishermen, at least those at a higher level of literacy, are discouraging their sons from choosing fishing as an occupation, warning them of the hazards inherent in the work, and the consequent vicious circle of low incomes, constant indebtedness, and physical and economic distress for the families. The children appear to heed the parents' advice, and are deciding against following the profession of their fathers also because of its low social status (De Silva, 1964).

In many instances, mobility out of fisheries is restricted by lack of education and of knowledge of alternative opportunities as well as by the basic conservatism of fishermen. Many fishermen show extraordinary tenacity before they stop trying to wrest a living from depleted or unprofitable fisheries (Beever, 1955). As development progresses, and new opportunities arise, both in fisheries —as the result of industrialization of fishing operations and concentration of fishing centres—and in other sectors, marginal producers may stubbornly continue to seek employment where they have always lived, in small scale operations (such as inshore shell-fishing, for which the disadvantage of their ports is not so great) or by developing additional sources of income, e.g. from tourism (Morgan, 1956).

Willingness to make sacrifices, in regard to working conditions and wages, differs substantially between fishermen of different countries, and areas within countries according to alternative economic opportunities. In the Greek Islands, there is a centuries-old pattern of men going to sea as fishermen and staying away from their homes for many months. This parallels characteristic emigration patterns, where the men wait until they have saved up enough money in the new country to have their families follow them (Mead (Ed.), 1953). In the United States, differing economic opportunities in various sectors are probably reflected by the lower average age of fishermen making trips of shorter duration than of those having to stay at sea for longer periods (Alverson in Traung (Ed.), 1960).

The question of the availability of crews for trips of extended duration plays a prominent part in all plans for large scale factory ship operations. In the United Kingdom, it was thought that, while it might not be difficult to find crews for two or three factory ships staying at sea for three months or longer, plans for a large expansion might very well be defeated by the inelasticity of the domestic labour supply for operations of this type (Report of the Committee . . . , 1961).

Reluctance to take a berth on a boat making trips of several months' duration may, to some extent, be overcome by the lure of high earnings and by making life on board more palatable, e.g. through "labour easing", increasing crew comfort, improving leisure time utilization.

In this connection, characteristic likes and dislikes of

crews in regard to arrangements on board require study. At the Second Fishing Boat Congress a plea was made for providing better shelter to make life easier on board and to increase efficiency, since the crews tired less and worked better in sheltered space than when wet and cold (Kristjonsson in Traung (Ed.), 1960). Dislike of living forward, doubts about the safety of working on wide exposed aft decks, were other "crew factors" of influence on layout on board mentioned at the Congress (Tyrrell in Traung (Ed.), 1960).

Other labour availability factors:

Tradition, climate, and other factors, however, have a bearing on fishermen's attitudes toward craft and gear, and generalizations are of little value in this sphere. At the First Fishing Boat Congress, for example, fishermen in the Bombay area were reported to be prejudiced against fishing from decks and as preferring open decks (Setna, 1955). Also, the extent to which demands for increased safety and comfort can be met is determined by economic considerations. Fishing vessels that are 100 per cent safe, thus, are difficult to design because of the commercial requirements of the owners. Especially on small vessels, increased safety has to be attained by improved seamanship (Tsuchiya in Traung (Ed.), 1960). Technological compromises are necessary, where improvement in some sphere is possible only at the expense of sacrifice in another: more shelter while working, thus, may mean poorer quality of sleeping accommodation, with the quarters located in the foreship rather than aft (De Wit in Traung (Ed.), 1960).

In some developing countries, the fishing boat is not only a workshop but also the home of the fisherman. In Hong Kong, about 95 per cent of the fishing households are living on boats owned by them and only 5 per cent in rented houses or partly in rented houses and partly on boats (Szczepanik (Ed.), 1960). Patterns of this type must not be ignored by the promoters of technological development.

Where different tribes or racial groups fish side by side, peculiar craft and gear preferences are often observed. In Malaysia, the Malay fishermen use long and narrow boats with a shallow keel especially designed for speed and day fishing, whereas the Chinese rely on heavier and deeper boats that can stay out at sea for several days or weeks. Economic reasons and deep-rooted traditional beliefs are cited as reasons for these preferences (IPFC/FAO, 1961).

The Bozos and Somonos in the Niger Delta each have pronounced gear preferences which are related to the fishing places they frequent, the Bozos traditionally fishing in marshy areas, the Somonos in the main bed of the river (Charbonnier and Cheminault, 1964).

Pronounced equipment preferences are often explained by prestige factors, vanity of the owners, and similar elements. A bigger boat than necessary is often operated to impress others. Many fishermen want higher powered engines than are normally recommended by naval architects and marine engineers. Reaching the fishing grounds early and bringing the catch to the market before the other fishermen may at times raise earnings more than fuel costs but, in other instances, excessive

powering may merely be explainable in terms of psychological factors (Proskie and Nutku in Traung (Ed.), 1960). Distrust of mechanical power, equally, may lead to a pattern of operations not justifiable in economic terms. Not so long ago, some Maltese fishermen were reported to have had two or more engines installed on their boats for fear of engine failure at sea. With increased experience in repair and maintenance this practice was expected to disappear (Burdon, 1956).

Labour quality factors: Labour quality, as reflected by physical strength and skills, may have an important bearing on minimum size of crew for certain vessels and on the type of equipment that can be installed on board. Wide variations between regions and groups of fishermen exist. Training is expensive. Economically speaking, skill represents capital invested in labour. Fisheries requiring a high level of skill, consequently, tend to be capital-intensive. If skills are low, installations on board have to be simple (Netherlands Economic Institute, 1958). The better quality skippers and crews are said to seek employment on the better and newer boats. As fishing fleets are modernized in increasing measure, the advantage the newer boats derive, as a result of this tendency, diminishes (Report of the Committee . . . . , 1961).

Managerial quality has an even larger impact than labour quality on possibilities of realizing development opportunities. In many developing countries, entrepreneurial talent is at a premium. Skipper-ownership of vessels may stimulate better management. This may partially account for reluctance on the part of the processors to integrate backward into fishing (Netherlands Economic Institute, 1958).

Economic considerations influencing entrepreneurial decisions:

The influence of cultural and psychological factors on development and technology declines, and that of economic factors increases, as high levels of organization are attained. The economic objective of the individual firm is attained by maximizing profits, i.e. by maximizing the difference between total earnings and total costs.

Profits are affected by the following four variables: physical inputs, prices of inputs, physical outputs, and prices of outputs. Where fishing is carried out predominantly by many small producers, the individual entrepreneurs must accept input and output prices more or less as given. Strategic buying of inputs can result in some cost savings. Unless opportunities to preserve and store catches on board and on land exist, however, an inventory policy to take advantage of peaks in product prices is not possible.

For vertically integrated fishery companies, the situation is different in this respect since they are in a position to pursue a strategic inventory policy. Also, since they are interested in the overall profit from operations, they are prepared to carry along departments which do not make any or, in some instances, even lose money, provided that these departments support, in the long run, other, profit-making, activities. Some of the trawling companies in the United Kingdom, for example, which

have interests in related businesses appear to make rather substantial profits on the processing, wholesaling and retailing of fish. These companies are believed to derive sufficient advantage in continuing ownership and maintenance of their own fleets, to compensate for the losses sustained by the fishing vessels alone (Report of the Committee . . . , 1961).

The large integrated company also has other advantages in the market such as, for instance, the possibility of obtaining a higher price for products sold under its own brand.

Disregarding the specific situation of the large integrated enterprise, let us see how the independent fishing enterprise tries to attain its twin objectives of increasing value of output for a given cost of inputs and of reducing cost of inputs for a given value of output.

The first objective calls for orienting production and disposal policies toward reaping maximum benefits from market opportunities. This means, first of all, that the entrepreneur has to use the equipment and crews he has available for operations in such a manner as to bring the most valuable species (he can take) to the best-paying markets (he can reach), in such quantities, and in such relative proportions, as to maximize receipts. His success, aside from resource factors, depends on the skill with which he manages his inputs (entrepreneurial skill, the choice he makes of techniques within the limits of the range permitted by the equipment at his disposal). It also hinges on the knowledge he has of market conditions at the different landings at which his vessels are in a position to call.

Reducing input costs for a given product value presents different problems. The entrepreneur looks for the best possible bargain he can obtain as regards cost and quality of inputs. He also seeks to minimize the quantity of each input required for producing a given level of output. Finally, he tries to adjust input ratios so as to save on scarce and more costly items within the scope set by conditions of a technical nature (in fishing, this scope may often be rather small, since resource, oceanographic, and other conditions may make a certain type of fishing unit mandatory). If, for example, the capital-labour cost ratio is low, labour is relatively more expensive and the emphasis will be on labour saving; if high, there will be an effort to save capital (Netherlands Economic Institute, 1958).

Labour inputs:

Total labour force in the area, alternative employment possibilities, wage levels, skill levels, availability and cost of labour-saving capital, general economic conditions and conditions in the fishing industry, as well as expectations regarding future trends in these variables, all influence entrepreneurial decisions on labour inputs. These decisions are among the most important the entrepreneur has to make, since labour costs are, as a rule, the biggest cost item in fish production. The need to save on labour cost may, in turn, have technological implications and, among other things, may influence fishing vessel design.

Where labour is plentiful and cheap, installation of costly labour-saving devices would tend to reduce the profits of the enterprise, unless the excess of the expense on equipment over the saving in labour costs is more than compensated by receipts from increased production. Labour intensive operations appear uneconomic where the resource situation militates against their employment. In Japan, labour-intensive beach seining operations are still common in the fishing household sector of the industry; in heavily fished areas where the density of reasonably-sized fish in inshore waters is low, it has been pointed out, the technique may become uneconomic (Morgan, 1956).

Reduced crew needs have been cited among the advantages of small stern-trawlers in a study recently carried out at Aberdeen. Another advantage cited in favour of these craft is that, because of their light tonnage, they do not require certified skippers to take them to sea (Fish Trades Gazette, 1965). Aside from technical considerations, craft and equipment that require smaller crews are favoured in situations where the labour supply factor has become critical.

More highly skilled and trained staff —such as certified skippers— are, of course, harder to find and demand higher compensation, increasing the economic problems of the enterprise if earnings do not increase at least proportionately. Employment of sub-standard quality labour also has unfavourable consequences on economic results. In a report on the economy of the Province, progress in the Newfoundland industry was considered not just a matter of technological improvement but also of raising productivity within the scope of existing equipment. The backwardness of operations was blamed, in large measure, on human inefficiency (Copes, 1961).

In many countries of the world, fishing labour is increasingly in short supply. This is true even in Japan, where crew problems, because of the scarcity of alternative employment opportunities for the large supply of fishing labour until not so long ago, were virtually non-existent. Recently it was reported that some of the larger boats were unable to leave port because of inability to hire crews. Even small boats, it is said, are beginning to find it indispensable to mechanize to avoid crewing difficulties (IPFC/FAO, 1964). Rising wage costs often reflect growing crew shortages and, similarly, encourage the introduction of labour-saving devices.

Labour scarcity may have an impact on capital costs also in another direction: the premium to induce labour to accept employment on boats may have to be paid in terms of costlier installations on board, to meet a demand for increased crew comforts. The shortage of crews for longliners, which has developed in recent years in Hong Kong, thus, has produced a situation, where crews are reluctant to hire out on vessels which do not possess power-handled gear (IPFC/FAO, 1963).

Capital inputs:

Within the framework imposed by existing natural, technological, and political conditions, the entrepreneur tries to save on capital input costs by buying the minimum necessary quantities of serviceable equipment at the most advantageous prices. Cost comparisons between otherwise equally satisfactory items must be made on the basis of total cost over the service life of the items rather than

on the basis of original outlay only. This requires the capitalizing of expected operating costs which must be added to original investment. Assessing the relative advantages of aluminium versus steel funnels under existing price conditions in his country, one expert found some years ago that, while the initial investment was higher for aluminium funnels, the latter were substantially less expensive in the long run because of their longer service life and lower maintenance costs (Goldsworthy, 1955).

Every major investment requires a careful cost analysis to ensure that payment calculations will not be far off the mark. To assess economic results of freezing fish at sea, thus, it has been suggested that the following be considered in addition to the costs associated with the handling of iced fish:

- factors affecting vessel costs
- extra personnel required to operate freezing equipment
- additional cost of vessel due to freezing equipment and additional space required for storing frozen fish
- repairs and maintenance of freezing equipment
- insurance for freezing equipment
- depreciation of freezing equipment
- fuel for operation of freezer
- additional equipment and labour required for unloading the frozen fish (Slavin, 1960)

A proposed change from one material to another, e.g. from wood to plastic, must be studied from the standpoint of its potential effect on marine insurance premiums (MacCallum in Traung (Ed.), 1960). In the introduction of electro-fishing, savings in gear costs must be measured against increased power and fuel costs (Morgan, 1956).

Initial cost must be considered in relation to existing level of purchasing power and financing opportunities. Running costs should largely be defrayed from earnings. In introducing better thermally insulated fishholds in Hong Kong, a craft technician in 1963 was reported to have made recommendations providing the greatest possible increase in thermal efficiency at the lowest cost compatible with conditions in the fishery, which were characterized by the low economic resources of the fisherfolk. The conservative attitude of the fishermen in the Crown Colony also was said to account for the fact that few of them were prepared to pay even a small premium for better material and more advanced workmanship (IPFC/FAO, 1964). Desire for a quick turnover constitutes another reason for unwillingness to make a bigger initial investment. Malaysian boat owners are reluctant on this account to pay more for better engines. Engines for new craft are mostly improvised units of industrial types which are modified by local foundries (IPFC/FAO, 1964).

Lack of materials and facilities for manufacture of boats and other equipment in a country may be a serious handicap to fisheries development. Shortages of boat lumber, engine parts, sail canvas, nets, manila rope, fuel and lubricating oils are among the major problems of the industry in the Republic of Korea (IPFC/FAO,

1961). Where foreign exchange is scarce, or where severe import restrictions are imposed, such difficulties are exacerbated. The cost of imported equipment may not only come higher because of the initial outlay which may have to cover additional expenses for import duties, customs clearance, transport, etc., but also because of the frequent necessity to carry larger stocks of spares to prevent disruptions in operations due to long delivery periods (Netherlands Economic Institute, 1958).

Compared with other countries in the Indo-Pacific Region engines are cheaper in countries where no or very low import duties are imposed, e.g. in Hong Kong and Singapore. In general, it was found that choice of an engine did not depend so much on its performance—the primary considerations being availability, price, previous experience with any particular engine and the country's import-export trade relations. Availability of spare parts, and repair and maintenance services was secondary in the selection of engines, particularly in the countries where mechanization of fishing craft was of recent introduction and where aid-giving agencies supplied such engines.

Prices paid for boats and other equipment depend, to a large extent, on competition in the markets for capital inputs and on cost savings that can be effected in the boatyards and other manufacturing facilities. In Hong Kong, prices of diesel engines and spare parts as well as fuel and lubricating oils are considered reasonable because these markets are highly competitive (IPFC Inter-Session Report). Cost reductions in the boatyards are sought, for instance, through use of cheaper wood (India), elimination of timber waste (Thailand), use of power tools to reduce labour (Malaysia). Improved techniques may help to realize additional immediate cost savings, or to raise quality of the final product and, thus, lengthen service life and lower costs in the long run (Hong Kong, Japan).

Standardization in boat design and construction and layout on board are among the most important contributions the technologist can make toward the cost reduction objective. Economies effected in this manner may be shared by the yards with the buyer who may have to pay less on acquisition, and may benefit also as the result of savings in labour cost through increased efficiency of operations. One expert estimates that the cost of each of two identical vessels may be only 90 per cent of the cost of a single boat. If the number of repetitions reaches eight or ten, the unit cost should level out at about 80 per cent of the single contract cost (Benford and Kossa, 1960).

Labour efficiency is enhanced through standardization on board, in particular where there is a high turnover of crews, as on trawlers in the United States. If all gear and machinery are in the same places on different vessels, changing berth presents no problem of adjustment to work on another vessel (Ringhaver, 1960). Even without standardization, use of mass production methods, by itself already, has a cost-lowering impact.

External economies deriving from the size of the fleet in a port also may result in cost savings to the boat owner.

A large fleet makes it economic to store supplies and spare parts in quantity and, thus, reduce costs per unit. Large operations also carry with themselves a momentum for further development, attracting new related industries and stimulating erection of necessary shore facilities (Netherlands Economic Institute, 1958).

Running, repair, and maintenance costs, similar to capital equipment costs, are related to availability and price of fuel, spare parts, and other supplies; experience and skill of labour; shore facilities, etc. Availability may have played an important part in locating certain industries. According to one source, the advent of steam power for fishing vessels tended to favour the development, in the United Kingdom, of ports near coalfields. The higher price of coal fuel in the southern English fishing ports was an important factor retarding the conversion of operations to power (Morgan, 1956).

Another source refers to the influence of regional differences in relative prices of coal, oil, and petrol on the complexion of the industry in some countries. In 1952, thus, the relative prices of fuels in Germany were such that the operation of steam trawlers (coal) was cheaper than that of diesel-trawlers. The same was true for the United Kingdom. In the Netherlands and France, the reverse was true (Netherlands Economic Institute, 1958).

Fuel costs may be so high that sails are still the cheapest method of propulsion. In some areas of North America costs and scarcity of spare parts and fuel made some experts think, not so long ago, that the improvement of sails would do more to lower costs than motorization (Chapelle, 1955).

Before leaving the subject of fixed capital and working capital costs, a word must be said about capital consumption and money capital costs. The latter are represented by the prevailing rate of interest at which the entrepreneur can borrow or which he must consider in assessing alternative employment opportunities of his money capital. Capital consumption costs must be considered as given, where governments stipulate depreciation methods, rates and periods. In the economic sense, capital consumption is affected by the care, or lack of care, exercised in handling equipment and by the rate of obsolescence (the pace of technological progress in the industry).

Entrepreneurship and financing opportunities:

Again and again, slow progress in fisheries is blamed on poor financing opportunities or lack of entrepreneurship. The backwardness of the bulk of Japanese fisheries before the last war was attributed to a shortage of capital rather than to lack of enterprise or technical know-how (Morgan, 1956). As a rule, the three phenomena, backwardness, lack of entrepreneurship, and inability to obtain financing, are closely inter-dependent. It may be just because fisheries are poorly developed that they find it difficult to obtain financing at reasonable cost and/or to attract imaginative entrepreneurs. The bigger, more highly developed ports find it much easier than the small ones to meet capital and manpower needs. They have a higher degree of organization, a greater reputation, and a greater industrial and social capital on which to base new

enterprises (Morgan, 1956). In the United States, the favourable post-war profit history of shrimp trawlers has been cited as a major reason for the ease—compared to other fishing craft—of borrowing funds for their purchase from financial institutions (Chapelle, 1955).

The risk element, which, because of the vagaries of nature, is perhaps greater in fisheries than in many other industries, adds to the problems of securing adequate financial help and management talent. To some, though, the gambling opportunity is an attraction rather than a deterrent. Side by side with marginal elements one finds, therefore, some of the most courageous investors in fisheries (Beever, 1955). In a large part of the world, however, the most important limiting factor is on the management side. Provision of financing, donations of capital equipment, etc., may be of no avail, and may now and then even hasten the ruin of operations which have been carried on so far on a scale proportioned to existing management potentialities. Typical results that can be expected when financing is expanded beyond existing absorption capacity are described in a report on a loan programme instituted a few years ago in a country in Central Africa:

> "In a good many cases the acquisition of a loan and the opportunity to increase the scale of operations has led not to the expansion of a business but to its collapse. . . .
> ". . . too often the case of failure is mismanagement. In general the lesson is still to be learned that the keys to success are personal attention to the detail of fishing operations by the owner of the business; the setting aside, in periods of affluence, of money to provide for the eventual replacement of worn gear; and contentment with modest profits on individual sales so long as those sales are quick and repeated" (Report of the Department . . . , 1962).

Success in the fishing sector is closely linked to sound planning and management in the secondary and tertiary sectors. If facilities, entrepreneurship, organization, and financing in processing and distribution is inadequate, fishing is bound to suffer, since markets are insufficiently exploited. Similarly, if the fishermen are not aware of existing limitations in the economic disposal of their catches, their investments may turn out to be "misinvestments", i.e. capacity installed may be too large or of the wrong type (Netherlands Economic Institute, 1958).

Institutional factors:

With the progressive development of fisheries, independent, owner-skippered operations decline in relative importance. Only big companies have the necessary capital for the larger, and more expensively equipped ships and the ancillary organization that are likely to be needed for deep sea fishing operations, for instance with mother ships and attendant catching and carrying vessels (Report of the Committee . . . , 1961). As the scale of operations increases, there is a tendency not only toward integration at the company level but also institutional arrangements relating to the activities

of groups of operators or all fishermen become more frequent. Such arrangements are arrived at by agreement among the operators themselves or under the aegis of public bodies.

By its nature, one observer writes, fishing must be carried on by small groups of men, and personal relationships cannot be submerged to the extent that they are in most modern industries. Notwithstanding his strong sense of belonging to a group, however, the fisherman's individualistic character has made him very much slower to acknowledge this by entering into formal organization (Morgan, 1956).

The problems of promoting co-operative activities are quite different in developing countries from what they are in developed countries. In the latter, co-operation refers usually to a group created to satisfy the needs of the individual members at some future time. In the developing countries, co-operative units, in contrast, derive their origin in the past. "Here an individual is born into a family, a village, a church group and when he acts for the welfare of the unit he is often merely filling his prescribed role. The co-operation is incidental" (Mead (Ed.), 1953). This difference in the roots of co-operative endeavour accounts for the conservatism and resistance to change often characteristic of commercial patterns in the less developed areas of the world.

Lack of immediately apparent evidence of the economic benefits resulting from co-operative membership has been considered the main obstacle to a faster spread of the movement, among other countries, in Hong Kong (Szczepanik (Ed.), 1960). Elsewhere, co-operative organization has contributed toward creating the means for the acquisition and operation of improved facilities, has enabled fishermen to present their case more effectively before public authorities, and has strengthened their bargaining position vis-à-vis the trade sector (Netherlands Economic Institute, 1958).

Financing for development is facilitated by establishment of co-operatives, not only because of the opportunity it affords of pooling the resources of the members but also by the circumstance that public bodies often prefer to channel their aid to fishermen via co-operatives. The opportunity to obtain such financing through co-operative membership frequently constitutes a strong incentive for joining such organizations. Conversely, where distribution of loans through co-operative channels is abandoned, fishermen's societies have at times collapsed (Szczepanik (Ed.), 1960).

Organization at the distribution end, too, has very often been of great influence on development in the fishing sector. Financial dependence on the middleman in the Far East, on the mammy in West Africa, has restricted the fisherman's freedom in the purchase of necessary requisites for his operations. The stranglehold the trader has over the fisherman results in low prices being offered for the latter's fish, exorbitant prices demanded for goods purchased, and heavy cost of financing, the trader functioning as money-lender as well as supplier of requisites and purchaser of products (Szczepanik (Ed.), 1960). In the Thana District in India, the middlemen were said to be reluctant to supply capital for development and were ready to advance loans for short-term

working capital only. They also shunned the additional risks that would have been attendant to an expansion of markets farther inland and pursued a price policy which robbed the fishermen of all incentive to increase output. The responsibility for slow development was, therefore, put directly at their doorstep (Szczepanik (Ed.), 1960).

Sometimes it is not so much the peculiar form of organization on the marketing side which discourages investment, or reduces incentive to economize or increase output, but characteristic institutional arrangements relating to hours, wages, or unemployment compensation in fishing. Attempts to regulate hours of work on board have created severe economic problems in Guinea, and so has a system of compensation based on fixed monthly salaries in Uruguay, because there was no incentive to increase catches. The traditional system of compensating crews on a share basis is only gradually being modified as a result of increased industrialization of operations and a lessening of entrepreneurial risks. In the more advanced fishing countries, the way toward a fixed wage system with production bonuses may be via introduction, in lay agreements, of a guaranteed minimum.

Extension of unemployment insurance to fishermen, to lessen the uncertainty connected with the exercise of their profession, may have an adverse influence on productivity. In Newfoundland, unemployment benefits may add just enough to family income to lessen the urge to work harder. "Unemployment insurance may thus become a subsidy on indolence. This is particularly evident in the difficulties that are experienced in getting fishermen to work in the winter season. New boats have been introduced that can prosecute the fishery in the winter. But fish companies have experienced difficulty in obtaining and maintaining crews on their trawlers. It has also been observed that operators of longliners on the North-east Coast will prefer to remain idle and collect unemployment insurance, rather than continue to fish on the South Coast during winter." Protection of the fisherman and his family from the consequence of a disastrous failure of the fishery, it was thought, could best be achieved in the Province by a scheme of catch failure insurance (Copes, 1961).

Not only output but cost structure, too, may be adversely affected by provisions relating to the administration of unemployment indemnity schemes. Under Belgian legislation, fishermen may do maintenance work on board only, in order not to forfeit their entitlement to the payment of indemnities. For shore maintenance work, the boat owners, therefore, must employ special crews. In the marginal coastal fishery, the owners' earnings are too low to enable them to incur this additional expense (Vanneste and Hovart, 1959).

Government and the development of fisheries:

Government policy affects fisheries and other industrial enterprises by allocating, transferring, and controlling the use of the means necessary to attain an increase in output or a reduction in inputs. It achieves its purpose either by direct legislative intervention or, indirectly, by activities designed to encourage or discourage private initiative.

An understanding of possible alternative goals of public policy is necessary for evaluation of specific action. The goals of maximizing (or increasing) economic progress in the country, maximizing total economic welfare, maximizing the total welfare of individuals in a given industry, maximizing income or maximizing net income in an industry, are not identical and without conflict. While government policies are seldom as well defined as to allow a clear identification of these aims, and while several aims may be pursued simultaneously, an industry may seriously delude itself if it expects public issues resolved solely in terms of its parochial interests. In highly developed countries, economic progress will lead to a transfer of resources from primary industry to other sectors. This may have as consequences the lowering of total fishing income as well as a redistribution of that income within the industry, and eventually the exit of marginal producers. Governments may decide to accelerate rather than retard this process, while simultaneously trying to alleviate the attendant hardship.

Welfare considerations make it mandatory to bring policies for economic progress in line with capacity of other sectors to absorb marginal elements. The pleas of an industry that is destined to decline within the natural course of economic evolution, on the other hand, should not, in the national interest, always be answered with increased financial support.

There may be a need to aim for a better economic performance by redressing the balance between various elements in the industry. The resource situation in inshore fisheries, as in Newfoundland, may make for action in this direction even more acute. As long as limited catches had to be shared by the same large number of men, incomes were thought to have to remain low and new techniques and equipment were considered of no avail. Only by transferring men from the inshore fisheries to deep-sea fisheries, where the much higher production of the average fisherman could keep several plant workers busy, could one hope for an economic improvement (Copes, 1961).

In the centrally planned economies, government controls all investment and operations, with central and local bodies participating in varying proportions (in different countries, and in one country over a period of time) in decision-making (Swiecicki, 1960).

In Western countries, governments have, in some instances, hesitated to assume too drastic a role in shaping the course of future development (e.g., by discriminating for or against certain classes of vessels in its support policies). In the U.K., for instance, the need for flexibility in policies is considered paramount. A comprehensive enquiry on the industry carried out a few years ago, thus, argued in the following terms: "Tastes at home and markets abroad change, new processes open up new demands, technical advances in vessel and gear design reveal new possibilities, new competitors appear, fish stocks themselves advance and recede with sometimes startling speed. It is particularly important to preserve flexibility in a subsidized industry, for there is always some danger that a subsidized industry will become ossified, and that economic change will be met by

pressure for modification—usually by way of increase—in the subsidy. We do not think that anyone can predict in detail what will be the best size and shape for the fleet in even five years' time; and we do not therefore support the idea of a balanced fleet cut to a pattern imposed from above" (Report of the Committee . . . , 1961).

Generalizations on fisheries policies in developing countries are as difficult to make as on policies in developed countries. The general tendency is to give attention, where prospects for substantial foreign exchange earnings from the establishment of an export-oriented industry do not exist, to social and welfare aspects as well as to economic aspects. In the Indo-Pacific Region, for instance, increased attention is being devoted to the welfare implications of progressive modernization in the fishing sector and one of the recurrent recommendations of the Indo-Pacific Fisheries Council has been a proposal for the conduct of a comprehensive study on this subject.

Another tendency sometimes encountered in developing countries is to do too much and too fast, both in relation to availability of inputs and to market capacity within the foreseeable future. The scope of the Ghanaian long-range trawling programme has been commented upon on this score; the rationale of government policies is not questioned, in view of population growth trends and the economic necessity to develop import-substituting industries (Crutchfield and Zei, 1964). Elsewhere, overly ambitious programmes may merely reflect a desire to make a spectacular showing, to win political support at home, to impress neighbouring countries, etc.

In implementing policies, governments may use one instrument, e.g. finance, to achieve a variety of objectives. Conversely, the attainment of one objective, e.g. improvement of productivity in the fishing sector, often is sought by various means.

Financial assistance may be rendered in different ways. In the centrally planned economies, the governments allot non-repayable investment funds to individual enterprises and, as a rule, also exercise a decisive influence on the character and technical features of the investments (Swiecicki, 1960).

Elsewhere, grant assistance usually covers only a part of total investment costs, with additional help sometimes being provided in the form of loans at low interest rates. Direct and indirect subsidies to meet costs of operations, tax concessions, exemption from payment of customs duties on imported requisites, provision of guarantees to encourage loans by private lenders, are among other forms of financial assistance to entrepreneurs in the fishing sector (Beever and Rudd, 1960, and Holliman, 1962).

Provision of financial help may aim to ensure the economic survival of the fishing fleet, in general, or may have a more specific objective such as technological improvement, redress of the economic balance between different classes of operators, etc. Among the means of achieving these objectives are establishment of eligibility criteria and intentional discrimination in the consideration of loan applications. In the United Kingdom, until recently, only vessels under 140 ft (43 m) in length were eligible for grants and subsidies. This was thought to

have had a decisive influence on the building of a high proportion of trawlers just within this limit (Report of the Committee . . . . , 1961). Recommendations made some years ago for the establishment of a Fisheries Loan Fund in Malta envisaged preferential treatment of applications from fishermen whose sons were to be employed on the vessels, since this was felt to encourage younger fishermen to stay in the industry and thus avoid dependence on hired crews. The loan system also was to be used to raise productivity in the fishery by extending the fishing season. No loan was to be considered, unless the applicant intended to work in the winter fisheries (Burdon, 1956).

Encouraging co-operation:

To ensure more effective use of public funds in the economic sense, and to attain the social objectives of assistance, governments—in some developing countries at least—seek to promote co-operative organizations through which such assistance is channelled. Formation of co-operatives may be stimulated through extension activities, favoured treatment under taxation laws in the allocation of financial assistance, granting of various concessions in connection with employment practices, etc. When, for instance, a few years ago, possibilities were studied of establishing a mixed fishermen settlement with Chilean and Mediterranean fishermen (to introduce changes in the social and economic structure of the fishing population in Northern Chile), the only form under which organization of such a settlement appeared to be feasible was a co-operative. Only co-operatives were exempt from the provision of the country's Labour Code under which no more than a small fraction of the staff of any association could be foreigners. Chilean co-operatives also enjoyed certain tax concessions (Molteno, 1962).

Other development assistance given by government:

In most countries, governments take a major part in carrying out scientific and technical research for the benefit of fisheries. The modest size of individual fishery firms in these countries makes dependence on public assistance in this sphere a matter of necessity.

In addition to providing services that tend to promote the interests of the industry, the government uses its legal power to protect consumers, producers, and the resource. The consumer is protected against harmful market practices affecting the price or quality of product offered for sale. The entrepreneur may receive protection against unfair—or too much—competition. Although ordinarily associated with resource conservation objectives, a fishing licence system may be operated to safeguard the economic interests of the fishermen or a group of fishermen. In Japan, for instance, the maintenance of catch quantities or profit margins per boat and the protection of inshore fishermen against the competition of trawler operators were among the declared aims of licensing policies after the last war (Asia Kyokai, 1957). Legal restrictions, fishing licence and import regulations, may be enforced to discriminate in favour of domestic and against foreign entrepreneurs, crews, boat builders, and suppliers of requisites.

Sometimes the basic intent of protective regulation may have become obscured as the result of changes in the complexion of the industry since the time the laws were instituted. Alaskan regulations limiting fishing boat length are said to be based partially on resource conservation aims, partially on the desire to protect local fishermen. Chapman (1965) recently blamed antiquated State laws in the USA for preventing the rational expansion of sea fisheries off the Pacific Coast in the ways demanded by modern economic conditions and national interest. The regulations he referred to included licence refusals for fish meal and oil operations, prohibition against carrying trawls on vessels fishing in certain waters (which made it impossible to fish sizeable hake resources), against electronic fishfinders to locate—and against gill nets to catch (on the high seas)—salmon, against trawls to catch halibut, etc. Restrictions of this sort (in addition to regulations limiting size or type of vessel), which reduce technical efficiency, require re-examination to determine whether they still serve the purposes for which they were originally instituted, as well as whether they have not become altogether obsolete in the light of changed policy objectives (FAO/UN, 1962).

Welfare and safety regulations enforced for the benefit of crews have a substantial impact on technology and the economics of fishing operations. Laws fixing the minimum size of crews may make it impossible to operate vessels of a more economic size and may impose a degree of labour-intensiveness that impairs profitability. The development of a fishery may be seriously hampered where the law makes large units the only possibility, while the finances and skills required for such operations are not available (Netherlands Economic Institute, 1958).

In Poland, welfare policies aim at the attainment, on fishing boats, of standards comparable to those usually met in the merchant marine. In the Indo-Pacific Region, in contrast, rigid enforcement of legislation applicable to other classes of vessels has been held as seriously hampering fisheries development. Such action reportedly has resulted in impracticably high standards for the certification of fishermen, coxswains and engineers; for safety requirements related to number and type of life-saving appliances to be carried on board fishing vessels; and for harbour entry and clearance procedures (IPFC/FAO, 1958).

The character, amount, and costs of permits, licences, and sundry "red tape" provisions controlling investment, operation, landing and disposal of catches in some Latin American countries are said greatly to handicap entrepreneurial incentives and hold back development of fisheries (various FAO technical assistance reports).

Private enterprise sometimes may be even more severely affected, where government enterprise enjoys exclusive privileges and franchises. Monopoly position, in some instances, has been accompanied by technical stagnation which could not continue under the spur of competition.

Technological and economic difficulties have arisen also through legal changes with international implications. These changes relate to fishing limits and agreements on sharing of fishing grounds and catch quotas

negotiated between countries under international fishing conventions. Extension of fishing limits by a number of nations in recent years has frequently been named as a cause for the reorientation of structures of, and policies in regard to, fishing fleets of other countries which had traditionally fished the waters now forbidden to them (Report of the Committee . . . , 1961). Changes in the salmon fishery of Japan imposed under renegotiation of agreements with the USSR were reported to have led to an influx of salmon fishermen into the tuna fisheries and this, in turn, was said to have prompted design of a new tuna longliner able to carry more fish than previous types of the same size (IPFC/FAO, 1961).

Political factors, finally, also play a role in the availability, type, and amount of foreign assistance a country may be able to obtain for the development of a fishing industry as well as in regard to opportunities for improving economic results of operations through exports to hard currency countries.

TECHNOLOGICAL CHANGE

The rate of technological change influences obsolescence and, consequently, the need for replacement of equipment and the demand for equipment designers and builders. Some attention, therefore, must be paid to conditions tending to promote or hold back technological change in the fishing sector. First, the questions of what are the means of bringing about, and what are the aims of, technological change must be answered.

Technological improvement in the fishing sector is effected through changes in (a) craft and equipment used on board, (b) methods of production (utilization of equipment), and (c) organization of production.

The aim of technological improvement is development of a new production function so that a greater quantity of fish can be produced from a given total input of resources (output-increasing innovation) or a given quantity of fish can be produced from a smaller input (factor-saving innovation).

Considerations affecting public sponsorship of technological change

For the economy as a whole, innovations are all output-increasing in the aggregate, since they free resources for output expansion in other industries (even though the innovation may result from a smaller resource input made by the individual firm). In this sense, all innovations stand to extend economic progress regardless of the industry to which they apply, provided, of course, opportunities exist of using the "freed resources" in other industries (Heady, 1949). In the long run, such opportunities will arise with progressive development; in the short run, however, they may not be present. The latter accounts for the frequently encountered opposition to mechanization of fishing operations in developing countries, because it displaces labour which is cheap, abundant, and has no alternative employment opportunities in the immediate future. The situation is contrasted to that in developed countries where mechanization in primary industries actually became a necessity because of the labour needs of other industries (Stenstrom, 1963 and 1964).

Public support for some innovations may not be forthcoming because of market considerations. If the aim of government policy is maximization of the total net income of the fishing industry, innovations which increase total output and decrease total cost, and which are related to products characterized by inelastic demand, are likely to be sponsored only if the decrease in total revenue (as the result of the lower prices the market will pay for the larger output produced) is smaller than the decrease in total cost (and where net revenue, consequently, is larger).

Government reluctance to lend strong support to modernization programmes in certain sectors of the fishery industry has at times, in some developed countries, had its roots in uncertainty of whether the benefits expected from rationalization would be nullified by failure of the market to absorb larger quantities at prevailing prices.

In developing countries, the market obstacles may not be related as much to price factors as to lack of processing, transport and storage means that would permit distribution of increased output over a larger area. Speaking of experience in the Indo-Pacific Region in connection with fishing boat mechanization, one expert a few years ago counselled caution in introducing highly advanced techniques on grounds that there was not always a guaranteed market for the larger output that would result from mechanization. For the same reason, the possibility of using indigenous materials for nets and ropes was to be given careful examination before a decision to introduce synthetic fibres was taken (IPFC/FAO, 1957). More recently, conditions in this respect, at least, appear to have changed, even in comparatively remote areas such as New Guinea. According to reports on the Island, fishermen are increasingly being persuaded to buy outboard motors on their own accord due to "fairly satisfactory fish prices and the purchasing power of the urban centres" (IPFC/FAO, 1963).

As compared with the special case of output-increasing and cost-decreasing innovations under conditions of inelastic demand, net revenue always increases if the innovations relate to commodities the demand for which is elastic - or inelastic, as long as in the latter case the innovations have output-constant and cost-decreasing effects.

If government policy is primarily concerned about maximizing total income (rather than total net income) in the fishing sector, research might be directed primarily towards increasing price elasticity in the market by developing new product uses and not so much toward promotion of technical innovations.

Welfare considerations, finally, may require government attention to the likely impact of innovations on the distribution of total income between interest groups or between individual firms in the industry. New techniques may transfer income between groups regardless of whether total net income of the industry is increased or decreased. The transfer may be of an intra-industry nature (when the techniques for one commodity or geographic region are improved beyond what applies for a

competing commodity or region). Also, the first few firms which adopt an innovation will have greater incomes than their competitors. This is true even if the innovation is an output-increasing technique relating to a commodity the demand for which is inelastic, since, in a competitive market such as the one for the sale of fish on landing, small changes in supply have a small effect on prices.

In the special case discussed above, where output-increasing innovations under conditions of inelastic demand may lead to a decrease in net revenue for producers, there is the possibility of another type of income transfer. The loss in the fisheries sector may be translated into a real gain for the consuming economy, which, under certain circumstances, may be a more important public policy objective than assistance to a specific sector of the economy (Heady, 1949).

Public policy considerations in regard to the introduction of technological improvements have been discussed, both because in an industry where small enterprise is still prevalent government has to play a key role in research, and because the industry needs to know the amount of public support it may be able to expect in launching a rationalization programme.

Economic factors relating to technological changes at the individual firm level

The individual firm will institute technological improvements if they promise to increase its profits (or decrease its losses), at least in the short run. Readiness to risk capital on new inventions, new methods, etc., depends to some degree on the general state of the economy and, to some degree also, on trends in the output and input markets of concern to the enterprise. In a rising economy, producers are of an optimistic frame of mind and willing to risk their capital on untried ventures. Yet, where competitive pressure is absent and profits may come easily even with continued use of traditional methods, the incentive to innovate may not exist. As far as conditions in the fishery industry itself are concerned, the generalization has been made that the optimum degree of mechanization, which varies from fishery to fishery, becomes higher as wage-rates increase, range of operation extends, and capital becomes more easily available (Morgan, 1956).

The larger items of new equipment and the more radical new methods are, as a rule, first introduced in developed countries, and there, by the larger firms with the capital and skilled manpower resources to undertake major investment. Generally speaking, types of equipment that assure a high catch per day are of the high-priced type. Their use presupposes considerable skills, and wages are correspondingly high; in compensation, they often permit a saving of labour that is not possible with less advanced types of equipment (Netherlands Economic Institute, 1958). Against possible savings in total labour costs through reduced crew size must be set the increased equipment, running and maintenance costs connected with the installation and operation of more complex machinery. Capital-intensive operations, therefore, often require a large turnover to make them worthwhile (Morgan, 1956).

If he has the choice of applying his capital for the purchase of innovations that will have a direct effect on output (e.g., fish-finding equipment) or for equipment that tends to have a more indirect effect on factor cost (e.g., crew safety devices), the entrepreneur will generally give preference to the former. This accounts for public intervention through promulgation of regulations on safety requirements. Where the labour factor, however, becomes critical, the effort may be both in the direction of accelerated mechanization and of accommodating insistent demand for increased crew comforts and safety.

The tendency to substitute, where specific inputs are in short supply or excessively high-priced, is not limited to the labour factor. Depletion of good shipbuilding timber (coupled with the declining number of skilled shipwrights) encouraged the introduction of the steel gillnetter in the fisheries in the Great Lakes area (Calvin, 1960). An unfavourable price relationship between machinery purchasing prices and catch prices is one of the most commonly given explanations for the slow pace of mechanization. The disincentive effect of this ratio is felt the more acutely, the lower the ability of the fisherman to buy the engine or other equipment. Existing cost-price relationships are also given as reason for the limited possibilities of introducing the more costly methods of preserving fish at sea: the overall profitability of operations would compare unfavourably with results from more traditional methods (Proskie in Traung (Ed.), 1960).

Capital-intensive operations are handicapped also by lack of mechanical skills and low standards of maintenance which discourage investment in machinery. Improvement of labour productivity, techniques, and modernization of equipment, are considered the most effective means of enabling the Newfoundland industry to exploit its locational advantages to offset the advantages presently enjoyed by its foreign competitors in terms of low wage and capital costs. Indirectly, the locational element had, in the past, worked against, rather than for, the interests of the fishing industry, because of relative difficulties of obtaining financing for modernization of the small scale operations of Newfoundland fishermen against the much greater capital outlays that were necessary from the start to support the large operations based on distant ports of the European nations exploiting the same fishing grounds (Copes, 1961).

Introducing technological improvement

A study of the appropriate ways of introducing change is a key element in any programme of promoting technological improvement. Too many generously endowed modernization efforts have misfired because the likelihood of resistance to change was either under-estimated or altogether ignored in planning.

Much has been written about cultural and psychological factors accounting for such resistance. What has been said above with regard to development, in general, applies. In addition, there are elements which have a more specific bearing on acceptance or resistance to technological change.

Change is resisted, it is said, because it threatens basic securities or does away with long-inherited traditions. Resistance is that much stronger, the less well the

proposed changes are understood. Acceptance comes forth more readily if persuasion rather than force is used (Spicer (Ed.), 1952).

Basic securities are involved when the introduction of new craft or equipment threatens to deprive crews of their maintenance. The case of the opposition encountered by one of the major trawler firms in the United Kingdom when it commissioned a vessel which made substantial crew savings possible is fresh in mind (Ross Group's Valiant). Industrialization of fishing operations may mean loss of social status, loss of a skill monopoly, or simply loss of freedom of action to the independent fisherman.

Great stress is placed on the essentially conservative nature of the fisherman which makes him hold on to uneconomic techniques and out-moded equipment, even when he is not entirely unaware that they are responsible for the miserable conditions in which he lives. The poorer fishermen in Ceylon view any innovation with suspicion and even hostility. They will seldom even consider any deviation from the fishing methods their forefathers had used for generations: "the introduction of a more effective type of fishing gear or craft into a particular area is deemed to be destructive tampering with the fishing in that area and the innovators run the risk of bodily harm and damage to the innovation" (De Silva, 1964). In Vietnam, too, the majority of the fishermen are described as conservative and poor and unwilling to abandon traditional equipment and methods (IPFC/FAO, 1964).

Aside from poverty, geographic isolation, age and lack of education, are listed most frequently as the underlying causes of the conservative attitude of fishermen. The resigned attitude of the older fishermen is given some of the blame for the stagnation of coastal fisheries in Belgium (Vanneste and Hovart, 1959). Geographic isolation and the static life in the small outports of Newfoundland is said to be the reason that opportunities for improving facilities and techniques are not grasped by the fishermen who "lack the necessary initiative, knowledge, and imagination" (Copes, 1961).

Psychological elements play a role not only in connection with the introduction of technological improvement. They also constitute a limiting factor in the extent to which such improvement can be carried out in practice. The degree of centralization that goes with it is thought to place a limit on automation in fishing boats. Centralization of responsibilities tends to increase the anxiety and strain on the skipper. One expert, consequently, recommends that the equipment on the bridge be restricted to what is absolutely necessary (Eddie in Traung (Ed.), 1960).

Sociologists recommend that, where resistance to change is related to the "innovators" and the methods they use rather than to the specific character of the innovation, the following questions, among others, be investigated with care:

- Have the new facilities and/or methods been introduced through the existing social organization or have social organizations been set up which conflict with those previously in existence?

- How are the innovators' purposes and ways of behaviour regarded?

- Has the maximum possible participation been encouraged and allowed to develop?

- Have the cultural linkages been discovered and utilized in introduction, i.e., has an effort been made to relate the new element to some familiar pattern? (Spicer, 1952)

The answers to these questions may reveal the mistakes that have been made in introducing technological change and may suggest ways of avoiding their repetition in the future.

There is always a nucleus of leaders in a community who may be prepared to do new things, to acquire an engine, etc. If some members of this group can be persuaded to adopt the new technique or buy the equipment, the battle is half won. Where authority is firmly vested with tribal chiefs, as in the earlier cited examples of Tropical Africa, progress will be much faster if the co-operation of the chiefs is enlisted and innovations are introduced with their specific sanction. Where fishermen's co-operatives are strong, as in Japan, the facilities of the societies may be used with advantage. In Japan, thus, the changeover to nylon nets by small fishermen has been, to a large extent, accomplished through the co-operative movement (Digby, 1961).

Co-operatives may find it easier than other agencies to persuade small producers to accept new ways of doing things. Confidence exists, or at least should exist, between the member and his co-operative. He does not feel that something is being forced on him by high pressure salesmanship or recommended to him by someone with theoretical rather than practical training.

Demonstration and encouragement of imitation are the best means of ensuring participation of the community. "Seeing is believing", especially in cultures where there is little understanding of abstract ends or speculative results. If the benefits to be desired from the institution of change are slow to materialize, it often behoves to attach some form of satisfaction to the adoption of new practices. This may take the form of praise, privilege, or material reward. The pleasure which flows from exercising a new skill also may have some influence in arousing interest in new techniques (Mead (Ed.), 1953). Once the superiority of new techniques has been practically demonstrated in a number of instances, a certain momentum is created for its adoption among the rest of the fishing population. This was observed, for instance, in connection with the rapid expansion of mechanized operations in Hong Kong, Malaya, and Sarawak after the British colonial administration had started to motorize fishing boats in these countries shortly after the last war (Production of Fish . . . ., 1954).

Frequently, however, it is necessary to start what has been called a "revolution of rising expectations" to have the fishermen copy the new techniques which have been demonstrated to them. They must be persuaded that they will be able to attain, by their own effort, a higher standard of living. To this end, they often must be taught to appreciate material rewards which have spurred

on the workers of successful industrial societies (Copes, 1961).

While it is not always possible to link new ways to the past, care must nevertheless be exercised to avoid too radical a departure from the familiar and to adapt the pace at which change is introduced to the capacity of the fisherman to absorb instruction. "Revolutionary changes of craft and techniques may alarm and repel . . . (and) too many changes all at once usually confuse the fisherman" (Beever, 1955).

Education is the key to progress in the long run. Even where, as in Hong Kong, the fishermen have, through motorization of their craft, made a great leap forward in recent years, there is a need for continuous education on proper engine installation, propeller selection, and maintenance practices (IPFC/FAO, 1964).

Training needs are great also for the skippers, officers and crews of the more industrialized operations, especially as more complicated devices are being installed on board. On the other hand, automation may reduce skill requirements to a certain degree or for certain occupations. Also, some of the specialized operations on board the larger vessels may be more closely related to occupational specialities of land-based personnel. This may have an impact on recruitment and the need for specialized training.

Facilities for the training of government personnel responsible for development and promulgation of new technologies also must not be neglected, especially in developing countries, where the fisheries administration must be prepared to accept a pioneering responsibility in this field.

Aside from taking an active part in the promotion of technological improvement, government can perform a useful service by assembling and disseminating information on inventions. A programme along these lines, it has been suggested, might include preparation of forecasts for the uses of specific inventions, assessment of their probable social effects, proposals for speeding the removal of lags in adjustment to inventions, as well as organization of training programmes and financial support facilities. Finally, where serious barriers exist to mobility of fishermen, whose skills have become obsolete, or who have lost their livelihood as the result of technological progress, governments will want to assume the responsibility for facilitating transfer to other locations or occupations, through underwriting the cost of transfer, retraining, improving employment services, etc.

The impact of technological change on society and on the complexion of fishing industries

Empirical research on the effects of technological change is indispensable for the formulation of policies of rationalization and modernization of industry.

Technical change may not consist merely in the modification of a branch of knowledge but in a changed pattern of life and of the social structure as a whole. A change in techniques may lead to shifts in the balanced division of labour, may disrupt the pattern of relationship between man and wife, father and son, may mean a break with sustaining tradition which gives security (Mead (Ed.), 1953).

Where desires and aspirations have limits, mechanization may mean that the producer may work less. In developing countries, the replacement of subsistence by "cash crop" operations may, in the short run, result in a lowering of nutritional levels, since the fishermen may be tempted to concentrate on the cash crop, e.g., catching shrimp for export. In countries like Burma and Thailand, where more than one pound of polished rice per capita is consumed daily, the vegetables, herbs, and fish products which accompany the rice in the rural areas are believed to make up for the nutritional deficiencies of a rice diet. In Lower Burma, however, where a cash crop economy flourishes, malnutrition is reported (Mead (Ed.), 1953).

At times, the impact on nutrition of increased productivity is quite the opposite of that described above. In Hong Kong, mechanization of fishing operations was reported to have increased home consumption of fish by the fishermen. The consumption of fish per head of fishing population in "mechanized households" was estimated to be about 20 per cent higher than the consumption in "unmechanized households" (Szczepanik (Ed.), 1960). Advocates of a shift in development efforts in the Colony towards deep-sea fishing in international waters envisaged a radical transformation in the social structure of Hong Kong's fishing population in addition to far-reaching technological changes and needs for finding new methods of financing that such changes would imply (Szczepanik (Ed.), 1960).

Changes in the structure of fishery industries can also be expected as the result of technological advances. Again taking Hong Kong as example, mechanization of fishing vessels was found to have led initially to a decrease in processing operations. Before mechanization, a large portion of catches was salted. Mechanization made it possible to sell the bulk of the fish fresh. Expectations were that, processing operations would be on the upsurge again only when landings would exceed market absorption capacity for fresh fish, (Szczepanik (Ed.), 1960).

Technical advances tend to increase the size of capital requirements in fishing and break-even catch values. They will account for vessels becoming obsolescent within a shorter time and building costs becoming higher. As the capital-labour ratio in fishing rises, the entrepreneur expects the increased catch to result in a higher value per unit of capital employed (Netherlands Economic Institute, 1958).

With the change in the size of the average production unit, changes take place in the pattern of the firm. Growth in the size of craft employed will encourage organization of larger fishery enterprises and may lead to the gradual proletarianization of the fishermen themselves (Morgan, 1956), which may encounter resistance.

The increased financial burdens on the entrepreneur may bring about changes in employment patterns. The cost of the installation of engines, it has been observed in the Thana District in India, produces a tendency to employ more relatives who can be better relied upon in sharing commitments and who are also more favoured in sharing the benefits of mechanization. As a result, mechanized teams employ comparatively more relatives than sailing teams (Szczepanik (Ed.), 1960).

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Among other employment effects observed has been the aggravation of recruitment problems. In Hong Kong, motorization of fishing craft and the addition of simple mechanical deck working gear in certain boat types—such as power windlasses (with clutch operated warping ends) in the pair trawlers, and capstans in the shrimp beam trawlers—has made the better fishermen more selective in their choice of employment. For example, skipper-owners of large longliners—these vessels require a big crew complement to man the pairs of small fishing sampans operated from the mother boat, and to hand-haul the lines—now find it almost impossible to recruit adequate numbers of men; many of the boats registered as large longliners have accordingly been converted into pair trawlers. The position is that the fishermen prefer the better paid employment, and less arduous work, either on shore or on the other more modern classes of boats (IPFC/FAO, 1964). This development has led to boats fishing farther afield, using labour-saving deck machinery and synthetic fibre fishing gear, and fishing throughout the year and working longer hours than previously (IPFC/FAO, 1964).

The effect of mechanization on number of fishermen employed and earnings has been commented upon in many instances. Evaluations in terms of net welfare effect are, however, lacking and it is precisely at this objective that recommendations for the assessment of mechanization programmes made in recent years by such bodies as the Indo-Pacific Fisheries Council have aimed.

There seems to be some evidence that increased industrialization of operations tends to affect remuneration systems, with greater emphasis being placed on the basic wage and less on settlement by share (Report of the Committee . . . , 1961). On Pakistani trawlers, captains and mates are paid monthly salaries (IPFC/FAO, 1963).

With mechanization, the number of crew members per boat seems to have been reduced and the earnings of the fishermen working on the mechanized boats increased. This, at least, is the experience reported from India (IPFC/FAO, 1963). Early experience with mechanization in the country seemed to indicate that capital invested in non-mechanized craft provided employment for over four times as many fishermen as when invested in mechanized craft (IPFC/FAO, 1958).

A 30 per cent increase in the real per capita gross income of the fishing population in Hong Kong over the 1946/47–1958/59 period was credited mainly to the increase in catches brought about by mechanization, which raised fishermen's earnings in spite of falling prices (Szczepanik (Ed.), 1960).

Sharp increases in fishermen's earnings as the result of mechanization have been noted also in Pakistan. Over a 3–4 year period, the mid-point of which was approximately in 1960, fishermen's earnings in the country were reported as having almost doubled (IPFC/FAO, 1963).

The advantage mechanized fishing households in Hong Kong held over unmechanized households was attributed also to disposal procedures and distribution channel factors. The mechanized households were able to sell through less expensive and more remunerative channels, and were not as much at the mercy of middle-men in their marketing operations as the unmechanized households (Szczepanik (Ed.), 1960).

PROMOTING FISHERIES EXPANSION IN DEVELOPING COUNTRIES

A basic issue in the formulation of policies for fisheries expansion in developing countries is the determination of the pace at which development should proceed. The choice often is put in terms of a gradual improvement of indigenous craft and methods and a more rapid growth to be achieved with modern equipment fishing outside the narrow coastal zones frequented by the traditional fishery. A third possibility, of course, is parallel development on both fronts.

Before more closely examining these choices, it may be worth while to list some of the factors most frequently cited, in discussions of development potential of specific countries, as impeding or encouraging the growth of the industry.

Factors affecting realization of development potential

On the market side, low purchasing power, consumer prejudices, lack of market information (on the part of consumers and marketing agents), lack or inadequacy of transport and storage facilities, and restraints of trade exercised by marketing agents, are among the most prominent obstacles to expansion.

Conversely, among the strongest incentives for rapid development have been the discovery and exploitation of export possibilities. Mexico and other Central American countries as well as some countries in the Asia and Far East Region were able to start profitable development in the post-war years as the result of a flourishing demand for shrimp and other luxury-type crustacean products in the United States and in other developed countries. Mention has already been made of Peru's and Chile's fishmeal exports which account for the tremendous expansion of the industries of these countries in recent years. Morocco's fisheries development has benefited, among other things, from the country's nearness to European markets.

Elsewhere, fisheries development often offers the best opportunity to diversify "one cash crop" economies. In the Caribbean, for instance, the continuance of the position of the islands as a major world producing area of sugar cane, it has been pointed out, may depend on expansion of foodstuff supplies—such as fish—which do not compete for land with the sugar cane (Morgan, 1956). In some countries, there has always been a strong and stable demand for fish which is likely to increase with increasing population pressure and unchanged poor prospects of raising the productivity of limited and low quality agricultural resources.

Sometimes failure to exploit fully the demand potential is blamed on scarcity of resources in traditionally fished waters. More often, though, failure to expand can be explained in terms of the "human" factors described earlier, which accounts for stagnation.

Fisheries off the coast of Somalia are still at a low level of development, although the waters are relatively well stocked with fish. Development has been retarded

by the fact that the Somali are neither substantial consumers of fish nor have been traditionally fishermen (Production of Fish . . . , 1954). The inhabitants of the many small islands in the mid-Pacific are good fishermen but have, for the most part, retained the simplicity and small-scale character of operations that is found in small communities in rather sparsely settled areas (Morgan, 1956). Small scale operations elsewhere, e.g., in India and other densely populated countries of the Indo-Pacific region, still predominate, largely because of lack of capital and entrepreneurial talent. In the Philippines, lack of qualified naval architects, technically trained boatbuilders and marine engineers are believed to be among the principal factors retarding development of deep-sea fishing (Rasalan *et al* in Traung (Ed.), 1960). Lack of co-ordinated planning and of foreign exchange for the importation of engines have contributed to slowing development of mechanization in some countries in the Far East (IPFC/FAO, 1958). In the least developed areas, e.g., in New Guinea, the absence of a drive toward economic improvement is still cited as a factor in restricting progress. Living requirements are limited, and the fisherman appears content that he can attend to his immediate needs with the modest income he derives from his occupation (IPFC/FAO, 1963). At times, the lack of incentive to expand and/or improve operations manifests itself also among the merchants who dispose of the catches. This reluctance to increase turnover tends to impose its own limitations on the fishing effort (Beever, 1955).

In Tropical Africa, where development in some countries has merely begun, all the above obstacles are encountered, with those relating to human motivation often being the most conspicuous. In Madagascar, for example, the following have been given as explanations for the failure of industrial fishing ventures: insufficient financing, inadequate fisheries experience of the promoters, dispersion of limited resources over too broad a range of activities, difficulties in finding suitable transport and adequate market outlets and, above all, unsatisfactory catch results because of the low productivity of the fishermen (after receiving their pay, the fishermen often did not return to work until they had spent their money) (Couvert, 1963).

Considerations relating to scale and pace of development

Much has been written in defence of a cautious approach to expansion and against doing too much in too short a time and thereby risking wastage of a substantial part of the limited resources available for development.

Mechanization, as seen in its wider aspect, is not an end in itself. Mechanization is a means to produce more, better and cheaper. In developing countries, where the real costs of production are high and the prices the producer can obtain for his products are low, the technological improvements to be supported should above all have a potential for increasing yields; less emphasis need be given to labour-saving devices (Stenstrom, 1963).

A slower pace makes it easier to adjust necessary changes in economic and social structure to prevailing conditions, customs and habits (Stenstrom, 1963). Too ambitious steps forward in adopting new techniques may place an unduly heavy burden on a developing country's capital resources. Also, additional costs such as those connected with expenses of storage, underutilized or idle vessel capacity, shorter depreciation periods as a result of more rapid obsolescence, must be reckoned with. If simpler methods are employed, the equipment tends to be less costly, and less foreign exchange may be needed. Thus, capital and foreign exchange which tend to be in short supply in most developing countries can be applied for other purposes (Netherlands Economic Institute, 1958). The danger of having all one's eggs in one basket is particularly real in the more primitive fisheries where there is so little past experience to assist in measuring the financial risk. Heavy concentration of capital as, for example, in costly deep-sea vessels, may not only prove commercially unjustifiable, but may divert capital from more essential, more immediate uses—such as the purchase of small engines or better fishing equipment (Beever, 1955).

The argument for proceeding gradually, by first improving and motorizing existing craft, in line with opportunities arising under integrated development planning, was well summarized at the Second Fishing Boat Congress in Rome. Speaking on planning craft for the developing countries, one participant expressed the view that "development of improved fishing boats should have a close relationship to the economic developments in a fishing area. The utmost caution should be exercised so that the fishing boat owner is not over-capitalized in an effort to get the most developed boat. Thus, to some extent at least, the development of the fishing boat of a given area must be slightly behind that of the improvement in other factors—the retail and wholesale market, distribution, fish handling and storage, fish supply and possibilities for exploitation. . . . These matters can and must be explored . . . before any extensive development can take place in the production of improved boats, particularly where mechanization is concerned" (Chapelle in Traung (Ed.), 1960).

The "gradual approach" was strongly criticized in a paper submitted to the FAO Meeting on Business Decisions in Fishery Industries in 1964. Motorization of pirogues, West African experience had shown, according to the authors, had proven economical only in cases where hydrological conditions had made it impossible to reach the grounds most suitable for handlining operations. Traditional craft always would permit only very limited development and, in some cases, the cost of the engines could not even be amortized through increased catches. It was a mistake on the part of governments and technical assistance agencies to place emphasis on motorization programmes instead of on establishment of modern installations and methods permitting large scale development. The latter would, of course, require organization of enterprises with participation of developed countries contributing a major share of the capital and the skilled manpower, and letting the fish enter their markets as long as outlets in the developing countries remained inadequate (Moal and Lacour, 1964).

A survey mission recently carried out in connection with plans to organize a UN Special Fund project in Ghana concluded that there was scope for both approaches, gradual improvement of the inshore canoe fishery and larger scale trawling development (Crutchfield and Zei, 1964). Natural conditions tended to place economic limitations on what could be done at certain locations. Market outlets, foreign exchange reserves, availability of foreign capital and access to foreign markets, had an influence on how far prospects for large scale development could be realized. Last, but not least, how far governments were prepared to go to satisfy income, nutritional, employment, political and economic independence, and other aims was a matter of basic policy considerations and no one formula to cover all combinations of aims could ever be devised.

Topographical Factors in Fishing Boat Design

by K. Chidhambaram

Facteurs topográphiques intervenant dans le dessin des bateaux de pêche

Les dessinateurs de bateaux de pêche doivent tenir compte de divers éléments relevant de la géographie, du climat, du littoral, du type de pêche, de l'éloignement des terrains de pêche, des vents, des vagues, des variations des marées, des saisons, des courants et des installations portuaires, facteurs qui varient tous d'une région à l'autre. La communication étudie les divers types de bateaux de pêche et leur évolution en fonction de ces facteurs pour ce qui est de l'Inde, où l'on distingue six zones géographiques distinctes.

Factores topográficos en el diseño de las embarcaciones pesqueras

Los proyectistas de embarcaciones pesqueras deben tener en cuenta factores tales como la geografía, clima, línea de la costa, tipo de pesca, distancia a los caladeros, vientos, olas, variaciones de la marea, estaciones, corrientes e instalaciones portuarias, elementos todos ellos que varían entre las distintas regiones. Respecto a la India, que cuenta con seis claras zonas geográficas, se describen los tipos de embarcaciones y su evolución de acuerdo con estos factores.

THE fishing boats of the world of all types, shapes and sizes, represent the largest single collective investment in the world's fishing industry. Upon their efficiency of design and operation depend the economy of millions and the livelihood of a large number of fishermen. Globally, designers attempt to produce the ideal fishing boat. Opinion varies considerably as to what constitutes the ideal vessel.

It is evident that the geographical location of a country, and even the region within that country for which a new type of mechanized fishing vessel is to be developed, will have a considerable influence on the design. The broad geographical or climatic classification of the country, such as tropical, sub-tropical or temperate, will decide a number of important features of the boat, such as general arrangement, accommodation, ventilation and material Tropical and sub-tropical countries generally border oceans, where the warmer salt water encourages electrolytic corrosion of ferrous metal surfaces and devastating attacks on timber surfaces by marine borers and fouling organisms.

Geographical influences of wind and weather materially influence boat design. Countries with specific monsoon or other rain and storm seasons in the Indo-Pacific region should carefully examine the nature of fisheries that would be profitable during those seasons before designing boats for fishing in or through such seasons (fig 1).

Modern fishing vessels need not differ from village to village as traditional designs do. By considering regional features the extent of that region must be determined. India, for example, may be divided into six distinct zones:

- Gujarat and Maharashtra States West Coast
- Mysore and Kerala West Coast
- Madras East Coast
- Andhra Pradesh East Coast
- Orissa and West Bengal States East Coast
- Andamans, Nicobar and Laccadives islands

Geography and hydrography of these areas have an important bearing on such characteristics as maximum draft. Prevailing wind and sea conditions, wavelength, ocean waves and tidal variations also influence design (Gurtner, 1963). Many places either have no natural shelter or harbour, construction is too expensive, or water and current prevent such construction. In these places fish are landed on the beach. Large and efficient beach-landing boats have been designed. These beach fisheries often assumed great economic importance.

Naval architects should consider the type of fisheries, nature of fishing grounds, geography and other factors of the coastline, communications, location, local conditions, tidal variations and tidal currents. He must understand also clearly those factors relating to fish abundance, and availability of suitable boatbuilding materials and should know the capabilities of boatyards and timber types available in each region.

The evolution of different boat types in different Indian coastal regions shows these boats have been developed through trial and error and experience. Modifications based on regional conditions have resulted in efficient operation in these particular areas. These work well because their ultimate design has taken all the above natural conditions into account. In addition, their design has been influenced by distance to the fishing grounds and whether fish caught on distant grounds were to be fresh, salted or cured fish.

Geographical and physical influences

Along shelterless surf-beaten coasts, craft had to be developed which could be rigged and manoeuvred in surf. For such areas in India's east coast the commonly-used craft is the catamaran (fig 2), operating from open beaches. Between Colachel and Cape Comorin, the coast is particularly exposed and surf-battered throughout the year without any landing place suitable for dugout canoes. Some types of catamarans are operated over 100 miles off

INDIA

JAMMU & KASHMIR

WEST

PAKISTAN

HIMACHAL

PRADESH
Simla

Chandigar

PUNJAB

DELHI   UTTAR

PRADESH

Jaipur

Lucknow

RAJASTAN

Patna

BIHAR

Bhopal

KANDLA

GULF OF KUTCH

GUJERAT

AHMADABAD

SAURASHTRA

VERAVAL

JAFRABAD

MADHYA   PRADESH

FRASERGANJ

HALDIA

PARADEEP

Bhubaneshwar

MAHARASHTRA

VERSOVA

SASSOON DOCK

KARANJA

RATNAGIRI

REVADANDA

VIJAYDURG

MALVAN

MURMAGAO   GOA

VISAKHAPATNAM

KAKINADA

Hyderabad

ANDHRA

PRADESH

KARWAR   MYSORE

ARABIAN   SEA

MALPE

MANGALORE

Bangalore

ROYAPURAM

Madras

CANNANORE

CUDDALORE

BEYPORE

(MALABAR)

COCHIN

NEENDAKARA

VIZINJHOM

COLACHEL

Trivandrum

LEEPURAM

TUTICORIN

CEYLON

CAPE COMORIN

PAMBAN

RAMESWARAM

SCALE

KM   100   200   300 KM

Fig 1. General map of Indian fishing ports

north-east of Cape Comorin. The same types are used on the surf beaches of Andhra and Orissa. Catamarans and other simple craft have evolved from these conditions along most of India's east coast. Catamarans in certain regions can be fitted with outboard motors.

On surf-beaten coasts with sheltered bays, where wind conditions are favourable and grounds are a little further offshore, craft must be fast and able to negotiate swells and rough seas. The Tuticorin types (fig 3) of canoe are examples. Outrigger fishing canoes on this coast are similar to those of Ceylon. Carvel-built boats, Rameswaram and Pamban machwas, are heavily-built boats with low draft for landing on coral beaches. In rivermouths and sheltered basins, larger boats have evolved.

Dugout canoes (fig 4) are the common craft where seas are not very rough most of the year and where fish are abundant in shallow inshore waters. Dugouts fish from open beaches with boat-seines and gillnets. The evolution of the dugout is directly linked with geographical, wave and beach conditions and the availability of large quantities of good timber along the Kerala and Mysore coasts.

From Bombay to Ratnagiri the coast is generally rocky and has harbours, sheltered bays and creeks. Fishing

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Fig 2. *Catamaran commonly used on the east coast of India in Orissa, Andhra Pradesh and Madras States where coasts are surf-beaten and are without shelter*

Fig 3. *Tuticorin vallam used on the south coast of India in Madras State where coasts are surf-beaten but shelter exists*

Fig 4. *Dugout canoe used mainly on the south-west coast of India, in Kerala and Mysore States where seas are not so rough and timber is available*

grounds are distant. Here, the satpati type (fig 5) has developed, and is considered one of the best fishing boat types.

Along the Bombay coast, shoal water and sandy bottom extend far out to sea. There is not a single sheltered fishing harbour. The estuaries are silting fast and fish resources are limited. Here, types similar to machwas are used but they are essentially different from the Arab types of the north-west coast (fig 6).
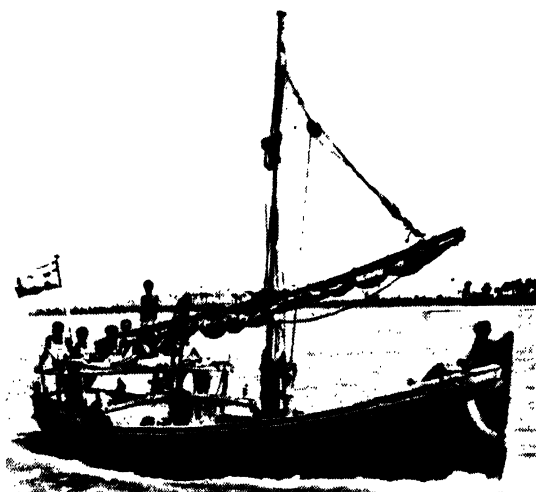
Fig 5. *Satpati type used along Bombay coast in Maharashtra where rocky shelter exists*
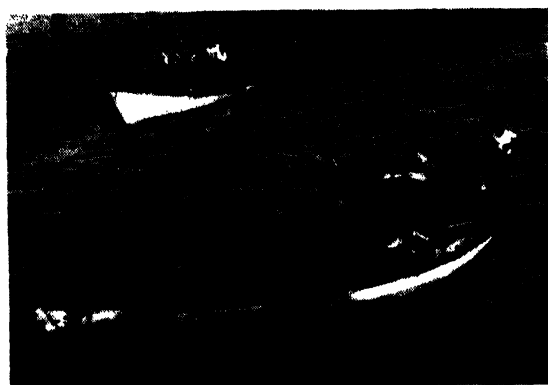
Fig 6. *Karanja type used along Bombay coast in Maharashtra where shoal water and sandy bottom extend far out to sea*

In regions of great tidal variation and where large mud flats or coral beds are exposed, the vessels are of shallow draft, but large enough to negotiate tidal currents. Machwa and Bedi boats of Gujarat and the Dhonies of Rameswaram are examples evolved in such conditions. The north-west coast is arid, physically and climatically closely approximating the Arabian coast. The predominant boat designs are characteristic of Arab influence caused by trade contacts (fig 7).

Effect of distance and fishery

Design is influenced by distance to the fishing grounds and whether the fishery is bottom, surface or pelagic. On the Indian west coast, abundant shoaling fishes occur near the coast at surface and in midwater. Here, boat

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range is limited to inshore areas and speed and hold capacity are restricted. Dugout canoes can be manoeuvred easily here and they fish for sardine, mackerel, prawn and other species inshore. Similar craft operate gill nets along the Saurashtra coast for Pomfrets, Hilsa and other species. Recently these craft have been fitted with outboard motors to enable them to extend their range for catching good quality fish.

Fig 7. Kutch type used on the arid coasts of the north-west of India in Gujerat State

The fishing grounds on the south-east coast are a little further offshore. The design must reflect the speed with which the boats should reach and return from the grounds to marketing. The Tuticorin canoe and Kulia Dhonie of Ceylon are examples.

A larger boat is used on the north-west coast. The grounds are distant from the home ports. Fishermen follow the migration of fish in different seasons, sometimes going 300 to 400 miles (555 to 740 km) along the coast. Moreover, fishing for Bombay Duck away from the coast and in areas with strong currents, these craft must be large and seaworthy with draft shallow enough to enter tidal creeks and basins.

Fish-hold capacity need not be large where fish are caught close inshore and can be landed fresh. In areas where grounds are distant and in the open sea or where fish must be processed at sea, boats must have adequate space for cleaning, salting and storing dried fish and fish products.
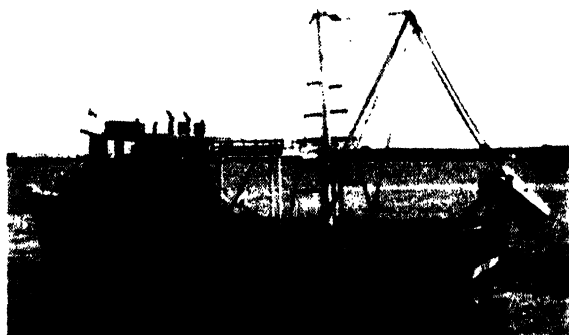
Fig 8. Improved trawler designed by an FAO naval architect

Fishing boat mechanization for India was studied. Some factors considered were costs of marine diesel engines and/or outboard motors, the economic return from such boats and facilities available for landing catch, servicing and maintenance. Catamarans show some potential for outboard mechanization in selected centres where grounds are a little beyond the present non-mechanized range, where the quality of fish is good and the price high. This may prove effective in Cape Comorin areas.

On the south-west coast, efforts were made to determine the utility of an inboard or outboard engine on dugout canoes. The engine power was not required for reaching the fishing ground but for fishing operations. The outboard was not powerful enough and the dugout had not sufficient space to install an inboard engine of sufficient power for this purpose. But outboard motorization of dugout canoes on the Saurashtra coast was effective and economical, because fishing grounds are rich and fish quality high, realizing good prices.

Larger craft on the north-west coast were suitable for mechanization without much alteration, as they fished in distant waters and subsequently used the power for sea bottom fishing.

On the south-west and east coasts, the indigenous boats could not be mechanized and so new designs had to be developed. The Rameswaram or Pamban type machwa was one type considered for mechanization. Allowing for fishing conditions and types of gear, the designs had to be developed to cover from 22 to 40 ft (6.7 to 12.2 m). Gradually, the operational range had to be extended and the size increased.

Influence of seasonal fisheries

Most of the non-mechanized indigenous craft have a limited range due to small size and lack of power. The catamarans, dugouts and the Tuticorin canoes normally operate within 50 to 60 miles (90 to 110 km) from port. They may operate from selected ports, following movements of the fish.

In certain parts of the south Kerala coast, catamarans during the pre-monsoon season cannot operate from the open beach. They are transported to Vizhinjom, which has a sheltered bay and a protected shore. These catamarans operate from this base for some time even though fishing is not possible from the open beaches outside.

In areas where boats follow seasonal fish migrations and where boats are big enough for proper fish handling, the fishermen move with the fish for hundreds of miles. Mechanized craft fishing for Dara and Bombay Duck off the Saurashtra coast move from the Bulsar area to Jaffrabad for Bombay Duck and to the Gulf of Kutch for Dara fishing, about 600 miles (1,100 km) from their home ports. Large-scale movement of fishing boats following the fish is possible, because of the size and types of boats and the similarity of coastal conditions, tide and current. But these movements are restricted to the coast and not to deep-sea fishing.

Availability of boatbuilding material

When developing the fishing craft in different regions one of the primary considerations besides the geographical,

physical and fishing conditions, is the availability of suitable timber for boatbuilding in large quantities in the vicinity. Dugout canoes were developed on the Malabar coast, where ample timber is available. As coastal traffic developed, these boats found their way to most of the countries bordering the Arabian Sea. With the increasing cost and the difficulty of obtaining timber in quantity and the effort made in developing new designs, the use of the dugout in other parts of the country has been declining gradually. Catamarans are found in areas where soft wood is available locally or nearby. The availability of good quality teak in the north-west forests resulted in the large north-west coast vessels.

For non-mechanized boats, the traditional method of preserving the timber from borers was to apply fish oil and, to some extent, lime. When boats were mechanized and had to remain in water for a longer time, they needed copper and aluminium alloy sheeting. In areas of considerable tidal variation and complete exposure at low tide, there was no need for copper sheeting. Protective measures are still restricted to periodical application of lime and wood resins, as in the case of the large north-western boats.

Influence of harbour development

As fishing becomes more intense, the need arises for harbours with berthing, landing distribution and servicing facilities to replace beach landings.

Harbours can be developed only in certain places. These will be determined by their distance from fishing grounds, their natural shelter, communication facilities and other factors. With harbours, the sizes and designs of fishing boats could be increased and improved for large-scale fishing. Such facilities normally lead to the development of standardized fishing boats for working different types of fisheries and in various grounds. Such standardization also leads to economic and efficient operation. Some of the local factors relating to shore and tidal conditions do not greatly influence designs of large fishing boats operating from harbours.

CONCLUSION

Physical and geographical conditions, coastline, nature of the fishery, distance to grounds and species of fish are all factors that have influenced indigenous boat designs. A correlation between particular designs and physical coastline or regional features has been carried out for India. Overlapping was not significant. The prevalent indigenous designs of fishing craft are the same today in these regions as a hundred years ago. Each has its own boat types; its own characteristics of weather, climate and coast formation.

On the north-western coast, where the physical and climatic conditions are similar to the Arabian coast, Arab boat designs are characteristic. In the Bombay sector, these boats are mixed, but Indian in type. In the indented coastal region south of Bombay to Mangalore, the Arab influence is replaced by indigenous and polynesian types. This is reversed partially on the Malabar coast, where the dugout designs predominate. East of Cape Comorin, Polynesian and indigenous boat types have held their own successfully against foreign influence. The indigenous designs of catamarans and canoes are well marked and characteristic.

Many boats in India, especially those from the north-west coast, are well developed from the modern naval architectural point of view. They could still be improved by sharpening the stern posts, modifying the distribution of displacement, mechanical propulsion, rigging for handling improved types of fishing gear, providing insulated fish holds and by improving the general arrangement to increase the working efficiency of the crew. These boats, with slight modifications, could be mechanized. The Pamban-type machwa form the basis for development of designs for small mechanized boats on the south-west and north-east coasts. New designs developed in India with FAO assistance took these factors into consideration (fig 8).

A small number of American launches have been developed by trial and error, to meet the demands of local conditions, which are so rigid that boats must be efficient to survive. There is, already, a very high level of design, but it can be effectively improved if it is done with a working knowledge of the local physical and economic factors. Some of the North American types of boats such as the Gaspé boat, Cape Island boat and Sharpe launch, have been developed according to beach conditions and/or types of fishery (Chapelle, 1955).

In different parts of the world, boats are modified gradually through experience gained in their ability to work different types of gears in different regions. Fishermen who are not boatbuilders and have no knowledge of naval architecture are reluctant to change designs without being sure of results.

There are still too many unknown factors in Indian fisheries to predict effectively the future development of different boat types. Development will be directed gradually on the basis of experience gained here and elsewhere and on the operation of newly-introduced boats rather than by suddenly introducing complicated and expensive types of fishing craft.

Techno-Socio-Economic Problems Involved in the Mechanization of Small Fishing Craft

by Atsushi Takagi and Yutaka Hirasawa

Problèmes techno-socio-économiques de la mécanisation des petits bateaux de pêche

La flottille de pêche japonaise, composée il y a 60 ans d'environ 420 000 bateaux non motorisés, compte actuellement à peu près 200 000 bateaux à moteur. La motorisation de la flottille ne constitue qu'un aspect de la modernisation, puisque même les bateaux de petite taille disposent également aujourd'hui de matériel électronique tel que radios et détecteurs de poisson. Le Gouvernement japonais a imposé de sévères limitations tant à la taille des bâtiments qu'à l'effectif total et au tonnage des bateaux pratiquant certaines pêches. Cette réglementation affecte par exemple les flottes travaillant le thon, le saumon et la truite, le maquereau, ainsi que les baleiniers et les chalutiers. Les restrictions apportées à la taille des bâtiments ont incité les architectes navals à s'efforcer d'augmenter au maximum la capacité des cales à poisson. La pénurie de main-d'oeuvre pour la pêche, causée par l'essor rapide d'autres industries, devra être compensée par une mécanisation plus poussée.

Problemas tecno-socio-económicos de la mecanización de pequeñas embarcaciones pesqueras

En 60 años la flota pesquera jap nesa ha pasado de unas 420 000 embarcaciones sin motor   s 200 000 unidades motori-
          las embarca   nes menores no sólo están
ahora dotadas de mot ', sino tambi   de equipo electrónico, como radio y localizadores d bancos de p   do. El Gobierno japonés ha impuesto rigurosas limitaciones al tamaño de los barcos y al número total y tonelaj de los dedicados a una pesca determinada. Por ejemplo, las fl   del atún, el salmón y la trucha, la caballa, la ballena   del ar astre, están estrictamente reglamentadas. Las restricciones impuestas al tamaño de los barcos han obligado a los arquitectos navales a hacer enormes esfuerzos para elevar al máximo la capacidad de las bodegas. El rápido desarrollo de las demás industrias na reducido la mano de obra pescadora. Para contrarrestar esta perdida en brazos habrá que mecanizar más las operaciones.

MECHANIZATION of the Japanese fishing fleet began with trawlers and whalers around 1900. Before mechanization, 420,000 Japanese rowing or sailing vessels produced 1,000,000 tons of fish annually. Fishing methods were primitive. The catch was not enough to supply necessary animal protein to the nation and mechanization started as a Government policy. A few firms were established to operate trawlers and whalers as mechanized fleet units, and these types of vessels were successfully mechanized under this system. Coastal craft were mechanized, individually. Mechanization gave fishermen access to better, but more distant, fishing grounds and the size of vessels increased. An increased number of crew for larger vessels could easily be found, because the population of fishermen increased as a part of the explosive increase of national population, caused by the rise of living standards through industrialization of the country. Nowadays, the fishing industry faces problems of conservation of fish resources, exploration of new markets, and acquisition of necessary labour, as well as maintenance of a reasonable profit. These complex problems lead to a conclusion that fishing operations should be restricted to a limited number of the most efficient boats.

MECHANIZATION OF SMALL FISHING CRAFT

The progress of mechanization in the past ten years is shown in fig 1. The steady progress reflects the fact that there was a limit on the speed of mechanization. This limit was set by the size of fish resources and the market,
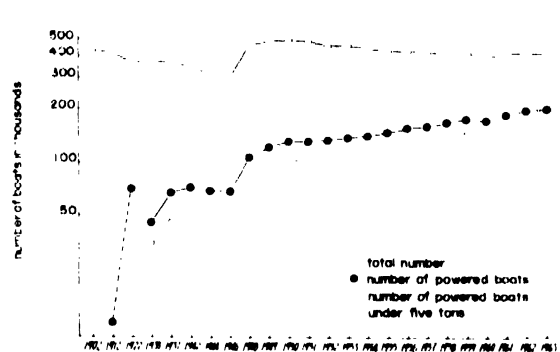
Fig 1. Mechanization of Japanese fishing boats

and if mechanization progressed beyond the limit, the whole fishing fleet might have faced bankruptcy. In some cases, however, mechanization of fishing vessels was done simply to retain the crew, as crews tend to move to better boats. This indicates that the problems are not only economic but social.

TABLE 1

Mechanization of fishing boats under 5 GT

	Year	Below 1 GT	1-3 GT	3-5 GT	Total
(1)	1953	23,412	67,798	15,031	106,241
(2)	1958	31,695	85,320	19,054	136,069
(3)	1963	43,840	99,858	23,986	167,684
Ratio (2)/(1)		1.38	1.26	1.26	1.28
Ratio (3)/(1)		1.87	1.47	1.60	1.58

Note: About 10,000 fishing craft equipped with outboard engines are excluded from the above table.

TABLE 2

Change of type of engines in powered fishing boats under 5 GT

		1953 (1)	1958 (2)	1963 (3)	Ratio (2)/(1)	(3)/(1)
0–0.9 GT	D	364	4,291	20,296	11.78	55.75
	H	8,065	807	384	0.10	0.05
	E	21,967	26,597	23,160	1.21	1.05
1.0 2.9 GT	D	5,450	26,031	70,551	4.77	12.97
	H	13,219	12,113	4,768	0.91	0.36
	E	49,129	47,176	24,539	0.96	0.49
3.0–4.9 GT	D	2,251	5,930	16,910	2.63	7.56
	H	9,295	10,571	6,047	1.14	0.65
	E	3,485	2,553	1,027	0.73	0.29

Note: D - diesel engine; H hot bulb engine; E - electric ignition engine

Most of the vessels over 5 GT in Japan have already been mechanized with diesel inboard engines. Therefore the non-powered vessels in fig 1 are vessels under this size and the number of such non-powered craft is still half the total number of the whole fleet. The progress of mechanization therefore, is best observed when fishing craft under 5 GT only are discussed (table 1).

Types of engines produced in Japan are diesel, hot bulb and electric ignition engines. Electric ignition engines are most popular among small vessels under 5 GT, followed by hot bulb engines and diesel engines.

In these ten years, diesel engines increased for all sizes of vessels, 0 to 0.9 tons, 1.0 to 2.9 tons and 3.0 to 4.9 tons. The hot bulb engine increased only for the range 3.0 to 4.9 tons, and electric ignition engines for the ranges 1.0 to 2.9 and 3.0 to 4.9 tons (table 2). Table 3 shows the average size of a family fishing unit, while table 4 gives the average balance sheets for these units. Table 4 shows that fishermen with non-powered vessels earn much less than fishermen with powered vessels.

The percentage of earning from fishing is also less for fishermen with non-powered vessels and therefore they must have other incomes from other businesses. It is also indicated that the larger boats earn more. However, the heavy initial investment for powered vessels, especially for larger vessels, should not be overlooked, and their mechanization is often not justified.

Investment in equipment needs control to avoid over-investment, as with other industries. The tremendous number of family-owned vessels, however, makes such control difficult.

LOCATIONING OF VESSELS AND COMMUNICATION

Before radios were installed in fishing vessels, distant-water fishing was extremely risky. Now, distress calls can be made, medical advice for sick men obtained and bad

TABLE 3

Average size of a family fishing unit

		with non-powered boats			with powered boats under 3 GT			3 5 GT
		1961	1962	1963	1961	1962	1963	1963
Family members on board		1.0	0.8	1.0	1.6	1.6	1.5	1.8
Total family members		5.2	5.0	4.9	6.1	6.0	5.8	6.3
Fishing boats								
non-powered	No.	1.1	1.1	1.2	0.3	0.3	0.3	0.3
	GT	0.8	0.8	0.8	0.2	0.2	0.2	0.2
powered	No.	—	—	—	1.0	1.1	1.1	1.1
	GT	—	—	—	1.5	1.7	1.6	3.7

TABLE 4

Balance sheet for average size of a family fishing unit

	with non-powered boats £ ($)			with powered boats £ ($) under 3 GT			3-5 GT
	1961	1962	1963	1961	1962	1963	1963
Initial investment	165 (462)	180 (506)	197 (554)	510 (1,420)	620 (1,700)	645 (1,800)	1,370 (3,825)
Total annual earning	374 (1,046)	369 (1,032)	533 (1,490)	441 (1,233)	637 (1,780)	633 (1,770)	874 (2,445)
By fishing income (a)	159 (447)	244 (683)	267 (747)	533 (1,489)	652 (1,830)	703 (1,969)	1,595 (4,470)
running cost (b)	46 (128)	81 (228)	88 (247)	250 (700)	316 (886)	322 (902)	966 (2,705)
earning (a) (b)	113 (319)	163 (445)	179 (500)	283 (789)	336 (944)	381 (1,067)	629 (1,765)
Annual fish catch (ton)	2.59	6.08	5.05	7.36	7.63	7.63	20.27
Labour for fishing per year (man-hours)	867	865	1,394	2,132	2,754	3,610	6,517

weather avoided by using the radio. The radio gives information about fishing conditions on various fishing grounds, sea water temperature and even market prices of fish in different fish landing places.

Japan has an exclusive radio network for fishermen. Such a system was first established in 1921 and special frequencies allocated for fishing vessels. Radio shore stations were opened in fishing ports. In 1933 radio equipment became compulsory for all fishing boats over 100 GT. By 1942, 1,300 fishing boats had radios. After the war, radio telephones were installed on small off-shore fishing boats. Later VHF (very high frequency) radio telephones were installed aboard smaller boats operating in the coastal area. Table 5 shows the number

On the other hand, boats operating in coastal and pelagic fisheries are equipped with radio telephones with MW/SW bands of 10 watt to 1 kW capacity, depending on the distance between shore and fishing grounds. Operators of this type of telephone have to complete a vocational training course of at least 40 days. Telegraph operators of lower grade have to have a 6-month training course. These two types of operators should have a licence.

Navigation equipment, such as direction finder, radar, loran and facsimile are installed aboard ocean-going boats. Radio buoys are also popular. More than 9,000 of such buoys are now in use to locate killed whales, longlines and drift nets. These radio buoys are also put aboard inflatable life rafts.

TABLE 5

Fishing boats with radios

| GT | 1961 | 1962 | 1963 | 1964 | Breakdown 1964 | |
					Telegraph	Telephone
0–4	656	987	1,154	1,561	0	1,561
5–9	563	842	1,049	1,322	1	1,321
10–19	2,791	2,931	2,800	2,687	13	2,674
20–49	3,499	3,779	4,004	3,873	526	3,347
50–99	3,267	3,522	3,467	3,427	1,707	1,720
100–499	905	927	1,071	1,276	1,217	59
500 and over	177	250	157	237	237	0
Total	11,858	13,238	13,702	14,383	3,701	10,682

of radios installed in fishing boats from 1961 to 1964. As VHF radio telephones become popular there will be a continuous increase in the number of fishing boats under 10 GT equipped with radios. The VHF telephone has a 27-megacycle band and an output of 1 to 10 watts. Now about 3,900 vessels are equipped with such VHF radio telephone sets.

Some of the boats in table 5 have VHF telephones as an auxiliary to a larger capacity radio for pelagic fisheries. One disadvantage of VHF is that it cannot cover a large area. There are 217 shore stations used exclusively for fishing vessels, 108 of which serve those boats with VHF radios. The licence to operate VHF radios aboard fishing boats, and licence to operate VHF telephone sets is obtained by attending a vocational training course of about one week.

DETECTION OF FISH

Fish finders are used extensively on board fishing boats regardless of size, and were originally simple echo sounders to measure depth. Later on they were used on skipjack pole-and-line vessels to detect reefs where fish schools were found. From about 1947, fish finders were installed on purse-seiners to locate fish schools. Fish finders became very popular after the Fishing Boats Research Laboratory made a systematic analysis of frequencies from 14 to 200 kc/s and made several models to cover shallow waters to deep seas. With visual information on hand, the fishing activity has become extremely efficient. Table 6 shows the numbers of fishing vessels with fish finders. Some vessels have two or more units.

TABLE 6

Fishing boats with fish finders

GT	1959	1962
0–5	1,729	2,652
5–9	971	1,249
10–20	2,392	2,632
20–50	2,267	3,045
50–100	1,838	2,365
100–200	311	309
200–500	269	441
500 and over	60	110
Total	9,837	12,803

TABLE 7

Comparison of boatbuilding costs with electronic equipment costs £ ($)

Class	Hull	Engine		Radio (1)	Fish finder (2)	Total (3)	(1) + (2) (3)
3 GT	420 (1,175)	440 (1,230)			150 (420)	1,010 (2,830)	0.15
5 GT	725 (2,030)	640 (1,790)			150 (420)	1,515 (4,250)	0.10
15 GT	2,400 (6,720)	1,500 (4,200)	250 (700)	200 (560)	150 (420)	4,500 (12,600)	0.80
30 GT	5,500 (15,400)	4,200 (11,750)	580 1,625	700 (1,960)	300 (840)	11,330 (31,250)	0.09

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TABLE 8—*continued*

(2) tuna longline fishing boats
(a) L - 12,350-13,250 ft³ (350-375 m³)

Period and no. of vessels involved		1930-1940 (1)	1941-1950 (0)	1951-1954 (14)	1955-1958 (33)	1959-1963 (13)
GT/LBD	ft³	0.00730	—	0.00755	0.00750	0.00768
	m³	0.258		0.267	0.265	0.271
hp/LBD	ft³	0.0154	—	0.0201	0.0232	0.0265
	m³	0.546		0.711	0.818	0.936
NC/LBD	ft³	0.00139	..	0.00181	0.00181	0.00181
	m³	0.049		0.064	0.064	0.064
hp/GT		2.11		2.67	3.09	3.45
FH/LBD		0.244	—	0.286	0.266	0.259
FO/LBD		0.071		0.103	0.101	0.094
FH/FO		3.43	--	2.79	2.62	2.75
FO/hp	ft³	4.59	—	5.08	4.38	3.53
	m³	0.130		0.144	0.124	0.100
Δ_i/LBD	ft³	0.00860	-	0.00930	0.0102	0.0104
	m³	0.304		0.328	0.358	0.367
Δ_d/LBD	ft³	0.0138	--	0.0172	0.0179	0.0175
	m³	0.487		0.607	0.630	0.619

(b) L = 13,250-14,200 ft³ (375-400 m³)

Period and no. of vessels involved		1930-1940 (0)	1941-1950 (4)	1951-1954 (7)	1955-1958 (25)	1959-1963 (4)
GT/LBD	ft³	—	0.00725	0.00731	0.00722	0.00737
	m³		0.256	0.258	0.255	0.260
hp/LBD	ft³	—	0.0176	0.0192	0.0228	0.0256
	m³		0.622	0.677	0.807	0.903
NC/LBD	ft³	—	0.00221	0.00162	0.00167	0.00170
	m³		0.078	0.057	0.059	0.060
hp/GT			2.43	2.63	3.16	3.46
FH/LBD		—	0.268	0.265	0.275	0.254
FO/LBD		--	0.075	0.083	0.104	0.085
FH/FO		—	3.56	3.19	2.65	2.99
FO/hp	ft³	—	4.27	4.30	4.52	3.22
	m³		0.121	0.122	0.128	0.094
Δ_i/LBD	ft³	—	0.0102	0.00910	0.00950	0.0102
	m³		0.358	0.321	0.335	0.360
Δ_d/LBD	ft³	—	0.0178	0.0161	0.0172	0.0172
	m³		0.628	0.566	0.606	0.607

39-GT type wooden skipjack and tuna boats

These types of vessels appeared in 1957 when the Government regulation excluded tuna boats under 40 GT from the licence restriction. One reason why vessels excluded from the fishing licence system were built in number was due to the system of transferring the licence from one individual to another. Because of the limited number of fishing licences, a fisherman who wished to add a vessel to his own fleet had to purchase the licence for such a vessel from another fisherman. The price of the licence therefore once became £360 ($1,000) per GT. This made the initial cost of licensed vessels almost double that of vessels out of the licence system. Another reason was the fact that such a small vessel as 39 GT could still find fishing grounds for fairly profitable operation.

Fifteen hundred such vessels have been built over a short period. Lack of safety was a great difficulty in this type of vessel. The Pacific around Japan can be rough in winter and this type of boat figured prominently in many disasters. The story of 39-GT tuna boats may be summarized as follows. A fisherman found this size of

TABLE 9

Change of particulars of 95-GT type wooden skipjack and tuna boats

(1) skipjack/tuna pole-and-line fishing boats

(a) LBD 12,350–13,250 ft³ (350–375 m³)

Period and no. of vessels involved		1930–1940 (5)	1941–1950 (3)	1951–1954 (21)	1955–1958 (15)	1959–1963 (8)
LBD	ft³	12,950	12,950	12,980	12,880	12,910
	m³	367	367	368	365	366
GT		98.85	93.96	98.36	98.91	98.93
NC		47.4	60.0	55.8	49.2	49.6
hp		197	207	267	296	338
FH	ft³	3,035	3,035	3,035	2,860	3,110
	m³	86	86	86	81	88
FO	ft³	670	742	882	847	812
	m³	19	21	25	24	23
Δ_1		119	108	125	130	132
Δ_d		210	206	214	209	225

(b) LBD 13,250–14,150 ft³ (375–400 m³)

Period and no. of vessels involved		1930–1940 (12)	1941–1950 (12)	1951–1954 (12)	1955–1958 (5)	1959–1963 (4)
LBD	ft³	13,540	13,590	13,450	13,470	13,510
	m³	384	385	381	382	383
GT		98.01	98.22	99.18	99.36	99.42
NC		56	51	52	47	48
hp		200	231	268	322	343
FH	ft³	3,140	3,250	3,070	3,140	3,280
	m³	89	92	87	89	93
FO	ft³	812	742	812	883	883
	m³	23	21	23	25	25
Δ_1		116	117	128	138	142
Δ_d		213	214	215	236	232

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TABLE 9—*continued*

(2) tuna longline fishing vessels

(a) LBD — 12,350 13,250 ft³ (350-375 m³)

Period and no. of vessels involved	1930–1940 (1)	1941–1950 (0)	1951–1954 (14)	1955–1958 (33)	1959–1963 (13)
LBD ft³	12,970	—	12,970	12,870	13,000
m³	367		367	364	368
GT	94.71	—	97.91	96.57	99.96
NC	18	—	23	23	24
hp	200		261	298	345
FH ft³	3,140	—	3,710	3,430	3,360
m³	89		105	97	95
FO ft³	917	—	1,340	1,305	1,235
m³	26		38	37	35
Δ_1	111	—	121	130	135
Δ_d	178	—	223	230	228

(b) LBD — 13,250-14,150 ft³ (375 400 m³)

Period and no. of vessels involved	1930–1940 (0)	1941 1950 (4)	1951–1954 (7)	1955–1958 (25)	1959 1963 (4)
LBD ft³	—	13,630	13,650	12,980	13,480
m³		386	387	368	382
GT	—	98.81	99.69	98.52	99.50
NC	—	25	21	23	23
hp	—	240	262	312	345
FH ft³	—	3,640	3,600	3,740	3,430
m³		103	102	106	97
FO ft³	—	1,023	1,160	1,420	1,165
m³		29	32	40	33
Δ_1	—	138	124	129	137
Δ_d	—	242	218	239	232

[64]

Table 10

Change in design parameters of 39-GT type wooden skipjack and tuna boats

(1) tuna/skipjack pole-and-line fishing boats

Year and no. of vessels involved		1957	1958	1959 (3)	1960	1961 (10)	1962 (9)	1963 (4)	1964 (8)
GT/LBD	ft³	—	—	0.00638	—	0.00633	0.00630	0.00638	0.00641
	m³			0.226		0.224	0.223	0.226	0.227
hp/LBD	ft³	—	—	0.0245		0.0276	0.0283	0.0337	0.390
	m³			0.868		0.975	1.053	1.192	1.382
NC/LBD	ft³	—		0.00605	—	0.00574	0.00586	0.00506	0.00515
	m³			0.214		0.203	0.207	0.179	0.182
hp/GT		—	—	3.84		4.32	4.71	5.27	6.07
FH/LBD		—		0.286		0.255	0.267	0.270	0.278
FO/LBD				0.038		0.050	0.051	0.056	0.059
FH/FO				7.53		5.07	5.00	4.82	4.68
FO/hp	ft³	—	—	1.518		1.835	1.695	1.625	1.518
	m³			0.043		0.052	0.048	0.046	0.043
Δ_1/LBD	ft³			0.010		0.0110	0.0112	0.0115	0.0112
	m³			0.354		0.391	0.397	0.407	0.396
Δ_d/LBD	ft³		—	0.0175		0.0193	0.0168	0.0171	0.0192
	m³			0.618		0.683	0.598	0.603	0.678

(2) longliners

Year and no. of vessels involved		1957 (9)	1958 (13)	1959 (20)	1960 (64)	1961 (62)	1962 (26)	1963 (12)	1964 (15)
GT/LBD	ft³	0.00680	0.00662	0.00667	0.00633	0.00622	0.00630	0.00627	0.00627
	m³	0.241	0.234	0.236	0.224	0.220	0.223	0.222	0.222
hp/LBD	ft³	0.0180	0.0213	0.0254	0.0250	0.0266	0.0280	0.0312	0.0334
	m³	0.637	0.755	0.898	0.884	0.942	0.991	1.102	1.180
NC/LBD	ft³	0.00294	0.00297	0.00294	0.00280	0.00280	0.00283	0.00280	0.00269
	m³	0.104	0.105	0.104	0.099	0.099	0.100	0.099	0.095
hp/GT		2.67	3.50	3.78	3.95	4.29	4.46	4.95	5.32
FH/LBD		0.274	0.293	0.278	0.258	0.246	0.256	0.217	0.223
FO/LBD		0.059	0.077	0.080	0.080	0.075	0.076	0.068	0.079
FH/FO		4.64	3.69	3.48	3.21	3.27	3.35	3.20	2.83
FO/hp	ft³	0.00257	0.00266	0.00252	0.00257	0.00226	0.00215	0.00175	0.00190
	m³	0.091	0.094	0.089	0.091	0.080	0.076	0.062	0.067
Δ_1/LBD	ft³	0.00992	0.00966	0.0111	0.0109	0.0108	0.0110	0.0115	0.0117
	m³	0.351	0.342	0.392	0.385	0.384	0.389	0.409	0.417
Δ_d/LBD	ft³	0.0163	0.0176	0.0188	0.0185	0.0182	0.0186	0.0185	0.0188
	m³	0.588	0.623	0.664	0.654	0.645	0.659	0.655	0.666

boat could be profitable and many others followed his idea but incorporated a lot of additional requirements in design. The first fisherman could not compete with others, as the design of his boat became out of date, and thus he was forced to follow the new trend. The majority of these vessels were extremely unsafe because of the fishermen's demands for maximum hold space. Table 10 shows how the design of these boats has been changed.

GT/LBD: This parameter has not changed in the past seven years, indicating that the principal dimensions of this type of boat have remained constant.

hp/LBD, hp/GT, FO/LBD, FH/LBD: These parameters have conspicuously increased, indicating that fishermen wanted to increase engine output. Increase of horsepower means increased fuel oil tank capacity. Need for better refrigeration and insulation systems for extended fishing trips also decreased hold capacity. In spite of the fact that the fuel oil tank capacity was increased, the amount of fuel oil was often not sufficient

and a system of carrying fuel oil in a huge plastic bag in the fish hold was devised. This led to unsafe vessels due to movement of liquid in the fish hold.

Δ/LBD: The light weight of the boats increased by 15 per cent in seven years. The weight of the departure condition also increased by 10 per cent over seven years.

Influence of restriction on the design of vessels in the past

Mechanization of fishing craft for better productivity is a common slogan all over the world. Once mechanization starts, the productivity of fishing operations will certainly increase, and soon boat size will be enlarged. The problem of either market or natural resources, or even both of them at the same time, will then have to be faced gradually. The Government then starts to establish regulations, first to limit the number of vessels and then the size of individual vessels.

Fishermen try to survive under such restrictions and this leads to unreasonable design of fishing vessels and results in loss of fishermen's lives. This is especially true when the industry is supported by cheap labour based on a dense population, as automation of fishing operations does not contribute to the economy of fishing operations. Under such circumstances, better productivity simply means increase of production. This has long been the specific feature of mechanization of fishing craft in Japan.

LACK OF LABOUR AND NEW STAGE OF MECHANIZATION

Decrease of fishing population

In the past ten years, the Japanese economy has developed rapidly. The rate of increase of industrial production has been more than 10 per cent every year. The rate is estimated at about 8 per cent for the coming five years, according to the economic plan made in 1964. This indicates that demand for labour has been large and it will remain large in future.

The fishing population has been greatly absorbed into

TABLE 11

Change of particulars of 39-GT type wooden skipjack and tuna vessels

(1) tuna/skipjack and pole-and-line fishing boats

Year and no. of vessels involved		1957	1958	1959 (3)	1960	1961 (10)	1962 (9)	1963 (4)	1964 (8)
LBD	ft³	·	·	6,220	—	6,250	6,280	6,220	6,140
	m³			176		177	178	176	174
GT		·	—	39.87	—	39.70	39.73	39.80	39.51
NC		—	—	38	—	36	37	32	32
hp		—	—	153		172	187	210	240
FH	ft³	—	—	1,770	—	1,590	1,695	1,695	1,695
	m³			50		45	48	48	48
FO	ft³	—	—	233	—	315	318	350	364
	m³			6.6		8.9	9.0	9.9	10.3
Δ_1		—	—	62	—	70	71	72	69
Δ_d		—	·	109	—	121	106	106	118

(2) longliners

Year and no. of vessels involved		1957 (9)	1958 (13)	1959 (20)	1960 (64)	1961 (62)	1962 (26)	1963 (12)	1964 (15)
LBD	ft³	5,780	5,970	5,900	6,270	6,350	6,350	6,320	6,320
	m³	164	169	167	178	180	180	179	179
GT		39.66	39.64	39.41	39.70	39.73	39.86	39.78	39.65
NC		17	18	19	18	18	18	18	17
hp		106	139	150	157	170	178	197	211
FH	ft³	1,590	1,695	1,620	1,620	1,550	1,550	1,380	1,410
	m³	45	48	46	46	44	44	39	40
FO	ft³	340	460	470	500	480	480	430	500
	m³	9.6	13.0	13.3	14.1	13.5	13.5	12.1	14.1
Δ_1		58	58	65	68	69	70	73	75
Δ_d		97	105	111	116	116	118	117	119

Fig 2. Annual percentage decrease in fishermen

Fig 3. Variation in coastal and pelagic fisheries

TABLE 12
Trends of fisheries labour

	1961	1962	1963	1964
Coastal fishery*	509,000	491,000	469,000	446,000
Pelagic fishery †	214,000	208,000	198,000	180,000
Total: ‡	723,000	699,000	667,000	626,000

* fishery with under 10-ton fishing boats
† fishery with boats of 10 tons and over
‡ includes those who are engaged in fisheries more than 30 days a
year or those who earn more than half of their annual income from
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12, which indicates that the decrease in the fishing
population is larger for pelagic than for coastal fisheries.
This decrease was slower from 1956 to 1961 than from
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in decrease of pelagic fishermen between these two
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pelagic fisheries are employees of vessel owners and
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coastal fisheries are operated mainly by family labour
and these workers cannot change jobs as easily as
pelagic fishermen.

Decrease in the number of fishing enterprises
Decrease of labour in fisheries resulted in decrease in the
number of enterprises, as shown in table 13. The rate of
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This decrease in the number of enterprises is analysed in
respect of size of fishing vessels, and it is clear from fig 2
that there is a decrease in the number of enterprises
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pelagic fisheries happened because of the decrease of
enterprises operated with small fishing vessels under
200 GT, as shown in fig 3. This figure also shows that
in spite of the decrease in the total number of enterprises
both in coastal and pelagic fisheries, coastal enterprises
with small power craft and pelagic enterprises with large
vessels over 200 GT have increased.

TABLE 13
Number of enterprises

	1961	1962	1963	1964
Coastal fishery	225,200	222,100	218,200	212,900
Pelagic fishery	9,600	9,300	8,800	8,400
Total:	234,800	231,400	227,000	221,300

Economy of coastal fishermen
As already mentioned, the decrease in the number of
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Table 15 shows that a decrease of labour has been
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prises with vessels over 100 GT, than those operating
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Fig 5. Economic efficiency of pelagic fishermen

c 2

and a system of carrying fuel oil in a huge plastic bag in the fish hold was devised. This led to unsafe vessels due to movement of liquid in the fish hold.

Δ/LBD: The light weight of the boats increased by 15 per cent in seven years. The weight of the departure condition also increased by 10 per cent over seven years.

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[66]

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Fig 5. *Economic efficiency of pelagic fishermen*

[67]

TABLE 14

Economy of an average family fishing unit in coastal fishery

		1958	1961	1964
(1) Persons engaged		2.2	2.0	1.9
(2) Employees (non family member) included in the above figures		0.7	0.6	0.5
(3) Working hours on board per person		1,834	1,741	1,788
(4) Fixed capital investment	£	249	271	372
	($)	(697)	(758)	(1,040)
(5) Earning	£	282	329	490
	($)	(788)	(920)	(1,370)
(6) Productive index (5)/(4)		1.132	1.214	1.317
(7) Earning per person	£	128	136	196
	($)	(359)	(380)	(548)

Note: Earning = (income) – (cost of fuel oil, ice and bait)
= profit + wage + interest + depreciation
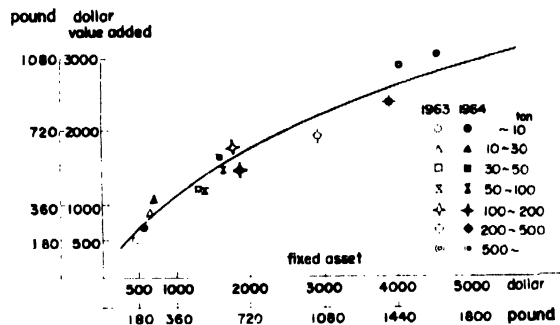
Fig 6. Relation of fixed asset and value added per person

Future of fishing industries

From tables 14 and 15, it is found that (1) productive index is larger when the scale of enterprise is smaller; however, (2) absolute value of *per capita* earnings is greater in large enterprises. If the wage amount could be reduced, there is more possibility of making a large profit in large-scale enterprises. Fig 6 shows the relation between fixed capital investment per person and value added per person.

Tables 14 and 15 also show that in a specific size of

enterprise, it is possible to increase *per capita* earnings without decreasing productive index. This is most true when either mechanization of fishing vessels enables the number of crew to be decreased, or when increased production is possible.

Effort should be applied to both decreasing the crew and increasing production. In Japan the attention of fishermen has been concentrated in the past on how to increase production. However, they are now forced to pay more attention to how to decrease the number of crew. Such a change in fishing operations has happened in Japan not because of the intention of fishermen, but because of the shortage of labour.

Anything which could save labour should be adopted; for example, remote control systems governing engines and propellers, synthetic fibre fishing nets and plastic hulls which save labour on maintenance. It is also important to organize co-operatives so that small-scale operations can be changed into large-scale enterprises. The importance of mechanization to save labour is further shown by the results of the Fisheries Census in 1953 and 1963. Fig 7 shows that a large number of young people were engaged in fisheries in 1953 but the age pattern of fishermen has changed drastically in 1963.

The future of the Japanese fishing industry depends entirely on whether mechanization can overcome the shortage of labour.
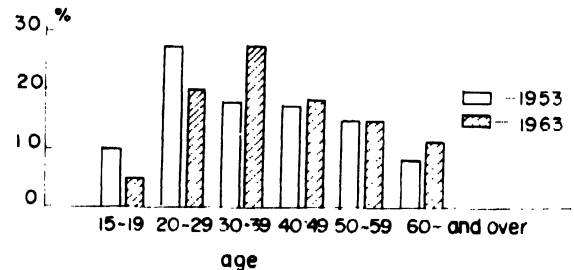
Fig 7. Age distribution of fishermen

TABLE 15

Economy of an average pelagic fishing enterprise

		1958	1959	1960	1961	1962	1963	1964
1. Persons engaged								
10–99 GT		14.7	14.4	14.4	13.8	13.0	13.0	12.5
over 100 GT		32.5	31.1	29.2	30.0	29.1	27.6	27.7
2. Fixed capital investment								
10–99 GT	£	4,611	5,791	6,223	6,389	6,175	6,822	7,293
	($)	(12,890)	(16,210)	(17,410)	(17,890)	(17,300)	(19,090)	(21,000)
over 100 GT	£	53,253	58,727	53,941	57,167	65,547	73,757	79,856
	($)	(149,100)	(164,400)	(150,700)	(159,900)	(183,700)	(206,500)	(223,500)
3. Earning								
10–99 GT	£	3,976	4,176	4,660	5,525	5,978	6,338	6,405
	($)	(11,130)	(11,700)	(13,040)	(15,460)	(16,740)	(17,740)	(17,930)
over 100 GT	£	30,567	35,998	42,687	42,867	46,886	50,512	49,335
	($)	(85,300)	(100,600)	(119,300)	(119,900)	(131,400)	(141,400)	(138,200)
4. Productive Index (3/2)								
10–99 GT		0.862	0.720	0.750	0.865	0.968	0.929	0.879
over 100 GT		0.573	0.613	0.791	0.752	0.715	0.684	0.618
5. Earning per person								
10–99 GT	£	270	290	324	400	460	488	513
	($)	(757)	(812)	(907)	(1,120)	(1,288)	(1,366)	(1,435)
over 100 GT	£	940	1,155	1,460	1,430	1,610	1,830	1,780
	($)	(2,630)	(3,230)	(4,100)	(4,000)	(4,520)	(5,125)	(5,000)

Discussion: How technical, social and economic conditions influence the design of fishing craft

INDIGENOUS CRAFT DEVELOPMENT

Stoneman (Uganda): Uganda is a small East African nation about the size of France, where the fishing industry has been of importance since before contact with Europeans in about 1860. Fishing takes place on 13,000 square miles (33,000 km²) of freshwater lakes, rivers and swamps and has always been of considerable importance.

Before the European influence fishing was by means of baskets, traps and spears. Seine and gill nets were introduced in about 1925, but little major development took place in the industry until 1949. In this year when the total annual production was about 10,000 tons of fish per year a Fisheries Department was established as a technical branch of the Game Department and a definite effort was made to increase production. At that time fishing was undertaken by few specialized tribes of Ugandans, markets were also specialized and localized and there were many taboos against eating fish by non-fishing tribes. Transport of fish catches from the lakes was difficult and localized markets restricted fishing effort to areas within close reach of the landings.

The pattern of the industry was obviously that of a very primitive under-developed industry.

Fishing boats and canoes in use varied very little from 1860 until 1949. Types were the primitive dug-out canoes up to 40 ft (12·2 m) long by 4 ft (1·2 m) beam, hollowed from logs

Fig 1. Primitive dug-out canoes used on Lake Victoria

(fig 1) and the "Sesse" canoes of Lake Victoria (fig 2) which were of African origin but owed much to the Arab influence from the East African Coast. The "Sesse" canoe is made of four planks sewn with palm fibres in a hard-chine configuration on a rudimentary dug-out keel member. At one time these canoes were 70 to 80 ft (21 to 24 m) long war canoes used by the Ugandan Tribes in their inter-tribal warfare but since 1910, they have become purely fishing boats, now 28 ft (8·5 m) long, open fishing craft.

Seaworthy but shortlived

They were propelled only by paddles or poles, in very few cases sails being used on Lake Victoria. The costs of these canoes in 1949 were: dug-out canoes between £20 to £50 ($60 to $140), "Sesse" canoes £40 ($110). They were rarely paid for in cash, the builders being housed and fed by the

canoe owner during the construction. These canoes had many disadvantages and were unsuited to anything more than the purely local fishing which was then the pattern. The dug-outs were long-lived, but unstable, dangerous in rough water and of small carrying capacity. The "Sesse" canoes, while seaworthy, and effective craft were very short lived, the poor

Fig 2. Sesse canoes of Lake Victoria

timber and sewn construction that were used restricting their life to about three years. Many of the East African lakes are large, subjected to severe storms and bad weather and many of the best fishing grounds lie well off shore. Some 4,000 to 5,000 of these boats were in use in 1949.

Unlike the position in many other tropical countries, the Ugandan fishermen have always been completely independent, own their own canoes, and fish in their own right, never being tied to an on-shore moneylender as often happens elsewhere. However, their economy was based very little on cash, the crews working for a fish salary and the catch often being bartered for food by the canoe owner. Boats worked intermittently and canoe owners would stop fishing to take part in other activities such as cotton harvesting etc. Catch per boat in these days was of the order of 10 tons per year, then valued at some £40 ($110) per ton on the lake side.

The typical pattern of fishing activity was for the canoe owner and crew to work for one to two months building up a stock of salt or dried fish, which would then be sold or traded for food, after which the owner and crew would stop fishing until economic necessity forced them back on to the lake. This meant that canoe owners were not eligible for normal commercial credit as they could offer no security or regular income.

After the formation of a Fisheries Department in 1949 a great deal of work was done to develop the fishing industry, improved types of gear were introduced, communications to the lake-shore and markets were improved, new markets were set up and generally production increased considerably.

Search for improvement

The need for improved boats was obvious to the Department and as a first step three or four different types of fishing boats were imported from overseas. In order not to try and advance too fast beyond the fishermen's ability to learn, imports were restricted to open boats up to 30 ft (9·1 m) long. These were powered with simple inboard engines. Boats from Scotland, Denmark and Hong Kong were imported by the

Department and demonstrated to fishermen. However, while successful fishing boats, these failed to suit conditions in Uganda, partly due to very high costs and to the lack of familiarity of Ugandan fishermen with motor driven craft. It had not been appreciated also that all fishing boats to be used in Uganda would have to be beached for maintenance and repair, as there were no slips or dry docks available to the fishing industry. It also appeared very rapidly that boats designed and built in Europe were most susceptible to wood

Fig 3. Kabalega boats—an improved Sesse canoe

rot in Ugandan conditions and, in fact, most of the imported boats were useless from this cause within twelve months.

In 1954 it was realized that a new approach was needed. By this time a number of outboard motors had been used in Uganda on traditional "Sesse" canoes and had proved popular with fishermen and most efficient in the field. While delicate and difficult to maintain the outboards could readily be taken to a major town for repair and overhaul and, in fact, many fishermen found it convenient to own two outboards, one on the boat working, one away in the repair shop

Fig 4. Kabalega boats under power on Lake Victoria

being overhauled. Despite other faults the outboards certainly appeared to be the immediate answer in Ugandan conditions. It was, therefore, decided to encourage outboard driven fishing craft and to attempt to make these boats in Uganda from local materials. In this way a suitable boat could be evolved and costs could be kept to the minimum.

A training scheme for boat builders was started in Uganda, training being given by expatriate experts whose first task was to evolve a prototype boat suited to Ugandan conditions. This was to be a 20 to 30 ft (6 to 9 m) open wooden boat, outboard driven. As a first step a modified "Sesse" canoe was designed and built in mahogany timber and copper fastened throughout, in accordance with good European practice, on sawn frames. This type of boat known as the "Kabalega" boat proved extremely successful (fig 3 and 4). It was later modified to a round bilge clinker built craft, still outboard driven. In 1956 a commercial boat building firm designed a

slightly different type of modified "Sesse" canoe known as the "Nyanza" canoe, also a hard chine "Sesse" type, again

Fig 5. Nyanza canoe—being also a modified Sesse canoe

built in accordance with good European practice (fig 5). Both of these types of craft proved to be easily built by Ugandan boat builders and successful in Ugandan conditions. Prices were higher than for locally built craft, the "Kabalega" boat costing £170 ($475) and the "Nyanza" canoe £100 ($280). Both types of boat were properly finished with paint and preservative and had a life under good conditions exceeding 10 years.

Having evolved a suitable type of boat it was necessary to get it adopted by the industry and at first there was a good deal of resistance by fishermen to these boats. They had noted and remembered the unsatisfactory, very expensive, imported craft and were distrustful of another innovation. They also found it difficult to raise even the fairly small amount of capital needed for these two new improved boats. Even where individual fishermen could raise the money required they could not visualize the advantage from the new boats being great enough to justify the extra expenditure over the traditional type.

Financial aid

As this question of finance appeared a major stumbling block the Fisheries Department adopted an Agricultural Credit Scheme which had been designed to assist progressive farmers, and made it applicable to the fishing industry. The Government sponsored Uganda Credit and Savings Bank made loans to progressive farmers and traders and this scheme was extended to cover progressive fishermen. On the recommendation of a Fisheries official suitable fishermen were eligible for a 100 per cent loan from the Credit and Savings Bank, secured by nothing more than the boat and engine which this loan would buy. This was a much more favourable type of contract than any available from commercial banking institutions, even if a fisherman could secure these.

On this basis the first two boats to be built were sold to fishermen. These first two boats succeeded even better than had been hoped by the Fisheries Department and very rapidly made large profits for the first two owners. The example was taken by the rest of the fishing community, and some 60 boats were sold in the first eighteen months of the scheme. New powered boats proved much more effective fishing vessels than old type canoes and were also used as fish carriers, ferries and so forth.

Encouraged by this start many more loans were approved and granted and building of the improved boats continued apace. However, unfortunately, shortly after the scheme got into full swing the developments in Congo caused a slump in

one of the major markets for Uganda fish and, at the same time, a trade recession within Uganda caused a fall off in internal markets. This resulted in a considerable number of loan defaulters both amongst farmers, traders and fishermen. The Credit and Savings Bank had thus to suspend entirely its loans scheme and fishermen once more found that it was impossible to obtain finance for buying new canoes.

Despite this development, however, the loan scheme had done very valuable work and had demonstrated to fishermen throughout Uganda the necessity of better boats for efficient exploitation of the fishery, and the advantages of the improved boats were now widely recognized by fishermen. A disturbing factor had appeared, however, in the boatbuilding programme in that many of the improved canoes were not being maintained and were failing and deteriorating long before they should have done. This was partly due to poor maintenance by the canoe owners in trying to treat their new boat as they had their old dug-out canoe (i.e. providing no maintenance whatsoever) and also partly due to poor construction by boat builders who cashed in on the wave of rapid building of boats, and used cheaper inferior materials and hurried construction methods. This last problem could be and was met by a considerable drive by the Fisheries Department to ensure good standards of construction, and by education of fishermen to demand suitable timbers and construction methods in boats they bought. Finance, however, was still the major problem due to the failure of Ugandan fishermen to save or invest their money during good months to build new boats when the old was worn out, and there was still a back-log of conservative reluctance to spend more than the limit of £50 ($140) or so for the traditional old type of canoe.

Canoe subsidy scheme

To attempt to get away from the drawbacks of the loan scheme the Fisheries Department produced a new Fishing Canoe Subsidy Scheme. This again was an adaptation of an Agricultural Credit Scheme intended to subsidize tractors and so forth for farmers. Details of the Canoe Subsidy Scheme were based on similar schemes in UK, Canada etc. The scheme, which is in operation at the moment, permits the Department to give an outright subsidy of 33 per cent of the cost of new fishing boats which have been built in approved yards to approved standards. Strict control is exercised by the Fisheries Department on the applicants for this scheme and on the builders who are allowed to build to it. The amounts involved so far have been small—£1,000 ($2,800) in the first full year of the scheme, £2,000 ($5,600) in the second year which is 1964/5. Considerably larger sums have been estimated for in future years and the scheme will be applicable to much larger vessels than those at the moment under consideration. The scheme so far has been extremely successful and provided a considerable stimulus to both the fishing and boatbuilding industries.

From experience in Uganda it would appear that this is an extremely useful way of financing the improvement of fishing vessels in a small and very primitive fishing industry.

As has been said it was planned to produce the new fishing boats required within Uganda and it was obvious that in the end a fair volume of craft would be required. Traditional craft were and are made by local canoe builders, untrained men, and at one time the Fisheries Department attempted to convert these native craftsmen to the construction of new canoes. However, there was a great deal of reactionary, conservative objection to new boats by traditional builders, and this attempt had to be abandoned.

The prototype boats and the early production models were made in the Government training establishments concurrently with the training programme and at one time the sale of canoes to industry helped to finance the training schools. Eventually the schools began to produce about 10 trained boat builders per annum of which only 50 per cent were eventually absorbed into the boat building industry for various reasons.

All competent boatbuilders, these men had no training at all in business methods or organization, and there was no existing industry to which they could be apprenticed. For these reasons the Fisheries Department attempted to set up groups of these men as independent, small scale, boatbuilders in various centres, each year's off-take of boatbuilders being

Fig 6. Modern boatbuilding in Uganda

established in a different region. A typical firm would consist of four trained boatbuilders in partnership who were assisted to obtain loan capital up to approximately £500 ($1,400) by the Department. The Department also provided a boatbuilding yard, a simple open sided shed 60 by 30 ft (18 by 9 m) and housing for the boatbuilders. Departmental staff assisted with the ordering of supplies and materials, bookkeeping, sales and so forth. As would be expected such embryo firms needed two to three years very careful "nursing" by the Department before they could be considered independent and to date the failure rate is very high (33 per cent). The better firms have become firmly established independent entities, and have repaid all their loans and built up considerable stocks of materials and bank balances.
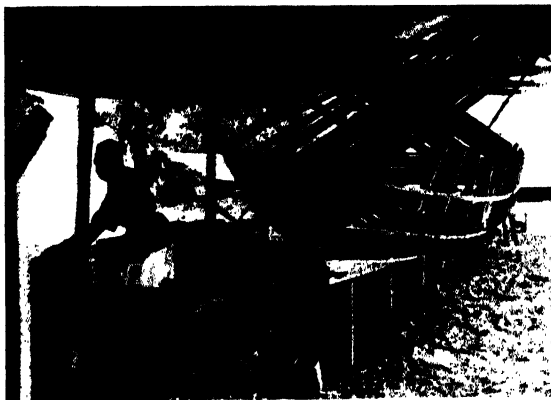
Fig 7. Self-financed boatbuilding in Uganda

Some five of these small firms are now established throughout Uganda and the better ones operate their own, self-financed hire purchase schemes to fishermen (fig 6 and 7).

Production of boats from such yards is now running at about 10 per month of which 60 per cent are subsidized

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vessels. Training continues and it is fairly clear that within a relatively short time Uganda will be in a position to construct all the improved type boats that will be used by the fishing industry.

Experience gained in Uganda may well be of value in other countries faced with a similar problem.

The major factors involved in bringing about this replacement in Uganda have been:

● Government assisted finance by means of loans and subsidies to fishermen for the purchase of new fishing boats   .
● The design of prototype craft suited to local conditions using local materials and keeping costs to a minimum
● Training and setting up local boatbuilders to produce these craft, again with the aid of Government finance

It should be recognized that certain conditions in Uganda were and are very favourable to this type of development and these should not be overlooked when a similar scheme is considered in another territory. Such conditions were:

● The independent nature of fishermen, and the tradition of self ownership and use of fishing craft
● The high level of employment and ability among fishermen enabling them to make good use of improved craft
● The very much greater power of improved craft ensuring great demand for them once this had been demonstrated

The success of the scheme can be judged by the number of improved boats now in use, approximately 400, coupled with the considerable year by year increase in fish production now (1965 figure) running at 72,000 tons per annum valued at £2.8 ($8) million.

North Atlantic problems

Danielsen (Switzerland): The following figures pertaining to the North Atlantic provide an illustration of the importance of the organizational problems of fishing boat operations:

● Labour costs on board: 35 50 per cent of turn-over
● Raw material cost: 60 70 per cent of factory cost
● Labour costs on shore: 10 15 per cent of factory cost

These figures speak for themselves and emphasize the fact that in the heavily increasing competition on the market, no pains must be spared in making the raw material supply, and thus the fishing boat operations, more effective.

The problems of manning the fishing fleet in the North Atlantic area have grown bigger every year, in spite of the fact that conditions on board have improved considerably.

In some places traditions have been preserved and the crew seems to have identified itself with its job and stayed aboard the same vessel year after year. Group feelings seem to have been very strong. This emphasizes the important role the skipper plays. An important factor may be that trips have been to distant waters (from the Western coast of Norway, to Greenland and to Newfoundland) and it may be that men, being together for such a long time—sharing what is good and what is bad—get a feeling of confidence in each other and in their skipper.

The conditions for the crew have improved over the last 40 years. One needs only to consider:

● The accommodation now and before World War II, where 30 men were sleeping in the same room, where they had their meals and where all their meals were prepared
● The working hours before were up to the skipper to decide upon. It was not unusual to work 20 hours a day during all the fishing time. Today, the working hours are in most cases limited to 12 hours a day
● The payment before was very poor compared with what other people were paid for their work. A fisherman was, in many cases, paid somewhere between 10 and 20 per cent of the payment given to salaried people (school teachers for instance). Today, the difference is very much less and in some cases fishermen are even better paid than school teachers

Altogether a considerable change for the better has taken place as regards fishermen, but in spite of this *manning problems have grown bigger and bigger and there are many examples of where it was not possible to man the boats at all.* In some areas in the North Atlantic, the "turnover" of fishermen during the last 15 years has increased up to 500 per cent. In many cases the boats have been under-manned or they have been out with a major part of the crew below the minimum quality level.

What is the reason for this development? The answer can be found in the following:

● The standard of living has, as a whole, increased considerably and there has been an evening out of the living standards between the most developed parts of a country and the "under-developed" parts of the same country (from this latter part the fishermen have normally come). There has been an increasing need for office clerks, construction workers, shop assistants, etc., and normally people have preferred this kind of work to being a fisherman
● Communications have improved. Shipping lines and motorways have been established. It has been easy for people to come from one place to another, and further travelling costs have been low compared with pre-war costs
● Education systems have been built up. All young people, independent of social status, have had the same possibilities as regards education. The scope of young people has increased and they have been looking for a job giving them the highest possible satisfaction and status in the society
● Technology has changed. Fish-handling is now being carried out partly on board the ship and partly on shore and the tendency has been towards more and more refined products. The need for factory workers has increased and this part of the business has taken many good fishermen

Modern boats have been designed and equipped with modern tools. But because of the changes in the environments, more should have been done as regards the training and education in order to make the job interesting and constructive for the crew.

Objectives in making the social design can be defined as follows:

● To obtain a more efficient crew
● To obtain a more stable crew
● To reduce the manning on board the boats

Work flow

In some countries a fresh-fish trawler is operated with 12 to 14 people (1 skipper, 1 mate, 2 engineers, 1 cook, 7–9 fishermen). The corresponding figure for other countries may be 22 men (1 skipper, 1 mate, 2 trawler bosses, 2 engineers, 1 cook, 1 mess and 14 fishermen). Why such a difference? In many cases the working methods and manning have been determined by the feelings, intuition, etc., and have been put down in the agreements between the fishermen's union and

the trawler owners. If time and method studies had been done, considerable inefficiency would in many cases have been revealed. This does not at all mean that it is not a hard and stressing life for the crew on board, but a better planning and a better synchronization of the jobs would, without doubt, have given considerable results.

Authority

The authority system on board has to be designed so that everybody feels he belongs to the vessel and feels he contributes to the objectives. The atmosphere is to be so that the people feel that they also have a say, that they also are important and that they themselves are equally *responsible* for the planning and performance of their job. The skipper must feel responsibility for the full utilization of the potentialities of his crew.

Evaluation

If people are given the opportunity to check (or better, review) their performance, they will feel challenged to improve it and to improve their standards. Goals must not be forced on people, as this will create a resistance or a position of self-defence, but the crew is to be given the opportunity to influence or participate in goal setting as this will increase their responsibility feeling and thus their performance.

In evaluating the individuals one has to take into consideration:

● Quality of work done
● Quantity of work done
● How the crew member is attending his work?
● Is he independent in his work?
● How is he performing his job?
● For how many jobs is he fit?
● Is he careful with the equipment, tools, etc.?
● Is he interested in his work?

Evaluation is normally a sensitive problem, but people usually like it, if it is done in the right way. Therefore there will be an incentive in the evaluation.

Remuneration

The salary system has to be so designed that the crew feels challenged to do a good job. In most countries today, working hours on board are limited to 12 to 14 hours a day. For these working hours and for staying away from family and home about 320 days a year, the fisherman receives in many cases a salary that is not very much better than he would have obtained working 7½ hours a day in the factory which he is supplying with raw material. This seems to be a typical "output approach".

Rewarded in accordance with the possibilities people have on shore, a fisherman's salary should be:

● Basic salary (corresponding to payment
  for 7½ hours work per day ashore)   –100 per cent
● Overtime payment   75 per cent
● Allowance for dirty and hard work   –– 10 per cent
● Deprivation allowance   — 15 per cent
                                          ———
                            Total   200 per cent

In some countries, fishermen really have an income that is about 200 per cent of the income possibilities on shore, but in other countries this is not so. For these countries, an adjustment in payment would result in an increase in the price of the raw material. The remuneration system must be redesigned, aiming at evening out this difference, and this must be done in such a way that *the fishing boat operators receive a compensation in an increased efficiency.*

In addition to:
  ● A fixed minimum salary normally determined by law and/or agreements between fishermen and boat owners
  ● A linear or progressive quantity bonus, and
  ● A progressive quality bonus,
there has to be some kind of a qualification allowance, giving an extra reward to those who are doing a better job than others.

If the crew is not satisfied with the financial reward, this will undermine and erode the responsibility that the crew has to take in order to reach peak performance. The attitude of the crew towards the salary question must not be to gain as much as possible without feeling any responsibility for quantity and quality of work done.

Communication

People must be told how they are expected to reach the objectives that have been stated. As fishermen are away a great deal of their time, special efforts must be made to create mutual confidence between the crew and other parts of the organization. Information about future activities, company's results etc, give security and congenial feelings, and confusion can thus be avoided.

The crew and the other parts of the organization must exchange ideas and trace their view points against the right objectives, the result of which will be optimum quality, quantity, etc. The enterprise needs ideas and support from all employees, also fishermen.

Identification

Everybody has heard about people who went to sea at the age of 14 and stayed with the same skipper until they bought their own boat, after which they chose their own crew members, who subsequently stayed with them for years until they again went aboard their own boat.

Why has a change taken place? Has the increase in the standard of living and technical progress been a threat to the development of fishing? A social class must be maintained with which the fishing people can identify themselves. This class must be recognized and the members of this class must be offered attractive conditions, so they feel proud of their class and feel challenged to belong to it.

The first impression which people get when joining an organization is very often the impression which will stay in their minds for ever and will be decisive for their career in the organization. Therefore, the enlisting procedure is of greatest importance and has to be organized as follows:

  ● Introduce a newcomer to his skipper and the other members of the crew
  ● Give him information about:
      a. How the rules for work on board are and eventually instructions for work;
      b. breaks;
      c. how he has to behave when the boat is in port;
      d. when and how his salary will be paid;
      e. questions in connection with agreements, etc
  ● Take him through all departments that he will be concerned with ashore. Show him all facilities of importance for him, such as cloak-rooms, wash-rooms, canteen, etc
  ● Give him the personnel handbook rules, etc
  ● Give him the opportunity and encourage him to meet crew members from other boats in order to exchange view points
  ● Give him a description of the organization. Information about the company's fringe benefits, etc

Frequent contact with the newcomer and frankness is necessary for overcoming misunderstandings.

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The conditions must be created so that the crew's personal goals can be identified with the company's goals. The crew must understand that their contribution to the company's objectives is maximized when their work is done in such a way that maximum output for the company as a whole is reached.

Perpetuation
The job of a fisherman has become less and less attractive. Fishermen are mostly coming from small places where the standard of living is low and where they have not had other possibilities for income other than fishing. Fishermen stay away from their homes for a long period, after which they are in port for a few hours, or maybe a couple of days. This problem could be minimized by having a spare watch so that the crew could be given the opportunity to stay ashore a part of the year.

Many young people come on board a fishing vessel, are given the worst jobs and nobody tells them how the gear works. This will give them an immediate unpleasant feeling and a feeling of not belonging to the vessel on which they have to stay. This could be improved by employing young people as apprentices and by giving them a training period of two to four years, after which they could be certified. The apprentice should be given the opportunity to move from boat to boat and of trying different working methods in order to get an all-round background for his future profession.

Certifying the crew might be in contradiction with the theories for "technical revolution". Many will say that the crew members should be looked upon as if they belonged to an "assembly line" and should in a few days be trained in making certain movements, etc. Perhaps the skipper does not need to know anything about fishing, ice and stream conditions, etc, the vessel could be directed from a computer in an office ashore. Just before leaving the port the skipper could be given some punch cards that he has to put into an auto-pilot and then he need not worry about what is happening, everything being done automatically.

Up to now, however, the success of a fishing vessel has been much dependent on the crew and especially the skipper, but as much as possible ought to be done to eliminate the importance of certain qualified crew members. Even if it will not be possible to get as far as using punch cards in connection with an auto-pilot, fishing boats ought to be mechanized so that the fewest possible people are needed aboard.

There must be good facilities for the people on board with all the necessary modern equipment. Living quarters aboard must be kept clean. Facilities must be arranged ashore so that the crew has access to newspapers, telephones, canteen, etc. Facilities have to be arranged for cleaning of personal clothes, bed linen, etc.

In the future one must not only be concerned with technical changes but also with psychological changes for both fishermen and administrators. People have to be trained and educated. Objectives have to be clearly stated. All details and information for reaching goals must be known. They must identify themselves with their work, their company, the remuneration system, quality standards, quantity standards, etc.

How to proceed? The following three points seem of major importance:

- Time and method studies in order to establish an efficient work flow
- Social architects have to study conditions on board, to get an idea how conditions can be improved, how much people can tolerate, how the crew could be better utilized, etc

- Social architects have to help crew and administrators to realize the need for changes and to help them overcome all obstacles in accepting them

The responsibility of the social architect is the following:

- To make the crew familiar with the ship, each other, changed methods, quality and quantity standards, etc
- To enable the crew to identify itself with the ship, skipper, group, company, etc
- To enable the crew to feel responsible for the tools they are dealing with and feel responsible for the results they will obtain
- To give them the feeling that this is their company, their ship, their work, "the best ship in the world" etc
- To create one group out of crew and administrators and to give this group the feeling that they are all "in the same boat" with the same objectives

Much work in the past has been spent on improving fishing vessels, methods of handling gear, mechanization, etc. But the right balance between technical standards and social standards on board has not been achieved. The results of further technical improvements will be lacking if the social design is not improved correspondingly.

Chapelle (USA): The naval architect engaged in a project of aid in the expansion of an underdeveloped fishery has a dual role, teacher and taught; teacher in boat building and design, taught in economic and social areas.

The economic factor is perhaps the more effective limitation. A lack of capital may be said to be the universal problem.

The success of the naval architect will depend upon his utilizing these limitations to the utmost. The effects of the economic factor will be most marked in the introduction of new building techniques, new gear and new materials.

The social aspects he will meet and understand as he goes, but the economic factor is the one that requires his prime attention.

Local Problems
Høgsgaard (Denmark): In Greenland there is a similar problem to those Hamlisch described. In earlier times, seal and whale fishing was the only fishing practised and hunters living in small settlements had to be persuaded to change from hunting to fishing.

In Scandinavia, the first engine was introduced to fishing boats in 1900 and in 1904 there was an exhibition at Marstrand, near Göteborg of both boats, engines and fishing gear. Thus long experience in Scandinavia could be applied to mechanization in Greenland. Two-stroke low compression oil engines were used and at first the open boats and then later the small cutters were mechanized. One of the most difficult problems was that the fishermen in kayaks were used to fishing close to the shore and had no experience of deeper sea fishing. Therefore, the fishermen had to be educated to go off-shore. In the Faroes, excellent fishermen with considerable experience of deep-sea fishing were available. Therefore, skippers from the Faroes were used on Greenland boats with a Greenland crew in such a way as to train the Greenland fishermen in off-shore fishing.

Experience in India
Gnanadoss (India): While complimenting Hamlisch on his masterful presentation of two very important aspects that affect the development of fishing, particularly in developing countries, Gnanadoss liked to make a few observations—mainly with reference to the impact these factors have had in fishery development in India.

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Improvement of marine fisheries by the mechanization and modernization of the fishing fleet and methods present more of sociological and economic problems than technological ones. For instance, one of the maritime states in India, the State of Madras, has a coastline of about 600 miles (1,000 km) with about 300 fishing villages spread out along the coast. The entire coast is mainly surf-beaten and harbour or berthing facilities for mechanized fishing vessels exist in only about five or six places. The fishermen all along this coast operate from catamarans or rafts made of logs of wood, and from small sailing canoes, which together number about 20,000. These have limited efficiency and have not been found to be quite suitable for mechanization.

Well, then, how could the lot of these fishermen be improved? A logical answer is to provide them with with mechanized fishing boats with modern fishing gear. Even assuming that this impossible task of replacing all the indigenous craft with modern fishing vessels is achieved, it would be possible to berth these boats only in a few centralized harbours. The bigger question is then--could the fishermen be induced to leave their home and move to a distant fishing harbour. This is really a human and sociological problem. In many cases, the fishermen refuse to improve their lot, rather than to leave their homes.

One of the likely solutions for this problem was to introduce a craft, which he could operate right from his beach -namely the beach or surf-boat. But the surf-boat, apart from its technical limitations on efficiency and safety, was also an expensive craft, well beyond the scope of the catamaran fisherman. Furthermore, if the surf-boats were to ultimately replace all the indigenous craft operating from the beaches, it would have involved such a phenomenal investment on a venture, whose ultimate success was not very definite. Therefore, in this case, the problem assumes a techno-economic character.

Yet another state in India, the State of Gujerat, has a predominantly non-fish eating population, although the seas off the State are foremost among the richest fishing grounds of India. In developing the fisheries of this area, the main problem has not been one of lack of technological knowledge. In fact this area has one of the finest types of indigenous boats which have been mechanized by just installing an engine in the existing craft. The problem is that of finding import markets for the fish outside the State, because of social and religious prejudices in the area where the fish are landed.

Consumer preferences based on culture and traditions is another factor which has greatly influenced the development of fisheries in certain areas. The State of Bengal is a classic example, where the people would pay any price for a fresh-water fish like Rohn or Catla, but at the same time would be very reluctant to buy a top quality marine fish at comparatively low price. This has naturally resulted in a highly developed inland fishery in that area and a comparatively less developed marine fishery, in spite of good marine resources.

It will be appropriate here to make some observations on the role the Government is playing to overcome some of the factors that affect the development which has been commented on by Hamlisch.

The fishermen in India today receive good assistance from the Government through Fishermen Cooperatives both financially and in terms of supply of fishing boats, fishing gear and technical knowhow. The financial assistance is mainly intended to enable the fisherman to pay off and get himself released from the clutches of the middleman and join the cooperatives to enjoy the other benefits.

Liberal subsidies allowed by the Government for supply of

mechanized fishing boats and modern fishing gear have made it economically feasible for the fisherman to possess this otherwise costly equipment and thereby improve his economic and social status.

Mechanization of fishing is closely integrated with training of technical personnel and plans for construction of fishing harbours and facilities for proper handling, storage, processing and marketing of the commodity.

Newfoundland practice

Harvey (Canada): In Newfoundland a large inshore fishery is undertaken, which has a duration of from five to eight months. Cod netting, gill netting, longlining, Danish seining are carried out. The boats in use are of wood construction and from 36 to 60 ft (11 to 18 m) in length. Most of the boat-building material is being cut by the fishermen on the island. The type of propulsion fitted consists of diesel engines of different reduction gear ratios or direct drive, with horse power ranging from 35 to 180.

The boats are designed and laid out with the accommodation and wheelhouse forward, with engine under the wheelhouse and fish hold aft, or the engine, wheelhouse aft, with cargo hold and accommodation space forward. The most successful of these boats are the 45 to 50 ft (13.7 to 15.3 m) trap boat—longliner.

The boats are built under Government inspection, the Department of Provincial Fisheries maintaining a staff of wood inspectors and engineers who besides carrying out inspection duties, instruct the fishermen builder in the construction. This consists of supplying a set of full size lines. Assistance is given by the Government (provincial) who pay a bounty of $160 (£57) per GT.

Federal government subsidy of from 25 per cent to 35 per cent of the approved costs is also available to the fisherman if he qualifies. These vessels cost approximately $850 to $1,000 (£300 to £360) per GT which would make a 20 GT boat cost about $18,000 (£6,500) completed.

Government payments would be $7,700 (£2,750) leaving a balance of $10,300 (£3,750) in which the fisherman reduces the amount by a down payment of 10 per cent or to a lower figure by supplying the timber which he cuts for himself and sometimes free labour. A loan for the remainder of the amount can be repaid over a period of several years.

The most costly part of the venture is the engine and other equipment. It is important that these costs be kept low so that the fisherman is able to obtain a boat.

Evolution in Peru

Jimenez (Peru): The experience of Peru in developing its fishing industry during the last decade should be of interest to all those who study the evolution of fisheries in developing countries. In ten years, Peru has gone from a yearly catch of 120,000 tons employing primitive methods and boats of less than 36 ft (12 m) to a catch of nearly 9 million tons employing about 2,500 modern purse-seiners of an average of 65 ft (20 m). As Hamlisch points out, this has been possible by developing fishing of anchovy for the manufacture of fish meal, a product in high demand for cattle and poultry feeding. In order to accomplish this, it was necessary to create practically from scratch nearly 20,000 fishermen and 2,000 shipyard workers, which implied a number of socio-economic developments.

As regards ship construction, two things were done:

a. The limited number of shipwrights in existence was spread out, each experienced carpenter becoming the foreman of an independent yard in which new carpenters were trained; and

b. A steel boat construction industry was created by

recruiting labour from the existing metal-working trades.

People were easily attracted to the new industry by the higher rates of pay offered. Quality naturally suffered initially due to the large influx of unskilled workmen, but this was overcome in a few years by the experience acquired and the gradual disappearance of wood construction, where the more serious problems of lack of skilled workmanship occurred. In 1963, 500 boats of 60 to 65 ft (18 to 20 m) in length were built. At present, with the industry stabilized, about 150 boats per year of 65 to 100 ft (20 to 30 m) length are built to the rules of classification societies and some boats are even exported to neighbouring countries. The workers (about 2,000), are mostly paid in proportion to their productivity, and they earn well above the average for industrial workers in the area. A final contribution to the solution of the ship construction problem was the standardization of designs. Most of the shipyards have built over 100 boats of a single design, and this has allowed appreciable savings.

As regards the crews for the fishing vessels, a system of payment was developed based on the amount of fish caught. The owner provides the boat, with fishing gear, fuel and food. The crew goes out fishing and the skipper receives a fixed amount per ton, which he distributes among the crew in accordance with agreements among them. The skipper averages a high income, which has allowed several of them to become owners of their own boats; the rest of the crew also receive a higher income than they would obtain in other activities. As a result, there is no problem in hiring the required crew members, nor in obtaining their acceptance of any technical development that increases the catch.

In addition to a good income, the Peruvian fisherman enjoys very favourable working conditions due to the proximity of the fishing areas. Weather is good; storms are unknown. The boat returns to port every night. Echo sounders, asdics, fish pumps and power blocks are in increasing use, thus decreasing the physical effort required of the fisherman. Besides, each fisherman enjoys a one-month, paid, yearly vacation and a compensation upon ceasing his fishing activities, paid from a fund financed by the shipowners, as well as medical assistance and hospital service paid from another fund jointly financed by the shipowners and fishermen in the proportion of three to two.

Hamlisch also pointed out that "cash-crop" fishing may have a negative effect on the nutritional level of the population. This has not happened in Peru because people have not developed the habit of eating fish and the price of fish is relatively high, resulting in a very limited demand. On the contrary, indirectly, fish meal has allowed the production and import of other foodstuffs to increase, as it is at present the main source of foreign exchange. However, this situation is not fully satisfactory. A fishing nation like Peru should not permit a lack of proteins in its diet, and this must be improved. Two things are being done:

    a. Trying to lower the price of fresh fish, introducing modern techniques in those fisheries and simultaneously carrying out an educational campaign on the advantages of eating fish; and

    b. Supporting research in the adaptation of anchovy fish meal to human consumption.

Neither of these solutions will give results overnight, but in time they will allow the nutrition to be improved.

Independent Fishermen

O'Meallain (Ireland): The following remarks concern the independent fisherman, as understood in Europe for example, the fisherman who is self-employed either as owner or part-owner of a fishing boat or as a crew member on a share basis.

There is a tendency to discount him on purely short-term economic grounds and the arguments seem cogent enough; but this need not always be so.

At the moment he is under severe pressure on two sides. Competing against him are large vessels carrying fish a quarter way around the globe. Even though the economics of large vessel operation may often be unsound, and in spite of the fact that, as Hamlisch says, "Skipper ownership of vessels may stimulate better management", the weight of the large-scale enterprise and the very fact of uneconomic operation could drive the independent fisherman out of business, the end result being general depression in fishing.

The second course of pressure is the rapidly rising costs of boats, gear, equipment and maintenance, without a corresponding increase in the unit price of the fish. At the Scantlings Meeting in Copenhagen in 1964, Tyrrell drew attention to the seriousness of the question of building costs and suggested determined efforts rather towards means of reducing building costs than towards refinement of design. One cannot deny or decry the technical advances that have been made and are being attempted, but they must be clearly measured in economic terms.

Hamlisch, in his comprehensive review, seems to write-down, more than is justified, the economic importance of the independent fisherman and perhaps to oversimplify the position. There are examples in many countries, notably in Sweden, of the prosperity of large bodies of independent fishermen. Nevertheless, the pressure of increasing costs is there and this combined with the other pressure mentioned, may drive him to the wall unless appropriate measures are taken. In the long run, the independent fisherman is the basis of the industry. If he disappears, only a fully socialized undertaking can replace him.

A large part of the increase in costs may originate with the fishermen themselves. It is believed, for example, that the smaller vessels such as are being considered here are often grossly overpowered, even for the hull shapes involved. This cannot be put down to lack of sophistication on the part of fishermen, because it is precisely among the most progressive that the demand for increased power is found. It is urgent that the facts be determined, and that the fishermen be persuaded of their validity. This is altogether independent of economics in power that could result from improved hull shapes. It is also important that authoritative advice be available to fishermen as to materials and equipment, somewhat on the lines of that given by building centres.

Most important of all, but most difficult is advice as to the boat. Apart from technical considerations, a great deal will depend on what a man can afford. Where substantial state assistance is available, the question might reduce to a technical one.

Apart from ships engaged in the pursuit of ocean species, the maximum tonnage and horse power need not exceed those necessary to enable the vessel to fish effectively and economically the extent of waters to which it has access by virtue of its nationality, because the extension of fishery limits is likely to render the operation of distant water trawlers less profitable than at present. Whether such reduction in profitability can be accepted over a long period is questionable.

Eventually, the greater part of fishing activity, apart from that for ocean species, may be confined to relatively small highly efficient vessels with small crews and owned by the skipper or by the skipper and crew jointly. Trade in fish may eventually replace fishing in waters off coasts other than one's own.

Mechanization

Kvaran (FAO): Mechanization of existing craft versus con-

struction of new craft is a problem which is met in many fields of development other than fisheries. In "Economic Philosophy" (page 114-15, Pelican Edition, 1964) Robinson (1964) has this to say:

> "There is another topic, in connection with problems of underdevelopment, that has been much discussed in terms of theoretical analysis; that is the choice of technique when a variety of methods are available for the same product. The field is clouded by two opposite prejudices. One is the snob appeal of the latest, most highly automatic equipment and the other the sentimental appeal of the village handicraftsman."

She then proceeds to propose two simple guide lines, first that no equipment be scrapped or methods of production be rejected so long as better use elsewhere cannot be found for the labour and materials used in them and second, that no technique be chosen because it provides employment. The continuation of the analysis might have been made with fisheries mechanization specifically in mind:

> "There remains cases of genuine doubt where a less capital using technique, with lower output per head, promises more output per unit of investment, or a quicker return on investment, than another which is more mechanized and requires less labour. It has been argued that in such a case the correct policy is to choose the technique that yields the highest rate of surplus, so as to make the greatest contribution to further accumulation. At first sight this seems very reasonable, since development is the whole object of the operation. But when we look closer, it is not so obvious. The surplus which a technique yields is the excess of net product over the value of the wages of the workers who operate it. A higher surplus means a faster rate of rise in output and employment, starting from a smaller beginning. The more capital-saving technique yields more output and pays more wages. It is for that very reason that it offers a smaller surplus.
>
> "There is a choice between some jam today and more jam the day after tomorrow. This problem cannot be resolved by any kind of calculation based on 'discounting the future' for the individuals concerned in the loss or gain are different. When the more mechanized, higher-surplus, technique is chosen, the loss falls on those who would have been employed if the other choice had been made. The benefit from their sacrifice will come later and they may not survive to see it. The choice must be taken somehow or another, but the principles of Welfare Economics do not help to settle it."

In making the above assessment Miss Robinson makes the basic assumption that output per unit of investment can be predicted in advance. In new fishing ventures this is true only within wide limits, a fact which favours solutions using low capitalization.

Analysing the figures

De Wit (Netherlands): In Takagi's and Hirasawa's paper it is stated that fishermen with non-powered boats earn much less than those with powered vessels. A glance at table 4 however, reveals that a non-powered boat in 1961 had an annual production of 2.59 tons of fish from 867 man hours for a crew of one (table 3).

This means a production of 6.6 lb (3 kg) per man hour and secondly, an average working week of 16.6 hours, per man hour.

When using the corresponding figures for the powered boats of 3-5 GT in 1963 it is found that the production per

man hour is almost the same, i.e. 6.8 lb (3.1 kg) per hour but that the working week increased from 16.6 to 76.4 hours. Even in the case of powered boats of under 3 GT, the working hours have increased and the production per man hour decreased from 7.7 lb (3.5 kg) to 4.6 lb (2.1 kg) per man hour in 1961 and 1963 respectively. If mechanization leads to excessive working hours and reduction in production per man hour, fisheries are losing the battle they have to fight with land leisure, industry and comfort ashore. This is not only true in Japan, but in many other countries all over the world.

Economic studies

Hildebrandt (Netherlands): Hamlisch and his colleagues have given most interesting papers about the techno-socio-economic problems.

Hamlisch stressed the fisheries of the developing countries. Of course!

Fish is the cheapest protein and in those countries there is a big shortage of protein food. It is therefore that especially for developing countries the fishing industry is a good business. Techniques are therefore of the greatest importance. In the highly developed countries, however, very good fishing vessels are built, but the profitability is such, that the governments have to subsidize the fishing industry. This is an important question for the vessel builders too.

There are two problems:

One is the marketing of fish in developed countries. In these countries there is a very keen competition with other protein. To get a higher value for fish it is necessary to do market research in order to find out how to stimulate the market But getting higher earnings is not enough, there must also be lower costs.

The Dutch fishermen are still building bigger ships. Here in Göteborg a fisherman said that he had a fishing vessel with a motor of 800 hp but that his colleagues want to build cutters with 1,000 hp. Several different answers are given.

For instance:

- If my neighbour builds a new vessel, I want a bigger one. Rivalry among fishermen
- Because the biologists tell us that there is a declining stock of fish
- More modern equipment requires ever more space on board. Therefore, we need bigger ships
- And lastly, to earn more

What is true:

- Which were the main factors determining the profitability of fishing vessels during recent years?
- This can determine the economically optimal fishing vessel for a certain fishing ground and a certain method of fishing. That may be a question of linear programming
- The results of these micro-economic studies may possibly give an answer to the question: are the fishing grounds exploited in an economically rational way?

Hildebrandt gave some preliminary results of his study of the first question: What determined the building of a fishing vessel in recent years?

The only way of studying this is empirical. Over the period 1955 till 1965 Hildebrandt worked with 24 variables and about 200 observations of costs and earnings and technical data of the same type of fishing vessel of different size and different motor capacity on the same fishing ground during the same period of time and the same method of trawling herrings on the North Sea.

Then there is the question of the method of research.

Variables	I	II	III	IV	V	VI	VII	VIII	Total
			Squared factor loadings—Percentages						*Total*
(1) Abundance estimate	7−	48+	41+	—	—	4−	—	—	100
(2) Trend	82+	10−	8−	—	—	—	—	—	100
(3) Value added pd, pm	14−	—	9 ·	42+	5+	—	19+	—	89
(4) Investment ship	8+	—	4−	—	—	—	66+	18+	96
(5) Net profit pd, pm	21−	—	10−	33+	7+	—	15+	—	86
(6) hp pm	7+	—	3−	3−	—	—	86+	—	99
(7) GT pm	—	—	—	3+	—	—	28+	65+	96
(8) Number of days absent	—	—	7−	—	—	88+	—	—	95
(9) Total quantity pd, pm	—	—	26+	40+	4+	—	28+	—	98
(10) Total value pd, pm	12−	—	6−	46+	3+	—	27+	—	94
(11) Fuel pd	18−	8+	3+	—	—	—	32+	—	61
(12) Maintenance motor	28+	—	3 ·	—	—	—	27−	—	58
(13) Price of fresh herring	30−	—	53−	—	—	—	—	—	83
(14) Price of salt herring	—	—	87·−	—	12+	—	—	—	99

pd = per day; pm — per month.

In economics one has nearly always to do with many variables which are nearly all intercorrelated. This gives difficulties for the regression analysis. That is why for the past couple of years Hildebrandt has been using the factor analysis method, which takes into account the inter-correlations.

The preliminary results are found on the table of squared factor loadings of 14 following variables:

(1) Abundance estimate of herring, which were received from biologists
(2) Trend, the variable of time
(3) Value added per day absent per member of the crew
(4) Investment in the ship
(5) Net profit per day absent per member of the crew
(6) Horse power of the motor per man
(7) Gross tonnage per man
(8) Number of days absent
(9) Total quantity landed per day absent per man
(10) Total value landed per day absent per man
(11) Fuel per day
(12) Maintenance of motor
(13) Price of fresh herring
(14) Price of salt herring

The aim is also to learn what determines the profitability of a fishing vessel. But what is the profitability of a fishing vessel?

The crew has no fixed remuneration, but gets a share of the value of the fish landed. It is therefore that net profit is no ideal measure for the profitability of the fishing vessel. A better measure is the value added per member of the crew.

The value added is the sum of the shares, the net profit and the calculated interest on the invested amount. It is the contribution of the fishing industry to the national income.

For the analysis of this contribution he had chosen 14 variables. Of these variables a correlation-matrix has been made. This correlation matrix has been divided into two triangles: the root and the transposed root.

All this work is done by computer, otherwise it requires too much time and labour.

The rank of the correlation matrix determines the number of dimensions of the space in which one works. The direction of the axes is not determined, but one can choose a number of orthogonal axes as basis of this space. By means of rotation of the orthogonal axes, the best plausible orthogonal axes can be found. The result gives the table of squared loadings. The square loadings in each column (the percentage of variance) gives a measure of relation between the variables. The plus or minus signs indicate in which direction the variable varies. Each column represents a factor or aspect interwoven with the variables represented in that column. These aspects are orthogonal and as such independent of each other.

What the table reveals

A point in the column means that in that column the variable is not related with the other variables of that aspect. The total of the percentages of the squared loadings for any one variable tells how far the variable has been explained, and has a maximum of 100.

What can be learnt from this table of squared loadings? The first column gives the relation of distinguishing variables with time—the trend. In the years 1955 till 1965 only 7 per cent of the abundance estimate varied with 82 per cent of the trend, but in opposite direction. This means that the stock of herring was slightly declining.

In column III 9 per cent of the value added, 53 per cent of the price of fresh and 87 per cent of the price of salt herring varied with 41 per cent of the abundance estimate, but in opposite direction. It also varies with 26 per cent of total landings in the same direction, but with 6 per cent of total value in the opposite direction.

This all means that better herring catches give higher landings, but lower prices for fresh herring and especially for salt herring, and also a lower total value of the landings and a somewhat lower value added per member of the crew.

The fourth column shows that at constant abundance estimate and constant prices 42 per cent of the value added varies at the same time with 40 per cent of total landings and 46 per cent of total value. More important is that independent of this fourth column the seventh column shows that under the same conditions 19 per cent of the value added varies with 66 per cent of the investment, 28 per cent of the total landings and 27 per cent of the total value. All in the same direction. This means that higher investments give better results. During the last ten years fishermen have built bigger vessels in an effort to earn more. This meant replacing labour by capital investments. It is a question of large scale production. An optimal ship is often seen as static, but in reality it changes with time. It is dynamic.

As Hamlisch shows: for developing countries technology is most important. For the highly developed countries the economic side of the question is very important too.

Of course it is not only a question of economics but also of biology and technology. At any point therefore the biologist, the technician and the economist have to co-operate.

Assessing complex factors

Doust (UK): Owners often have great difficulty in taking decisions in fishing enterprises because of the complex situation caused by the interrelation of both the technical and economic factors. A few of these factors follow:

(a) Primary vessel characteristics, such as form, dimensions, power, capacity, etc

(b) Secondary vessel characteristics involving stability, seaworthiness, catchability

(c) Fishing grounds

(d) Port of landing

(e) Economic outgoing factors

(f) Economic income factors

It is estimated that such decisions should be based on approximately 58 variables, and each of these six sections would require its own particular specialist. Hamlisch warns us of the difficulties but gives nothing numerical, and it is essential to do so if we are to solve these problems. This can be done by building up econometric models to ascertain in which areas the main effort is required. From the economic point of view, we can at present only take steps after a situation has occurred, and a more econometric approach is required before the introduction of a sound investment policy. For such an approach the whole function of the vessel must be presented numerically. As far as the present state of knowledge in each section permits it is essential to utilize the computer, so that the effects of change on profitability and economic efficiency in any one variable can be estimated. For example, we could investigate the situation where the catching rate is decreasing and the appropriate changes could be made in the working model to derive the adjustment of the optimum vessel size, or we could investigate the relationship between skipper and size of vessel. For instance, a top skipper obviously needs a different vessel to the average. Another procedure could be to vary the skippers by vessel rotation in order to obtain the best group profit. The influence of shipbuilding costs on the best choice of vessel for different grounds maintenance costs and engine requirements for various speeds are typical factors which require to be solved. As the capital investment costs of construction steadily rise, it is logical that the invester will require a greater economic and technical assurance that the investment is sound. Only by utilizing the specialist services of teams drawn from all the various branches of fisheries can this be achieved.

Avoiding catch failure

Kojima (Japan): Hamlisch said that a scheme of catch-failure insurance is important.

Kojima agreed with this opinion. Japanese fishermen have established a mutual benefit society to insure catch-failure by a mutual relief system. This society is licensed by national law, and the Japanese Government disbursed £250,000 ($700,000) as a portion of fund money for this society.

Fishing operations at sea are fatiguing, and accommodation aboard some Japanese fishing vessels is considered poor, but a policy is being promoted to improve conditions. An example of the way in which this policy works is that an important fishery may not be licensed to an owner who does not provide certain standards of accommodation.

Thirdly, Kojima agreed with Hamlisch's opinion that the fishing of one country may contribute to the growth of the fishing in another country.

Kojima pointed out that although the fishing industry will always employ cheap labour, that type of labour requires machinery to make it viable, and therefore such devices must be economic to buy and use if they are to have a place in fishing.

Fourthly, Kojima mentioned the fondness of the Japanese for fresh raw fish, which necessitates the use of special vessels for bringing live fish from the grounds to market. These boats have tanks below deck through which fresh seawater is constantly circulated by pumps. By this method, live fish have been carried 650 nautical miles (1,200 km) over a period of three days.

Frechet (Canada): The fishermen need aboard the fishing vessels certain essential facilities to make life pleasant. A recreational area and pleasing surroundings are required in this day and age to prevent fishermen from going to other industries ashore where they can enjoy life in common with their fellow citizens; a pleasing place on the pier is also necessary, where they may discuss matters of common interest and enjoy some relaxation. Naval architects must always keep in mind that aboard fishing vessels, besides the sleeping area and the manoeuvring area, there is need for space where fishermen may assemble and really live like human beings.

Safety at sea

Lee (UK): Hamlisch is to be congratulated on the excellence of his well-documented paper. Comment may seem superfluous and he would mention only one item, namely the fatalism of the fisherman in the face of death. Very considerable progress has been made in recent years in the design of life-saving equipment and in survival techniques generally. The chances of human survival following disaster at sea are greater than ever before and there is a welcome sign that seafarers, in Western countries at least, are taking full advantage of the equipment now available to them. It is worthy of note also that schoolchildren are receiving more and more instruction in swimming, thus preparing them psychologically for emergency at sea. The general attitude to survival is, therefore, likely to become very different from that which Hamlisch describes as applying today.

Colvin (USA): Hamlisch has made an excellent contribution, and Colvin was in agreement with his statements. He thought it would be only fair to say that Hamlisch has put forth a basic philosophy as it applies to the fishing industry throughout the world. It is singular to note that in almost every instance where the superstitions or customs of one country retard the progress of the fishing industry, in some of the other countries, especially one's own country, one can see similar traits and characteristics among the individuals in a collective group of fishermen.

The dissemination of information regarding the fishing industry has always been left to the few. If it were not for the FAO and for the papers put forth at the Technical Meetings, there would be very little, if any, information available to anyone aspiring to enter the fishing boat building or to specialize as a naval architect in the design of fishing boats.

Capital expenditure

Eddie (UK): Nearly everything in Hamlisch's paper is true; there is only one quarrel that Eddie had: The same old argument is presented that technical progress must mean higher capital expenditure. This is not inevitably so in terms of weight of fish caught per unit expenditure as is evident in the UK and Eddie suspected in other more recently developed industries like the Russian, but the general effect, to Eddie's mind is unnecessarily depressing. Perhaps it would have been better to have attributed Hamlisch's paper to a development engineer: they always suspect economists of being opposed to technical innovations because these produce discontinuities in the economic curves.

Be that as it may, the question is asked whether there is a career for young people in fisheries development, and the disturbing feature is that this question is not directly answered but a negative answer is implied. This impression needs counterbalancing especially since its origin was FAO.

Introducing technological changes may be more difficult in fisheries than in other fields because the results are not so predictable, but Eddie agreed with Chapelle that it is pro-

bably as difficult to introduce changes in developed countries with a well-established industry as it is in the developing countries. Developed countries have tabus and shortage of capital, conservative fishermen and fish merchants and, of course, the civil servants! The process of introducing an innovation is never as orderly as they would like it to be and never democratic—but the engineer can usually find an individual who is in a position to give an innovation a trial. Previous contributors have shown that there is every reason for hope. Hamlisch's paper omits to mention two very fundamental economic facts: the sea covers 7/10 of the world's surface and receives as much sunshine per m² as does the land. Perhaps because there was a length limit on the papers, Hamlisch did not add another section on similar lines to Jackson's introductory note in order to answer the question he posed. Eddie suggested that the editor of the proceedings print Hamlisch's paper immediately following Jackson's introductory note, so that it will acquire therefrom some of the hope and purpose that Jackson expressed so well. (Editor: It is printed as first paper.)

Co-ordinate the techniques

Cardoso (Portugal): In coastal and middle distant waters already intensely fished by old traditional methods, the application of a more technological approach, the mechanization and the rationalization of operations obtain immediately a better productivity for each new ship.

This in turn initiates a rapid process of reconstruction and renewal in the fishing fleet. Old ships, old gear and old methods are discarded to meet the new competition. From experience this may bring about the following chain of events:

1. An enormous and quickly applied increase in the fishing effort over a well-defined and naturally limited stock.
2. A gradual falling off of the productivity of every vessel fishing that stock.
3. Emergency regulations, often without a scientific basis, are introduced, limiting the number and size of vessels and sometimes the fishing areas and/or the unloading ports.

It is not difficult to visualize that, in many instances, these same regulations, added to the fact that fishing boats have to go farther and faster in order to be profitable, strike at the very heart of the process of technological progress and do not help in achieving better designs.

Many a little "monster" is bound to be born, and in a way technology defeated itself.

The point therefore is that all the techno-socio-economic factors discussed have to be taken into account in a much wider concept.

The technologist, the economist and the naval architect can never correctly solve their problems before the oceanographist and biologist have solved theirs. In many instances, it is feared that naval architects may be a little too eager to present the fishermen with the best boats to fish what is really not known. Cardoso moved, therefore, that FAO should urge every member nation to apply every possible effort to further the study of oceanography and biology of the seas of the world.

Jackson (FAO): In Cardoso's comment he suggested that designers should wait for biologists and oceanologists to provide information for the designers. However, one cannot wait for the biologists for several reasons. Firstly, the sea covers two-thirds of the earth surface and secondly a principal tool of the biologist is the fisheries itself—therefore both must develop together.

Jackson agreed with Hamlisch on two main points. For developing countries:

1. Transmission of technical information is not necessarily followed by action. This is true and it is not enough to publish the transactions of a meeting and simply send it to the developing countries.
2. Lack of development results in hunger, but hunger does not necessarily produce development.

The purposes of a meeting are also to promote national and regional development and aid fishermen and the fishing industry to compete in their own nations and regions. Development is a difficult art and a slow one. It is not an easy and orderly process. There are occasional opportunities for giant steps and there the developments, promoted by meetings such as this, are extremely useful. For example in Ghana the step has been made from the canoe directly to the operation of 50 factory stern trawlers without the intervening steps.

Similarly, Rumania has leaped ahead from small coastal vessels to the operation of 3,500 ton integrated factory stern trawlers.

Jimenez (Peru): Commented on Jackson's words in saying that the proceedings of previous fishing boat congresses have been most helpful in developments in Peru.

Cardoso (Portugal): In reply to Jackson, Cardoso clarified that he did not suggest that naval architects can wait for the biologists and oceanologists.

As Jackson said, development must be simultaneous. Speaking from experience, Cardoso merely pointed out that the biologists' lack of knowledge is indeed hindering naval architects' progress and many times even defeating the purpose.

Consequently, Cardoso still maintained that it is of the utmost importance that every effort be taken urgently for the biologists to hurry up and provide, may be not all information, but as much as possible.

Marketing and education

O'Connor (Ireland): Congratulated Eddie on his comments on fisheries development work. He felt that the challenge presented to young people in this sphere is a considerable one and would form the basis of a very worthwhile career. Cardoso called for expanded biological and oceanographic work and with this he agreed, but would look for a much more commercial attitude from these people.

Two of the greatest problems facing expansion of fisheries in any country are marketing and education. If these two problems can be overcome, then fishermen will want better boats, more young men will enter the industry and fishermen will have a better income. The "revolution of rising expectations" referred to by Hamlisch, can be most easily brought about by the provision of markets for all the fish the fisherman can possibly catch.

On the question of education, O'Connor felt that part of this problem concerns the education of the general public to the acceptance of the important place the fisherman occupies in the realm of food provision which is one of the most important spheres of activity in the world today. If one can build up in the fisherman also an improved morale, so that he will live up to the new public impression of him and his colleagues, then the demand coming from the catching side will force naval architects and designers to provide the standards of comfort and work ease which will match the conditions the fisherman is accustomed to ashore.

Recruitment and training of new entrants to the industry is looked after in Ireland through a state-financed scheme of

training new entrants and prospective skippers established about five years ago. This scheme involves inspected commercial fishing boats, navigational, boatmanship and manual skill training in the naval service and in local vocational schools. It has been successful as is proved by the fact that some of the original trainees have now, after five short years reached the stage where they can skipper boats of 56 to 65 ft (17 to 20 m) providing a net skipper income of upwards of £2,000 ($5,800) per annum from reasonable effort.

The "resigned attitude of older fishermen" referred to by Hamlisch can normally not be changed, but the effort should be made to ensure that the younger members of the fraternity grow up with a progressive outlook by proper educational programmes and study tours to other countries, and also by the expansion of a well-informed trade press.

FAO concept approved

Bjuke (Sweden): He was happy for FAO's initiative of taking up the social, economic and geographic factors for discussion.

Consideration to all these factors has to be taken for a successful development of the fishery. It is of no use to introduce modern fishing boats in developing countries as long as there are no crews educated to navigate them, no proper harbours for the boats, and no built-up organization for processing and marketing of fish. The development of all these matters has to be run parallel. A close co-ordination and co-operation of the advisers for the various fields of the fishery, therefore, is of the utmost importance.

Before the selection of a fishing centre for development, there are many factors to be carefully studied. Physical and geographical conditions of the site, fishing tradition and distance to fishing grounds are not the only decisive factors. The site also should have resources to meet future growth in fishing activity and should provide ample room for the various ancillary operations and industries which are associated with a thriving fishing centre, attractive residential environments not to be neglected. Furthermore, the site should have a convenient location with regard to the potential market and should afford expedient facilities to dispatch fresh fish to regions far off the coast. The vicinity of the harbour to an airport would be an advantage, as in the future the dispatch of fresh fish to distant places may be an ordinary event.

Naval architects as well as harbour designers must consider a proceeding development of types of boats all the way from beach-landing catamarans to advanced vessels for large-scale fishing. As to decide adequate depth of water in the harbour basins, for instance, the draft of the vessels considered has to be discussed together.

It would take too long time to state all details of desirable co-operation. However, he was sure that FAO will push forward strongly the question of consideration to be taken to all factors concerning the development of fishing vessels as well as the fishery as a whole.

Authors' replies

Hamlisch (FAO): Eddie had chided him for an alleged bias against technological innovation and an unduly pessimistic view on the potential contribution of fisheries to world food supplies. Hamlisch pleaded "not guilty" on both counts.

He did not think Eddie really wanted to question the validity of the observation that technical progress tends to increase the size of capital investment in fishing (this, after all, is a characteristic feature of progressive industrialization). The difference in the cost of a modern, fully equipped long distance trawler and a traditional craft fishing in coastal waters is a very substantial one. The entrepreneur is aware of the greater "capital efficiency" of the larger, more expensive,

craft and has modernized, and will continue to modernize, where the anticipated increase in net economic returns seems to warrant this. In his paper, Hamlisch was merely implying that the increase in the financial burden and in the break-even catch value compel the entrepreneur to do his investment planning more carefully. He hoped technological advances will be promoted by governments and industry, wherever physical, economic, and social conditions appear favourable for the adoption.

Hamlisch's attitude of caution, which Eddie felt inclined to interpret as pessimism, derives from the economist's obligation to insist on a balanced approach in development work. The physical scientists want to give priority to searching the oceans for more fish, the technologists to improving catching equipment and methods, the chemists to development of better products. The economists introduce the questions Hamlisch touched on in his paper: is the market ready and equipped to absorb the additional quantities of fish; is the producer able to operate the improved equipment; is the institutional structure flexible enough to adjust to the changed mode of operation; is the investor prepared to make the plunge? The economists' priorities shift with the discovery of new lags; they argue that any sector lagging behind should be first brought up to the same level as the other sectors before radical advances are made on a new front.

There are those who believe that the Fisheries Revolution is just around the corner, that fisheries development should have an over-riding priority, since the world will, before long, badly need the harvest of the seas to feed itself. Hamlisch was the last to argue that this may not be the case in the long run. He was much more doubtful about the situation in the near future. There is a highly respected school of thought that urges us to concentrate on the short time span, considering the difficulty of imagining, not to speak of predicting, what revolutionary scientific and technological developments may take place in various sectors of the economy over the next few decades.*

As several writers (Hamlisch and Taylor, 1962) have noted, per capita consumption of edible fish has remained stable or even has been on the decline in recent years in some of the richer, developed countries. The trend cannot be blamed only on the condition of fish stocks and on the lack of technical know-how. Hamlisch suspected that the phenomenon is due in large measure to a merchandizing failure. He thought the trend is not irreversible if imaginative promotional techniques are applied.

In developing countries, technical progress has not always automatically brought along the expected nutritional and income effects. One could think of several conspicuous examples of moth-balled or underutilized or excess fleet and plant capacity, where failure of systematic planning or lack of balance in the growth of the different sectors of the industry has been responsible for substantial economic waste.

Final note of caution

It may be argued that major development requires an initial spurt—involving a certain measure of gamble—on

* Professor Gunnar Myrdal, the distinguished Swedish economist, stated this point of view most effectively in his 1965 McDougall Memorial Lecture at the opening of the 1965 FAO Conference: "... I feel much less concerned about how things will look at the turn of the next century. In the long run much will happen; we will perhaps have entirely new techniques to produce the food; the entire world situation will be different in all sorts of ways; forecasts are bound to be proven wrong; perhaps we may feel optimistic that things will in some way take a radically new turn as we have often seen happening before. It is the years to come in this decade and the next about which I am worried. In the short run our forecasts are more reliable. ..."

some front. The question must be raised to what extent developing countries can afford to put on risk a large share of the limited financial and managerial resources at their disposal. The decision as to whether, and if so on what scale, a developing country should launch major fishing ventures to substitute fishery imports can only be made on consideration of overall economic and political objectives of the government. It is wrong to think in terms of global priorities, both with respect to fisheries within general economic development, and with regard to emphasis to be given to the different aspects of fisheries development. Even within a given region or country, priorities will change with time. Where yesterday the crucial problem may have been in the technological sphere, today it may be the resource condition, and tomorrow the marketing situation.

On Eddie's comment on Hamlisch's failure to give a general reply to the young man who weighs the pros and cons of becoming a naval architect or boat builder: the young man will have to answer this question himself, in the light of the peculiar characteristics of the "market" for these professions in his country. All Hamlisch set out to and could do in his note was to discuss the "demand" considerations that would bear on the decision.

Hamlisch fully shared Doust's desire to find a quantitative expression for the various factors on which investment policies should be based. Fortunately, there are able researchers (such as Doust himself) already at work on these problems. FAO does not have the facilities nor the manpower to undertake such research. FAO is very keen, however, on assembling and eventually disseminating information on research progress in this field and to make a contribution, in this manner, to the expansion of knowledge.

One word of caution: the large number of assumptions, many of which are based on very inadequate empirical data, does not yet permit the use of some of the econometric models for forecasts of a desired degree of reliability. For some time to come, therefore, the models will remain in the category of "direction finders". Within the frame of these models it should, however, become possible to make timely adjustments of forecasts, when additional data become available.

Takagi (Japan): In answer to de Wit, Takagi added that non-powered boats operate only in the best season and therefore give the maximum results of earning per man-hour. On the other hand, powered boats operate throughout the year and give lower results. Therefore, fishermen want to have high-speed powered boats for fishing all the year.

Mechanization of non-powered boats is to improve the productivity and total fish catch if there is an abundance of fish. In Japan, however, there are too many powered boats on limited fishing areas and their catches are small. Takagi hoped that mechanization in developing countries will not lead to the same situation.

PART II

PERFORMANCE

Measurements on Two Inshore Fishing Vessels

by M. Hatfield

Essais de deux bâtiments de pêche côtière

L'Industrial Development Unit de la White Fish Authority a soumis à une série complète de mesures (charges, vitesses et puissances) deux bâtiments écossais de pêche côtière commerciale de 70 pieds (21 m): le senneur *Opportune II* et le *Rosebloom*, récemment converti pour le chalutage. Les essais en mer, d'une durée de cinq jours pour chacun des bateaux, ont porté tant sur la marche libre que sur l'allure de pêche. Cette étude visait à obtenir des renseignements de base sur le dessin des bâtiments à l'intention de plusieurs programmes et études de développement ayant pour objet l'amélioration de ce type de bateau des points de vue technique et économique.

Mediciones en dos embarcaciones de pesca de bajura

La 'Industrial Development Unit' de la 'White Fish Authority' ha realizado una amplia serie de mediciones de cargas, velocidades y potencias en dos embarcaciones comerciales escocesas de pesca de bajura de 70 pies (21 m), una de las cuales, la *Opportune II*, es un barco de redes de cerco, y la otra, el *Rosebloom*, se ha convertido recientemente en arrastrero. Las mediciones abarcaban la marcha libre y las condiciones pesqueras durante las pruebas en el mar que duraron cinco días en cada caso. El objeto de estas investigaciones era obtener la información del diseño básico para cierto número de proyectos y estudios de desarrollo encaminados a mejorar este tipo de embarcación, tanto desde el punto de vista técnico como del económico.

THE inshore fishing fleet numbers some 1,500 vessels, between 50 and 80 ft (15 to 24 m) in overall length, operating from ports all around the British coast. These vessels spend the whole or part of the year fishing for demersal species, the majority using seine nets. Their design and their machinery has been a long evolutionary process, and although they generally operate effectively with a high level of productivity, opportunities of investigating possible alternative equipments and designs have been neglected due, partly, to a lack of systematic development. It was felt therefore that

designers and operators may be able to profit from basic investigations into their performance, with particular reference to power requirements at the propeller and winch.

The urgency of this work has been emphasized by a recent trend for numbers of this class of vessel to convert from seine netting to trawling, which is regarded by some as a more profitable method. The power requirements for trawling, for a 70 ft (21 m) vessel, were even more debatable than those for a distant-water trawler.

Two sets of performance trials were performed, one
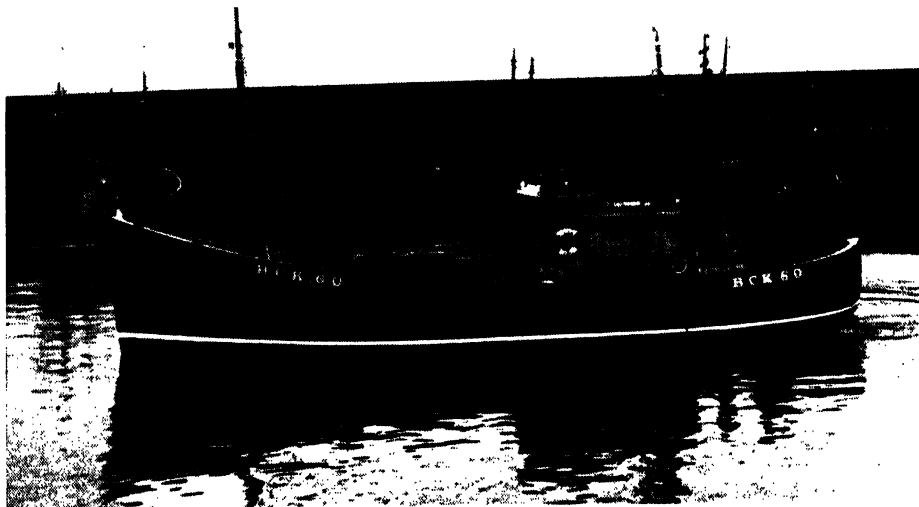
Fig 1. MFV Opportune II

Fig 2. MFV Rosebloom

TABLE 1. **Seine netter,** *Opportune II*

Building date	December 1956	Builders	Herd and Mackenzie Buckie, Banffshire
Skipper	G. Murray	Register	BCK 60

Hull dimensions and materials
Loa   69 ft 9 in (21.25 m)
Breadth   20 ft 4 in (6.20 m)
Lpp   66 ft 8 in (20.32 m)
GT   51.9
Hull of wooden construction with aluminium superstructure

Winch details
6-speed seine winch, belt drive from engine-driven layshaft.
Winch builders Sutherlands, Lossiemouth

Fishing gear details
Warps: 2½ in (64 mm) manila seine rope in 125 fm (228.6 m)
    coils 15 fm (27.4 m) bridles

Footrope: 1.75 in (45 mm) combination wire protected by "Grass
  Rope" and weighted by lead rings

Engine details
Gardner 8L3 8 cyl oil engine rating 150 hp at 900 rpm
Drive to propeller through 3:1 reduction gearbox. Winch
layshaft drive through 2:1 reduction gearbox

Propeller details (fixed pitch)
Diameter   52 in (1320 mm)
Pitch ratio   0.875
Blade area ratio   0.47

Net: 520S polythene Gourock trawl net 520 - 6¼ in (159 mm)
    mesh around mouth. Headline 90 ft (27.4 m). Footrope
    110 ft (33.5 m)
Floats: 7 small floats on each wing, 4 large floats on headline

TABLE 2. **Trawler,** *Rosebloom*

Building date (seine netter)	1959	*Builders* (seine netter)	Herd and Mackenzie Buckie, Banffshire
(converted to trawler)	mid-1963	(converted to trawler)	H. Fleetwood
Skipper	T. Ross		Lossiemouth,
Register	INS.94		Morayshire

Hull dimensions and materials
Loa   73 ft (22.25 m)
Breadth   20 ft 4 in (6.20 m)
Lpp   68 ft 7 in (20.90 m)
Hull of wooden construction with aluminium superstructure

Winch details
Twin-barrel winch with band brakes and friction clutches, carrying
400 fm (725 m) 1½ in (38 mm) GSWR warp, belt drive from
engine-driven layshaft. Winch builders Andre. Hensen and
Sønner

Fishing gear details
Nets: "A" 1.65 in (42 mm) mesh around mouth, 4.5 in (114 mm)
mesh in bosom, 2.75 in (70 mm) mesh in belly and codend.
Headline 80 ft (24.38 m), groundrope 100 ft (30.48 m) 10 Standard
aluminium floats on headline, 3 in (76 mm) rubbers on ground-
rope and legs, groundrope heavily chained. Sweeps 15 fm
(27.43 m). Spreaders 40 fm (73.15 m) "B" mesh sizes as for
light net "A". Headline 90 ft (27.4 m). Groundrope 110 ft
(33.5 m). 15 aluminium floats on headline

Engine details (after conversion)
Caterpillar 6 cyl oil engine rating 325 hp at 1,800 rpm
Drive to propeller through 4.5:1 reduction gearbox. Winch
layshaft drive through 4:1 reduction gearbox

Propeller details
Diameter   53 in (1346 mm)
Pitch ratio   0.811
Blade area ratio   0.47

Warps: 425 fm (777 m). 1.5 in (38 mm) GSWR warp
Trawl doors:
  Doors "A" 4×3 ft (1.22×0.91 m) 6 in. (152 mm). Weight
  3 cwt (150 kg) approx.
  Doors "B" 6×3 ft 6 in (1.83×0.91 m) 6 in (152 mm).
Gear normally rigged with heavy net and light doors

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on a typical, fairly modern, 70 ft (21 m) seine net vessel, the other on a similar vessel converted for trawling.

Particular reference is made to the measurement of warp load. Not only was this an essential measurement for the purposes of the investigations but also the equipment used was the prototype of a warp loadmeter system for use in commercial fishing.

THE VESSELS

Except for engine power and fishing gear, the vessels are very similar in design. The details are given in tables 1 and 2. The trials were carried out at a time of year when fishing is usually good and the vessels in continuous operation.

INSTRUMENTATION

Trials instrumentation

The measured quantities are listed in table 3. All instruments, with the exception of those for wind speed and direction, had electrical outputs which were fed through simple electrical balance and smoothing circuits, without

amplification into an 18-channel ultra-violet galvanometer recorder. All signals were thus recorded continuously and simultaneously, and since the galvanometers have a high frequency response, the effects of ship motion could be studied.

The instruments for the parameters shown in table 3
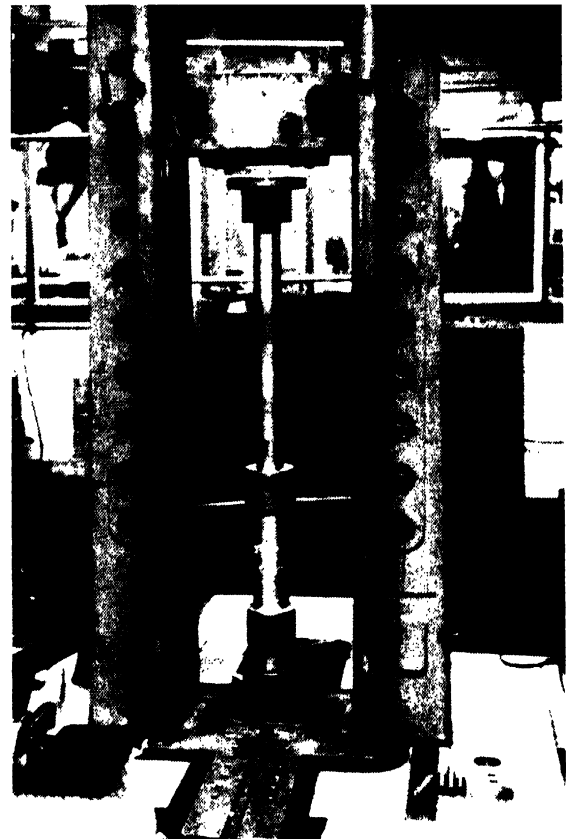
Fig 4. Intermediate shaft undergoing thrust calibration

Fig 3. Instrumented portion of a special intermediate shaft

TABLE 3. Measurement of parameters

Parameter	*Method of measurement*
Propeller shaft torque	Strain gauges bonded to special hollow intermediate shaft. Supply and signal to gauge bridges by silver slip rings and silver/graphite brushes. Shaft calibrated in torsion and compression testing machines
Propeller shaft thrust	
Propeller shaft revolutions	Magnet and reed switch
Winch layshaft torque	Strain gauges bonded to shaft. Calibrated in torsion testing machine
Winch layshaft revolutions	Magnet and reed switch
Warp load (port and starboard)	Strain gauges on link supporting pulleys (see fig 9 and 11)
Warp speed (port and starboard)	Seine netter: magnet and reed switch on coil drive Trawler: magnet and reed switch on fair-lead pulley visually checked against warp marks
Pitch Roll	A 2-axis gyroscope in the accommodation space
Vertical acceleration Longitudinal acceleration Lateral acceleration	A 3-axis accelerometer, mounted below the winch
Ship speed	A Walker "Trident" log. Calibrated on measured mile trials
Wind speed	An R. W. Munro anemometer
Wind direction	Burgee

were calibrated before the beginning of the trials. The rigs used in the calibration of the intermediate shafts for thrust and torque are shown in fig 4 and 5 respectively. With the exception of one or two commercially available items, the equipment up to the recorder input was designed, made and installed by the staff of the Industrial Development Unit.
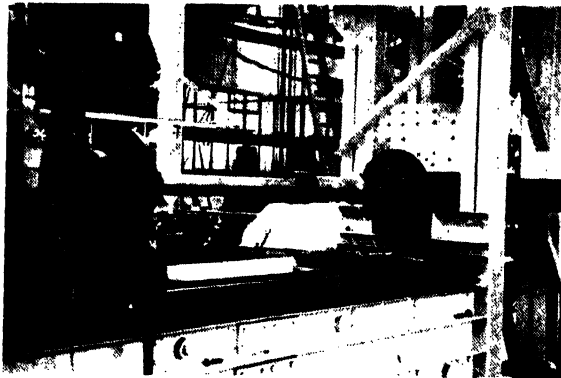
Fig 5. Intermediate shaft undergoing torque calibration

The recording equipment aboard the *Rosebloom* is shown in fig 6 and a typical section of trace record from the galvanometer recorder appears in fig 7.

Warp loadmeters

It was hoped that these meters would prove to be as useful as similar instruments fitted to distant-water stern
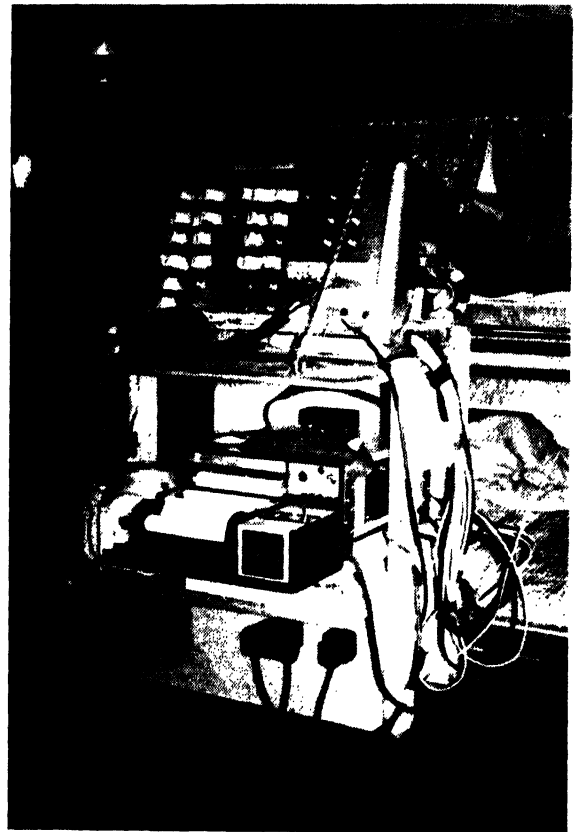
Fig 6. Recording equipment
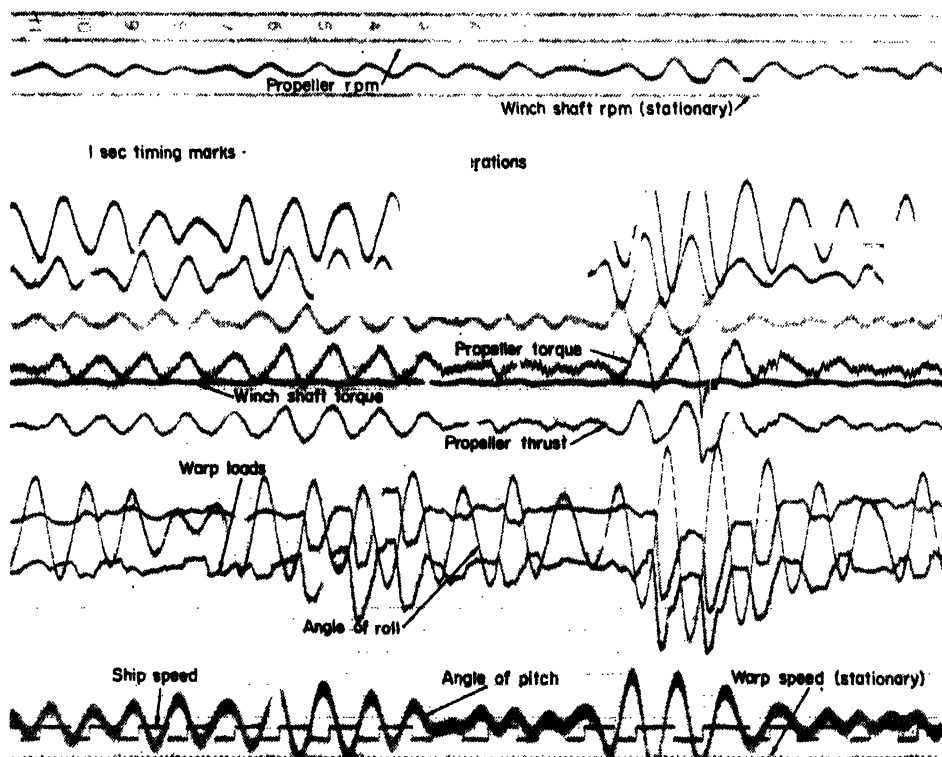
Fig 7. Section of recorder film during trials

[88]
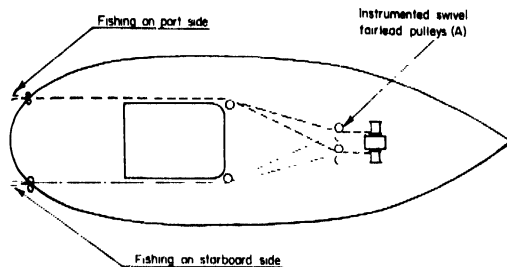
Fig 8. Layout of warps on seine netter

trawlers, in giving warning of fasteners, indicating whether the gear is fishing properly, assisting the skipper in setting his power in conditions of strong tide, etc.

The basic test procedure was similar for both vessels. It consists of measuring the reaction load on a pulley which is positioned to cause a known change of direction in the warp run. Provided the angle of wrap of the warp round the pulley remains constant then the load on the pulley is directly proportional to the tension in the warp, whether it is moving or stationary.
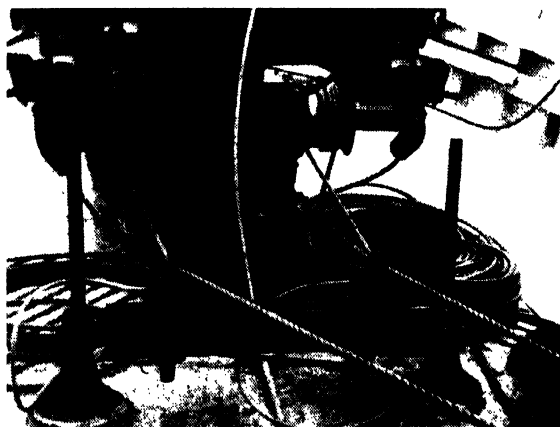
Fig 9. Warp loadmeter on seine netter

The pulleys referred to were mounted on specially designed brackets which were fitted with electrical resistance strain gauges to measure the load. For the trials, the signals from these gauges were fed into the recorder as described above. For the prototype commercial system, however, the signals were fed into dial indicators commercially available in Great Britain. These indicators, which are fed with the raw 24-volt ship's supply, consist of a voltage stabilizing unit, a DC amplifier, and a millivoltmeter, giving a pointer readout of load on a 3-in (76 mm) diameter scale. Fig 8 and 10 show the warp layouts and installation details on the two vessels.
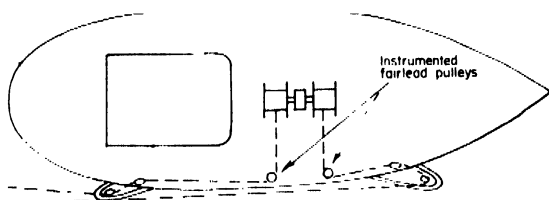
Fig 10. Layout of warps on trawler

(a) Seine net vessel, fig 9: The forward fairlead pulleys (A on fig 8) were selected as the only suitable location for a meter because fishing is carried out from either the port or starboard side and they are the only pulleys continuously in operation. On the standard Scottish seine net vessel these pulleys are mounted on a simple carriage which is slid athwartships by one pulley diameter when changing from port to starboard fishing. Measurement of load on this existing arrangement was discarded in favour of mounting the pulleys on a specially designed swivel arm of the same radius. This arm was fitted with the strain gauges. Since it is free to swivel, it performs the same function with regard to warp alignment as did the sliding carriage.
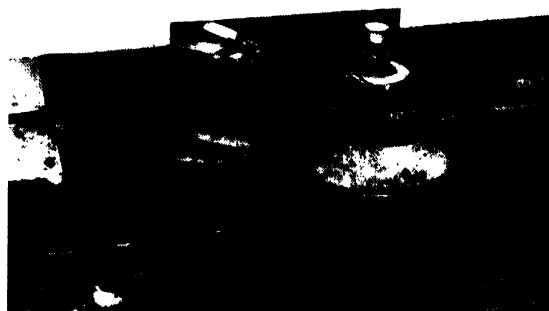
Fig 11. Warp loadmeter on trawler

Fig 12. Calibration of warp loadmeter on trawler

Fig 12a. Warp load indicators in wheelhouse of trawler

(b) Trawler, fig 11: The winch shaft lies fore and aft, and the fairleads on the starboard bulwark, over which the warps pass at 90° angles, are ideally situated for the measurement of load, using specially designed strain gauged brackets.

On both vessels calibration of the warp loadmeters was carried out *in situ* by fixing a warp over the pulleys in the configuration which occurs in normal use and applying known loads by a turnbuckle and spring balance (fig 12).

TRIALS PROCEDURE

Free running—measured mile trials

The measured mile at Kilmuir, near Inverness, is sheltered by hills and at the time of both trials the sea was flat calm with negligible wind. Particulars are:

Position: approx 57° 35′ N, 4° 13′ W
Course: 025, 300 yds (275 m) offshore
Length: 6,093 ft (1,852 m)
Depth: 4 to 8 fm (8 to 16 m)

The procedure was to select an engine speed for each run and allow about 5 min for engine conditions to stabilize. The ship was then steadied on course about a half to three-quarters of a mile (1 km) from the first post and the recorder started. The time taken to cover the measured distance was taken by stopwatch, and the recorder trace record was marked at each post. The ship was run for about three-quarters of a mile (1 km) past the second post before switching off the recorder.

Wind speed and direction were read. In the trials of the *Opportune II* the ship's speed log was seen to be reading high by about 12½ per cent. The records taken on the mile were used to provide a correction for the subsequent trials. In the case of the *Rosebloom* the log was corrected during the first few runs on the mile. The powers ranged from full power down to about 15 per cent of maximum. In the case of the *Rosebloom* one pair of runs was included with the trawl down, primarily to check the log at very low speed.

Free running performance—open sea

Throughout the subsequent trials in commercial fishing conditions an attempt was made to ascertain, wherever possible, the effect of weather, sea state, deep water etc., on the calm water measured mile performance. Usually this was done by taking a complete set of readings at regular intervals on journeys to and from the fishing grounds. In the case of the *Opportune II* an additional set of readings was taken at reduced powers on one occasion when maximum ship's speed had been reduced by bad weather.

Fishing trials

Selection of grounds: For most of the skippers operating in this area the selection of grounds is based largely on experience of the likelihood of obtaining marketable fish, taking into account knowledge of weather, time of year, time of month, location of most profitable markets and so on. The choice of the actual spot at which to shoot the gear is governed partly by the fish finder, if this is being used, but is very much influenced by the

location of hard ground and snags. This applies particularly to the seine net operation using very light gear. In recent years many of the more successful skippers have been fishing increasingly close to wrecks and hard ground, locating these features with great accuracy using the Decca Navigator and continuously building up fishing charts on that system. Mutual exchange of information on this aspect is common between skippers.

Fishing methods during trials:

(a) Seine net fishing: The direction and speed of the operation, the length of warp and the selection of port or starboard fishing depend largely on wind and tide direction relative to the ship and the type of gear used. Bottom topography is also important in some cases. In some situations, it is considered advisable to tow against the tide but with it in others. The warp length paid out varies considerably over the range of conditions and is not necessarily a function of depth. The skipper of the *Opportune II* has used from four to 15 coils (500 to 1,875 fm or 900 to 3,500 m) per side in a recent six-month period.

The fishing cycle is as follows: Having decided from which side of the vessel the tow is to be taken, the warp on the opposite side is paid away from a dhan buoy at about 20° from the desired line of tow, in the opposite direction ("shooting the first leg"). When about 80 per cent of this warp is paid out, the vessel turns sharply to cross the line of tow at right angles. At the end of the first warp, the net is paid out followed by 20 per cent of the second warp ("shooting the second leg"). The vessel then turns again to return to the buoy and pays out the remainder of the second warp up to the dhan buoy ("shooting the third leg"). The two free ends are then passed over the various fairleads, winch and coiler and fishing commences.

On the *Opportune II* it is the usual practice to start fishing with a short tow of about 5 to 10 min. The winch is then started in first gear which is usually maintained until the net starts to close although second and third gear may be enaged in certain tide conditions. When the net starts to close and lift, fourth, fifth and sometimes sixth gear are used to reduce non-profitable handling time.

During the entire operation the vessel moves very slowly through the water but the ground speed, of course, depends on the tide conditions. If a snag or fastener is encountered during this operation, the action taken depends on some sort of assessment of the type of snag and the likelihood of loss of gear against loss of catch so that

- if the snag appears to be a "soft" one, e.g. the rope or trawl digging into mud, the skipper would continue forward, possibly at increased power, to try to pull the net free. Or,
- if the gear appeared to be caught fast he would stop hauling and retrace his path over the net in an effort to save the net at the expense of the fish already caught

The provision of an instrument to assist in making the right decision in this situation is one of the main reasons

for development of a warp loadmeter for this type of vessel. The first seine net warp loadmeters, were built by the Marine Laboratory in Aberdeen and used on *FRV Mara* but to speed commercial application the idea was handed over to the WFA industrial development unit. (Dickson and Mowat, 1963.)

(b) Trawling: The general method of trawling on the *Rosebloom* is virtually identical to side trawling on larger vessels. Long spreading wires are used (40 fm or 73 m) which are wound directly on to the winch barrels when hauling, after the sweep wires. The length of warp paid out relative to the depth varies much more than is the case on distant-water trawlers. It is general practice to use as much warp as experience has shown can be towed over a particular ground, up to 425 fm (850 m) carried on the winch. Warp length to depth ratios of up to 10 : 1 are not uncommon. The crew can turn round the fishing gear from knocking-out to squaring-up in about 30 min even with 425 fm (850 m) of warp and 40 fm (73 m) spreading wires and since fairly long tows are usual (4 hours in normal fishing) there is a high ratio of fishing to handling time.

Trials procedure: Both skippers were requested to carry out normal fishing operations until sufficient records were taken, the only interference with normal procedure being to request a variety of depths and bottoms and some deliberate fasteners or snags. Sometimes an entire operation was recorded, but at other times the recorder was run intermittently, although for several minutes at a time. A code of event marks was used to indicate signicant events on the trace record and visual readings of wind and weather were taken regularly.

On the *Opportune II* the bulk of the fishing trials was done at about 58° 28′ N, 2° W and 58° 45′ N, 1.5° W
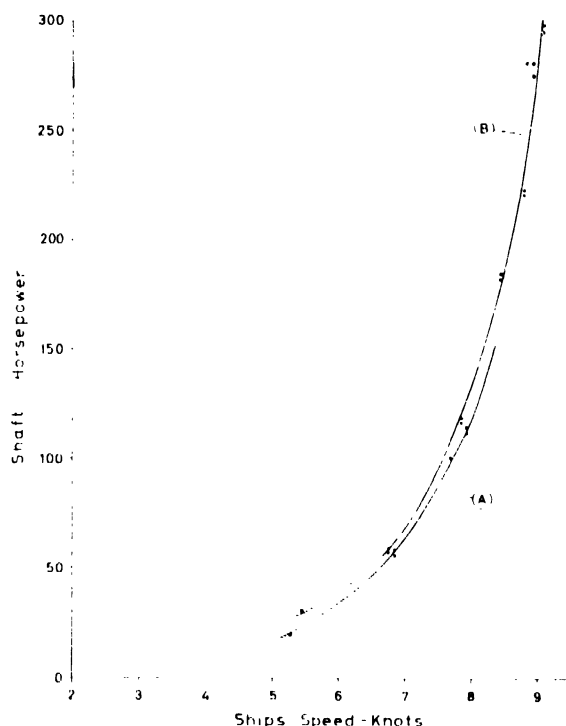
Fig 13. Free-running power-speed characteristic. A Opportune II *B* Rosebloom

on 4th and 5th May 1965, with additional work in the Moray Firth on 3rd and late 5th May. Table 4 gives the fishing records list.

The skipper took the *Rosebloom* through the Pentland Firth, fishing on two grounds, Stormy Bank (58° 55′ N, 4° W) and The Noup (59° 23′ N, 3° 35′ W). In addition to

TABLE 4. List of hauls—seine netter, *Opportune II*

Ref. No.	Date May 1965	Time start shoot	Depth fm	Depth m	Coils per side	Bottom	Approx. catch stones	Approx. catch kg	Remarks
H.1	3	0400	18/22	33/40	10	Sand	20	125	
H.2	3	0615	58/60	106/110	10	Mud	30	190	
H.3	3	0925	50	90	11	Sand/mud		....	Broke port warp
H.4	3	1020	55	100	11	Hard	40	225	Several deliberate snags
H.5	3	1340	45/60	80/110	11	Sand/mud	20	125	
H.6	4	1645	50	90	11	Mud	150	950	
H.7	4	1750	55	100	11	Mud	350	2,220	
H.8	4	1950	55	100	11	Mud	200	1,270	
H.9	5	0400	110/80	200/145	10	Hard		—	Snag steamed back
H.10	5	0600	100	180	10	Hard		...	Snag pulled clear
H.11	5	1750	20	36	8				Chain in place of net to catch snag

TABLE 5. List of hauls   trawler, *Rosebloom*

Ref. No.	Date July 1965	Time start shoot	Depth fm	Depth	Warp length fm		Bottom	Approx. catch	kg	Net	Doors
H.1	10	1530	5	9			Sand/stones		—	A	A
H.2	11	0600	60	110	300	550	Sand	240	1,525	A	A
H.3	11	0900	60	110	250	460	Sand		—	A	A
H.4	11	1530	86/98	160/180	425	780	Mud	160	1,025	B	A
H.5	11	2050	85/95	155/175	425	780	---	240	1,525	B	A
H.6	12	0135	90	165			Mud	320	2,030	B	A
H.7	12	0630	100	180	425	780	Mud	240	1,525	B	A
H.8	12	1030	100	180	425	780	Mud	160	1,015	B	B
H.9	12	1300	100	180	425	780	Mud	160	1,015	A	B

[91]

numerous records of normal fishing operations, the effect of towing at various propeller revolutions was investigated systematically on tow H7 of table 5 which lists the various records taken.

TRIALS RESULTS

Analysis work is still in hand on some of the trace records taken during the trials, particularly on the *Rosebloom* work. The results given here and the observations on them refer only to the data analysed to date. Further information will be published by the White Fish Authority in Technical Memoranda.

Free running—measured mile trials results

The curves of propeller shaft power against ship speed for both vessels are shown in fig 13. Both sets of tests were run under conditions of flat calm and the plotted points are each the mean of two runs, one in each direction. The other relevant parameters including propeller thrust (Pt) are plotted against propeller rpm in fig 14 and 15 for the *Opportune II* and *Rosebloom*, respectively.

Also on fig 14 and 15 an apparent propulsive efficiency (η) has been plotted. Since there is no model or full-scale data from which to obtain thrust deduction fractions or wake fractions, it is not possible to produce either the propeller or propulsive efficiencies as usually defined. The apparent propulsive efficiency, therefore, has been obtained by dividing the thrust horsepower

$$\frac{TV}{33,000}$$

by the propeller shaft power

$$\frac{2\pi NQ}{33,000}$$
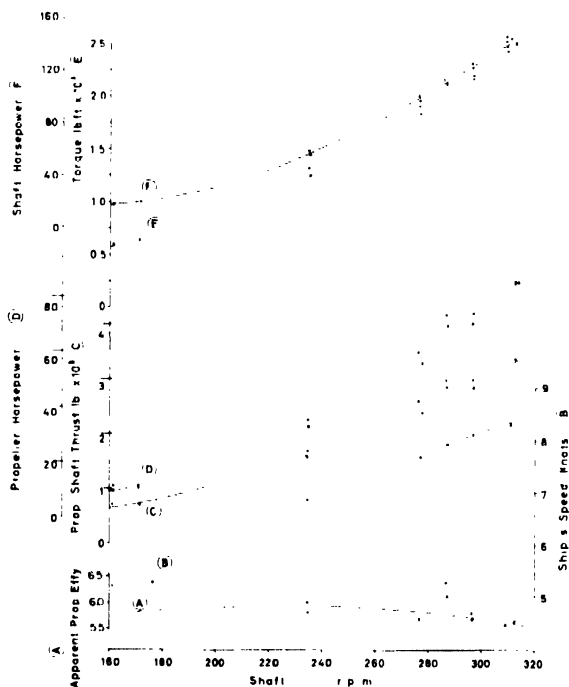
where T (lb)   : measured thrust
V (ft/sec) : ship's speed
N   : propeller rpm
Q (ft/lb) : shaft torque.
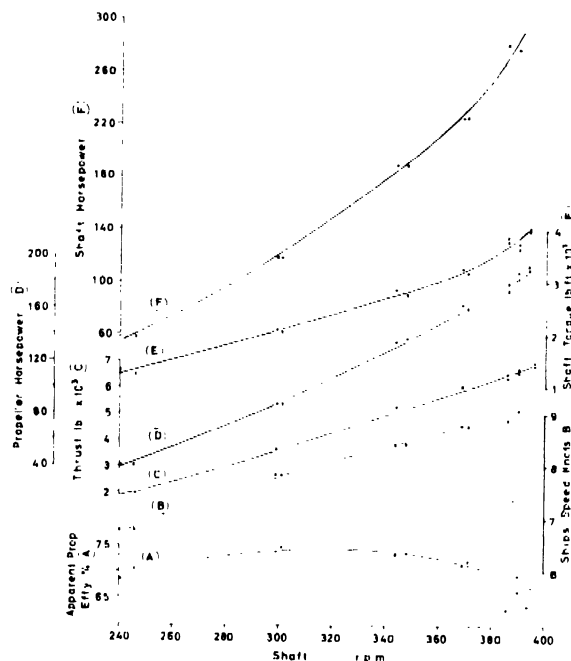
Fig 15. Rosebloom: *Free-running power characteristic*

Free running—open sea trials results

As mentioned earlier, a set of readings was taken at varying powers on *Opportune II*, in weather Beaufort Number 5 wind force and with a sea state producing angles of pitch and roll up to the order of $\lfloor 3^\circ$ and $\perp 10^\circ$ respectively. The power versus speed curve for that condition is shown (fig 16) and the other relevant parameters are plotted against propeller rpm (fig 17).
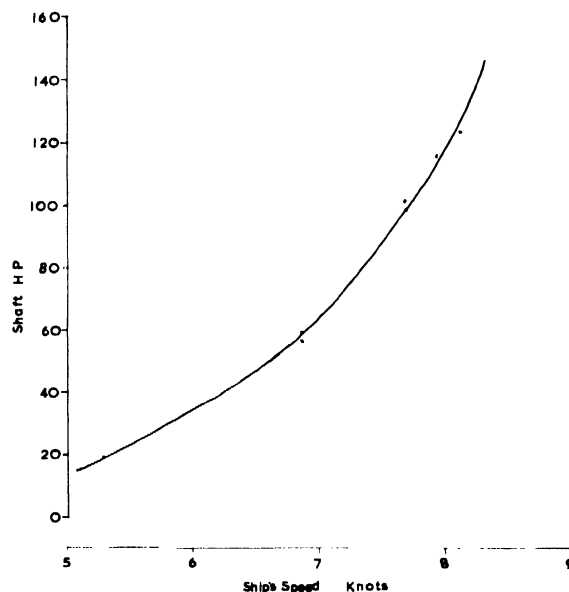
Fig 16. Opportune II: *Power/speed characteristic in open waters. Beaufort Number 5. Pitch Angles up to $\pm 3^\circ$. Roll angles up to $\pm 10^\circ$*

Fig 14. Opportune II: *Free-running power characteristic*
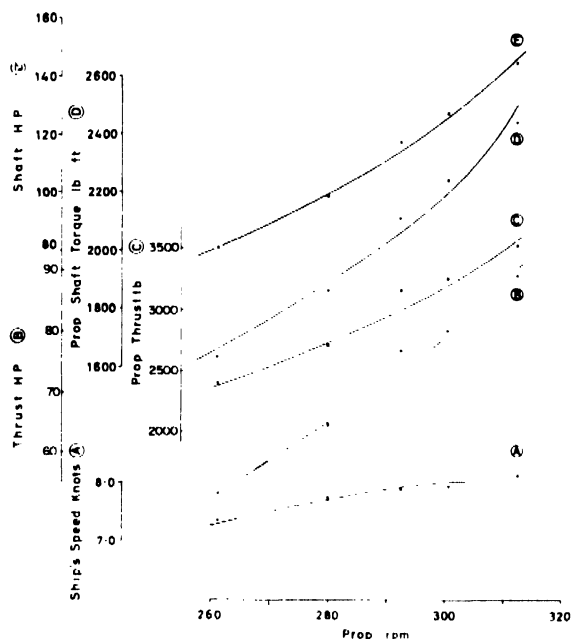
Fig 17. Opportune II: *Free-running power characteristic in open water. Pitch angles up to* 1·3°. *Roll angles up to* ± 10°

The other open sea tests consisted of taking a set of readings at nominal full power setting in as wide a variety of weathers as possible. Because of the erratic nature of the ship motion it is difficult, however, to settle on a reliable criterion when quoting angles of pitch and roll for any given condition. On these particular records it was observed that the second largest amplitude usually recurred frequently on any given occasion and this value has, therefore, been quoted throughout this paper. When time permits, a more detailed analysis will be carried out. Also, engine rpm was not set precisely at the same value on each occasion so that to reduce scatter from that cause all powers and thrusts have been corrected to the nominal maximum 313 rpm. The results of these particular tests are listed in table 6. Each of the tabulated values is the average value over a long record except for the ship motion figures.

Fishing trials results

Seine net vessel: Fig 18 and 19 give the results of the analysis of one complete cycle, No. H1, in which, during the haul, all six gear ratios were used in the winch drive although this would not necessarily occur in practice. Fig 19 gives the information relating to the winch and the warps and fig 18 gives the ship and pro-

TABLE 6 Effect of ship motion, *Opportune II* free running

Ship pitch angle ± degree	Prop torque lb/ft	kg/m	SHP	Prop thrust lb	kg	Ship speed knots	Thrust hp
0	2,520	349	150	3,250	1,470	8.3	81.5
1	2,520	349	150	3,250	1,470	8.3	81.5
1.5	2,470	342	148	3,550	1,620	8.1	89.6
2.5	2,520	349	150	3,600	1,640	8.2	90.0
3	2,570	355	154	3,620	1,650	8.06	99.6
4.5	2,600	360	155	3,700	1,700	7.85	90.0
7.5	2,620	362	156	3,700	1,700	7.8	89.6
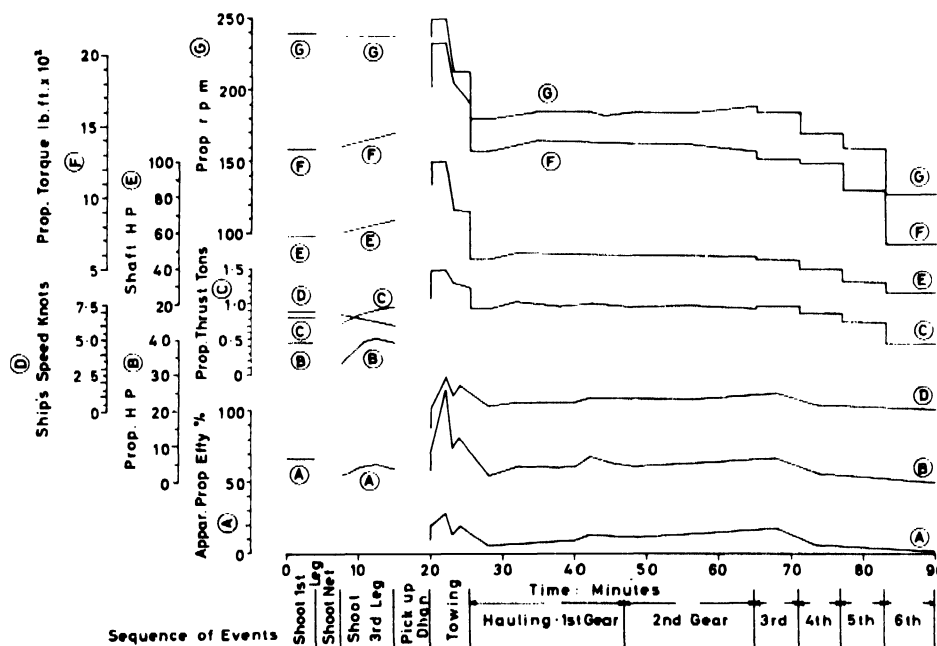
Fig 18. Opportune II: *Fishing cycle, Haul H1 Ship Data*

[93]

TABLE 7. SHP and warp powers related to catch, *Opportune II*

Ref.	Approx. catch		Depth		Hauling in gear	SHP	Warp load Port		Starboard		Total warp power hp
	stones	kg	fm	m			cwt	kg	cwt	kg	
H.9	—		100	185	1	5.8	12.1	615	8.0	410	5.45
						47.3	9.6	490	9.4	480	5.45
					2	47.3	9.6	490	9.4	480	7.0
						47.3	10.6	540	9.4	480	7.35
					5	26.8	4.55	230	6.1	310	10.2
						26.8	6.6	335	3.3	165	10.1
H.1	20	125	20	36	1	45	9.2	465	8.7	440	4.95
						47.1	8.67	440	8.5	430	4.85
					2	48	8.98	455	8.7	440	5.9
					3	45.5	8.28	420	8.15	415	7.71
					4	40	8.05	410	8.25	420	15.3
					5	32	7.53	380	7.11	360	15
					6	15.25	4.4	225	5.1	260	10.75
H.6	150	950	50	90	1	53.2	10.6	540	10.3	525	6.0
					2	53.7	11.1	565	10.3	525	7.5
						53.7	9.6	490	9.5	485	6.65
					5	26.4	9.1	460	8.5	430	16.85
						29.0	9.6	490	8.0	410	17.5
H.7	350	2,220	55	100	1	54.2	9.6	490	10.3	525	7.75
						53	9.6	490	10.3	525	7.75
					2	53	9.6	490	10.3	525	6.82
						51.4	9.1	460	9.5	485	6.4
					5	36.4	9.6	490	9.8	500	20.1
						35.4	9.6	490	9.0	455	19.7

peller parameters. Although the trace record was analysed at 30-sec intervals the results have been averaged over several minutes for plotting, except where sudden changes occur. Warp horsepower (fig 19) is the total output winch power obtained from the product of the two warp loads and their linear speed. The winch efficiency is this warp power divided by the input power to the winch.

Table 7 summarizes some of the hauling characteristics on four hauls on which both size of catch and depth varied considerably. Some typical effects of ship motion are shown in table 8, in which the pitch and roll values are given.

Figures 20 and 21 show the time history of catching a snag. In the first case, fig 20, the first action taken was to de-clutch the winch, then when the warp tension was
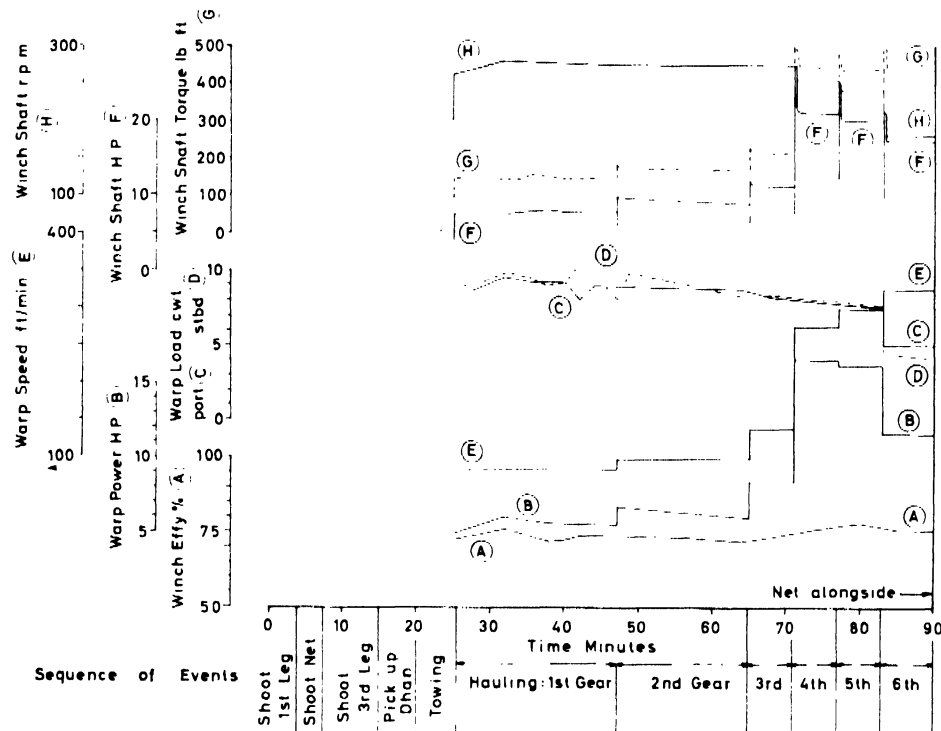
Fig 19. Opportune II: *Fishing cycle, Haul H1. Fishing gear data*

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TABLE 8. Haul H6—effect of ship motion on loads during haul, *Opportune II*

Condition	Pitch ± deg	Roll ± deg	Port warp tension				Winch shaft torque				Propeller shaft torque				Propeller thrust			
			Mean		Oscil ±		Mean		Oscil ±		Mean		Oscil ±		Mean		Oscil ±	
			cwt	kg	cwt	kg	lb/ft	kg/m	lb/ft	kg/m	lb/ft	kg/m	lb/ft	kg/m	lb	kg	lb	kg
Start haul 1st gear	4	11	11	560	1	50					1,500	207	240 P	33.2	2,540	1,150	420 P	190
End haul 1st gear	2	11	10	510	.75	38					1,460	202	150 P	20.7	2,540	1,150	250 P	115
Hauling 2nd gear	2	17	9.5	485	.75	38	175	24.2	22	3.04	1,460	202	180 P	24.9	2,540	1,150	340 P	115
Hauling 5th gear	2	10	9	455	2	100	510	70.5	150 P	20.7								
Towing, net surfacing	4	2	4	205	1 R	50					1,250	173	150 P	20.7	2,540	1,150	170 P	75
Towing, net surfacing	4	8	10	510	10 R	510					1,250	173	150 P	20.7	2,540	1,150	170 P	75
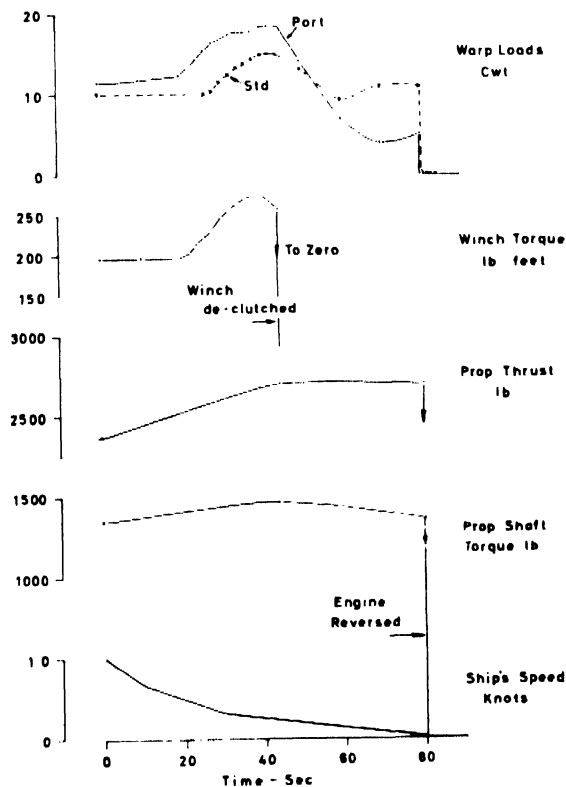
Fig 20. Opportune II. *Haul H9 response to snag. Skipper declutches winch, then reverses engine*

Fig 21. Opportune II. *Haul H11 (towing) response to snag. Skipper reduces power slightly, continues towing*

seen to remain high the engine was reversed and the ship turned towards the net in order to free it. In the second case, fig 21, the skipper decided to tow on, at slightly reduced power until the ropes pulled clear, as can be seen from the rapid reduction in load.

Fishing trials—trawler: The performance characteristics of this vessel, when towing Trawl B in 100 fm (180 m) are shown in fig 22. The power versus speed curve for this condition is shown in fig 23. Figures 24 and 25 show a typical fishing sequence.

DISCUSSION AND OBSERVATIONS

On free running trials

The speed power curves for both vessels show the characteristically steep slope near maximum speed and indicate that marked fuel economy could be achieved by reducing cruising power whenever possible. For example, continuous operation of the *Opportune II* at ¼ knot less than her maximum would reduce the fuel consumption when running free by about 20 per cent. Undoubtedly there is a psychological aspect in desiring maximum

Fig 22. Rosebloom. *Fishing trials 12th July, 1965. Towing power characteristic. Haul H7*

speed and there must be occasions when the last ¼ knot will be a considerable advantage but a detailed study of the pattern of fishing over a year should show if and when this expensive speed is justified. This applies even more to the *Rosebloom*, with a more powerful engine for trawling, where the highest ¼ knot costs 24 per cent of the fuel consumption.

Both propellers appear to be slightly mismatched with respect to the engines installed. On the *Opportune II* the propeller pitch is slightly low in that the engine does not develop its full rated power until its revolutions are 4 per cent above the nominal maximum. On the *Rosebloom*, the propeller pitch is slightly coarse since the engine is on limits 1½ per cent below the maximum nominal rpm at about 92 per cent maximum rated power. Again a detailed study will indicate the economic significance of these findings.
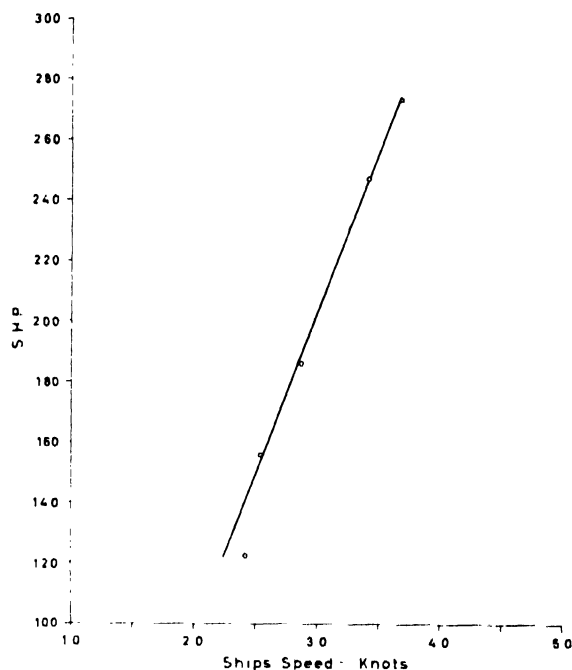
Fig 23. Rosebloom. *Haul H7 towing power– speed characteristic*

Table 6 shows the effect, on full power performance, of the various weather conditions encountered during the course of the trials. Even in quite moderate weather conditions, there is a speed loss of 0.5 knot, about 6 per cent compared with the measured mile conditions. There is an associated increase in thrust developed by about 16 per cent. These figures will vary considerably in different combinations of wind force and direction, sea state etc., and at this stage these results can only be regarded as typical of the orders of magnitude involved.

On fishing trials results

Seine net vessel: The powers, efficiencies etc. quoted (fig 18 and 19) may be regarded as typical for this class of vessel. Worth noting is the very low apparent propulsive efficiency during the tow, of the order of 0.15.

The results given in Table 7 show that size of catch has little or no effect upon the warp loads for most of the

haul, in first and second gears, but when the net begins to close and higher gears are engaged the power is significantly higher with the larger catch, and the warp loads do not decrease as they do when the catch is small. 20 hp was recorded with a catch of 5,000 lb (2,300 kg) and this could presumably be higher with much larger catches which are not unknown. This table also shows that the depth has little effect on warp loads and power requirements during the haul.

These and the other records show that the mean loads are little affected by variations in the type of bottom, sand, mud, stones etc.
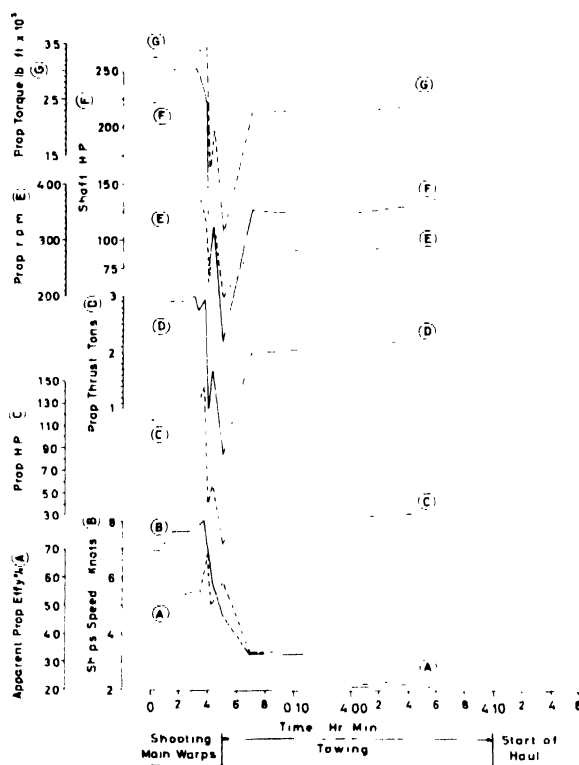
Fig 24. Rosebloom. *Haul H2 Ship data*

The weather throughout the trials varied from Beaufort No. 2 to 5 with ship motions up to ∓10° pitch and +20° roll. The fishing records show no significant change in mean load or power due to weather alone. However the oscillatory loads are affected by ship motions and the results for record H6, summarized in table 8, are typical. These results show that, as the net is hauled in, the fluctuating load in the warps increases, becoming increasingly affected by ship roll as the warps shorten, and fluctuating warp tension can equal the mean value (i.e. 0.5 tons ± 0.5 tons).

The records shown in fig 20 and 21 are typical of a number of records taken when a snag was encountered. These records and the skipper's reaction at the time show that a snag is first noticed by the skipper primarily as a difference in the appearance and feel of the warps. The time between actually catching a snag and it becoming apparent to the skipper was generally of the order of 30 sec, by which time the load in the snagged warp

can have risen three or four times the value previous to the snag developing. One of the potential benefits of a visual warp loadmeter is to give a much more rapid warning of snags, particularly to less experienced skippers than that of the *Opportune II*. Figures 20 and 21 also illustrate the skipper's dilemma when faced with a snag. To steam back (fig 20) may lead to 2½ to 3 hr loss of fishing time while to proceed (fig 21) may cause considerable gear damage, even complete loss. The visual loadmeter should assist considerably in making the correct decision in this situation.
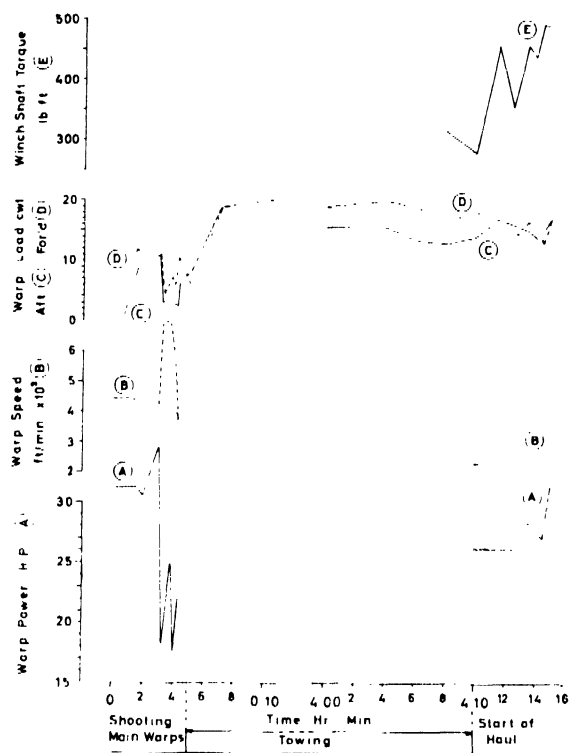
Fig 25. Rosebloom. *Haul II2 Fishing gear data*

On trawler trials: The analysis of the various hauls, taken in a variety of conditions, is still in hand. Some comments can be made, however, on the set of readings taken at various propeller rpm at 100 fm (180 m). In these trials, which are summarized in fig 22 and 23, the maximum shaft power developed was 273 hp at 365 rpm, probably because with this particular propeller and this trawl the engine was on torque limits at that power and speed. It is however doubtful if more power could be of any advantage in these conditions, since even with the 3.7 knots, 273 hp, 365 rpm, the skipper felt that there was a tendency for this gear to lift which tends to be confirmed by a reduction in warp tension (fig 22).

Using this particular trawl, the benefits of having installed the larger engine are seen in fig 23 where the

increase from 150 hp to 250 hp gives towing speed increase from 2½ to 3½ knots. The remaining 75 hp is not usable when towing this gear in 100 fm (180 m) for the reasons given above, but further study of the remaining fishing records is necessary before this conclusion can be applied generally.

Figures 24 and 25 show the powers, speeds, etc. associated with shooting and hauling, and may be taken as typical values but further analysis is in hand to show the range of values involved.

DIRECT INDICATING WARP LOADMETERS

During both sets of trials the warp load signals were fed into the recorder for most of the time and only switched to the dial instruments on a few occasions. Both installations were left for assessment by the skippers over a long period of commercial fishing. To date, it has only been possible to obtain a progress report from the *Opportune II*. The skipper reported favourably on the system and, in particular, uses the meters (a) to determine whether or not to tow the gear clear of a snag, using 1.5 tons as a maximum safe load and, (b) to set towing power and speed in a tideway. On coming to a new ground the loadmeters are studied carefully to obtain the usual 0.4 to 0.5 tons per side, until the skipper is familiar with the run of the tide. The system is covered by UK Provisional Patent Application.

FUTURE ACTION

The information summarized in this paper will be used as basic data for a programme of design and development work on the types of inshore vessel concerned. In particular the following items are in hand or under consideration:

(1) Development of a hydrostatic drive for seine net winches. A drive of this type, not geared to the propeller shaft, could show operational advantages and the information obtained in these trials has allowed an accurate specification to be drawn up for load, power and characteristics.

(2) Design work on optimum propulsion machinery characteristics for these vessels. With an accurate knowledge of the requirements, it is possible to make a comparative assessment of various types of propellers, including CP propellers, to try to achieve an optimum in terms of capital and running costs.

(3) Techno-economic studies in general, of which item (2) is a major part.

(4) Consideration of possible improvement in hull form.

Technical Survey of Traditional Small Fishing Vessels

by N. Yokoyama, T. Tsuchiya, T. Kobayashi and Y. Kanayama

Etude technique des petits bateaux de pêche traditionnels

Etude technique détaillée des petits bateaux de pêche japonais utilisés sur tout le littoral, s'attachant particulièrement à leur bonne tenue à la mer et à la simplicité de leur construction. L'emploi de sections polygonales et de bouchains vifs, outre qu'il simplifie la construction et réduit les travaux d'entretien à terre, augmente parfois aussi le rendement des opérations de pêche.

Análisis técnico de las pequeñas embarcaciones pesqueras tradicionales

Son técnicamente estudiadas en sus detalles las pequeñas embarcaciones que más se ven en todas las costas japonesas, especialmente en lo que se refiere a sus favorables condiciones marineras y sencilla construcción. Sus secciones poligonales y la robustez de su doble arista no sólo simplifican la construcción y reducen la manutención en tierra, sino que a veces favorecen las operaciones de la pesca.

MODEL resistance and structural testing of traditional Japanese small fishing vessels were presented at the Second FAO World Fishing Boat Congress; now, investigations are introduced concerning the sea-keeping performance in waves and methods of construction. In the distant past the empirical design provided safety and easy maintenance which was essential to the fishermen, and they could reach the coast of China crossing 500 miles of the East China Sea. Their practicability is proved because, even today, nearly 400,000 fishing vessels smaller than 20 GT are, without exception, of the Japanese traditional type (fig 1). Low building and maintenance costs are advantages of this type of fishing vessel, and therefore such a design may be a good guide to those intending to set up small coastal fisheries with limited capital in developing countries.
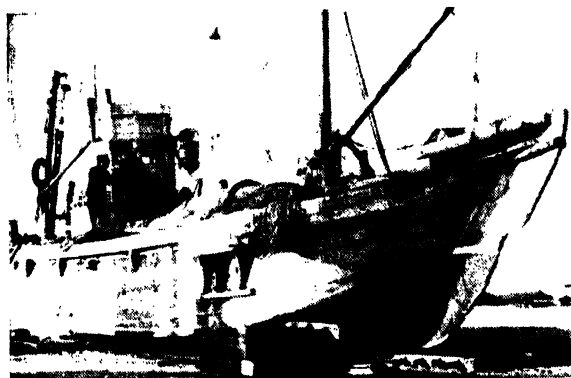
Fig 1. Traditional type Japanese fishing vessel

Beach landing can be easily performed with assistance of housewives from neighbouring families even for craft up to 50 ft (15.3 m). Boats of 30 ft (9.2 m) may be handled alone by the aged or a married couple. Nowadays,

outboard motors or small diesel engines are utilized and also the beach landing winch, formerly manually operated, has been mechanized by drum and small motor. The device for lifting the propeller and rudder and the wide flat bottom of the keel keep the boat stable whilst being slid on either sandy or pebble beaches. Wooden slats are sometimes used as a slipway for heavier boats larger than 30 ft (9.2 m) on soft sandy beaches (fig 2).
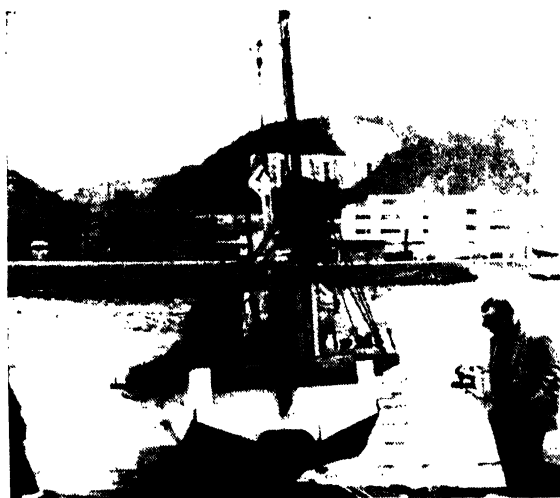
Fig 2. Stern detail of Japanese fishing vessel

Although the angular shape of the hull might appear to give bad sea-keeping properties the empirical design methods have reasonably avoided the dangerous resonant conditions better than the conventional round-bilge type when subjected to tests in waves. The longitudinal distribution of section shape and area controls the value of the longitudinal GM and the inertia coefficient, including the entrained water mass, and gives a

moderate longitudinal motion with the encountering wave, even in the worst synchronized conditions at low speeds. The angular shape of the hull and the deep rudder tend to damp the motion in waves, and is one of the most important factors in producing favourable seakindliness.

The same is true of the safety margin in the synchronous rolling conditions, and it is possible to maintain an ample righting potential in specific weather conditions by good design. The hard chine tends to damp the roll in resonant conditions and, because of the small transverse GM, there is little possibility of resonance in short-crested waves just off-shore.

The reserve of buoyancy should be obtained by providing sufficient freeboard to overcome the worst conditions.

The long and narrow rudder compensates for the low lateral resistance of the shallow keel, thus reducing the tendency to transverse drift in cross seas and wind.

According to statistics, a large proportion of sea casualties are caused by incorrect steering and misuse of engines. The safety margin should be high for all circumstances and engine reliability is very important.

The various properties of good ship performance mentioned above can be obtained comparatively easily for round-bilge European vessels. But special care and sound experience are required to obtain these properties and approach the ideal of good performance for the traditional Japanese type of boat.

In the design, certain longitudinal and transverse members are deleted. This saves labour during construction but, as all loads must be carried by the shell plating, good techniques are required for constructing the hull skin. Many types of soft wood may be used, according to availability; and with good maintenance, especially of the seams of shell plates and bottom knees, an average boat's life should exceed 20 years.

The price obviously varies according to cost of materials and labour. Recently, the local labour cost variation has become small, but material costs vary immensely depending on the type and quality of the wood, and it has become difficult to obtain timber of large dimensions with natural curvature. The hull prices, from statistical data of 1963, Ministry of Agriculture and Forestry, are shown in table 1.

The total number of fishing boats less than 20 GT in 1963 was 391,545, of which only 179,409 were mechanized. The mean tonnage of the unpowered boat was 0.81 GT and that of the powered 1.79 GT. The mean engine power was 7.88 hp. The general trend between 1953 and 1963 may be seen from fig 3, which shows an

Number of unpowered boats

Gross tonnage of unpowered boats

Number of powered boats

Gross tonnage of powered boats

Horse power of engines
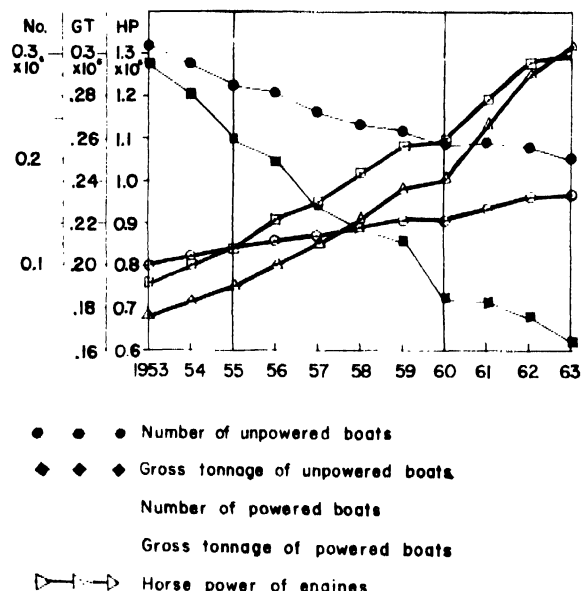
Fig 3. Statistical data of Japanese fishing boats under 20 GT

increase in powered vessels of 64 per cent and a decrease in unpowered of 32 per cent.

RESISTANCE AND PROPULSIVE CHARACTERISTICS

Resistance characteristics

The Japanese traditional chine boat can be designed to give the same resistance characteristics in calm water as European round-bilged vessels. Some test results of three Japanese and three European boats are compared in fig 4; the frictional resistance was derived from the Schoenherr line. The small Japanese traditional boat M-7, 26 ft (7.9 m) for general fishing, has excellent results up to Froude Number, Fn = 0.40 (6.4 knots), whereas the M-8, 36 ft (11.0 m) pole-fishing boat is good up to Fn = 0.35 (6.3 knots)

M-57, 52 ft (15.9 m) purse seiner (fig 2) has a higher resistance over its entire speed range, even below Fn = 0.30 (6.8 knots). The fish hold occupies a large part of the boat and the low and flat bottom is necessary for daily launching at surf side.

M-11, 72 ft (22.0 m) trawler, and M-13, 61 ft (18.7 m) purse seiner, have a round and full hull form and their practical speed should be lower than Fn = 0.30 (about 8 knots). M-61, 47 ft (14.35 m) trawler, has fine lines (Cp = 0.582) and shows an excellent performance over all the speed range.

TABLE 1. **Cost of hull of traditional Japanese fishing vessels**

Quality of Materials	3 GT £ ($)	5 GT £ ($)	10 GT £ ($)	20 GT £ ($)
High	480 (1,340)	875 (2,450)	1,750 (4,900)	4,100 (11,500)
Low	275 (770)	500 (1,400)	1,150 (3,220)	2,500 (7,000)

Note: Hard wood —Quercus glandulifera, zelkova, camphor
Medium —Cherry, Japanese cedar
Soft wood —Pine, Japanese Judas
GT —0.55 LBD in metric unit (19.4 LBD in ft unit)
The hull price includes the complete vessel and gear, except for the electrical equipment.

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Fig 4. *Comparison of residual resistance coefficient between Japanese and European types*

Fig 5. *M-7 self propulsion test results*
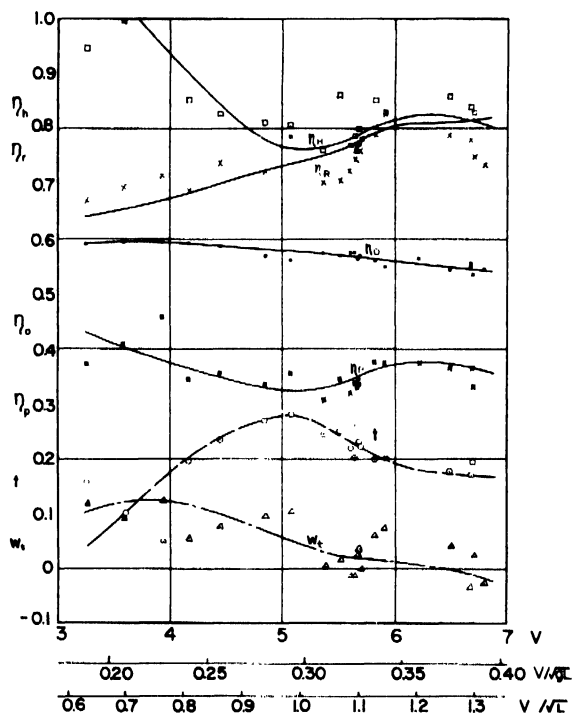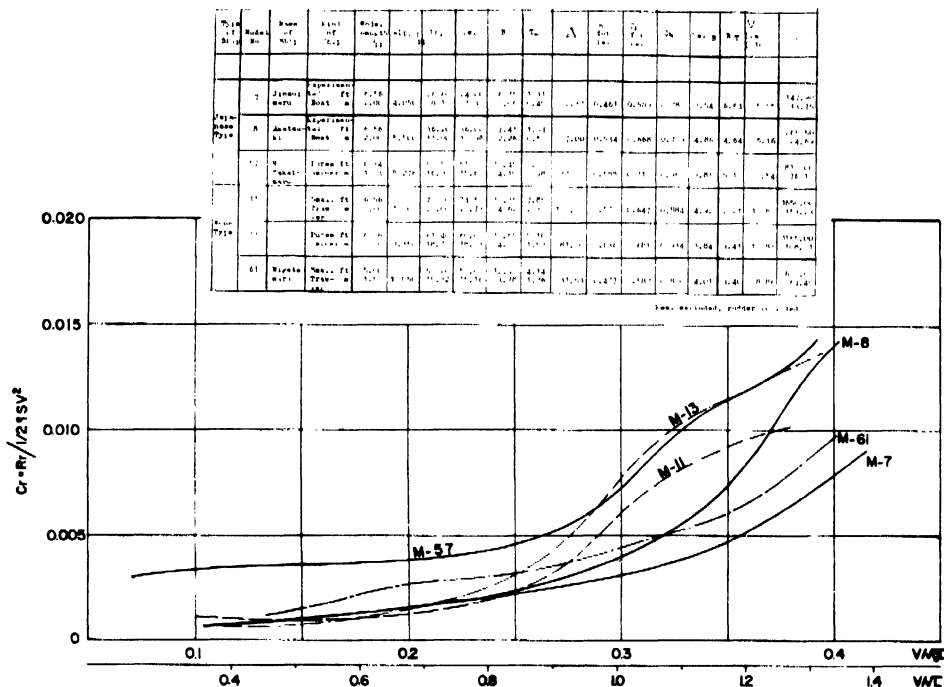
Generally the trim and draft affect the resistance of the chine form, especially in the lower speed range, Fn = 0.25, whereas at higher speeds above Fn = 0.30 the longitudinal volume distribution has more effect on the resistance of both types, chine form and round bottom form, than the sectional shape. This may be proved by the results of M-57 (chine, Cp = 0.710) and M-13 (rounded, Cp = 0.681). In the initial design stage, therefore, the trim of the draft

should be decided considering chine and sectional area curve. For small boats the hydrodynamic flow velocity is so high that the flow along the hull may separate from the angular edge and the effect of volume may become much higher than the eddy-making resistance caused by the polygonal section-shape.

Fig 6. *M-57 variation of wake fraction and thrust deduction coefficient due to propeller position*

Fig 7. Comparison of pitching amplitude between Japanese and European types

Calm water propulsive characteristics

In spite of the good resistance characteristics, the disadvantage of the Japanese boat lies in the low propulsive characteristics. These are difficult to improve because stern construction is not easy to simplify further than the existing transom. The propulsive factors of M-7, 26 ft (7.9 m) are given for tests with a 2-m model (fig 5). The wake fraction, w_t is quite small and disadvantageously decreased from 0.1 to 0 or negative depending on the increase in speed, $Fn = 0.2$ to 0.4. On the other hand the relative rotative efficiency, η_r, of the propeller rises from 0.7 to 0.8 with the speed but is much lower when compared with ordinary ships. The thrust deduction factor, t, is rather small, possibly because of the suction effect at the submerged transom but in the higher range from $Fn = 0.25$ to 0.4, it rises up to the normal value of 0.2. The hull efficiency results from w_t and t, and so remains in the order of 0.8 and the resultant propulsive coefficient $\eta_D = Pe/Pd$ is between 0.3 to 0.4 depending on the speed.

Effect of propeller position

Since the stream flow line cannot follow around the angular square stern, and the flat bottom gives low w value, the Japanese traditional boats must have an excessive thrust deduction.

When a propeller is put parallel to the flow, separated from the transom edge, and its centre immersed at least to its radius, the hull efficiency should become 100 per cent, but in practice the loss due to an increase of the thrust deduction fraction t will always exceed the small gain of w_t. This presumption was made quantitatively evident in tests in fair conditions, namely, with the propellers raked at 7°, 12° and 17° to the standard WL, plus less immersion at 12° of rake, as illustrated in fig 6. The result shows that L-12 deep immersion has the best

hull efficiency above 9 knots followed by L-12, L-17, L-7 respectively, where L-12 may be affected by the influence of the rake. The negative wake has been derived from the potential flow along the hull surface and the deep immersion of propeller gives a hull efficiency over 90 per cent,
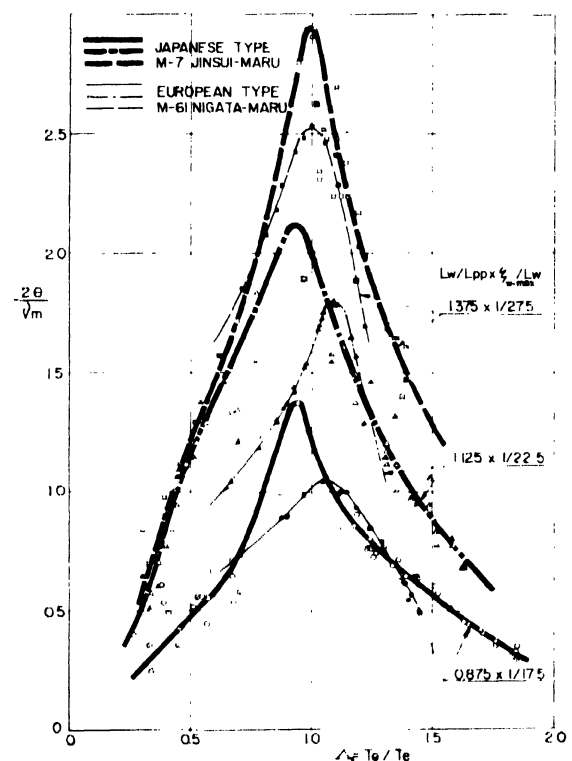
Fig 8. Comparison of pitching amplitude between Japanese and European types

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but a deeper draft at the stern is not advantageous both to t and w_t.

The propeller lift is a typical device of the Japanese traditional boat, and the fishermen often use it when they navigate in shallow water, run over fish nets, or land their boat on a beach. A test was planned to clarify the effect of the propeller position, relative to the stern profile, on the factors of w_t and t. There are optimum values for the rake and the distance from the hull in the test, but in practice the fishermen operate the elevator quite freely according to the water depth.

Longitudinal motion in waves

Essential factors for the longitudinal motion are natural period of free pitching, length of maximum synchronous wave, and damping characteristics at resonance. A boat of long free period encounters the significant synchronous wave in the low speed range, which will seldom happen. M-7, 6.5 ft (1.98 m) chine model, had an experimental natural period of 0.945 sec, and M-61, 5 ft (1.52 m) rounded model corresponding to the 6.5 ft (1.98 m) model, of 0.804 sec. Generally the strong damping of the
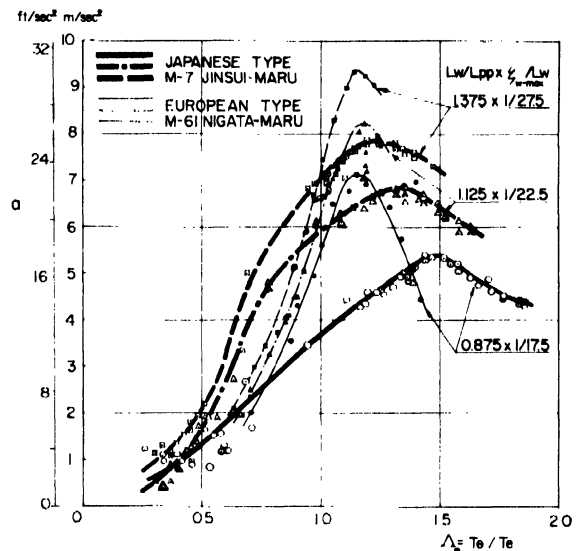
Fig 9. Comparison of bow acceleration between Japanese and European types
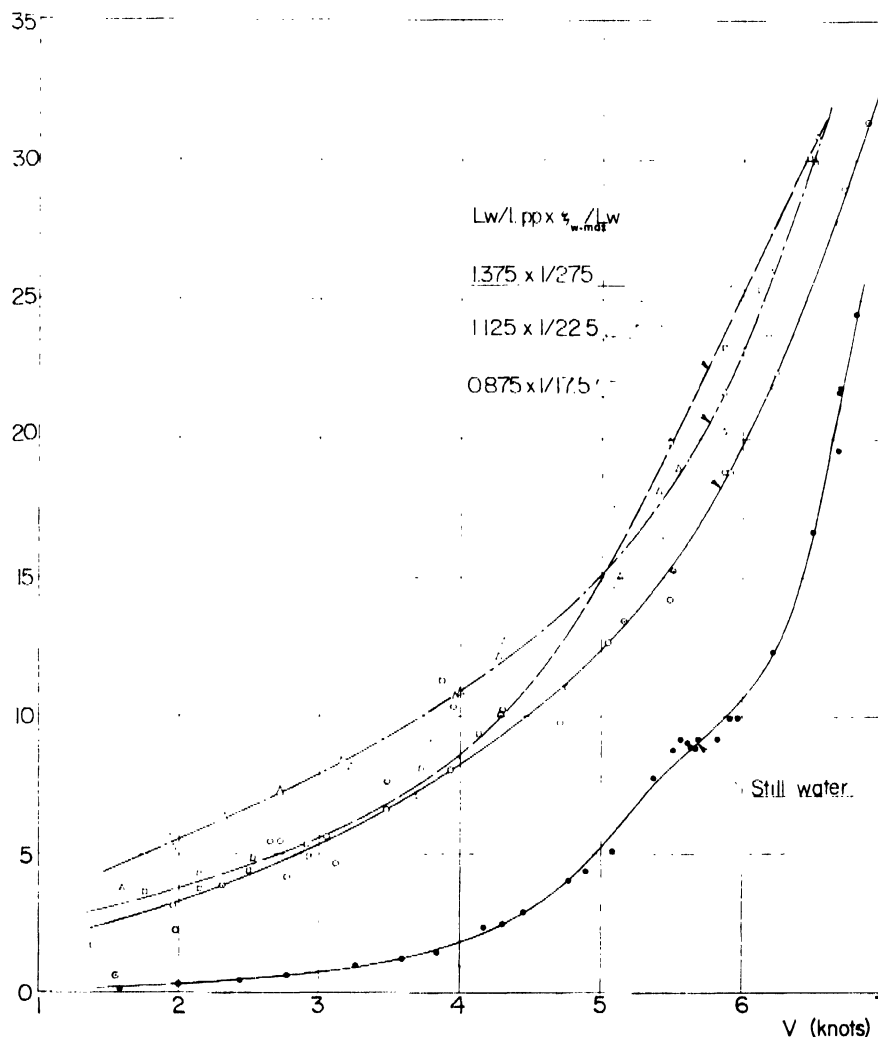
Fig 10. Increase in still water SHP due to waves

motions makes the measurement of the period so difficult that its accuracy might not be fully reliable. Assuming $K_{yy} = L/4$, the free period is represented by $2 \pi K_y / \sqrt{gGM_1}$ where K_y includes the added mass of water and depends on the form and speed, the value GM_1 depends on the form of water plane and the height of G. M-7 has a fine fore body and wide transom stern, and the BM_1 for the model is 6.11 ft (1.85 m). M-61 is a normal boat having $\overline{BM_1} = 7.61$ ft (2.18 m). The added mass of water will increase more for M-7 than for M-61 when the flow separates from the chine and transom at high speed. These characteristics cause the difference in the free period.

The wave length having maximum synchronous force on the ship's motion is decided by the pitching force distribution along the surface, which mainly depends on the volume distribution. M-7 is excited by rather a short wave, since the buoyancy is increased at the stern, and the resonant speed for a short wave is low. The test with M-7 and M-61 were not conducted at the maximum synchronous conditions, but it can be seen from the result (fig 7) that the resonant speed for M-7 is about Fn = 0.1 and that of M-61 above Fn = 0.25. Since the usual running speed is around Fn = 0.3, M-7 will be the more comfortable in waves.

When a boat meets the synchronous condition, the motion depends upon the damping effect of the hull form. At a first glance, the flat chine form seems to have a longer synchronous motion in the maximum exciting condition, but the result in fig 8 is contrary to expectations, although further study should be made on this subject, as well as the relationship between dynamical exciting and damping.

M-7 has so fine a fore body and so full a stern that the resultant motion of pitching and heaving may bring the virtual centre of pitching rather aft. The combined effect of acceleration of pitching and heaving at the bow is smaller for M-7 than M-61 (fig 9). Such a result comes from the phase difference between them, where the heave of M-7 is in advance of its pitch, but on the other hand the pitch of M-61 is only a little in advance of its heave.

Power increase in waves

To maintain the same speed in waves as in calm water, the power should be increased and the more violent the motion the more power is required. Self-propulsion in rough water tests were run with M-7 (fig 10) but the M-61 model was too small to fit the dynamometer and so the model was towed in the same waves. Table 2 is the ratio of the increase of SHP to that of EHP, assuming

propulsive coefficients are the same for both models. The trend is similar to that of the pitching amplitude, and M-7 is a little better than M-61 above Fn = 0.26.

TABLE 2. $\triangle SHP/SHP$ of M-7/$\triangle EHP/EHP$ of M-61

Wave	Fn – 0.26	0.30	0.34	0.38
0.875 L	0.902	0.675	0.773	1.300
1.125 L	0.986	0.705	0.697	0.925
1.375 L	0.880	0.735	0.772	0.870

ROLLING AND STABILITY

Rolling

It is very important to design fishing boats which do not roll excessively during the fishing operation. In order to damp the rolling, bilge keels are usually fitted to the hull but most small Japanese fishing boats have hard chines at the bilge instead. The effect of the chines should be clarified by using Bertin's extinction co-efficient N, for roll damping which is used in the example below.
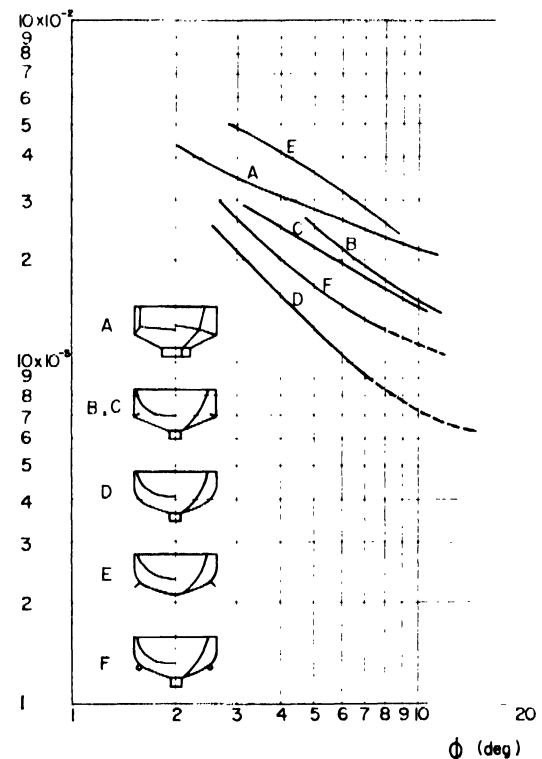
Fig 11. N values of boats having typical hull form

TABLE 3. **Principal dimensions of boats A to F (fig 11)**

Mark	Lpp ft	(m)	B ft	(m)	D ft	(m)	Length of bilge keel	Length of chine
A	26.2	8.00	6.77	2.06	2.82	0.86	none	through Lpp
B	29.5	9.00	6.56	2.00	2.95	0.90	none	about ⅔ Lpp
C	80.01	24.42	18.05	5.50	8.10	2.47	none	about ¼ Lpp
D	68.50	20.88	14.40	4.40	7.05	2.15	none	none
E	95.20	29.00	17.70	5.40	8.86	2.70	about ⅔ Lpp (steel)	none
F	78.20	23.80	17.65	5.39	8.50	2.59	about ⅔ Lpp (wood)	none

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(1) **N coefficient:** The values of extinction coefficient measured for many actual boats operating under load conditions are shown in fig 11. Their principal dimensions are shown in table 3. The lines plan of "A" marked in fig 11 are shown in fig 23. Fig 11 shows clearly that the N value of A is the largest, with the exception of E. This indicates that the damping action of the hull form having hard chines throughout its length is greater than those having partial or no chines. The damping action of A is rather comparable with that of E which has sharp-edged bilge keels made of steel. The actual effect of these N values is shown as follows:

(2) **Comparison with round-bottom boats:** When a boat rolls synchronously on a regular beam swell having the maximum wave slope v_m (degree), the maximum rolling angle is calculated by:

$$\phi_m \doteqdot \ \backslash\ \pi \gamma v_m / 2N \text{ (degree)} \qquad (1)$$

where γ is effective wave slope coefficient.
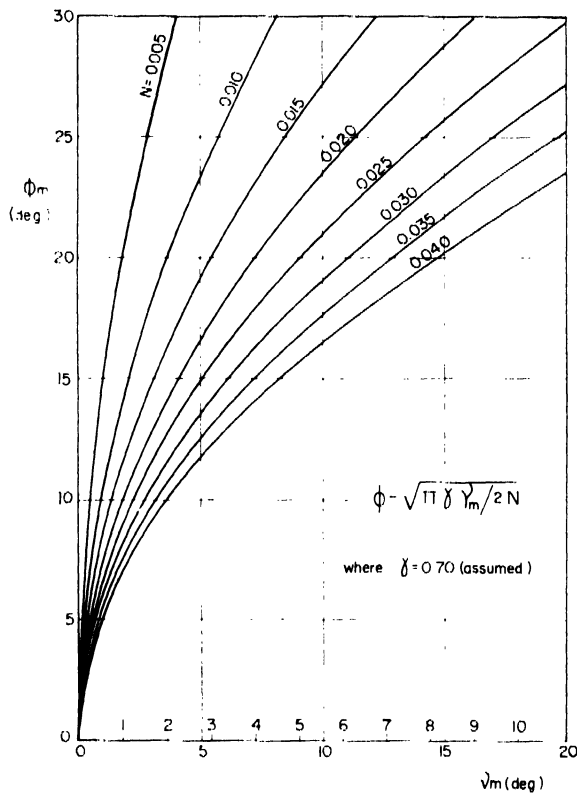
Fig 12. Relation of synchronous rolling angle ϕ_m, maximum wave slope v_m and extinction coefficient N

If γ value is assumed 0.70, ϕ_m values are calculated by (1) and shown in fig 12 as the function of v_m and N. If $v_m = 5.0$ is assumed, the synchronous rolling angle of boat A which has hard chine throughout its length is ϕ_m (boat A) $\doteqdot 16.5$ in fig 12 by using its $N_{a\ 16.5^\circ} \doteqdot 0.020$* in fig 9. In the same waves, the synchronous rolling angle of boat D which is round-bottom hull form without bilge keel ϕ_m (boat D) > 30 is found by using its $N_{a\ -30^\circ} \doteqdot 0.006$ (assumed). The reason for comparing A with D is that most of the Japanese wooden round-bottom boats do not have large effective bilge keels

* $\doteqdot$ approximately equal to.

because of the fear that the watertightness of the shell plank around such a keel might easily be broken by accidents.

TABLE 4. Comparison of boats A and D

Boat	Maximum circular velocity	Maximum circular acceleration
A	2.0 ft/sec (61 cm/sec)	4.2 ft/sec² (128 cm/sec²)
D	>3.6 ft/sec (>110 cm/sec)	>7.6 ft/sec² (>230 cm/sec²)

Note: 1. wave period, Tw: 3.0 sec ($-$Ts when synchronized)

wave length, λ:	46 ft (14 m)
maximum wave slope, v_m:	5.0°
maximum wave height, H_w:	1.3 ft (39 cm)
H_w/λ:	1/36

2. Limit value of unbearable acceleration

by Kempf	1.97 ft/sec²	(60 cm/sec²)
Inoue	3.93 ft/sec²	(120 cm/sec²)
Kawashima	6.55 ft/sec²	(200 cm/sec²)

3. Maximum circular velocity at the deck edge

$$\doteqdot \frac{B}{2}\ \phi_{max}\ \frac{2\pi}{T_\phi}\ (\text{where}\ \phi_{max}\ \text{radian})$$

Maximum circular acceleration at the deck edge

$$\doteqdot \frac{B}{2}\ \phi_{max}\ \left(\frac{2\pi}{T_\phi}\right)^2\ (\text{where}\ \phi_{max} - \text{radian})$$

Under such rolling conditions, the circular maximum velocity and acceleration at the deck edge of each boat is shown in table 4. (Assuming the breadth B = 2.0 m and free rolling period $T_x = 3.0$ sec). The difference in the results are thought to be significant from the fishing efficiency viewpoint in rough seas. In Japan, some pole-fishing boats are designed empirically to make them as close to the permissible lower limit of stability with lower $\overline{KG}/D$ value and hard chined hull form. This is reasonable because they have longer rolling period, T_x, smaller effective wave slope coefficient, γ, and higher extinction coefficient, N, and so have a tendency to roll more slowly and to smaller angles.

In Japan, there is a small number of round-bottom wooden fishing boats having wooden bilge keels, but their N values are much smaller than those that have sharp-edged bilge keels made of steel (fig 11). This is because the keel depth is rather small and the edge not usually sharpened. On the other hand, the sharp-edged chines of vee-shaped boats are thought to be quite effective to damp the rolling.

(3) **Fishing platform:** Most of the Japanese small fishing boats have fishing platforms outside of both deck edges, as shown in fig 22, 23 and 24. These parts are actually not watertight and therefore do not affect $\overline{GZ}$ curves in a rough sea. They are known, however, empirically to be quite useful in damping rolling, although systematical analysis of this has not been performed.

Stability

There is no basic criterion to judge the stability of small fishing boats in rough seas and therefore, in order to compare it, the theory of C value (Yamagata, 1959) now being used in Japan for passenger ships has been used for the small fishing boats.
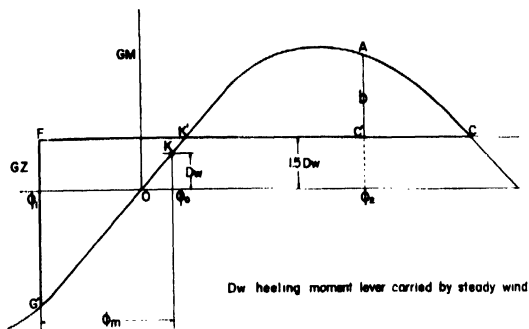
Fig 13. Explanatory diagram of C coefficient

(1) **Wind and waves:** When boat A heels by ϕ_0 degrees to the lee side under steady beam wind, the boat rolls around ϕ_0, and rolls to the maximum rolling angle ϕ_1 (fig 13) on the weather side under synchronous rolling. If a gust blows suddenly from the same direction, the boat rolls much further to the heeling angle ϕ_2 on the lee side, where area K'G'F = area K'C'A as shown. The heeling moment lever of the gust around Japan is nearly 1.5 times of the steady wind. Therefore, if area K'G'F = a and K'C'A = b are measured on the diagram, and b/a > 1, the boat is considered to be safe.
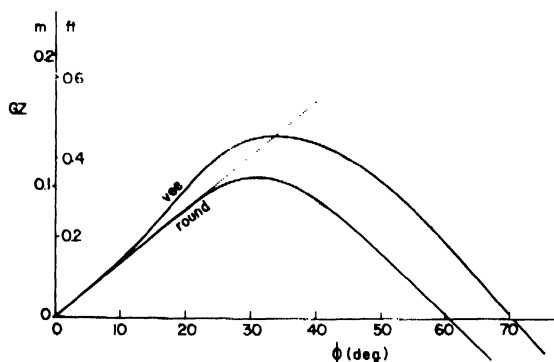
Fig 14. Comparison of GZ curves of Vee- and round-bottom boat

If the stability of a vee-shaped boat is compared with that of a round-bottom boat having the same GZ curve, the former is safer, as N value of the vee-shaped boat is larger, and therefore ϕ_m of the former is smaller.

(2) **Strong wind or deck water:** It is evident that the boat having a larger GZ maximum value is safer when the boat receives only a constant heeling moment caused by, say, a strong wind or deck water. GZ curves are compared between vee-shaped and round-bottom boats of equal displacement (fig 14). In this comparison the latter's bilge is amended into round form from the former's lines drawing by using a radius = B/4, and GM and freeboard are accordingly modified. The comparison indicates that the vee-shaped boat is less dangerous than the round-bottom boat under steady heeling moment.

CONSTRUCTION

The construction methods employed in the building of traditional Japanese boats are of great interest because they are simple and cheap.

Building procedure

(1) **Keel plank:** At first, the wide keel plank is set on the keel block (fig 15). Sometimes it is built with two timbers, depending on the size of the boat, one fore and another aft.

(2) **Aft keel (fig 15):** The aft keel is fixed to the main keel by a scarf joint with a wooden wedge and no nails (fig 16). The wedge is necessary for watertightness. If a keel consists of timber, it is bent a little upward at this point.

(3) **Stem and transom (fig 17, 18):** The stem is attached to the fore end of the main keel mainly by a scarf joint with a wooden wedge and no nails. The transom is fitted to the aft end of the aft keel with nails.

(4) **Bottom planks (fig 15):** Built up and shaped bottom planks which are developed on the ground, are fixed to the keel plank, stem and transom by nails simultaneously and symmetrically in order not to twist the hull. Then the
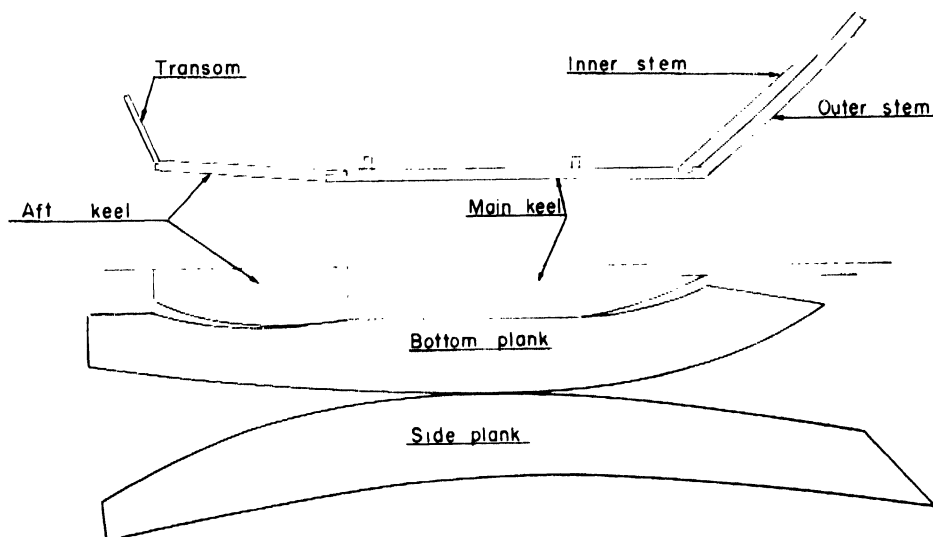
Fig 15. Keel and shell expansion

rise of floor is settled at several fixed positions and upper edges of the bottom plank are smoothed symmetrically.

(5) **Floor timber (fig 19)**: Built up and shaped floor timbers are fixed in set positions to the bottom planks by nails. If a transverse bulkhead is necessary, it is built up, usually on the floor timber.

(6) **Side planks (fig 15 and 19)**: Shaped side planks on both sides are fixed to the bottom planks, stem and transom, from midships towards both ends. Simultaneously the distance of their upper edge is fixed by temporary small tying timbers. The aft ends of shell planks are extended a little, then cut. The aft edge is covered by small planks.

(7) **Side frames (fig 19)**: Side frames, or sometimes bilge brackets only, are fixed to shell planks at essential points. Side frames are unnecessary near transverse bulkheads.
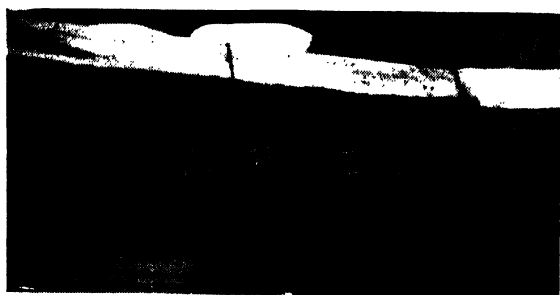
Fig 16. Keel joint
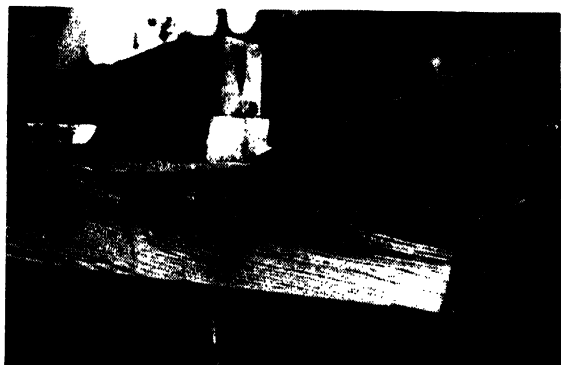
Fig 17. Stem joint

Fig 18. Transom joint
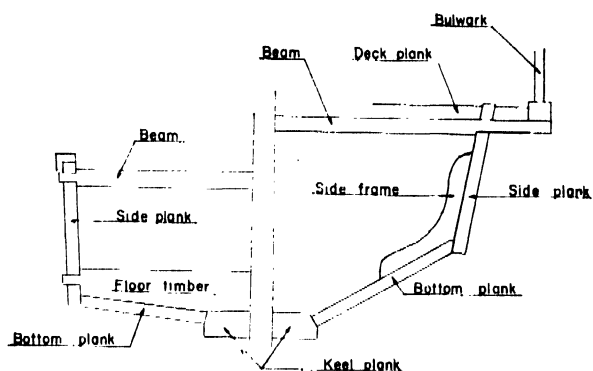
Fig 19. Two sections
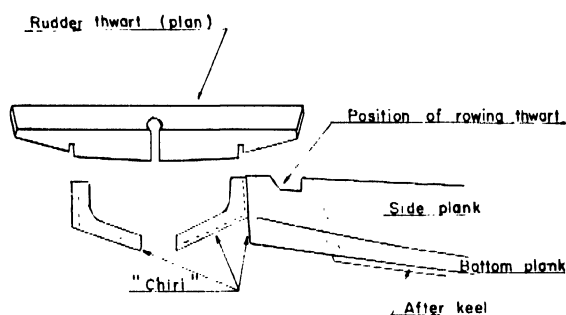
Fig 20. Rudder thwart and "chiri"
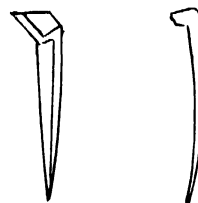
Toori - Kugi   Nui - Kugi

Fig 21. Japanese nails

(8) **Beam and deck plank (fig 19)**: Beams are fixed through side planks at their upper edge. The deck planks are fixed to the beams or top of the transverse bulkheads.

(9) **Rudder thwart (fig 20)**: A rudder thwart is fixed on the upper side of the side planks just aft of the transom. On the beam extended through the side planks, deck planks are generally secured to increase the deck area, and small bulwarks are constructed at both edges of the deck beam.

Scantlings

There is an empirical scantling rule for Japanese wooden boats which is based mainly on the keel length but it is not suitable for use in other countries without considering the strength, rigidity, specific gravity, etc., of the timber used.

Nail

The Japanese wooden boat is assembled by a special nail, as shown in fig 21. The grain of the timber should be considered when they are used. Round section bolts or tacks are not generally used.
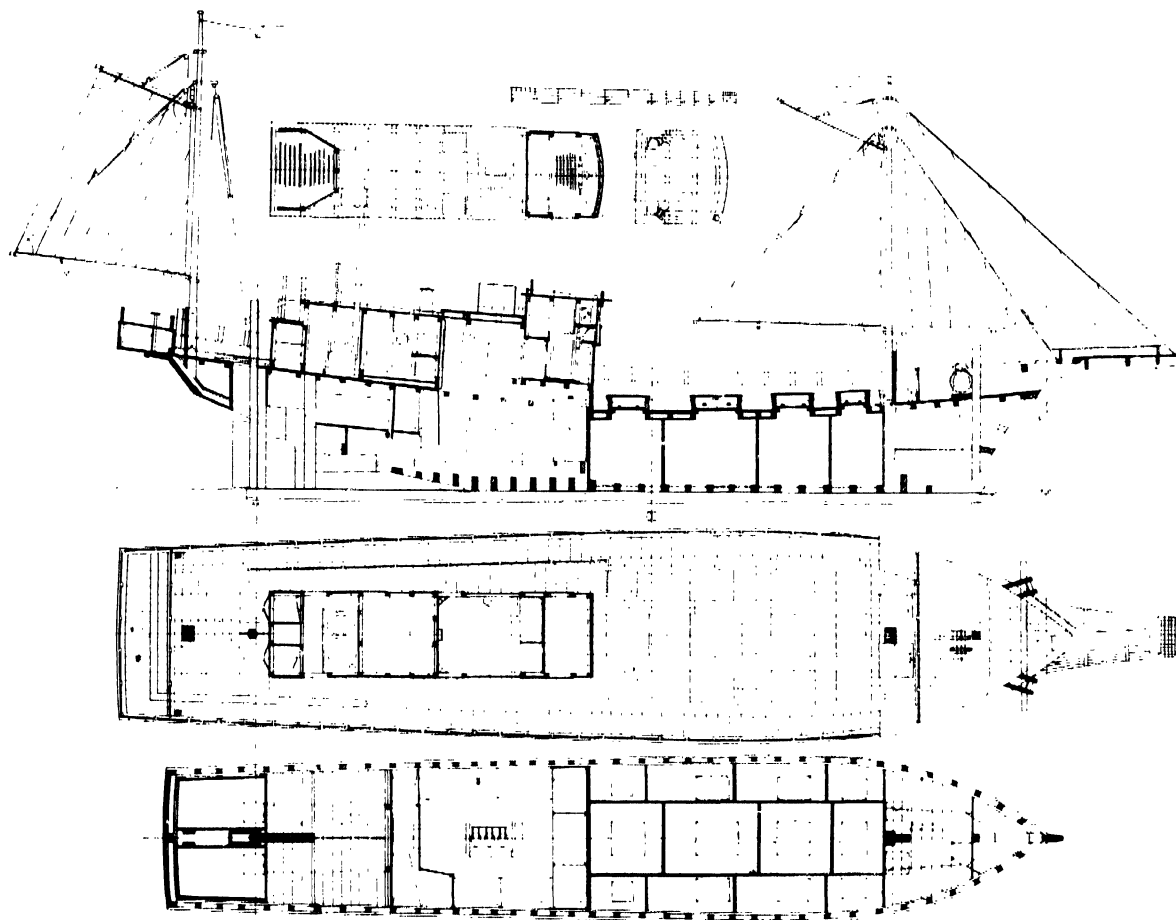
Fig 22. 20 GT mackerel boat

General description

As mentioned above, the Japanese wooden boat is built on basic simple sectional shapes by utilizing the flexibility of soft-wood planks, and therefore it does not require skilled techniques in the design and building. The construction is believed to have been developed because of the abundance of large soft-wood planks in Japan. Now there is a shortage and most of the bottom or side planks are made of built-up wide planks connected side by side by nails. There are thousands of small fishing boats of this construction in Japan, which seems to prove that the construction is strong enough.

Modernized construction

Most of the small wooden boats over 30 ft (9.2 m) in length are now built by modernized Japanese construction (fig 22). They have complete frames in the engine room and cant frames in the fore part. Some of their propeller shafts cannot be lifted, and consequently the construction method of the stern is similar to the European.

The reason why larger wooden fishing boats are not built by traditional Japanese construction methods has been discussed, but there is no fixed opinion.

EXAMPLES OF ACTUAL BOATS

Group fishing boats

To raise the efficiency of fishing in some areas, the group-fishing system has been introduced, consisting of a 10- to 20-GT mothership and about ten 2- to 3-GT small boats. The mothership guides the catcher boats to the fishing grounds and, after fishing, gathers and transports the catch to a suitable market (fig 23 and 24, table 5). These boats have their base ports on islands scattered in western Japan and can go to the fishing grounds in one or two days. They are built in small shipyards by traditional and rather simple methods, without any calculations, but the fishermen claim they are very seaworthy even in rough seas of 32 to 38 ft/sec (10 to 12 m/sec) wind velocity and about 7.6 ft (2.5 m) maximum wave height and can also operate under conditions of 26 to 32 ft/sec (8 to 10 m/sec) wind velocity and about 3.7 ft (1.2 m) maximum wave height.

The mothership shown in fig 24 was designed by the Fishing Boat Laboratory, the main objective being to give it enough seaworthiness and stability.

Small mackerel pole-fishing boats

Drawings and principal dimensions of a typical Japanese traditional boat are shown in fig 22 and in table 6. GM
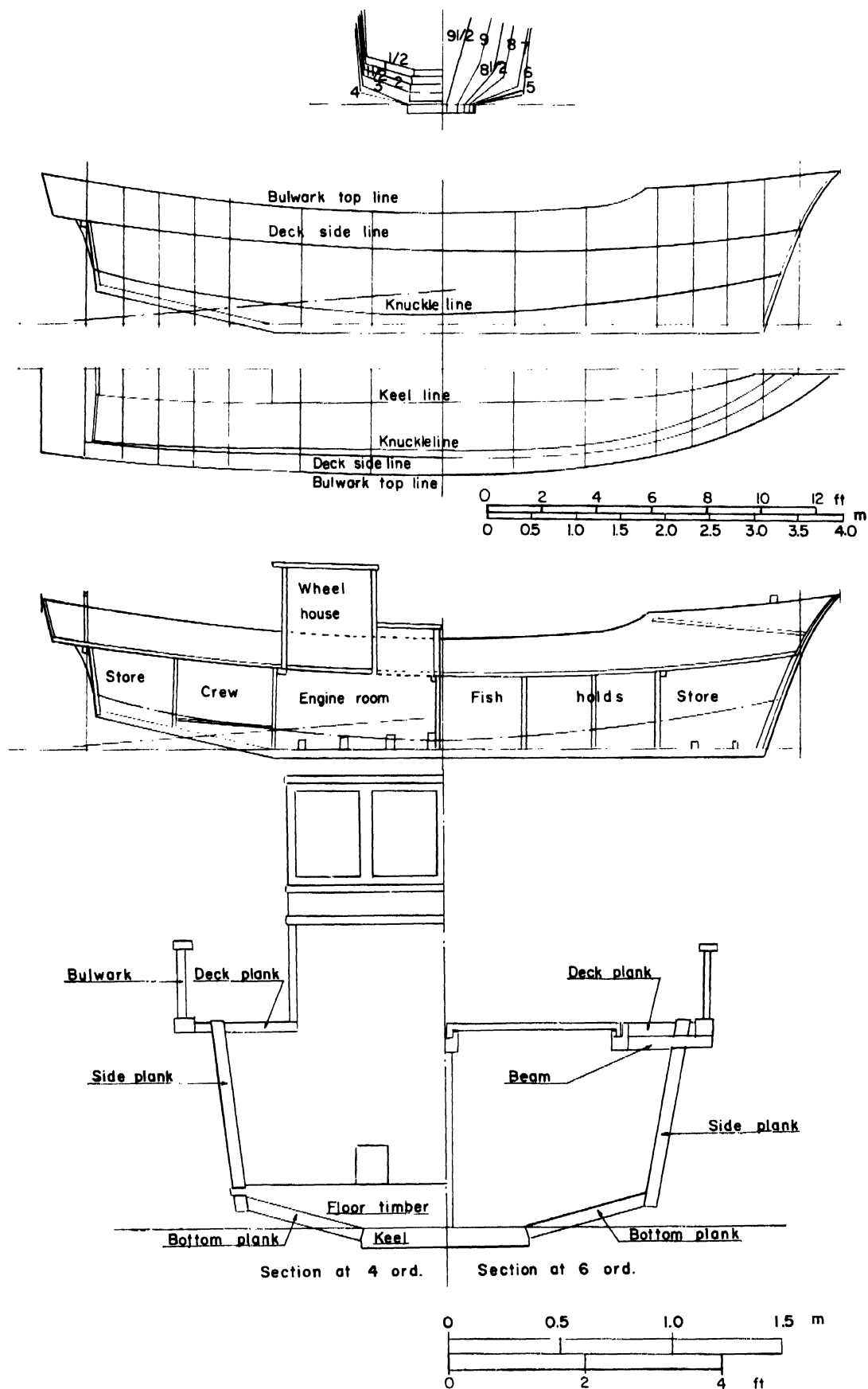
Fig 23. 24 ft pole fishing boat

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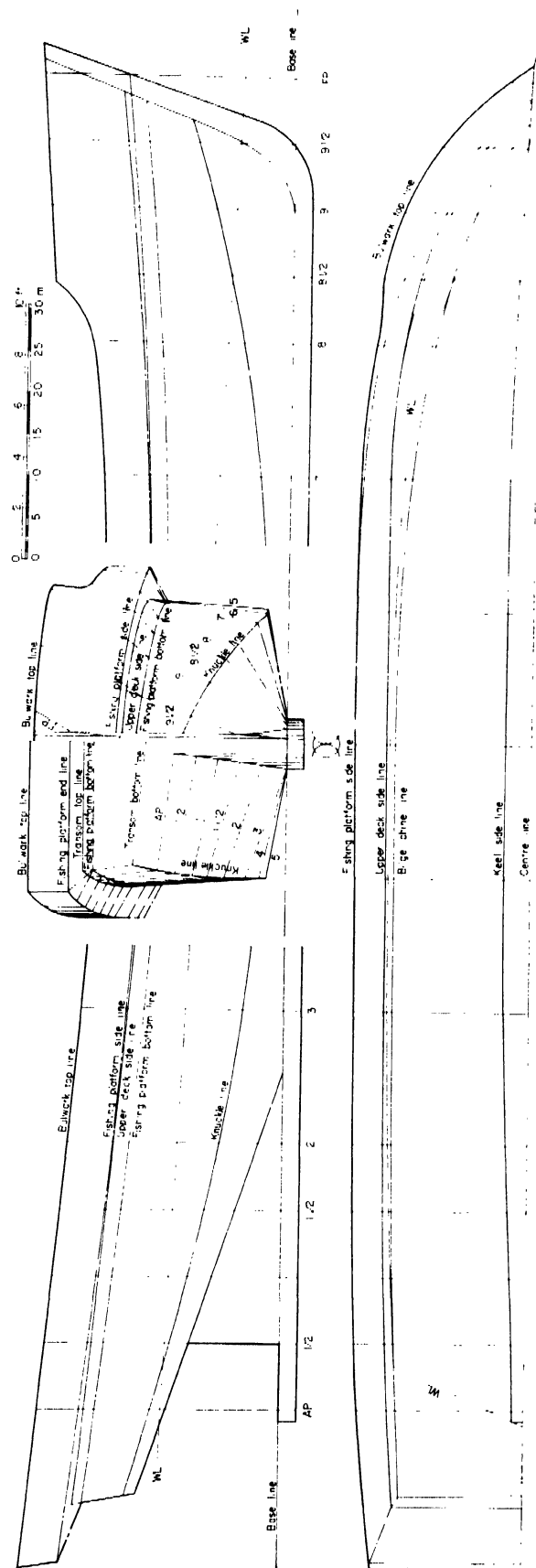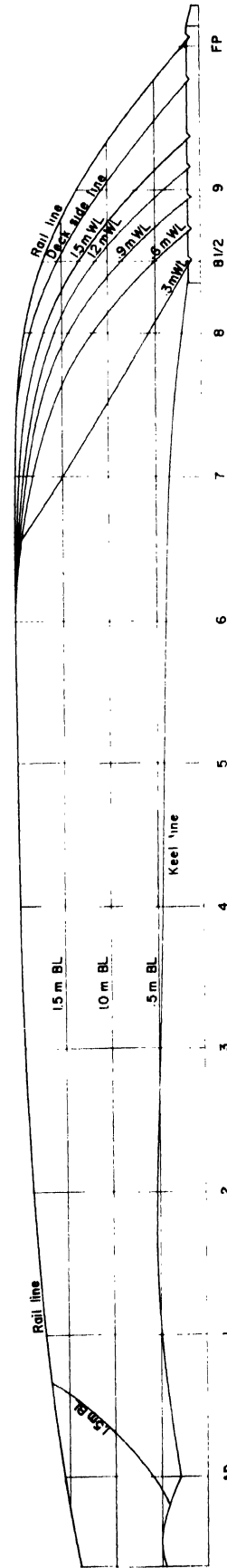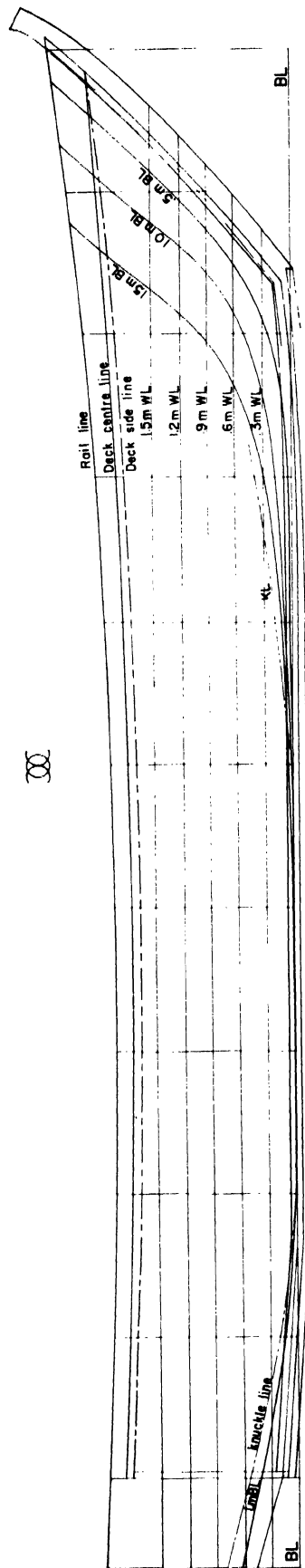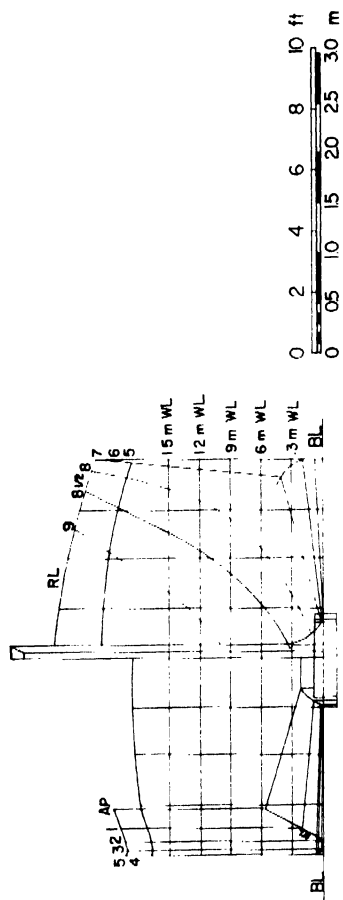
Fig 24. Mothership

Fig 25. Lines of a flat-bottom purse seiner (M-57)

TABLE 5. Principal dimensions and operating condition of group fishing boats

		Small catcher boat		Mothership	
GT		2.8		19.9	
Lpp	ft (m)	26.20	(8.00)	52.50	(16.00)
B	ft (m)	6.75	(2.06)	11.15	(3.40)
D	ft (m)	2.82	(0.86)	5.25	(1.60)
hp of main engine		17		120	
Fish-hold capacity	ft³ (m³)	105.8	(3.0)	777	(22.0)
Number of crew		2		7	
Operating condition					
Displacement	ton	6.5		50.4	
GM	ft (m)	0.85	(0.26)	1.41	(0.43)
Freeboard	ft (m)	0.99	(0.30)	1.05	(0.32)
GZmax	(deg)	32		35	
	ft (m)	0.46	(0.14)	0.82	(0.25)
C coefficient		1.6		2.0	
Wind velocity	(m/sec)	39.40	(12)	62.30	(19)

Note: C coefficients ($-b/a$) are calculated for the weather condition of steady wind velocity of 62.30 ft/sec (19 m/sec) or 39.40 ft/sec (12 m/sec).

value of these boats is rather small and results in a longer rolling period and high fishing efficiency. The main reasons for this are their vee-shaped hull form, low $\overline{KG}$, narrow breadth and little exposed profile area on the water line. The fish pond is built with Japanese traditional type construction, the remainder by combined construction.

TABLE 6. Data of vee-shape mackerel pole-fishing boat

GT		19.50
L×B×D	ft (m)	55.70 (16.95) × 11.52 (3.52) × 5.45 (1.66)
hp of main engine		75
Fish-hold capacity	ft³ (m³)	797 (22.6)
Full load condition		
Displacement	ton	56.9
$\overline{GM}$	ft (m)	0.79 (0.24)
Freeboard	ft (m)	1.18 (0.36)
$\overline{KG}$/D		0.75

Coastal purse seiner Sakai-Maru (M-57)

The lines drawing of a coastal purse seiner is shown in fig 25. It has a nearly square midship section and a very wide flat keel, which makes it very convenient to land or launch on a wide shallow beach. This hull form can easily float at a small draft and also has enough stability in shallow waves or water. The boat is launched on the latticed wood (fig 1) by winding an anchored wire with its own winch driven by its main engine (about 60 hp), temporarily cooled by water in a drum on the deck. On returning with a displacement of nearly 40 tons, it is wound up by a shore winch. The square body is, therefore, indispensable to such operations and some increase in resistance must be accepted (fig 4).

Nomenclature

lpp = length between perpendicular of a model

N = Bertin's extinction coefficient for roll damping force

T_m = mean draft

ϕ_0 = angle of initial keel

ϕ_1 = maximum rolling angle by synchronous wave

ϕ_2 = maximum rolling angle by synchronous wave and gust

ϕ_m = maximum rolling angle

γ_p = resultant propulsive coefficient = Pe/Pd

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Méthode de Projet des Nouveaux Types de Navires de Pêche

by E. R. Gueroult

Les chiffres auxquels on a fait référence dans cette communication sont incorporé dans la traduction anglaise qui suit.

EN principe l'Armateur fournit à l'Architecte Naval les éléments de son projet, les dimensions principales, les volumes de cale, le rayon d'action, la puissance, d'après des résultats de bateaux précédents prudemment extrapolés.

L'Architecte n'a pas à connaître les données d'exploitation et il se contente de traduire et d'inclure de manière ordonnée dans un ensemble, les demandes de l'Armateur.

C'était la marche suivie dans le passé, et c'est encore parfois le cas. De moins en moins fréquemment pour les raisons suivantes:

- le nombre de types nouveau de bateaux croit constamment
- l'expérience acquise avec les nouveaux types est récente et les fluctuations du marché du poisson imprévisibles
- pour chaque type de bateau ou genre de pêche, le nombre des paramètres est très élevé, D. J. Doust n'en dénombre pas moins de 58. L'analyse de ces éléments dépasse les possibilités de résolution de la plupart
- le nombre important de facteurs irrationnels fait considérer une étude systématique comme sans objet et nous prive le plus souvent de la coopération des Armateurs

Cependant, les très nombreux travaux déjà existants sur l'économie de l'industrie de la pêche et la détermination du navire optimum, prouvent l'actualité du problème.

Le décalage général entre le technique et l'économique existe également pour cette industrie, il faut donc essayer de le réduire.

Des études telles que celles de Doust et de Bogueki qui traitent de tous les aspects du problème pris dans son entier, visent à fournir l'information qu'un ordinateur électronique pourra transformer en résultat, suivant les règles rigides de la logique arithmétique, plus rigoureuses que celles de la pensée humaine.

Il est cependant nécessaire, pour que les résultats soient corrects, qu'un premier travail de dégrossissage soit fait, qui tienne compte des facteurs irrationnels en réduisant le plus possible le nombre des paramètres et en les simplifiant.

Cette première phase du travail est en réalité la plus importante car le reste en découle et l'on ne pourra plus compter que sur la vérification à posteriori des résultats obtenus, vérification pour laquelle les machines électroniques sont irremplaçables.

La relation entre le tonnage du navire et le genre et le lieu de pêche, constitue la base de départ qui doit reposer autant sur les facteurs économiques que sur tous ceux que l'on ne peut mettre en équation, tels que: variation de richesse des lieux de pêche, rendement du travail humain, influence du climat, qualité de la détection, habileté des capitaines, politique de prestige, limites imposées par les règles d'administration ou syndicales, concurrence commerciale, etc.

Les calculs de vérification du rendement économique montrent que la marge d'erreur possible sur le tonnage est très faible.

L'Armateur sait en général quelle pêche il veut pratiquer, quelles sont ses possibilités financières. Il doit être renseigné rapidement sur ce qu'il peut attendre et c'est à ce stade de départ que la coopération est la plus fructueuse.

En plus des nations pour lesquelles la pêche est une vieille industrie et qui en connaissent les données, il y a celles, de plus en plus nombreuses, qui veulent par nécessité participer à l'exploitation des ressources de la mer et qui ont besoin d'être guidées. En fait, l'écart entre les premières et les secondes n'est pas si grand qu'il paraît; on peut considérer du point de vue de la composition des flottes que tous les pays sont "en voie de développement". C'est donc avant tout une méthode d'investigation qui est nécessaire, qui puisse être appliquée, avec les correctifs appropriés, aux différents cas particuliers.

En regard de la complexité du problème tel qu'il se pose actuellement, nous disposons de moyens récents d'analyse fournis par les statistiques de plus en plus nombreuses, bien exploitées par les spécialistes de cette discipline, en plus des travaux déjà anciens de la recherche en construction navale qui ont été amplifiés pendant les dernières années, en particulier pour la propulsion, la tenue à la mer, la sécurité.

Nous sommes beaucoup mieux armés que nous ne l'étions à l'époque du dernier congrès de la FAO il y a six ans.

L'objet principal de ce mémoire est de présenter une

méthode, de souligner les objectifs des futures recherches et de provoquer leur discussion. Nous nous sommes efforcés de tirer parti des travaux parallèles de nos collègues et de notre propre travail quotidien.

Pour définir les possibilités d'application des renseignements que nous donnons, admettons que la pêche soit envisagée dans tout l'océan Atlantique Nord et Sud. Les différents graphiques donnés dans ce mémoire n'ont qu'une valeur d'exemple pour certains types de navires et malgré la présentation destinée au projet, ne doivent pas être tenus pour solution en valeur absolue d'un problème généralisé.

Nous pensons qu'il faut étendre la notion de projet à celle de prévision basée sur les tendances que révèlent les statistiques, en particulier économiques.

Pour l'Armateur qui pense en valeurs réelles et le projeteur en quantités non dimensionnelles, le dialogue sera facilité si l'on traite une dimension à la fois et si l'on écarte les formules à nombreux termes et les diagrammes élaborés.

DIMENSIONS ET CARACTERISTIQUES PRINCIPALES

Volume de cale

Le volume de cale est la donnée la plus importante à connaître pour l'Architecte et doit être reliée au facteur le plus important pour l'Armateur, celui qui entraine sa décision, la durée du voyage.

Quand il a tenu compte de l'éloignement des lieux de pêche, des moyennes de capture, du temps maximum de conservation s'il s'agit de poisson frais, du nombre de voyages par an possibles pour assurer le repos de l'équipage et l'entretien du navire, du temps limite par voyage que l'on peut demander à l'équipage, des rotations nécessaires pour la vente, des possibilités de soutage et d'approvisionnement, il arrive à une durée d'absence qui est déterminante.

C'est avec intention que nous avons donné une simple courbe reliant la durée au volume de cale (fig 1) à l'exclusion de toute formule comprenant le rayon d'action, la vitesse, le déplacement, les moyennes de capture, la densité d'arrimage.

Il est évident que cette courbe qui est applicable dans la partie basse aux navires de pêche fraîche avec une durée d'une douzaine de jours, plus le voyage aller, et dans la partie haute aux navires de pêche congelée pêchant dans l'Atlantique, doit être complétée par des valeurs correspondant à d'autres pêches et d'autres champs d'action.

Des courbes différentes pour la pêche salée, les congélateurs avec ou sans filetage et traitement des sous-produits, les thoniers ou navires qui conservent le poisson dans l'eau froide, doivent être établies.

Nous voyons dans cette relation de durée à volume l'objectif principal des recherches pour les années à venir.

Déplacement

En nous basant sur un travail de normalisation des navires de pêche entre 20 et 90 mètres, navires à deux ponts et grand volume de cale à partir de 40 mètres,

pêche par l'arrière, nous donnons la relation entre volume de cale et déplacement (fig 2). Ces navires, par les volumes, les proportions, le prix et les possibilités de production, n'ont plus grand chose de commun avec les chalutiers à un pont de pêche par le côté tels qu'ils ont été construits dans les dernières 20 années.

Pour le poisson congelé, la surface nécessaire au traitement du poisson, la puissance auxiliaire de congélation et la faible densité d'arrimage, la conception des grands navires s'est trouvée complètement modifiée. Il ne semble pas que la nécessité des volumes de cale importants soit apparue dans les dernières réalisations.

Le rapport de volume de cale à déplacement ne peut se déduire que de navires exécutés ou d'études très poussées puisqu'il recouvre l'équation des poids propre et de chargement.

Longueur

Le prochain et très important pas dans l'élaboration du projet est la détermination de la longueur en partant du déplacement.

Nous disposons pour cela d'une grande richesse de résultats d'essais dans les bassins de carènes et depuis 1963, avec le travail de D. J. Doust, de renseignements très sûrs et faciles à utiliser pour tous les chalutiers de moyen tonnage.

Pour les tonnages supérieurs des gros congélateurs et navires usines, les résultats d'essais de carènes pour les cargos rapides ou petits paquebots sont également très nombreux.

La fig 3 donne, avec une représentation non dimensionnelle, les résistances de carène en fonction de la vitesse relative et de la finesse $L/V^{\frac{1}{3}}$ pour des carènes de chalutiers.

A l'aide de ces courbes, la longueur, la vitesse et la puissance peuvent être calculées en première approximation et vérifiées ensuite avec le travail original de D. J. Doust (1963), (après détermination des autres dimensions), dans lequel l'influence séparée de 6 paramètres importants de la géométrie du navire est fournie et aisément estimée.

On pourra très rapidement, pour plusieurs valeurs de finesse et de vitesse, calculer les puissances correspondantes et choisir les combinaisons les plus favorables.

La simplification voulue dans la présentation de ces relations ne dispense pas l'Architecte d'exercer ses talents et connaissances en résistances des carènes.

Largeur

Après la longueur, le dernier stade du dimensionnement consiste à fixer les dimensions transversales. Là aussi, une grande quantité de recherches systématiques, de statistiques, d'observations à la mer sont à notre portée pour nous aider.

La largeur, le tirant d'eau et le franc-bord sont en général choisis ou vérifiés par les calculs classiques pour donner une stabilité initiale suffisante en charge.

Les nouvelles proportions pour satisfaire aux conditions de volume, de sécurité et de tenue à la mer, obligent à vérifier la stabilité inclinée en charge et la stabilité initiale à lège.

La quasi impossibilité de dégager un critère simple de

stabilité, et les règles internationales de franc-bord pour navires de charge inapplicables aux navires de pêche, ont été jusqu'ici cause d'incertitude ou d'erreur. Les réglements d'Administration tels que les russes ou les japonais, qui portent sur une vérification après réalisation ou étude complétée, ne sont d'aucune aide pour le projet et risqueraient d'avoir comme les règles de jauge, une influence peu souhaitable sur l'évolution du navire de pêche.

C'est donc dès l'avant projet que l'Architecte doit introduire les caractéristiques qui donneront la stabilité et les qualités nautiques requises.

Nous avons préparé la fig 4 pour la détermination de la largeur et du franc-bord pour une valeur associée du bras de levier à 30° d'inclinaison.

La présentation en partie non dimensionnelle en partant du déplacement, est celle qui convient le mieux aux calculs initiaux. L'examen de ce graphique ne manquera pas de soulever quelques commentaires.

(a) Nous avons indiqué les longueurs plutôt que des $L/V^{\frac{1}{3}}$ pour faciliter la lecture et illustrer le point suivant.

(b) L'écartement entre les droites de longueur est irrégulier et nous l'avons maintenu tel volontairement. Si l'on prend comme base de calcul une forme que l'on fait varier systématiquement entre les limites de déplacement, on obtient un écartement régulier.

Si l'on prend comme référence des navires exécutés très semblables mais qui ne sont pas entre eux dans un rapport exact de similitude, il n'est plus possible de les mettre en courbes et la dispersion risque d'être embarrassante pour le non spécialiste.

Nous attirons l'attention sur la nécessité de comparer les résultats de navires exécutés qui présentent des variantes de formes et des différences de hauteur de centre de gravité.

Ce graphique doit être établi pour chaque type de navire de pêche différant radicalement du chalutier de moyen tonnage.

Franc-bord

En plus des valeurs relatives de $F/V^{\frac{1}{3}}$, nous donnons une courbe de franc-bord théorique en valeurs absolues qui satisfait à la condition de stabilité inclinée suffisante et qui peut être utile pour les navires à un pont (fig 5).

Pour les navires à deux ponts avec coque intacte, il est sans doute souhaitable de se départir de la règle de franc-bord des navires de charge à pont shelter et dans ce cas le franc-bord indiqué peut également être utile.

Nous avons représenté une droite comme valeur approchée, en fait c'est une courbe, surtout pour les faibles longueurs.

Bras de levier de redressement

Les valeurs de $GZ/V^{\frac{1}{3}}$ seront sans doute trouvées élevées par rapport aux bras de levier admis jusqu'à présent.

Les récentes études sur la stabilité inclinée sur vague montrent que, lorsque la crête de la vague est au milieu du navire, le bras de levier de redressement peut être réduit

de moitié, condition qui peut être dangereuse par mer de l'arrière.

De plus, une marge est utile pour tenir compte de l'imprécision des calculs de bras de levier et de centre de gravité.

En aucun cas $GZ/V^{\frac{1}{3}}$ ne devra être considéré comme critère de stabilité. La grandeur du bras de levier de redressement à 30° d'inclinaison n'a pas un grand intérêt prise isolément, elle relie le franc-bord et la largeur dans la condition en pleine charge. Elle est cependant facile à calculer pour un volume de déplacement donné.

Centre de gravité

La fig 6 donne des valeurs moyennes de centre de gravité à lège et en charge. Pour les navires à deux ponts on doit tenir compte du relèvement du centre de gravité avec le temps, à mesure que les installations de traitement de poisson prendront de l'importance. L'augmentation de la hauteur du centre de gravité avec le temps est bien connue et nous en avions déjà parlé au cours du Congrès de 1953.

Stabilité initiale

Pour vérifier, dès le projet, la stabilité initiale dans plusieurs cas de chargement nous donnons la fig 7, également non dimensionnelle. Elle est basée sur des formes de chalutier de 0,52 de S et fournit des valeurs plutôt élevées de KM pour les bateaux actuels.

Une vérification de la stabilité à lège du navire s'impose pour tous les navires à deux ponts, pour le séjour au port, entre les périodes d'armement pendant lesquelles la stabilité doit être assurée sans lestage. La nécessité de couvrir les variations de tirant d'eau assez grandes entre les deux conditions lège et en charge, nous a conduit à des échelles beaucoup plus étendues de $B/V^{\frac{1}{3}}$ que dans la fig 4 qui est tracée pour la seule condition en charge.

Tirant d'eau

Le tirant d'eau se déduira de l'équation des poids et de la finesse admise pour la meilleure résistance de carène, et le creux du tirant d'eau et du franc-bord.

Puissance et vitesse

On pourra, arrivé à ce point, calculer la puissance avec suffisamment d'éléments pour obtenir une précision satisfaisante.

La puissance et la vitesse ont une importance telle dans le calcul de rentabilité, qu'elles justifient un effort spécial au cours du projet.

Il est par exemple important de montrer très tôt à l'Armateur les conséquences d'une vitesse choisie à priori très élevée, et le gain que donne une vitesse économique.

A défaut d'une documentation personnelle suffisante, on trouvera dans les travaux de Doust les coefficients propulsifs et les valeurs pratiques des corrections à apporter pour l'état de la mer.

VERIFICATION ET CHOIX FINAL

Il est maintenant possible d'entreprendre le calcul de vérification de l'économie du navire. Le prix du navire

est essentiel et doit être fourni à l'Armateur, les autres éléments de dépenses et recettes sont à tirer de sa comptabilité et des cours commerciaux publiés.

Ce calcul pour une série de navires répondant à un même programme ou à des programmes voisins, fait ressortir le tonnage et la vitesse optimum.

On pourra en cours d'étude vérifier que la vitesse de route ne dépasse pas les limites raisonnables pour l'économie d'exploitation, en appliquant la règle des cargos de ligne, par exemple: dépenses de combustible = $\frac{1}{3}$ dépenses totales. Il n'y a pas de voie royale pour cette dernière partie de l'étude qui doit entraîner la décision. Il faut effectuer, pour chaque hypothèse choisie, le calcul d'exploitation dans son entier. Le travail matériel peut être facilité par un programme ou modèle économique destiné à un ordinateur électronique; le travail de L. K. Kupras (FAO, Rome 1964) est un bon exemple.

L'emploi des machines calculatrices n'est toutefois pas indispensable en première approximation.

Pour illustrer le choix du tonnage optimum, nous donnons avec la fig 8 quelques exemples groupés sur une base de longueur, dimension la plus évidente pour l'Armateur.

Ce groupement n'est fait que pour éviter de multiplier les graphiques, il ne faudrait pas cependant tirer une conclusion quelconque de la valeur relative des types de pêche. Ces travaux ont été conduits pour différents pays à différentes époques et se rapportent à des cas particuliers qui n'ont aucun lien entre eux.

CONCLUSION

Le projet doit être exécuté rapidement sans négliger aucun des aspects qui ont une influence sensible sur l'économie d'exploitation.

Au début du projet, l'évaluation de la durée d'absence est faite par l'Armateur.

Le volume nécessaire en fonction de la durée du voyage engage la responsabilité partagée de l'Armateur et de l'Architecte.

Les dimensions principales sont fixées par l'Architecte, leur influence sur l'économie du navire devrait être examinée conjointement.

La décision finale motivée est prise par l'Armateur.

Les travaux d'analyse devraient porter dans les prochaines années sur:

● la durée d'absence
● la vérification du rendement d'exploitation

L'importance de ces travaux ne peut être sous-estimée et demande une coopération, si possible entre pays voisins.

Au point de croisement des études techniques et économiques on s'efforcera de maintenir l'équilibre entre la rigueur mathématique des moyens mécaniques d'investigation et les cheminements de la pensée humaine.

An Approach to the Design of New Types of Fishing Vessels

by E. R. Gueroult

Le projet des nouveaux types de navires de pêche

L'auteur présente un schéma de base, fondé sur une combinaison de résultats analysés statistiquement et de l'expérience pratique. Les plans doivent être établis par étapes, en utilisant les paramètres appropriés. Le projeteur, partant des facteurs économiques, commencera par déterminer le volume de cale, pour aborder ensuite successivement déplacement, longueur, franc-bord, bras de levier de redressement, centre de gravité, stabilité, tirant d'eau, puissance, pour conclure par une nouvelle étude de la rentabilité, afin de contrôler la validité du projet. En opérant ainsi pour une série de navires pouvant remplir les conditions voulues, on pourra déterminer le type optimal.

Método para el diseño de nuevos tipos de embarcaciones de pesca

Se expone un modelo de diseño fundamental, basado en una combinación de resultados estadísticos analizados y de experiencia humana. El diseño debe hacerse siguiendo el método de la máxima prudencia, mediante parámetros de diseño pertinentes. Partiendo de una consideración de los factores económicos para decidir la capacidad de la bodega, la cadena del diseño se ocupa sucesivamente del desplazamiento, eslora, manga, obra muerta, brazo de palanca de adrizamiento, centro de gravedad, estabilidad, calado y, por último, se hace un reanálisis de los beneficios económicos previstos para comprobar el procedimiento del diseño. Esto se realizaría para una serie de diseños que se podrían ajustar a las necesidades económicas, obteniendo de este modo las mayores ventajas de los diseños considerados.

THE owner generally supplies the naval architect with the basic elements for the design of a ship: principal dimensions, hold capacity, range of operation, power etc., carefully extrapolated from previous vessels.

In this case the architect requires no operational data about the vessel: he merely interprets the wishes of the owner and incorporates them into the design as a whole in a carefully ordered manner.

This was the usual procedure in the past and although still followed in certain cases, it is becoming less and less frequent for the following reasons:

- The number of new types of craft is constantly increasing
- Experience acquired with these new types of craft is only recent and it is impossible to anticipate fluctuations in the market for fish
- The number of parameters for each type of boat or method of fishing is very high; Doust (1964) gave not less than 58, and on analysing these one would find that most of them could not possibly be solved
- The number of irrational factors involved makes a systematic study of the problem seem pointless and very often leads to lack of co-operation on the part of the owner.

However, the very considerable volume of work already carried out on the economy of the fishing industry and the determination of an optimum fishing vessel prove that the problem is a topical one.

In this industry, too, it is difficult to equate the technical with the economic aspect and efforts must be made to bridge the gap between them.

Mathematical Logic

Doust (1964) and Bogucki (1964) in their studies dealing with all aspects of the problem as a whole, aim to feed information in to a computer and obtain results based on strict mathematical logic rather than on the more fallible workings of the human mind.

Nevertheless, if results are to be correct, one must sketch out a rough programme which takes the irrational factors into account, reducing the number of parameters and simplifying them as far as possible.

This first phase of the work is in fact the most important one, since it provides a basis for all the rest, and one can only rely on verification a *posteriori* of the results obtained, for which electronic computers are indispensable.

The relation between the tonnage of a vessel and the type and place of fishing constitutes a basis for departure which depends as much on economic factors as on all other data which might be brought into play, such as: variation in the potential of fishing grounds, human output, climatic influences, quality of detection, skill of the captain, prestige policies, restrictions imposed by administrative or union rules, competition etc. . . .

Calculations of the economic returns of a fishing vessel show that the possible margin of error on tonnage is very small.

The owner generally knows what kind of fishing he intends to practise and he knows his financial position. He must be told what to expect at an early stage and it is during this initial stage that co-operation can be the most rewarding.

In addition to those nations for which fishing is an old-established industry and which have all the facts at their disposal, an increasing number of countries are finding it

necessary to exploit the resources of the sea and are in need of guidance. The gap between the two groups is not so great as would appear; as far as composition of the fishing fleet is concerned they can all be considered as "developing" nations. What one needs above all, then, is a method of calculation that could be applied, with the necessary corrections, to individual cases.

Modern Methods

To help sort out the complex problem one has new methods of analysis furnished by an ever-increasing amount of statistical data, fully exploited by specialists in this field, plus all the research work on shipbuilding done in the past and extended in recent years, particularly with information on propulsion, stability and safety. Naval architects are thus far better equipped than they were at the last FAO Boat Congress six years ago.

sion at a time and dispenses with long-winded formulae and elaborate diagrams.

PRINCIPAL DIMENSIONS AND CHARACTERISTICS

Hold capacity

The most important item of information for the architect is the hold capacity; this must be related to the major factor for the owner —the one which prompts his decision —namely the duration of the voyage.

Taking into account the distance of the fishing grounds from the home port, the average haul, the maximum keeping time, if the owner is marketing fresh fish, the number of trips which can be made in one year allowing for the crew to rest and for ship's maintenance, the maximum length of time the crew can be
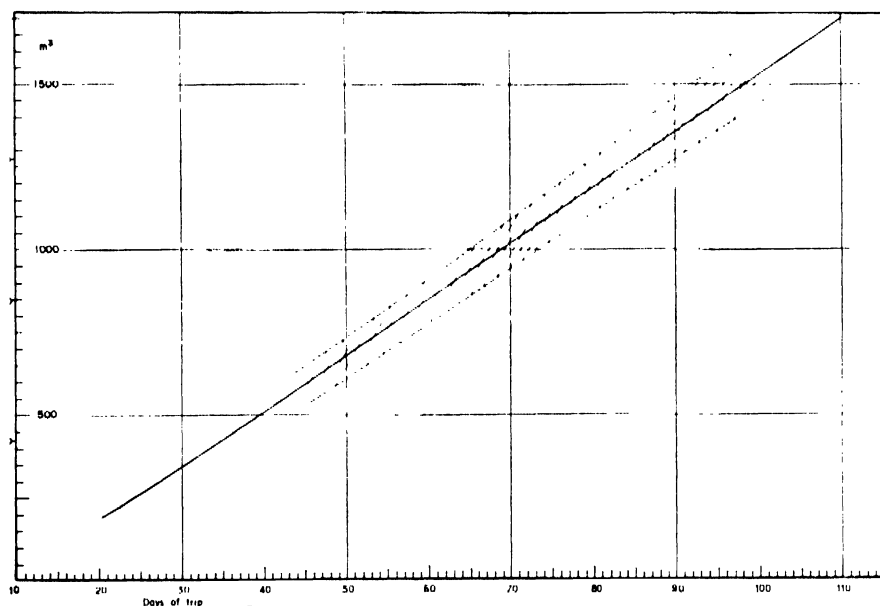
Fig 1. Relation between hold capacity and duration of a fishing trip

The main purpose of this paper is to present an approach, to underline the objectives that should be sought after in future research work and to invite discussion on these. Naval architects have tried to make use of results of parallel work by their colleagues and of the fruits of their own day-to-day labours.

To define the possibilities of application of the data given here, it is assumed that the owner envisages fishing in the whole of the Atlantic, both North and South. The various graphs included in this paper only show examples for certain types of vessel, and although intended for design purposes, they must not be considered as absolute values to be applied in solving general problems.

The concept of design should be extended to signify an expectation of economic returns based on statistical data and market trends.

For the owner who thinks in terms of real values and the designer who thinks in non-dimensional quantities, this talk will be made easier if one deals with one dimen-

expected to remain at sea, the necessary sales rotations, supplies and storage possibilities, the owner arrives at a period of absence that is determinant.

A simple curve has been drawn up here relating the duration of the journey to the hold capacity (fig 1), deliberately avoiding any formula involving radius of action, speed, displacement, average hauls, and stowage density.

The lower part of the curve is applicable to fresh-fish vessels away for some twelve days, plus the outward trip, and the upper part refers to refrigerated ships fishing in the Atlantic; the curve must of course be completed by other values for different types of fishing and other fields of action.

Different curves must be drawn up for vessels preparing salted fish, refrigerated ships filleting or storing whole fish and processing plant for by-products, tuna fishing vessels or boats which preserve the fish in cold water.

This ratio between the duration of voyage and hold
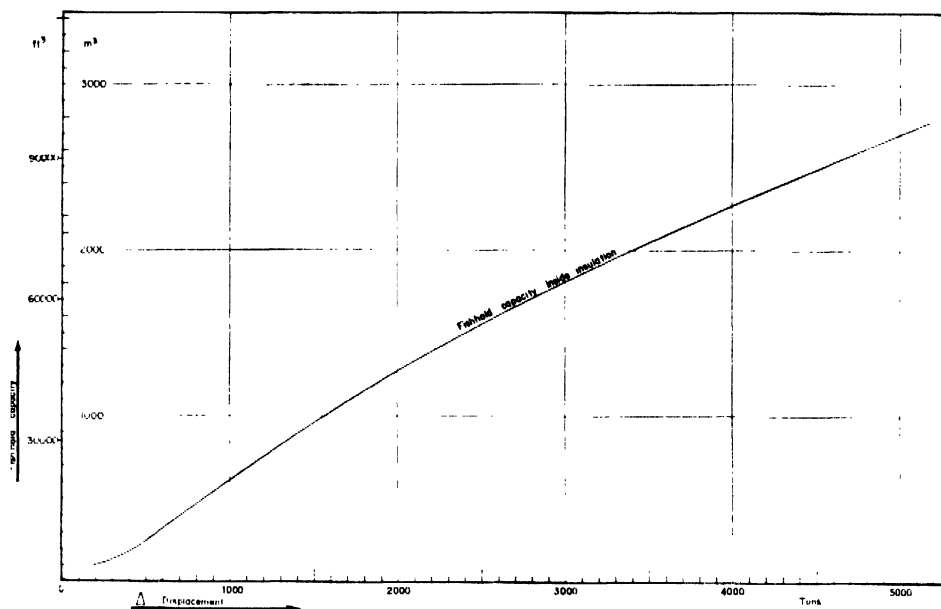
Fig 2. Ratio of hold capacity (inside insulation) and displacement of fishing vessels

capacity should be the main target for research work in years to come.

Displacement

Fig 2 gives the ratio between hold capacity inside insulation and displacement based on known designs of fishing craft of between 65 and 300 ft (20 and 90 m) and two-deckers with a large hold capacity, of 130 ft (40 m) and over, where fishing is done over the stern. These vessels, by their volume, proportions, price and production potential, no longer have very much in common with the single-decked, side-fishing trawlers built during the last twenty years.

For frozen fish, the old concept of large boats has been
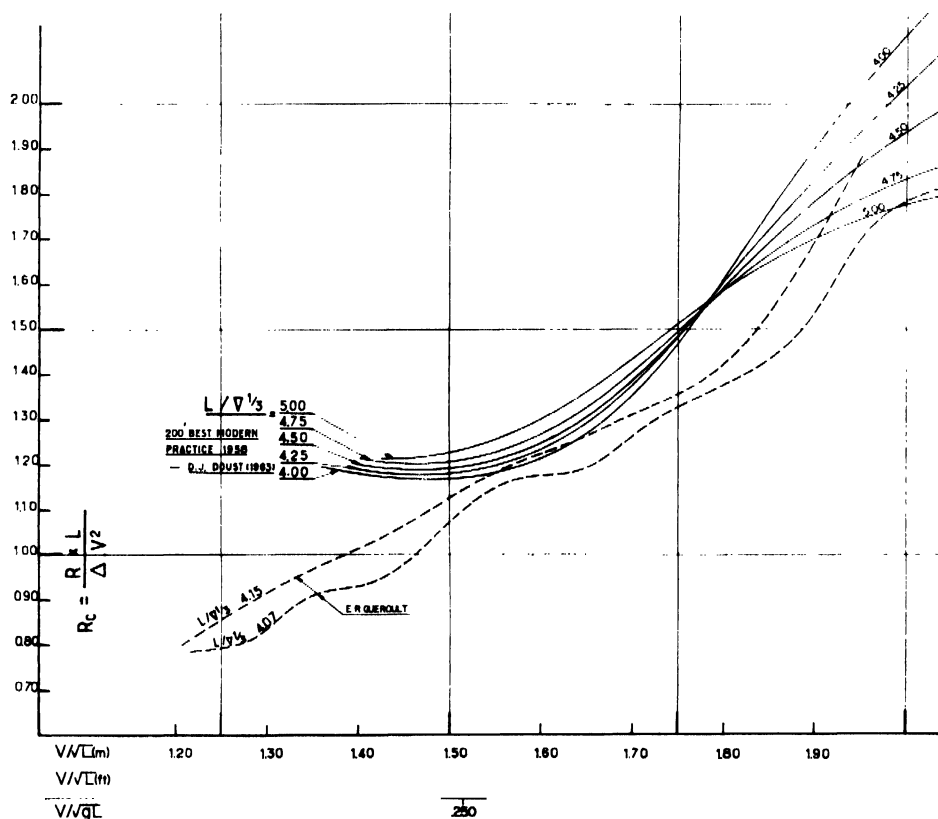
Fig 3. Relation between resistance and speed of trawlers (in the resistance coefficient, R_c, L is in metres, R in kilograms, V in knots and Δ in m^3)

[118]

completely modified to allow for the necessary space for processing the fish, auxiliary power for freezing and the small stowage density. It does not appear that the need for large capacity holds has been sufficiently taken into account in the latest examples of these vessels.

The ratio of hold capacity to displacement can only be calculated from vessels already built or after detailed and thorough studies, since it involves the light ship weight and the dead weight.

Length

The next major step in design is to determine the length of the ship from the displacement.

There is a great wealth of figures available from model tests, and since 1963 Doust's work has provided accurate, easy to use information applicable to all medium-tonnage trawlers.

For larger tonnage vessels, such as big refrigerated factory ships, there are also available results of numerous model tests on fast cargo boats, and small passenger vessels.

Fig 3 shows a non-dimensional representation of resistance of trawler hulls in terms of the relative speed and the coefficient of fineness $L/V^{1/3}$.

With the help of these curves, the length, speed and power can be roughly calculated and then (once the other dimensions have been determined) checked against Doust's (1963) work, where the individual influence of six important parameters in the geometry of the vessel is given and can be easily assessed.

The corresponding power can very quickly be calculated for several values of fineness and speed and the most favourable combinations chosen.

These ratios have intentionally been presented in a simplified form but the naval architect will still have to use his talents and know-how as far as resistance is concerned.

Breadth

After the length, the last dimension to be determined is the beam; here again there is a great deal of systematic research information, statistics, and results of observations at sea, to help us.

The breadth, draught and freeboard are generally chosen and checked by means of traditional methods of calculation to give sufficient initial stability when the vessel is loaded.

To meet the requirements of volume, safety and stability, with the new proportions, statical stability in the loaded condition and initial stability in the light condition must be checked.

Hitherto there has always been some measure of uncertainty and error because of the near-impossibility of laying down a simple standard for stability and because international freeboard rules governing cargo boats are not applicable to fishing vessels.

Government rules such as are applied by the Russians and the Japanese, prescribing verification after the ship has been built or the design completed, are of little help in designing, and like the tonnage regulations, are liable to have an undesirable effect on the development of fishing craft.

Consequently, the architect must incorporate into the preliminary design the necessary features to give the vessel the required stability and seaworthiness.

Fig 4 relates breadth and freeboard for a given value of the righting lever at 30 degree heel.

This partly non-dimensional representation, worked out on the basis of displacement, is the most suitable method of making the initial calculations; the graph will no doubt give rise to some comment.

(a) to facilitate reading the graph and to illustrate the following point, lengths are shown rather than values of $L/V^{1/3}$.

(b) the spacing between the lines of length is irregular
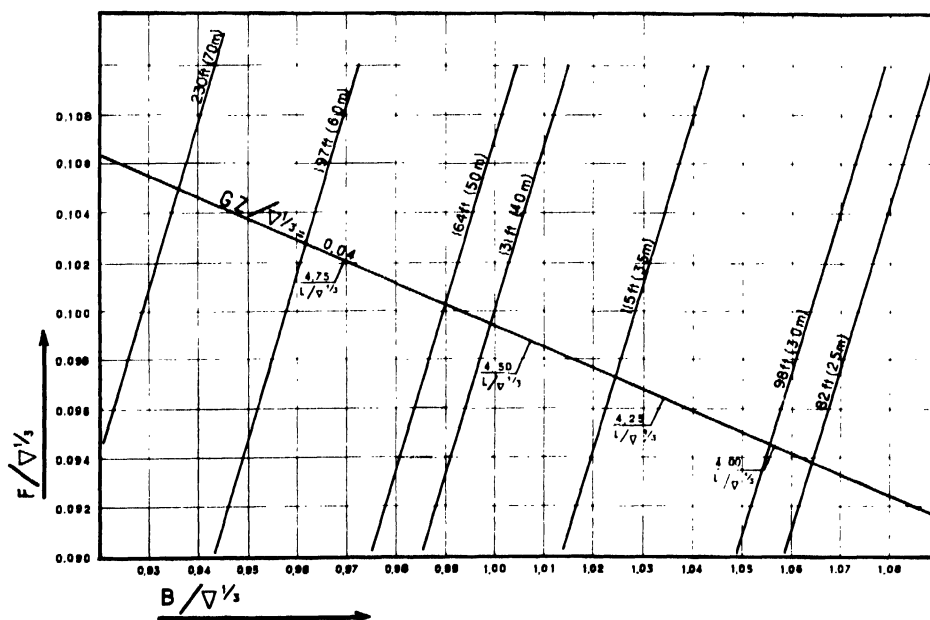
Fig 4. Relation between freeboard and breadth for a given value of righting lever at 30 degrees heel

but it has been purposely left so. Instead, as the basis for calculation, a form that can be made to vary systematically between the limits of displacement is taken, in order to obtain regular spacing. F faired values of L/V⅓ are shown.

If consideration is given to ships built on similar lines, but which do not have an exact ratio of similarity to each other, it is no longer possible to draw up curves for them; the values would be so scattered that non-specialists would become highly confused.

Stress should be placed on the need to compare results of vessels with varying forms and differing heights of centres of gravity.

A similar graph must be drawn for every type of fishing vessel that is radically different from the medium-tonnage trawler.

Freeboard

In addition to the relative values of $F/V^{⅓}$, a theoretical freeboard curve in absolute values is shown which will

Under no circumstances should $GZ/V^{⅓}$ be considered as a criterion for stability.

Centre of gravity

Fig 6 shows average values for the centre of gravity in light and loaded conditions. For two-deckers, it must be borne in mind that the centre of gravity will gradually rise as more fish processing plant is installed. This alteration in the centre of gravity is a well-known phenomenon.

Initial stability

Fig 7, also non-dimensional, enables the initial stability under different loading conditions to be verified at design stage. It is based on trawler forms of 0.52 block coefficient and gives conservative KM values for present-day boats.

All two-deckers must be checked for stability in the light condition for the time spent in port between fishing trips when stability must be maintained without ballast.

Fig 5. Relation between length and freeboard which gives positive stability

give a positive moment of statical stability and could be useful for single-decked vessels (fig 5).

For two-deckers with intact hull, it is undoubtedly wise to deviate from the freeboard rules governing cargo boats with shelter decks and in this case the freeboard shown may prove useful.

A straight line is shown as an approximate value; but this is in fact a curve, especially for the smaller lengths.

Righting lever

The values of $GZ/V^{⅓}$ will no doubt be found somewhat high as compared with the normally accepted values of the righting lever.

Recent studies on statical stability of ships in waves show that when the crest of the wave is in the centre of the ship, the ship's righting lever may be reduced by half, which could be dangerous in a following sea.

Moreover, it is useful to have a margin to allow for lack of accuracy in calculation of the righting lever and the centre of gravity.

Draught

The draught will be calculated from the equation of weights and the fineness coefficient giving the best resistance; the moulded depth is to be calculated from the draught and freeboard.

Power and speed

At this stage, there are sufficient factors to allow a reasonably accurate calculation of the power. Power and speed are so important in calculating the profitability of a vessel that they justify a special effort throughout the design stage.

For instance, at a very early stage the owner must be shown the consequences of choosing a very high speed *a priori* as contrasted with the advantages of choosing an economic speed.

Doust's (1963) work gives coefficients of propulsion and the practical values of corrections to be made according to conditions at sea.
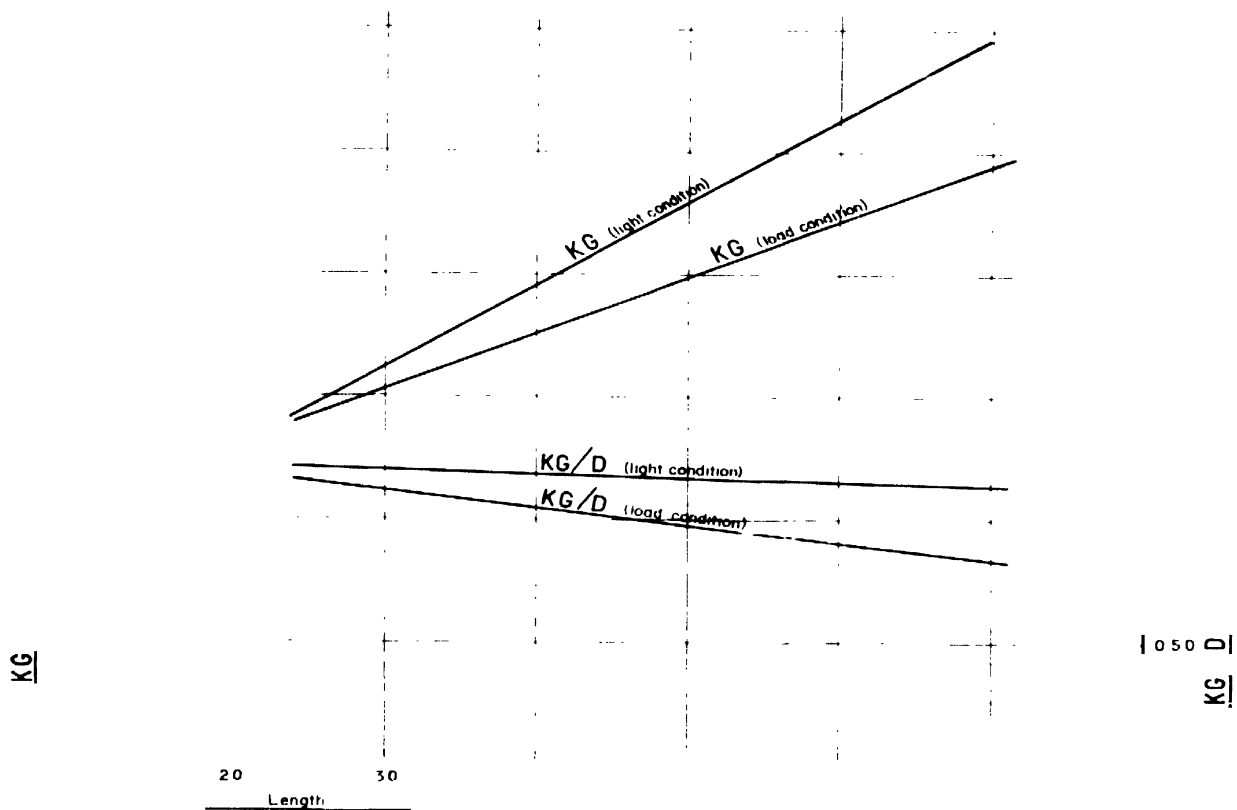
Fig 6. Average values of centre of gravity in light and loaded conditions
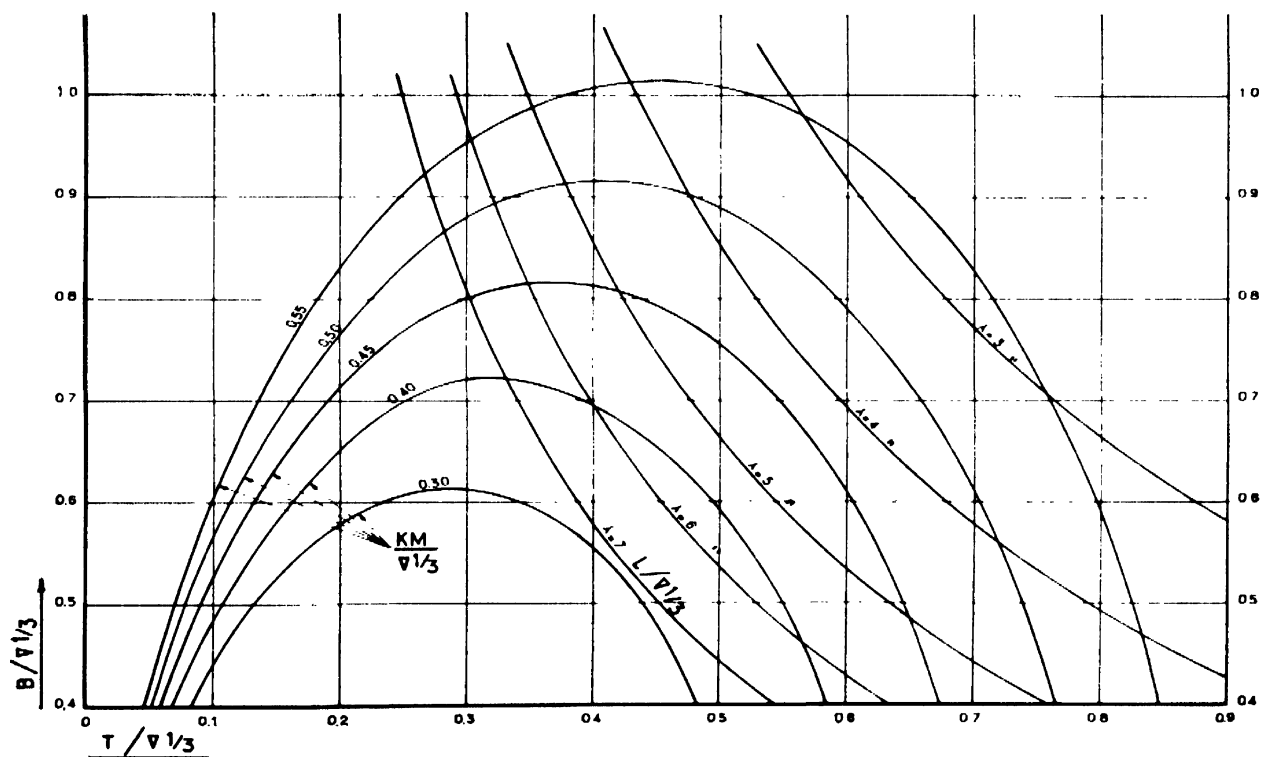
Fig 7. KM estimations based on L, B and T

for vessels of smaller length, tested at NPL, had shown the importance of afterbody shape in certain cases, particularly the penalties in performance incurred with high values of buttock slope. Before specifying the parameters used to define afterbody shape we note that as length between perpendiculars, commonly used in large vessels, became a rather meaningless dimension of length for the smaller vessels being considered, it was decided to use the FAO definition of absolute length on the floating waterline. This definition of length therefore includes that portion of the vessel incorporating the stern and avoids making separate distinctions between cruiser, transom and unorthodox sterns, although obviously artificial overhangs were faired out and an "equivalent" length determined. To cater for differences in afterbody shape then, two additional angles were evaluated for each design, viz., the maximum angle of run of any waterline up to and including the designed floating waterline ($\frac{1}{2}\alpha_r^\circ$) and the maximum buttock slope (α_{BS}°).

The maximum angle of run is measured at a section 5 per cent of the waterline length forward of the after end, whilst the maximum slope of the buttock line drawn at 25 per cent of the full beam is measured relative to the floating waterline. Although trim as such was not considered to be an important variable, its influence generally being reflected in a change of the remaining form parameters, it was decided to investigate its effect for these vessels as quite large variations in trim were apparent in the data. Trim is defined as the change in moulded draft at the forward and after ends of the floating waterline, expressed as a fraction of the length of the floating waterline. The following nine parameters of the hull shape and dimensions were therefore used to specify each vessel and evaluated up to the floating waterline:

viz., $[L/B, B/T, C_m, C_p, l.c.b. \%_0, \frac{1}{2}\alpha_e^\circ, \frac{1}{2}\alpha_r^\circ, \alpha_{BS}^\circ, \text{trim}]$
See nomenclature.

As in the earlier NPL analyses, the resistance performance criterion first proposed by Telfer (1933) was used, viz., $C_R = R \cdot L / \Delta V^2$ and values of this criterion were derived from the measured data for each model at discrete values of speed-length ratio. The values of speed-length ratio at which the data were scanned run from $V/\sqrt{L} = 0.70$ to $V/\sqrt{L} = 1.20$, at intervals of $V/\sqrt{L} = 0.05$, making eleven values in all. We therefore aim to express the resistance criterion, C_R, as a function of the nine hull shape and dimension parameters, i.e.,

$$C_R = \psi[L/B, B/T, C_m, C_p, l.c.b. \%_0, \frac{1}{2}\alpha_e^\circ, \frac{1}{2}\alpha_r^\circ, \alpha_{BS}^\circ, \text{trim}] \quad (1)$$

in which ψ will be estimated independently for each speed-length ratio considered. In order to make valid comparisons of performance and subsequent estimates of ship resistance, all the model data were standardized to a basic model length of 16 ft (4.877 m) using the 1957 ITTC formulation given by:

$$C_f = \frac{R_f}{\frac{1}{2}\rho S v^2} = 0.075 [\log R_N - 2] \quad (2)$$

Originally it had been considered that the analysis might be made retaining the Froude frictional coefficients,

since the bulk of the FAO data sheets had been calculated on this basis. Subsequent re-examination however, showed that it was necessary to refer back to the basic model resistance-speed data in many cases, to achieve the required accuracy of resistance evaluation. It was therefore decided to use the basic model data throughout, applying a relatively small correction to the model results given by equation (2), in order to derive the equivalent resistance of a model having a waterline length of 16 ft (4.9 m). For subsequent extrapolation to full size, the ITTC or any alternative formulation can therefore be applied.

The resistance data for these vessels is derived from several sources, and inter-tank differences therefore had to be eliminated as far as possible, so that the real effects on resistance of parametric changes in hull shape and dimensions could be estimated. The following effects were considered likely to be present and included in the measured resistance data for each tank, and therefore should be quantitatively isolated, as far as possible, from the real effects being studied.

- Blockage effects on resistance due to changes in model size and tank dimensions
- Shallow water effects on resistance due to draft of the models in relation to tank depths
- Differences in measured resistance due to stimulated and unstimulated boundary-layer flows
- Differences in measured resistance due to model surface finish and different materials
- Differences in measured resistance due to dynamometer accuracy
- Effects on resistance of appendages fitted to some models
- Differences in measured resistance due to thermal gradients in the tank water
- Personal errors of observers recording the resistance and speed data

Blockage effects: The effects of tank blockage on the measured resistances of the models included in the analysis have been estimated using the type of correction proposed by Hughes (1961). This correction takes the form of a speed correction δv_m which when added to the speed of the model in the tank v_m, gives the speed of advance of the model in water of infinite breadth and depth, having the same resistance as the model in the tank. This correction is given by:

$$\delta v_m = \frac{\dfrac{\nabla_m}{l \cdot b \cdot h}}{1 - \dfrac{\nabla_m}{l \cdot b \cdot h} - \dfrac{v_m^2}{gh}} = B_1 \quad \text{say.} \quad (3)$$

Since the change in the model speed of advance δv_m is proportional to the slope of the resistance-speed curve, we have defined the slope of the $(C_R - V/\sqrt{L})$ curve as n at any point, in which case the change in C_R due to a corresponding change in $V/\sqrt{L}$ is given by:

$$C_{R(n)} = \phi[B_1 n] \quad . \quad . \quad . \quad (4)$$

where ϕ is an auxiliary function to be determined from the subsequent analysis. Since Hughes' work suggests that

[124]

ϕ may be a simple linear function, we have included blockage terms in our expression for $C_{R_{(b)}}$ up to the second order, without much risk of losing any important effects, viz.,

$$C_{R_{(b)}} = a_r(B_1 n) + a_{r+1}(B_1 n)^2 . . \qquad . \quad (5)$$

It should be noted, therefore, that the appropriate values of a_r and a_{r+1} will be determined by the subsequent statistical analysis, and it is only necessary to compute the appropriate values of "B_1" and "n" at each speed-length ratio being considered. This procedure not only reduces the magnitude of the already considerable analysis involved, but also avoids the use of the rather ill-defined values of a_r, a_{r+1} which would have to be applied in the range of speed-length ratio with which we are concerned for these vessels.

Shallow water effects: The exact solution, giving the correction to model speed due to the influence of shallow water on the resistance characteristics of a model being towed at speed v_m in a tank is given by Schuster (1955/56) as:

$$\left(1 + \frac{\delta v_m}{v_m}\right)_h^2 = \coth\left(\frac{gh}{(v_m + \delta v_m)}\right) \qquad (6)$$

and this solution for $(\delta v_m/v_m)_h$ when $h \to \infty$ gives zero as one would expect. Hughes (1961) has given good approximate values of the function $[\delta v_m/v_m]_h$ for various values of (v_m^2/gh), so that the correction of each model results to allow for these shallow water effects can be readily obtained. Fortunately, this speed correction was found by Tsuchiya to be negligibly small for the FAO data and can therefore be ignored.

Turbulence stimulation of boundary-layer flow: In the previous NPL analyses for the large deep-sea trawlers, a correction allowing for laminar flow was applied to measured resistance values of models tested without fully-developed turbulent flow conditions. In this manner, the whole of the data was standardized to turbulent flow conditions, prior to subsequent analysis. Such corrections were relatively small and only for a few cases was the magnitude of the corrections up to 3 per cent of the measured resistance. In this case, for the FAO data, not only are there considerably more models involved, but the effects of turbulence stimulation are less well defined, as these vessels are rather outside the range of form parameters usually covered by studies of boundary-layer flow conditions. It was therefore decided to determine the effect of boundary-layer flow stimulation statistically, by including a term in the regression equation for C_R to estimate this effect. Since approximately half of the data were applicable to turbulent flow conditions and the other half unstimulated flow conditions, there was sufficient coverage of the data to make a first-order estimate of this effect at each speed-length ratio considered.

Effects on resistance of hull appendages: A study of the data showed that approximately 60 per cent of the models were tested with wooden keel pieces, which could be expected to produce an increase in resistance relative to naked models built to the moulded lines and, excluding the keel as an appendage. It was therefore necessary to allow for the differences in measured resistance, relative

to a naked model, and an appropriate term was added to the regression equation for $C_{R_{(b)}}$ to estimate the influence of the wooden keel piece independently, at each speed-length ratio.

Effects of other factors on resistance: The effects on resistance measurement of model surface finish, materials used in their manufacture, dynamometry, thermal gradients and possible local currents induced in the tank water and errors of the personnel conducting the experiments cannot be quantitatively assessed without independent examination, and must be regarded in our analysis as random errors. The question arises as to the possible magnitude of their combined effects, in relation to the order of accuracy required in making realistic estimates of ship performance. An error of ± 1 per cent in speed estimation for the ship, considered to be sufficiently realistic for most practical requirements, allows a permissible variation in resistance estimation of between ± 5 per cent and $+7$ per cent in most cases with which we will be concerned for fishing vessels (resistance varies between (speed)' and (speed)''). Our aim therefore is to formulate an equation for $C_{R_{(b)}}$ in terms of the nine hull parameters and the auxiliary functions expressing the effects of blockage, wooden keels and turbulent flow stimulation, such that the residual errors given by the differences between measured and estimated values for each model are of the order of 5–7 per cent or better, in each case.

THE HULL FORM PARAMETERS

Prior to the commencement of the computational work, it was necessary to study the dependency of the data values of each form parameter on those of all the others. In the ideal situation, each parameter will vary over its full range for the whole range of values of each of the other parameters and a rectangular distribution of data points will be revealed by plotting each pair of parameters on the usual Cartesian co-ordinates. Fig 1–36 show the distributions of data points for all the models used in this analysis, which are mainly derived from European or American tanks, and comprise a total of 308 designs. A larger amount of data is available from Japanese and other sources, but, since these cover an even wider range of parameter values, it was decided to make a separate study of these data at a later stage when further experience of the use of the results of this first analysis has been obtained. For the present data it was found that all

TABLE 1

Form parameter	Extreme values		Range within which independence of parameters is applicable	
L B	2.8 to	5.8	3.1 to	4.3
B T	1.5 to	4.0	2.0 to	3.2
C_m	0.44 to	0.88	0.5 to	0.8
C_p	0.48 to	0.73	0.55 to	0.65
l.c.b "₀(aft)	-12.0 to · 3.5		6.0 to · 1.0	
½ α_e	6 to	40	15 to	34
½ α_r	22 to	80	30 to	60
α_{us}	10 to	57	16 to	34
trim (; by stern)	0.04 to · 0.13		− 0.04 to −	0.13
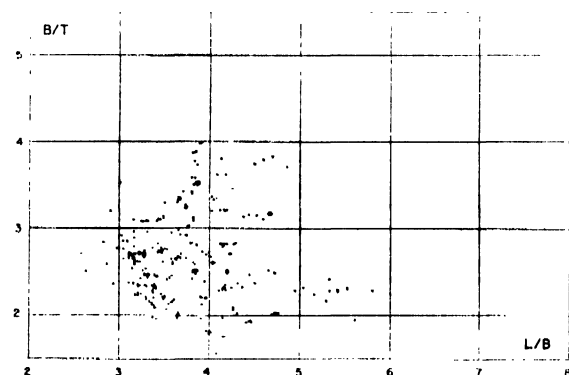
*Fig 1. Relation between B/T and L/B of models analysed in the
computer study*
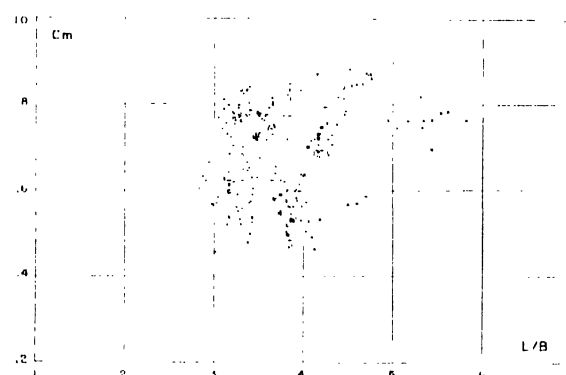
*Fig 2. Relation between C_m and L/B of models analysed in the
computer study*
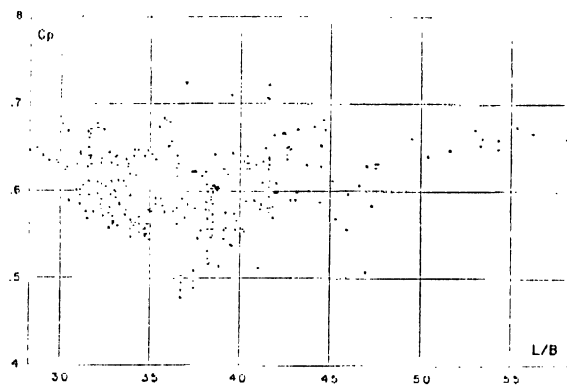
*Fig 3. Relation between C_p and L/B of models analysed in the
computer study*
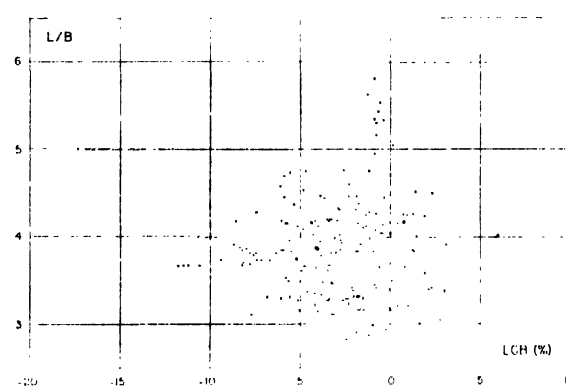
*Fig 4. Relation between L/B and l.c.b.(%) of models analysed
in the computer study*
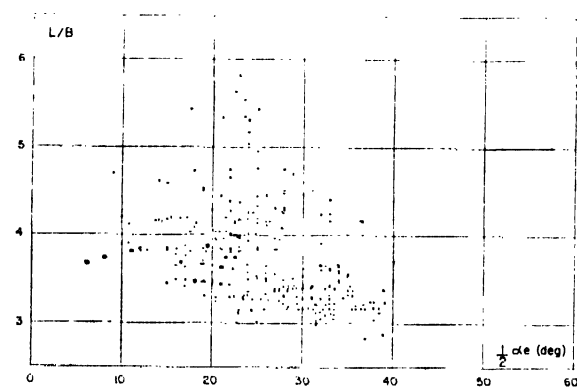
*Fig 5. Relation between L/B and $\frac{1}{2}\alpha_e$(deg.) of models analysed
in the computer study*
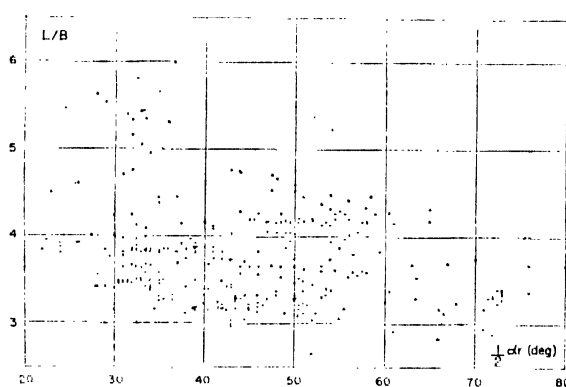
*Fig. 6. Relation between L/B and $\frac{1}{2}\alpha_r$(deg.) of models analysed
in the computer study*
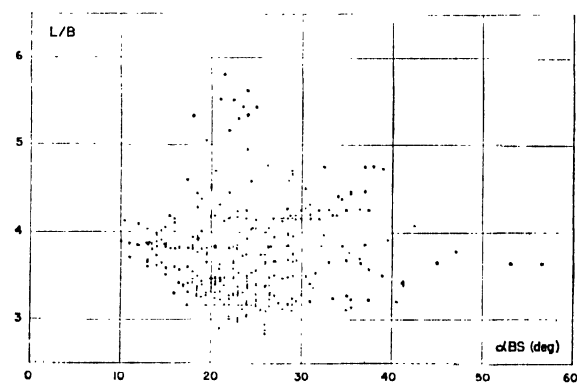
*Fig 7. Relation between L/B and α_{BS}(deg.) of models analysed
in the computer study*
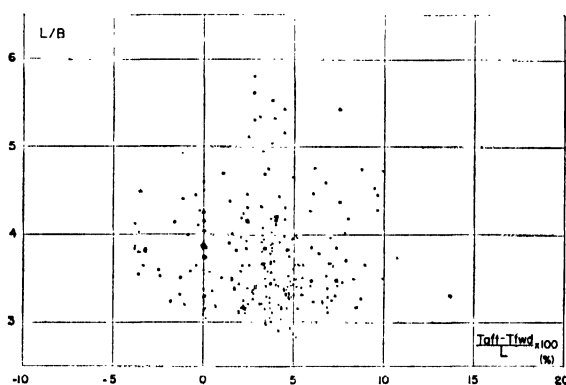
*Fig 8. Relation between L/B and trim of models analysed in
the computer study*

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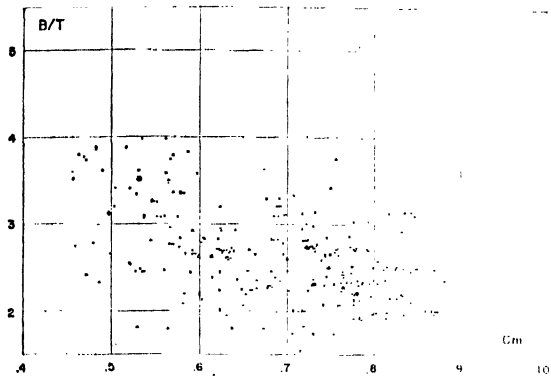
Fig 9. Relation between B/T and C_m of models analysed in the computer study
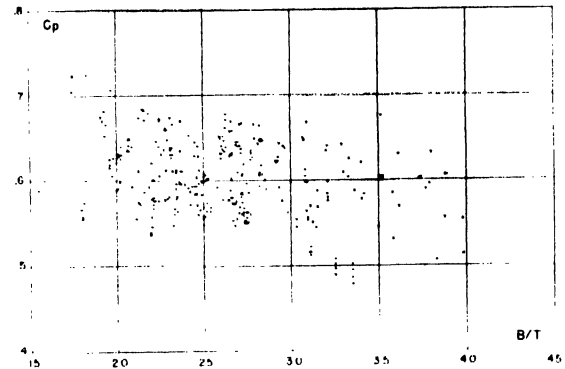
Fig 10. Relation between C_p and B/T of models analysed in the computer study
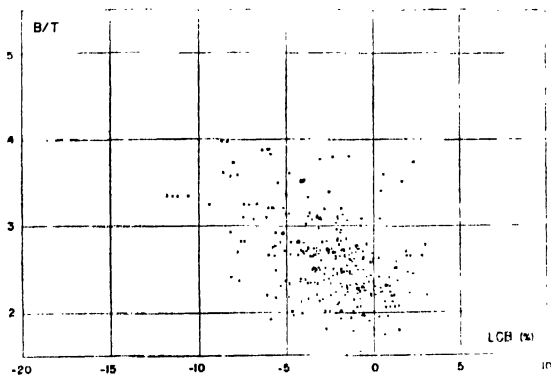
Fig 11. Relation between B/T and l.c.b.("o) of models analysed in the computer study
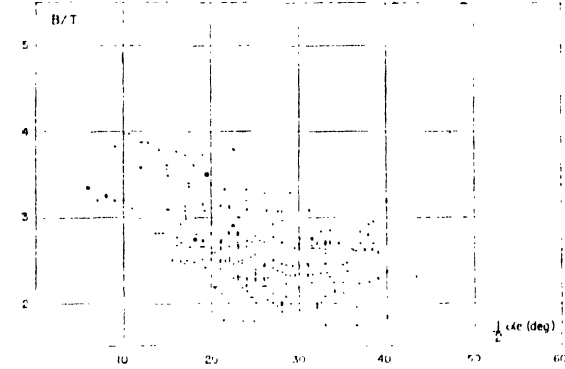
Fig 12. Relation between B/T and $\frac{1}{2}\alpha_e$(deg.) of models analysed in the computer study
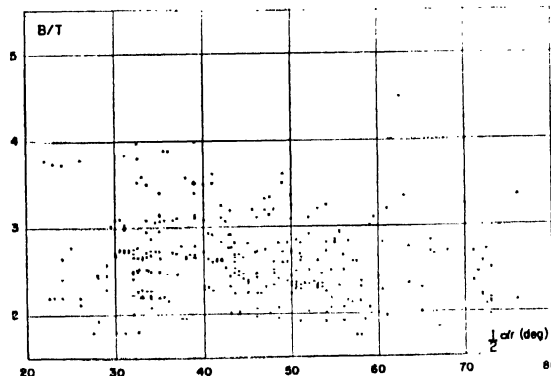
Fig 13. Relation between B/T and $\frac{1}{2}\alpha_r$(deg.) of models analysed in the computer study
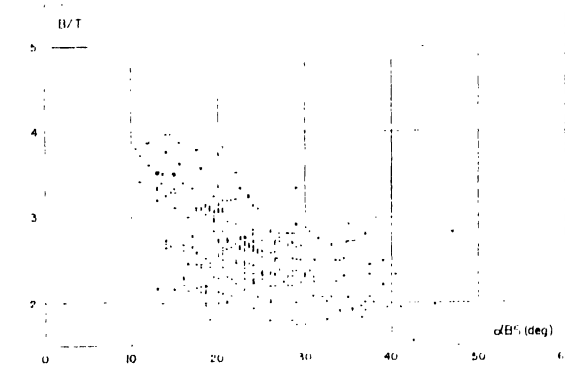
Fig 14. Relation between B/T and α_{ns}(deg.) of models analysed in the computer study
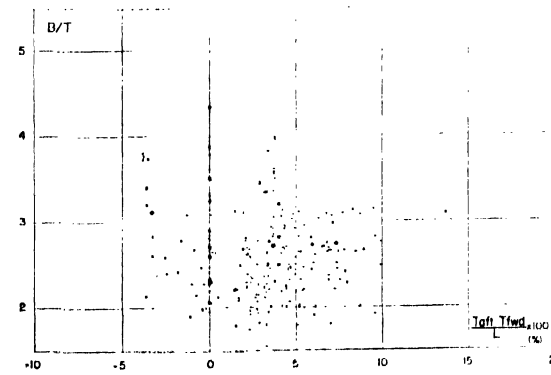
Fig 15. Relation between B/T and trim of models analysed in the computer study
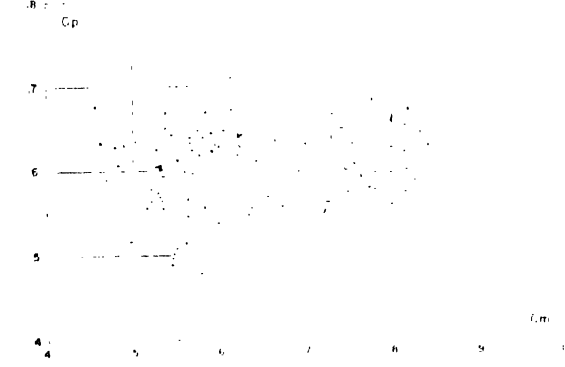
Fig 16. Relation between C_p and C_m of models analysed in the computer study

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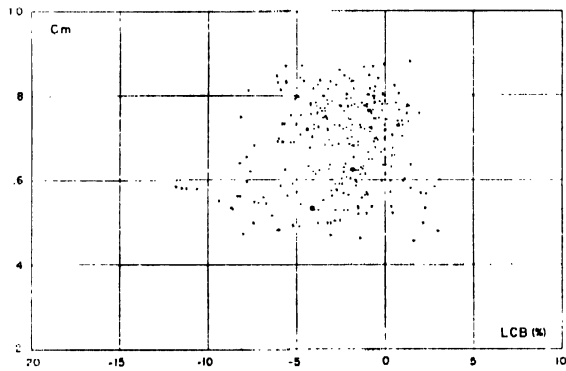
Fig 17. Relation between C_m and l.c.b.($%$) of models analysed in the computer study
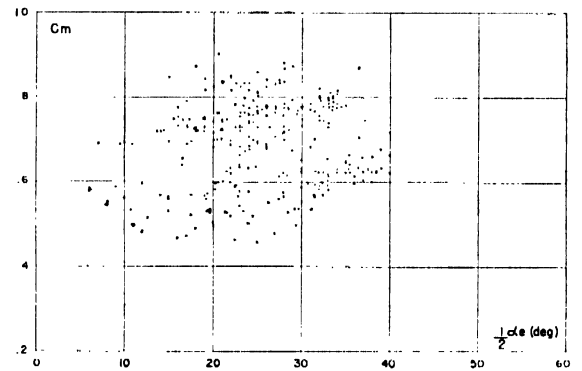
Fig 18. Relation between C_m and $\frac{1}{2}\alpha_e$(deg.) of models analysed in the computer study
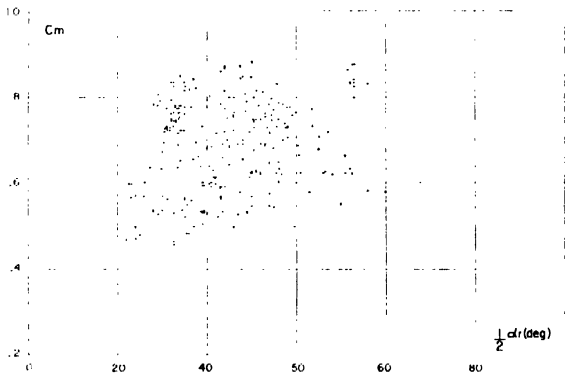
Fig 19. Relation between C_m and $\frac{1}{2}\alpha_r$(deg.) of models analysed in the computer study
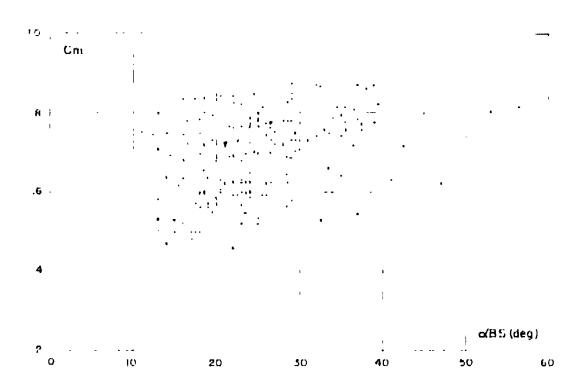
Fig 20. Relation between C_m and α_{BS}(deg.) of models analysed in the computer study
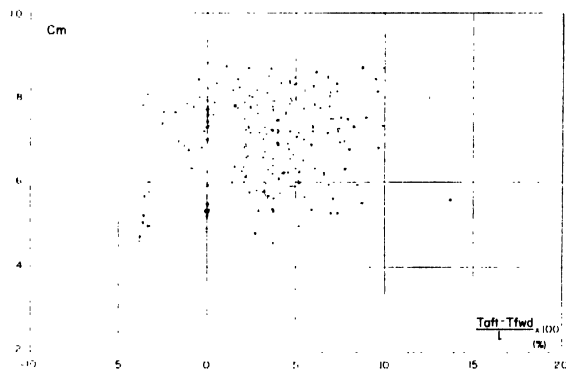
Fig 21. Relation between C_m and trim of models analysed in the computer study
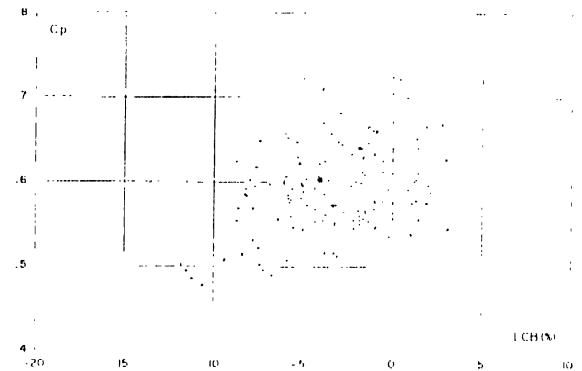
Fig 22. Relation between C_p and l.c.b.($%$) of models analysed in the computer study
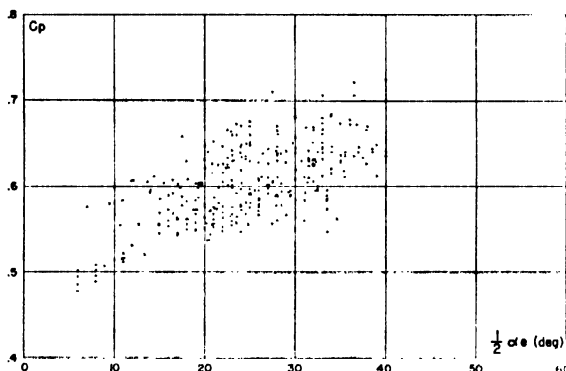
Fig 23. Relation between C_p and $\frac{1}{2}\alpha_e$(deg.) of models analysed in the computer study
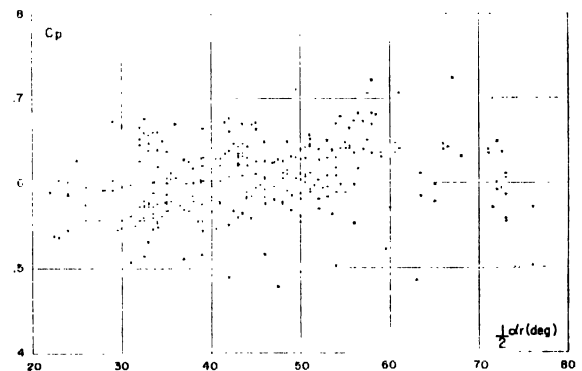
Fig 24. Relation between C_p and $\frac{1}{2}\alpha_r$(deg.) of models analysed in the computer study

[128]
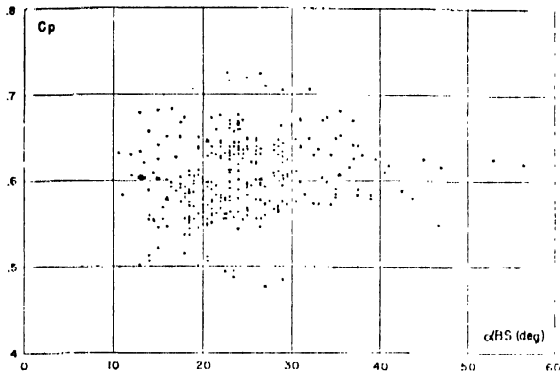
Fig 25. Relation between C_p and α_{BS}(deg.) of models analysed in the computer study
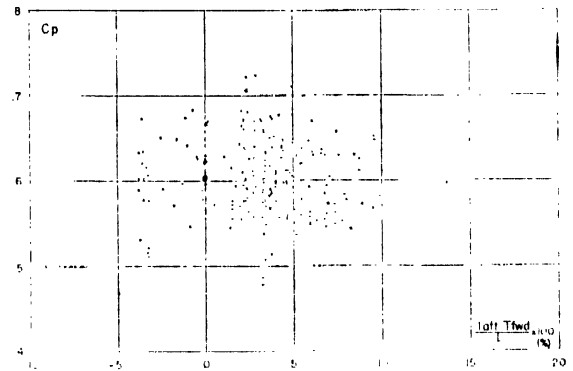
Fig 26. Relation between C_p and trim of models analysed in the computer study
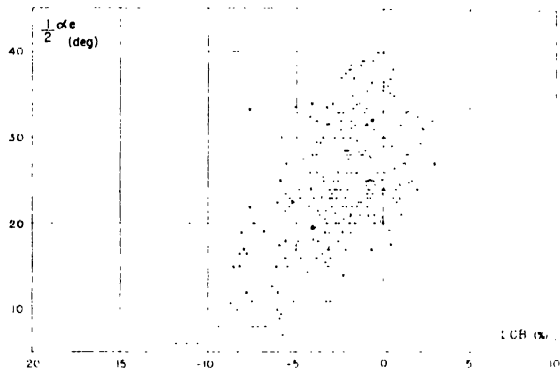
Fig 27. Relation between $\frac{1}{2}\alpha_e$(deg.) and l.c.b.(^o_o) of models analysed in the computer study
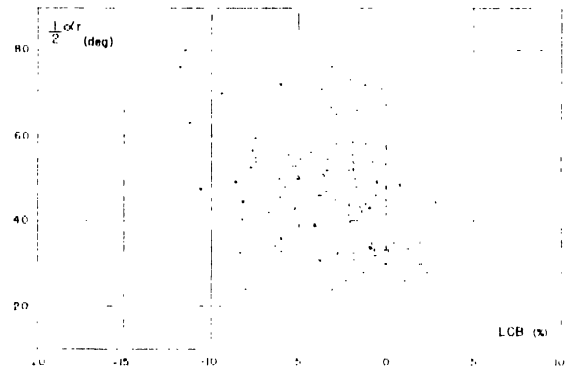
Fig 28. Relation between $\frac{1}{2}\alpha_r$(deg.) and l.c.b.(^o_o) of models analysed in the computer study
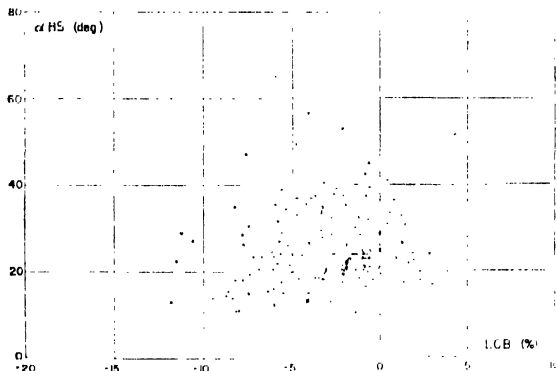
Fig 29. Relation between α_{BS}(deg.) and l.c.b.(^o_o) of models analysed in the computer study
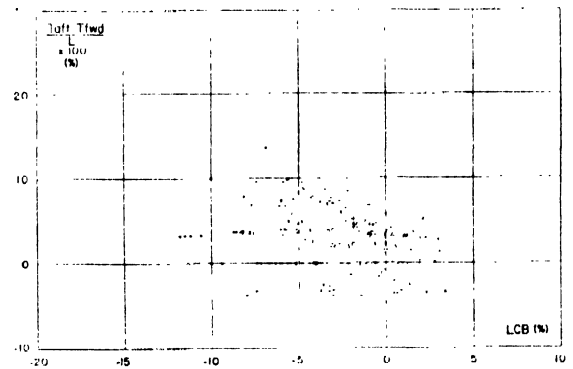
Fig 30. Relation between trim and l.c.b.(^o_o) of models analysed in the computer study
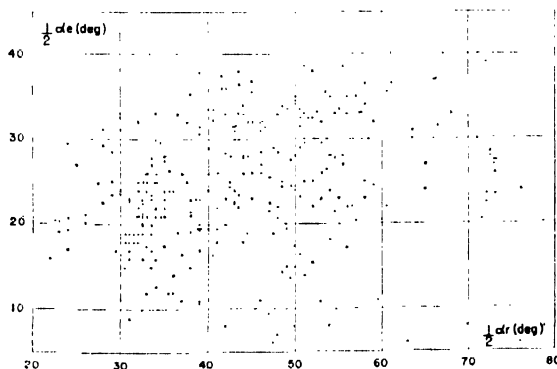
Fig 31. Relation between $\frac{1}{2}\alpha_e$(deg.) and $\frac{1}{2}\alpha_r$(deg.) of models analysed in the computer study
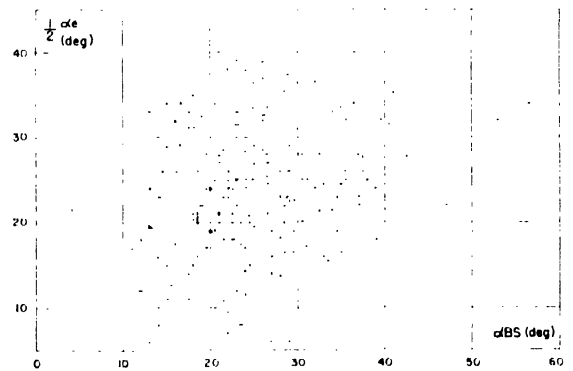
Fig 32. Relation between $\frac{1}{2}\alpha_e$(deg.) and α_{BS}(deg.) of models analysed in the computer study

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E
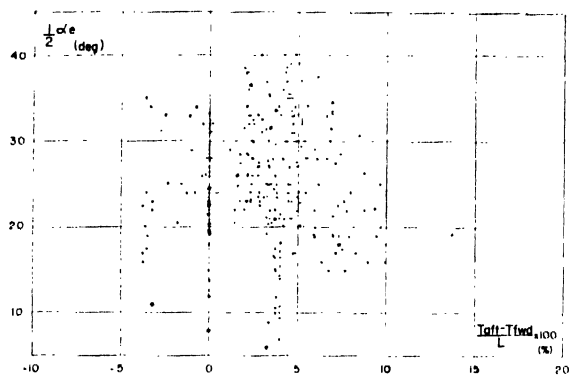
Fig 33. Relation between $\frac{1}{2}\alpha_r$(deg.) and trim of models analysed
in the computer study
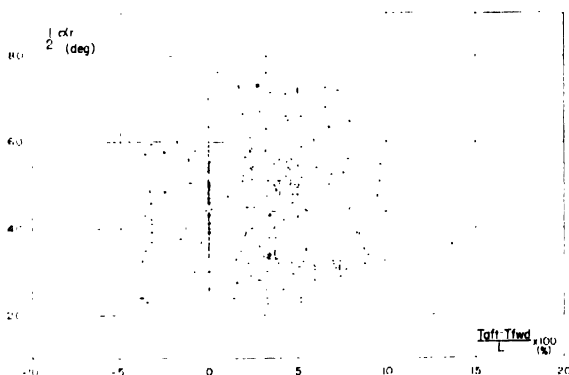
Fig 34. Relation between α_{BS}(deg.) and $\frac{1}{2}\alpha_r$(deg.) of models
analysed in the computer study

Fig 35. Relation between $\frac{1}{2}\alpha_r$(deg.) and trim of models analysed
in the computer study
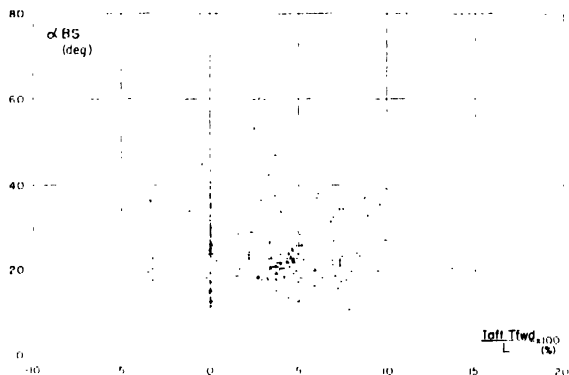
Fig 36. Relation between α_{BS}(deg.) and trim of models analysed
in the computer study

pairs of form parameters are reasonably independent of each other, that is, a substantially rectangular distribution of data points is available for quite a wide range of each parameter. The extreme values of each form parameter, together with the ranges within which reasonable independence of parameters is applicable are given in table 1.

The main departure from a rectangular distribution is in the plot of C_p against $\frac{1}{2}\alpha_e^\circ$, in which there is an absence of data for high values of C_p with small values of $\frac{1}{2}\alpha_e^\circ$.

By referring to fig 1-36, it can be seen that outside the rectangular distribution of data points, there exists a considerable number of vessels, often having form parameters occurring in small groups. The importance of these forms in making performance estimates for new designs is referred to in the concluding remarks.

THE REGRESSION EQUATION FOR RESISTANCE CRITERION $C_{R_{1s}}$

Having established that the parameters used to define each vessel were reasonably independent over a wide range of parameter values, it is now required to formulate equation (1) in such a manner that it conforms as closely as possible to the known or likely behaviour of each design parameter, and provides a satisfactory approximation to the data. Fortunately, some guidance was given by the earlier NPL analysis in formulating the regression equation for larger fishing vessels. The equation derived in that analysis was of polynomial type, that is, it consisted of a sum of individual terms, 30 in number, each

of which was a constant multiple of a power of a parameter or of a product of such powers. In this equation, the parameters were cross-linked in pairs, though by no means all possible pairs were cross-linked. Where a pair of parameters, say X_1 and X_2, were cross-linked, the following 9 terms appeared in the equation:

$$
\begin{array}{ccc}
1 & X_1 & X_1^2 \\
X_2 & X_1 X_2 & X_1^2 X_2 \\
X_2^2 & X_1 X_2^2 & X_1^2 X_2^2
\end{array}
\quad \text{Array type (i)}
$$

This array contains all the possible cross-products of positive (or zero) powers of X_1 and X_2 when the power of each parameter is limited to a maximum of 2. It may be described as a square array of degree 2. Physically, the inclusion of this array in the equation allows for each of the two parameters to have an optimum value within its practical range, an optimum, if it exists, which is allowed to vary both in position and in sharpness with the value of the other parameter. Only six parameters (L/B, B/T, C_m, C_p, $l.c.b.$ and $\frac{1}{2}\alpha_e^\circ$) were included in this earlier analysis and the pairs of parameters which were cross-linked in the equation, in the way described (with one minor variation which is not relevant to the present discussion), were:

$$(C_p, L/B), \quad (C_p, B/T),$$
$$(C_p, l.c.b.), \quad (C_p, \tfrac{1}{2}\alpha_e^\circ),$$
and
$$(L/B, \tfrac{1}{2}\alpha_e^\circ).$$

[130]

The only other term in the equation was a simple linear term in C_m.

The parameters $\frac{1}{2}\alpha_r^o$ and α_{BS}^o were introduced in the subsequent NPL analysis of passenger-cargo vessels 1964 in order to take into account the shape of the after-body. Each of them was cross-linked with C_p in the regression equation for these vessels—the total number of terms then being 44.

These 44 terms, together with five additional ones, formed the starting point for building up the regression equation for the present analysis. These extra five terms were:- a simple linear term for trim, the two terms $(B_1 n)$ and $(B_1 n)^2$—see Section on Blockage Effects, a term to take into account the first-order effect on resistance of a wooden keel, and a term to take into account the first-order effect on resistance of omitting turbulence stimulators. In these early stages also, an attempt was made to take into account the variation of this latter effect with changes in C_p, by including an appropriate term in the regression equation, but the results obtained were unsatisfactory and the attempt was abandoned. With regard to trim, it may be repeated in passing that the effect of varying the trim of any particular hull form will be largely taken into account by the consequent modification of the other parameters, such as *l.c.b.*, and that the pure effect of trim, i.e. with all other parameters fixed, is likely to be small. This was confirmed by the analysis.

It was, of course, clear that this initial equation of 49 terms would need considerable expansion before a satisfactory fit to the data could be achieved: the ranges of the parameters in the FAO data are substantially wider than in the NPL data and so terms that were negligible in the latter case could become effective in the former case. Nevertheless, it was helpful to have a nucleus of terms, known to be important, round which to build. Fortunately, the much larger number of models available in the FAO data (over 300), made it possible to contemplate such a major expansion. On the other hand, the total number of possible combinations of 8 or 9 parameters up to, say, degree 4, is also very large, and so it was still necessary to be very selective in deciding which terms to add to the initial equation.

The general procedure adopted was to add to the equation, a few at a time, new terms which were considered likely to be effective, to fit the extended equation to the data, and then to assess the effectiveness of the new terms by considering the improvement in the closeness of fit. The purpose of the fitting procedure is to determine the best values of the constant multiples occurring in the equation, the best values, that is, in the sense that they minimize the sum of squares of the differences between the data values of C_R and the values calculated from the equation. (These differences are the "residuals".) Thus the fitting procedure was carried out using the usual least-squares criterion. With equations of the size we are considering, a great deal of computation is involved and this was carried out on the ACE computer at NPL. The improvement in the closeness of fit was assessed by consideration of the residuals: if the addition of the new terms to the equation resulted in a satisfactory reduction in the sum of squares of the residuals, the new terms were

accepted as part of the final equation, otherwise they were rejected.

In considering ways of expanding the regression equation, there were three main directions we could contemplate:

- Pairs of parameters could be cross-linked which were not already cross-linked
- Products containing more than two parameters could be introduced
- Pairs of parameters which were already cross-linked could be taken to a higher power, e.g., the square array of type (i) could be increased from degree 2 to degree 3

Each of these three ways had to be considered. In the first category, the parameter which stood out as requiring further attention was the maximum area coefficient C_m. In the original NPL analysis, this parameter was found to be relatively unimportant, but in the present data C_m varies between 0.44 and 0.88, a very wide range which represents very substantial differences in the character of the hull forms. Consequently C_m was introduced into the equation cross-linked with both L/B and B/T, and this was found to be beneficial. In the second category, four major parameters, L/B, B/T, C_p and $\frac{1}{2}\alpha_c$, were considered and the four triple products obtained by multiplying these parameters together three at a time were introduced into the equation. The result was unsatisfactory and so it was decided to consider only terms containing not more than two parameters.

At about this stage in the analysis, it was decided that, instead of the basic square array of type (i), which limits the power of each parameter separately, it would be more logical to use an array which placed a limit on the combined powers of the two parameters concerned. Consequently, the regression equation was modified so that, for each cross-linked pair of parameters, e.g., X_1 and X_2, the equation contained the following 10 terms: –

$$\begin{array}{cccc} 1 & X_1 & X_1^2 & X_1^3 \\[4pt] X_2 & X_1 X_2 & X_1^2 X_2 & \\[4pt] X_2^2 & X_1 X_2^2 & & \text{Array type (ii)} \\[4pt] X_2^3 & & & \end{array}$$

This array contains all the possible cross-products of positive (or zero) powers of X_1 and X_2 when the sum of the powers of the two parameters is limited to a maximum of 3. It may therefore be described as a triangular array of degree 3. In effect, it removes the term $X_1^2 X_2^2$ from the square array of degree 2 and adds the two terms X_1^3 and X_2^3. Physically, as before, this array allows for each of the two parameters to have an optimum value which varies both in position and in sharpness with the value of the other parameter, and at the same time allows for some departure from the purely quadratic form of the previous array.

At this point the equation was still some way from giving a satisfactory fit to the data, and so we undertook an extensive investigation into possible additional terms in categories above. As a result of this, the following

new pairs of parameters, cross-linked to degree 3 were added to the equation:

$$(B/T, \tfrac{1}{2}\alpha_e^\circ), \quad (l.c.b., \tfrac{1}{2}\alpha_e^\circ),$$

$$(L/B, \alpha_{BS}^\circ), \quad (B/T, \alpha_{BS}^\circ), \quad (l.c.b., \alpha_{BS}^\circ).$$

Also, the fourth degree terms of the following pairs of parameters, already cross-linked to degree 3, were added to the equation so that these pairs became cross-linked to degree 4:

$$(B/T, C_m), \quad (L/B, \tfrac{1}{2}\alpha_e^\circ), \quad (C_p, L/B).$$

The fourth degree terms of the following pairs were similary tested, but rejected as unnecessary:

$$(L/B, C_m), \quad (C_p, B/T), \quad (C_p, l.c.b.),$$

$$(C_p, \tfrac{1}{2}\alpha_e^\circ), \quad (C_p, \tfrac{1}{2}\alpha_r^\circ), \quad (C_p, \alpha_{BS}^\circ).$$

These pairs were therefore kept in the equation cross-linked to degree 3. Finally, three terms in the block coefficient $C_B = (C_p \times C_m)$ were tested but rejected, namely: C_B, C_B^2 and C_B^3.

At this stage, the standard error (root mean square) of the residuals for the data at $V/\sqrt{L} = 1.0$ was down to 0.74 corresponding to a basic scatter about the fitted expression of approximately $\pm 3\tfrac{1}{2}$ per cent of the average C_R value. Consequently, the equation was accepted as satisfactory. The final form of the regression equation contains 86 terms and is given in full in the Appendix.

All the above work of building up the regression equation was carried out on the data for $V/\sqrt{L} = 1.0$. Once the final form of equation was settled, it was fitted to the data for each of the other values of $V/\sqrt{L}$ for which there was a sufficient number of models to yield a satisfactory result, namely $V/\sqrt{L} = 0.85$ and then at intervals of 0.05 up to 1.20. There was an insufficient number of models at $V/\sqrt{L} = 0.7$, 0.75 and 0.80.

During the work of building up the equation for $V/\sqrt{L} = 1.0$, a check was kept on models which persistently gave high residuals. These could be genuine departures from the regression equation, since a number of larger residuals must be expected simply because of random variations, but it was also possible that there was some extraneous reason why the equation could not be expected to fit a particular model, possibly because it contained some unusual feature which was not taken into account, and in this case its inclusion in the fitting process might unnecessarily distort the fit. Consequently, all the models with persistently high residuals were referred back to FAO for investigation into the detailed records, and where there was a satisfactory reason to explain a poor result, the model was rejected from the analysis. The rejected models included, for example, cases where the bar keel had been carried up to the waterline forward, and had not been tapered off, cases where the running trim differed abnormally from the static trim, so that the parameters used were not applicable to running conditions, and cases which squatted an abnormal amount. There were also six models with bulbous bows, which, as in the previous NPL work, were not fitted satisfactorily by the equation. Then, of course, there were the definite human errors which are bound to

occur in a collection of data of this magnitude. These were picked out by their gross inconsistency with other data, either with the same model at other speeds or with other models having almost identical parameters. In all 32 models were rejected for one such reason or another. The total number of models remaining after rejecting these 32 is given for each value of $V/\sqrt{L}$ in table 2, together with the root-mean-square of residuals.

TABLE 2

$V/\sqrt{L}$	0.85	0.90	0.95	1.00	1.05	1.10	1.15	1.20
Number of models	184	222	245	249	245	240	229	196
Standard error (root mean square) of residuals of $C_{R_{1s}}$	0.55	0.64	0.68	0.74	0.75	0.83	0.94	1.05

ESTIMATION OF PERFORMANCE FOR PARTICULAR HULL FORMS

Having determined the regression equations for $C_{R_{1s}}$ at a series of values of speed-length ratio from $V/\sqrt{L} = 0.85$ to $V/\sqrt{L} = 1.20$, an auxiliary computer program was prepared to evaluate resistance performance for any required combination of hull form parameters. This program was written for the KDF 9 Computer in Mathematics Division, NPL, and requires as input data the regression coefficients a_0 a_1 a_2 ... a_{85} together with the numerical specification of parameters $[X_1 \ X_2 \ X_3 \ ... \ X_9]$ and the individual terms such as X_1X_2, X_4^4, $X_2^3X_3$, etc., of which the regression equation is composed. The program can be used if required to evaluate other regression equations of this type up to the ninth power in 13 variables, including the constant term a_0.

In addition to evaluating the values of $C_{R_{1s}}$ for each speed-length ratio, the program also determines the values of C_R at any required ship length (L) together with the corresponding values of EHP using the ITTC formulation, i.e.,

$$C_{R(L)} = C_{R(1s)} - 0.212847 \left(\frac{S \cdot L}{\Delta} \right) \left[\left(\log 88 \cdot \frac{V}{\sqrt{L}} \cdot 10^3 \right)^{-2} \right.$$

$$\left. - \left(\log 1.2834 \frac{V}{\sqrt{L}} \cdot L^{\frac{1}{2}} \cdot 10^3 \right)^{-2} \right] \quad (7)$$

where S = wetted hull surface area (ft²)
L = Length on waterline (ft)
Δ = ship displacement (moulded) in tons (35 ft³/ton)
V = ship speed (knots)

and

$$\text{EHP (using ITTC formulation)} = \frac{C_{R(L)} \cdot \Delta \cdot V^3}{325.7L}. \quad (8)$$

To illustrate the use of the computer program and the types of $C_{R_{1s}}$ curves which are obtained for particular combinations of parameters, estimates of performance have been made for seven forms covering a fair range of each parameter, and are plotted against $V/\sqrt{L}$ in fig 37 to 43. In the case of Model Nos 40 and 48 (fig 37 and 38),

[132]
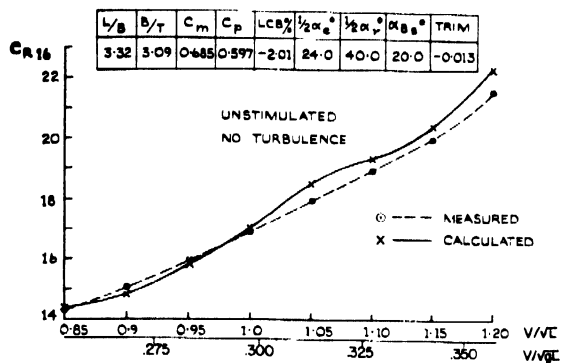
Fig 37. Model No. 40
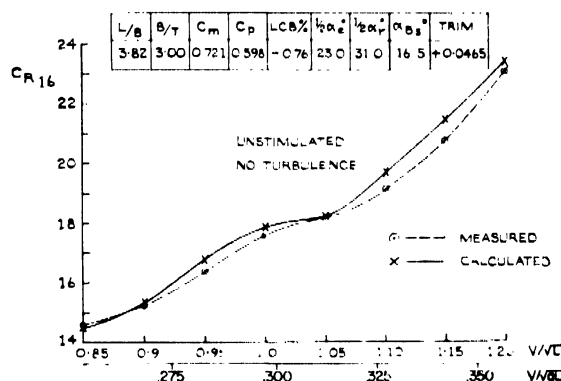
Fig 38. Model No. 48
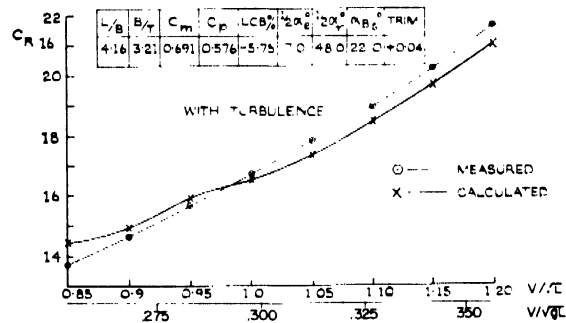
Fig 39. Model No. 199

Fig 40. Model No. 203

Fig 41. Model No. 193

Fig 42. Model No. 2021

Fig 43. Model No. 2004
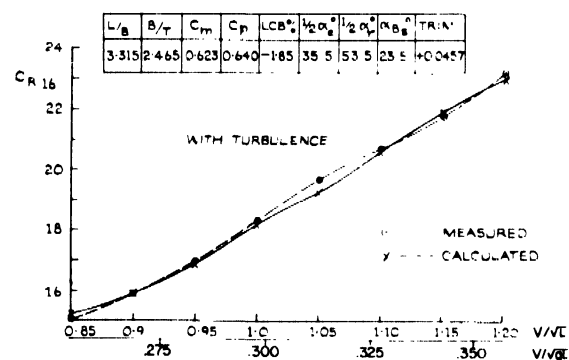
estimates have been made for the case where no turbulence stimulators were fitted, corresponding to the actual test conditions for these models. Although the measured results are less stable than those obtained with turbulence stimulators fitted to the model, it can be seen that the estimates obtained using the regression equation are in good agreement. It should also be noted that each estimate of $C_{R_{16}}$ is independently derived and that even so the general character of the resistance curve in terms of speed-length ratio is reasonably well simulated. Models 199 and 203 (figs 39 and 40), both having turbulence stimulators fitted, again show good general agreement between the measured and calculated resistance-speed curves, although the "hump" at $V/\sqrt{L}=1.00$ has been somewhat suppressed in the case of Model 203. Model 193 (fig 41) shows the largest differences between the measured and calculated results, although the two curves agree at $V/\sqrt{L}=1.00$. There is some evidence to suggest that the measured results below $V/\sqrt{L}=1.00$, which show a rising characteristic as speed reduces, may be suspect due to over-stimulation, and the estimated curve of $C_{R_{16}}$ is certainly more in keeping with practical experience. Models 2021 and 2004 (fig 42 and 43) are derived from a separate Tank and are again reasonably well fitted by the regression equation.

[133]

SOME EFFECTS ON RESISTANCE CRITERION OF INDIVIDUAL PARAMETERS

The effects on resistance criterion $C_{R_{16}}$ due to changes in individual hull form parameters are rather complex and vary both with speed-length ratio and the values of the other parameters. In order to give some guidance to designers of the smaller fishing vessels, fig 44 to 51 have been prepared to show several effects of individual parameters on resistance criterion for central values of the remainder at $V/\sqrt{L} = 1.10$. It was therefore considered a basic form having the following hull form parameters and discrete changes were made in each parameter.

The hull form parameters of the basic form are:

$[L/B = 3.75, B/T = 2.75, C_m = 0.65, C_p = 0.61, l.c.b.\% = -2.0, \frac{1}{2}\alpha_e = 25.0, \frac{1}{2}\alpha_r = 45.0, \alpha_{BS} = 25.0, \text{trim} = +0.05]$.

(a) *L. B* ratio The effect of length-beam ratio has been studied between 3.1 to 4.2 at various values of prismatic coefficient between $C_p = 0.55$ to $C_p = 0.65$, for fixed values of the remaining parameters of the basic form.
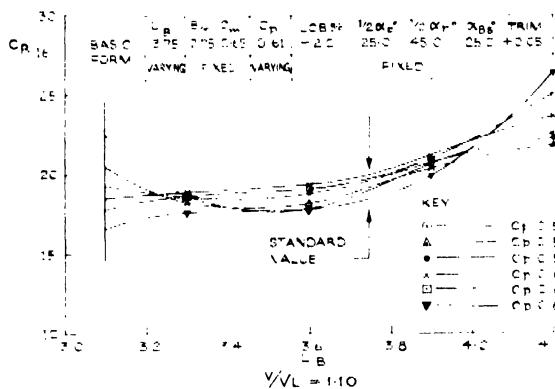
Fig 44. The effects of variations in L/B ratio from the standard value of 3.75 for various prismatic coefficients

Fig 44 shows that reduction in L/B ratio down to a value of approximately 3.40 is generally beneficial for all prismatic coefficients. Below values of $C_p = 0.59$ however there appears to be some penalty in resistance criterion for L/B ratios less than 3.40.

(b) *B/T* ratio The effect of beam-draft ratio for fixed values of the remaining parameters has been studied for B/T ratios between 2.0 and 3.2 and for C_p values between 0.55 to 0.65. Fig 45 shows that increase in B/T ratio always results in a penalty in resistance criterion for all values of prismatic coefficient. With the exception of $C_p = 0.65$, which is on the edge of the rectangular range of data points included in the analysis, the penalty change in resistance criterion due to changes in B/T ratio is generally the same for all prismatic coefficients.
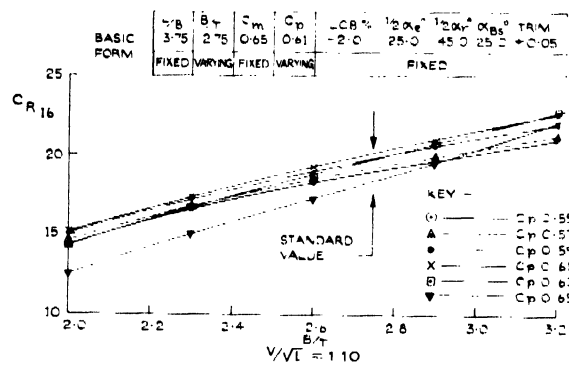
Fig 45. The effects of variations in B/T ratio from the standard value of 2.75 for various prismatic coefficients

(c) C_m The effects of variations in maximum area coefficient C_m have been calculated over the range $C_m = 0.50$ to $C_m = 0.80$. This large range covers a wide variety of hull forms from the yacht-shaped hulls with fine midship sections up to the fuller-sectioned and generally larger fishing vessels around 100 ft in length. As can be seen from fig 46
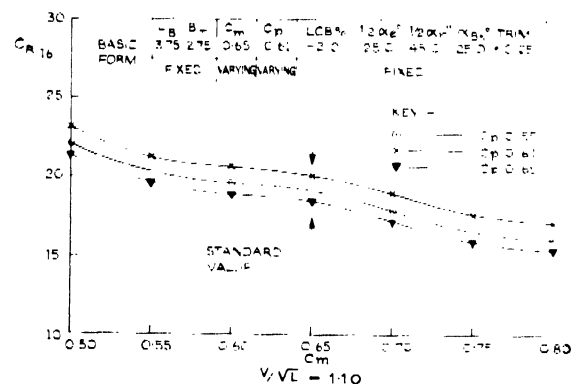
Fig 46. The effects of variations in maximum section area coefficient from the standard value of C_m 0.65

there is a penalty in resistance criterion as C_m is reduced and this penalty is the same for all values of prismatic coefficient within the range $C_p = 0.55$ to $C_p = 0.65$. The slope of the $C_{R_{16}}-C_m$ curve, however, is rather less for values of C_m in the region of $C_m = 0.75$ to $C_m = 0.80$, suggesting that for these fuller sections the benefits of further increase in maximum section area are not so great.

(d) C_p The effects on resistance criterion of changes in prismatic coefficient from the standard value of $C_p = 0.61$ have been calculated for fixed values of the remaining parameters of the basic form. It can be seen from fig 47 that a prismatic coefficient of 0.61 is about the worst value for the basic form and that both higher and lower values are advantageous.

[134]
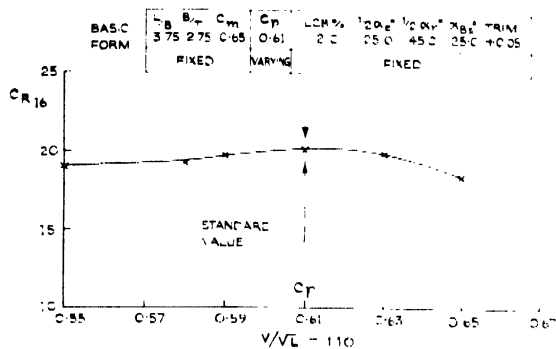
Fig 47. The effects of variations in prismatic coefficient from the standard value of C_p 0.61

Fig 49. The effects of variations in half-angle of entrance of the floating waterline from the standard value of $\frac{1}{2}\alpha_e$ 25 or various prismatic coefficients

(e) l.c.b.^{0} The effects on resistance criterion of changes in position of the longitudinal centre of buoyancy can be seen in fig 48 for values of prismatic coefficient between $C_p = 0.55$ to $C_p = 0.65$. It can be seen that there is generally a benefit in locating the position of the l.c.b. up to 6.0 per cent aft of amidships, although for C_p values in excess of 0.63 the optimum position appears to be at or near amidships.

importance in relation to the remaining form parameters (see fig 50). For the ranges of hull form parameters with which we are concerned in our analysis, therefore, it is generally permissible in design work to allow the run angles of the form to increase if required to make the buttock angles less steep.

Fig 48. The effects of variations in position of longitudinal centre of buoyancy from the standard value of − 2.0 per cent for various prismatic coefficients

Fig 50. The effects of variations in half-angle of run from the standard value of $\frac{1}{2}\alpha$, 45 for various prismatic coefficients

(f) $\frac{1}{2}\alpha_e$ The effects on resistance criterion of changes in the half-angle of entrance of the load waterline are very marked as can be seen in fig 49. Generally speaking, the advantages of adopting a low value of $\frac{1}{2}\alpha_e$ are apparent at all values of prismatic coefficient, although for C_p values of 0.55 and 0.57 it appears that almost equally good performance can be obtained for values of $\frac{1}{2}\alpha_e^\circ$ between 30° and 35° as for values of $\frac{1}{2}\alpha_e^\circ$ between 15° and 20°. Both of these ranges of $\frac{1}{2}\alpha_e$ are better than the standard value of 25° for the basic form.

(g) $\frac{1}{2}\alpha_r^\circ$ The effects on resistance criterion of variations in half-angle of run from the standard value of $\frac{1}{2}\alpha_r^\circ = 45°$ for various prismatic coefficients, are of secondary

(h) α_{BS} The effects on resistance criterion of variations in buttock slope are generally significant for all values of prismatic coefficient and show a benefit in C_{R16} as buttock slope is reduced down to 15° (the lower limit of the data). These effects can be seen in fig 51.

(i) trim The effect on resistance criterion of changes in trim from the design value of ± 0.05 are not significant.

It is emphasized that the independent changes in L/B, B/T, C_m and C_p discussed above will all affect displacement. In practice, if changes are investigated which keep length and displacement constant, a change in

[135]

BASIC FORM	L/B	B/T	Cm	Cp	LCB %	½αe°	½αr°	αBs°	TRIM
	3·75	2·75	0·65	0·61	-2·0	25·0	45·0	25·0	+0·05
	FIXED			VARYING	FIXED			VARYING	FIXED
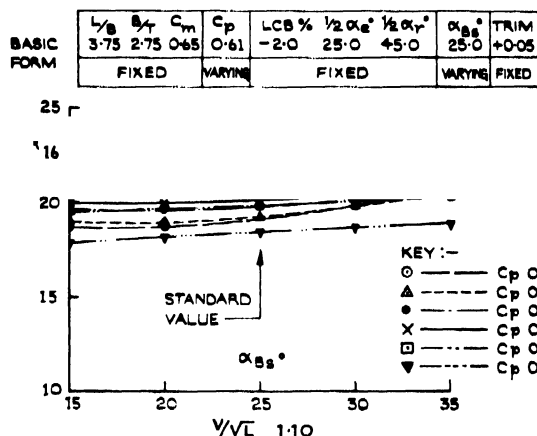
Fig 51. The effects of variations in buttock slope from the standard value of $\alpha_{BS} = 25°$ for various prismatic coefficients

any one of these four parameters will necessitate appropriate changes in one or more of the other three, and the several resulting effects on C_R will counteract or reinforce one another, thus modifying the above conclusions in particular cases.

CONCLUSION

Similar trends showing the influence of hull form parameters at all speed-length ratios between $V/\sqrt{L} = 0.85$ to $V/\sqrt{L} = 1.20$ can be derived from the computer program. As we have demonstrated however, the effects on resistance criterion are quite complex. Estimates for individual vessels and suggestions for improvement in performance should therefore be made using the computer program as a design tool.

This analysis covers a wide range of hull form parameters and fishing vessel types. As more data sheets for new vessels are included in the FAO store of information however, it should be possible to extend the coverage of the present analysis even further. The process is therefore seen as one of continuous appraisal, modification and improvement in the design of fishing vessels.

The expressions in the regression equations derived from this analysis can be explored in order to seek combinations of hull form parameters which will give improved performance. This exploration can be carried out either by some form of systematic evaluation of the expressions or by using one of the methods of mathematical optimization which are currently available. Four different sets of hull form parameters have been derived by these methods and forms having these parameters have been designed by FAO and Chalmers Technical University, Göteborg, and models have been tested at NPL and Chalmers. This work is presented on page 139.

As already noted, there are a considerable number of vessels included in the present analysis having hull form parameters outside the ranges given in table 1. For new vessels which have hull form parameters in these regions of existing data, satisfactory estimates of performance can usually be made using the regression equation given in the Appendix.

NOMENCLATURE

	length on the floating waterline. Obvious long stems, etc., are faired out and the appropriate length determined. In some cases L is determined from drawings, as length between perpendiculars is sometimes the only length given in reports
B	beam, maximum, usually at the midlength of dimension L, measured at the floating waterline WL
T_{aft}	draft at the aft end of L to an elongation of the centre bottom line of a steel hull (excluding a possible bar keel) or to the elongated rabbet line of a straight keel of a wood hull
T	draft moulded at $\frac{1}{2}L$
T_{fwd}	draft at the fore end of L to an elongation of the centre bottom line of a steel hull (excluding a possible bar keel) or to the elongated rabbet line of a straight keel of a wood hull

[136]

A_m	maximum immersed section area (the area of the vertical transverse underwater section of the model which has the greatest section area)
∇_m	volume of displacement of the model up to the floating waterline (ft^3)
∇	metric displacement volume of the underwater body of the vessel, including keel and appendages to waterline WL in (m)^3
Δ	displacement of ship in salt water, floating at waterline WL, based on 35 ft^3 of salt water per ton, corresponding to a specific gravity of 1.026 in long tons of 2,240 lb (1,016 kg)
S	wetted area of the underwater body of the model to waterline WL. This includes the wetted surface of all appendages in the appendage list at the top of the FAO data sheets, excluding struts and open shafts
V	ship speed in knots
v	ship speed in ft/sec
ν	coefficient of kinematic viscosity; assumed to be 1.2285×10^{-5} for model at 59°F in fresh water and 1.316×10^{-5} for ship at 59°F (15°C) in salt water
R_N	Reynolds number $= (vL/\nu)$
$v/\sqrt{gL}$	Froude number
$V/\sqrt{L}$	speed-length ratio
C_m	maximum area coefficient evaluated to waterline WL ($C_m = A_m/BT$)
C_p	prismatic coefficient based on the maximum section area and the moulded displacement including stern ($C_p = 35\Delta/L.A_m$)
$C_B = C_m.C_n$	block coefficient: the volume of the underwater body of the ship divided by the volume of a rectangular block having dimensions L, B, T as the ship
L/B	length-beam ratio
B/T	beam-draft ratio
$l.c.b.$ %	position of the longitudinal centre of

buoyancy in relation to the midlength of the dimension L, expressed as a percentage of the length L

+ indicates the position forward of $\frac{1}{2}L$ and

− indicates the position aft of it

$\frac{1}{2}\alpha_e^\circ$	the angle which the waterline WL makes with the centreline of the model at the stem. Normally this is the average angle for the first $\frac{1}{20}$ of the length L, but when measuring, care is taken to disregard excessive rounding or hollowing near the stem.
$\frac{1}{2}\alpha_r$	the maximum angle of run up to and including the designed floating waterline WL. This angle is measured at a section 5 per cent of the waterline length forward of the after end of L, except where this section cuts the deadwood, when the maximum waterline slope at the intersection with the forward end of the deadwood is taken.
α_{BS}	the maximum buttock slope of the $\frac{1}{4}$ beam buttock measured relative to the floating waterline WL. This angle is evaluated *exclusive* of the slope of the stern contour in the case of vessels with transom sterns
R	ship resistance in lb
$C_{R(L)} = \dfrac{R \cdot L}{\Delta V^2}$	resistance criterion proposed by Telfer
C_{R16}	resistance criterion when $L = 16$ ft (4.9 m)
R_f	three-dimensional frictional resistance component given by ITTC Formulation
ρ	relative density or specific gravity
v_m	model speed of advance in ft/sec
l	length of model in ft corresponding to ship length L
b	breadth of model in ft corresponding to ship breadth B or breadth of water in tank (Formula 3)
h	depth of water in Tank (ft)
g	acceleration due to gravity (ft/sec^2)

Final Regression Equation

$$C_{R_{16}} = a_0 + a_1 X_1 + a_2 X_2 + a_3 X_3 + a_4 X_4 + a_5 X_5 + a_6 X_6 + a_7 X_7 + a_8 X_8 + a_9 X_9$$
$$+ a_{10} X_1^2 + a_{11} X_2^2 + a_{12} X_3^2 + a_{13} X_4^2 + a_{14} X_5^2 + a_{15} X_6^2 + a_{16} X_7^2 + a_{17} X_8^2$$
$$+ a_{18} X_1^3 + a_{19} X_2^3 + a_{20} X_3^3 + a_{21} X_4^3 + a_{22} X_5^3 + a_{23} X_6^3 + a_{24} X_7^3 + a_{25} X_8^3$$
$$+ a_{26} X_1^4 + a_{27} X_2^4 + a_{28} X_3^4 + a_{29} X_4^4 + a_{30} X_6^4$$
$$+ a_{31} X_2 X_3 + a_{32} X_2^2 X_3 + a_{33} X_2 X_3^2 + a_{34} X_2^3 X_3 + a_{35} X_2^2 X_3^2 + a_{36} X_2 X_3^3$$
$$+ a_{37} X_1 X_6 + a_{38} X_1^2 X_6 + a_{39} X_1 X_6^2 + a_{40} X_1^3 X_6 + a_{41} X_1^2 X_6^2 + a_{42} X_1 X_6^3$$
$$+ a_{43} X_1 X_4 + a_{44} X_1^2 X_4 + a_{45} X_1 X_4^2 + a_{46} X_1^3 X_4 + a_{47} X_1^2 X_4^2 + a_{48} X_1 X_4^3$$
$$+ a_{49} X_2 X_4 + a_{50} X_2^2 X_4 + a_{51} X_2 X_4^2$$
$$+ a_{52} X_4 X_5 + a_{53} X_4^2 X_5 + a_{54} X_4 X_5^2$$
$$+ a_{55} X_4 X_6 + a_{56} X_4^2 X_6 + a_{57} X_4 X_6^2$$
$$+ a_{58} X_4 X_7 + a_{59} X_4^2 X_7 + a_{60} X_4 X_7^2$$
$$+ a_{61} X_4 X_8 + a_{62} X_4^2 X_8 + a_{63} X_4 X_8^2$$
$$+ a_{64} X_1 X_3 + a_{65} X_1^2 X_3 + a_{66} X_1 X_3^2$$
$$+ a_{67} X_2 X_6 + a_{68} X_2^2 X_6 + a_{69} X_2 X_6^2$$
$$+ a_{70} X_5 X_6 + a_{71} X_5^2 X_6 + a_{72} X_5 X_6^2$$
$$+ a_{73} X_1 X_8 + a_{74} X_1^2 X_8 + a_{75} X_1 X_8^2$$
$$+ a_{76} X_2 X_8 + a_{77} X_2^2 X_8 + a_{78} X_2 X_8^2$$
$$+ a_{79} X_5 X_8 + a_{80} X_5^2 X_8 + a_{81} X_5 X_8^2$$
$$+ a_{82}(B_1 n) + a_{83}(B_1 n)^2 + a_{84} \delta_1 + a_{85} \delta_2$$

where
$$X_1 = L/B$$
$$X_2 = B/T$$
$$X_3 = C_m$$
$$X_4 = C_p$$
$$X_5 = l.c.b.$$
$$X_6 = \tfrac{1}{2} \alpha_e^{\circ}$$
$$X_7 = \tfrac{1}{2} \alpha_r^{\circ}$$
$$X_8 = \alpha_{BS}$$
$$X_9 = \text{trim}$$
$$\delta_1 = \begin{cases} 0, & \text{if there is no wooden keel} \\ 1, & \text{if there is a wooden keel} \end{cases}$$
$$\delta_2 = \begin{cases} 0, & \text{if turbulence stimulators are fitted} \\ 1, & \text{if turbulence stimulators are not fitted} \end{cases}$$

$a_0, a_1, a_2, \ldots, a_{85}$ are constants determined by the least-squares fitting, a different set for each value of $V/\sqrt{L}$.

New Possibilities for Improvement in the Design of Fishing Vessels

J. O. Traung, D. J. Doust, J. G. Hayes

Nouvelles possibilités d'amélioration du dessin des bateaux

Il a été décidé, pour contrôler le programme FAO/NPL (National Physical Laboratory) pour le calcul sur ordinateur de la résistance des bateaux de pêche, de construire et de soumettre à des essais des modèles de 4 bateaux de pêche, mesurant 40, 55, 70 et 85 pieds (12,2, 16,8, 21,4 et 26 m) à la flottaison. Après une étude du déplacement, de la largeur et du tirant d'eau des bâtiments de cette catégorie, il a été décidé de procéder aux essais de ces 4 bateaux avec des rapports longueur/déplacement de 4, 4,25, 4,5 et 4,75 respectivement.

La communication décrit le procédé d'optimisation ainsi que le travail de dessin proprement dit. Les lignes de coque ont été conçues eu égard à l'efficacité propulsive et à la tenue à la mer. Les résultats des essais des modèles de 40 (12,2 m), 55 (16,8 m), 70 (21,4 m) et 85 pieds (26 m) sont comparés aux prédictions fournies par l'ordinateur. On montre comment les résultats peuvent être appliqués pour diverses longueurs à la flottaison, autrement dit à des navires de déplacements et de largeurs différents. Étant donné que la hauteur du centre de gravité dépend des matériaux de construction utilisés, des machines, des superstructures, etc., il est recommandé de n'employer qu'avec discernement les lignes proposées. La stabilité des 4 navires a également fait l'objet d'une étude sur ordinateur, dont la communication présente certaines conclusions d'ordre général.

Nuevas posibilidades de funcionamiento del diseño de las embarcaciones de pesca

Con objeto de comprobar el programa de calculadoras FAO/NPL para estimar la resistencia de las embarcaciones de pesca, se decidió diseñar y probar modelos de cuatro barcos pesqueros de 40, 55, 70 y 85 pies (12,2, 16,8, 21,4 y 26 m) en la línea de flotación. Se hizo un estudio del desplazamiento, manga y calado de las embarcaciones de pesca de esta serie y se decidió probarlas con valores de desplazamiento de eslora de 4, 4,25, 4,5 y 4,75 respectivamente.

Se describe el procedimiento de optimización así como la composición real de los planos de formas. Los planos se desarrollaron considerando la eficacia de la propulsión y las condiciones del oleaje. Los resultados modelo de los barcos de 40, 55, 70 y 85 pies se comparan con las predicciones de las calculadoras. Se muestra cómo se pueden emplear los resultados para las diferentes longitudes de la línea de agua, es decir, tamaños de barcos de desplazamiento y mangas diferentes.

Como la altura del centro de gravedad dependerá de las clases del material de construcción, maquinaria, superestructuras, etc., se advierte el peligro de usar sin discriminación alguna los planos propuestos. También se puede investigar la estabilidad de los 4 barcos con ayuda de una calculadora y se dan algunas conclusiones generales de esta investigación.

FISHING boat hull shape must vary greatly due to different local conditions, fishing methods, construction material, engine weights, distance to the fishing grounds and other factors.

It is obviously impossible to design a few standard hulls which are suitable for all conditions.

FAO has in the past collected and published results of model tests and full-scale trials in an attempt to indicate the trend in the factors which influence resistance, powering and sea-keeping qualities.

With the recently completed statistical analysis of fishing vessel resistance data (Doust, Hayes, Tsuchiya, page 123), it will be possible when time and funds permit to draw important conclusions on how to find optimum hull shape when designing new fishing boat types.

The statistical analysis is also intended to be used for estimating the performance of an existing design so it can be investigated whether there is room for improvement.

In order to test the validity of the analysis it was agreed to design and test four models of varying sizes and it was also considered desirable if these could be made as good hydrodynamically as possible to indicate ways in which small and medium sized fishing boats could be improved.

SELECTION OF MAIN DIMENSIONS FOR FOUR TYPICAL FISHING VESSELS

It is an unfortunate fact that very few performance figures exist for small and medium sized fishing vessels. Even for those built to professionally made drawings, there seems to be no time or interest after the completion of the vessel to determine precisely displacement, stability, loading conditions and power requirements.

Although FAO has collected whatever information was available over the years, its data are scanty and incomplete in this respect.

In fig 1 displacement against length has been plotted for a number of fishing vessels from 30 to 100 ft (9 to 30 m). The displacement represents the completed vessel ready to go to sea but without water, fuel, ice and fishing gear (lightship condition).

It was found that while there is considerable spread between figures, the displacement curves conform generally as the cube of the length, which confirms an old impression that, when dealing with small fishing vessels, one could use the length-displacement ratio ($M = L/\nabla^{\frac{1}{3}}$) as a guide to the estimation of displacement from length.

Fig 1 shows curves of length-displacement ratios 4,

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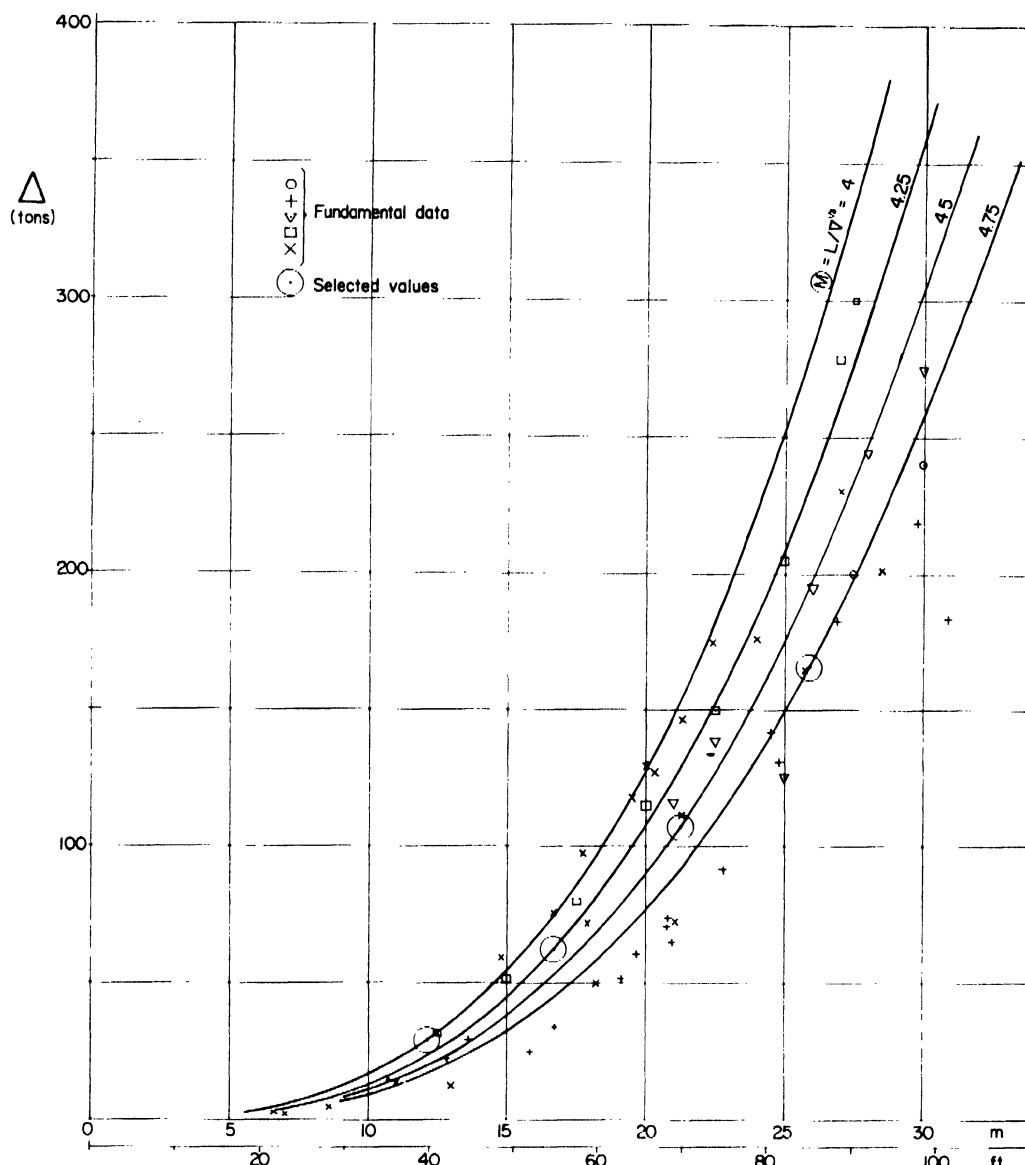
Fig 1. Displacement of completed fishing vessels ready to go to sea but without water, fuel, ice and fishing gear (light ship condition) plotted against length. Curves for equal length/displacement ratio are also drawn

4.25, 4.5 and 4.75 and generally the assumption might be permitted that a ratio 4.5 represents the light condition of most vessels and a ratio 4 a displacement about 43 per cent higher which could be considered as representing the loaded condition. However, construction practices vary in various countries, as do the weight and size of marine engines.

It is well known, the length–displacement ratio has a large effect on ships' resistance. It was, therefore, found to be practical to make the four models represent vessels 40, 55, 70 and 85 ft (12.2, 16.8, 21.4 and 25·9 m) in length and the displacement–length ratios 4, 4.25, 4.5 and 4.75 respectively. In this way the results could be expanded, so that eventually, for any length between 40 and 85 ft the resistance could be determined for boats having length–displacement ratios between 4 and 4.75.

Simultaneously, the relationships between beam and length and draft and beam were plotted, and it was found that for the fishing vessels in question, the beam varied from $L/B = 3$ at 30 ft (9 m) to $L/B = 4$ at 100 ft (30 m). There was a variation of about ± 10 per cent in the beams. The B/T varied approximately between 2.5 and 3 for investigated types. The L/B ratio of 3 to 4 is somewhat more restricted than is modern practice, which is normally about 10 per cent higher.

OPTIMIZATION OF REGRESSION EQUATIONS

Doust, Hayes and Tsuchiya (page 124) have described the derivation of regression equations of the form

$$C_R = \psi[L/B,\ B/T,\ C_m,\ C_p,\ l.c.b.\ \%,\ \tfrac{1}{2}\alpha_e^\circ,\ \tfrac{1}{2}\alpha_r^\circ,\ \alpha_{BS}^\circ,\ trim],*$$

which enables the resistance performance of a particular vessel to be estimated from its parameter values at each of a series of speed–length ratios. With these equations,

* For nomenclature see page 136.

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it is also possible to explore the effects of varying these hull form parameters, with a view to minimizing $C_{R_{16}}$ and so deducing new combinations of parameters giving improved performance. These changes may be performed for an existing design of current interest, restricted only by basic design specifications or may provide the most advantageous solution where alternatives exist. As in previous work (Doust, 1962; Hayes, 1964), the case is considered when ship speed, length and displacement are specified,* i.e. $[V, L, \Delta]$ are given.

Hence we know $V/\sqrt{L}$ and $\mathbb{M} = \dfrac{L}{(35\Delta)^{\frac{1}{3}}}$

But

$$\mathbb{M}^3 = \frac{(L/B)^2(B/T)}{C_m \cdot C_n},$$

so that the variations of these four parameters must be restricted to satisfy this equality. Thus, for example, if L/B, B/T and C_p are fixed, the value of C_m follows. The variations must definitely also be restricted to the parameter ranges of the original data used to derive the regression equations.

Three ways were considered for exploring the effects of changes in the values of the form parameters.

Evaluation over a mesh

This is the most direct method and consists of selecting, say, five values of each parameter covering the range, evaluating C_R for all possible combinations of these sets of five values, and examining the results to find a minimum C_R. This process, however, involves a very large number of evaluations. Nearly 400,000 evaluations would be needed if all the parameters were allowed to vary in the above manner subject to $\mathbb{M}$ being constant, and, even if variations in $\frac{1}{2}\alpha_r^\circ$ and trim are ignored, because the effects of these are negligible, over 15,000 evaluations would be required. In practice, therefore, it would usually only be reasonable to take all possible combinations for the most important parameters and to vary the remainder singly about some arbitrary standard. This might not always be satisfactory since significant effects might be overlooked.

Systematic tabulation

The situation can be considerably improved, however, by taking into account the precise form of the regression equations and noting which pairs of parameters are interrelated and which are not. In fact, by this means, from a few thousand evaluations, tables can be compiled which allow all the parameters to be correctly taken into account and which are valid for all values of $\mathbb{M}$. As it happens, the task is appreciably simplified in the case of $V/\sqrt{L}=1.1$, since the terms relating $l.c.b.\%$ and $\frac{1}{2}\alpha_e^\circ$ are small enough to be neglected initially. Thus, in this case, it can be observed from the equations that the effect of changing $\frac{1}{2}\alpha_e^\circ$ depends only on L/B, B/T and C_p, so that $\frac{1}{2}\alpha_e^\circ$ can be optimized for particular combinations of these parameters independently of the others. Similarly, the best values of $l.c.b.\%$ and α_{BS}° can be found for particular combinations of the same three parameters,

* From the stability point of view also beam could be specified.

independently of the rest. The effect of $\frac{1}{2}\alpha_r^\circ$, which depends only on C_p, can be considered independently of all parameters except C_p.

The general procedure is illustrated in table 1. Five values are taken for L/B and five for B/T covering the appropriate ranges, giving 25 possible combinations of these two parameters. For each of these combinations, a set of tables is drawn up, a particular example of which is shown in table 1. For this purpose, the effects of $\frac{1}{2}\alpha_r^\circ$ and trim, which are small, were neglected though in fact they add only a little to the complication. Initially table 1(a) is surveyed and for each value of C_p the best value of C_R and the corresponding value of $\frac{1}{2}\alpha_e^\circ$ is selected. Thus, for $C_p=.575$, $\frac{1}{2}\alpha_e^\circ=15$ and the first approximation to be best C_R value, for this C_p, is 15.71. This latter value corresponds to the arbitrary standard values of the parameters not so far considered, which will now be dealt with. Table 1(b) shows the amount to be added to C_R when particular values of $l.c.b.\%$ and α_{BS}° are selected. In the column for $C_p=.575$, the maximum reduction possible (greatest negative value) is -0.67, corresponding to an $l.c.b.$ of -4 per cent and α_{BS}° of 20 degrees. The second approximation to the best C_R value is therefore $15.71-0.67=15.04$.

It now remains only to consider the effect of C_m; it has been observed earlier, when L/B, B/T and C_p are fixed with $\mathbb{M}$ constant, the value of C_m follows. Table 1(c) gives the values of C_m corresponding to different values of C_p and $\mathbb{M}$. Assuming 4.5 to be the value of $\mathbb{M}$ of current interest, it is found that for a C_p value of .575 that $C_m=.758$. By interpolation in table 1(d) for this value of C_m the appropriate addition to C_R is obtained and it is $+0.1$, giving a final value of $15.04+0.1=15.14$ for C_R. This corresponds to the following parameter values:

L/B	B/T	C_m	C_p	$l.c.b.\%$	$\frac{1}{2}\alpha_e^\circ$	$\frac{1}{2}\alpha_r^\circ$	α_{BS}°	trim
3.7	2.9	.758	.575	-4.0	15	45	20	0.03

This is the best set of values given these particular values for L/B, B/T and C_p. A similar set can be selected from table 1 for each value of C_p, and the best of these gives the best set for these values of L/B and B/T. The whole process is repeated for all the other combinations of values of these two parameters and the best one of these gives the final optimum.

Mathematical optimization

The problem of optimizing mathematical functions has received a great deal of attention from numerical analysts in recent years, and many methods, of varying degrees of effectiveness, are now available (e.g. Fletcher and Powell, 1963). Essentially, these methods start at an arbitrary, or otherwise predetermined point (combination of parameter values) and by computing function values and sometimes derivatives in the neighbourhood of this point, obtain a direction in which to proceed to a more advantageous region. This process is repeated until no further improvement is possible by small steps in any direction.

This process has the advantage over the earlier one in that an optimum can be more accurately pin-pointed than is possible with the tabular values of the systematic
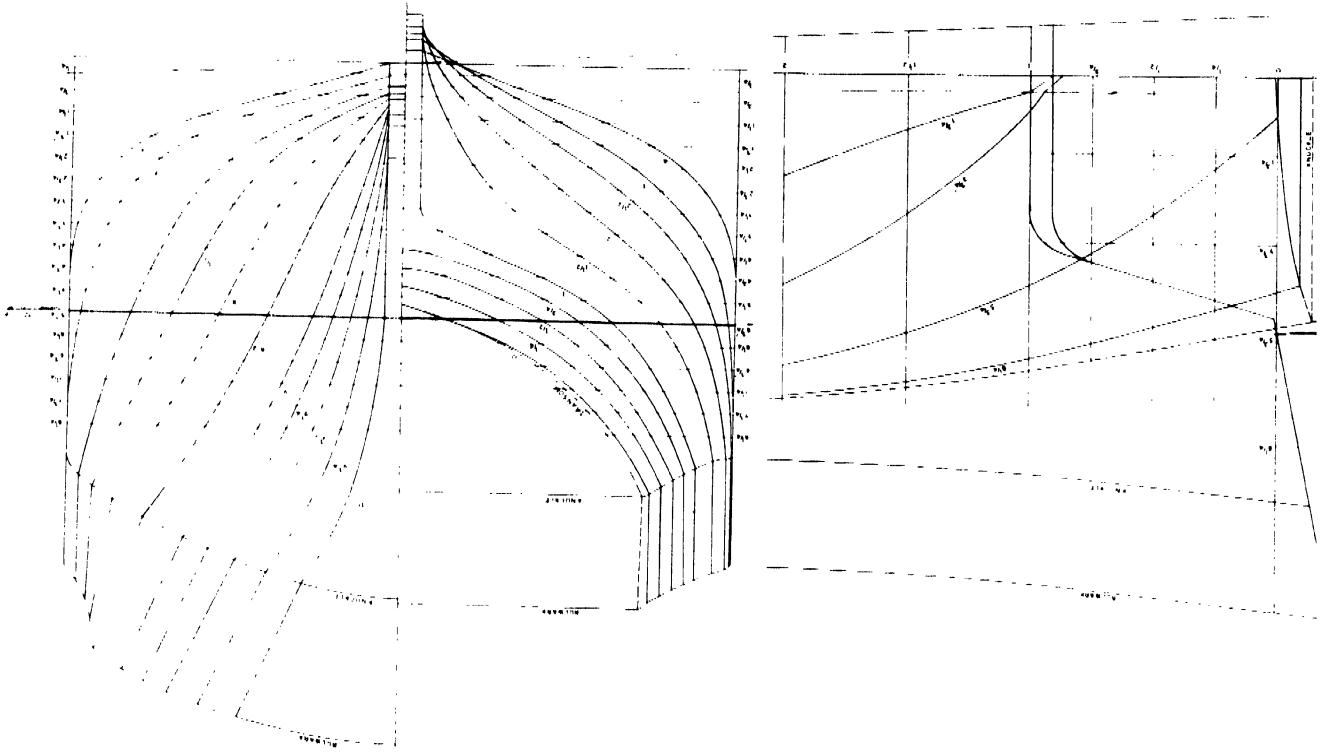
SCALE IN FEET
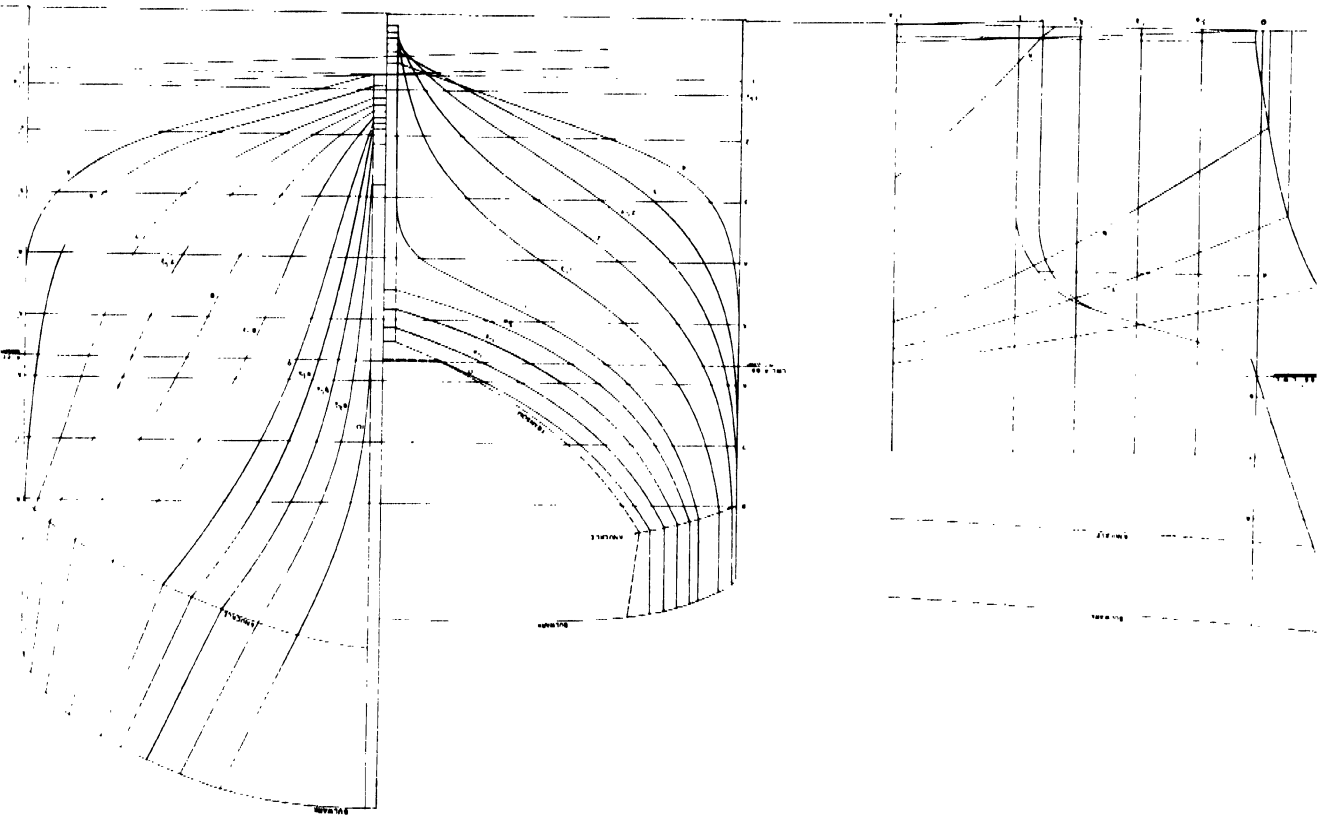
SCALE IN FEET
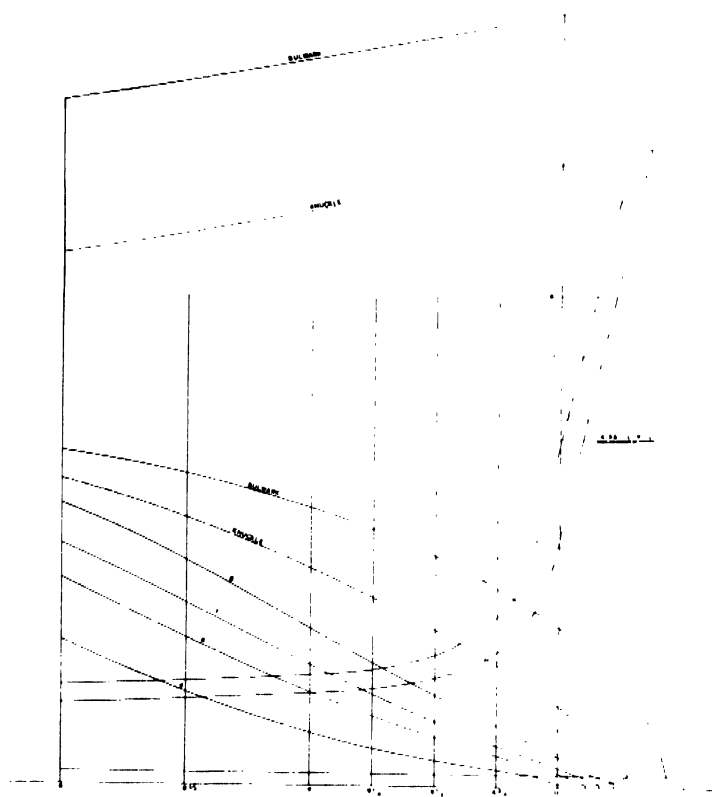
Fig 3. 40 ft (12.2 m) optimized fishing vessel. The lines were designed by FAO and the model tested by NPL
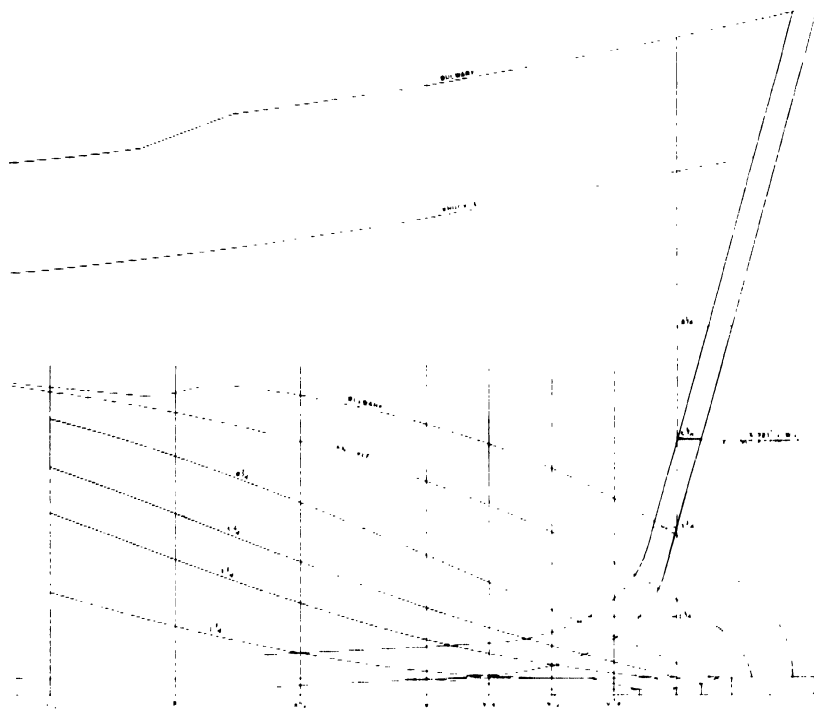
Fig 4. 55 ft (16.8 m) optimized fishing vessel. The lines were designed by FAO and the model tested by NPL
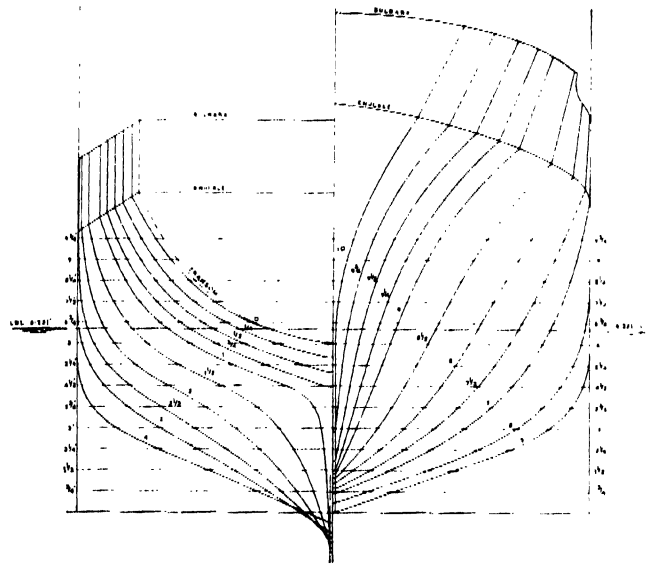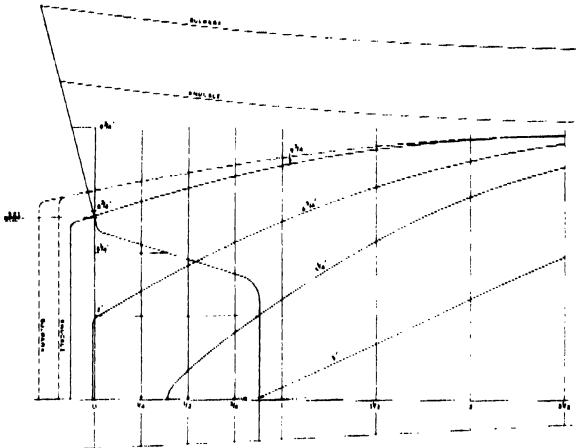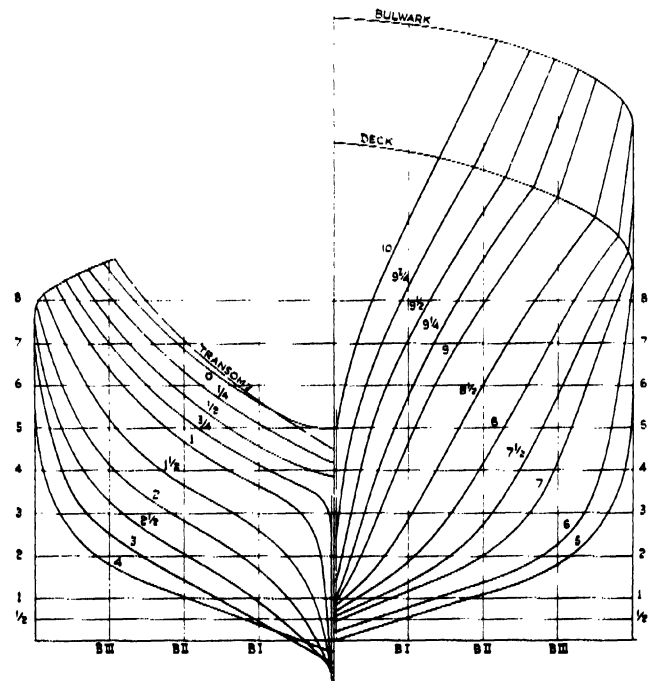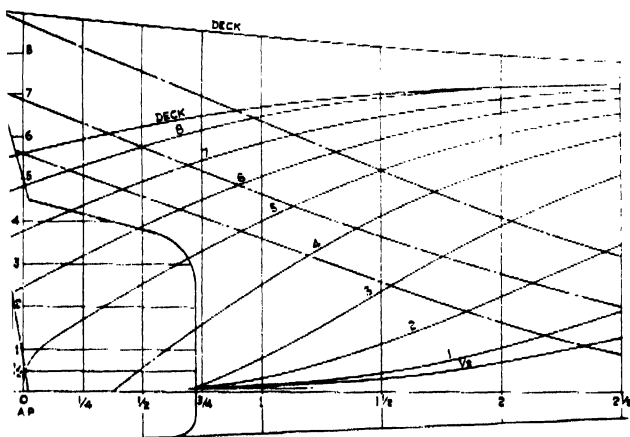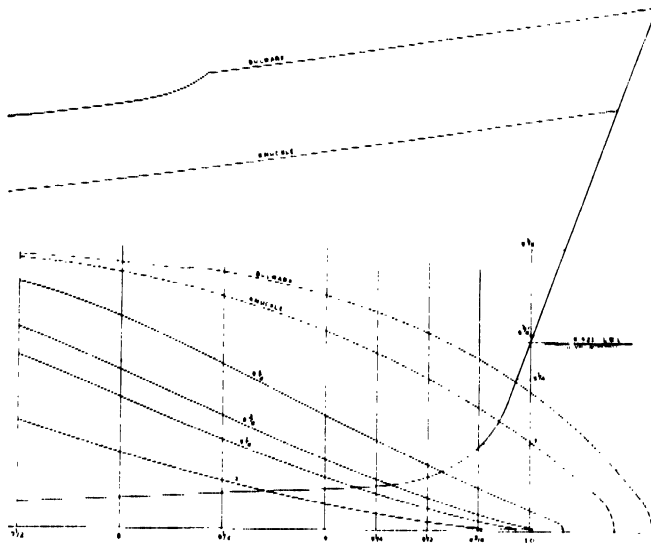
Fig 5. 70 ft (21.4 m) optimized fishing vessel. The lines were designed and the model tested by NPL
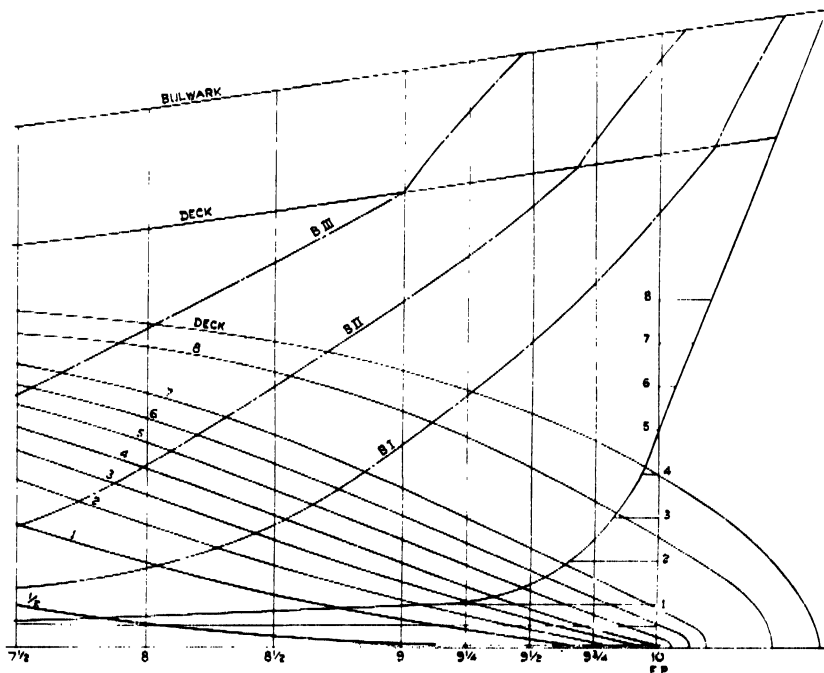
Fig 6. 85 ft (26 m) optimized fishing vessel. The lines were designed and the model tested by Chalmers Technical University

which required adjustment to accommodate the fine angle of entrance and the longitudinal centre of buoyancy.

In doing this, great care was taken to ensure that the sectional area curve was not too steep in the after body as experience has already shown this requirement for larger fishing vessels, although a somewhat steeper curve had to be accepted. Care was also exercised in avoiding too hard a shoulder on the waterline. Fig 7 shows the area curve for the 40-footer.
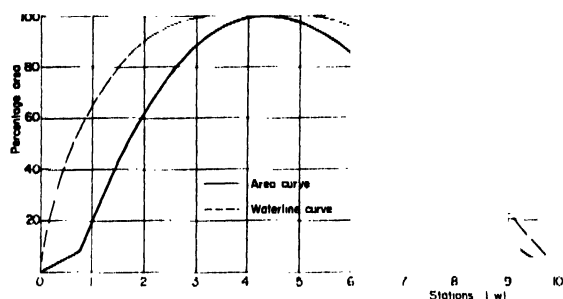
Fig 7. Displacement curve for the 40-ft vessel

The stern aperture for all vessels is made so large that it can accommodate a 300 rpm propeller able to produce a maximum speed of about 1.2 Froude number and produce full thrust at 100 per cent rpm while towing.

The power required for such towing is higher than that required for steaming and is estimated at 60, 120, 350 and 500 hp respectively for the four designs.

MODEL TESTS

Models of the 40-, 55- and 70-footers were made to scale — 1 : 6, 1 : 8 and 1 : 12 respectively — and tested by the Ship Division of the National Physical Laboratory in their No. 1 tank, whereas the model of the 85-footer was made to scale 1:7 and tested by the open-air model testing facility of Chalmers Technical University, Gothenburg, Sweden.

Fig 8 to 11 show the wave profile for various $V/\sqrt{L}$ for the 40-, 55-, 70- and 85-ft models.

Table 3 gives the measured C_{R16} values for the models. The models were equipped with turbulence stimulating studs and as the results include any parasitic drag, results are also given for C_{R16} with estimated resistance for the turbulence stimulators subtracted. Fig 12 to 16 show these C_{R16} values compared with the original data included in the statistical analysis, which were plotted according to the second author's recommendations.

In order to be able to compare individual designs with best current practice, fig 17 has been prepared from the FAO data sheets, such as fig 12 to 16. The FAO data are derived from many hydrodynamic laboratories and differing degrees of turbulence stimulation were applicable to many of the models and it was necessary to standardize all the measured results to constant physical conditions before true comparisons of performance could be made. It was decided, therefore, to standardize all the FAO data to infinite depth and breadth of water and to correct all model results to the fully turbulent condition, using the appropriate values of $B_1 n$ and the regression coefficients given by the equation in Appendix 1 of Doust, Hayes and Tsuchiya (page 138).

A plotting of C_{R16} against Δ_{16} was made for each of the four speed–length ratios 0.90, 1.00, 1.10 and 1.20, correcting each model result to infinite water, with turbulence stimulators fitted, as already indicated. The minimum envelope of $C_{R16} - \Delta_{16}$ was determined for each of these speed–length ratios, whilst on the same diagram were shown the C_{R16} values at speed–length ratio = 0.90 and 1.20 given by the 1957 ITTC formulation for a value of ⑤ = 6.0. It was of great interest to note that for the best current design values, the amount of viscous to total resistance at a representative design speed of, say, speed–length ratio = 1.10 is approximately 53 per cent for all values of ⑩ between 3.75 and 5.00. As in the earlier NPL analyses (Doust, 1962; Hayes, 1964) it can be seen that forms having low values of ⑩ have generally less resistance per ton of displacement (⑩ = 3.75 to 4.0).

With the aid of such diagrams it is now possible to derive the minimum C_{R16} values over the practical range of speed–length ratio 0.90 to 1.20 for infinite water and with fully turbulent boundary layer flow, given by best current practice. These values may be compared with either measured or estimated values of C_{R16} for new designs and decisions taken regarding their quality of performance. It should be noted, however, that in general a hull form having good performance values at one value of speed–length ratio will not necessarily maintain all this advantage at other values of speed–length ratio.

Fig 17 shows the results of the four models already tested compared at $V/\sqrt{L} = 1.1$ for infinite water.

TABLE 3

Model test results expressed in C_{R16}

$V/\sqrt{L}$	40 ft; ⑩ = 4.0		55 ft; ⑩ = 4.25		70 ft; ⑩ = 4.5		85 ft; ⑩ = 4.75	
	1	2	1	2	1	2	1	2
0.85	13.23	12.43	14.35	13.55	12.30	11.50	14.08	13.28
0.90	13.55	12.35	14.55	13.35	12.94	11.74	14.17	12.97
0.95	13.84	12.48	14.96	13.60	13.51	12.15	14.64	13.28
1.00	14.08	12.69	15.17	13.78	14.29	12.90	15.18	13.79
1.05	14.10	12.61	15.58	14.09	14.91	13.42	15.72	14.23
1.10	14.73	13.16	15.97	14.40	15.51	13.94	16.28	14.71
1.15	16.51	14.86	17.17	15.52	16.77	15.12	16.71	15.06
1.20	19.66	19.08	19.96	19.38	18.98	18.40	18.00	17.42

Column 1 C_{R16} measured on model fitted with turbulence studs.
Column 2 Measured C_{R16} corrected with estimated subtraction for condition without turbulence studs.
All results exclude keel.

$V/\sqrt{L} = 1.0$

$V/\sqrt{L} = 1.1$
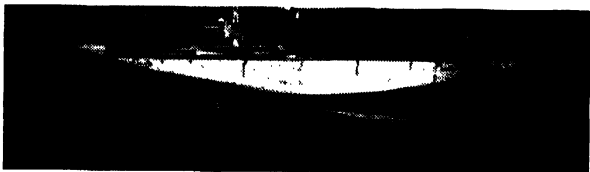
$V/\sqrt{L} = 1.2$

Fig 8. Wave profile at various speeds for the 40-footer

$V/\sqrt{L} = 1.0$

$V/\sqrt{L} = 1.1$

$V/\sqrt{L} = 1.2$

Fig 10. Wave profile at various speeds for the 70-footer
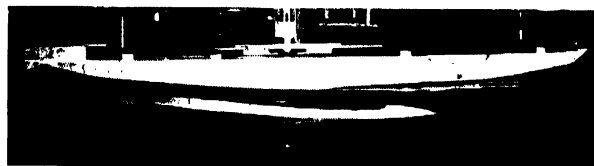
$V/\sqrt{L} = 1.0$

$V/\sqrt{L} = 1.1$

$V/\sqrt{L} = 1.2$

Fig 9. Wave profile at various speeds for the 55-footer
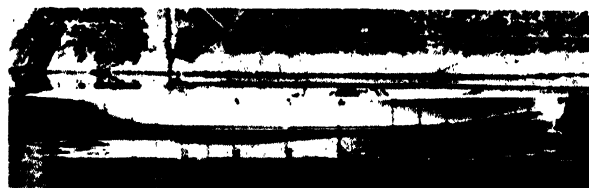
$V/\sqrt{L} = 1.0$

$V/\sqrt{L} = 1.1$
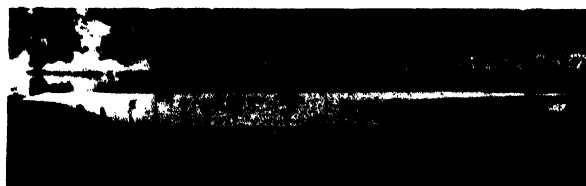
$V/\sqrt{L} = 1.2$

Fig 11. Wave profile at various speeds for the 85-footer
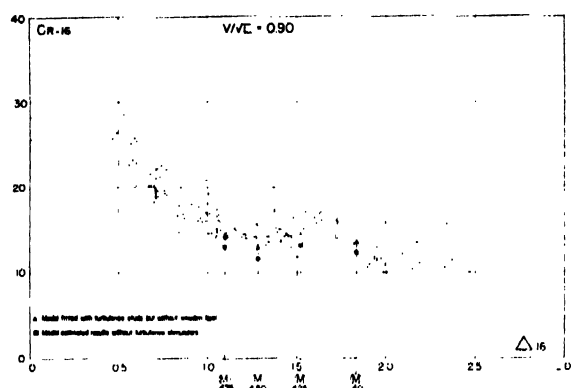
Fig 12. Resistance curves of the four optimized vessels compared
with input data
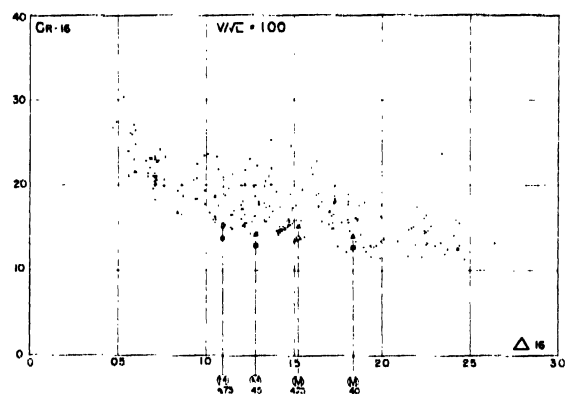
Fig 13. Resistance curves of the four optimized vessels compared
with input data
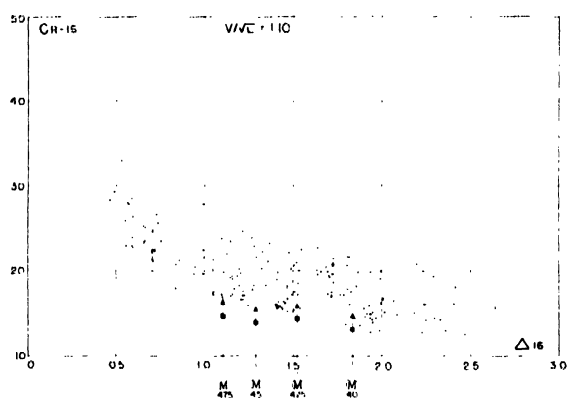
Fig 14. Resistance curves of the four optimized vessels compared
with input data
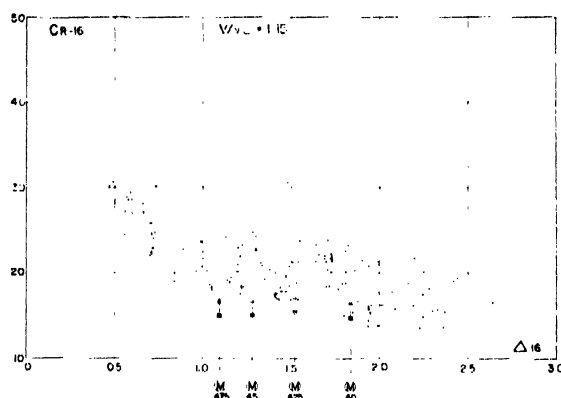
Fig. 15. Resistance curves of the four optimized vessels compared
with input data
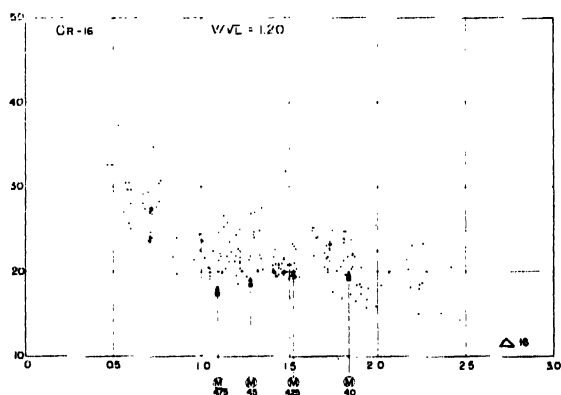
Fig 16. Resistance curves of the four optimized vessels compared
with input data
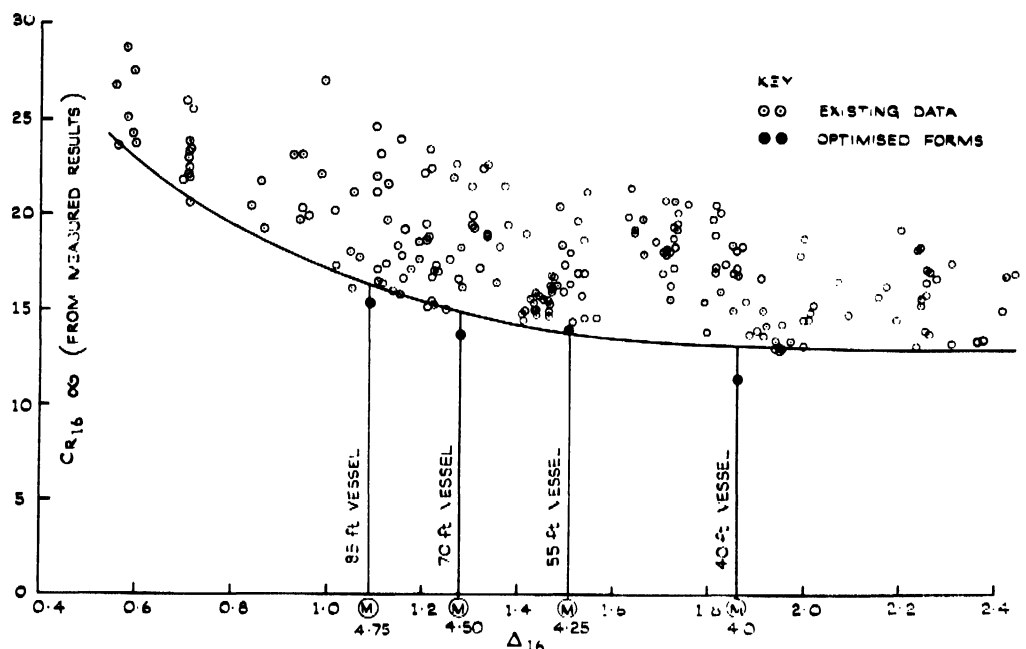
Fig 17. Results for the 40-, 55-, 70- and 85-footers at 1.1 speed length ratio compared with existing data

Table 4 gives computer calculated EHP for the four models.

If time and funds permit, it is hoped that these models can be tested also at other displacements and possible trims to complete the data of model tests for the statistical analysis, and to cover the range of operational conditions when fishing.

TABLE 4

Computer calculated EHP

$V/\sqrt{L}$	40 ft; ⓜ = 4.00	55 ft; ⓜ = 4.25	70 ft; ⓜ = 4.50	85 ft; ⓜ = 4.75
.85	3.5	8.8	20.1	36.0
.90	5.0	11.4	24.0	42.0
.95	5.3	13.4	28.6	52.2
1.00	5.7	15.8	34.7	64.9
1.05	6.0	18.6	40.5	72.5
1.10	6.2	21.1	48.6	82.7
1.15	6.6	23.1	56.6	100.3
1.20	11.6	27.1	72.0	139.6

These results are based on ITTC friction formulation and infinite water.

STABILITY

The stability of the 40-, 55- and 70-ft designs was investigated by the Danish Ship Research Institute (DSRI), Lyngby, Denmark. The computation was performed on their advanced computer GIER. The stability of the 85-ft design was investigated by Chalmers Technical University, Gothenburg, Sweden, on a Facit EDB computer using the program of the Swedish Shipbuilders Computing Centre, Gothenburg, Sweden.

Each type was investigated with freeboards of five different heights in order to study the influence of freeboard on stability. The variations were made in 10 per cent of D increments against the normal height.

Space does not permit giving the hydrostatic curves and the five isocline stability curve diagrams for each

model. The isocline stability curves were presented for the case $GM = 0$. Thus they were showing the residuary stability levers $M_0 S$ for inclinations 5, 10, 15, 20, 30, 45, 60, 75 and 89.9°. The values were given for a range of drafts so that, while the following stability evaluations were mainly made for the same displacement at which the models had been tested, other displacements can also easily be investigated.

The GZ values are thus calculated

$$GZ = M_0 S + GM_0 \times \sin \varphi.$$

Fig 18 illustrates this further. When in the proceeding investigation each of the models will be expanded or reduced in length to be comparable with the other models, GM is then not enlarged or reduced. Only the factor $M_0 S$ is enlarged or reduced in proportion to the length.

The vertical position of the centre of gravity of a fishing vessel is sometimes expressed as the ratio KG/D.
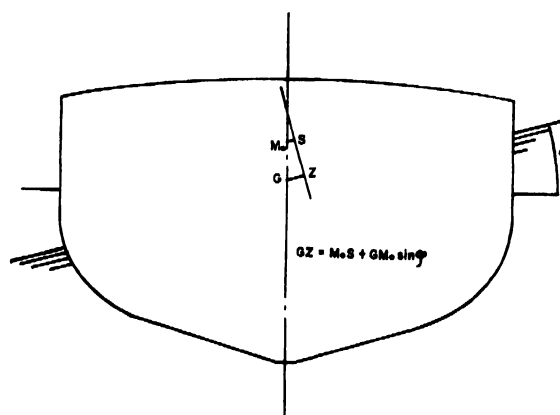
Fig 18. Sketch showing how the righting lever GZ is made up of a fixed value depending on GM$_0$ and one factor, M$_0$S, following the form and size of the ship

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It mostly varies between 0.7 and 0.8, the higher value often representative of the light condition and the lower the loaded condition.

If the freeboard could be increased without increasing the displacement, the metacentre would remain at the same height and the centre of gravity would then eventually become so high that a negative GM would result. In practice, of course, it is not possible to increase freeboard without making an increase in displacement.

Requirements to fulfil Rahola at design displacement

The stability investigation was originally started in order to find out the optimum freeboard, assuming a constant KG/D of 0.7 and 0.8 but with the variations selected it was unfortunately not possible to determine such an optimum. A more careful analysis made it obvious that the KG/D constant approach was impractical and misleading.

Table 5 shows the results of the stability calculation for the 40-ft vessel. This hull was expanded to 55, 70 and 85 ft and the table gives the resulting drafts, beams and displacement.

L	40	55	70	85
B (L/B = 3.43)	11.66	16.05	20.45	24.80
D	7.00	9.62	12.25	14.90
T (B/T = 2.5)	4.66	6.42	8.18	9.92
freeboard	2.34	3.20	4.07	4.98
Δ (L/∇⅓ = 4) tons	28.6	74.3	154	275
$\overline{KM}$	5.77	7.94	10.10	12.25
Constant $\overline{GM}$ (= 1.9 ft)				
$\overline{KG}$	3.87	6.04	8.20	10.35
$\overline{KG}/D$	.553	.628	.670	.695
$\overline{KG}$-T	−.79	−.38	.02	.43
T_r (= B in m) sec	3.6	4.9	6.2	7.6
Rahola minimum				
min $\overline{GM}$	1.20	1.25	1.30	1.35
$\overline{KG}$	4.57	6.69	8.80	10.90
$\overline{KG}/D$	.654	.695	.718	.731
$\overline{KG}$-T	.09	.27	.62	.98
T_r sec	4.5	6.0	7.6	9.0
$T_r\sqrt{(g/B)}$	7.4	8.5	9.6	10.2

All linear measurements in ft

A first investigation was to obtain the GM with which the hulls were to have a period of roll corresponding to their beams in metres, which is an experience rule for agreeable rolling. Simplifying the problem and using the same inertia factor of $m=0.38$ (Weiss reference), the required GM is 1.9 ft for all beams.

If the GM is maintained constant and as the height of the metacentre above keel varies linearly, the increase in the height of the centre of gravity is relatively greater. Thus the ratio KG/D being .553 for the hull being 40 ft long increases to .695 for its 85-ft version. Therefore, a longer boat of the same form as the shorter can have the centre of gravity comparatively higher and still have comfortable rolling motions.

It was then investigated what minimum GM would be required to fulfil Rahola's stability criterion, which was used as a yardstick only, and for the 40-ft boat in question it was found that the minimum permissible GM according to Rahola increases from 1.2 ft for the 40-ft version to 1.35 ft for this form expanded to 85 ft. However, also the ratio KG/D increases, in this case from .654 to .731; thus, in spite of the larger GM, the centre of gravity can be comparatively higher for the longer versions. The centre of gravity of a vessel of the 40-ft type should not be higher than indicated in table 5 (Rahola minimum) without careful consideration of specific working conditions.

Table 6 shows the influence of varying freeboards on the 40-ft vessel. As draft is constant, the deck enters the water at inclinations from 9.2° to 32.7°, depending on whether the freeboard is .94 ft or 3.74 ft, representing a variation of ±20%D.

Freeboard variation	−20%D	−10%D	D	+10%D	+20%D
D	5.60	6.30	7.00	7.70	8.40
T	4.66	4.66	4.66	4.66	4.66
freeboard	.94	1.64	2.34	3.04	3.74
φ to deck	9.2°	15.7°	21.8°	27.6°	32.7°
$\overline{KM}$	5.77	5.77	5.77	5.77	5.77
$\overline{KG}/D = .7$					
$\overline{KG}$	3.92	4.41	4.90	5.39	5.88
$\overline{GM}$	1.85	1.36	.87	.38	−.11
$\overline{KG}$-T	−.74	−.25	.26	.73	1.22
φ at $\overline{GZ}$ max	30°	32°	35°	37.5°	45°
φ at $\overline{GZ}$ = 0	77.5°	75.2°	72.6°	72°	67.7°
Rahola minimum					
min $\overline{GM}$	2.05	1.40	1.20	1.00	1.00
$\overline{KG}$	3.72	4.37	4.57	4.77	4.77
$\overline{KG}/D$	.665	.695	.654	.613	.562
$\overline{KG}$-T	−.94	−.29	−.09	.11	.11
T_r sec	3.4	4.1	4.5	4.9	4.9
$T_r\sqrt{(g/B)}$	5.6	6.8	7.4	8.1	8.1

All linear measurements in ft

L	40	55	70	85
B (L/B = 3.7)	10.81	14.86	18.92	22.95
D	6.37	8.75	11.13	13.52
T (B/T = 2.6)	4.16	5.72	7.27	8.83
freeboard	2.21	3.03	3.86	4.69
Δ (L/∇⅓ = 4.25) tons	23.6	61.9	126	226
$\overline{KM}$	5.35	7.36	9.37	11.37
Constant $\overline{GM}$ (= 1.9 ft)				
$\overline{KG}$	3.45	5.46	7.47	9.47
$\overline{KG}/D$	.542	.623	.670	.700
$\overline{KG}$-T	−.71	−.26	.20	.64
T_r (= B in m) sec	3.3	4.5	5.8	7.0
Rahola minimum				
min $\overline{GM}$	1.20	1.20	1.30	1.30
$\overline{KG}$	4.15	6.16	8.07	10.07
$\overline{KG}/D$	.652	.704	.725	.744
$\overline{KG}$-T	−.01	.44	.80	1.24
T_r sec	4.1	5.7	7.0	8.5
$T_r\sqrt{(g/B)}$	5.0	8.4	9.1	10.1

All linear measurements in ft

The minimum permissible *GM* for the vessel with varying freeboards varies from 2.05 ft to 1 ft to satisfy the Rahola criterion, and the *KG/D* ratio is highest at the −10%*D* version indicating that this freeboard might be the optimum. However, it must be noted that *KG/D* = .7 for this vessel and length is too high to fulfil Rahola.

TABLE 8
Results of stability analyses of 55-ft (16.8-m) hull (Ⓜ 4.25) with different freeboards

Freeboard variation	−20%D	−10%D	D	+10%D	+20%D
D	7.00	7.88	8.75	9.62	10.50
T	5.72	5.72	5.72	5.72	5.72
freeboard	1.28	2.16	3.03	3.90	4.78
φ to deck	9.8°	16.2°	22.4°	27.7°	32.8°
K̄M̄	7.36	7.36	7.36	7.36	7.36
K̄Ḡ/D = .7					
K̄Ḡ	4.90	5.42	6.13	6.74	7.36
ḠM̄	2.46	1.94	1.23	.62	0
K̄Ḡ-T	−.82	−.30	.41	1.02	1.64
φ at ḠZ̄ max	32.5°	35°	38°	42.5°	45°
φ at ḠZ̄ = 0	83.5°	81°	79°	78.5°	72.5°
Rahola minimum					
min ḠM̄	2.30	1.70	1.20	1.00	.90
K̄Ḡ	5.06	5.66	6.16	6.36	6.46
K̄Ḡ/D	.723	.718	.704	.662	.615
K̄Ḡ-T	−.66	−.06	.44	.64	.74
T, sec	4.1	4.8	5.7	6.3	6.6
T√(g/B)	6.1	7.1	8.4	9.3	9.8

All linear measurements in ft

Table 7 for the 55-footer shows a similar trend as that for the 40-footer. Table 8, showing the influence of the height of freeboard, differs somewhat from table 6 for the 40-footer, the "best" *KG/D* values for minimum Rahola are, in this case, for the −20%*D* version. For freeboards equal to −20%*D* to *D* the *KG/D* = .7 con-ᵈⁱᵗⁱᵒⁿ ᵈᵒᵉˢ fulfil the Rahola criterion; here the longer length seems to permit a higher *KG*.

TABLE 9
Results of stability analyses of 70-ft (21.3-m) hull (Ⓜ 4.50) reduced to 40 and 55 ft and expanded to 85 ft

L	40	55	70	85
B (L/B = 3.7)	10.81	14.86	18.92	22.95
D	5.72	7.86	10.00	12.13
T (B/T = 2.9)	3.72	5.12	6.52	7.93
freeboard	2.00	2.74	3.48	4.20
Δ (L/∇⅓ = 4.50) tons	19.8	51.7	106.6	190.0
K̄M̄	5.87	8.08	10.28	12.48
Constant ḠM̄ (= 1.9 ft)				
K̄Ḡ	3.97	6.18	8.38	10.58
K̄Ḡ/D	.694	.787	.838	.872
K̄Ḡ-T	.25	1.06	1.86	2.65
T, (= B in m) sec	3.3	4.5	5.8	7.0
Rahola minimum				
min ḠM̄	1.60	1.90	1.90	2.20
K̄Ḡ	4.27	6.18	8.38	10.28
K̄Ḡ/D	.746	.765	.838	.847
K̄Ḡ-T	.55	1.06	1.86	2.35
T, sec	3.6	4.5	5.8	6.5
T√(g/B)	6.2	6.6	7.5	7.7

All linear measurements in ft

Table 9 for the 70-footer shows again that the longer the vessel, the higher is the permissible centre of gravity. In this case quite high *GM*s are required to fulfil Rahola's criterion but, because the metacentre is comparatively high, the centre of gravity is still higher than for the 40- and 55-footers.

Table 10 shows that for 70 ft length, a *KG/D* = .7 well fulfils Rahola's criterion; again the longer vessel permits a larger *KG/D* value. The maximum *KG/D* for the 70-footer is at −20%*D*, the lowest freeboard investigated.

TABLE 10
Results of stability analyses of 70-ft (21.3-m) hull (Ⓜ 4.50) with different freeboards

Freeboard variation	−20%D	−10%D	D	+10%D	+20%D
D	8.00	9.00	10.00	11.00	12.00
T	6.52	6.52	6.52	6.52	6.52
freeboard	1.48	2.48	3.48	4.48	5.48
φ to deck	8.9°	14.7°	20.2°	25.3°	30.1°
K̄M̄	10.28	10.28	10.28	10.28	10.28
K̄Ḡ/D = .7					
K̄Ḡ	5.60	6.30	7.00	7.70	8.40
ḠM̄	4.68	3.98	3.28	2.58	1.88
K̄Ḡ-T	−.92	−.22	.48	1.18	1.88
φ at ḠZ̄ max	32°	32.5°	36°	37°	46°
φ at ḠZ̄ = 0	>90°	>90°	>90°	>90°	>90°
Rahola minimum					
min ḠM̄	3.40	2.70	1.90	1.60	1.20
K̄Ḡ	6.88	7.58	8.38	8.68	9.08
K̄Ḡ/D	.861	.843	.838	.790	.757
K̄Ḡ-T	.36	1.06	1.86	2.16	2.56
T, sec	4.3	4.9	5.8	6.3	7.3
T√(g/B)	5.6	6.4	7.5	8.2	9.5

All linear measurements in ft

TABLE 11
Results of stability analyses of 85-ft (25.9-m) hull (Ⓜ 4.75) reduced to 40, 55 and 70 ft

L	40	55	70	85
B (L/B = 4.02)	9.95	13.70	17.40	21.20
D	5.31	7.30	9.28	11.28
T (B/T = 2.94)	3.39	4.66	5.93	7.33
freeboard	1.92	2.64	3.35	3.95
Δ (L/∇⅓ = 4.75) tons	17.1	44.3	91.5	163.2
K̄M̄	5.05	6.95	8.83	10.72
Constant ḠM̄ (= 1.9 ft)				
K̄Ḡ	3.15	5.05	6.93	8.82
K̄Ḡ/D	.593	.692	.747	.782
K̄Ḡ-T	−.24	.39	1.00	1.49
T, (= B in m) sec	3.0	4.2	5.3	6.5
Rahola minimum				
min ḠM̄	1.20	1.30	1.40	1.50
K̄Ḡ	3.85	5.65	7.43	9.22
K̄Ḡ/D	.725	.774	.801	.817
K̄Ḡ-T	.46	.99	.150	1.89
T, sec	3.8	5.1	6.2	7.3
T√(g/B)	6.9	7.8	8.4	9.0

All linear measurements in ft

Table 11 and 12 for the 85-footer show similar trends as in previous cases.

If the 55-, 70- and 85-ft hulls are all reduced to 40 ft, tables 13, 14 and 15, one still finds that at lower free-

TABLE 12
Results of stability analyses of 85-ft (25.9-m) hull ($\bar{\mathrm{M}}$ = 4.75) with different freeboards

Freeboard variation	$-20\%D$	$-10\%D$	D	$+10\%D$	$+20\%D$
D	9.02	10.15	11.28	12.41	13.54
T	7.33	7.33	7.33	7.33	7.33
freeboard	1.69	2.82	3.95	5.08	6.21
φ to deck	9.1°	14.9°	20.4°	25.6°	30.3°
$\overline{KM}$	10.72	10.72	10.72	10.72	10.72
$\overline{KG}/D = .7$					
$\overline{KG}$	6.32	7.11	7.89	8.68	9.48
$\overline{GM}$	4.40	3.61	2.83	2.04	1.24
$\overline{KG}$-T	−1.01	−.22	.56	1.35	2.15
φ at $\overline{GZ}$ max	36°	37.5°	41°	44°	49.5°
φ at $\overline{GZ}=0$	>90°	>90°	>90°	>90°	>90°
Rahola minimum					
min $\overline{GM}$	2.90	2.10	1.50	1.00	.90
$\overline{KG}$	7.82	8.62	9.22	9.72	9.82
$\overline{KG}/D$	.867	.848	.817	.783	.724
$\overline{KG}$-T	.49	1.29	1.89	2.39	2.49
T, sec	5.2	6.2	7.3	8.9	9.4
$T,\sqrt{(g/B)}$	6.4	7.6	9.0	10.9	11.5

All linear measurements in ft

TABLE 13
Results of stability analyses of 55-ft hull ($\bar{\mathrm{M}}$ = 4.25) reduced to 40 ft with different freeboards

Freeboard variation	$-20\%D$	$-10\%D$	D	$+10\%D$	$+20\%D$
D	5.09	5.73	6.37	7.00	7.64
T	4.16	4.16	4.16	4.16	4.16
freeboard	.93	1.57	2.21	2.84	3.48
φ to deck	9.8°	16.2°	22.4°	27.7°	32.8°
$\overline{KM}$	5.35	5.35	5.35	5.35	5.35
Rahola minimum					
min $\overline{GM}$	1.90	1.40	1.20	1.00	1.00
$\overline{KG}$	3.45	3.95	4.15	4.35	4.35
$\overline{KG}/D$	.677	.689	.652	.622	.569
$\overline{KG}$-T	−.71	−.21	−.01	.19	.19
T, sec	3.3	3.8	4.1	4.6	4.6
$T,\sqrt{(g/B)}$	5.7	6.6	7.1	7.9	7.9

All linear measurements in ft

TABLE 14
Results of stability analyses of 70-ft hull ($\bar{\mathrm{M}}$ = 4.50) reduced to 40 ft with different freeboards

Freeboard variation	$-20\%D$	$-10\%D$	D	$+10\%D$	$+20\%D$
D	4.57	5.14	5.72	6.28	6.86
T	3.72	3.72	3.72	3.72	3.72
freeboard	.85	1.42	2.00	2.56	3.14
φ to deck	8.9°	14.7°	20.3°	25.3°	30.2°
$\overline{KM}$	5.87	5.87	5.87	5.87	5.87
Rahola minimum					
min $\overline{GM}$	2.40	2.00	1.60	1.30	1.20
$\overline{KG}$	3.47	3.87	4.27	4.57	4.67
$\overline{KG}/D$	.760	.752	.746	.727	.681
$\overline{KG}$-T	−.25	.15	.55	.85	.95
T, sec	2.9	3.2	3.6	4.0	4.2
$T,\sqrt{(g/B)}$	5.0	5.5	6.2	6.9	7.2

All linear measurements in ft

boards more *GM* is required to satisfy Rahola. Fig 19 shows the freeboard and the centres of gravity for the models compared at the 40 ft length. This figure is then for boats of the same length but with different displacements.

The freeboards have different heights because, as was stated earlier, while they are inter-related, the freeboard/length ratio was not kept the same. In fig 20 the values from fig 19 have been re-plotted so that the height of the centre of gravity for each model could be compared at the same freeboard. The trend is the same as in the previous figure and generally it can be said that the centre
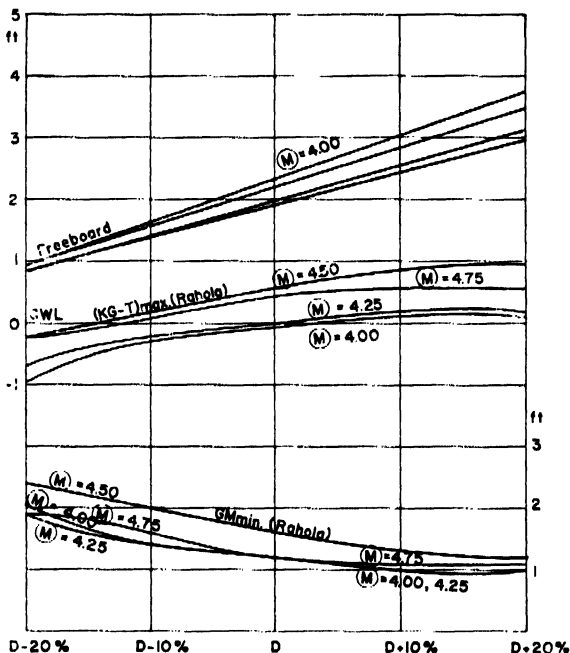
Fig 19. Comparison of freeboards, permitted height of the centre of gravity and required GM for the four optimized models at various heights of freeboard and all reduced to a length of 40 ft

Fig 20. Comparison of the permitted height of the centre of gravity in relation to the waterline of the four optimized models all reduced to 40 ft and compared at the same freeboard. Due to the fact that L/B was not varied concurrently, there is a different trend in the $\bar{\mathrm{M}}$ values

TABLE 15

Results of stability analyses of 85-ft hull (Ⓜ — 4.75) reduced to 40 ft with different freeboards

Freeboard variation	− 20%D	− 10%D	D	+ 10%D	+ 20%D
D	4.25	4.78	5.31	5.84	6.37
T	3.39	3.39	3.39	3.39	3.39
freeboard	.86	1.39	1.92	2.45	2.98
φ to deck	9.8°	15.6°	21.1°	26.2°	30.9°
$\overline{KM}$	5.05	5.05	5.05	5.05	5.05
Rahola minimum					
min $\overline{GM}$	1.90	1.60	1.20	1.10	1.10
$\overline{KG}$	3.15	3.45	3.85	3.95	3.95
$\overline{KG}$/D	.741	.721	.725	.677	.621
$\overline{KG}$-T	·.24	.06	.46	.56	.56
T_r sec	3.0	3.3	3.8	4.0	4.0
$T_r\sqrt{(g/B)}$	5.4	6.0	6.9	7.2	7.2

All linear measurements in ft

of gravity in the smaller displacement boats can be higher. This must be due to the fact that the height of the metacentre depends largely on the moment of inertia of the water plane divided by the displacement (I/∇) and to a smaller extent to the vertical distribution of displacement. The curve for Ⓜ =4.50 does not fall between the curves for 4.75 and 4.25 where it perhaps could have been expected. However, this can be explained by the fact that L/B, according to table 2, has not been varied in proportion to length but was simply selected as the one giving the lowest resistance during the computer optimization process. Thus the beam for the models having Ⓜ =4.25 and 4.50 are the same and as the displacement for the 4.50 version is the smallest, the resulting height of the metacentre will be higher.

It was earlier found from table 9 and 10 that the 70-footer required comparatively large GM to fulfil the Rahola criterion. This seems to be due to a somewhat particular relationship between water plane area and displacement. For a long time it has been known that deep and narrow ships have an entirely different type of GZ curve from wide and shallow ones and this seems to be an example of this.

Had L/B as well as B/T been varied equally for the models, the curves for highest permissible G in fig 19 would probably have fallen more concurrently.

The evaluation shows now how much the stability range seems to be influenced by the choice of main dimensions and should constitute a warning not to generalize from one case to another.

Rolling motions in relation to minimum stability

It has been suggested by Möckel (1960), Traung (1955; 1960) and Gurtner (p. 429) from interviews with fishermen and personal observations that the most agreeable period of roll is in relation to the beam of the vessel. Values of 1.0 to 1.1 B (B in metres) have been mentioned as suitable periods of roll (in sec). Kempf (1940) proposed a non-dimensional roll number $= T_r\sqrt{g}/B$, now known as Kempf's roll number. He interviewed operators of vessels of various types and sizes to obtain their opinions on most pleasant rolling motions and he suggested that the roll number should be between 8 and 14. The Kempf roll number, in fact, contains the roll accelerations which

are determined by comparing the period of roll with the square root of the beam of the vessel.

The suggestion to use B as a yardstick can have practical advantages because, in this way, one can use the period of roll as a measure of GM and simply specify, if one considers GM alone as a suitable stability criterion, a maximum permissible period of roll in relation to beam. As a matter of fact here, too, it has often been stated that the period of roll of 1.0 to 1.1B in metres always ensures a safe ship if the freeboard is reasonable.

The Kempf roll number definitely permits better comparison between vessels of widely differing sizes but it seems to be difficult to specify a certain number above which the stability of a vessel would be critical.
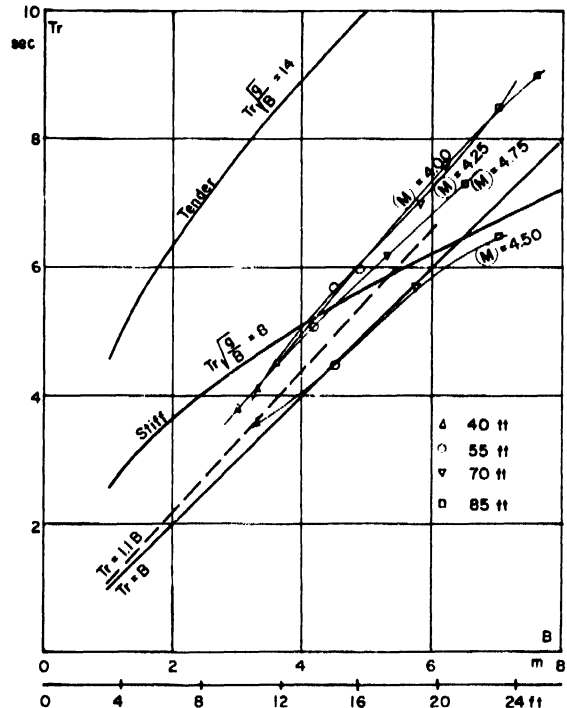
Fig 21. Maximum permissible periods of roll for the models all reduced to 40 ft plotted against their beams at normal depth. These values are compared with curves showing Kempf's recommendations for stiff and tender ships and with other curves showing periods of roll being 1·0 to 1·1 B. Obviously smaller ships have to be stiffer than Kempf found agreeable.

Fig 21 shows, for the investigated vessels, plots of the different lengths and length displacement ratios at normal depth compared with the above-mentioned values of the rolling period. Table 5, 7, 9 and 11 also show the Kempf roll numbers for each specific case.

The general conclusion is that for boats with a beam of less than about 20 ft the suggestion to use beam in metres as a criterion for agreeable rolling periods in sec, produces boats which, according to Kempf, are too stiff. On the other hand, a longer period of roll would not be possible if the boats should fulfil Rahola.

Fig 21 shows that for the 40-, 55- and 85-footers (Ⓜ =4, 4.25 and 4.75) a permissible period of roll to fulfil Rahola is about 1.2B in metres. Thus, in this case, if one stipulates that the boats shall have a period of roll of maximum 1.1B, one is certain that they will fulfil

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Rahola. However, the plots for the 70-footer (Ⓜ = 4.50) show that it requires a shorter period of roll so it is really impossible to generalize and say that a period of roll of 1.1B would be safe.

Fig 21 compares boats of normal depth and thus normal freeboard. For higher freeboards, up to a certain point, GM could be less because the higher freeboard produces better stability levers and a longer stability range. Fig 22 demonstrates this. In this case the ratio period of roll/beam has been plotted in relation to the ratio freeboard/beam.
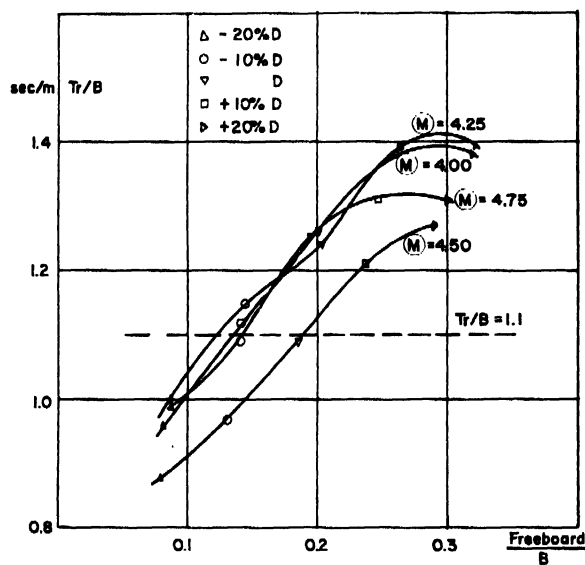
Fig. 22. Maximum permissible T_r/B-ratios for different freeboard/B-ratios compared with $T_r = 1.0$ to 1.1 B. All hulls reduced to 40 ft length

The periods of roll express the minimum GM required to fulfil Rahola and indicate that the ideal freeboard from the minimum GM point of view would be about $.3B$. However, as fishermen feel unsafe at periods of roll longer than $1.1B$ in metres, it might be difficult to utilize the improved stability characteristics associated with an unusually high freeboard, this will also make operation of fishing gear more difficult.

The whole problem of optimum freeboard from the point of view of stability, roll behaviour and economy of construction can therefore not yet be determined after this investigation. So far the stability has been discussed for the designed waterline and the next investigation was to consider how much the hulls can be loaded before the stability becomes insufficient.

Influence of loading

Even if a vessel has satisfactory stability at the designed waterline, it must naturally be investigated that it also has satisfactory stability when light or loaded. Normally it is more difficult to obtain sufficient stability at the loaded condition than the light but this is not always so. The following investigations are only concerned with heavier loading than at the designed displacement.

Furthermore, it is important to know whether during loading the centre of gravity rises or not. In fishing vessels

with normal storage of fuel (not bottom tanks) the centre of gravity doesn't usually rise unduly and for simplicity's sake the vessels have been investigated assuming the centre of gravity to be in the same position as before.

Table 16 to 19 summarize the calculations for the 40-, 55-, 70- and 85-footers. Because the height of metacentre varies with loading there will be a change in GM and this naturally affects stability levers and stability range. The M_0S curves also vary with the draft. Table 16

TABLE 16
Influence of loading on dynamic level of 40-ft hull (Ⓜ = 4.00)
(normal D)

T	4.66	5.00	5.50	6.00
freeboard	2.34	2.00	1.50	1.00
$\overline{KM}$	5.77	5.81	5.89	6.00
$\overline{GM}$	1.90	1.94	2.02	2.13
$\overline{KG}$	3.87	3.87	3.87	3.87
$\overline{KG}$-T	−.79	−1.13	−1.63	−2.13
φ at $\overline{GZ}$ max	45°	46°	45.5°	45.5°
φ at $\overline{GZ}$ = 0	>90°	>90°	>90°	>90°
e at φ = 40°	.467	.461	.439	.362

All linear measurements in ft
e = dynamic lever (Rahola minimum .262 ft)

TABLE 17
Influence of loading on dynamic lever of 55-ft hull (Ⓜ = 4.25)
(normal D)

T	5.72	6.50
freeboard	3.03	2.25
$\overline{KM}$	7.36	7.42
$\overline{GM}$	1.90	1.96
$\overline{KG}$	5.46	5.46
$\overline{KG}$-T	−.26	−1.04
φ at $\overline{GZ}$ max	41°	42.5°
φ at $\overline{GZ}$ = 0	>90°	>90°
e at φ = 40°	.466	.448

All linear measurements in ft
e = dynamic lever (Rahola minimum .262 ft)

TABLE 18
Influence of loading on dynamic level of 70-ft hull (Ⓜ = 4.50)
(normal D)

T	6.52	7.52	8.52	9.00
freeboard	3.48	2.48	1.48	1.00
$\overline{KM}$	10.28	10.05	10.03	10.06
$\overline{GM}$	1.90	1.67	1.65	1.68
$\overline{KG}$	8.38	8.38	8.38	8.38
$\overline{KG}$-T	1.86	.86	−.14	−.62
φ at $\overline{GZ}$ max	32°	25.5°	20°	15.5°
φ at $\overline{GZ}$ = 0	58°	50°	42.5°	36.5°
e at $\overline{GZ}$ max	.271	*	*	*

All linear measurements in ft
* Non-sufficient according to Rahola
e = dynamic lever (Rahola minimum .262 ft)

to 19 assume a "starting" GM of 1.9 ft, which was the one selected to provide a period of roll equal to the beam in metres. This GM has varying degrees of built-in safety factors. Minimum GM according to Rahola, is 1.2, 1.2, 1.9 and 1.5 ft for the 40-, 55-, 70- and 85-footers respectively. From this it is obvious that it should be possible to decrease stability by loading of the 40- and

TABLE 19 Influence of loading on dynamic lever on 85-ft hull (Ⓜ = 4.75) (normal D)				
T	7.33	8.00	9.00	9.50
freeboard	3.95	3.28	2.28	1.78
$\overline{KM}$	10.72	10.68	10.75	10.83
$\overline{GM}$	1.90	1.86	1.93	2.01
$\overline{KG}$	8.82	8.82	8.82	8.82
$\overline{KG}$-T	1.49	.82	—.18	—.68
φ at $\overline{GZ}$ max	36°	34.5°	30°	28°
φ at $\overline{GZ}$ = 0	70°	68°	63°	60.5°
e at $\overline{GZ}$ max	.377	.338	.247*	.216*

All linear measurements in ft
* Non-sufficient according to Rahola
e=dynamic lever (Rahola minimum .262 ft)

TABLE 21 Influence of loading on dynamic lever for 70-ft hull (Ⓜ = 4.50) reduced to 40 ft				
T	3.72	4.30	4.87	5.14
freeboard	2.00	1.42	.85	.58
$\overline{KM}$	5.87	5.75	5.73	5.75
$\overline{GM}$	1.90	1.78	1.76	1.78
$\overline{KG}$	3.97	3.97	3.97	3.97
$\overline{KG}$-T	.25	—.33	—.90	— 1.17
φ at $\overline{GZ}$ max	36°	34°	32°	31°
φ at $\overline{GZ}$ = 0	>90°	85°	>90°	>90°
e at $\overline{GZ}$ max	.342	.286	.223*	.188*

All linear measurements in ft
* Non-sufficient according to Rahola
e=dynamic lever (Rahola minimum .262 ft)

TABLE 20 Influence of loading on dynamic lever on 55-ft hull (Ⓜ = 4.25) reduced to 40 ft		
T	4.16	4.73
freeboard	2.21	1.64
$\overline{KM}$	5.35	5.40
$\overline{GM}$	1.90	1.95
$\overline{KG}$	3.45	3.45
$\overline{KG}$-T	—.71	—1.28
φ at $\overline{GZ}$ max	47.5°	46°
φ at $\overline{GZ}$ = 0	>90°	>90°
e at φ = 40°	.459	.448

All linear measurements in ft
e=dynamic lever (Rahola minimum .262 ft)

TABLE 22 Influence of loading on dynamic lever for 85-ft hull (Ⓜ = 4.75) reduced to 40 ft				
T	3.39	3.70	4.16	4.39
freeboard	1.92	1.61	1.15	0.92
$\overline{KM}$	5.05	5.02	5.06	5.10
$\overline{GM}$	1.90	1.87	1.91	1.95
$\overline{KG}$	3.15	3.15	3.15	3.15
$\overline{KG}$-T	—.24	—.55	—1.01	— 1.24
φ at $\overline{GZ}$ max	45°	44°	45°	45°
φ at $\overline{GZ}$ = 0	>90°	>90°	>90°	>90°
e at φ = 40°	.446	.436	.414	.398

All linear measurements in ft
e=dynamic lever (Rahola minimum .262 ft)
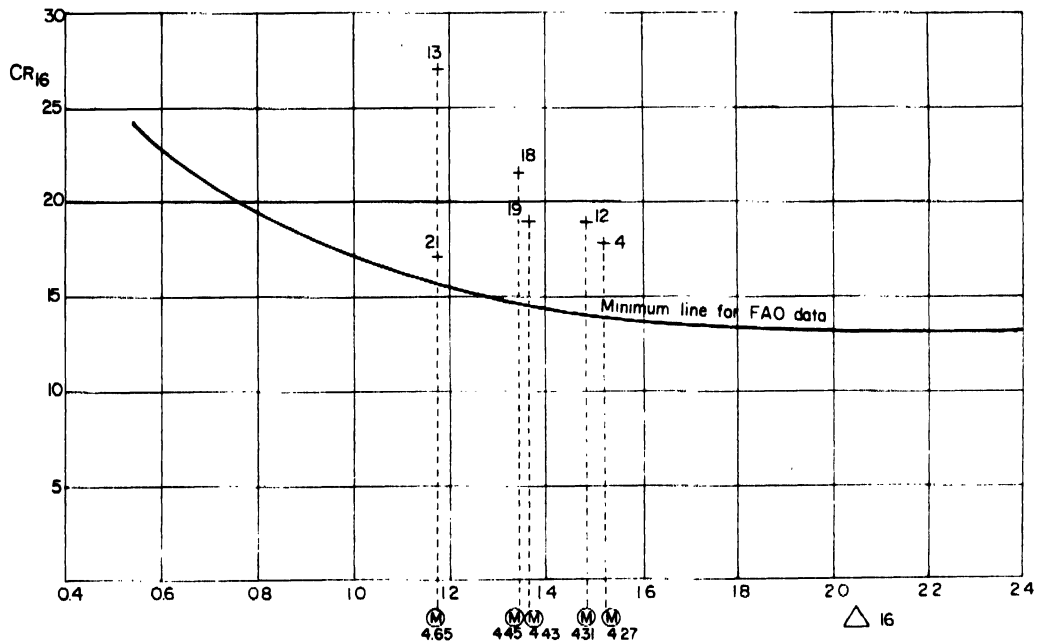
Fig 23. *Computed resistance values for some typical fishing vessels compared with the minimum line for the FAO data at 1.1 Froude number*

55-footers more than the 70- and 85-footers. Table 16 to 19 also show that the 40-footer can be loaded down to 1 ft freeboard but that the 70-footer cannot be loaded at all without increasing the GM at the designed waterline.

If the 55-, 70- and 85-footers are reduced to 40 ft the resulting GM will be according to table 20, 21 and 22, which indicate that the same form of hull which, in its original size, had a rather restricted range of stability now has improved stability levers. Except the 70 ft type, table 21, which seems to be a special case, the

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TABLE 23

Computer analysed results for some existing fishing vessels

File No.	Country	L ft	Ship Δ tons	Ⓜ	L/B	B/T	C_m	C_p	l.c.b.%	$\frac{1}{2}\alpha_e{}°$	$\frac{1}{2}\alpha_r{}°$	$\alpha_{BS}°$	trim	$C_{R_{16}}$ at $V/\sqrt{L}=1.1$
4	Australia	57.50	69.60	4.27	3.36	2.73	0.667	0.580	−2.14	21°	36°	20.5°	0.041	17.8
12	Sweden	86.0	171.8	4.31	3.57	2.55	0.641	0.629	−0.605	28°	38.5°	22°	0.040	18.9
13	Sweden	102.75	234.6	4.65	4.28	2.44	0.672	0.661	−1.01	29°	45°	26.5°	0.048	27.1
18	Senegal (FAO)	39.37	19.65	4.45	3.20	3.24	0.670	0.552	−1.50	26°	40°	16°	0.043	21.6
19	India (FAO)	45.0	30.10	4.43	3.41	3.10	0.700	0.595	−1.19	25°	55°	17°	0.038	19
21	Thailand (FAO)	47.93	31.20	4.65	3.88	3.14	0.790	0.578	−3.17	20°	53°	12°	0.042	17.2

55 and 85-ft types will be stable within the whole depth range investigated when reduced to 40 ft.

The investigations show that when the same type of hull form is changed in size, completely different stability conditions prevail and this may well be the reason why boats can become utterly different when changed in size without any alteration in the form shape.

To have sufficient stability the centre of gravity must be kept below the values given.

INVESTIGATION OF EXISTING BOATS

Time did not, unfortunately, permit a comprehensive evaluation of a number of existing designs in an attempt to ascertain how much these designs could be improved.

Table 23 shows parameters of some typical designs in FAO's files and their $C_{R_{16}}$ values for $V/\sqrt{L}=1.1$ are shown in fig 23. This fig is similar to fig 17.

Boats 12 and 13 represent modern Swedish steel trawlers and are specially interesting because model 13 is a simple elongation, with a parallel middle body, of model 12. By elongating the vessel some of the parameters are changed and the result is rather surprising.

Fig 23 shows that the short boat has about 35 per cent larger resistance than the minimum line for vessels investigated for the statistical analysis. Thirty-five per cent increase in resistance means roughly 35 per cent increase in fuel consumption. There should really be a saving for the elongated vessel rather than an increase in power requirement.

A Free Surface Tank as an Anti-rolling Device for Fishing Vessels

by J. J. van den Bosch

Utilisation d'une citerne á carêne liquide comme amortisseur de roulis á bord des bateaux de pêche

L'auteur passe en revue divers systèmes d'amortissement du roulis pour voir s'ils satisfont aux besoins des bateaux de pêche. Le choix se porte sur une citerne constituée par un parallélépipède rectangle, dans lequel l'énergie est fournie par un simple effet de "mascaret". Des équations mathématiques théoriques de mouvement sont formulées pour un bâtiment roulant librement dans un fluide, et l'on étudie l'influence de divers paramètres sur le mouvement. L'équation est ensuite modifiée pour tenir compte de l'installation à bord du bâtiment d'une citerne simple à carêne liquide. La section qui suit est consacrée aux données relatives à un réservoir parallélé-pipédique et à l'effet des paramètres du réservoir sur le roulis.

L'auteur décrit une citerne conçue pour un bâtiment particulier, pour trois conditions de déplacement, et construit des courbes théoriques qui sont comparées avec les résultats de quatre séries d'essais sur modèle. Il étudie les variations par rapport aux résultats théoriques, et termine en présentant diverses suggestions.

El tanque de balance con superficies libres como estabilizador para barcos de pesca

Se estudian y comparan varios tipos de estabilizadores, en orden a los requisitos de uno adecuado para los barcos de pesca. Se elige un simple tanque rectangular, de forma de caja, que aprovecha la energía de la ola de marea. Se desarrollan ecuaciones teórico-matemáticas de movimiento de una embarcación que se balancea libremente en un líquido, estudiándose el efecto de los diversos parámetros sobre el movimiento. La ecuación se modifica después para instalar en la embarcación un simple tanque con superficies libres. La sección siguiente trata de los datos de un tanque rectangular y la influencia de sus parámetros en el movimiento de balanceo.

Se expone un ejemplo de diseño de tanque para un tipo determinado de embarcación, con tres condiciones de desplazamiento, y se presentan cubiertas teóricamente calculadas, comparándolas con cuatro series de ensayos de modelos. Se discuten las variaciones de los resultados teóricos y se hacen, por último, algunas sugerencias.

THERE is no doubt that many fishing vessels would benefit from the installation of some means of roll damping to ease deck working conditions and increase effective fishing time. The major types of roll damping devices now in use are:

- Active fins
- Passive tanks based on the U-tube principle
- Active tanks based on the U-tube principle
- Passive free-surface tanks

This paper deals with the application of the passive free-surface tank in its simplest form.

Bilge keels are excluded from this discussion because other roll damping devices are considered as supplementary rather than as an alternative to bilge keels. This is discussed more fully at the end of the paper.
A fishing vessel's damping system should be:

- Effective even at low or zero speeds
- Efficient for many conditions
- Inexpensive to install and maintain
- Trouble-free in normal use

Active fins are not effective at low speed. Initial costs are relatively high.

Passive tanks based on the U-tube principle are often rather sensitive to differences in the natural roll period of the ship, and if designed to cover a wider frequency range the overall efficiency falls.

Activated U-tanks are efficient over a wide range of conditions. They seem good for large boats, but are complicated and may be too costly for small boats.

Although passive free-surface tanks are less efficient than activated U-tanks, they are simple to install and perform satisfactorily in most conditions.

ROLLING MOTION ACCORDING TO SIMPLIFIED THEORY

Rolling without tank in operation

The equation of motion. In recent years the theoretical approach to ship motions has been improved, and frequently a simplified mathematical model is used, such as the damped linear mass-spring system (Vossers, 1960). For the calculation of the influence of the tank on the ship's rolling motion this same method is used only considering the rolling motion. The equation of motion is given by the expression:

$$I_\phi \ddot{\phi} + N_\phi \dot{\phi} + R_\phi \phi = K$$

If the exciting moment K varies sinusoidally with time, the resulting motion would also be sinusoidal and of the same frequency. The moment, however, will always be in advance of the motion. The phase angle between the moment and the motion varies from zero, for very low frequencies, to 180°, for high frequencies. If the moment is expressed by:

$$K = K_a \sin(\omega t + \varepsilon_{K\phi})$$

and the motion by:

$$\phi = \phi_a \sin \omega t$$

The solution of the above equation is expressed by:

$$\phi_a = \frac{K_a}{\sqrt{(R_\phi - I_\phi \omega^2)^2 + N_\phi^2 \omega^2}}$$

and:

$$\text{tang } \varepsilon_{K\phi} \quad \frac{N_\phi \omega}{R_\phi - I_\phi \omega^2}$$

[159]

Often the amplitude is written in the form of a magnification factor, that is, the ratio of the motion amplitude at a certain frequency to the static angle of heel under influence of a heeling moment of the same magnitude. At the natural or resonance frequency:

$$\omega_\phi = \sqrt{\frac{R_\phi}{I_\phi}}$$

the phase angle becomes 90° and the magnification factor can become very large if the damping is relatively small. A criterion of damping is the non-dimensional damping coefficient:

$$v_\phi = \frac{N_\phi}{\sqrt{I_\phi R_\phi}}$$

At resonance the magnification factor amounts to:

$$f_\phi = \frac{1}{..}$$

The influence of the separate coefficients

Using the above expressions a qualitative analysis of the influence of the separate coefficients can be made:

- An increase of I_ϕ is accompanied by a decrease of the natural frequency. At the same time the magnification factor increases because of the influence of I_ϕ on v_ϕ
- An increase of R_ϕ results in a shift of ω_ϕ towards a larger value and also in an increase of the magnification factor at resonance
- An increase of N_ϕ results in smaller amplitudes over the entire frequency range

These tendencies are illustrated in fig 1 Starting from an amplitude characteristic with $v_\phi = 0.1$ (a probable value for rolling) and $\omega_\phi = 1$, the effect is shown of a doubling of one of the coefficients while the other two remain unaltered.

Influence of the tank on rolling motion

Fundamental behaviour of the tank

When a tank, partially filled with a liquid, say water, is forced to oscillate about a fixed axis, the water movement creates a moment acting about the same axis. When the motion of the tank is sinusoidal the moment appears to be mainly sinusoidal of the same frequency as the motion, with a phase lag ranging from zero to 180° depending on the frequency. The natural frequency of the system is defined as the frequency at which the phase angle equals 90°.

The moment can be resolved in a component which is in phase with the motion and the quadrature component which has a phase lag of 90° with the motion. Expressed mathematically:

the motion is:

$$\phi = \phi_a \sin \omega t$$

and the moment:

$$M = M_a \sin (\omega t + \varepsilon_t)$$
$$= M_a \sin \omega t \cos \varepsilon_t + M_a \cos \omega t \sin \varepsilon_t$$

The first term is the in-phase term and the second is the term with a 90° phase difference. In fig 2 the amplitude and the phase angle are shown as functions of the frequency, and in fig 3 the corresponding components are given. Both figures serve only as examples to illustrate the tendencies.

Fig 1. Influence of coefficients of equation of motion
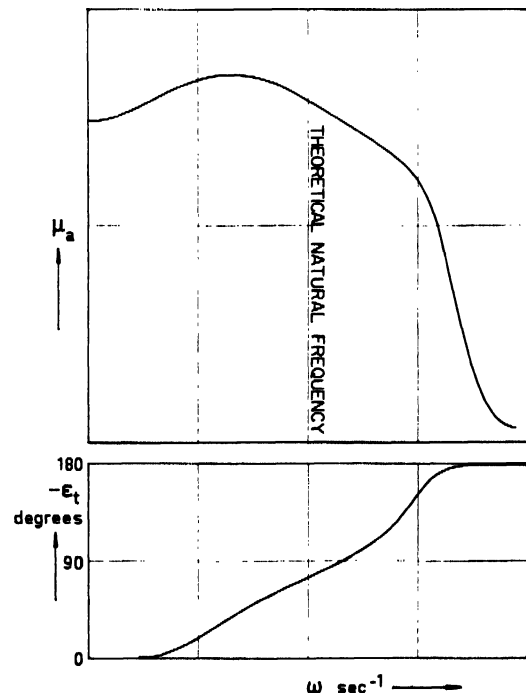
Fig 2. Amplitude and phase of tank moment

[160]
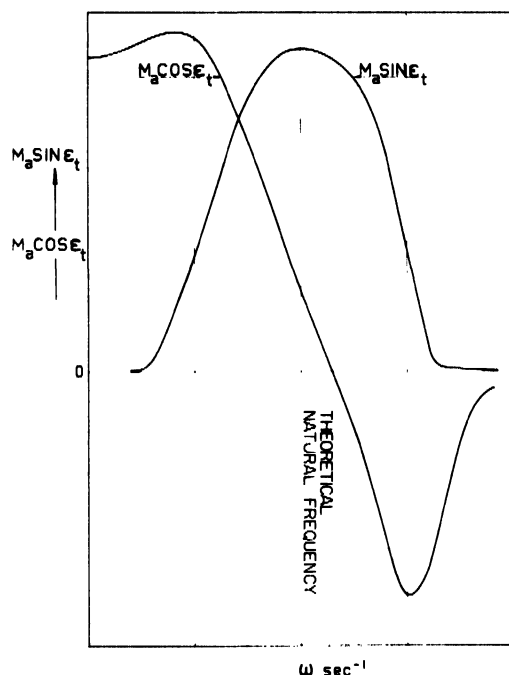
Fig 3. Components of tank moment

The equation of motion with the tank in operation

Consider the tank moment as an external moment acting on the ship on a fore and aft axis through the centre of gravity of the ship. The equation of motion is:

$$I_\phi \ddot{\phi} + N_\phi \dot{\phi} + R_\phi \phi = K_a \sin(\omega t + \varepsilon_{K\phi}) + M_a \sin(\omega t + \varepsilon_t)$$

With $\phi = \phi_a \sin \omega t$ this expression becomes:

$$\left(R_\phi - I_\phi \omega^2 - \frac{M_a}{\phi_a} \cos \varepsilon_t \right) \sin \omega t +$$

$$+ \left(N_\phi \omega - \frac{M_a}{\phi_a} \sin \varepsilon_t \right) \cos \omega t = \frac{K_a}{\phi_a} \sin(\omega t + \varepsilon_{K\phi})$$

The reduced in-phase component $(M_a/\phi_a) \cos \varepsilon_t$ can be considered as a reduction of $R_\phi - I\omega^2$. The reduced quadrature component $(M_a/\phi_a) \sin \varepsilon_t$ can be considered as an augmentation of the damping when $\sin \varepsilon_t$ is negative, i.e. throughout the entire frequency range considered.

Influence on amplitude characteristic

Utilizing the above, the influence of the components of the tank moment (fig 3) can easily be combined with the curves in fig 1. Assuming that the natural frequencies of the tank and the ship differ little, it follows:

● From fig 3 it appears that the in-phase component of the tank moment is positive for frequencies below the natural frequency of the tank. For this range the amplitude characteristic of the ship, including the tank, tends to the curve on the left in fig 1. The positive value of (M_a/ϕ_a) cos ε_t has the effect that the vessel seems to have a longer natural period. (Reduction of R_ϕ or augmentation of I_ϕ.)

● The quadrature component can be considerable if compared to the ship's own damping and because of this the reduction of the amplitude in the range around the combined natural frequency can be very large

● For the range beyond the natural frequency of the tank the vessel obtains the character of a stiffer ship due to the negative in-phase component
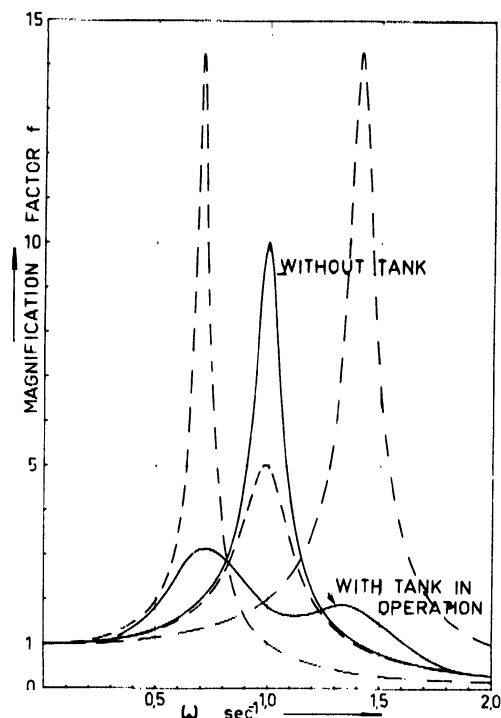
Fig 4. Schematic presentation of tank influence

Fig 4 shows a tentative curve of the amplitude versus frequency for the ship-plus-tank system. Notable is the occurrence of the two secondary peaks in the curve. This is a principal feature of a system with two degrees of

Fig 5

[161]
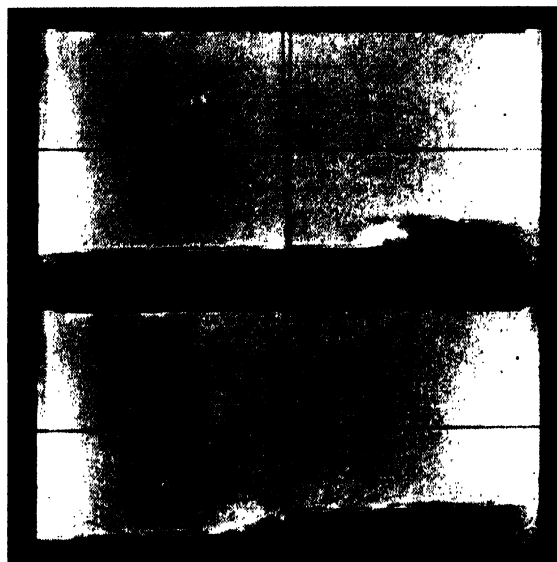
freedom, which are here the rolling of the ship, and the motion of the tank water. The flatter the phase characteristic of the tank, the wider the frequency range which is covered by the quadrature component, and the more these two secondary peaks are smoothed.

If the natural frequency of the tank is higher than the natural roll frequency of the ship, the secondary peak in the lower range is more accentuated, while the other one can disappear completely.

RECTANGULAR TANK DATA

General

The free surface tank owes its damping characteristics to the development of a bore, a typical shallow water wave. Fig 5 shows two photographs of this phenomenon in two consecutive stages. It is evident that with every roll work is done in raising the tank water, thus reducing the energy of motion. The theoretical natural frequency for small amplitudes can be derived as follows:

The velocity of propagation of this type of wave is:

$$c = \sqrt{gh}$$

The distance travelled in one period is twice the breadth of the tank so the natural period is:

$$T_t = \frac{2b}{\sqrt{gh}}$$

and the natural frequency is:

$$\omega_t = \frac{2\pi}{T_t} = \frac{\pi}{b}\sqrt{gh}$$

A series of tests shows that an increase of the amplitude of the motion induces the actual natural frequency to increase.
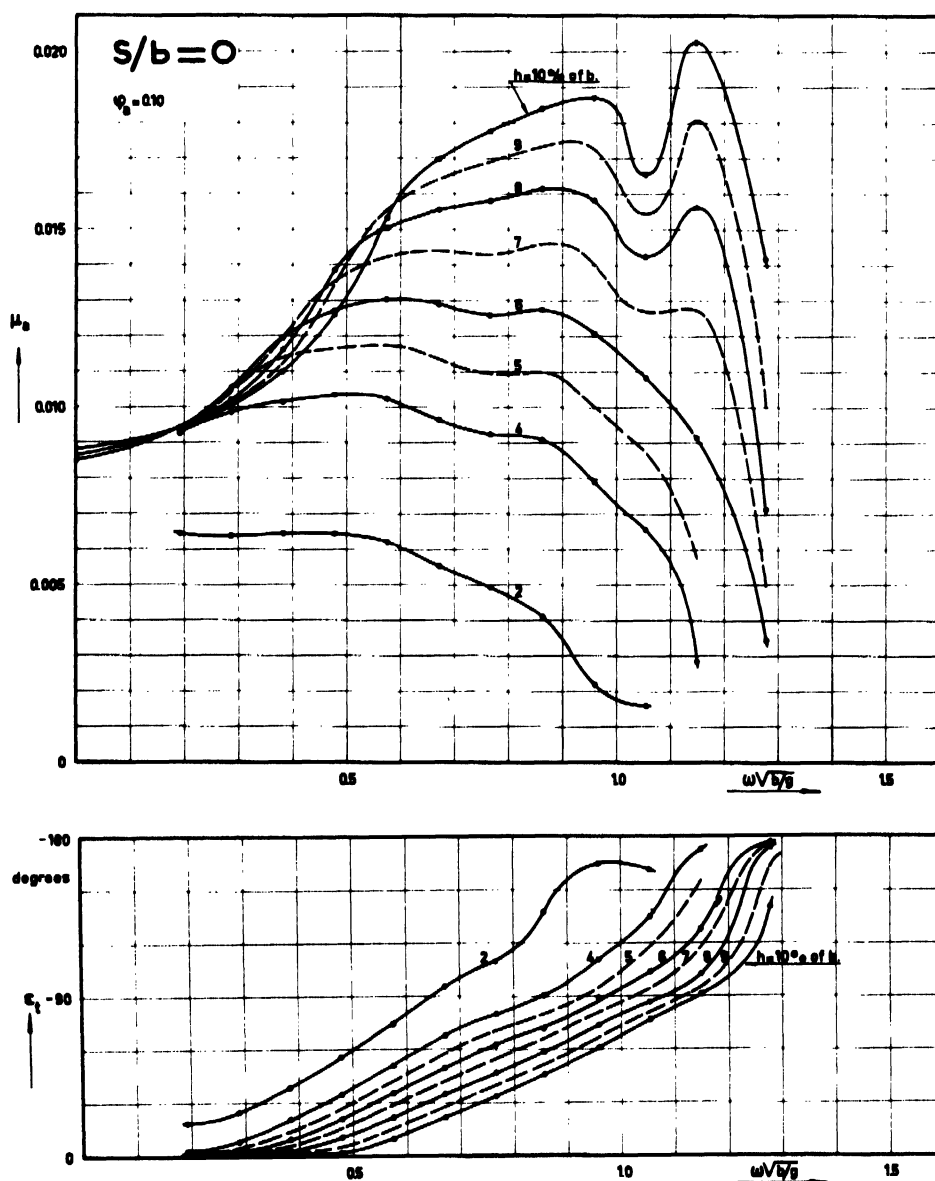
Fig 6. Non-dimensional amplitude and phase of tank moment for S/b=0

[162]
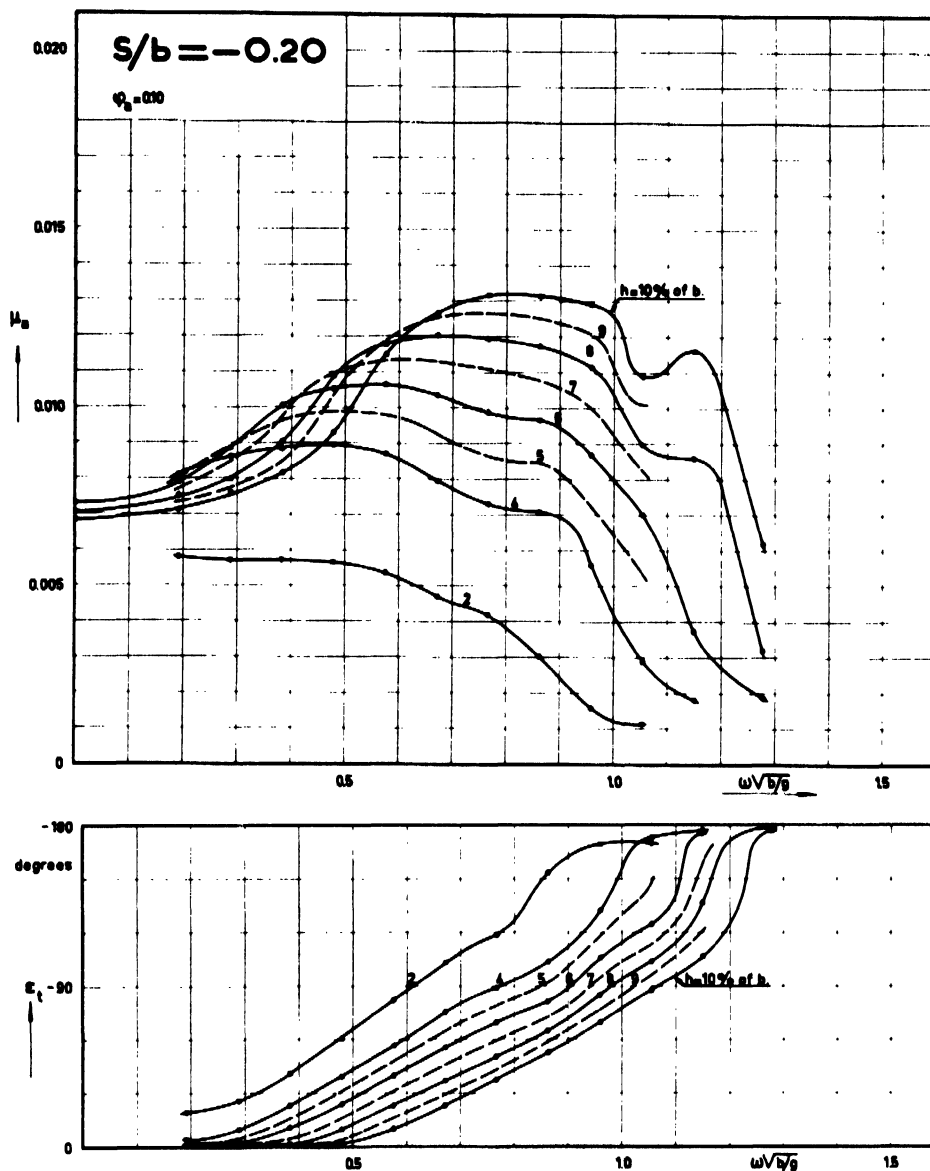
Fig 7. Non-dimensional amplitude and phase of tank moment for S/b − 0.20

The data shown in fig 6, 7, 8 and 9 are results of experiments with a model tank excited by an oscillating mechanism. While the tank performed a swinging motion the moment about the axis of rotation was measured. In fig 6 and 7 the phase and the reduced moment amplitude are shown versus the reduced frequency $\omega\sqrt{b/g}$ and in fig 8 and 9 the sine and cosine components are given. The amplitude is made non-dimensional by dividing by $\rho_l g b^3 l$.

Influence of parameters

There are six parameters which control the tank moment:

● The motion amplitude ϕ_a
If ϕ_a increases the moment amplitude does not increase at the same rate and so the tank is less effective when the motions are large

● The influence of the frequency of the motion ω is evident from fig 6, 7, 8 and 9
● The tank breadth b
The moment amplitude varies with the third power of the tank breadth provided that the ratio of the water depth and the breadth is kept constant; (the breadth is measured across the ship)
● The tank length l
The moment is directly proportional to the tank length (measured in fore and aft direction)
● The water depth h
As is shown, the natural tank frequency depends on the breadth and the water depth. In addition to this influence on the phase relation, the depth of the water influences the total weight and therefore the moment
● The height of position s
The vertical height of the position of the tank is

[163]
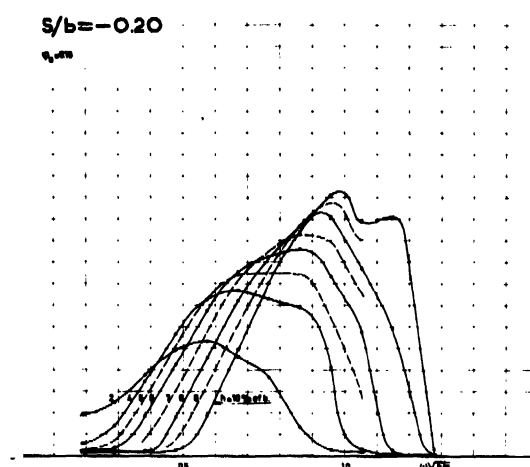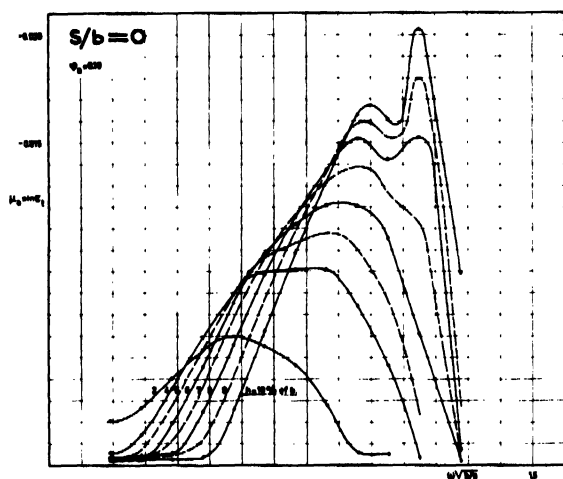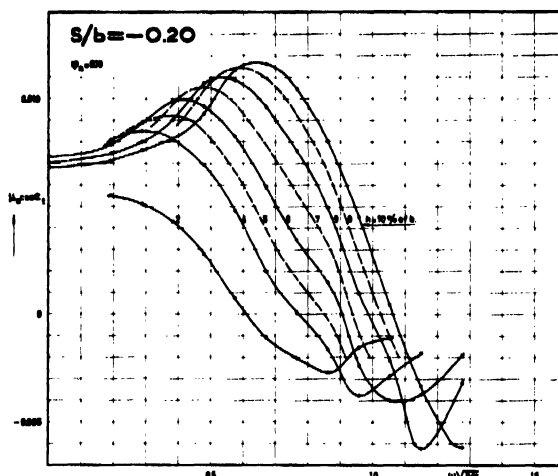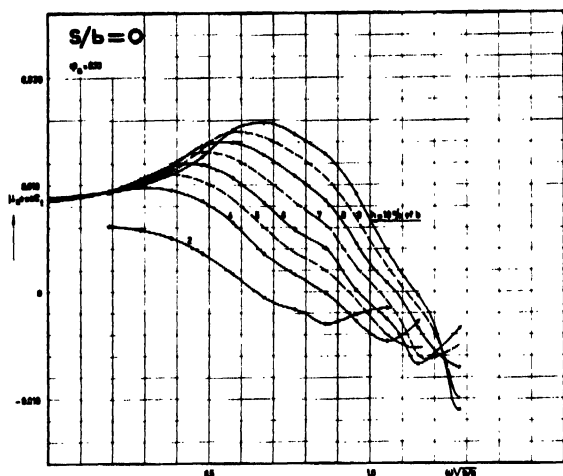
Fig 8. Non-dimensional components of tank moment for S/b=0

Fig 9. Non-dimensional components of tank moment for S/b=−0.20

measured from the axis of rotation to the tank bottom. A negative value means that the tank bottom is situated below the axis of rotation

A comparison of fig 6 and 7 or 8 and 9 indicates that a more highly situated tank produces a larger stabilizing moment

Considerations for application

● The presented data can be used for ships with $\dfrac{\overline{GM}_t}{B}$ values ranging from 0.03 to 0.18

● The static reduction of $\overline{GM}_t$ due to the free surface of the tank must be acceptable. The loss of static stability can demand a restriction of the tank dimensions. The reduction of $\overline{GM}_t$ should not be taken into account while the ship's own natural period is being calculated

● A roll damping tank should, if possible, extend over the full breadth of the vessel because of the large influence of the breadth on the moment amplitude

● The tank should be situated as high as possible

● From experience it is known that the minimum depth of the tank should be approximately three times the water depth in the tank. This influences the position of the tank in height. As a preliminary estimation for the tank depth the value $D_t = 2\,\overline{GM}_t$ can be used

● The data which are shown in fig 6, 7, 8 and 9 are results of measurements with $\phi_a = 0.10$ radians or about 6°. The calculation of the influence of the tank on the rolling motion is based on the assumed linearity of the system. When the results are interpreted, it has to be borne in mind that this assumption is not strictly true

● The diversity of conditions under which a vessel has to fulfil its task makes it very difficult to suggest an optimal design for the anti-rolling tank, and for that reason a compromise has to be found.

EXAMPLE OF APPLICATION

Ship and tank data

As an example the design of an anti-rolling tank for a small trawler is discussed. The $\overline{GM}_t/B$ values of this

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ship are fairly high in order to comply with Rahola's stability criteria. Such a vessel, operating on the North Sea or in comparable areas, often meets conditions which may cause it to roll heavily.
The main dimensions are:

$Loa = 91.87$ ft (28.00 m)
$Lpp = 78.42$ ft (23.90 m)
$B = 20.28$ ft (6.18 m)
$D = 11.36$ ft (3.46 m)

From a variety of possibilities three tentative loading conditions were selected for further investigation. The conditions are summarized in table 1.

TABLE 1: Considered loading conditions

Condition	A	B	C
Quantity	Leaving port	During fishing	Average of other conditions
Δ tons (ton) .	161.4 (164)	184.1 (187)	172.2 (175)
$\overline{GM}_t$ ft (m) .	2.75 (0.84)	1.87 (0.57)	2.36 (0.72)
$\dfrac{\overline{GM}_t}{B}$.	0.136	0.092	0.117
$K_\phi = 0.4\,B$ ft (m)	8.11 (2.46)	8.11 (2.46)	8.11 (2.46)
T_ϕ sec . .	5.39	6.55	5.83
ω_ϕ sec^{-1} . .	1.165	0.960	1.079
ν_ϕ . . .	0.07	0.07	0.07
$\overline{KG}$ ft (m) . .	9.12 (2.78)	9.97 (3.04)	9.55 (2.91)
s/b . . .	−0.125	−0.175	− 0.150

The "fishing condition" (B in the table) was rather extreme. For the calculation of $\overline{GM}_t$ it was assumed that the consumption of fuel and stores was about 22 tons, that the fish hold contained about 15 tons catch and that a new catch weighing about 30 tons lay on deck.

The values of GM_t for the conditions A and C satisfied the criteria of Rahola, also if the reduction of GM_t due to the free surface in the tank was accounted for.

The position of the tank was chosen approximately amidships taking up part of the bunker space between the engine room and the fish hold. It extended over the full breadth of the vessel, so $b = B = 20.28$ ft (6.18 m). The length of the tank was restricted to 4.40 ft (1.34 m) in accordance with the mentioned $\overline{GM}_t$ values and the criteria of Rahola. The values of s/b in table 1 show rounded-off values following from an assumed height of the tank 6.56 ft (2.00 m) above the base line.

Determination of water depth and discussion of the tank effect

The choice of depth of water in the tank is governed by the requirements of easy operation. It is important that the captain of a small fishing vessel is not burdened by such matters as adjusting the water level in the tank to the momentary GM_t value. Once it is filled to its pre-scribed level in port it should be unnecessary to give it any attention, except in emergencies.

In fig 10 the curves of $\mu_a \sin \varepsilon_t$ and $\mu_a \cos \varepsilon_t$ are given for the vertical tank position $s/b = -0.150$. These curves were obtained by interpolation from the diagrams in the figures. Although the ratio s/b varies slightly for the three loading conditions, the mean value was sufficient
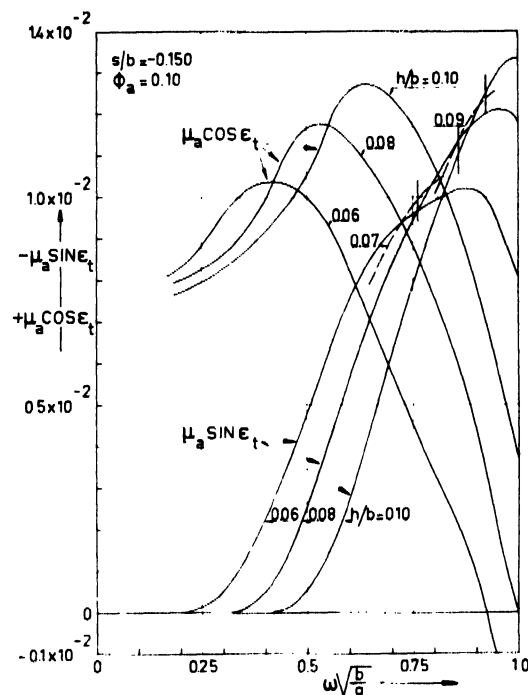
Fig 10. Components of tank moment
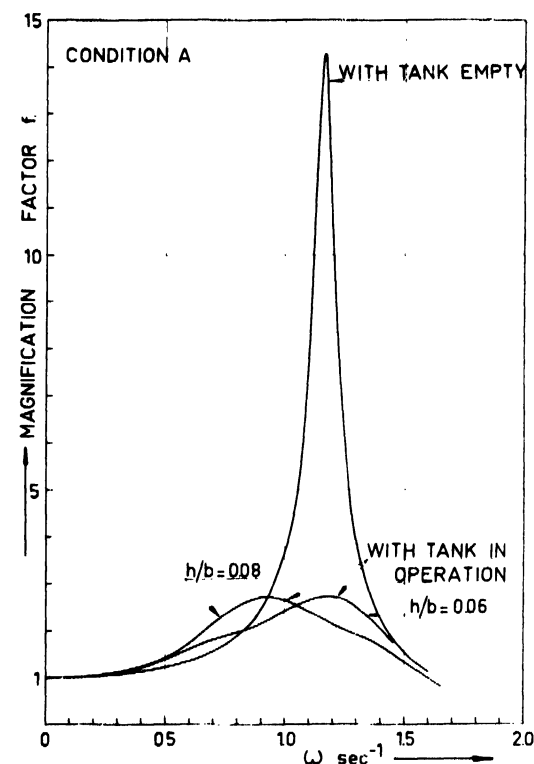
Fig 11. Results of calculation

to determine the desired water depth for all conditions. The appropriate quantities for these conditions are listed in table 2.

● The reduced frequency $\omega_\phi \sqrt{b/g}$ corresponding to the natural frequency of the ship with an empty tank

[165]
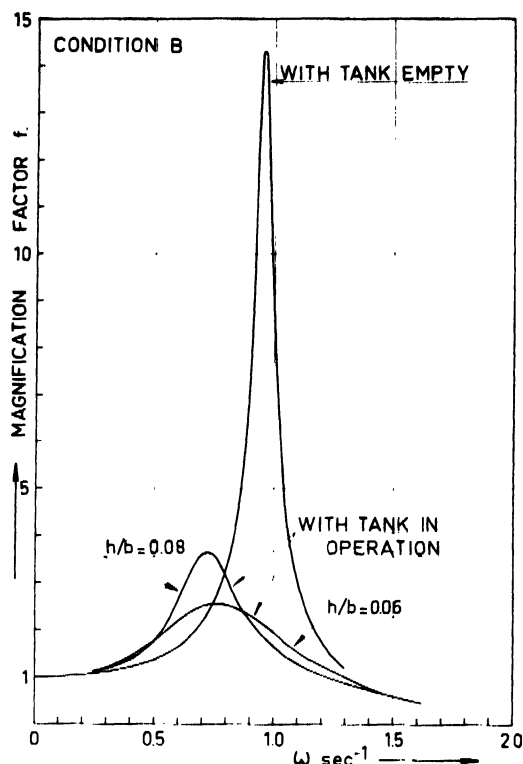
Fig 12. Results of calculation
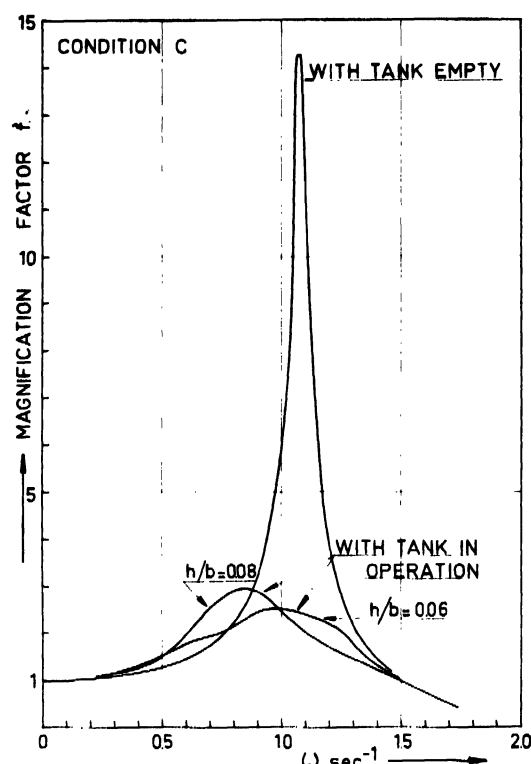
Fig 13. Results of calculation

- The water depth ratio $(h/b)_{th}$ which was derived from the consideration that the theoretical natural frequency of the tank and the ship should be equal

- The water depth $(h/b)_o$ which was derived from fig 10 giving the largest sine component of the moment at the stated reduced frequency

Evidently, as table 2 shows, the water depth for which the largest damping effect at a given frequency was obtained, was somewhat larger than the theoretical value. To comply with the demand for simplicity, one value of h/b must be chosen. In order to make a correct choice, the effect of the tank on the amplitude characteristic was calculated for all three loading conditions, for their respective s/b ratios and for two water depths, namely $h/b=0.06$ and $h/b=0.08$. The tank was assumed to be filled with fresh water.

TABLE 2: **Reduced natural frequencies of the ship and water-depth ratios under consideration**

Item \ Condition	A	B	C
$\omega_\phi \sqrt{\dfrac{b}{g}}$	0.925	0.762	0.856
$(h/b)_{th}$	0.087	0.059	0.074
$(h/b)_o$	0.094	0.070	0.082

The actual calculation is omitted from the paper. The results are shown in fig 11, 12 and 13. Fig 11 represents condition A. It was evident that with both depths the

tank gave considerable damping. Although the peak amplitudes of both curves were approximately equal, the largest water depth was to be preferred because, with the peak occurring at a lower value of ω, the accelerations of the vessel will be less. In fig 12 the results of the calculation are shown for condition B. In this condition the vessel was less stiff. The natural frequency of the ship was considerably lower than that of the tank for $h/b=0.08$, which accounted for a marked peak in the lower frequency range. Although the curve for $h/b=0.08$ was certainly an improvement in comparison with the original characteristic, the amplitude characteristic for $h/b=0.06$ was better. For the third condition fig 13 shows a result which was somewhere between the other two conditions as was to be anticipated.

The main conclusion from these figures was that, in spite of the different water depths in the tank and the different loading conditions, the calculated amplitude characteristics were all very similar and all show a rather large improvement over the amplitude characteristics of the ship without the tank operating. A sound choice was $h/b=0\cdot07$, which gave a water depth of $h=0.07\times20.28 =1\cdot42$ ft (0.433 m). The total amount of water was $L\times b\times h=126.71$ ft^3 (3.586 m^3). This was about 2 per cent of the average displacement.

MODEL EXPERIMENTS

Purpose and performance

The large number of simplifications which had been introduced in the course of the calculation procedure required checking.

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The tests were carried out with a 1 : 15 scale ship model in which a roll oscillator and a recording gyroscope had been installed. In this model a tank was installed with dimensions according to those mentioned previously. Next, the model was ballasted and trimmed so its stability and natural roll period corresponded to the condition A specified in table 1. By means of the roll oscillator the model was subjected to a moment with a sufficiently constant amplitude having any desired frequency within the considered range. The gyroscope served to measure the roll angles.

The following test series were carried out with the model with the tank empty, then filled to the level corresponding with $h/b = 0.08$:

- An oscillation test with the model subjected to roll moments with a constant amplitude of 0.289 lb.ft (0·04 kg.m) but with different frequencies
  The object was firstly to determine an acceptable value of v_ϕ for the ship with empty tank (the value of $v_\phi = 0.07$ which was introduced in table 1), and secondly, to furnish a comparison with the calculated curve for the stabilized ship
- A similar test but with a larger moment amplitude, namely, $M_a = 0.434$ lb.ft (0.06 kg.m). The aim of this was to obtain an impression of the degree of the non-linearity of the system, both with and without the tank in operation
- The third series consisted of experiments in regular waves. The model was held at zero forward speed and the waves on the beam, but was free to roll, drift and heave. The wave dimensions and roll angles were measured. From these measurements the ratio between the rolling amplitude and the wave slope amplitude has been calculated as a function of the frequency $[\phi_a/k\zeta_a(\omega)]$
  The purpose of this test series was twofold. Firstly, it should provide a comparison with the results of the oscillation tests and with the calculation from which it could be determined if the motions of drift and heave did have a significant influence on the performance of the stabilized ship. Secondly, these measurements should form the basis for comparison with the results obtained in an irregular wave pattern
- The object of the fourth series was the measurement and analysis of the model rolling motion with zero forward speed in irregular beam seas. A check on the correctness of the mathematical assumptions in this particular case was provided by a comparison between the experimentally determined spectrum of the rolling motion and the spectrum calculated from both the results of tests in regular waves and the measured spectrum of the waves

The results

In fig 14 the results of the first series of tests are shown. The measured and calculated amplitude characteristics for the ship without the tank closely resemble each other. The curves with the tank in operation differ. The calculated curve appears to be a mean of the experimental curve. The curve of measured roll amplitudes, presented
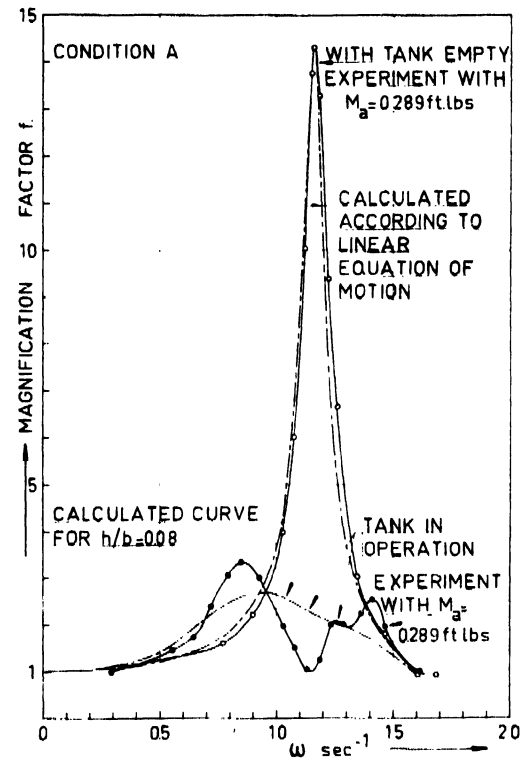
Fig 14. Results of oscillation tests compared with calculated curves
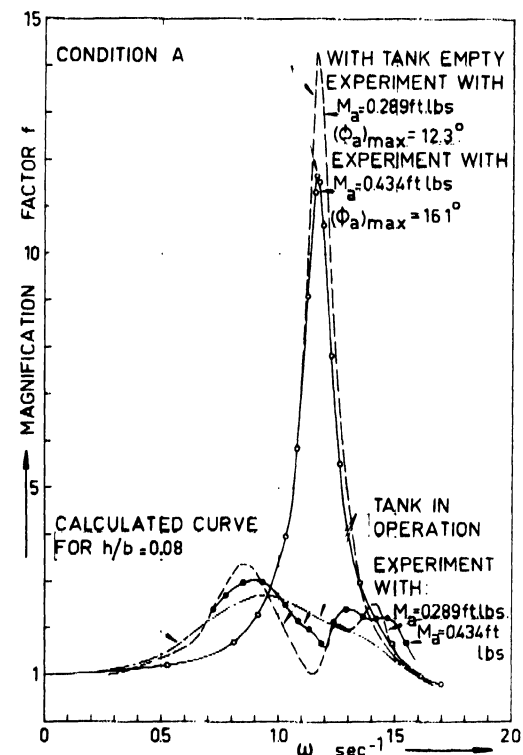
Fig 15. Results of oscillation tests for different moment amplitudes

in dimensionless form, shows two pronounced secondary peaks. The reason for this discrepancy is the non-linearity of the tank moment. The dimensionless presentation obscures the fact that the measured values

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were all considerably lower than the 0.1 radians (5.7°) which was the basis of the calculation. For such small amplitudes the curve of ε_t versus the frequency is much steeper than for an amplitude of 0.1 radians, which results in a greater damping in the neighbourhood of the tank's natural frequency and a less damping elsewhere. These differences are not of practical importance as the measured values are small.

In fig 15 the results for the largest moment amplitudes are shown. The amplitude characteristic for the ship without the tank is lower than in the previous case, indicating that the damping coefficient increases with increasing amplitude. The curve for the stabilized ship shows the same tendency as has been described in the former section but to a lesser degree. For the larger (but still small) rolling angles, the measured values for the largest moment amplitudes show the least deviation from the calculated curve.

In fig 16 the results of the tests in regular waves are given. The non-dimensional roll amplitude curve for the unstabilized ship seems to be shifted somewhat when compared with the previously determined amplitude characteristics, and the peak is considerably reduced. This last point is undoubtedly partly due to the larger rolling angles, for the deck entered the water; and probably there is also a decrease of the wave moment due to the orbital motion mentioned earlier.

It is possible that part of this larger damping and probably the slight shift of the curve are caused by the coupling of the rolling motion and other motions; i.e. sway and heave. This, however, is not yet clear. In any case, this appears to be of no practical significance as is shown by the good agreement between the measured

and the originally calculated values, for the stabilized ship.

Before considering the next figures some quantities have to be defined. The roll angles in regular waves are given as ratios to the wave slope. Therefore, the spectral density of the irregular wave pattern is presented by a wave slope spectrum which is defined by:

$$S_{k\zeta}(\omega)\,d\omega = \frac{\omega^4}{g^2}\,S_\zeta(\omega)\,d\omega$$

The average value of the highest third part of the observed amplitudes of a random fluctuating quantity, say the roll angle, is often called the significant ampli-

Fig 16. Results of tests in regular waves
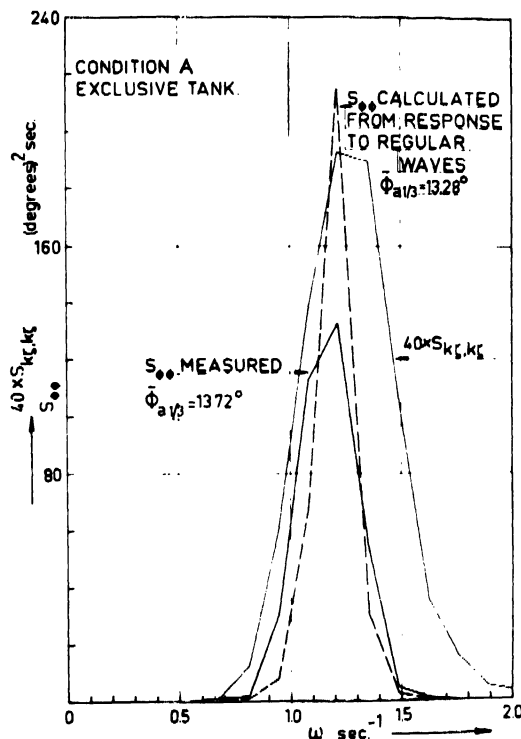
Fig 17. Comparison of calculated and measured roll spectra for the ship alone

tude. The significant roll amplitude can be regarded as a measure of the impression the amplitude of the rolling motion makes on the observer. For a stationary time series and a spectrum of small width this quantity can be calculated from the expression:

$$\tilde{\varphi}_{a1/3} = 2\sqrt{m_{0\phi}}$$

where:

$$m_{0\phi} = \int S_\phi(\omega)\,d\omega$$

In fig 17 the wave slope spectrum is shown with two roll spectra, one measured, one calculated from the experimental results in regular waves with the tank not operational. The agreement is good, as regards the significant roll amplitudes and the frequency range.

In fig 18 the spectra for the model with the tank in operation are shown. One spectrum is measured, another

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is calculated from the results in regular waves, and a third is calculated from the originally computed response shown in fig 14. The agreement is good.

A comparison of the significant roll angles for the stabilized and the unstabilized ship reveals that an overall reduction of 50 per cent is achieved in this wave spectrum.
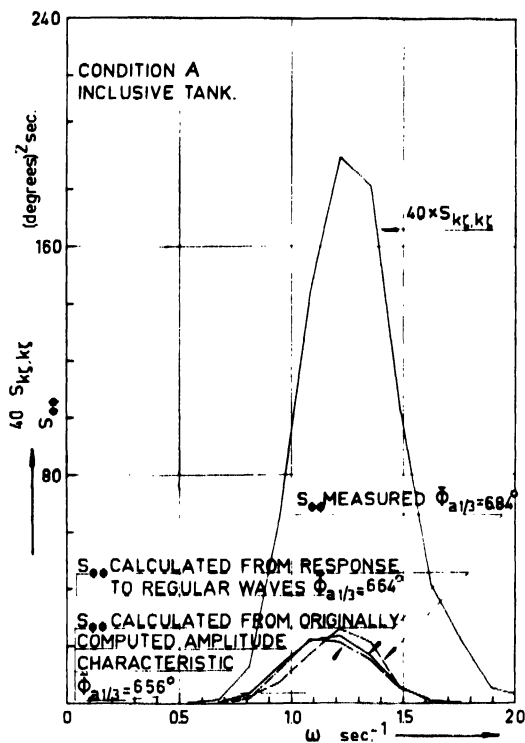
Fig 18. Comparison of calculated and measured roll spectra for the ship with tank

SUGGESTIONS

Bilge keels

As has been mentioned, the omission of bilge keels is not advised. There are two reasons for this. The first and most important is that there can be emergency situations (i.e. icing up) when it will be necessary to empty the tank because of its negative influence on the statical stability. If no bilge keels are fitted it will leave the ship with extremely low roll damping.

The other reason is that the non-linear effect of the tank is somewhat neutralized by the bilge keels. When the motion amplitudes become large because of bad sea conditions the tank moment is not so effective. The damping of bilge keels, on the contrary, increases considerably with increasing motions.

Dimensioning the tank

In the foregoing pages little is said about the amount of water a roll damping tank of this type should contain. In this case it was about 2 per cent of the displacement which is certainly not an insignificant amount. An overall reduction of 50 per cent was achieved but it depends on the sea conditions what this reduction will be. It is dependent on many factors, which roll amplitudes

and roll accelerations are found acceptable, and it is very difficult to define a basic criterion. The ultimate answer can only be found by experience. It is the author's opinion that it does not pay to economize too much on the dimensions of the anti-rolling tank, especially if one has a free hand during the design stage of the vessel.

Position of the tank

If an anti-rolling tank is wanted, one has to provide space for it where it will work efficiently, and the same remarks hold as for the dimensioning of the tank.

Obstructions in the tank

It is not always possible to avoid placing stiffeners in the tank side. If the obstruction is small, say the stiffener height is not more than about 10 per cent of the tank length, the influence, as has been shown by tests, is not serious.

CONCLUSION

A free surface tank of the type presented here, that is a rectangular tank with flush front and rear bulkheads and bottom, can provide an efficient means of roll damping. Its simplicity of installation, ease of maintenance and reliability makes it especially attractive for small vessels.

Nomenclature

b	Breadth of the tank measured athwartships
D_t	Depth of the tank
f	Magnification factor
f_ϕ	Magnification factor at the natural frequency of roll
h	Depth of water in the tank measured from the water surface at rest to the bottom of the tank
I_ϕ	Virtual mass moment of inertia of roll
k_ϕ	Virtual radius of gyration of roll
l	Length of the tank measured in fore and aft direction
M	Moment produced by the anti-rolling tank
M_a	Moment amplitude produced by the anti-rolling tank
$m_{0\phi}$	The integral of the roll spectrum over the frequency from zero to infinity
N_ϕ	Damping coefficient of rolling
R_ϕ	Stiffness coefficient of rolling
$S_{k\zeta}(\omega)$	Spectral density of wave slope
$S_\phi(\omega)$	Spectral density of roll
s	Vertical distance of the axis of rotation to the bottom of the anti-rolling tank
T_t	Theoretical natural period of the water motion in the anti-rolling tank
ε_t	Phase angle between the rolling motion and the tank moment
$\bar{\phi}_{a1/3}$	Significant roll amplitude
μ	Non-dimensional tank moment
μ_a	Non-dimensional tank moment amplitude
ν_ϕ	Non-dimensional damping coefficient of roll
ω_t	Theoretical natural frequency of the water motion in the tank
ρ_t	Mass density of the tank fluid

Catamarans as Commercial Fishing Vessels

by Frank R. MacLear

L'emploi des catamarans pour la pêche commerciale

Les catamarans offrent des possibilités intéressantes pour la pêche commerciale, pour les raisons ci-après: (a) Plate-forme de travail de grandes dimensions; (b) Possibilité de lever des charges sans entraîner pour le bâtiment d'inclinaison transversale ou longitudinale importante; (c) Possibilité, si besoin est, de se maintenir à la même place; (d) Souplesse en matière de tirant d'eau, celui-ci pouvant au choix être très grand ou très faible; (e) Grande manoeuvrabilité due à l'écartement des hélices, qui peuvent se trouver éloignées l'une de l'autre d'une distance supérieure à la largeur totale des bâtiments comparables à une seule coque.

Los catamaranes como embarcaciones comerciales de pesca

Los catamaranes tienen grandes condiciones como embarcaciones comerciales de pesca debido a que poseen las características siguientes: (a) Plataforma de servicio grande; (b) Capacidad de elevación de peso con escora o ángulos de trimado mínimos; (c) Capacidad para mantener una estación si se desea; (d) Flexibilidad de calado. El calado se puede hacer muy profundo o muy superficial, según se desee; (e) Maniobrabilidad debido a la gran separación de las hélices. Las hélices pueden estar más separadas que la manga total de las embarcaciones comparables de casco sencillo.

DURING the last century there were very few power catamarans and these were primarily designed, built and operated as ferry boats or personnel transport for relatively short distances. Only very recently has a power catamaran been specifically built for commercial fishing. In spite of this, catamarans show promise as commercial fishing boats.

ADVANTAGES

Large working platform

The large beam, running the length of the vessel, provides a large working deck for easy handling of fish and gear. The beam can be 33 per cent greater and the deck area about 35 per cent more than a single-hulled vessel of similar length. The additional construction costs should not be in excess of 35 per cent.

Weight-lifting ability

Large weights may be hauled aboard with minimum heeling or trimming angle. The above-mentioned beam provides phenomenal stability and permits the raising of large weights over the side, stern, bows or through a well between the hulls. A large oil-drilling catamaran has been built for service in the Gulf of Mexico which is said to be able to handle the large drilling rigs down between the hulls in a way previously impractical for single-hulled vessels. The stability and small rolling angle is said to be of great advantage. The same qualities that make this boat desirable as an oil-drilling platform should be advantageous for fishing.

Draft flexibility

The draft can be varied as desired because the stability is not dependent on the individual hull form, but rather the distance between the two hulls. Therefore an extremely shallow draft can be obtained if required, by giving each hull a hard chine and flat bottom with relatively generous beam. Should a deep draft be beneficial for station holding, deep narrow hulls would prevent lateral drift. This deep form would in addition ease the roll by increasing the period of roll. The depth to beam ratio should not be too excessive because it can result in excessive wetted surface and pitching. A deep narrow catamaran hull permits a wider tunnel between the hulls with less drag than a catamaran with too small a distance between the hulls.

Station holding

The flexibility of draft could create a boat that would hold station excellently and not be blown about by the wind, as just explained in the previous paragraph.

Manoeuvrability

The widely-spaced screws provide excellent manoeuvrability, either at sea or in congested harbours. A 52-ft (15.8-m) catamaran yacht when in Dutch inland waterways was particularly manoeuvrable and could reverse into very restricted spaces. Her two propellers were 18 ft (5.5 m) apart, allowing the craft to turn in her own diagonal length with great precision. This would be very advantageous for fishing vessels.

Compartmentation and safety

A catamaran is easier to subdivide than a single-hulled craft because the two separate hulls can be bulkheaded to reduce the floodable volume of compartments and increasing safety.

Beachability

Beaching is easy because stability is not lost when bows ground as in a single-hulled boat with one point contact. Except in excessive surf, beaching is simple, permitting a greater flexibility of operations, including cleaning and even repainting the bottom.

Stern ramps

Stern ramps can be incorporated that can be raised for conversion from a stern to a side trawler.

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HISTORY

Catamarans and their outrigger cousins have been used for thousands of years in the Pacific Islands and have proved their seaworthiness as fishing vessels and personnel transports, having high speed and surprisingly good seakeeping qualities. These craft were either sailed or paddled and often equipped for both. Powered catamarans are a new innovation and, although tried in the very early days of steam engines, there have been relatively few compared with single-hulled power craft. It is difficult to find twenty or even ten successful powered catamarans.

STRUCTURE

A sufficiently strong catamaran can be built to withstand storms at sea, if properly designed. Two 52-ft (15.8-m) catamarans, one of aluminium, the other of wooden construction, have made offshore voyages from the Virgin Islands to New York City without showing any signs of fatigue. Both are twin-screwed diesels also fitted with sails as yachts. The rigs in the boats only add to the strain placed on the hulls and they certainly could be converted to fishing vessels without any loss of sea-keeping ability. One was used for sport fishing in the Caribbean and all agreed that the 21-ft (6.4-m) beam at the stern was excellent for fishing on a boat only 52 ft (15.8 m) long. Amateur built catamarans and trimarans have crossed both the Atlantic and Pacific and it is strongly felt that professionally built multi-hulled boats are safe and need only prove their economic value to become successful.

COMFORT AND MOTION

Head seas

In head seas, power catamarans have no great advantage. If the wing (the structure connecting the two hulls) is not high enough the operator will have to reduce speed to avoid undue pounding under the wing. In the design stage every precaution must be taken to ensure the connecting structure between the hulls has sufficient height above the waterlevel throughout its length and particularly near the bow. The "wing" is so named because the longitudinal section is somewhat similar to an aeroplane wing. The pitching motion, if anything, is shorter and less comfortable than a single-hulled vessel. Spray protection for the bridge can be improved if the wing is extended far enough forward.

Seas at 45° on the weather bow

As soon as the catamaran turns 10 to 30° from head seas, the motion greatly improves. The angle effectively increases the length of the boat because the distance from the weather bow to the lee stern is greater. Seas at 45° to the bow are acceptable and the 40-ft (12.2-m) catamarans at Waikiki Beach in Hawaii go out through breaking surf at this angle.

Beam seas

Beam seas are no problem unless the wave length is exactly twice the distance between the centrelines of the two hulls. In this condition, the most violent rolling occurs because one hull is on the crest while the other is in the trough, but the angle will seldom exceed the surface angle of the sea. This seldom occurs, but a change in course by 10 or 15° either "up" or "off" greatly alleviates the situation because waves lift the bow or the stern before the rest of the hull, in a longer and smoother fashion than a direct beam sea.

Quartering seas

While this is often the very worst condition for a single-hulled vessel, it poses far less problems to a well-designed catamaran. A good powered catamaran shows no tendencies to broach and does not roll outboard to a greater angle than the slope of the wave. Catamarans can come in through surf where no other vessel can survive. This is well proved in the Hawaiian Islands where sailing catamarans and paddled outriggers operate through surf most of the year. This has been done for centuries by Hawaiians and in the past 15 years with many thousands of tourists on board.

Seas dead astern

Seas dead astern are of even less concern to the catamaran than quartering seas and operators have reported there is no tendency to broach or to get into cumulative rolling whatsoever.

Comfort

There is a difference of opinion when considering the comfort of catamarans compared with that of single-hulled vessels. On a powered catamaran with ten people aboard, seven thought the catamaran was more comfortable and the other three did not like the motion. Under somewhat different conditions, all ten would agree that the catamarans were more comfortable. Under certain very exceptional conditions, such as were mentioned previously, all ten might say the motion is too quick and have difficulty keeping their footing.

On power-driven catamarans of 70 ft (21.3 m), 57 ft (17.4 m), 45 ft (13.7 m) and 37 ft (11.3 m) at least 80 per cent of the people aboard thought the motion with the sea at 45° to the bow was substantially more comfortable and permitted greater workability on deck than a comparable single-hulled powered boat. (Five per cent of the minority thought the motion was not as comfortable.) To generalize, most people like the motion of catamarans better most of the time.

REPORT OF VARIOUS EXISTING CATAMARANS

Tropic Rover

This 140-ft (42.7-m) catamaran was designed, built and operated for quite a few years by Captain Sidney Hartshorne. He made the bows quite full because he feared bow burying but after several years of operation this proved unfounded and he said he would make the next catamaran somewhat finer since his craft showed no signs of bow burying even when seas lifted her stern. *Tropic Rover* is a tourist trade vessel and trips are of one to two weeks' duration. Built of plywood, her struc-

tural integrity never worried her owner. She has crossed the Gulf Stream at the Straits of Florida many times and took most of her cruises in Bahamian waters with persons who were not used to the sea.

US Johnson

This is a 45-ft (13.7-m) aluminium catamaran owned and operated by the U.S. Army Engineers as a work boat for hydrographic surveys of the Great Lakes of U.S.A. It was designed by MacLear and Harris and built by Marinette Marine Corporation, Marinette, Wisconsin. She replaced small survey vessels which had to be loaded and off-loaded by a large mother ship and has been in operation for three years. The vessel is self sufficient and is used for shallow-water surveys, making passes straight on and off the beach while taking soundings. Her draft is only 3 ft (0.9 m) and grounding is not harmful to her because of her underwater hydrojet propulsion. With two 6-cylinder diesels, she has a top speed of about 13 mph (11.3 knots) and is exceptionally manoeuvrable.

Margay

This 52-ft (15.9-m) twin-screw double planked mahogany over oak frames diesel catamaran, has operated in the North Sea and English Channel as a yacht and has cruised from Venezuela through the Caribbean Islands to Florida. She is equipped with sport-fishing equipment.

Stranger

This 52-ft (15.9-m) twin-screw aluminium catamaran, owned by Robert C. Graham of New York City, has gone from New York to the Virgin Islands and returned with extensive chartering. Her skipper, Peter Vandersloot, an experienced charter skipper who has been on single-hulled vessels previously, stated that the vessel does 18 knots in following seas with absolutely no tendency to broach while surfing down seas for one or two minutes at a time. The vessel is spacious and has excellent accommodation with an exceptional amount of stowage space and deck area. The two diesels produce a cruising speed of 9 knots.

Incredible I, Incredible II

These are two small powered catamarans of "W"-bottom shape. Each hull is a very sharp Vee shape that would have an excessive deadrise for a single huller but can be used in a catamaran. These relatively small craft of 15-ft (4.6-m) and 25-ft (7.6-m) length are only mentioned because they are the softest riding fast boats of their

kind that either the author or their owner, Mr. Harold T. White, Jr., have ever encountered. The boats operate at 30 to 40 knots in very rough water and while motion is somewhat short, it is far softer and easier than comparable boats or even boats twice their size. This is attributed to the very fine high deadrise hulls which absorb shock better than single-hulled vessels. They can operate faster in very much rougher water than any existing hydrofoils of their size or cost. A commercial fisherman could use them for transportation from one fishing vessel to another if helicopters were not available or too expensive.

Caribbean Twin, fig 1 and 2

This twin-hulled craft of Keasbey, New Jersey, is the only one of its kind known to the author which was specifically designed and built in recent years as a commercial fishing boat. Her particulars are shown in table 1. This craft was built by the Twin Hull Boat Company at Keasbey Shipbuilding and Storage Yard at Keasbey,
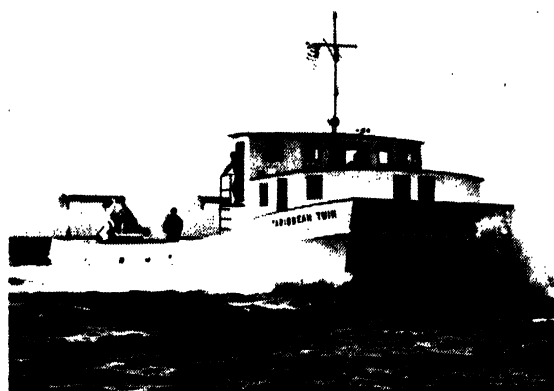
Fig 1. Caribbean Twin —general view

New Jersey, and owned by William W. Bucher. Entirely of steel, she will be engaged in commercial fishing, including shrimping in Florida waters. The stern ramp can be raised for use either as a stern or side trawler. The rolling angle is far less than a single-hulled vessel and the deck area is substantially greater. The craft can be beached for scraping of the bottom and painting, thus reducing time and cost at shipyards. She could easily

TABLE 1. *Caribbean Twin*—particulars

Loa	70 ft	(21.3 m)	Beam of each hull	10 ft (3.05 m)
Beam	28 ft	(8.56 m)	Fish holds	3,500 ft³ (100 m³)
Draft (loaded)	7 ft 6 in	(2.29 m)	Capacity holds	60 tons
Draft (light)	5 ft 6 in	(1.68 m)	Speed	12 knots
Depth of hull	9 ft	(2.75 m)	Propeller diameter	48 in (1,220 mm)
Engine	2 × 350 hp diesel		Propeller pitch	44 in (1,115 mm)
	(228 hp continuous rating)		Shaft diameter	3 in (76 mm) bronze
Generator	10 kW diesel		Fuel capacity	11,800 Imp gal
Reduction ratio	4.5 to 1			(14,000 gal, 53,000 l)
Ice	30 tons		Fresh-water capacity	1,000 Imp gal
Fish hold insulation	6 in (150 mm)			(1,200 gal, 4,600 l)
	styrofoam			

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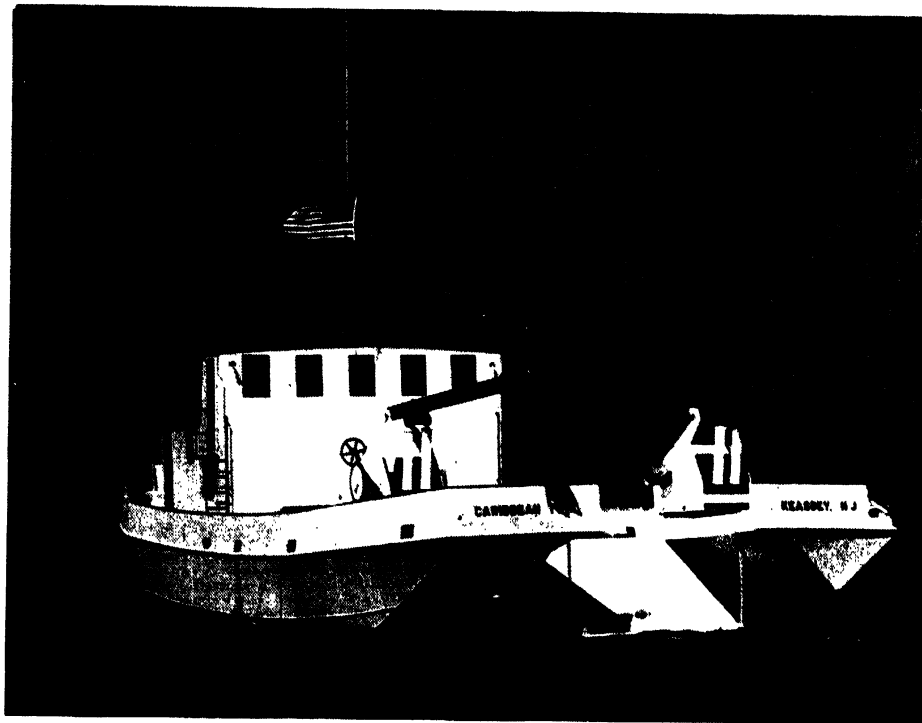
Fig 2. The stern ramp lowered

be rigged with twelve bunks for scalloping or oceanographic work, providing pleasant crew accommodation.

Although this craft has twice as many diesel engines as the conventional fishing boat of her length, the operators maintain that this is an advantage because of the reliability of a second engine and the exceptional manoeuvrability. Her earning capacity is large enough to offset the added cost and maintenance of a second diesel engine. The main advantage of this craft is the ease of convertibility from one type of fishing method to another. The cargo capacity is 20 per cent greater than a single-hull trawler of equivalent length or cargo capacity equal to a single-hulled craft 10 ft longer.

The cost was 15 per cent more than a single-hulled craft but this was primarily because of the additional engine. The builders were well satisfied and are now building an 81-footer (24.7 m) with the capacity and cost of a 91-ft (27.8-m) conventional vessel. The quarters are above deck and the fishermen find this far better than the conventional accommodation in the forepeak (fig 3). The living space is 50 per cent greater than an equal length single-hulled vessel. The net tonnage is 20 per cent greater, giving approximately 20 per cent more volume below decks. The insurance is less than that of a wooden vessel and is further reduced by the fact that she has twin screws.

Some fish boat operators believe that they can almost double the size of their nets with the large stern deck area and buoyancy of this particular catamaran (fig 4). The adaptability is particularly important to investors. If the commercial value of one type of fish should fall, it would be easy quickly to convert to some other type of fishing because of the large unobstructed deck aft.

The deck house causes no obstruction. The two hyd-

raulic cranes on the stern can be used for fishing or alternately used to anchor by the stern during the day while waiting for an evening catch of shrimp.

SUMMARY

It should not be construed from this paper that the catamaran fishing vessel will completely replace all other commercial fishing craft, for that is not the intention. On the other hand, the possibilities of this type of craft should be investigated since it is believed that it has certain features that could be advantageous to certain fishing boat operators. How good catamarans are as

Fig 3. An impressive bow view

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commercial fishing vessels can only be decided by experience and time. All that can be done is to discuss their potential in the hope that there will be enough people who are experimentally-minded and would be willing to try catamarans to prove their advantages and bring to light some other important features that might potentially make them more productive with larger earning capacity than other types of fishing boats.
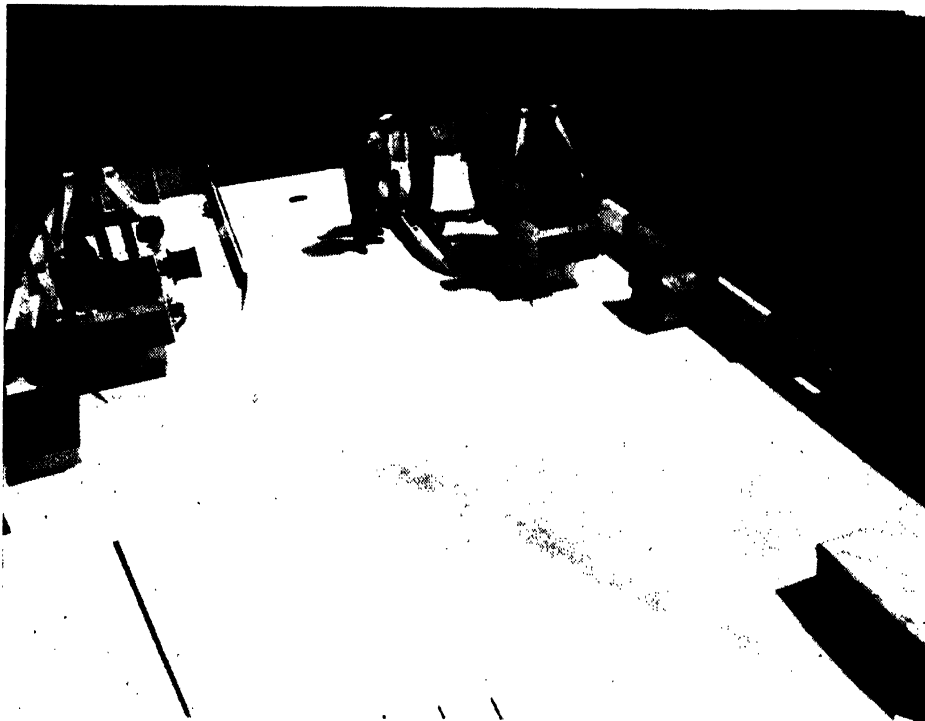
Fig 4. The after deck with the ramp in the raised position. The twin hydraulic cranes can be used either for fishing or for anchoring by the stern

Discussion: How knowledge of performance influences the design of fishing craft

VALUE OF FULL-SCALE MEASUREMENT

Sainsbury (Canada): Hatfield's paper is very welcome for its quantitative data, something which is regrettably too rare in the field of the smaller fishing vessel. Although data emerging from experiments such as these is invaluable to the naval architect, one must not forget a very practical result which comes out of the actual conduct of the tests and the taking of measurements: that is the greater understanding by the boat operator, the fisherman, of his boat.

In Newfoundland, they had recently embarked on a series of trials with a number of fishing vessels varying in size from 35 to 65 ft (10.5 to 20 m). Until now no measurements or trials had been made with the craft, and calculations in the design stage had been omitted, so that practical performance and stability was not available. The present work was started with the intention of obtaining the basic performance characteristics in terms of speed, fuel consumption, etc., together with practical stability tests, weights, working displacement. While the data now being gathered is invaluable in improving the boats technically, the actual trials and measurements have aroused far more interest among the practising fishermen than could ever have been expected. Not only the owners of the boats, but the majority of fishermen in the area now have a much better understanding of their boats' capability, and this is a result certainly as important as the actual technical data itself.

In both the developed and developing countries, naval architects often feel that the fisherman who uses the boat does not always do so as efficiently as might be, because he does not understand some of the basic principles, e.g. power, speed, propellers. Much of this is their own fault as the facts can be demonstrated very simply by going on board, taking a few measurements, and explaining the reason for them and the meaning of the results. This does not require any complicated equipment and in Newfoundland owners are now queuing up to have their boats tested, and are extremely quick to grasp the meaning behind it.

Sainsbury felt very strongly that this "side effect" of small boat trials could be exploited much more, as to a large extent the boat is only as efficient as the operator, and this, in many cases creates a barrier to rapid improvements in design.

Leathard (UK): The question of matching propellers is touched upon by Hatfield. In the UK Leathard had often found a lack of understanding of what may be achieved with a fixed pitch propeller. It may be designed to absorb given power at given revolutions at only one forward speed of the ship; this chosen speed may be anywhere between zero and the maximum attainable. Assuming that it is at some intermediate position, a reduction, such as may occur when a trawler is fishing, will cause the engine revolutions to fall off, the torque being held constant by the fuel rack setting on the engine: an increase will cause the torque to fall off, the rpm being held constant by the governor setting on the engine.

The situation is represented diagrammatically below:

torque constant		torque falling
← .... —	Design speed	— . ... →
rpm falling		rpm constant
← ————————		—— — ——————— →

0   Speed   Max
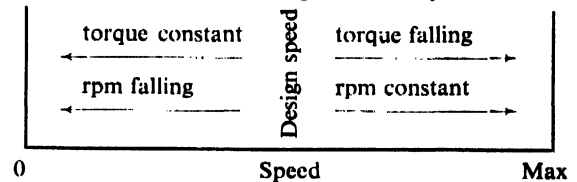
In the normal free-running design, the chosen speed is at the extreme right of the diagram. Leathard had often heard of high engine exhaust temperatures when trawling, suggesting overload torque conditions on the engine necessary to achieve the required power and pull, and he suggested that there is a good case for designing a trawler propeller so that it absorbs full power when trawling. Some sacrifice in free-running speed has to be accepted, but it may be lessened by allowing an increase in rpm in this condition. The propellers for trawlers designed in this way produce no reports of high engine temperatures when trawling. Compared with previous vessels of a similar type, there is a loss in free-running speed of about half a knot on about 5 per cent overspeed in engine rpm. Incidentally, an approach to design along these lines would have automatically reduced the free speed of the two vessels in Hatfield's paper by a quarter of a knot or so, giving his proposed saving in fuel consumption.

Real contribution

Dickson (FAO): Hatfield's paper is a real contribution to the understanding of the job that fishing boats, their engines and their deck machinery must be designed to do. The very low apparent propulsive efficiency while the seine net is being towed is not a reflection on the propulsive system, because in this method of seining – fly dragging as it is called—the boat is more or less at bollard with the winch fighting against the propeller and at zero headway the apparent propulsive efficiency would be zero. Dickson used to sail on an old underpowered seiner with only three winch speeds and it actually used to go astern when the winch was put into top gear. Hatfield's fig 18 and 19 show very clearly the advantage of a six-geared winch, where in the final stages of hauling the engine speed can be slowed down to give the fixed pitch propeller less thrust, at the same time as the ropes are speeded up to bring them in more quickly.

Hatfield stated that the mean warp loads are little affected by variations in the type of bottom. This is true enough in the sense that mean warp load is determined by propeller thrust more than by anything else so long as the net does not snag. If one warp is on catchy stones or sticky mud while the other is running on clean sand, one soon notices the difference in load between the two. The sort of stony ground that a seine net will come across is very limited and the skipper will then shoot very little cross rope, or second leg, so that the net will close quickly and keep coming, for it is only so long as it keeps coming that propeller thrust and mean warp tension are matched. As soon as the net sticks,

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the momentum of the ship, even if only making a fraction of a knot headway, causes the warp tension to rise rapidly. There are few seconds in which to stop the winch and reverse the propeller. Another factor that affects warp tension is windage and on a boat of this 70 ft (21 m) size ± 3 cwt (±150 kg) for a 20 knot, force 5 wind can be added or subtracted dependant on whether it is astern or ahead. A stern wind and the pitching caused by a following sea can in themselves bring the ropes to breaking point on a big seiner.

The limits of weather in which a seiner can work its gear are not set by the safety of the ship as is sometimes the case on a small trawler, a seiner's gear can part all too easily. Seining is much less hard on the boat than trawling, by virtue of the manilla rather than the steel warp, by the lower ship speeds during towing and partly because less engine power is required. The *Rosebloom* so far as Dickson recalled from discussions with her skipper works on fairly good trawling ground. It is however shallow water and rough ground trawling that impose the severest stresses, for then when the gear snags on the bottom the whole momentum is taken off the ship quickly, because the warps in shallow water are short and have not enough sag in them to give much spring. In this kind of trawling one hits snags often enough, and the fisherman's reaction to this is to use heavier warp in rough ground trawling and this increases the possibilities of damage. One wooden boat Dickson fished in was twisted and strained after a year or two of such work and she had to be strengthened. She is about the same size and type as the two described in Hatfield's paper.

The virtue of a paper like Hatfield's and research development work of this sort is that it gives a measure of the effect of the fishing method on the ship. This will lead not only to improved ship design but also to improved fishing methods. With instruments to give fair warning of excess loads, with past records to show as examples, the subject becomes teachable as an item of fishermen's training and training is the key to fisheries development.

Corlett (UK): Much more quantitative work is required in this field of small fishing vessels and Hatfield is to be congratulated on some very interesting work. Turning to detailed points in the paper Corlett was, contrary to Hatfield, rather surprised at the small amount of propeller mis-match actually noted; this is much less than that sometimes seen. The pitch of the propeller of *Opportune II* is quite acceptable for working conditions, but in this respect controllable pitch propellers are very helpful for this type of vessel and the flexibility obtained is much greater than with a fixed propeller. Corlett could not really understand the lack of use of controllable pitch propellers on motor fishing vessels in Britain.

Alternatively nozzle rudders, which also have a direct effect upon rough water performance, can be considered and give a significant increase in propeller flexibility as against open screws. Admittedly it is not easy to fit nozzle rudders into the stern apertures of some existing motor fishing vessels, especially wood construction, but there is no fundamental difficulty in this with new vessels. Indeed with existing vessels it might well pay to do this, even though modifications have to be made, because of the significant increase in work capability that can be produced in an existing boat with an existing engine. Indeed this can be a method of upgrading the existing ships.

Author's reply
Hatfield (UK): The design of propeller in the UK for fishing vessels usually comes to a compromise between the cruising requirement and the fishing requirement, but with the bias heavily in favour of cruising. This is natural because a good

"cruising" propeller immediately pleases the owner by giving a high ship speed. However, a propeller designed to suit the fishing condition is more profitable overall, and it is good to hear that this is being done.

Hatfield agreed with Corlett on the almost complete absence of controllable pitch propellers in the UK fleet; there is a strong reaction against them on the part of the operators which seems to be based principally on suspected unreliability.

Hatfield did not like quoting weather conditions in reports of this kind except as auxiliary information. The external conditions which the ship and its machinery are aware of are wind, speed and direction, and wave configuration. It is well known that a ship can be in almost flat calm in a force 7 in some waters, but pitching and rolling violently in a force 2 in others. Thus Hatfield preferred to quote wind, speed and direction, and angle of pitch and roll. In fact, the weather throughout the fishing trials of *Opportune II* was force 2 to 6 and at the time of his table 8 was about force 5.

SURVEY OF TRADITIONAL JAPANESE BOATS

Foussat (France): Could Yokoyama indicate whether he had undertaken tests on the flow pattern on hulls with sharp bilges? The flow pattern varies with the angle of entrance. Similarly, with the same displacement and same form for the curve of water plane areas, it is possible to design a hull offering minimum resistance, by modifying the form of the angle for speed and trim (given, or variable corresponding to experimentally-obtained values). Has Yokoyama conducted any research on this point?

Selman (UK): Selman thought everyone would admit that straight-framed boats are more easily built than the more conventional round-bilged types, but he had yet to be convinced that they can be more economically propelled. Although M-7 has less resistance than the best and most comparable M-61, the latter has a displacement length ratio some 49 per cent larger so that on the balance Selman made the round bilge form 20 per cent less resistful for the same displacement. He regarded the comparison of rough weather tests useless because one model was self-propelled and the other towed.

Coming now to fig 5 of Yokoyama's paper Selman would considerably modify the curve of wake as shown in that diagram. If the lowest spot is ignored or omitted as has the corresponding spot for thrust deduction and also the third spot, it is then possible to draw a curve similar in shape to that already drawn for thrust deduction. The two curves would follow one another and have similar characteristics as one would normally expect. The propulsive efficiency curve would remain unaltered as would that for the open propeller, but both the hull efficiency and relative rotative efficiency curves would have the same characteristics and markedly different values at low speeds.

Selman found it difficult to believe the low wake values quoted for this M-7 form and believed such low values could be caused by a breakdown in flow due to the proximity of the propeller tips to the surface at the transom. Indeed some confirmation of this may be found in the fact that fig 6 shows higher values of wake for deeper immersions: for L-7 as compared with L-12. Selman had often found a pronounced suction at such transoms, particularly at the centreline, and he believed that the propeller in this instance is sucking down air from vortices formed at the surface. The effect being to increase revolutions required to give the required thrust in the model propelled condition and so producing an apparent small and negative wake.

Selman concluded that he was in his 70th year and speaking for himself would certainly require more than one wife to assist him manage to beach a 50 ft (15 m) or even a 30 ft (9 m) boat, as referred to by Yokoyama and his associates in their paper!

Kilgore (USA): Yokoyama *et al* have presented curves showing significant improvement in longitudinal motions of hard-chined craft of high midship section coefficient over "European types". The value of the paper would be enhanced if the authors would show specifically what they mean by "European types". Also the value of their observations would be greater if they would not only supply the geometrical specifics of the models compared, but also information as to whether or not the mass distribution was the same.

Interesting development

Corlett (UK): It is most interesting to see how an entire range of fishing vessels has developed owing nothing to Western type practice. The statement that aged couples can haul 30 ft (9 m) fishing boats up the beach indicates that aged Japanese couples must be exceptionally vigorous.

Turning to the details of the various ships, Corlett agreed with the model test results for Japanese type M-7, namely a flat trend to the resistance curve at high Froude numbers. This is fundamentally obtained by a fairly flat run and energy recovery from the wave system. Corlett had found it possible to do just this and to obtain significantly higher speeds on a given length of hull than conventional form, although often the resistance of this type of vessel has been slightly higher

at low Froude numbers. At the same time, the actual horsepowers are important and the slight increase of C_r at low Froude numbers possibly represents 5 to 6 hp, whereas the saving obtained with this type of form at high Froude numbers may be of the order of 100 hp or more. Equally it is found that this type of form has good pitching characteristics and this is borne out by the Japanese experience in the paper.

Furthermore, with an aft fishing platform as is common nowadays in these small ships, a far aft pitching centre is desirable in association with highly damped characteristics at the bow in pitch. A form such as M-7 gives this although Corlett had found that it may be advantageous to use a full angle of entrance and to shape the forward sections very carefully to obtain the highest possible degree of damping at small pitch angles. Nozzle rudders help in this respect, moving the pitching centre aft and damping the stern. It cannot be emphasized too strongly that in a small vessel with men working at and over the stern, everything possible must be done to prevent movement at this end.

Turning to the propulsive efficiency of these Japanese fishing boat hulls, it is clear that they are low mainly due to relatively high thrust deduction and relatively low wake fraction. This is, of course, to be expected with the rather clumsy wooden sternpost fitted and Corlett would suggest that the possibility exists of using prefabricated steel sternframes specially adapted to mate up with the wood structure and which would give the opportunity of a cleaner ending to the skeg. At the same time the low wake fraction is basically because most of the wake around the hull goes up the buttock flow stern and is not shed into the propeller. This, of course,

Type of ship	Model No.	Name of ship	Kind of ship	Model length ft (m)	λ = Lpp/l	Lpp ft (m)	LwL ft (m)	B ft (m)	Tm ft (m)	Δ t	Cb for Lwl	Cp for Lwl	Cm	LwL/B	B/T	V/(√(LwL/10))³	δ ft (m³)
Japanese	7-(1)	Jinsui-maru	Exp. boat	6.56 (2.00)	4.050	26.60 (8.10)	24.00 (7.30)	6.75 (2.06)	1.31 (0.40)	2.37	0.461	0.589	0.783	3.54	6.63	5.95	147.00 (13.75)
"	7-(2)	"	"	"		"	25.20 (7.70)	"	1.94 (0.59)	4.59	0.541	0.625	0.866	3.74	4.07	9.76	139.20 (17.62)
Round	61-(1)	Niigata-maru	Small trawler	5.00 (1.52)	10.050	50.20 (15.32)	50.00 (15.16)	12.40 (3.78)	4.14 (1.26)	31.53	0.477	0.582	0.820	4.01	3.40	8.86	695.00 (64.40)
"	61-(2)	"	"	"			49.20 (14.99)	"	3.34 (1.02)	21.43	0.424	0.556	0.762	3.97	4.34	6.??	574.00 (53.43)
"	61-(3)	"	"	"			48.50 (14.78)	"	2.98 (0.91)	17.58	0.404	0.543	0.744	3.91	4.97	5.33	527.00 (48.99)
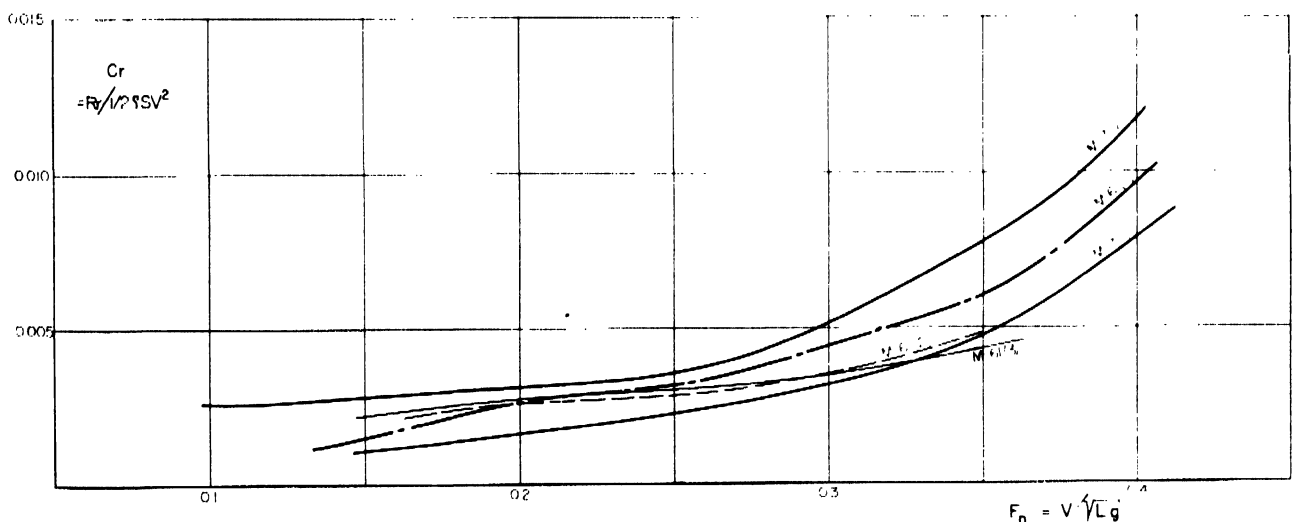
Fig 1. Further analysis on various conditions of M-7 and M-61

does produce a quiet running propeller which is capable of higher loading than otherwise, but gives a low hull efficiency. Various devices can be adopted to improve this position and a simple angled skeg can be of considerable help, producing wake fractions nearly as high as with the conventional form but associated with the low thrust deduction of the type of stern shown. There is a good deal to be learnt from Yokoyama's paper.

Safety factors

Lee (UK): Commenting on the effect of hull shape on stability, fig 14 of Yokoyama's paper shows a V-bottom or single chine form to advantage over the round-bottom form in respect of maximum GZ and range. He had expected to see a discontinuity in the GZ curve of the V-bottom boat where the chine emerges. Some British 75 ft (23 m) wooden MFVs of deep round-bottom section are being replaced by steel boats of double chine construction. Admittedly there are some variables, but it may be of interest to note that although the maximum value of GZ is the same, the range of the double-chine is less. Regarding Yokoyama's statement that the V-bottom boat is less dangerous than the round-bottom one, the deep round-section MFV has proved itself in rough seas over many years; full experience with the double-chine boat is awaited It has already been necessary, however, to strengthen the flat bottom aft of double-chine boats in order to prevent damage from pounding.

Author's reply

Yokoyama (Japan): Answering Selman, he said that fig 4 was not drawn for the purpose of a quantitative contest among the boats with different conditions, but should be understood to reveal hydro-technical feasibility for the various types of hull forms. Both models with straight frame (M-7) and with round section (M-61) have a similar trend over $F_n > 0.3$ and, as is pointed out, the difference is insignificant when disregarding displacement-length ratios.

For the reference (fig 1) however the old test results with M-61 having $\nabla/(0.1L)^3$ of 5.33 and 6.23, are a little above M-7 up to $F_n - 0.30$ and come down about to cross that near $F_n = 0.35$, whereas an additional test with M-7 having $\nabla/(0.1L)^3 - 9.76$ gives a little higher (10-20 per cent) line than that for M-61 with 8.86. As a general concept the fact should be remarked that all these results, straight or round, have not any noticeable hump even over $F_n - 0.30$, and a simplified form is able to realize the same excellent characteristics as the best boat with normal section.

The importance should be placed on the behaviour of boats among waves not only for seaworthiness but for construction and economy of materials, wide and thick planks. And ship's motion is not so restrained by the mechanism of free surging that the difference between towing and propeller condition may become secondary level of consideration. The comparison of power increase could not be rejected for the present assumption of nearly the same propulsive coefficient, if there were not found any comparable report of wave test with small boats. Sometimes the experiences are heard that a Japanese small boat is able to cruise with dry deck even when the inspection boat with round section is fighting hard against waves.

The curves in fig 5 of Yokoyama's paper are derived from the smoothed results for respective torque, thrust and revolution, so the line of w and t may become unfamiliar and a snaky line is not so meaningful as faithful saw-tooth line passing every spot. But the facts of quite low or negative wake at higher speed are witnessed at some tank or sea tests, and may be explained with potential flow running near the deep and wide bottom like transom stern or midship of
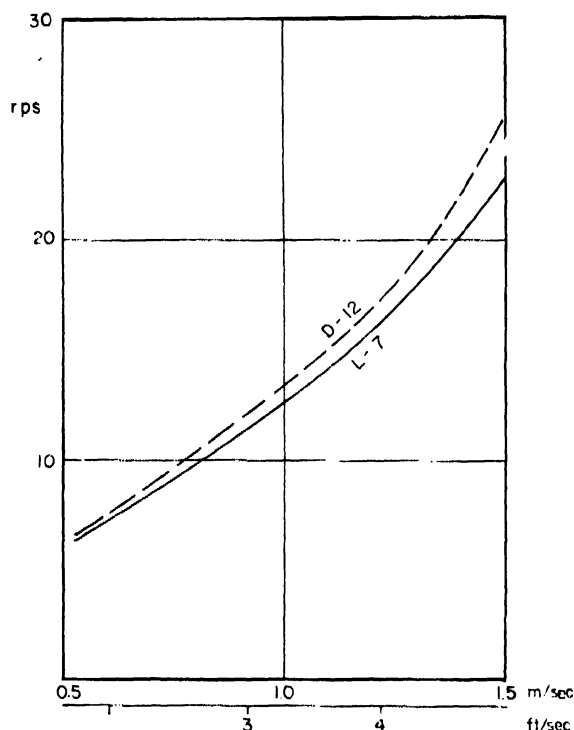
Fig 2. Revolution of model propellers

normal boats. A little abnormal trend at low speed cannot be relied on because of scale effect inevitable for such small model propeller (3 in or 75 mm dia) that the blade runs far under a critical Reynold's number.

Although 7° and 17° in fig 6, the illustrated rake of shaft, have to be interchanged, the result of the lowest propeller, L-12 low, is lowest compared with the highest, L-7. The air-draw effect must be possible at transom, as suggested, but fig 2 (above) does not show any pronounced difference of revolution even between shallow L-7 and deep D-12, so the apparent small and negative wake may be independent on the air suction and resulted from a distribution of flow velocity around the bottom.

The mis-estimation of launching power is caused by a trouble of English translation. The phrase "with only female assistance", should be revised to "with assistance of housewives from several families". A man-powered winch, fig 3, is operated by two to four persons for a 30 ft boat (3 to 5 tons) and four to eight persons for a 50 ft boat (about 20 tons), but petrol-engined drum should be recommended even to keep bigamous trouble out!
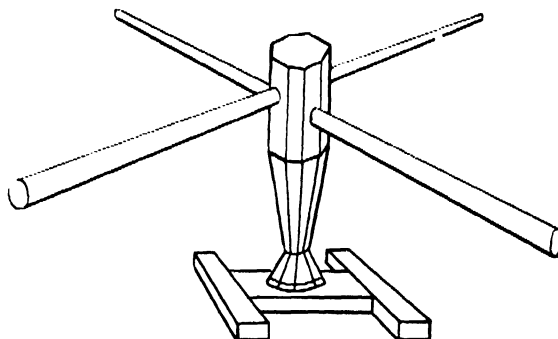
Fig 3. Manual capstan

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EVALUATION OF EXISTING DESIGNS

Kilgore (USA): Gueroult has supplied some wise observations, and the approach he proposes certainly should be pursued. Kilgore was not so optimistic about Gueroult's hope for sharing of findings by neighbouring countries when even neighbouring fishermen are notoriously secretive.

The curves, fig 1 to 7 in Gueroult's paper, are of value as general guides, but they will vary rather widely from fishery to fishery, as Gueroult observes. Some of these curves are based on hydrodynamic efficiency. Some are the averages of current practice, but not necessarily the optima for any particular fishery. Kilgore's interest above all is in fig 8. These curves are important enough to receive an explanation longer than one sentence. What does Gueroult mean, specifically, by profitability? How did he obtain the input for this family of curves? If the data were from the performance of certain boats, how many boats were considered as suitable for a sample? Kilgore's concern here is that length is the single independent variable, but the way the curves were obtained might significantly affect their optimum points.

Despite these obscurities, due no doubt to Gueroult's wish to be brief, fig 8 does illustrate a notion that must be valid: for any fishery at a place and time, there must be an optimum length. Perhaps this is all Gueroult wished to illustrate.

von Brandt (Germany): Three short remarks on Gueroult's paper from the point of view of a gear technologist, in connection with the calculation problem mentioned:

1. There may be a constant influencing the design of vessels, that is the nearly equal size of fishing gear on small and large vessels. This happens to some extent for mid-water trawling with small or big boats or in fishing with lobster pots etc.

2. There are some gear with a high influence on design of fishing vessels and others with a low one. The degree of this influence depends sometimes on the size of the vessel. For driftnetting and line fishing one needs almost no arrangement for small boats, but one needs hauling devices for bigger vessels and special engines to give the vessel a better manoeuvrability.

3. One needs in many cases vessels with the possibility to operate with more than one fishing technique, e.g. drift nets plus trawls, bottom trawls plus mid-water trawls, trawls plus purse-seines. In Europe as well as in many developing countries, one needs not so much greater flexibility. This will make the calculations more complicated.

Doust (UK): Congratulated Gueroult on his paper. Much of Gueroult's reasoning agrees very well with ideas at the NPL and the effectiveness of these methods would also seem to be verified by the results obtained.

Author's reply

Gueroult (France): There is an apparent contradiction between a method evolved on the basis of statistics and the desire to use such a method for new types of boats, for which no such statistics are available. He was anxious to forestall this objection, the fact being that there are any number of unseeable sources; these are mentioned in the references given in the paper.

Gueroult illustrated his method from evidence which was immediately available to him—namely, ships of over 100 tons. If the method proves to be applicable, it can later be made for values for boats of less than 100 tons. There are a certain number of constants common to large and small boats—men, fish, sea and, in large measure, fishing gear, which therefore warrant similar treatment for small and large tonnages.

COMPUTER DESIGN OF BOATS

Leathard (UK): Two aspects of the series of papers under discussion are illustrated by a group of five 90 ft (27.4 m) North Sea trawlers currently under construction in a UK shipyard. Firstly, the hull forms were designed by NPL using the results of computer analyses carried out on trawler forms and reported elsewhere by Doust and others. The first vessel landed the top catch of the week at her home port when she returned from her maiden voyage and she continues to perform well. The second vessel has also received good reports and the other three are due to enter service shortly. This is an illustration of the satisfactory results which can be achieved with a hull designed for efficient powering and sea-kindliness by methods similar to those outlined in the computer papers.

Swedish interest

Williams (Sweden): Doust points out that model tests for vessels below 100 ft (30 m) are too expensive in relation to the capital costs of the ships. He also suggests that resistance qualities can be established from the performance diagrams and thus, designing the lines of smaller fishing vessels can be carried out on basis of present analysis results.

The general impression of this research work carried out at NPL is that the investigations are performed in a distinct way and that the mathematical methods are well defined. Further, the results are most valuable for the future design of fishing vessel hulls. But it is doubtful, in the present situation, if the mathematical optimization can replace the conventional model tests. Even if this analysis covers a wide range of fishing vessel types and corresponding shape parameters it will always be suitable, both from the technical and economical points of view, to carry out model tests also for small vessels.

If a series of ten well-equipped trawlers of 80 ft (24 m) in length are to be built for a cost of £50,000 ($140,000), a short experimental investigation including, say, five hull versions will cost about £4,000 ($11,000), that is less than one per cent of the total capital costs. Besides the resistance qualities, the influence of hull form variations upon propulsion factors at free running, trawling and heavy towing is tested, properties which are not fully covered by the present analysis. Further, it is a well-known fact that the best resistance hull form must not be the best propulsion full form either at free running or at towing.

However there is no doubt that Doust provides very good recommendations for planning such systematical investigations which will be performed in case of a short series of fishing boats as mentioned above.

The statistical analysis of FAO resistance data has drawn the attention to the propulsion properties of the Swedish common trawlers, especially those built of wood. The free running speed qualities have not been tested enough. In recent years the distances to the fishing grounds have been increased and therefore it is important to reduce the "steaming-time" and above all try to get a better profit in form of a higher free running speed from the very powerful engines which are now installed. It is of course difficult within a time of some years to introduce a quite new trawler design which could better meet the new demands of free running speed. Therefore it is important to modify those existing types, which are favourable from other points of view. In this connection the design trends received from the NPL analysis will be most useful.

It is understood that the choice of a set of suitable hull form parameters must have been difficult. At the Swedish State Experimental Tank (SSPA) a corresponding analysis of resistance and propulsion data are prepared on the basis of draft functions. The draft functions indicate the influence

of the draft upon a selected set of waterline form parameters and the formulation of these functions is a part of the procedure for defining ship lines mathematically, see SSPA publication No. 55 and SSPA general report No. 13.

Regarding the "over-all" form parameters length to beam, beam to draft, maximum area coefficient, prismatic coefficient and longitudinal centre of buoyancy, Williams agreed with Doust. These parameters correspond to the draft functions for maximum waterline breadth and waterline area in fore and afterbody. But there will be some discussion about the "local" parameters including angle of entrance at designed waterline, maximum angle of run and maximum buttock slope. These values characterize only limited parts of the hull and will have different meaning for different types of hull forms. It is perhaps more suitable to choose the remaining parameters from the draft functions for waterline angle and curvature fore and aft as these affect a larger part of the hull.

The introduction of draft functions instead of local coefficients in the performance analysis of course will increase the number of parameters and perhaps also influence the rectangular distribution of data points. However, if the NPL work is to be continued and more input data are to be treated, it is possible that the number of significant form parameters must be increased in order to reach a still better and more valuable result. An analysis based on draft functions can then be considered, as these have the advantage to give the hull form directly.

Practical and Helpful

Corlett (UK): Doust's and Traung's papers really point a way and are practical and helpful. It is a pity that the 40 and 55 ft (12.2 and 16.8 m) vessels are depicted as being of wooden construction, as there is an increasing tendency to build this size of vessel in steel with beneficial results, particularly with respect to capacity and propulsive efficiency.

The regression analysis approach, using a computer, to the optimization of data is a powerful weapon but is nevertheless dependent upon the quality of the forms used in the analysis. It is felt that it would be advantageous if more data could be made available and, of course, all tend to keep their better results to themselves—especially on these smaller ships, many of which are not model tested. However, Doust's fig 10 to 15 are valuable in that they give an individual designer an opportunity to check out his designs.

The optimum forms themselves appear good but Corlett suggested that the breadth is not adequate in view of the tendency of $\frac{KG}{D}$ to increase in modern boats. Corlett suggested furthermore that the C_{R18} curve should aim at optimization at economical cruising speed as there does not seem to be much point in doing so at any other speed. The amount of power used at low speeds is small and, short of making radical changes to hull forms, it is not possible materially to increase the speed of a boat of given length.

Finally Corlett said that he completely agreed with fig 49 to 51 of Doust's paper. The half angle of entrance is a matter of considerable importance, particularly in wood construction and he felt that the bow shape shown in the optimum forms is possibly expensive and difficult to construct in wood. It is not cheap in steel comparatively, but in wood could be difficult. Therefore, in fig 49 of Doust's paper the dual nature of the optimum half angle at a given prismatic coefficient is of considerable interest and value and he personally favoured, and always had favoured, using the higher half angle in small ships of this type rather than the lower. Corlett had found that it minimizes pitch and tends to make the vessel relatively independent of breadth in small design

changes. Additionally it gives much more room in the ship and better stability on a given breadth.

Regarding the waterline shape aft Corlett had, of course, been aware that in small high displacement/length ships, resistance is relatively independent of the waterline shape aft but fairly critically dependent upon the buttock angle. In a small fishing vessel, the waterline shape aft is more a matter of seakindliness than of resistance and it may well be that in a given case a compromise has to be adopted purely from this point of view.

Falkemo (Sweden): At Chalmers University they are particularly interested to co-operate with NPL and FAO in the respect of fishing vessels. This is further encouraged because this is the first time that a suitable mathematical equation has been developed that can produce forms on a statistical analysis. Naval architects have made attempts at this over a long period of years and at last a suitable equation seems to have been produced.

The model of the 85 ft (26 m) boat was so far only tested in calm water, but a plastic model will be made for tests in rough water and the results of these tests will be compared with rough water tests to be undertaken on models of typical wood and steel construction Swedish fishing vessels. The Swedish vessels can also undergo tests in the full scale as far as propulsion and seakeeping are concerned. These tests have been made possible by the close co-operation with local fishing skippers and it is hoped at least by the next conference to have the results of these tests.

Technical queries?

Cardoso (Portugal): What meaning does Doust attribute to the substantial increase in standard error with increasing $V/\sqrt{L}$? In small fishing boats in Portugal, quite a variety of values of $V/\sqrt{L}$ apply and may be up to 1.2 or more. It would be interesting to know whether the authors have looked into the choice of C_p in relation to the applicable value of $V/\sqrt{L}$. Referring to fig 47, Cardoso asked whether similar variations were studied at other values of $V/\sqrt{L}$. If so, were they found to coincide with previous tests and practice at coinciding values of other parameters.

In the Traung paper, why was not 14.51 taken as the best value of C_{R18} which would correspond to a C_p of 0.65 and a half angle of entrance of $22\frac{1}{2}°$?

More and more gear such as power blocks are now placed on the deck and above it so that the beam of many small boats has had to be increased. With high values of beam, it is difficult to obtain small angles of entrance and low values of C_p without creating shoulders on the hull form. Besides, especially in wooden boats, it is more difficult to construct boats with small entrance so that the importance of finding relatively good forms with high values of angle of entrance cannot be ignored.

Prohaska (Denmark): He made a few critical remarks on Doust's paper. He did not like the choice of the Telfer's coefficients used as a basis for resistance comparison analysis of this kind. It uses a C_R value containing length in the nominator and a speed coefficient having length in the denominator and therefore a comparison is only feasible for the same length vessels. Prohaska did not want to expand on this further as Froude discovered this situation a long time ago.

Prohaska felt that displacement may be more important for fishing vessels than length, as far as basis of design is concerned. In Doust's paper the length-displacement ratio shows variation from 4 to 5 giving greatly different displacements. An added argument is that cost mainly depends on displacement and not on length.

Prohaska would also like to inquire, especially to FAO, why are the 86 coefficients found from the computer investigation not published and not included in the paper. Without the actual figures it is impossible for any designer to use this work and it would be important to include these coefficients in the proceedings.

The extrapolation from the 16 ft (4.9 m) model to the ship is very much dependent on the extrapolation method adopted (in this case ITTC). If the form effect were to be included, it might well effect the optimization of the resistance.

Finally although these vessels are optimized in regard to resistance, this is not the final goal which should be optimization of propulsion and fuel consumption.

Calder (UK): Reference is made to the effects on resistance criterion of changes in the half angle of entrance of the load waterline. In the discussion Cardoso pointed out how difficult it is to obtain small angles of entrance and low values of C_p. Would a more accurate basis of comparison not be obtained by using the half angle of entrance of the mean draught waterline instead of using that of the load waterline?

When using the half angle of entrance of the load waterline widely differing results were obtained from vessels of similar proportions and dimensions. Analysis of these results pointed to the differences caused by V sections in the fore body as compared with U sections and this led to using the half angle of entrance of the mean draft waterline instead of that of the load waterline. This method was used by Middendorf in his investigations into forms of least resistance.

Praise and gratitude

Kilgore (USA): Had nothing but praise and gratitude to express for the Doust and Traung papers. Doust and his colleagues at NPL have achieved a scientific breakthrough with their concept of applying the regression matrix to the formidable assortment of variables in residuary resistance.

The next logical step in this project is publication of these results in a form modelled perhaps after the Taylor-Gertler curves. This is a big undertaking. It is hoped that Traung will be able to find the means, and that the scientists at NPL will continue to give this work their inspired attention.

One question: It is not clear to Kilgore the combination of buttock slope and slope of load waterline adequately describes the afterbody, and Kilgore hoped the authors would show how they justify these two important parameters.

van den Bosch (Netherlands): Williams suggested that more data would lead to more parameters. One should not only seek the optimum in resistance and propulsion in smooth water condition, but also investigate more in detail the rough water condition. Introducing more variables would be more valuable from the seakeeping point of view.

Tyrrell (Ireland): Traung's paper is very exhaustive and must be of considerable help in the earlier stages of new designs. Model test results however must be applied with the utmost caution; for example, low prismatic coefficient with fine bow lines make for decreased resistance, but do not necessarily preserve other qualities of greater importance for fishing vessels. Foremost of these is longitudinal balance of the hull above datum waterline as well as below—there must be little movement of location of centre of buoyancy from light to loaded condition. A vessel must not be sensitive to considerable movement of weight, e.g. stowing the fish hold unevenly fore-and-aft.

The model test revelations of the desirability for buttock lines of small angle confirms established practice in sailing yacht hulls over a great many years.

Jimenez (Peru): Wooden boats in Peru are equipped with thick stern pieces which make much turbulence and result in bad inflow to the propeller and cavitation. As a result the speed of the wooden boat is less than that of steel boats with their sharper stern pieces. A great deal of cavitation was eliminated by simply rounding the corners of the stern piece of the wooden boats.

Author's replies

Doust (UK): Thanked Leathard for his comments on the vessel that they had successfully designed together and which his firm had built in some quantity. From the design point of view, it is encouraging that the application of the statistical method has been proved down to vessels below 100 ft (30 m) in length.

Answering Corlett's remark that the breadth was not adequate, Doust said that the forms satisfy the stringent Rahola criteria and also considering the results of the analysis further increases in beam would not materially affect the resistance performance.

Williams seemed to be concerned with the possibility that the demand for model tests will be decreased after making such mathematical analyses. As a member of a sister towing tank organization also deriving income from model tests, Doust had found that, because of the increased interest on the part of vessel owners in utilizing the results of such analyses, the services of the towing tank are required even more. There is also the additional aspect that tank facilities can be used more effectively in conducting much needed wave tests. One of the most important factors found at NPL for such vessels is that low resistance forms can also be made to have good seakeeping performance by paying proper attention to the above-water form.

Doust thanked Falkemo for telling of his plans for future co-operative research. Doust particularly looked forward to the results of the tests in waves with plastic-hulled models and, eventually, full-scale trials on shipboard.

Cardoso will note that as speed increases the percentage accuracy of the results is more or less constant, since the average level of C_R rises as speed is increased.

In reply to Prohaska, Doust stated that the use of Telfer's resistance criterion can provide both the effect of length and displacement, since both are incorporated in the regression equation stored in the computer. There does not seem to be any difficulty in presenting the regression coefficients requested by Prohaska, but it was not felt that they had their place in a paper of this nature. If people started computing resistance with hand calculators etc., it would take a long time and it would therefore be much simpler if they wrote to FAO and they together did the work.

But it should be stressed that these coefficients will require modification as more data become available and new improved forms are incorporated in any further analysis. Regarding the use of the 1957 ITTC line, it seemed logical to use this internationally accepted formulation for predicting ship performance. It was Doust's intention to allow for any possible future changes in the extrapolation procedure by presenting basic 16 ft (4.9 m) model data so that any subsequent adjustments could be made by minor revision of the computer programme.

Kilgore had asked for design charts similar to the Taylor/Gertler curves. It is to be hoped that such charts can be prepared and incorporated in an FAO design book on some future occasion. The use of the buttock slope angle and run angle is justified by the results. For example, the fact that several designers from many countries and also participants in the FAO/Swedish Training Centre on Fishing Boat Design have been able to use these form parameters and produce

designs from them, having the required performance, is evidence enough.

Doust agreed with van den Bosch that propulsion tests in waves are urgently required for small fishing vessels and it is the intention to make such experiments as soon as time and events permit.

Tyrrell seems to be concerned, as a boatbuilder, with the pace of fishing vessel development in the conservative fishing industry. Doust pointed out, however, that as Tyrrell himself had said some of the conclusions were first proposed some sixty years ago, but not apparently acted upon. Urgent attention should be given to these design requirements, so that substantial gains could be made in fishing vessel performance without waiting for the *ad hoc* step-by-step method envisaged by Tyrrell.

Doust agreed with Selman's general remarks on the question of straight-framed versus round bilge boats. Although there are some constructional advantages for straight-framed boats, particularly in developing countries, as pointed out by Selman, he thought that a round bilge form in general could be made superior in terms of both resistance per ton of displacement, and power per ton of displacement. Sea-keeping qualities covered a wide range of interest and importance and it was not possible to generalize. Some vessels needed minimum speed loss as the prime requirement, whilst others needed minimum bow or stern motion, accelerations or wetness. Doust therefore felt that Yokoyama's paper should be checked out on a wider range of forms, perhaps including a current, European, well-known successful form.

Hayes (UK:) *For written reply see page 197*

Traung (FAO): The question as to what speed to optimize on was taken after much discussion. It was extremely difficult to decide the proper speed because of the lack of reliable full-scale data on such fishing boats; as speed and power are difficult and comparatively time-consuming to measure on a small boat. Fishermen usually exaggerate the speeds their boats are making. The final decision was to optimize at $V/\sqrt{L} = 1.1$. It is believed that such a speed really corresponds to the economical operating speed of most fishing vessels. Maximum trial speeds with light load and a clean bottom and the engine in peak performance are certainly higher but that is not the condition for which one has to design.

Corlett said it was a pity that the 40 and 55 ft vessels were designed for wooden construction. While it could be argued that wood is still a most important material for boats of such sizes, this shall not be done. The reason for designing in wood is simply to see how the optimizing exercise would work for vessels built both in wood and steel. Furthermore, the optimizing exercise was really not made so much to develop the final answer to hull-shape of boats of 40, 55, 70 and 85 ft but to see how the computer predictions would compare with actual model tests. One could have chosen other length-displacement ratios, other L/B, etc. As a matter of fact, now that it is known that the computer programme works satisfactorily, it is hoped to find time and funds to make "synthetic" model tests of whole families of optimized forms so that it will be possible to establish a kind of Taylor for fishing boats. Before that, however, it would be useful if it were possible to include the Japanese data in the programme and lately investigations have been made which indicate that a further parameter might make it possible also to use that mass of important information.

STABILITY AND SEA BEHAVIOUR
The work of IMCO
Nadeinski (IMCO): The Inter-Governmental Maritime Consultative Organization (IMCO) is a specialized agency of the UN. IMCO is a sister-organization of FAO. Sixty States are now members of IMCO. Its headquarters are in London. The main objectives of IMCO are to facilitate co-operation among governments in technical matters of all kinds affecting shipping, and to encourage the general adoption of the highest practicable standards of maritime safety and efficiency of navigation. The Organization is responsible for convening, when necessary, international conferences on shipping matters and for drafting international conventions or agreements on this subject. So, for instance, in March 1966 was held the International Conference on Load-Lines.

IMCO also administers several international conventions including the International Convention for the Safety of Life at Sea, 1960. The Conference which prepared this Convention also adopted a number of Recommendations arising from deliberation of the Conference. One of the Recommendations called upon studies on intact stability of passenger cargo and fishing vessels, with a view to formulating such stability standards, as may appear necessary. The Conference further recommended that in such studies IMCO, to which this Recommendation was addressed, should take into account the studies already undertaken by FAO on stability of fishing vessels, in co-operation with FAO on this matter. Following this Recommendation IMCO initiated stability studies which are conducted by the Working Group on Intact Stability of Ships and by the Working Group on Stability of Fishing Vessels. The first Group is dealing with all types of ships and in particular with passenger and cargo ships. The second is concerned with fishing vessels only. Both bodies are working in close co-operation and are reporting to the Sub-Committee on Subdivision and Stability Problems. Prohaska (Denmark) is the Chairman of the Sub-Committee and Bardarson (Iceland) is the Chairman of the Fishing Vessel Working Group.

This came into being in July 1964, and held since their four sessions, the last being concluded on October 14, 1966. Experts from 17 countries are taking part in its work. Following agreement between IMCO and FAO, the Group is now in co-operation with FAO which is participating at the secretarial level. The terms of reference of the Group cover a wide range of subjects to be considered.

One of the items provides for drafting recommendations with regard to stability criterion to be used for fishing vessels of the different types. With this in view, the Group after thorough consideration, has chosen five parameters given below as possible future stability criterion and is studying them:

- Maximum righting arm, $\overline{GZ}_m$
- Angle of heel at maximum righting arm, ϕ_m
- Angle of vanishing stability, ϕ_v
- Initial metacentric height, $\overline{GM}_o$
- Angle of heel at which the edge of the upper deck immerses, ϕ_{rd}

Another item of the terms of reference calls for consideration of operational practices which have an unfavourable effect on the intact stability of fishing vessels, with a view to formulating reasonable and practicable precautions which would prevent reduction in stability. Consequently, the Group prepared its advice to fishermen, which contained certain suggestions as to precautionary measures which should be followed in order to maintain adequate stability of fishing vessels during operation. The Group recommended to inform all fishermen on these suggestions in a very simple language using terms and expressions readily understood by them, though most of the points should already be known by experienced fishermen. The Group also recommended that these suggestions should be included by fishery schools in their training of fishermen.

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Recommended practices

These suggestions were brought to attention of governments concerned. The Fishing Vessel Group worked out the "Recommended Practice for Freeing Ports" and "Recommended Practice for Exterior Hatch Coamings and Door Sills" and recommended to apply these to new fishing vessels and, similarly, to existing vessels as far as practicable. These two documents will be brought to attention of administrations, inviting them to inform all concerned including fishermen, builders and owners of fishing vessels.

The Group is studying national regulations and practices concerning icing and shifting board and other devices to retain cargo, with a view to drafting recommendations on these matters. The Group is examining and comparing national stability requirements for fishing vessels and in this work it is applying these various regulations to a number of selected fishing vessels. The work of the Group also includes analysis of casualties caused by unsatisfactory stability, the information being collected by means of intact stability casualty records, established by IMCO.

The Group examines the stability calculations carried out by various countries for a selected number of fishing vessels of different sizes and types. These calculations were made on the common assumptions prepared by IMCO, which are known as a "Uniform basis for compilation of comparative stability calculations" and which were published in the IMCO Bulletin and reprinted by several technical magazines.

The Group agreed to recommend the determination of ship's stability by means of the rolling period test, for fishing vessels up to 230 ft (70 m) in length. This recommendation had been arrived at by the Working Group on Intact Stability of Ships, as a result of theoretical studies and model tests. This Group worked out a memorandum to administrations on this subject which, among other things, contains a recommended text for the guidance to be supplied to masters of ships. This will enable the master to check approximately the stability of his vessel by simple calculations. Having determined the period of roll he will calculate the initial metacentric height (GM_o) and compare it with a critical value of GM, to be given by the administrations for each particular vessel and for various draughts.

The work programme of the Fishing Vessel Working Group includes other important items, such as:

- establishing of a simple method for judging stability of small fishing vessels which could be easily applied by their crews
- investigation of the desirability of the establishing minimum freeboard requirements for fishing vessels
- studies on external forces affecting stability of ships, etc

Spanish Requirements

Rebollo (Spain): The first step in the process of boatbuilding in Spain is to apply for the appropriate licence; this is the shipbuilder's responsibility. In the case of boats of over 35 GT, the application must be accompanied by designs showing the general layout, hull form, hydrostatic curves and scantlings and by a list of fire-fighting and life-saving equipment and also a statement regarding, *inter alia*, the work that the boat is intended to perform.

If the design does not comply with the statutory regulations, the authorities make the appropriate observations which must be taken into account in construction.

Once built and before they can go into service, all decked boats undergo a compulsory stability test. For boats over 35 GT, this test determines stability in conditions: empty, on leaving harbour, when leaving fishing grounds and when docking in port, the transverse stability curves being plotted in each case.

The research carried out by IMCO on fishing craft stability is studied with great care. Meanwhile, in Spain the Rahola criterion (including a permissible inclination of up to 60°) is applied.

A study is being made for assigning a freeboard to fishing vessels, related to the stability of the vessels. For that purpose a supplementary loading condition must be taken into account. This loading condition applies to the maximum allowable displacement of the vessel, with a stability that satisfies the statutory stability requirements, corresponding to "departure from the fishing grounds" with fish in the holds and on deck (when this might be possible) and with the consumables necessary to complete the proposed freeboard displacement.

Many fishing wrecks

Lenier (France): It is a well-known fact, borne out by the statistics of accidents at sea, that the vulnerability of ships is in inverse proportion to their tonnage. At present, over the oceans of the world and particularly near the coasts there are many wrecks of fishing craft. When these are due to collisions, running aground or errors of manoeuvre while fishing, they do not always have tragic consequences because the crews have enough time to make use of their radio and thus to alert coastal stations or other boats in the vicinity. Frequently, however, in an exceptionally heavy sea or sudden storm, a number of small boats, unable to withstand the fury of the elements, disappear leaving no trace. To mention one instance: off the French coast, specifically near Britanny, there was a sad experience of the loss of 13 fishing boats, without trace, in a single night. The boats in question had excellent scantlings, were sufficiently large for the grounds they habitually worked and had radio equipment in perfect running order, having been carefully serviced every time they put into their home port. An enquiry conducted by the Ministry of Merchant Marine yielded no more than surmises as to how these boats sank. They must have been heading for a violent storm and must have been caught by a wave which carried away their superstructures, so that the usual distress signalling system installed on them could not be used. Such events are not peculiar to France. With greater or lesser frequency, they occur in all the seafaring nations.

The Minister for the Merchant Marine has not hesitated to make it compulsory for virtually all small fishing boats to carry a new method of radio distress signalling which should do much to safeguard human lives at sea—that is worth reporting on for the sociological implications. The French radio and electric industry has developed a transmitting buoy which is thrown overboard when catastrophe strikes a boat. The buoy continues to float and emits radio distress signals which, while they do not give the boat's position, do give a call signal whereby the boat while yet in danger, or even after it has disappeared, can be identified. The same signal also enables other boats so alerted accurately to locate the disaster with their radio direction finders. The specifications of this buoy are the subject of a decree which will become operative very shortly. Something like 1,000 new fishing boats will be affected.

All countries concerned for the safety of their fishermen ought to adopt measures similar to those of France.

Anti-rolling tanks

Yokoyama (Japan): There are two kinds of devices for damping ship oscillations, passive and active ones. The normal bilge keel is an example of a passive damper turning natural flow action into useful depressing effect; whereas anti-rolling

Fig 4. Abkowitz' experiment with the model of series 60 with/without a bow fin (area ratio = 0.07)

fins activated by gyro-control is the other example. The possibilities are:

A. Passive anti-roll devices:
   1. bilge keel, centre board, fixed fin
   2. flume tank
   3. weight or large gyro

of stern. Heave control is not usually required, except special instrument for oceanographic observation.

A row of broken pieces of fin (A1) is more effective than normal bilge keel while steaming, but roll is more during anchorage. A Japanese fisheries inspection boat with such kind of fins could not board other ships side by side without contact damage. Flume tank (A2) is also effective except it requires tank space with 2 to 5 per cent of displacement (Frahm, 1911) and has somewhat noisy hiss. Shifting weight or huge gyro (A3) is becoming an old tale (Thornycroft, Cremieu). Automatically powered systems (B1, B2, D1 and D2) are possible for ships where cost is no limiting factor.

Fins and tanks have been considered for pitch damping after the anti-roll examples. As for anti-pitching fin (C1), pitching angle is resulted as a magnified or damped amplitude of external wave moment with fin action, which is proportional to its area, square of advance speed, distance between fin and midship, and rate of lift coefficient increase to pitching angle. Abkowitz (1959) gave the results of fig 4 in which the reduction of pitch angle becomes more than 50 per cent on the wave of longer than a model bearing bow fins with the area of 7 per cent of waterplane. The damping effect of active fin (D1) is not much larger than fixed fin, but it prevents from stalling at large attacking angle to flow and always keeps the most efficient work. A comparison is shown in fig 5 between the heaving force of fin and sphere near the water surface, experimented by Motora (unpublished) and calculated according to Haskind-Newman's formula. Those effects depend on heaving period. The damping effect of bulbous bow is experimented by Yokoyama (1961) as in fig 6 where the

Fig 5. Motora's experiment and Haskind-Newman's calculation for heaving force of various models near the water surface

B. Active anti-roll devices:
   1. automatically-controlled fin
   2. automatically-regulated water tank or weight

C. Passive anti-pitching devices:
   1. anti-pitching fin at bow and/or stem, bulb
   2. anti-pitching tank

D. Active anti-pitching devices:
   1. active fin electronically-controlled
   2. active tank.

Active yaw control by rudder is so familiar that it need not be added; and passive yaw control is practised by design

Fig 6. Damping effect of large bow bulb fitted to the waveless model experimented by Yokoyama

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pitching amplitude is reduced more than 50 per cent above an optimum speed, $v/\sqrt{gL} = 0.25$.

The passive tank (C2) is regarded ineffective for anti-pitching. When the natural frequency of tank water, however, keeps higher than encounter period, Motora (unpublished) makes it possible through a theoretical calculation to damp the motion with a particular device of flared tank, having side opening near the waterline through inside duct.

Foussat (France): Has van den Bosch studied the effect of the anti-rolling tank on a model which did not itself have fuel bunkers or water tanks? Now, with the real thing, it is rare not to have one or more such bunkers or tanks in the process of emptying and which, accordingly, have free surfaces and hence a certain impact on rolling, which is possible to study and which varies according to the shape of the free surfaces, the volumes of liquid in movement, their viscosity and so on.

In order to apply the free surface tank principle in a real boat, there should be difficulty in having a fuel bunker carrying out the required function. The tank in question would be the boat's standby tank, which means it would normally maintain a constant level throughout the voyage. If, in case of need, the voyage must be prolonged beyond the expected time, the fuel would be consumed by the engine. If, in an emergency, a rapid increase in the GM value becomes necessary, the tank would be discharged into a normal fuel bunker—by gravity or by pumping. This arrangement would make for more space on board. It would not involve reducing the capacity of the fish hold or of the space allowed for the engine.

However, the calculation of roll damping for any craft, whatever stabilization system is adopted, must allow for the inertia of liquids in all shipboard containers which are in the process of emptying.

Effect of gales

Gueroult (France): Fishing craft behave the same at sea as other boats, but have suffered from the conservative view that a craft with low initial stability is a better boat in bad weather. A better boat in what respect, and in what sort of bad weather? It is probably that at force 8 and above, a craft with low initial stability will be more comfortable. As a fishing craft, between calm sea/fine weather conditions and force 8 (which represents the normal range of working conditions) it will have a more stable working platform than if it has high initial stability.

The lack of precision in the terms "low stability" and "high stability" shows that only generalities are being considered. As a rule, by low stability is meant that deemed minimum for safety, whether the boat is upright or in an inclined position. For small boats, "high stability" is the highest obtainable without ballast and without exaggerated transverse dimensions. The naval architect cannot be content with general principles, but must specify dimensions which will offer the desired seakeeping performance. Fig 4 and 7 of Gueroult's paper were prepared with this in mind and have in large measure been verified.

Model testing for working platform stability up to force 8 and for different tonnages would be very useful. The inevitable consequence of a craft which is "too" stable in bad weather will have to be accepted and, as far as possible, offset by the usual navigational precautions. The question may also be asked as to whether anti-rolling devices can find their greatest usefulness under extreme conditions?

Stability aids crew efficiency

Grönningsaeter (Norway): Underlined the need for stabilizing fishing vessels with a passive system by mentioning that one of the most important aspects of economical fishing today is

to have the manpower reduced. In Norway they have just reduced the manpower in their purse seining fleet by several thousand men in two years and have increased the catching ability. They have seen no such rationalization in trawlers and longliners. Waterman mentioned at the White Fish Authority Conference in London in 1965 that one of the biggest needs in the trawlers was to eliminate the hard work of gutting and heading fish manually. Machines can do this in a fairly quiet ship, but will not work well in heavily rolling ships. Such a machine can do the work of 20 men gutting and heading 40 fishes per minute against 4 fishes per minute by a single man. The machines can work 24 hours a day. The same will apply to herring sorting machines which will not work well when the ship rolls more than 10 to 15°. One can reduce the trawlers and longliners crew by at least 50 per cent if the process of fish handling is mechanized after the catch is brought on deck. Passive stabilization can aid such rationalization and is therefore of primary importance in the earning capacity of the fishermen and the ship.

Grönningsaeter called attention to the fishing vessel builders that if they could build ships in series of, say, 5 to 10 ships of the same lines and general properties, the cost of passive stabilization will be very small indeed compared to the advantages gained.

Importance of damping

Field (USA): van den Bosch's paper advocates the introduction of undamped free surface roll stabilizer tanks into fishing vessels as a means of reducing rolling in heavy seas. Perhaps the word "undamped" is a misnomer, since van den Bosch appears to rely upon the development of a transfer wave (bore effect) as well as frictional damping to provide a necessary damping of the liquid within the tank. From his aversion to stiffening placed within the tank, it is assumed that primary reliance is placed upon liquid damping through the development of the transfer wave.

Basic papers on this subject, such as the works of Chadwick and Klotter and others, as well as proprietary research which, for commercial reasons, remains unpublished, show the possibility of large destabilization effects in a theoretically undamped tank which is tuned to the resonant frequency of the ship. Measurement of the damping developed in the liquid by the wave itself is difficult, and cannot be accomplished separately from frictional damping. This damping should also be, in the absence of full-scale data, subject to a relatively indeterminate scale effect. It may well be that an uncontrolled free surface tank such as advocated by van den Bosch will more closely approximate the theory of Chadwick and Klotter than is made apparent by the testing of models.

It is believed that the introduction of controlled damping to a free surface tank is necessary in order to make the tank useful over a wide range of sea conditions and variations of loading. If one accepts the analogy of Chadwick and Klotter as substantiated by Ward and others in unpublished reports, and assume that the crossing points remain fixed, or nearly so, then it must be possible to vary the internal damping of the liquid in order to achieve an optimum, thereby resulting in a nearly flat response over the entire frequency range. This is best done by the installation of flow restrictions. The flume stabilization system, a passive tank system, designed by this method has been selected for over 200 vessels, including a number engaged in the fishing industry, and the results obtained have been highly satisfactory. It is interesting to note the continuing increase of acceptance of free surface passive tanks since the commercial introduction of this system in 1960. This continuing acceptance is no doubt the cause and effect of continuing research in the field.

While van den Bosch refers to the limitation in tank size

which results in the 50 per cent roll reduction shown in his fig 17 and 18, he does not state the nature of the sea spectrum in which this reduction was measured, in other than mathematical terms. This sea spectrum appears to have an approximate significant wave height of about 1 ft (0.3 m). In this regard, significant wave heights exceeding 5 ft (1.5 m) occur in the North Sea and Grand Banks areas, according to the climatological tables, about 60 per cent of the total time. Recognizing the limited tank size stated and the tendency for the response of the stabilized ship to peak at a non-resonant condition, the result that would be obtained in more representative conditions would not be adequate. It would be interesting if van den Bosch would set forth the tank size that he feels to be required to obtain adequate roll reduction (for example, 75 per cent) for the sea spectrum used in fig 17 and 18, as well as for the areas described above.

It should also be stated that fishing vessels may be subject to greater variations of loading than those considered in this paper. In addition, captains of such vessels may or may not be concerned about stability, and the introduction of a large uncontrolled free surface may present problems if not handled properly. Here again, the introduction of sufficient damping within the liquid to provide a flat response over the entire frequency range is an added measure for safety and efficiency.

In addition to this basic disagreement with van den Bosch, as to the necessity for internal damping within the passive stabilizer tank, it is also necessary to dispute the statement relative to activated "U" tanks, since to Field's knowledge no successful activated tank system has yet been installed in a large vessel. It is believed that statements as to relative efficiency should, in fairness, be deferred until after sufficient operational experience has been obtained.

Experience with bilge keels

The necessity for retention of bilge keels depends upon several factors. Some 20 vessels fitted with the system of Field's firm have been operated in Arctic service by the Canadian Department of Transport, through the expedient of fitting heating coils within these tanks. Here again, the proper amount of internal damping within the tank allows a good stabilizer response even when the stability has been drastically altered by icing of the upper portions of the vessel. While it is true that the damping of bilge keels increases considerably with large motions, the relative effect of bilge keels depends on the size of the stabilizer tank. A properly sized and effective stabilizer tank will furnish good stabilization even at extreme angles of roll. This is not to advocate removal of bilge keels from fishing vessels as such, since this is dependent upon a basic decision as to whether minimum motion is the principal factor or if the highest possible speed and maximum fuel economy to and from the fishing grounds is of greater importance.

The conclusions of van den Bosch relative to a passive tank with flush bulkheads being an effective means of roll damping are disputed, particularly with regard to reliability, as the failure to obtain a flat roll response independent of frequency for loading can result in serious operational difficulty. In any event, it is difficult to refer to the reliability of a system without the presentation of full-scale results.

Further, it would have been of interest for van den Bosch to specify additional references, other than the mention of Vossers. The work of Watts, as reported in the INA Transactions of 1883 and 1885 bears some relationship to the system proposed, and there are possibly additional portions of the prior art, used in the study, which would be of interest.

Stabilization by a properly designed passive tank system will greatly improve the productivity and utility of fishing

vessels, and is a matter for further consideration by all concerned. Stabilization attempted by an unproven system containing inherent limitations and deficiencies presents a potential danger, particularly in smaller vessels. It is not a question of the benefits of passive tank stabilization, as these are now almost universally accepted, but rather a matter of obtaining these benefits fully rather than only in part or not at all. The most discouraging factor in obtaining general acceptance of the principles of passive tank stabilization is the damage which can be done by one poor installation.

Pitch and roll tested

Foster (UK): In June 1965 the White Fish Authority, on a normal commercial voyage, carried out measurements of the pitch and roll of a stern trawler fitted with a passive tank free surface roll stabilizer. The principal dimensions of the vessel were as follows: Lpp 215 ft (65 m); Beam 41 ft (12.5 m); Draught 15.4 ft (4.7 m); Displacement 2,000 tons (sea water); Virtual GM 2 ft (0.6 m); Sea water stabilizing tank 20 tons. Several measurements were taken with the ship in the stabilized condition, i.e. 20 tons of sea water in the tank, and immediately afterwards, in the unstabilized condition, i.e. stabilizing tank empty. Typical results obtained were as follows:

- In a force 5 beam sea at a speed of 5 knots without the trawl gear down, reduction in roll was 25 per cent.
- In the same condition but with a quartering sea, the reduction in roll was 33 per cent.

These results obtained in real seas were rather disappointing.

It must be pointed out that the tank was an afterthought and was placed on the vessel in a position which was far from the ideal. Its actual position was aft under the stern ramp, the water in it was therefore subjected to yaw accelerations as well as to sideways linear accelerations and roll.

Because the tank was so unsuccessful it has been removed. However, this does not mean the end of commercial appraisal of such stabilizers in the British fishing fleet. At the present time, there are a number of stern trawlers being built which are to be fitted with them. Two in particular are sister ships, one of which is to be fitted with a passive free surface tank, while the other with a controlled passive tank of the U-tube type. When these two ships come into service the White Fish Authority intend to arrange to have them operate together so that a direct comparison can be made on the performance of the different systems. Once this has been done, it is hoped to publish the findings.

Backed by experiments

Goodrich (UK): van den Bosch is to be congratulated on the presentation and contents of his paper. He has shown that it is feasible to reduce the rolling motions of fishing vessels using a free surface tank of plane rectangular section. Goodrich wished to endorse all the conclusions reached in the paper, but it is worth emphasizing one or two points.

The results indicate that, given an adequate length of tank a dramatic reduction in the roll response can be achieved. The one factor which can then control the damped roll response is the depth of water in the tank. Fig 11 to 13 in van den Bosch's paper show the effect of varying the parameter h/b from 0.06 to 0.08. It can be seen that a change of this order produces relatively large changes in the response and it is worth noting that for the ship considered, of breadth 20.28 ft (6.18 m), the depth of water would be 14.6 and 19.5 in (371 and 496 mm) for the two curves given. This illustrates that the depth of water must be measured very accurately in the ship. An increase in depth beyond 19.5 in will lead to a serious increase in the roll response at low frequencies, which could affect the vessel when moving in quartering seas.

The results of the tests in irregular waves show that caution must be exercised when considering the results of tests in regular waves, or from oscillator tests. Fig 15 in van den Bosch's paper for example shows that the peak magnification factor of 11.5 is reduced to 1.5, an apparent reduction. of 95 per cent. However in irregular waves the significant roll angle is reduced from 13.72° to 6.84° when stabilized, a reduction of 50 per cent. These figures are in line with the experience at NPL.

Experiments have been in progress with a stern trawler for some time at NPL. The results substantiate those given in the paper and help to emphasize the point made earlier regarding depth of water. A variation of h/b from 0.056 to 0.081 represented a change of 12 in (305 mm) in depth for the ship. In irregular seas corresponding to a wind force 5, significant wave height of 10 ft (3.05 m), the significant roll angle was reduced from 33° out to 15°, a reduction of just over 50 per cent. These results are for the model at zero speed. The effect of forward speed is to materially reduce the significant roll angle in both the unstabilized and stabilized condition.

Whilst roll spectra are of interest to the expert it is suggested that this form of presentation is of little interest to the ship owner. A statistical presentation of results in the form of cumulative distribution diagrams of roll angle are easier to explain than spectra and show the reduction in maximum roll angle as a percentage probability.

There is no doubt that stabilizer tanks, of the type described in the paper, can be used widely in fishing vessels provided that adequate space is available in the correct position in the ship. However in certain circumstances, it is necessary to introduce some form of constriction in the tank in order to obtain the maximum roll stabilization. Stabilizers of this kind have been designed and tested at Ship Division, NPL, and are being installed in many vessels including several stern trawlers.

More evidence wanted

McNeely (USA): He took some exception with van den Bosch, having had some personal experience with anti-rolling tanks. From a study of mathematical expressions and results of model experiments, one would conclude that anti-roll tanks or "surge" tanks would be a distinct advantage for fishing vessels. More convincing evidence would be the actual installation and successful use. On one occasion, McNeely had cruised in unprotected waters aboard a fishing vessel having an anti-roll tank and was not favourably impressed. Although model tests and calculations prior to construction were excellent, performance of the full-sized tank left considerable to be desired. It appeared that inconsistent peak frequency of swells interrupted a constant frequency of surge within the tank, causing correction of some rolls and greater amplitude to others. Of particular nuisance was occasional late correction in rolls, resulting in a mental overcorrection by the passengers. It was most difficult to get one's "sea legs". Two weeks aboard the vessel resulted in disenchantment with anti-roll tanks. Crew members having considerably more time to evaluate the tank expressed similar opinions.

Personal experience given

Nickum (USA): In considering the effects of anti-rolling tanks Nickum requested someone to come up with a specific definition on which everyone could agree for the term "roll reduction". The term is used to define the reduction in the amplitude of roll and is also used to define the reduction in number of rolls over a given figure in a particular sea spectra. A simple, clear-cut definition that would give a comparison of the operation of a vessel with and without roll tanks and

thus be a measure of the benefit of these tanks would be helpful to the industry.

Nickum had personally had practical experience with anti-rolling tank installation in two vessels. The first, a 145 ft (44.2 m) ship operating out of Honolulu, and the second a 160 ft (48.7 m) ship operating off the US Pacific Coast. In the first case the anti-roll tank design called for holes to be placed in the centre vertical keel which extended longitudinally through the tank. These holes were not put in by the builder and thus did not allow passage of water through the keel. Unfortunately adequate tests and trials could not be made before the vessel had to leave for her home port of Honolulu and the action of the tank on the delivery trip and in the first several voyages of the ship was very unsatisfactory. Subsequently the holes were installed and tests were made that indicated effective reduction in roll. The crew, however, was still dissatisfied with the action of the ship and felt that it was uncomfortable. It took two years before they got used to using it and realized its effectiveness. On the second ship, which was also an oceanographic vessel operated off the US West Coast, the tank was installed properly, was activated on the first trial voyages, and met immediate acceptance on the part of the crew, a number of whom had been on sister ships that had not had this type of tank. The accuracy of the subjective judgment of crew members on a ship's motion always makes it difficult to get an accurate reflection of the true value of any device affecting ship's motion.

Wave slopes analysed

Nonweiler and du Cane (UK): van den Bosch's paper provides most useful and comprehensive information on the dynamics of passive tanks. As van den Bosch notes, some obscurities remain due to non-linearities in the performance over a wide range of roll amplitude, and the experimental data in fig 14 to 16 are quoted as indicative of this. Certainly the oscillation experiment shown in fig 14 suggests some lack of precise tuning between tank and ship (of the kind illustrated in fig 4) and would seemingly bear out van den Bosch's remarks concerning the variation of tank natural frequency with amplitude: the roll amplitudes in this experiment are quoted as less than the 0.1 radian of the calculation, but a more precise indication would be interesting. On the other hand, the comparison between calculation and measurement in the experiments with irregular disturbances, which would be anticipated to be most revealing of non-linear effects, shows a good agreement.

Nonweiler and du Cane had recently completed a very comprehensive analysis of wave slopes as deduced from some 3,000-ten-minute observations (spread over a year) of the sea at Sevenstones Light, supplied by the National Institute of Oceanography. From this it would appear that a significant wave slope amplitude of $3\frac{1}{2}$ degrees is typical of an "average" sea: values as high as 6 degrees would be experienced for 10 per cent of the time (allowing for an arbitrary direction between wave fronts and ship motion) and values of 10 degrees would be encountered for 1 per cent of the time. It would be wrong of course to seek to find the corresponding roll angles in such steep seas by applying the magnification factors quoted by van den Bosch. As he mentions, the ship's natural damping improves with increasing amplitude, whereas the stabilizing effect of the tank would presumably be reduced. Nonetheless, it is in such steep seas that fishing becomes impossible, and the cost of an effective stabilizer would begin to be repaid.

van den Bosch in his introduction does not mention the moving solid weight (mounted, say, on a curved track, buffered at each end) as an alternative stabilizing device; it is one which has been apparently neglected as yet, but in which we have an active interest. It exists in various forms. It may

rely simply on "natural" mechanical friction, in which case suitable adjustment of this friction and track curvature can produce a roughly similar performance to any free-surface tank, with however the obvious advantage that the weight, being more compact, has a larger effective moment than the same mass of water, and occupies a tunnel of only about a tenth of the recommended tank volume; further, it avoids some of the operational disadvantages of water, and maintains its natural period independent of amplitude. In a second form, it appears as a "semi-active" device with a brake activated by an electrical switch and control system. Finally, it may be "active", driven, say, by a hydraulic pump-motor which conserves its energy, so remaining virtually independent of the ship's power supplies. These various degrees of sophistication result in improved performance and flexibility at, of course, some extra cost. A weight of 2 per cent of the ship displacement, with a value of GM/B of about 0.1 could provide a static heel of about $+5$ degrees (the so-called "wave slope capacity"), and in waves of smaller slope than this capacity, the active weight can produce reductions in magnification factor to well below unity, virtually eliminating roll.

Technical points raised

Norrbin (Sweden): van den Bosch's paper is interesting and very clear. It is perfectly appropriate to have such a paper read before an assembly of specialists, most of whom are not from this branch of the profession. It will help to dispel from the mind of many ship owners and ship operators that belief in magic formulae, which from time to time is encouraged by patent specifications.

Unlike the U-tube type of passive tanks, the free surface tanks mainly depend on energy losses due to flow discontinuities to achieve that degree of damping, which is necessary to avoid excessive tank liquid motions at resonance as well as to create, at all rolling frequencies, an out-of-phase-of-heel resisting moment high enough to even out the two response maxima associated with the two-degree-of-freedom system. These flow discontinuities may be initiated by a sudden increase of channel width or by the formation of a "bore" or "hydraulic jump"—"Wasserstoss"—in the shallow flow over the tank bottom. The flow velocities within the tank are so small that viscous damping will then be of second order. As a consequence, scale effects will also be small.

The oscillating motion of water particles in a free surface tank of moderate depth, h, which is forced to roll at resonance, takes place along lines of U-form near to the sides and bottom of the tank, and along an almost straight line parallel to the bottom on the surface at the centre of the tank. Still, the period of the standing wave is with a good approximation given by the time taken for a wave on depth h on an infinite surface to travel twice the width of the tank. Especially the celerity of the shallow water wave is equal to $\sqrt{gh}$, from which the suitable tank depth h is governed by the relation $h = \dfrac{b^2}{\pi^2 g} \omega_t^2$ as given in the paper. It will be noticed that the water particles of the ideal shallow wave move back and forth with equal velocity parallel to the bottom, in which case the so-called "critical depth" is equal to the water depth at the critical speed condition. If the actual motion of the particles is modified due to the end walls and due to a viscous boundary layer along the bottom, the critical depth may occur at a position below the surface. At the critical flow velocity a "roller" is formed at the critical depth, initiating the formation of the bore. Viscosity may indirectly affect the bore by changing the critical depth. It is also possible that surface tension may introduce another source of scaling errors. Still,

Norrbin was not as pessimistic as was Field about the application of van den Bosch's results to full-scale predictions.

At resonance the flow of water of a properly tuned tank is lagging 180 degrees behind the roll-angle of the ship. In the upper photograph of fig 5 in van den Bosch's paper, the ship is seen heeled to starboard, say: water starts moving down-slope rising the local depth at this side as the ship rolls back to port. At a certain stage the conditions become critical in a certain point and the roller appears. The bore front is now travelling upstream, and the maximum damping moment is reached in the upright position, where the rolling velocity also has its maximum. From the second photograph one can easily estimate two distinct levels upstream (to the left), and downstream of the bore, which in principle make it possible to calculate the loss of energy in the bore. Then it seems to be possible to calculate the instantaneous damping coefficient of the tank water, or a mean value during the cycle, and the transverse mass transport in the tank might finally be described by a second order differential equation with non-linear damping, in which the forcing function depends on roll angle and angular acceleration. Again, the roll-damping moment due to this mass transport will then be a function of transport amplitude and acceleration, and it will be possible to treat the rolling in waves on basis of two simultaneous equations in two degrees of freedom. Norrbin asked van den Bosch if he thinks it would be feasible to evaluate his tank oscillation tests along such lines.

It might be that the depth corresponding to a tank water period equal to that of the ship will be too large for the formation of the bore. In such a case it might be better to choose a smaller width of the tank, making it a little longer in fore-and-aft direction instead; alternatively, suitable obstructions may be placed in the channel, creating "Borda losses". Existing installations seem to rely on both types of flow damping phenomena.

Five questions asked

Corlett (UK): van den Bosch's paper is most interesting and is helpful to designers. Corlett awaited the comments of those with a specialist interest with bated breath and it is apparent that there is not complete quantitative agreement.

A practical passive tank must be insensitive to the natural roll period or it will not be used by fishermen. Fortunately the stability conditions rarely vary as much as is shown in table 1 of van den Bosch's paper, at any rate with trawlers, and fig 11 to 13 of his paper are thus most encouraging. The relative insensitivity to the depth of water in the tank is helpful provided the depth is kept less rather than more than the median value. Safety depends upon this factor, and being the predominant consideration, leads to the following questions:

- How does one determine $\dfrac{h}{b}$ when filling the tank unless the vessel is stationary? Would this perhaps best be done by using an auxiliary fixed capacity contents tank?
- How noisy is the tank when operating in a considerable seaway? If it is really noisy, some fishermen might not want to use it because of mistrust of this apparently large amount of water rushing around aimlessly in the tank.
- Can the out of phase component become displaced and produce a dangerous in phase situation in the event of the checked roll which can happen in small ships? Corlett referred to a case where a roll is starting and then the ship is checked by an odd sea and then flung back the other way as sometimes happens. He imagined the possibility in this case with

a relatively undamped tank that the water could become in phase temporarily with the ship motion.
- What is the effect of a temporary list say when handling gear over the side? It will be obvious that the water will run to the lower side but, provided the surface does not reach the top of the tank, in other words that the list is not too big, will the tank continue to operate efficiently and without danger?
- What modification to the amplification factor would van den Bosch expect if bilge keels were fitted on the ship in question?

The influence of underwater damping is critical and one finds that the use of interrupted plate bilge keels is most beneficial on these small ships. They must, of course, follow the flow line which may not be easy to arrange. Corlett was disappointed in the lack of papers concerning yawing and broaching. This aspect of seakeeping in some waters more than anything else separates the sheep from the goat. He would be interested also to have van den Bosch's opinion of the effect upon course stability and yawing of the presence of the anti-roll tank in a small ship. In many cases, especially with square plan view sterns for stern fishing, Corlett imagined controlling the roll under quartering sea conditions, etc. could be most beneficial, but, on the other hand, it could lead to an increase in yawing as the quarters are dug into oncoming waves.

In conclusion, Corlett thanked van den Bosch for a most interesting paper. Any competent designer can design a tank from the data given in the paper and Corlett looks forward to an opportunity in the future of trying van den Bosch's type of tank in a ship.

Author's reply

van den Bosch (Netherlands): In reply to Foussat, remarked that every tank in the vessel, which is partially filled can be treated along the lines set forth in the paper. If for a certain tank the natural frequency is calculated and this natural frequency appears to be much higher than the resonance frequency of the ship, the only influence which has to be taken into account is the loss of GM. When ω_t appears to be much lower than ω_ϕ, the influence can be neglected. When ω_t approximates ω_ϕ the tank acts as an anti-rolling tank. When a calculation is carried out, however, it will in most cases be evident that the influence is immaterial, as the tank moments are proportional to b^3 and most fuel or ballast tanks have a very limited width. When a large GM reduction is expected because of the large deep tanks for instance, the GM reduction should be taken into account when deciding on a design value for the tank.

Field suggested that the tank is "undamped" without explaining exactly what is meant by that. When considering fig 6 and 7 it is clear from the slope of the phase curve that the water motion in the tank is heavily damped. Nobody would doubt the damping of the breaking ocean swell on a gently sloping beach and in the tank energy is dissipated in the same way.

A theoretical treatment of the tank phenomena is given by Verhagen and van Wijngaarden (1965). Although the theory does not include viscous effects, the damping of the system is clearly proved. Theoretical and experimental results show a good agreement.

According to van den Bosch experience restrictions in the tank may have a favourable effect only for relatively low GM values, whereas, for the proportions of most fishing vessels a flush tank without restrictions will give the best results or the difference will be unimportant.

Field mentioned the work of Chadwick and Klotter (1954)

as a basic paper on the subject. van den Bosch did not agree with this. The "Theory of Chadwick and Klotter" is in fact an application of the general theory of oscillating systems with two degrees of freedom, in which the motion is described by two simultaneous linear differential equations with constant coefficients. van den Bosch believed that this theory is absolutely inadequate to describe the combined ship-tank system, because the motion is not linear and the coefficients are highly dependent on the frequency.

Contrary to the remark of Field, it is believed that scale effects are immaterial. This is substantiated by experiments not mentioned in the paper and by the theoretical approach of Verhagen and van Wijngaarden, and it is in accordance with the remarks of Norrbin.

van den Bosch did not see much sense in stating the significant wave height or wave slope, as this suggests that there is a direct relation between the significant wave height or wave slope and the significant roll amplitude. As the rolling ship responds only to wave moments in a rather limited frequency band, the motion has no bearing on the waves outside this range which, however, do contribute to the significant values of the height or the slope.

Anyhow the significant wave height of the model spectrum corresponds to about 2.7 ft (0.8 m) full scale and most of the wave energy was concentrated in the important frequency range.

As already stated in the paper the aim of the tests was not to show the model under extreme conditions but to check the validity of the applied procedure.

Goodrich is thanked for his favourable comments. He suggests that given an adequate length of tank a dramatic reduction in the roll response can be achieved. This has been brought into practice in the case of bulkcarriers which have excessive large GM values in ballast condition. By filling one hold with sea water to a predescribed level a huge anti-rolling tank is created, rendering the ship as steady as a rock.

Several contributors, Foster, McNeely, Nickum reported cases of installations which behaved unsatisfactorily. Often the causes can be traced to bad design or unproper handling. Work on this subject is often hampered by the tendency to emotional judgment.

Nonweiler and Du Cane suggest that there existed "some lack of precise tuning between tank and ship". Presumably this remark concerns the fact that the "cross points" between the characteristics of the ship with and without tank, did not lie at the same height as shown in fig 14. This consideration originates from the double pendulum theory. As already said in connection with the contribution of Field, van den Bosch believed that this theory is inadequate, because of the frequency dependence and the non-linearity of the quantities concerned.

van den Bosch disagreed with the use of the significant wave slope as a measure of comparison, as already mentioned in the reply to the contribution of Field.

The remarks of Nonweiler and du Cane about moving a solid weight are interesting. The moving weight certainly offers possibilities which have been neglected, but van den Bosch did not know of any installation in use nowadays.

Norrbin is thanked for his help to dispel the belief in magic formulae, and for his contribution concerning scale effects. His views are in agreement with van den Bosch's observations.

For very high $\frac{GM}{B}$ ratios the waterdepth in the tank has to be

so high that the bore is formed only in a very limited frequency range. In that case this bore principle is not usable and perhaps some other system may be more fit to cope with this situation.

van den Bosch did not believe that choosing a tank of smaller width will be the solution as the moment amplitude

is to a large degree controlled by the width of the tank and stiff ships need large stabilizing moments.

In reply to the questions of Corlett it was stated that the filling of the tank to the right level is not difficult. For instance an athwartship partition bulkhead with a sluice operated from outside, may divide the tank into two compartments, one of which having the desired volume. When this supply tank is filled to the overflow the sluice is opened and the water is distributed over the two compartments. During full scale measurements van den Bosch and his collaborators used a calibrated flow meter in the feed-pipe of the tank.

The noise of the tank can be damped considerably by fitting a perforated plate on the innerside of the frames, with about 75 to 80 per cent perforation.

In full scale and in model the response of the tank to irregular motions appeared to be almost immediate. As the tank is certainly not "relatively undamped" the danger that the tank water will get in phase temporarily seems not great. Moreover when the amplitude of motion increases the phase curve flattens, indicating that the damping action spreads over a much larger frequency range.

A temporary list will, if not too big, not much influence the behaviour of the tank. When the list is so great that the water remains mainly at one side, the efficiency of the tank is presumably less than in the upright position. The tank does not present any danger then because the effect will be reduced to the influence of the momentary free surface on the GM value. The loss of GM has to be considered in the design stage.

The model in question was fitted out with bilge keels. Knowledge about actual amplification factors at sea is very scarce. It appears that the short-crestedness of the seas brings about seemingly low amplification factors.

There is not much known about the coupling and phases of the ship motions in quartering seas and certainly there is not much known about the interaction of the tank with ship motions other than roll. Because of this lack of knowledge it is not advisable to place an anti-rolling tank in the ends of the vessel. If the tank is placed amidships it can reasonably not have much influence on yawing or course stability. Also the yawing motion cannot have an appreciable influence on the tank action.

CATAMARANS AND OTHER UNORTHODOX CONFIGURATIONS

History of "Cats"

Chapelle (USA): MacLear's conservative presentation of the catamaran is unusual where this subject is concerned. In his short introduction he may have given the impression that powered catamarans have been few in number. This impression is not correct. Sailing catamarans of vessel-size were built in England in the Restoration Period and have appeared in number since that time, of course. Power catamarans appeared in the 1790s when Miller built his manually-powered and sailing catamaran, with a paddle-wheel between the hulls, which he brought to Sweden. Here he proposed a man-of-war of this design to the king. The king referred the proposal to Chapman, the great Swedish naval architect of the 18th century, who condemned the plan. Fulton's steam battery sometimes called *Demologos*, built at New York in 1815, was the first steam man-of-war and a catamaran. A Hudson River steamer, having two cigar-shaped hulls was tried in the 1840s. A cross-channel steamer-catamaran was built in England later in the century. There were a large number of smaller catamaran steamers, ferry-boats and river craft, built in this century. In the 1840s the catamaran snag-boat was introduced on the Mississippi, propelled by a paddlewheel between the hulls or by side paddlewheels.

It must be admitted that the majority of catamaran steamers were intended to be very fast. In this, most of the promoters were disappointed. In many of these vessels the advantages of the catamaran defeated the project. The great deck space obtainable tempted the builders to add great accommodations and as a result the displacement became heavy to support this loading.

During the last war the German Army utilized catamarans as tank transporters; model tests of these were carried out in the Hamburg tank, Chapelle believed. Some of the boats built on these test data were air-propelled, others screw. Their speed was not very satisfactory, nor did they steer well.

In general, Chapman's comments seemed still sound; the catamaran is best employed as a small, very light craft. Displacement and draft determine manoeuvrability to a very marked degree.

Steering by use of twin screws seems wasteful. Chapelle had proposed that the twin-engines of the "outboard installation introduced before the last war" be used. These had drive arrangements so that the propeller steered the vessel as in the ordinary outboard engine. Linking these together would give more precise steering. The need for a constant loading in catamarans remains the chief objection as a commercial vessel.

In net fishing, where the deck space of a catamaran would be her great advantage, quick response in steering will be a necessity when the vessel is working close to her nets. So far this problem is not wholly solved.

Experienced comment

Adam (France): Wanted to use his 15 years' experience as a yachtsman on multi-hulled boats, to make some comments on the catamaran paper by MacLear. Firstly, waves hitting the central platform might cause very severe impact problems. Secondly, if their rolling motion is reduced, compared to mono-hulled boats, the high initial stability of catamarans brings about two disadvantages (1) brutal movements causing dangerous strains in the boatstructure; (2) rapidity of the motion which might create seasickness as well as or better than ample slow rolling. Lightness of construction is the best way of overcoming these disadvantages. It can be more easily achieved for yachting than for commercial utilization, the latter implying carrying of goods or fish.

Takehana (Japan): Agreed with MacLear's opinion on the advantages of catamaran fishing vessels. In Japan there are now two steel catamaran ferry boats. Takehana thought that smaller fishing catamarans under 20 GT and pleasure boats, constructed of fibre glass reinforced plastics could be introduced in the near future. This type of vessel should be well suited for catamarans for the following reasons:

- The draft of a catamaran hull can be easily adjusted to prevent excessive lee way of the light ship and retaining good stability.
- FRP construction is particularly suitable to make extremely light and strong hull structures required for catamarans ·and also to reduce construction costs below those for wood and steel construction.

Takehana believed that a combination of these new hull types and new construction materials would result in more seaworthy and more economical fishing vessels.

Recent study

Hamlin (USA): The catamaran has been given serious study for large craft only since the days of World War II. Perhaps the first to recognize its potential advantages was Gar Wood, who, during World War II, began the design and supervised construction of an experimental catamaran for the US Navy.

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The War ending before its completion, he purchased the vessel from the Navy and completed it at his own expense. 188 ft (57.4 m) Loa with a 40 ft (12.2 m) beam, the vessel was reportedly capable of speeds of 26 knots in rough Gulf Stream seas. She eventually disintegrated at sea, presumably because of inferior war-time materials used in her construction.

More recently, the catamaran has attracted considerable attention in USA, primarily for marine research and survey work, but also for yachts and fishing vessels. A 70 ft (21.4 m) ×28 ft (8.5 m) catamaran trawler is currently undergoing trials. The most ambitious catamaran in USA to date is a 278 ft (85 m) × 105 (32 m) deep drilling vessel of 5,100 deadweight tons with 3,000 hp giving a service speed of 12 knots; she was designed by Friede and Goldman (1965).

Japan is another major source of catamaran activity. There, the Nippon Kokan KK has been building steel passenger and vehicle ferries up to 136×40 ft (41.5 × 12.2 m) with larger ones projected, fig 7 and 8. Several are in use on the rivers of Thailand, others are crossing between Japanese islands.

This brief sampling of some of the worldwide activity in catamarans should encourage fishing interests to examine carefully the advantages accruing from the twin-hull configuration. Based on a comparison of single-hull and catamaran craft of equal displacement and hence assumed equal cost, some of these advantages are (Hamlin, 1965):

Fig. 7

● Approximately 50 per cent more deck space than a conventional vessel, enclosed and open areas combined, in efficient, rectangular shapes.

● 5 to 10 per cent greater cruising speed for a given horsepower or, conversely, a reduction of about 15 per cent in horsepower for a given speed which translates into a proportional increase in cruising range and an increase of approximately 30 per cent in reachable fishing area.

● Reduction of roll angles by up to 50 per cent or better, including elimination of rhythmic rolling, with a reduction of average accelerations and no significant increase of maximum accelerations.

● Ability to handle large loads (up to 10 per cent or more of the displacement) without dangerous heeling or trimming effects.

Structurally, the catamaran seems to offer no problems, at least within the size range of most fishing vessels. Calculations (Mandel, 1962) indicate that, in catamarans up to 4,000 tons displacement, scantlings adequate to meet local strength requirements are adequate for overall structural strength requirements. As an added feature, the hull form may be such as to permit the extensive use of flat plates and simple stock shapes for structural members.

There are some important questions about catamarans which still need clarification. Perhaps the most important from the fisherman's point of view is how his fishing gear should best be handled. Should he shoot and haul over the stern, over one side, or through a central hatch? Should he tow from each quarter, from a central point at the stern, or from some point forward of the stern? Is it possible to avoid hauling gear on deck by use of a hydraulically operated platform on to which the catch could be landed under water?

Hamlin suggested that these questions might be answered most efficiently and thoroughly by use of a man-carrying model catamaran. Such a vessel could be rigged with simulated fishing gear of any type, quickly and inexpensively, and such gear could be tried out in actual fishing operations. Towing tank testing will provide valuable information on horsepower
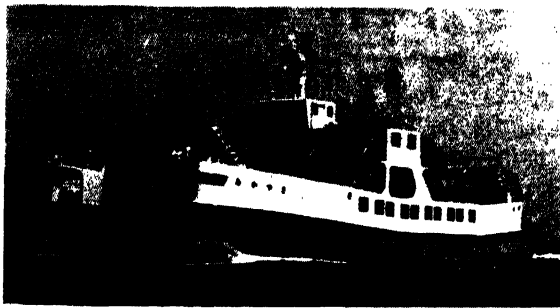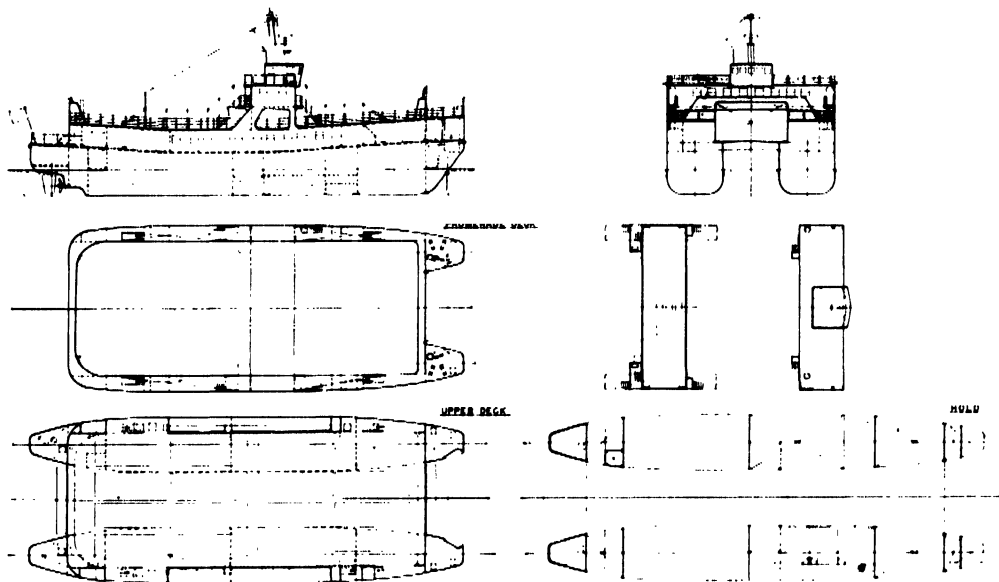
Fig. 8

Fig 7 and 8. A vehicle and passenger ferry, 136 × 53 ft (41.5 × 16.2 m) designed and built by Nippon Kokan KK

[191]
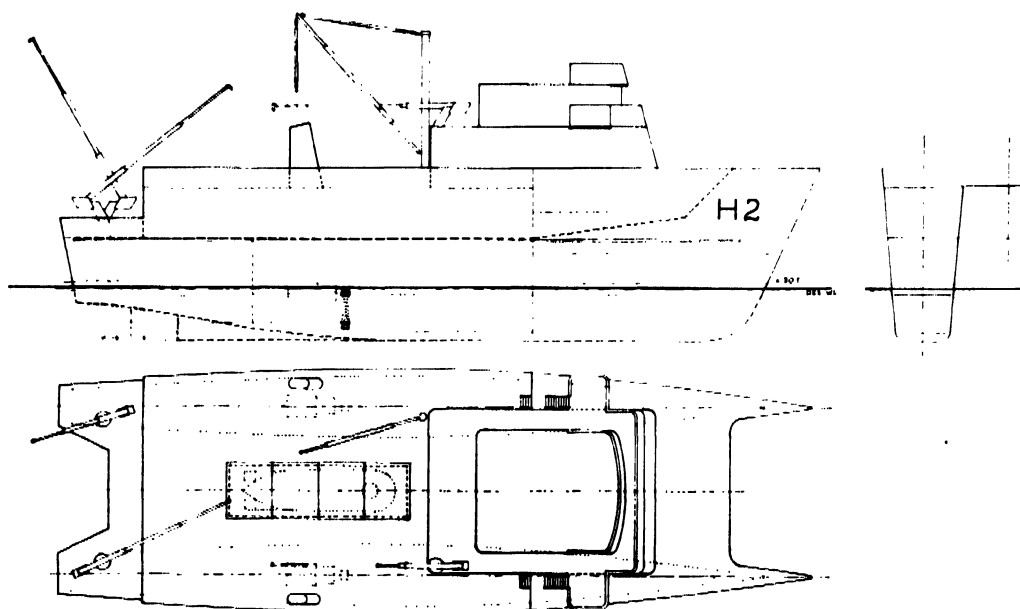
Fig 9. A catamaran oceanographic research vessel, 149 × 48 ft (45.5 × 14.6 m), by Hamlin. Speed approximately 13 knots. A submarine is stowed in the centre well

requirements etc., but cannot adequately answer the questions stated above.

The catamaran concept is relatively new in its application to modern seagoing usage. It is therefore important that the body of data on the type is augmented as rapidly as possible. Fig 9 shows a proposed 149 ft (45.5 m) oceanographic research vessel, and fig 10 a proposed 120 ft (36 m) passenger catamaran.
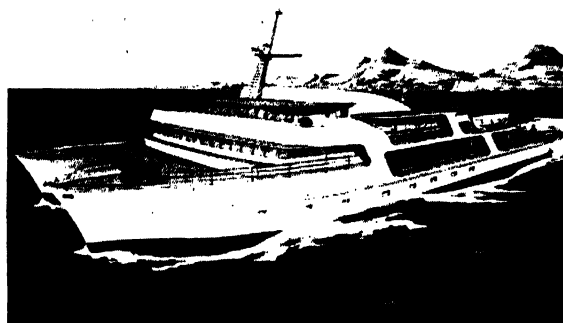
Fig 10. A passenger catamaran, 120 × 45 ft (36 × 13.7 m), by MacLear and Harris. Forty passengers, ten crew, 11 knots cruising speed.

New study of an old form

Melchert (Switzerland): It is amazing that catamaran craft, which figure among the oldest constructions in the history of ships, have been studied according to marine techniques only in the last few decades. Certainly they have a bigger weight and higher building costs than those of a conventional ship of the same deadweight. However, they have so many advantages that they will certainly have a wide field of application in the near future. It is therefore a real pleasure to read how these promising advantages have been pointed out by MacLear, especially from the viewpoint of catamarans as fishing craft.

There was one point which Melchert wanted to add to the questions of structure and drag. The firm of consultant naval architects, where he works, recently investigated the problem of how the open framework built up by the two hulls and by the wing could be closed below the water in order to make the construction stronger and more rigid. These endeavours led to a successful solution which has since been patented. In general, the wing structure, and especially its connection with the hull, has to be extremely strong and rigid. However, when a structural connection between both hulls is fitted, the stresses in the wing girders are considerably reduced. The problem was how to fit such a girder below the waterline so that the least possible increase in resistance would occur. As against the expectation of the experts for structural questions, this problem was solved by the hydrodynamic experts in such a way that not only was there no increase in drag but, on the contrary, a considerable reduction. It should be recalled that the bow waves of both hulls are superimposed upon each other within the channel created by the inner board walls of both hulls. At the point where their crests meet, a so-called fountain appears, and in the range beyond this fountain the divergent wave system disappears and a whole wave energy builds up an extremely pronounced transverse wave system. This wave system is very similar to so-called two-dimensional waves. Now Kelvin has already shown that any two-dimensional waves can be completely eliminated. He has even calculated the form of a ship with infinite breadth but finite length which would produce no free waves at all.

Analysing the wave system

Remembering these facts, the hydrodynamic experts started to analyse the wave system of a 10 knot catamaran craft of 95 ft (29 m) length, and they concluded that a similar wave system with reverse amplitudes could be produced in the following ways:

● introducing a cylindrical bar of a certain radius between both hulls at a suitable position

● a more exact adaptation of the secondary wave system could be achieved with certain elliptical or similar forms

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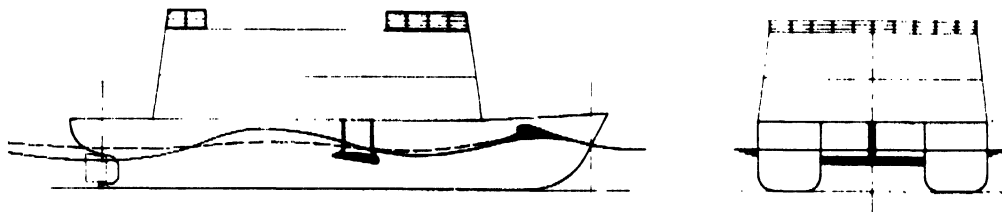
Fig 11. A girder with an aerofoil profile for reinforcement of a catamaran

- a similar effect could be obtained by introducing a girder with an aerofoil profile, the shape and the position of which have to suit the original channel wave profile (see fig 11)
- adaptation of the secondary wave system to a variable channel wave profile, which might become necessary when the craft sailed at variable draught, could be achieved by a suitable control of the angle of attack or by lifting control through a high lift flap or by telescopic suspension.

Of these possibilities, the high lift flap seems to be the most appropriate from the structural viewpoint. Good results can, however, also be achieved with completely fixed aerofoil connections when their position and angle of attack are selected on the basis of compromise for the varying draughts.

The secondary wave system produced by these wave-making bodies cancels to a great extent the channel wave. In the case of the 10 knot catamaran craft, there was also the advantage that, while the hollow of the channel wave touched the propeller tips at full speed in the original design, after application of a wave-cancelling connection, the water level was raised considerably at the aft ship so that the propellers were well immersed. As compared with the resistances of the original catamaran craft, the application of the wave-cancelling connection reduced the resistances by 20 per cent. The drag curves versus speed had a point of intersection at about 8 knots, and above that speed the gain increased continuously and had still a considerable positive gradient at 10 knots. Unfortunately, the model was on such a big scale that the model basin could not make measurements at higher speeds, so that the highest possible improvements at optimum speed could not be determined, though it is quite clear that this maximum improvement would have been far higher than 20 per cent.

It would certainly be possible to apply more than one connection between both hulls, provided that their own wave systems are correctly adapted to the original channel waves. This would permit the most effective frame construction to be made and would allow the wave-making bodies to be lowered, which would be of considerable advantage when sailing in stormy seas and also from the viewpoint of ship's structure.

In view of the above advantages, it seems to be advisable to make use of this possibility of constructing better catamaran craft.

Imaginative appeal

Grigore (USA): MacLear has made an outstanding technical contribution towards bettering the performance and productivity of the world's small craft fishing fleet. The acceptance of the catamaran hull as a floating work platform is beginning to dawn upon the imagination of the prospective user. It has been too long in coming, even though some of the delay has been keyed to the progress of design, metallurgical and welding developments.

As one of the initiators of the *US Johnson*, and as the project engineer for the development and test of amphibious vehicles of the US Government, Grigore felt he could discuss with authority the subject of catamarans and of negotiating surf zones.

Of the catamaran, if it is not properly designed and hydrodynamically model tested, it can result in being more of a "goat" than a boat. This almost happened to the *US Johnson* insofar as her anticipated versus actual water speed was concerned. The project engineer had been overruled by civil engineer management to wit: That sufficient know-how already existed about small boats, and that one of the better catamaran designers was conducting the naval architecture of the boat, therefore no funds should be expended to prove the hydrodynamic adequacy of the hull configuration. However, in every other respect the *US Johnson* completely fulfilled her requirements and upheld the judgment of her sponsors (see Military Engineer Magazine, May-June 1962). She also brought many converts to her favour. Insofar as beaching the *Johnson*, this has been done frequently with no effect whatsoever on either hull or the underwater jet propulsion system. Since surf is not a predominant factor in the Great Lakes, very little surfing experience could be gained with the *Johnson*. But this is not to say that it was desired to do so or was considered necessary.

Grigore considered that attempting to run the surf and to ground with any catamaran should best be left to amphibious vehicles of the surfing variety and that MacLear may be unconsciously trying to connect the romantics of Polynesia into the operation of catamaran fishing boats which absolutely have no need or place in a surf environment. Grigore could not stress this point too emphatically. It is totally unsafe for any inexperienced person to be caught in the powerful clutches of a plunging surf or the treacherous secondary currents, and undeterminable beach gradients which exist between the surf zone and beach line.

What Grigore really believed was that MacLear intended in lieu of surfing a catamaran fishing boat is actually beaching it in a calm water area where sufficient tidal range exists to bare the entire hull for maintenance purposes. Many such areas exist without the need to recourse to jeopardizing life and property unnecessarily in a surf zone.

Lastly, it is suggested that the co-operation of the USSR be solicited to obtain their experience with a self-propelled 300 ft (91 m) catamaran hull built for cargo transport on the Volga River and Black Sea routes.

Author's reply

MacLear (USA): Agreed with Adams concerning the fast motion of catamarans but would like to add that double-ended catamarans should be avoided to slow down pitching. He also agreed with Chapelle that quite a few owners had been disappointed in the speed performance of catamarans but aluminium construction should help reduce this problem. He was in complete agreement with Takehana in respect of new materials, such as aluminium, fibre glass or plywood etc.

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HYDROFOIL CRAFT AND HOVERCRAFT

Hareide (Norway): Since 1960/61 four hydrofoil boats have been trading regularly as passenger vessels in Norwegian waters. Two of them are PT-50, certified for 100 passengers between Stavanger-Haugesund-Bergen. The remaining two are PT-20, certified for 60-64 passengers. Two more PT-20's started trading in 1963.

The larger vessels cross two open stretches of sea of 9 to 10 miles, although both stretches are partly sheltered by islands and shoals. This route and such unsheltered stretches have so far been the limit to which regular trading has been permitted. The smaller vessels operate almost wholly within sheltered waters.

The vessels were initially only allowed daylight operation on the foils and only in May through September. Based on the experience gained, winter trading in ice-free waters has later been permitted. Likewise trading on the foils in what is termed "civil twilight" has been allowed. This permit was for the aforementioned route Stavanger-Bergen, subject to the condition that the owners at one of the open stretches provide a suitable port of refuge with arrangements for transport of passengers to the next regular port of call. The trading is at all times subject to the Master's discretion as regards weather conditions, but maximum permissible wind force and wave height have been stipulated as mentioned below. Experiments in night operation on the foils have been carried out. The question of such operation will be reconsidered in early autumn 1965. The authorities are aware that such operation is allowed in at least two heavily trafficated areas in other countries and that night traffic at a certain minimum distance from the coast has been allowed in other cases. This last question has not been brought up in Norway.

As to other general conditions the following may be of special interest:

Hull as accepted by the classification society, the Norwegian Veritas. Frequent surveys of bottom, foils, propellers, etc. on account of weaker construction than conventional vessels and cavitation problems.

Engine of "railway type". A lighter construction than the usual marine type. Cruising speed for PT-20 about 32 knots and for PT-50 about 35 knots. Fuel tank capacity about 10 hours at full speed.

Stability. Damage and intact stability calculations as for conventional passenger ships.

Life-saving appliances. As it is virtually impossible in passenger trade to have lifeboats on board hydrofoil craft, inflatable life-rafts have been accepted. Lifejackets etc. as usual.

Navigation and communication equipment. Usual requirements for other vessels in similar trades. In addition two-way radiotelephone and radar. Regular radio contact with shore stations to be maintained. Without first-class radar equipment and radar observer, operation on the foils in darkness is not sufficiently safe in coastal or congested waters. In this connection it must be taken into account that because of their high speed, hydrofoil boats will encounter about twice as much traffic as ordinary vessels. If Hareide was correctly informed however, radar is not at present required on hydrofoil craft operating at night in New York harbour.

Sea and wind conditions. Wave height below 6 ft (1.8 m). Maximum wind strength 6 Beaufort scale.

Usability for fishing purposes. The operation of hydrofoil boats for passenger service has been subject to stringent regulations as regards sea, weather and temperatures,

visibility etc. Some alleviations might be expected for the use of the craft as a fishing vessel, but the boat is not built for, and could presumably not be used in such rough sea and weather as fishing vessels operate in outside the Norwegian coast. In this connection one should take into account that in order to keep the weight sufficiently down for the hydrofoil craft to retain its ability to operate on the foils, it is necessary to exempt the vessel from the conventional requirements as regards structural strength, shell thickness etc. It will likewise be impracticable for the craft to use dorys or other working boats (even life-boats will be difficult to carry), and heavy fishing gear such as trawls and purse seines. In addition such gear might cause serious damage to the vessel which would have to operate on the hull while fishing. The foils will presumably also hamper or make impracticable the use of modern fishing gear.

Fishing with trolling lines would likewise have to be performed at low speed, that is on the hull. Quite apart from that, such fishing as well as the use of longlining and similar fishing tackle, could hardly be profitable considering that the hydrofoil boat itself costs more than a fishing vessel of the same size furnished with trawl, purse-seines or other modern fishing gear. The high building and operating expenses will of course reduce the usability of the hydrofoil boat in all kinds of fishing.

The only advantage of the hydrofoil boat in the fishing industry seems to be the rapid passage to and from fishing grounds, weather permitting. Under such conditions she might be used working in a team with conventional fishing vessels in the near coastal regions for the transport of special kinds of fresh fish or other sea food. With the present construction of the ship, the loading will however at the best be a cumbersome process.

In conclusion one might say that the hydrofoil vessel at present does not seem to provide practical possibilities for improved efficiency of the fisheries in waters similar to those adjacent to the Norwegian coast. The outlook for the hydrofoil boats in sports fishing seems more promising however, especially as regards smaller versions than the PT-20.

Two types of hovercraft have been allowed for test operations in passenger trade in Norway, viz. the SR-N5 and SR-N6.

Dimensions of SR-N5:

Length overall . . .	39 ft 5 in	(11.9 m)
Breadth	22 ft 9 in	(7.0 m)
Height (from lower lining of		
shirt)	16 ft	(4.9 m)
Maximum total weight .	15,000 lb	(6,804 kg)
Weight of craft fully equipped including fuel . .	11,020 lb	(5,000 kg)
Carrying capacity . .	3,980 lb	(1,804 kg)

Dimensions of SR-N6

Length overall . . .	48 ft 5 in	(14.8 m)
Breadth	23 ft	(7.0 m)
Height	17 ft 4 in	(5.3 m)
Maximum total weight .	20,000 lb	(9,080 kg)
Calculated weight of craft fully equipped including fuel	11,630 lb	(5,280 kg)
Carrying capacity . .	8,370 lb	(3,800 kg)

Fuel tank capacity when trading at full speed of about 60 knots is for 3½ hours. The craft shall not be used in passenger trade as mentioned if the wind force may be expected to exceed 20 knots (about 10 m/sec) or if the wave height may be expected to exceed 5 ft (1.5 m). The speed in combination with sea and wind conditions shall not subject the hovercraft

to a vertical acceleration greater than 2 g. The craft shall be hoisted up for inspection every 30 hours. Surveys are to be frequent.

The construction of the craft is in accordance with that of an aircraft rather than a ship. The skin (shell) is of paper thickness. The characteristic feature of the hovercraft is that its general operative purpose is to move while hovering freely in the air at a limited height. Even though it is not designed to move in water nor on land like ordinary vessels or vehicles respectively, it can in an emergency stay afloat and move at slow speed. It can also move on land or ice under certain circumstances.

It follows from the inherent qualities of the craft, and its method of operation included its high speed, that it has inferior manoeuvrability, susceptibility to wind effects and a high level of noise which makes it practically impossible for the crew to hear sound signals. It has therefore been considered necessary to provide special rules for the steering, signs and signals of hovercraft. Here it may be sufficient to mention that the hovercraft when airborne shall keep well clear of vessels. When waterborne it is regarded as a power-driven vessel.

Operation is allowed only in daylight and clear weather. Conditions for trading as a non-passenger ship have not been considered. It might be added that one SR-N5 capsized during a highspeed turn in Norway in April 1965. The main reason was supposed to be that the longitudinal stability keel had been torn throughout a considerable part of its length. The keel has since then been strengthened. Another SR-N5 capsized a little later in San Francisco during a similar turn mainly due it was supposed to lack of experience of the driver. Short modifications to prevent such "plough-in" have been incorporated in the vehicles.

Apart from its speed, the greatest advantages of the craft seem to be that it may navigate outside ordinary ship lanes and may land on beaches or further inland if the circumstances are favourable.

Further comments on the hovercraft seem unnecessary in this connection, as it will appear from the above that the present type of hovercraft is even less suitable than the hydrofoil boat for fishing purposes. It seems doubtful if it could be used even for sports fishing. It might, however, be used for transport purposes where the freight charges are of minor importance. These charges will presumably be higher than those of a hydrofoil (and consequently of conventional ships) as the hovercraft at least at present costs more to build than a hydrofoil of the same capacity and trading expenses are higher.

As will appear from the above, there is as yet rather scant experience concerning hydrofoil craft and especially as regards hovercraft. In addition both types of vessels may be considered still to be in the development stage. The problems in connection with them must be kept under constant observation in order that the rules and regulations may be adjusted to further development and experience. Such changes may of course also affect their usability as fishing vessels.

MacLear (USA): Hydrofoil boats have had considerable difficulties with fast wearing out of their engines. This is because present-day gasoline and diesel engines have too low a ratio of horsepower to weight, and gas turbines are still too expensive to buy and operate. This latter may soon change however and make hydrofoils more economic as passenger vessels. It would however seem that it will be a fairly long time before they are used for fishing.

THE RUSSIAN POPOFFKAS
Idea Worth Trying?
Sutherland (USA): In the late 1860's, Vice Admiral Popoff, of the Imperial Russian Navy, was apprised of a need for

additional coast defences. He is said to have believed: ". . . fixed forts require immense foundations, which prove to be extremely costly, and, notwithstanding their cost, sometimes weak. Besides, some points along the coasts, known to be of great strategical importance, have been so far left unfortified, because of the impossibility or difficulty of building such foundations. Finally, fixed forts are disadvantageous, simply because they are fixed." Floating batteries offered a solution to this problem. Popoff knew that by using a circular form, the greatest area and volume could be enclosed by a minimum weight of hull steel, and the heaviest guns and armour could be carried. Depth of water in the planned operational area limited ship draft to about 13 ft (4 m) and the available building and drydocking facilities limited the diameter. (Further discussion in Part VI).

Popoff's circular ironclad design was model tested by William Froude at the Admiralty Experiment Works, Torquay. At least two circular ships were built, the *Novgorod* of 101 ft (31 m) diameter, with 11 in (28 cm) armour and mounting two 28-ton guns, was completed in 1873. The *Vice Admiral Popoff*, of 121 ft (37 m) diameter, with 18 in (45 cm) armour and mounting two 41-ton naval guns, was finished in 1875. Both were of very low freeboard (only 18 in or 45 cm), of approximately 13 ft (4 m) draft, and were propelled by 6 propellers, at a maximum speed of 7 to 8 knots. They were slow, wet in a seaway, lacked directional stability, and were hard to steer. The resistance to propulsion of the pure circular hull was some 4 to 5 times as great as that of a conventional hull of the same displacement at 8 knots.

Novgorod and *Vice Admiral Popoff* had virtues as well as faults. Goulaeff (1876) describes the circular ironclads, comments as follows about *Novgorod;* "Her stability was immense, and her steadiness as a gun platform is greater than that of a ship of any other form. Owing to the great beam, low freeboard, and perhaps also to the flatness of the bottom, the rolling of the *Novgorod* is very limited indeed, and it seems to me that in the present state of the subject, instead of entering into the discussion of any theoretical hypothesis on the behaviour of a ship, whose resistance to rolling motion and other conditions are widely different from those of ordinary shaped ships, it would be preferable to state only that the greatest angle of roll which was observed while I had the pleasure of steaming on board the *Novgorod* for several days at sea, during the Equinoctial gales, never was such as to expose her lower edge of the side armour—the instrument for measuring the angle of heel showing at that time that the arc through which she was rolling was 6 or 7 degrees; and this was in waves in which ordinary ships steaming the same course as *Novgorod* were rolling very heavily . . ."

Sir Edward Reed said in the discussion: ". . . having made several passages in this *Novgorod*, over the Black Sea, one of them in eminently rough weather, I was gratified to find that I made those passages with the greatest possible comfort . . . and when the waves were running to considerable height . . . you sat in the cabin in the deckhouse with the ship in a state of almost absolute tranquillity no rolling worth mentioning to trouble you, and scarcely any pitching".

The success of Popoff's design is perhaps best summed up by another comment Reed made: "I should like to ask those gentlemen who spoke so strongly against this class of vessel, if they will be good enough to refer me and this Institution to any vessel whatever in the whole world, except the *Novgorod* which carries at from 7 to 8 knots armour 11 in (28 cm) thick, and two 28-ton guns. There is no other vessel in the world that does that." Later that same year, *Vice Admiral Popoff* considerably improved upon the *Novgorod's* characteristics.

Result of tests

It was obvious that by modifying the circular form to provide fine entrance and run, eddy-making at moderate speeds could be significantly reduced and total resistance to propulsion decreased. After extensive model tests, conducted under the guidance of Tideman, Chief Constructor of the Royal Dutch Navy, the Russian Imperial yacht *Livadia* was built in Great Britain by J. Elder & Co. of Glasgow, to Admiral Popoff's design and specifications. Explaining the near-circular form adopted for *Livadia*, Goulaeff (1881) stated: "As the *Livadia* had to be a yacht, it was decided to make all her qualities subordinate to the utmost safety of navigation, and to the utmost comfort depending on the possible limitation of rolling motion at sea, and on the provision of spacious apartments with a luxurious amount of light and air." In further support of the *Livadia* design, Goulaeff continued: "If I tell you now that the *Livadia* does possess, in addition to a double bottom, three sides, spaced not less than 6 ft (1.8 m) apart ensuring her against all possible contingencies of stranding or collision in a degree not possible to be attained in any other ship; if I tell you that her steadiness at sea, as tested in a storm last autumn in the Bay of Biscay, has proved to exceed anything that has yet been realized; if I further tell you that this ship carries extensive palaces, which are pronounced by many competent critics and by thousands of visitors who have inspected her, to excel, in the size of their apartments, light and air, anything one can expect to meet afloat; and if I add to this that her speed proves to be 15¾ knots instead of 14, as intended, then perhaps I may not be thought too bold in believing that the ship commends herself to your special attention."

Livadia was truly a floating palace, 230 ft (70 m) long, by 150 ft (45.7 m) beam, by 7 ft (2.1 m) draft, by about 4,500 tons displacement, propelled by 3 screw propellers at a trial speed of nearly 16 knots.

Official trials of *Livadia* were conducted after about 4 months in the fitting-out basin without her bottom neither cleaned nor painted. Goulaeff (1881) and Reed (1881) quote performance figures and *Livadia*'s performance is compared with that of British naval vessels. For instance, the following tabulation appears. Both *Penelope* and *Orion* were blunt-bowed ironclads.

Ship	Displace-ment	IHP	Speed
Penelope	4,394 tons	4,703	12.7 knots
Livadia .	4,420 ,,	4,770	13.0 ,,
Orion .	4,700 ,,	4,000	12.0 ,,
Livadia .	4,720 ,,	4,500	12.5 ,,

Another comparison is given of *Livadia* and *HMS Iris*. The latter ship made a maximum of 18.6 knots on official trials, at a displacement of 3,290 tons, requiring 7,556 IHP. *Iris* was 300 ft (91.4 m) in length and had an immersed midship section area of 700 ft² (65 m²). *Livadia*'s midship section area was 1,000 ft² (93 m²).

	Iris	Livadia designed	as built
IHP per ton displacement	2.28	2.35	2.79
IHP per of mid-area .	10.71	10.50	12.35

On the first day of official trials, *Livadia* had a mean speed, maintained during 6 consecutive hours, equal to 14.83 knots, with an indicated horsepower of 10,200. On the following day, on the measured mile, the ship attained a mean speed of 15.725 knots, with an indicated horsepower of 12,354. At moderate speed of 12 to 13 knots, not much penalty was

exacted for *Livadia*'s unusual form. At higher speeds, it has been variously estimated that *Livadia* required from 1.4 to 2 times the power that would have been needed for a ship of conventional form.

Commenting on Reed's (1881) paper about *Livadia*'s resistance to propulsion, Froude said: "Certainly it is not *prima facie* a bad form so far as wave-making resistance is concerned because all the displacement which is in the middle of the ship is almost in the condition of a submerged body—it is almost out of the reach of the surface of the water. Provided that you keep clear of the eddy-making, which is the great bane of the original Russian round-ship designs, there is no reason why you should have a very excessive resistance." Earlier, discussing Goulaeff's (1876) paper, William Froude said: "There is . . . rather a curious fact in relation to the resistance of these ships . . . up to the highest speed at which we drove them . . . their resistance was just as the square of the speed . . . you might infer from that that there would be some gain in pressing these ships to a high speed." It is other qualities than speed which is interesting in *Livadia*'s form, and justify further investigations. For a ship that is to remain on station for long periods, one might be more interested in minimum roll with a long rolling period, sea-kindliness and comfort, and the large and usable deck areas obtainable on minimum displacement.

Bay of Biscay test

His Imperial Highness the Grand Duke Constantine accepted delivery of *Livadia* from the builders and made the delivery voyage from Great Britain to the Black Sea, accompanied through the Bay of Biscay by several important British guests. One of the guests, Mr. W. Pearce, then managing director of the shipbuilding firm, said: "this ship has the steadiest platform of any in the world . . . this ship passed through the Bay of Biscay during a week when it is recorded that more ships foundered than in any week during the whole of last year, you will understand that she must be exceptionally steady, and as a matter of fact she rolled only 3" one way and 4" another, and the range of pitching was only 10". I am sure that no vessel in our Navy could have passed through that sea without rolling at the least 25 to 30'." Admiral Sir Houston Stewart, RN, also a guest aboard during the severe storm, opened the discussion after Reed's (1881) paper: ". . . I never was in so comfortable a ship at sea in a gale of wind . . . the absence of rolling, the easiness of motion, the great comfort on board, and the handiness of steering, were such as I have never seen before in any other ship under similar circumstances of weather and sea."

Many had expected that, like *Novgorod* and *Vice Admiral Popoff*, the *Livadia* would take seas aboard during rough weather, but *Livadia* had more adequate freeboard. Admiral Stewart commented: "Sir Edward Reed took every opportunity of investigating the height of the seas, because he went into places where I did not care to go even as an old sailor. The point where he showed you the Imperial Arms looks over the sea, and he went to the extremity when she put her nose down in the sea, and out to the end of those outriggers in the height of the gale. An ordinary ship would have rolled those in the water, but she did nothing of the kind, you simply saw the waves spring up like surge on an ordinary beach. Sir Edward is fully competent to tell you his opinion of her behaviour at sea, and all I can say is that I fully endorse all I have heard with regard to her."

Modern empirical rolling formulae, developed from experience with conventional hulls, suggest that with tremendous metacentric height due to her great beam, *Livadia* must have had a very short period of roll. However, Goulaeff (1881) stated: "The rolling in no case exceeded 3½ or 4° . . .

The period of oscillation, at the same time, is also very large. Such ships, as explained in an article in *Nature* (July, 1880), while obeying each wave, are by that very means exempted from the tendency to accumulate the effect of a succession of waves . . . The forward part of the superstructure divided the waves, which were met vertically in two parts, while the edge of the lower raft divided them horizontally, thus destroying the effect of the waves on the vessel."

Livadia had a few faults too. Reed (1881) reports on minor damage sustained during the storm—damage which went undetected at the time. *Livadia* was inadequately framed, leaving large unsupported area of $\frac{7}{16}$ in (11 mm) hull plating. In the storm, she cracked a plate, flooding a small void compartment on the starboard bow. Strongest criticism of *Livadia* focused on "pounding" experienced as she was driven against head seas. Commenting on pounding and structural strength, Reed (1881) stated: ". . . anyone who has observed a tumultuous sea in a storm must be prepared to learn that a ship of extremely light draft and of almost perfect steadiness, receives violent blows from the ascending water, and this more especially right forward, where the onward motion of the bow naturally subjects the bow to additional violence . . . I estimated the heights of the larger waves during the worst part of the gale as quite 25 ft (7.6 m) and, as the sea was confused, there were at times crests and peaks of leaping sea, so to speak, that were obviously capable of striking under the bottom with tremendous force . . . around the bow of the *Livadia*, in its outermost compartments, there were injuries inflicted . . . by the sea alone, and proving . . . that there was considerable local weakness at that part . . . As the ship is approximately circular, Admiral Popoff has seen fit to frame her radially, a system which naturally tends to concentrate strength near the central parts of the vessel, and to distribute it unduly at the exterior parts . . . It is easy to make up the deficiency in these outer parts by introducing additional frame angle irons . . . I can hardly believe that any experienced shipbuilder now present will be prepared to affirm that the weakness developed under the circumstances could not have been anticipated."

Moored buoy trials

Commencing in 1962 under an Office of Naval Research contract, the Convair Division of the General Dynamics Corporation (1963) undertook to develop a moored tele-metering oceanographic buoy, with a design station endurance of one year. Comparative evaluation of drag and stability of 24 configurations of buoy hulls, involving 957 gravity tows and 147 carriage runs in the Convair Hydrodynamics Towing Basin, was undertaken. Towing was conducted both in smooth water and in the presence of waves. Apparently without prior knowledge of the much earlier popoffkas, flat-bottomed circular buoys of shallow draft, so-called "discus" buoys, were among the configurations tested.

With the density of the discus model adjusted to correspond to a 40 ft (12.2 m) diameter full scale, the model behaved as a planing hull, above a certain equivalent full-scale velocity depending upon surface roughness. A significant reduction in drag was associated with this phenomenon. This appears to confirm Froude's findings on the resistance of circular ships. Towing of the discus models in the presence of waves showed large variations in resistance. But, because of the relatively large reserve buoyancy, the model was never swept over by wave crests, so long as model density was low enough to prevent towing under. This seems to confirm Reed's and Stewart's comments on the dryness of *Livadia's* weather decks in stormy seas.

Two discus models were tested for buoy hull model

stability in the presence of surface waves. The discus models showed minimum motion and nearly followed the slope of the waves. They were found incapable of resonant behaviour, regardless of wave period or shape. This confirms statements by Reed, Stewart, and others about *Livadia's* easy and limited motion in a seaway.

Observation of discus models in waves and analysis of films, showed slamming when the edge of the disc went into a trough after crossing an unstable crest. Digging-in of the leading edge or flooding of the upper surface were not observed, even with the wave machine set to produce the most precipitous waves within its capability, except when the model was ballasted to several times its normal gross weight. This appears to conform with *Livadia* experience in confused Bay of Biscay seas and with earlier experience of the circular ironclads, *Novgorod* and *Vice Admiral Popoff*. Faced with the choice between high-drag shapes that some-times achieved resonant motion, and low-drag shapes that never became resonant, the discus buoy was selected. To date, full-scale 40 ft (12.2 m) diameter discus buoys, now in ocean service, are understood to have lived up to all expecta-tions as regards hull performance. The popoffka has been tried. It has been tested in both model and full-scale by thoroughly reputable individuals. Goulaeff (1876, 1881) and Reed (1881) presented facts justifying claims of very unusual stability coupled with extremely easy motion. Yet conservative ship designers and operators are reluctant to depart from conventional practice, even to the extent of model testing the popoffka form and otherwise investigating its actual merit.

If alleged popoffka characteristics can be confirmed, the type would appear useful as factory ships for the fisheries, research vessels, tracking ships, mobile missile erection and launch facilities, salvage and heavy-lift vessels, underseas mining platforms, deepsea drilling ships and the like.

This written reply to the section headed "Computer Design of Boats" was received late:

Hayes (UK): Regarding Williams' proposals for using alternative parameters in a similar resistance analysis, it is appropriate to warn against any considerable increase in the number of parameters beyond the number used in the analysis of this FAO data, particularly if the parameters, when plotted against each other in pairs, do not yield a rectangular scatter of data points. In such a situation, a successful outcome would be extremely unlikely. Parameters which are directly applicable to the mathematical definition of ship lines tend to be of this type—large in number and highly correlated. A discussion of the statistical background to these remarks was given by Hayes (1964).

In reply to Corlett's remarks on the regression analysis approach, it is not necessary that all the forms used in such an analysis should be of high quality. On the contrary, it is necessary that the data contain a substantial number of forms of lower quality so that the parameter ranges and parameter combinations under consideration are adequately covered.

Cardoso asked why 14.51 at a C_p of 0.65 was not taken as the best value of C_R rather than 15.71 at a C_p of 0.575 (table 1(a) of the Traung *et al* paper). The answer is that this table gives only part of the C_R value for the design under consideration: in particular, it does not take into account the

effect of changing C_m. It can be seen from table 1(c) that, in order to keep Ⓜ constant at a value of 4.5, the increase of C_p from 0.575 to 0.65 necessitates a decrease in C_m from 0.758 to 0.670. From table 1(b), this decrease involves a penalty in C_R of about 2.2 units, which more than cancels out the difference in the C_R values in table 1(a).

On Cardoso's last point; the equations can, of course, be used to design vessels with high values of angle of entrance, when these are preferred.

In answer to Kilgore's question, the justification for the use of particular parameters must always, in the end, rest on how well the derived equation containing those parameters fits the data. If an adequate fit is obtained, it follows that the parameters must have adequately described the hull shape for the purpose concerned, at least for the variety of vessels represented in the data.

PART III

MATERIALS

Boatyard Facilities

by J. F. Fyson

Chantiers de construction navale

Il est possible de construire à peu de frais des bateaux de pêche adaptés aux besoins locaux à condition de pouvoir faire appel à un architecte naval connaissant bien les bateaux de petite taille et ayant étudié la situation locale. L'auteur récapitule les techniques modernes de construction de bateaux en bois, traitant du tracé sur plancher et de l'établissement des gabarits des différences entre membrures chantournées et membrures étuvées, du choix des bois, de l'étuvage et du ployage des membrures, de la préparation des éléments structuraux lamellés, et fournit les conseils sur les colles et techniques de lamellation à employer. La communication décrit de façon détaillée l'agencement du chantier de construction, en insistant sur la nécessité de prévoir des espaces suffisants pour l'entreposage et le séchage des bois, une disposition rationnelle des machines à travailler le bois, et l'évacuation des déchets. L'auteur traite de la production en série. Pour le relevage et la mise à l'eau, il préconise l'utilisation de slipways ou, pour des bateaux de petite taille, de mâts de charge (employés seuls ou en combinaison), tous ces appareils devant être conçus par des spécialistes. Il se déclare en faveur de la suggestion de Christensen visant le numérotage des diverses opérations à des fins comptables. Enfin, il insiste sur la nécessité d'une bonne planification de l'installation du chantier naval, de son exploitation et du recrutement de personnel qualifié, et présente des recommandations pour l'organisation et la gestion du chantier.

Instalaciones y medios en los talleres de construcción de embarcaciones

Contando con un arquitecto naval dotado de experiencia en el diseño de pequeñas embarcaciones y que haya estudiado las condiciones del país, se pueden construir embarcaciones pesqueras baratas que se adapten a dichas condiciones. Resume el autor los modernos procedimientos de construcción de embarcaciones de madera. Describe el trazado en la sala de gálibos y la fabricación de modelos, las diferencias entre la construcción de cuadernas de madera enteriza curvada y de madera curvada al vapor, la selección de la madera, tratamientos al vapor y curvatura de piezas, el modo de construir las piezas estructurales laminadas, y asesora sobre las colas adecuadas y las técnicas de laminación. Se describe detalladamente la disposición del taller de construcción de embarcaciones; la necesidad de disponer de un espacio adecuado de secado y almacenamiento de madera; la disposición de las máquinas que sirven para trabajar la madera; la eliminación de los desperdicios. Se examina la producción en serie. Respecto a la eficiencia para el remolque y la botadura, el autor aconseja varaderos diseñados por expertos, así como grúas y combinaciones de grúas. Se apoya la indicación de Christensen de numerar las distintas operaciones con fines contables. El autor pone de relieve la necesidad de una debida planificación para montar un taller de construcción de embarcaciones, dirigirlo y contratar personal capacitado. Formula recomendaciones respecto a la planificación y administración del mismo.

SMALL wooden boatbuilding has traditionally been an individualistic craft with most boats custom built for owners with very diversified requirements. Recent experiments, notably in the field of pleasure craft, towards mass production suggest the possibilities of streamlining the construction also of wooden fishing vessels.

Perhaps the most notable advance in small boat mass production methods is in the field of glass-reinforced plastics, which is outside the scope of this paper. Some of the lessons learned, however, could also be adapted for use in wooden construction.

In the prefabrication of sections, particularly deck-houses and superstructures, more use could be made of aluminium and fibreglass to reduce the weight of more conventional steel construction.

In the field of small light-weight craft for close inshore fishing, greater use could be made of composite ply-reinforced plastic construction which readily lends itself to mass production methods.

DESIGN CONSIDERATIONS

Series production and the rational use of labour are dependent on the stabilization of the production of boat-yards around a basic number of designs suited to local requirements. Developing countries which are about to make the step up from indigenous craft, which are no longer suitable for modern fishing methods, are in a particularly favourable position to adopt this approach.

The services of a naval architect experienced in small boat construction—preferably fishing boats—should be used to study local conditions and produce efficient, economical hull shapes and arrangements suitable for the conditions. Once a suitable hull shape has been decided, interior layout and superstructure should be carefully planned to enable the prefabrication of the maximum number of components consistent with fishing requirements. Consideration of the building procedure to be adopted and discussions with the builder can influence the siting of tanks and equipment so that their installation can become a logical part of the production plan.

GENERAL BUILDING PROCEDURES

Lofting and pattern making

For maximum use of prefabricated components for series building, lofting must be fully and accurately done and an extensive use made of patterns picked up from the loft floor.

Patterns and templates can be fabricated from plywood as its light weight, dimensional stability and resistance to breakage make it most suitable. Three-ply interior grade plywood, $\frac{1}{4}$ in (6 mm) to $\frac{3}{8}$ in (9 mm), depending on the size of the pattern, is satisfactory. For lightness and economy, Douglas fir, pine or oukoume (gaboon) are also recommended. For large templates the shapes are cut out from the lines on the loft floor, joined by gussets and braced by solid wood battens fastened by clenched nails or glue.

In one-off building the costs of detailed lofting and extensive pattern making are not justified, but in series

building with the cost spread over a number of boats, the time saved soon justifies the extra expenditure. Wastage can also be considerably reduced by careful positioning of patterns to enable more pieces to be cut from the available stock while avoiding knots, cross grain compression failures, shakes or other defects.

Sawn frame construction

Patterns can be made for the stem, deadwood and stern post assembly, frames, transom, bulk heads, deck beams and engine bearers.

Frame patterns should have the futtocks and the bevels, calculated from the loft floor, marked at appropriate distances on each.

If equipment for handling is available, bulkheads can be assembled complete with frame and deckbeam, and also insulated where appropriate, before setting up.

Templates for carvel planking can be made up as the first boat is built. For smaller boats plywood templates can be taken from the finished plank after spiling and before steaming and fastening into place.

For larger boats spiling templates can be made up by fastening battens of flexible timber around the frames so that one batten is provided for each edge of a plank. Then the two battens representing a plank are tied together by numerous strips of wood cross fastened to form a lattice girder. The templates can then be removed and used to mark off planks for a series of boats.

Large-scale use of patterns and templates, with components fabricated in advance and brought to the boat as work proceeds, demands careful and accurate setting up to ensure good fitting and to avoid wastage.

Bent frame construction

Construction procedure differs from that of sawn frame in the preparation and setting up of frames.

Selection of stock

Where considerable bending is required only hardwoods can be used, oak, elm, ash, hickory and beech being suitable timbers. The grain of the wood should not exceed a slope of 1 in 12; steeper slopes cause excessive breakage. Knots and surface checking should be avoided except near the ends of frames where small knots and some surface checking are permissible. Green timber is preferred for bending as it is usually free from surface checks, heats quickly and does not require pre-soaking.

Preparation and steaming

To prevent side buckling, the width of bending material should be greater than its thickness. Time of steaming should be of the order of 1 hr per in (2.5 cm) of thickness. Over-steaming should be avoided.

Bending

In small boats, frames are bent directly into the boat after steaming but for larger boats with frames of larger dimensions slight curves can be made over formers without straps. One end of the steamed member is fastened to the former and then pulled down progressively to the curve and clamped in place. More

severe bends require the use of tension straps (fig 1). These should have end fittings to hold the wood rigidly during bending. Blocks of soft wood should be placed between the timber to be bent and the end fitting to absorb the increase in end pressure as the bending proceeds.

The limiting radius to which hardwoods can be bent is of the order of four times the thickness, provided good quality selected timber is used.
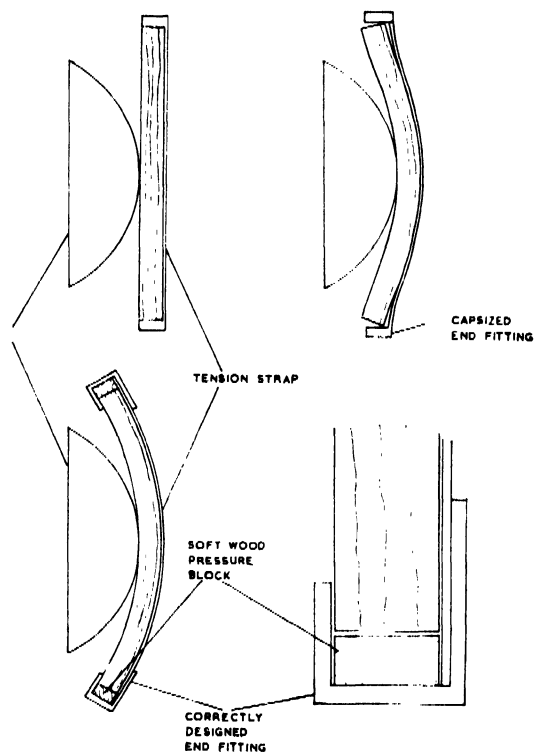
Fig 1. Tension strap

For bending timbers of a cross-sectional area greater than 20 in² (12.8 cm²) a bending apparatus is employed consisting of a cast-iron slab with a grid of holes to take steel spikes which act as stops. A wood former is then fastened to the slab and the steamed member in its tension strap is pulled down to the former using a block and tackle (or a power winch in the case of heavy frames).

The bend can be fixed by cooling on the former or battens can be fastened across the bent member to hold the curve. In the case of large frames a chain holding the tension strap to its curve allows the member to be removed from the slab and stored until ready for machining and assembly.

Lamination

The building up of structural members of large dimensions and the formation of curved members by gluing up from thinner material particularly lends itself to series production. Standard sawmill dimensions can be used or machine operators can prepare quantities of standard dimension timber in advance.

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Gluing

Phenol-resorcinol-formaldehyde adhesives are recommended as this type sets and cures at lower temperatures than the phenol resin adhesives. Tables 1, 2 and 3 give an indication of the range of temperatures, assembly and clamping times to be expected.

TABLE 1: Pot-life of phenol-resorcinol-formaldehyde adhesive in hours

Temperature	C 5°	10°	15°	20°	25°	30°	35°
	F 41°	50°	59°	68°	77°	86°	95°
Fast-curing resin	9–10	6–7	2½–3½	1½–2	—	—	
Medium-curing resin	—	—	4½–5½	3–3½	2–2½	1–1½	—
Slow-curing resin	—	—	—	5–6	3½–4	2½–3	1½–2

TABLE 2: Assembly time in hours

Temperature	C 5°	10°	15°	20°	25°	30°	35°
	F 41°	50°	59°	68°	77°	86°	95°
Fast-curing resin	4	3	1¼	1	—	—	—
Medium-curing resin	—	—	2¾	2	1½	1	—
Slow-curing resin	—	—	—	3	2	1½	1

TABLE 3: Clamping times in hours

Temperature	C 5°	10°	15°	20°	25°	30°	35°
	F 41°	50°	59°	68°	77°	86°	95°
Fast-curing resin	18	14	4	3	—	—	—
Medium-curing resin	—	—	8¼	5	4	2	—
Slow-curing resin	—	—	—	10	5½	4	3

Mixing of glue

Small amounts of glue can be mixed by hand but larger amounts require a mechanical mixer. Portable electric drills equipped with paddles can be used for moderate amounts of glue, but due to the high speed of the drill the area of paddle surface should be small to avoid foaming.

For large-scale mixing a dough mixer with two- or three-speed control, turning the paddles in a double rotary motion, is ideal.

Glue spreading

For good glue joints the correct quantity of glue should be evenly spread over the entire gluing surface. Small areas can be covered by brushing, but for large surfaces application by hand mohair paint rollers is suitable. These must be cleaned before the glue hardens to an insoluble state.

Methylated spirits can be used to dissolve glue while it is still liquid.

For large quantities of work, machine spreaders can be used. These are fitted with rubber-covered rollers and control rollers to regulate the thickness of the glue applied.

In conditions of high temperature and low humidity a thicker glue spread will permit a longer open assembly time. Conversely, if humidity is high and temperature low a more economical spread can be used. Under average conditions, of the order of 65°F (18°C) and at 65 per cent relative humidity, 9 lb per 100 ft² (0.45 kg/m²) is satisfactory. Half this quantity is used on each face if double spreading is used. The glue spread can be checked by weighing a trial sample, before and after spreading, before beginning a run.

Joints should be assembled and pressure applied within the times given in table 2. Pressures of the order of 150 lb/in² (10.5 kg/cm²) are recommended with the pressure evenly distributed by the use of hardwood packing strips, of maximum thickness consistent with the radius of the former, placed under the heads of the clamps.

The laminations are first assembled in the order in which they are to be placed in the jig with the bottom lamination on top. Waxed paper is placed against the jig face and on surfaces on which the laminations are to rest. The laminations then have the glue applied to both faces in order, either by hand with brush or roller, or in a glue spreader. They are then promptly assembled and pressure applied with the minimum possible delay to reduce the time for which the glue is exposed to the atmosphere.

It is recommended to surface the laminations just before assembly so that the wood will be clean and free from grease and dirt.

Thickness of laminations varies with type of wood and quality, but as a general rule clear-grained timber can be bent cold to a radius 40 to 60 times its thickness.

Curing

Provided the joints are not subjected to any great stress, the clamps may be removed after the times stated in table 3, by which time one-half the maximum strength of the adhesive will have been reached.

Curing can be accelerated in cold climates by the application of heat. Excessive heat, however, should be avoided to prevent drying out. If the clamped up laminate is covered with a canvas or polythene cover, a fan heater will provide a satisfactory means of raising the temperature to 65°F (18°C).

Phenol-resorcinol glues are rather more tolerant of moisture in timber than urea formaldehyde and phenol adhesives and successful joints can be obtained with a moisture content of up to 22 per cent.

Composite ply-reinforced plastic construction

Where light-weight hard chine hulls of small size for close inshore, lagoon and inland water fishing are required, this method of construction is particularly suited and lends itself to series production.

Joints at keel and chine are filled with resin putty and covered inside and out with glass fibre cloth or tape bonded to the hull with resin. Transverse bulkheads bonded into the hull by the same method give great strength combined with light weight. The use of exterior moulds enables rapid assembly and production line techniques for quantity.

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YARD LAYOUT

The location of building and machines in the space available should be planned to fit in with the handling and transporting of timber and materials during the successive processes so as to facilitate construction and reduce unproductive labour to the minimum.

Considerable increase in productivity can be realized if mechanization of the lifting and handling of timber is utilized during all stages of construction. The use of a mobile crane, fork lifts or straddle trucks, electric hoists and overhead travelling cranes in a large yard, or rubber-tyred trolleys in a small yard, can considerably increase the flow of timber to and from the machines and from boat to boat in a production line.

Timber storage and drying

The first step in this process is the storage yard whether simply for storage of timber prior to utilization or for the stocking of timber for air drying. In either case the storage area should be fairly level and well drained and the surface kept free from debris and vegetation. Ideally, it should be covered with ashes, gravel, shells or crushed stone with the roadways surfaced if cranes and fork lifts are to be used.

Air drying

For air drying the stacks of timber should be raised 12 to 18 in (0.3 to 0.45 m) from the ground and should be built on a solid foundation. These should be designed to permit air to move freely between the stacks and can consist of hard wood or concrete cross-members about 4×6 in (10×15 cm) in section supported on piers of brick, concrete or creosoted timber. The foundation should be arranged with a slope from end to end (fig 2). Stacks may be of any length and up to three times as high as they are wide but they should not be wider than about 6 to 8 ft (1.8 to 2.4 m), because in very wide

stacks drying takes place very slowly at the centre and stain and mould can occur.

As shown in fig 2, sticks are used to separate the layers and these serve the dual purpose of allowing the air to move freely over the timber and also to transmit the weight from layer to layer. It is therefore important that they should be arranged in neat vertical lines above the cross-members of the foundation. Thin board of less than 1 in (2.5 cm) should be stacked with the sticks at intervals of about 12 in (0·3 m), particularly timbers such as beech, elm, etc., which warp badly.

This spacing can be increased to 2 ft (0·6 m) for all timbers 1 in (2.5 cm) or more and to 4 ft (1.2 m) for dimensions greater than 2 in (5 cm) in straight-grained species.

The rate of drying within a stack can be controlled to some extent by the thickness of the sticks used. The denser hardwoods must be dried slowly to avoid splitting and if stacked during a hot season the sticks should not be thicker than $\frac{1}{2}$ in (1.2 cm), while 1 in (2.5 cm) sticks can be used during cooler damper periods. Soft woods and lighter hard woods tolerate faster drying conditions so that 1 to $1\frac{1}{2}$ in (2.5 to 4 cm) sticks can be used.

When timber is to be dried after through-and-through sawing, it is stacked in log form, thus usually providing plenty of air space around each log and the sticks should not be more than about $\frac{1}{2}$ in (1.2 cm) thick or drying may be too rapid.

Effect of weather on drying

Should a hot season or a period of strong drying winds follow immediately after green timber has been put out to dry, serious splitting can occur. Nearly all hardwoods require slow drying initially; therefore, it is preferable to stack them at the beginning of a cool season. The timber then has a chance to dry slowly during the first months and splitting will be lessened. The drying rate
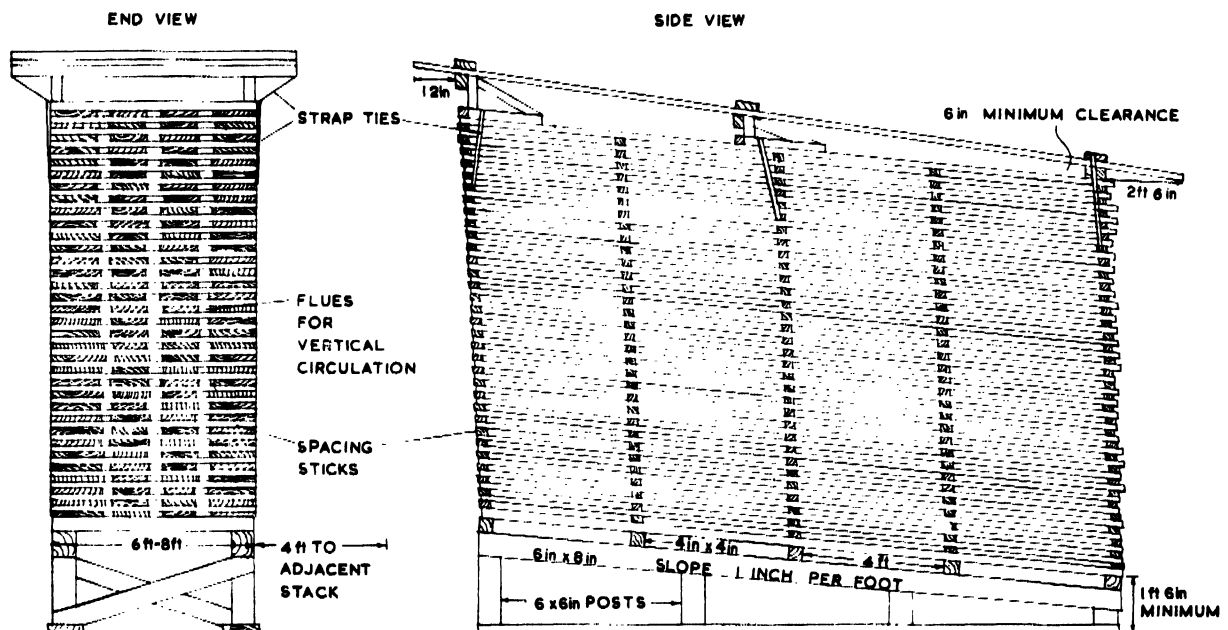
Fig 2. Timber stacks for air drying

can be controlled, to a certain extent, during a hot, dry season by end coatings or cleats, temporarily covering stacks with tarpaulins or wet sacks, or hosing the site occasionally during the hottest part of the day.

Storage

Storage space for matured timber should preferably be covered, with horizontal stacking if space permits. To avoid loss of time in finding timbers of various dimensions when required, separate stacks should be made of timbers suitable for the following:

- Keel, stern and deadwood
- Frames
- Stringers and clamps
- Deck beams
- Planking
- Decking
- Joinery

The stacks should be located as near to the appropriate machines as possible.

Machinery layout

The first machines should, normally, be a heavy-duty saw, surfacing planer and thicknesser for cutting to size, dressing the faces and thicknessing.

Space must be allowed for stacking and marking out, from which the timber proceeds either to final dressing and assembly, or to band saws for cutting of shapes and bevels, or to a spindle moulder for grooving, rebating and curving sections for rubbing strakes, etc. Additional machinery such as a scarf cutter, tilting frame band saw for bevel cutting, fine cabinet surfacer for dressing of laminations before assembly, drill presses, bench grinders and setting machine for saw blades, as well as a complete machine shop for engine fittings and other metal work, can be added to the basic layout according to the volume of work and capital available.

Individual solutions of the layout will have to be found for each particular yard but in all cases planning must allow the most direct possible flow of timber through the machine shop. Space must be provided around the
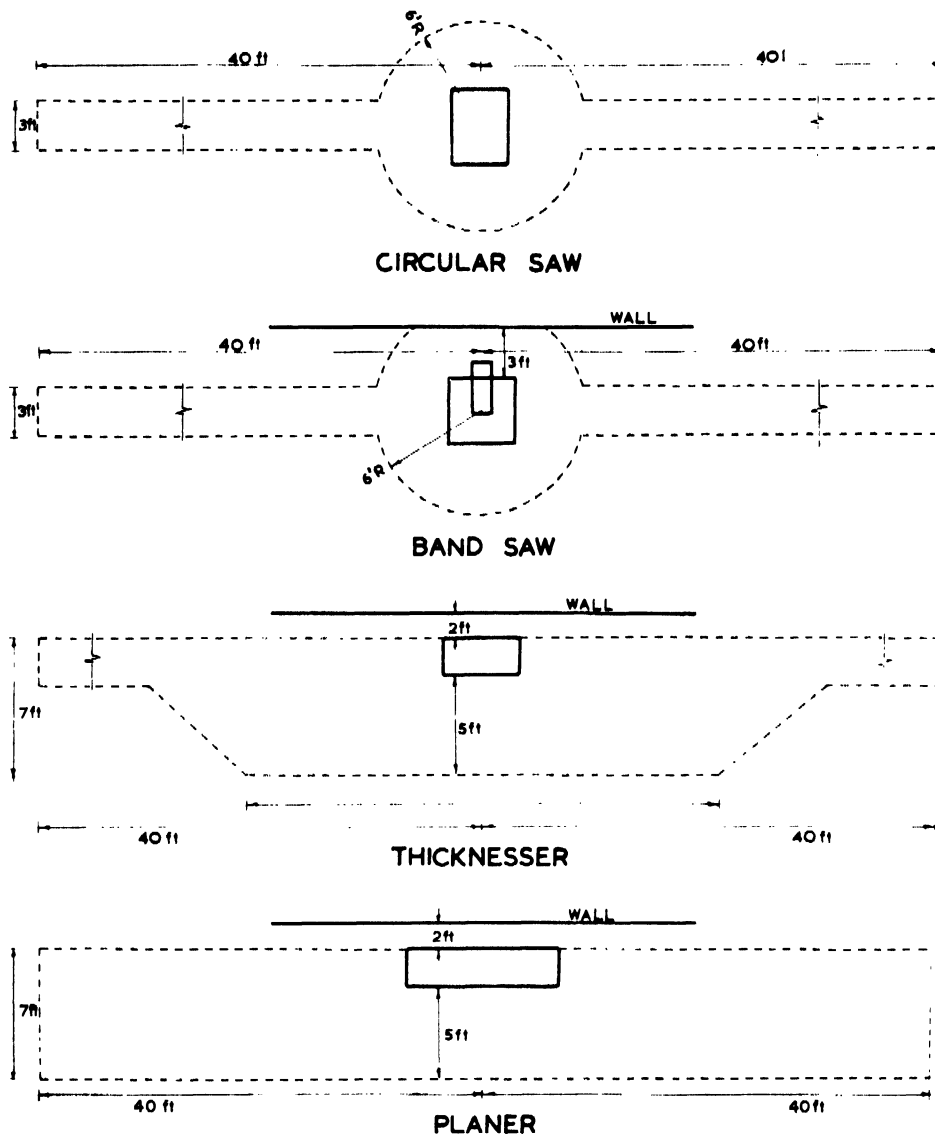
Fig 3. Dimensions for machine layout

machines for the stacking of timber at the end of a run and also for marking out prior to the next operation. Extension tables, with rollers adjustable in height to correspond with the machine tables, should be provided to cut down the labour involved in machining heavy items.

Rubber-tyred trolleys for light and overhead hoists or cranes for heavy items should be included and floor space for manoeuvring provided. Fig 3 gives proposed dimensions and clearances for the various machines. The use of portable power tools to supplement the stationary machinery and reduce the amount of additional handling will also influence the shop layout.

Waste disposal

The use of special gangs operating machines continuously for a series of boats raises the problem of waste disposal. Where production is considerable this can be done by the use of pneumatic collection plants. For clearing waste in the hulls under construction, use can be made of industrial vacuum cleaners.

The position and type of machines, the nature of the wood to be machined and the amount of waste to be handled must be considered when designing the plant. The diameter of the connecting branches to the various cutting heads and the velocity at which the conveying air moves through the ducts are important considerations. A fan provides the motive power for the air by which the waste is extracted and conveyed through the ductwork. This must be capable of dealing with the dust and chippings which are carried in suspension in the airstream and must be robust and fitted with dust-proof ball or roller bearings. It should preferably be sited in the workshop where it can receive the necessary servicing. The wood waste has to be separated from the conveying air and this is generally done by cyclone.

Correct duct design is an important feature of a refuse

A   THICKNESSER
B   PLANER SURFACER
C   CIRCULAR SAW
D   BAND SAW
E   FLOOR DISPOSAL - UP
F   FLOOR DISPOSAL - DOWN
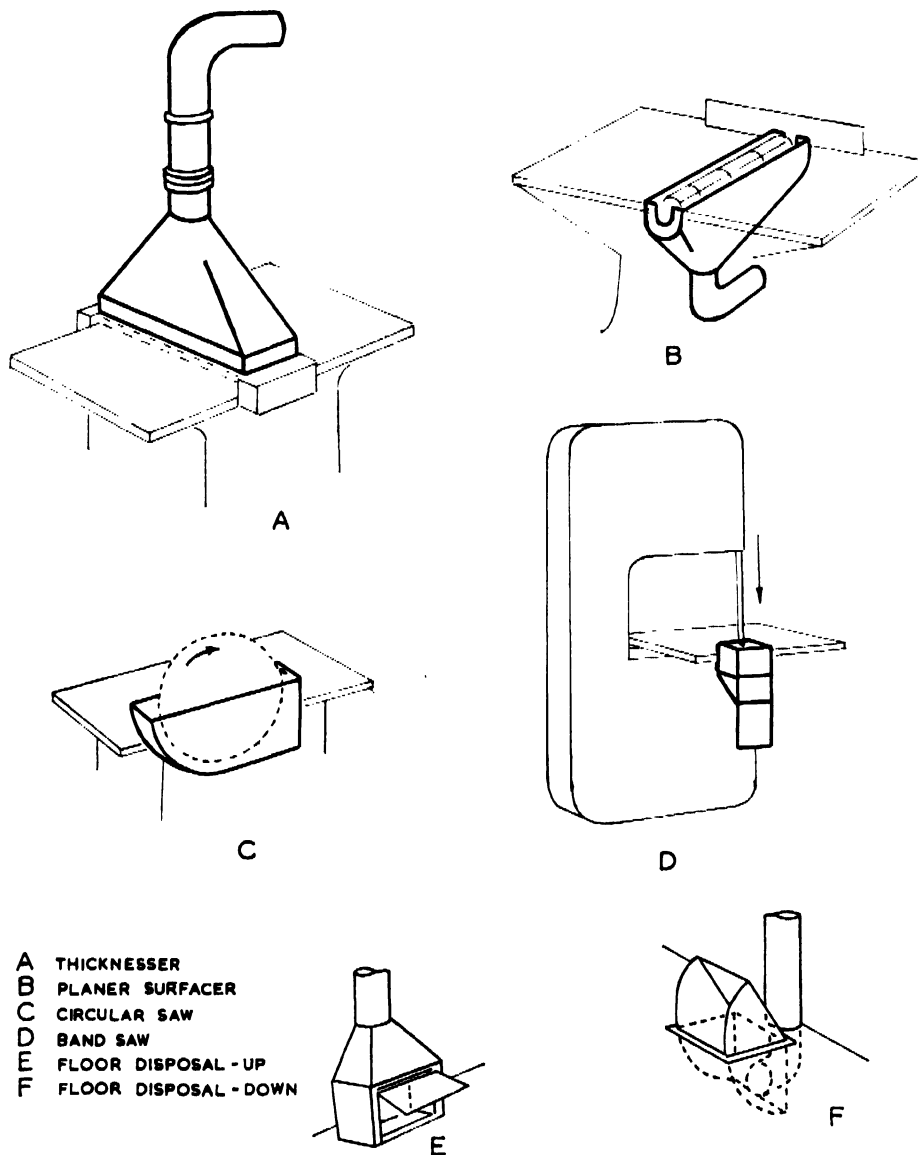
Fig 4. Waste extraction hoods.

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extraction plant. Cylindrical ducting is almost invariably used because of lower frictional resistance than square or rectangular. The ducting should run in the shortest practical direct line. Sharp bends should be avoided if possible to minimize friction. Bends should be constructed with a throat of large radius (a 6 in (15.0 cm) diameter pipe would have a 12 in (30.0 cm) radius in the throat of the bend). Branch pipes are attached to the main ducting at an angle not exceeding 20°.

Dust velocities for an extraction plant vary from 3,200 to 4,000 ft (1,000 to 1,200 m) per minute. For example, 3,500 ft (1,050 m) per minute is a suitable velocity for joinery work where light dry sawdust is to be moved while in the rougher work of cutting and planing keel timbers with the consequently heavier and wetter dust 3,750 to 4,000 ft (1,150 to 1,200 m) per minute would be required.

For a duct conveying velocity of 3,750 ft (1,150 m) per minute the following branch connection sizes are given as a guide:

24 in (0.6 m) cross-cut saw.	4½ in (11.5 cm) diameter pipe
36 in (0.9 m) vertical bandsaw	4½ in (11.5 cm) diameter pipe
18 in (0.45 m) surfacing planer	6 in (10.0 cm) diameter pipe
24 in (0.6 m) thicknessing planer	7 in (17.5 cm) diameter pipe
Spindle moulder . .	4½ in (11.5 cm) diameter pipe
Sweeping up point . .	6 in (10.0 cm) diameter pipe

The conveying velocity must not be allowed to drop or choking will take place, consequently, a common pipe required to serve two 6 in (15.0 cm) diameters needs to be twice the area of one 6 in (15.0 cm) pipe, i.e. 8½ in (19.0 cm). Starting from the branch pipe furthest from the fan, it is possible to calculate the size of the main ducting as each fresh branch joins it. Waste extraction hoods should be fitted with flexible pipes and telescopic joints to facilitate the setting of cutters and their adjustment. Fig 4 gives shapes and position of hoods together with two suggestions for floor disposal points.

Series production

An assembly technique in which a manufactured article passes from one process to another down a line is obviously not feasible with wooden boats of over 30 ft (9 m). However, by using gangs of workers passing from boat to boat, completing a single or a series of operations, appreciable time saving can be achieved. For example, laminated frames prepared by workers in one area can be set up by others passing down a line of boats in which the keels and stem assemblies have already been set. Bulkheads already built up on a frame and deck beam assembly can be installed directly on the keel, provided suitable lifting gear is available.

Mobile wheel-mounted tubular scaffolding of different sizes and heights suitable for the various operations could be used as the different stages proceed. Racks on the scaffolding could hold the various portable machine tools, clamps, etc., appropriate to each phase.

Reels to hold power cables for machine tools can be mounted at convenient points to reduce cable length and minimize snarling.

Lifting and transporting the various prefabricated items should be carefully studied and provision made for rails mounted on the roof beams to carry chain hoists or

electrical hoists to handle large laminated frames, installation of engines, etc.

If space allows, a long covered building, with one or two rows of boats under construction, would give the best results.

Hauling and launching of boats

A pair of rails for a cradle, running alongside the building berths, with a transfer or skids to each berth, will facilitate the moving out for launching of completed boats.

Marine railways

Large marine railways for hauling out and launching heavy boats should be designed by experts, but smaller installations can be laid down by the boatyard. Given a hard stable surface, it is possible to lay the railway directly on it, but unless the surface is fairly even and the gradient reasonably uniform, a foundation of wood piling below the surface and concrete blocks inshore will give better results.

The immersed portion of the track can be constructed of wood, assembled onshore as a unit, sunk on the previously prepared foundations, aligned and secured. All underwater woodwork should be chosen for resistance to marine borers and treated with creosote or, still better, by one of the proprietary brands of anti-worm preparations.

Track can be constructed on a uniform gradient usually between 1 : 10 and 1 : 20 or on the arc of a circle with the cradle designed so that the deck is horizontal when hauled out.

Whenever possible the cradles for smaller boats, as discussed here, should preferably be built entirely of wood because, if structural steel is used and the cradle is overloaded, the structural steel will assume a permanent bend which will be difficult to rectify. For very large boats it will naturally be necessary to use structural steel with cross beams, deck and blockings of wood, or cradles entirely of steel. Where the track is uneven the cradle should have only two wheels on either track to maintain straight keel block line.

For large vessels, sliding bilge blocks, running on a track and operated by lines to the side stanchions, can be used. For smaller vessels the keel of the vessel rests on the cross beams and adjustable bilge supports are set up to maintain the vessel in position when hauling begins.

Hauling machinery can be diesel or electric and for a large installation chain is superior to wire for hauling because of its much longer life.

Derricks and sheerlegs

For lighter craft and also for removing and replacing engines and the stepping of masts, derricks and sheerlegs can be constructed at the dockside. Feet of such fittings should be well fastened and staying should be carefully calculated to allow a good safety margin for the anticipated loads.

A pair of derricks working together can be used for lifts of up to 15 tons and for a small yard such an installation would be much cheaper to maintain and operate than a marine railway.

WOOD-WORKING MACHINERY FOR BOATBUILDING

Expenditure on machinery must be studied in the light of productive capacity of the yard, demands of the market and possibilities of capital recovery.

A limited range of fixed machinery can be effectively extended by a wise selection of power tools.

Fixed machinery

Less complex than the variety of machinery seen in a large joinery shop, with its high-speed multiple-head moulding machines, chain morticers, tenon machines, etc., the range can nevertheless include many of the items mentioned below.

Circular saw

A circular saw is principally used in a boatyard for rough cutting of stock into planking, framing material, beams, stringers, clamps and other heavy cuts, although it can also be used in cross cutting, resawing, mitering and with added attachments, grooving, rabbeting, etc. The universal type of saw, in which both rip and crosscut blades can be mounted, is the most useful. Where lamination is practised in large quantities it will be extensively used for resawing of laminations.

Bandsaw

Many of the operations for which a band saw is used in a boatyard involve the cutting of bevels. Bevel band saws are of two types, tilting table saws in which the bevel is cut by varying the angle of the table in relation to the saw or tilting frame bandsaws in which the angle of the blade is variable in relation to a horizontal table. Both are widely used, but the tilting frame saw has the advantage of a fixed horizontal table for manoeuvring of heavy timbers. Changes in bevel are controlled by a wheel and the range of bevel is usually 45° to the left and 15° to the right.

Both can also be used for all the other cuts normally made with a bandsaw. A smaller bandsaw or a jigsaw is often useful for cuts of sharp curvature in thin timber for joinery and plywood.

Planers

For the small boatyard, combination planers, performing both surfacing, thicknessing and various other operations depending on the attachments provided, are more desirable, but in larger yards separate heavy duty machines are required.

The surface planer dresses, faces and cuts square edges on keel, frame, deck and other timber and also tapers and bevels straight sections.

The thicknesser is used to reduce timber to dimension after dressing.

Where high accuracy and finish are required, such as in the preparation of laminations, a planer capable of finishing stock to a tolerance of ± 0.01 in (0.2 mm) is needed. A double cutterhead planer capable of planing two surfaces at once and with the number of knife cuts per in (2.5 cm) regulated between 20 and 30 should prove satisfactory.

Moulding machines

A two-speed spindle moulder for use with both square cutter blocks and French spindle head is used in trimming, shaping and moulding stock which is irregular in outline and also for cutting scarf joints in keels and other solid stock. Used with special wood jigs, such a machine can also be used to cut variable bevels on frames or for bevelling hog timbers for planking rabbets.

Sanders are used for sanding before assembly. Although the output capacity of a drum sander is high, unless it is fully occupied it is better to use the slower belt sander because its running costs are lower.

Portable machinery

Portable circular saws are used for cutting to length on the job, the rough cutting of scarfs in keels, keelsons, clamps stringers, etc., and other jobs requiring a straight shaping cut. Small electric jig saws are invaluable where complicated shapes are to be cut in plywood, e.g. planking for hard chine boats, plywood decks, etc.

Portable hand planers have many uses in the planing of curved members, such as the dressing up of laminated beams, frames and stems, where the shape renders planing in a machine inconvenient.

Portable electric drills are extensively used in all types of assembly work for drilling bolts, lead holes for drifts and boat nails, pilot holes for screws, etc. Where large numbers of screw holes are to be drilled, an adjustable bit which drills shaft, shank and countersink in one operation will prove a worthwhile investment.

In all drilling operations care must be taken to buy and use only the correctly powered drill for the size of hole. Forcing a lightly powered tool to drill out holes beyond its capacity is expensive in time and tools.

A special power borer is also available for the drilling of shaft holes, an exacting and time-consuming process when done manually.

In plywood construction and elsewhere where large numbers of screws are to be driven, power screw drivers can considerably reduce the time spent in the screwing of planking and deck panels.

Power hammers can be used for the driving of boat nails and drifts in heavy construction.

Disc sanders are used to sand planking and decks before painting and vibratory sanders and portable belt sanders for joinery items which are to be varnished.

MANAGEMENT AND PLANNING

Series production in boatbuilding, as suggested in this paper, using groups of workmen to perform the various operations down a line of boats, requires careful planning and organization. A clear idea of the time required to carry out each step, the materials and tools needed, as well as the indirect labour and administration to support the working gangs must be co-ordinated into a comprehensive work plan. An analysis such as this is directly linked with a cost estimate and an efficient costing system will be a valuable adjunct to all planning.

The size of each gang and its work must be decided in relation to the other groups so that delays and bottlenecks are eliminated. The number of machines and

machine operators must be geared to the requirements of the construction teams so that maximum output is achieved.

Investment of capital in machinery

When equipping a yard for series production or buying new machinery to reorganize an existing yard, the problem is not simply one of buying the most modern machines with the fastest productive capacity. Several factors should be considered. Of major importance is the question of recovery of capital.

The cost of a machine is retrieved by way of depreciation, which is an annual amount charged to the cost of production during the working life of the machine. Over-capitalization in machinery may result in such high depreciation charges that they cannot be recovered from the price fixed for boats under production and a part of the charges will have to be recovered from previous profits. Consequently each machine and piece of heavy equipment acquired, must be integrated into the overall production plan, with a careful balance struck between the increased production obtained and the higher depreciation charges to be supported.

The productive capacity of the machinery must be considered in relation to other processes in the series. To take a simple case, a yard contemplating the purchase of a fork lift truck or small mobile crane for the mechanical handling of timber and its delivery to the machines, must first calculate the quantity of timber which can be processed by its machinery over a fixed period and the amount of time which the lift or crane could be occupied in carrying out this operation. Other possible jobs which could be performed, such as transportation and installation of engines, are then taken into account and the maintenance and depreciation charges balanced against increased production and the reduction of labour costs by the elimination of labourers for handling. Investment in additional machinery to provide increased production must be based on an accurate estimate of the market possibilities so that expensive machinery is not idle, thus increasing the establishment costs on the number of direct-labour hours worked.

Cost estimates

An efficient costing system will provide detailed information on each stage of production and will show how each section contributes to the yearly output, thus providing, as well as the production cost of the boat, information on sources of waste and inefficiency. The expense involved in introducing and maintaining a costing system is likely to be quite heavy, therefore it should be kept as simple as possible within the limits of the information required.

Itemization of construction

Christensen (1955) has proposed a system of itemization to standardize estimation and such a system should be arranged to allow grouping of procedures performed by each gang.

The major headings are broken down into individual operations which are given a number on the decimal system. Job cards can then be filled out daily under the different numbers.

The division suggested is as follows:

1 **Backbone**
    1.1 Keel
    .2 Stem and apron
    .3 Stem knees
    .4 Deadwood
    .5 Stern frame
    .6 Skeg
    .7 Transom
    1.8 Fastenings
    1.0 Total backbone

2 **Framing**
    2.1 Frames
    2.2 Floors
    2.3 Fastenings
    2.0 Total framing

3 **Longitudinals**
    3.1 Keelson
    3.2 Bilge stringers
    3.3 Clamp and beam shelf
    3.4 Shaft log
    3.5 Engine foundations
    3.6 Breast hooks
    3.7 Fastenings
    3.0 Total longitudinals

4 **Planking**
    4.1 Planking
    4.2 Blockings
    4.3 Fastenings
    4.0 Total planking

5 **Decks**
    5.1 Deck beams
    5.2 Knees, partners, blockings
    5.3 Deck strapping, tie rods
    5.4 Covering board
    5.5 Deck planking
    5.6 Fastenings
    5.0 Total decks

6 **Interior joinery**
    6.1 Bulkheads, transverse and longitudinal
    6.2 Ceiling
    6.3 Fish hold
    6.4 Stanchions and pillars
    6.5 Flooring
    6.6 Built-in furniture
    6.7 Doors
    6.8 Ladders
    6.9 Fastenings
    6.0 Total joinery

7 **Superstructure**
    7.1 Deckhouse and cabin trunks
    7.2 Framing
    7.3 Exterior sheathing

7.4 Doors and windows
7.5 Interior sheathing and bulkheads
7.6 Hatches and skylights
7.7 Fastenings
7.0 Total superstructure

8 Deck fittings

8.1 Masts and spars
8.2 Rigging
8.3 Deck machinery
8.4 Steering gear
8.5 Miscellaneous deck fittings
8.6 Fastenings
8.0 Total deck fittings

9 Machinery and associated piping

9.1 Main engine
9.2 Engine installation (including shafting propellers, bearings)
9.3 Generators
9.4 Controls and instruments
9.5 Tanks
9.6 Fuel filling and transfer systems
9.7 Pumps, plumbing and sanitation
9.8 Refrigeration, heating and ventilation
9.9 Accommodation engine room
9.0 Total machinery

10 Finishing

10.1 Caulking
10.2 Paying
10.3 Sanding
10.4 Preservatives and painting
10.5 Miscellaneous
10.0 Total finishing

11 Electrical

11.1 Batteries
11.2 Panels and switchboards
11.3 Lighting fixtures
11.4 Wiring
11.5 Electronic equipment
11.6 Antenna and lead-in trunks
11.7 Searchlights
11.0 Total electrical

12 Equipment

12.1 Ground tackle
12.2 Fishing gear
12.3 Boats
12.4 Navigation equipment
12.5 Life-saving equipment
12.6 Fire extinguishers and equipment
12.7 Tools and spares
12.8 Bosun's stores
12.9 Galley equipment
12.0 Total equipment

13 Miscellaneous

13.1 Transport
13.2 Launching
13.3 Other items

Elements of costing

The total costs incurred in the construction of a boat can be divided into three main headings:

- Expenditure on materials
- Expenditure on direct labour
- Cost of establishment charges

Using the itemized construction plan set out above, materials and direct labour can be calculated for each item as proposed by Christensen (1955).

Establishment charges

This includes yard costs, administration costs, sales and advertising costs.

Yard costs group all the expenses incurred in the building yard and include rent, lighting, heating, power, plant maintenance, indirect labour, tool replacement and depreciation on machinery. Standing charges do not vary with production and include rent, rates, heating and depreciation. Variable charges such as tool replacement and electric power fluctuate according to quantity of production and must be calculated on the volume of the work estimated for the year.

Administrative costs include office and drawing office salaries, printing and stationery, depreciation on office equipment, audit fees, etc.

Sales and advertising costs must include the preparation of bids, display advertising, etc.

With direct labour hour costing, the wages expended on direct labour during one hour are calculated and the correct percentage of establishment charges added. This percentage is calculated by comparing the establishment costs over the previous year with the costs of direct labour for the same period.

The successful operation of the system is dependent on the accuracy of the estimated establishment charge percentage and on the continuity of production during the year. Evidently the standing charges are not dependent on production, hence if there are any delays in production the establishment charge percentage will be higher than calculated and this increase will have to be deducted from the profit.

The production plan

The itemized construction list can be analysed and sections relevant to the boat under construction timed to fit into an overall production plan. A basic timetable is established so that each section of work is co-ordinated into the general plan and work on various items proceeds simultaneously in order. This done, a breakdown of the labour force can be established to assign the correct numbers of workers to each gang so that production proceeds smoothly. Arriving at a co-ordinated plan is not a simple procedure and its application depends on considerable juggling with the limiting factors, the skilled labour force available, delivery dates of equipment and material, facilities available in the yard, etc. Such a plan will be subject to revision in the light of experience gained as production proceeds and here cost accounts are a valuable aid to increase production efficiency.

FACTORS IN THE ESTABLISHMENT OF A BOATYARD

The establishment of a new boatyard or the re-equipping of an old yard to undertake series production requires a careful study of the possible demand for new boats.

In developing countries, where a new type of fishing industry is being established, information as to the availability of financial aid for the purchase of boats either by government subsidy or loan, private loan capital or co-operative ownership will assist in assessing the possible market.

Economic and other factors connected with the fishing industry as a whole will provide guides to possible development with an increased demand for boats. Information on the following points will aid decisions:

- Materials for boatbuilding available locally
- Restrictions and import quotas which could hamper the supply of necessary materials and equipment
- Sources of skilled craftsmen for boatbuilding
- Resources of the local fishing grounds
- Ratio of supply and demand in the local marketing of fish
- Export possibilities for fish or fish products
- Storage and canning facilities and plans for new development
- Harbour facilities available or planned for increased fleets
- Availability of crews to man larger fleets
- Existence of government fisheries schools for training of fishermen

TRAINING OF PERSONNEL

One of the most important assets of a successful boatyard is the skill of its workmen and this is probably most difficult to provide in the establishment of a boatyard in many developing countries.

If sufficient skilled men can be found to provide a charge hand for each gang, the remainder can be composed of men trained in the use of tools (house carpenters for example) who, under the direction of the charge hand, will acquire the skills necessary for the particular operations which the gang is to perform. The transfer of the more able men from gang to gang as they achieve proficiency in one operation will over a period provide trained men with the all-round skills necessary for future foremen and charge hands.

Simultaneously, longer-term training of apprentices should be undertaken. Where craft schools are available, provision should be made for youths to attend courses for one day per week at the expense of the yard to acquire proficiency in the use of woodworking machinery, reading of drawings, use of tools, etc. Where such courses do not exist and for supplementary courses not provided at a craft school (lofting for example) instruction should be given at the yard by experienced personnel. In the yard apprentices should be moved from one gang to another to cover every phase of construction.

Investment in the training of young men as apprentices should be covered as far as possible by indenture for a stated period.

Money invested in such schemes should be included in establishment charges and will in the long term provide a pool of skilled labour which will result in a flexible and smooth-running organization.

Wood for Fishing Vessels

by Gunnar Pedersen

Le bois dans la construction des bateaux de pêche

Les essais normalisés mis au point dans les laboratoires d'étude des produits forestiers depuis 40 ou 50 ans ont permis au bois de passer du stade de matière première artisanale à celui de matière première industrielle. La communication énumère les facteurs structurels intervenant dans la fonction et la forme des bateaux de pêche, et mentionne les caractéristiques de résistance à certaines charges que doit posséder telle ou telle partie de charpente en comparant à cet égard le bois et les autres matériaux. On constate que, par rapport à ceux-ci, le bois possède en matière de résistance et de rigidité des propriétés supérieures; ses caractéristiques sous charge statique sont inférieures et ses caractéristiques sous charge dynamique nettement supérieures.

L'auteur montre la manière dont la résistance à la traction, au cisaillement et à la compression sont affectées par les noeuds, le fil tors, et autres défauts naturels du bois, et comment, à partir d'essais effectués au laboratoire, peuvent être obtenues des valeurs sûres pour la préparation du projet de navire.

L'auteur traite des assemblages homogènes (par collage), qu'il juge les meilleurs, et expose les avantages, ainsi que certains inconvénients, des membrures lamellées et collées par rapport au bois vert plein. Après avoir évalué les propriétés mécaniques des membres ployés, des pièces de quille, des membrures courbes, des barrots, il décrit brièvement des charpentes entières en bois, ainsi que diverses possibilités d'emploi du bois en combinaison avec d'autres matériaux.

La madera en las embarcaciones de pesca

Las pruebas normalizadas llevadas a cabo en los laboratorios de productos forestales durante los últimos 40 ó 50 años han elevado de nivel la categoría de la madera desde corresponder al de la artesanía hasta pasar a ser un material de ingeniería. En este documento se enumeran los factores estructurales en la función y forma de los barcos pesqueros, indicándose las características de resistencia necesarias para soportar cargas determinadas para una pieza estructural específica y comparando estos requisitos en la madera y en otros materiales. Las propiedades específicas de resistencia/rigidez de la madera se ha comprobado que son más elevadas que para otros materiales, las propiedades de carga estática inferiores y las de carga dinámica muy superiores.

En este trabajo se explica en qué forma influyen las resistencias a la tracción, al corte y a la compresión los nudos, las fibras desviadas y otros defectos naturales y de qué forma se pueden deducir valores seguros de resistencia para el diseño a partir de los valores de resistencia obtenidos en las pruebas de laboratorio.

El autor trata la cuestión de las juntas encoladas homogéneamente que considera las mejores, y expone las ventajas y algunos inconvenientes de las piezas estructurales laminadas y encoladas en relación con las de madera verde sólida. Se señalan las propiedades de resistencia para las piezas de madera curvada, las piezas de quilla, las de cuadernas curvas, baos y estructuras de madera completamente montadas, y también se describen brevemente algunas de las posibilidades de utilizar la madera en combinación con otros materiales.

FROM time immemorial, ships have been built of wood and one hundred years ago it was still the only important shipbuilding material. In this century, the use of wood in big ships has become negligible but for smaller vessels wood will continue to be important; however, its special properties must be kept in mind. Hard-gained knowledge of these properties, through trial and error methods, has been forgotten at times. For example, what has happened to the structural designer's ideal, the homogeneous unit structure in which the material uniformly distributes and assimilates load stresses? Fig 1 illustrates how the Egyptians built their obelisk carriers as homogeneous units. The clinker built boats in the right column are also one unit. The multi-layer clippership of the *Vision* class, built from 1850 (Murray, 1851), approaches the ideal (fig 1). Even today the *Vision* would be far advanced on general designs.

During the Middle Ages, the importance of one unit construction was forgotten. The result was the so-called European type ship (fig 1). In this design the many essential interrelated structural and design problems, known by masters for centuries, were ignored. But the large European ship became, by historical circumstance, the only important one. The design was copied and its principles were extrapolated downwards for smaller ships, indiscriminately. Shell built hulls went out of fashion.

Otsu (1960) reported upon an investigation of the longitudinal strength of a small wooden boat built in Japan. These were his calculations for "safety factors" for longitudinal strength properties (vessel age is not given):

Safety factor in compression	35
Safety factor in tension	88
Safety factor in shear	16.5

Otsu concluded that the results suggested a much stronger structure than previously estimated. (Author's note: with content and distribution of undestroyed material at time of investigation.) Otsu went on to say that scantlings might be reduced to save hull weight, but that there must always be a margin for deterioration and easy repair. Otsu sketches an "old type" vessel with interconnecting planks (clench built) and an "improved type" where these strength members have been excluded. The "improvement" claimed fulfils the easy repair criterion of many traditional shipbuilders. Otsu's values clearly indicate where strength is lacking and where material should be redistributed. From a wood technology viewpoint, it would seem that this point was reached to facilitate easy repair at the expense of the original aim of strength. The fact is that, if wood is properly protected from deterioration initially, it will last for the life of the ship without constant repair due to biological decay.
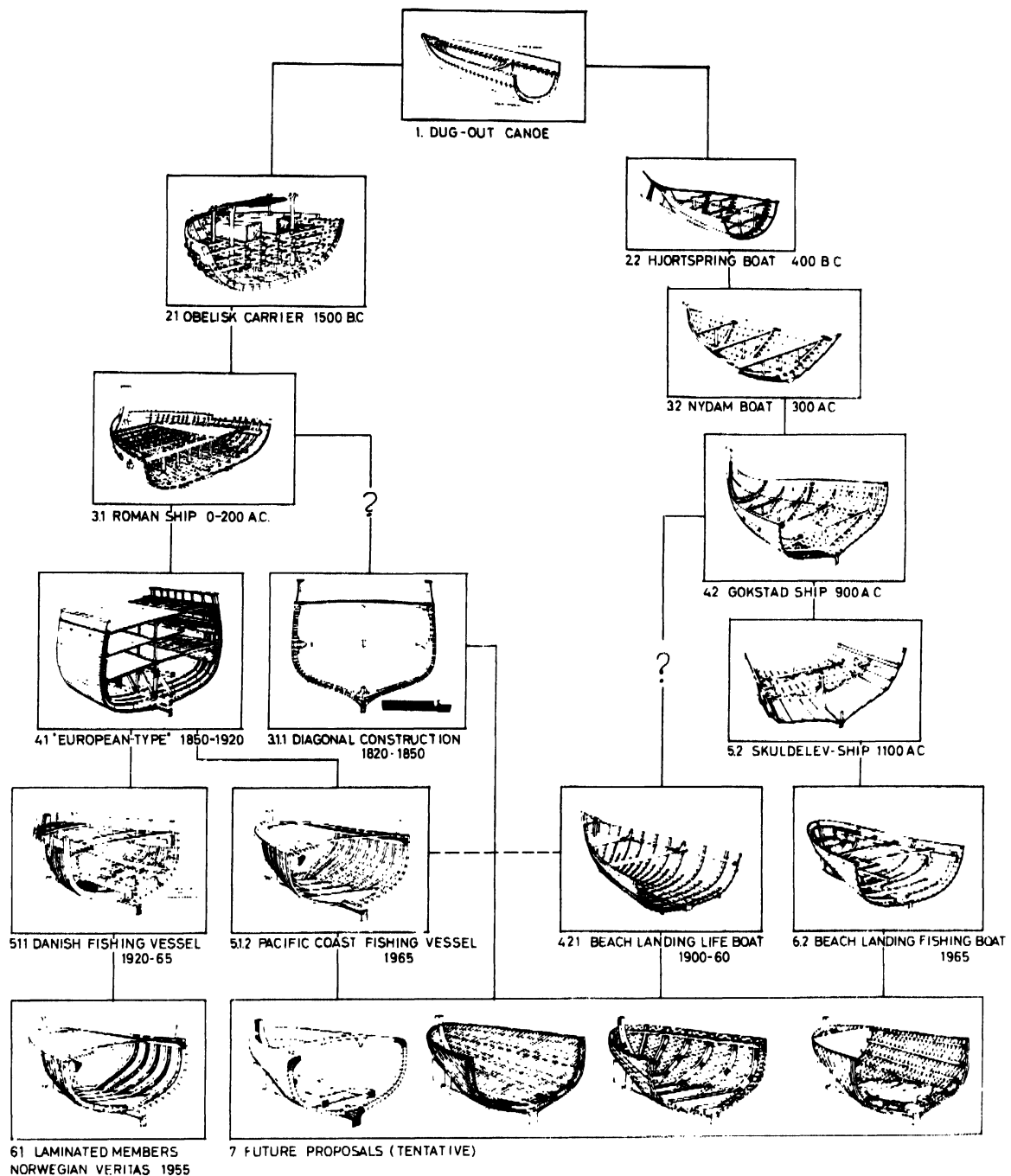
Fig 1. Historical review of wooden boat construction

Wood must be used as an engineering material if it is to survive competition from other shipbuilding materials. No material can be used successfully in engineering unless its properties are well known. The properties of wood have been investigated scientifically for only 40 to 50 years by forest products laboratories all over the world, but primarily in the USA and the UK.

Structural problems

An engineer's main aim is to create a perfect balance between function, form and material. In shipbuilding,

the structural engineer's problem is to find a rational method of structural design. The answers to this problem are constantly being refined for design of larger commercial ships by strength rules, loadline rules and other guidelines. Lewis (1959) says a rational design can be reached only where:

● the functions and requirements can be explicitly stated at the outset

● all loads to be expected can be determined and combined

- structural members can be arranged in the most efficient manner to resist the loads
- adequate but not excessive scantlings can be determined, using a minimum of purely empirical factors

The challenge for tomorrow's builders of wooden ships is to break free of traditional thinking, to study the teachings of the masters of centuries ago, to combine this with modern knowledge and to progress from there to improve and refine ship design without forgetting the properties of their material. Studies of wood reveal some excellent dynamic-strength properties, superior to other materials. The overall distribution of properties shows wood as more versatile than any other relevant material. If modern knowledge is conscientiously applied, builders in wood can look forward to being in a strong competitive position for vessels up to 100 to 150 ft (30 to 45 m). Progressive builders may even regain some of the ground lost to steel in the upper part of this range.

This paper lists first the members affected by the structural requirements of fishing boat function and form. The properties of wood are then assessed to show how well the use of wood, as an engineering material, satisfies these requirements. First the structural properties (*mechanical*) are discussed. It is shown how practical design stress values are evaluated from standard test values, taking all strength reducing factors for natural, undecayed wood into account. Next the non-structural properties (*physical*) are discussed. Environmental factors which affect physical properties and relevant combinations of these are mentioned. Biological decay, and protection from decay, are taken up separately. Strength properties of wooden joints, members and complete structures are outlined. Tentative design proposals are given for round and V-bottom fishing boats, based on the foregoing information.

STRUCTURAL FACTORS IN FISHING BOAT FUNCTION

To function as a consistent and economic unit for catching fish, a fishing boat must provide safe living and working conditions for the crew. It must be stable and strong enough to withstand rough treatment. Its material must be resilient and have good impact strength properties. Since a fishing boat may be considered a platform from which to catch, process and store fish, this "platform" must be strong enough to support all the necessary fish-finding and catching gear, plus processing equipment. The platform must be steady enough to allow convenient processing work. The hold must be big enough and strong enough to contain an optimum catch.

The overall strength properties required for various load conditions (at sea and when docked) determine distribution and scantlings of these structural members:

> Longitudinal deck and bottom
> Diagonal side, deck and bottom
> Transverse bulkhead and frames

Impact-load strength requirements determine distribution and scantlings of the following structural members, depending on load directions:

- For horizontal longitudinal loads:
  Longitudinal margin members and stringers
  Local easily replaceable rubbing members
- For horizontal transverse loads:
  Transverse bulkheads
  Transverse frames
  Longitudinal margin and stringers
  Local easily replaceable rubbing members along sides
- For vertical transverse loads:
  Transverse bulkheads
  Transverse deck beams
  Longitudinal deck stringers
  Pillars connecting deck and bottom
  Easily replaceable rubbing members (keel shoe, deck cover)

Arrangements of structural members must be a compromise between the most efficient arrangement to support the loads and the most practical arrangement to achieve inexpensive construction, maintenance and repair. Arrangement in the most efficient manner to support the loads affects the following classes of structural members:

- Longitudinal members (tension and compression):
  Longitudinal bulkheads in or outside centreline
  Keel
  Margin at side-deck connections
  Bilge and bottom
  Deck along hatch coamings
  Longitudinal deck and bottom planking
- Diagonal members in deck bottom and sides (shear):
  Diagonally laid side, bottom and deck planking, firmly fastened to longitudinal margin
- Transverse members (compression and bending):
  Transverse bulkheads
  Deep web frames
  Normal size frames and deck beams
- Perpendicular members (compression):
  Pillars connecting deck and bottom

The interrelation between longitudinal, diagonal and transverse members depends on the efficiency, number, type and distribution of joints and the efficiency, type and distribution of joint fastenings.

STRUCTURAL FACTORS IN FISHING BOAT FORM

Assuming a fixed gross tonnage or displacement, the following factors affect initial cost: choice of length, L/D, L/B, block coefficient, amount of material and construction method. Running costs are affected by:

Resistance (choice of length, prismatic coefficient, distribution of buoyancy along length, weight of light ship)
Propulsion (propeller must suit hull under various working conditions)
Maintenance and repair (costs should be small)
Influence of form upon strength.

Structural considerations include choice of principal dimensions and ratios between dimensions. The choice is dictated by the properties of the material when arranged in the most efficient and practical manner. Factors in the influence of form upon hull strength include L/D, L/B, dead rise, bilge radius, distribution or curvature along the hull and influence of sheer curvature.

It has been recognized for a long time that smaller ships, due to their form, are relatively stronger than bigger ships (Hajimu, 1961; Alexander, 1949; Bruhn, 1901/1904; Oehlmann, 1963; Bureau Veritas, 1963; Grim, 1952/1953; Pedersen, 1964). The shell action, greater dead rise and other form factors should be used with advantage to strengthen smaller ships, thus reducing scantlings and increasing pay-loads.

SPECIFIC GRAVITY AND STRENGTH/ STIFFNESS PROPERTIES

In order to convert raw wood material into a hull structure which fulfils form and function, the mechanical properties and interrelated physical properties of wood material must be known. It also must be known how the environmental factors affect physical properties, which in turn affect the mechanical properties, in order to protect the relevant properties from deterioration.

Specific gravity

Specific gravity is an excellent indicator of mechanical and physical properties. The substance of which wood is composed is heavier than water. Its specific gravity is about 1.56, regardless of species. In spite of this, the dry wood of most species floats in water, because a large part of the volume is occupied by cell cavities and pores. Variation in the size of these openings and in thickness of the cell walls causes some species to have more wood substance than others, and therefore to have higher specific gravity values, and greater strength.

It should be noted that specific gravity values are also affected by gums, resins and extractives, which may contribute slightly to certain strength properties. Fig 2 shows curves for average strength/stiffness properties for species of varying specific gravity ("ideal" wood). Formulae for the curves are given in table 1, taken from the Wood Handbook, (US Forest Products Lab., 1955). These curves are based on numerous strength tests of more than 160 species of varying specific gravity. The great difference between properties of dry and green wood is easily seen.

Static-load properties increase considerably when moisture content decreases (below fibre saturation point), while dynamic-load properties decrease slightly at the same time. Strength properties differ greatly

TABLE 1

Strength/Stiffness Properties as a function of Specific Gravity

		Green wood		Dry wood (12%) moisture content		Curve No. in fig 2	
		K	α	K		dry	green
Static bending:							
Fibre stress at proportional limit	lb/in²	10.200	1.25	16.700	1.25	1d	1g
	kg/cm²	0.720					
Modulus of rupture	lb/in²	17.600	1.25	25.700	1.25	2d	2g
	kg/cm²	1.210					
Work to maximum load	in-lb/in³	35.6	1.75	32.4	1.75	3d	3g
	cm-kg/cm³	2.510					
Total work	in-lb/in³	103		72.7	2	4d	4g
	cm-kg/cm³	7.255					
Modulus of elasticity	1,000 lb/in²	2,300		2,800		5d	5g
	1,000 kg/cm²	0.162					
Impact bending:							
Height of drop causing complete failure	in	114	1.75	94.6	1.75	6d	6g
	cm	290					
Compression parallel to grain:							
Fibre stress at proportional limit	lb/in²	5.250		8.750		7d	7g
	kg/cm²	0.370					
Maximum crushing strength	lb/in²	6.730		12.200		8d	8g
	kg/cm²	0.475					
Modulus of elasticity	1,000 lb/in²	2.910		3.380		9d	9g
	1,000 kg/cm²	0.205					
Compression perpendicular to grain:							
Fibre stress at proportional limit	lb/in²	3.000	2.25	4.630	2.25	10d	10g
	kg/cm²	0.210					
Hardness:							
end grain	lb	3.740	2.25	4.800	2.25	11d	11g
	cm	1.700					
side grain	lb	3.420	2.25	3.770	2.25	12d	12g
	cm	1.550					

The properties and values should be read as equations Property = K × Gⁿ. For example, modulus of rupture for green wood = 17.600 G,¹·¹ where G represents the specific gravity of oven-dried wood, based on the volume at the moisture condition indicated.

[215]
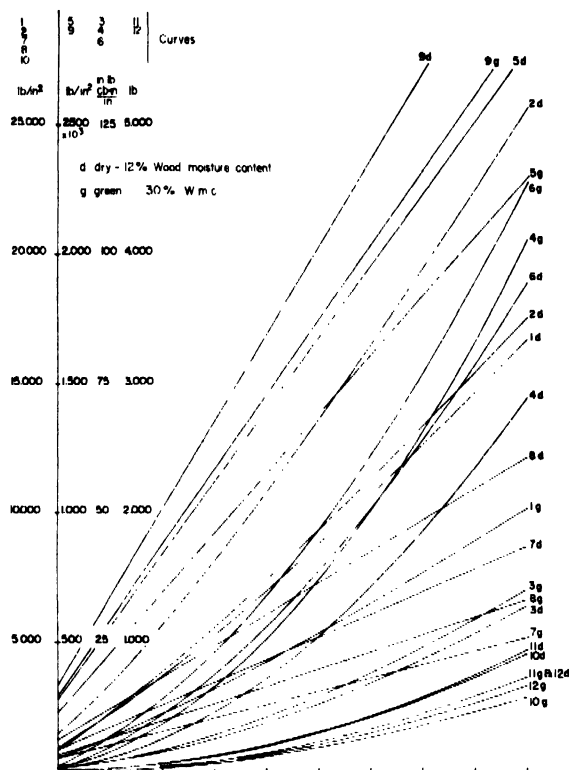
Fig 2. Strength/Stiffness properties of wood (US Forest Products Lab. 1955)

depending whether force is along or across the grain (see for example, compression strength curves 7 and 10).

Specific gravity also indicates such physical properties as swelling and shrinking. Denser species generally shrink and swell more than lighter. Here, influence of gums, resins and extractives may have a considerable

effect, as a large content of these generally reduces swelling and shrinking (see also Kollman, 1951).

Specific strength

Peery (1950) gives formulae for calculating specific strength values in tension/bending/compression for typical aircraft sheet materials. Assuming that shipbuilding materials may be calculated using the same formula, values given in table 2 have been derived. The values show:

- Weight ratios for tension members do not vary greatly for the different materials
- For members in bending, the lower density materials (plastic, wood) have a distinct advantage
- For members in compression (buckling), the lower density materials (wood), have even greater advantages than in bending

The values explain why Sitka spruce has been so widely used for bending and compression members in aircraft structures.

MECHANICAL PROPERTIES (STRUCTURAL)

Static-load properties

In table 3, values are given for static-load properties, obtained from laboratory tests with actual shipbuilding materials (Marin, 1962). It is seen that different shipbuilding materials are tested in different ways, depending on the nature of the material. Crystalline, inorganic materials such as metals are predominantly "tensile" materials, while fibrous materials such as laminated plastics and wood (organic) are "compression" and "bending" materials. Therefore the static-load properties cannot be compared directly. Although the static-load

TABLE 2

Specific strength/stiffness values

Material	$F^* \times 10^3$		w		$E \times 10^6$		Tension	Bending	Compression
	lb/in^2	kg/cm^2	lb/in^3	kg/cm^3	lb/in^2	kg/cm^2			
Mild steel	6.00	4,230	.283	0.0079	30.0	2.11	2.85	7.07	13.90
Aluminium alloy	3.50	2.465	.100	0.0028	10.6	0.75	1.74	3.26	3.22
Laminated plastic	3.00	2.115	.050	0.0014	2.5	0.18	1.01	1.76	2.68
White oak	1.20	.845	.024	0.0007	1.8	0.13	1.21	1.33	1.39
Sitka spruce	0.94	.660	.015	0.0004	1.3	0.09	1.00	1.00	1.00

Formula:

Tension $\dfrac{W_1}{W_2} = \dfrac{w_1}{w_2} \dfrac{F_2}{F_1}$

Bending: $\dfrac{W_1}{W_2} = \dfrac{w_1}{w_2} \sqrt{\dfrac{F_2}{F_1}}$

Compression: $\dfrac{W_1}{W_2} = \dfrac{w_1}{w_2} \sqrt[3]{\dfrac{E_2}{E_1}}$

F : Ultimate strength in tension
E : Modulus of elasticity
w : Density
W_1: Weight of amount of material No. 1: resisting the same load
W_2: Weight of amount of material No. 2: resisting the same load.
* Values for F vary with cross section. The values shown are only relative values for comparison.

[216]

TABLE 3

Static-load properties (from Marin, J. : Mechanical behaviour of Engineering materials, 1962)

(a) Mild steel and aluminium alloy

Material	Density lb/in² (kg/cm²)	Tempera-ture coefficient in/inF⁰ (cm/cm/C⁰) · 10⁶	Strength in tension lb/in² (kg/cm²) · 10³		Modulus of elasti-city in tension lb/in² (kg/cm²) · 10⁶	Percent-tage elonga-tion in/2in (cm/5cm)
			Yield	Ultimate		
Mild steel	0.28 (0.0078)	6.5 (11.7)	35 (2.46)	60 (4.23)	30 (2.11)	30
Alum-inium Alloy	0.10 (0.0028)	12.8 (23.1)	25 (1.76)	35 (2.46)	11 (0.77)	---

(b) Laminated plastic

Material	Ultimate strength lb/in² (kg/cm²) · 10³			Modulus of elasticity in tension lb/in² (kg/cm²) · 10⁶	Specific gravity
	Tension-	Com-pression	Bending		
Laminated Plastic	3.0 (0.21)	11.2 (0.79)	9.8 (0.69)	12 (0.85)	1.70

(c) Ideal wood small clear specimens 2 · 2 in (5 · 5 cm)

Material		Specific gravity	Moisture content per cent	Bending lb/in² (kg/cm²)			Compression parallel to grain lb/in² (kg/cm²)		Fibre stress at prop. limit in compression perpendicular to grain lb/in² (kg/cm²) · 10³	Ultimate shear strength parallel to grain lb/in² (kg/cm²)
				Fibre stress at prop. limit · 10³	Modulus of rupture 10³	Modulus of elasticity 10⁶	Fibre stress at prop. limit · 10³	Ultimate strength 10³		
White Oak	dry	0.68	12	8.2 (0.58)	15.2 (1.07)	1.78 (0.125)	4.76 (0.34)	7.44 (0.52)	1.32 (0.09)	2.00 (0.14)
	green	0.60	68	4.7 (0.33)	8.3 (0.58)	1.25 (0.09)	3.09 (0.22)	3.56 (0.25)	0.83 (0.06)	1.25 (0.09)
Sitka spruce	dry	0.40	12	6.7 (0.47)	10.2 (0.72)	1.57 (0.11)	4.78 (0.34)	5.61 (0.40)	0.71 (0.05)	1.15 (0.08)
	green	0.37	42	3.3 (0.23)	5.7 (0.40)	1.23 (0.09)	2.24 (0.16)	2.67 (0.19)	0.34 (0.02)	0.76 (0.05)

TABLE 4

Dynamic load properties (damping properties)

Material	Test method	Type of stress	Working stress as per cent of maximum %	Internal friction in solids: logarithmic decrement
Mild steel	Torsion	Pure shear	---	0.0049
Aluminium (aircraft alloy)	,,	,,	----	0.0034
Wood: maple	,,	,,		0.021
,, : Sitka spruce	,,	,,	---	0.0521
Wood: unspecified	Flexure	Bending		0.027
,, : Sitka spruce	,,	,,	---	0.035
Wood: laminated birch	,,	,,	- -	0.073
*Staypak—Yellow birch	,,	,,	---	0.128
*Compreg—YB high-impact type	,,	,,		0.238
,, —YB low-impact type	,,	,,		0.108
,, —maple	,,	,,	---	0.239
Wood—laminated birch	Compression	Axial	84	0.002
			88	0.012
			93	0.063
Staypak—Yellow birch	,,	,,	86	0.0013
			89	0.0465
			92	0.1435
Compreg—Yellow birch high-impact type	,,	,,	83	0.173
			89	0.232
Compreg—Yellow birch low-impact type	,,	,,	74	0.045
			87	0.157
			90	0.172
Compreg—maple	,,	,,	89	0.0002
			93	0.218

* Impr. wood products developed by US Forest Products Laboratory
Reference: Report Acn-18, US Department of Defence: "Wood in Aircraft Structures", 1951.

strength/stiffness properties of wood are smaller than other materials, this need not be a disadvantage. The larger cross section afforded by wood may better withstand buckling failures in compression and bending members than thin walled, built up, deep profiles in metals, laminated plastic and plywood. The low values for shear strength parallel with the grain may cause troubles in deep beams, which may split along the neutral axis if precautions are not taken (Beghtel, 1959).

Dynamic load properties

Fatigue: The fatigue resistance of a material may be defined as the ability to sustain repeated, reversed, or vibrational loads without failure (US Dept. of Defence Report, 1951).

Shock and impact: Of all construction materials only wood has the property of being able to sustain high loads for short duration (Liska, 1950). Where metal structures may buckle locally when exposed to impact loads, wood members are able to take about 100 per cent overloads (see: Load-duration).

Damping: Damping capacity may be defined as ability of a solid to convert mechanical energy of vibration into internal energy (heat). This causes vibrations to die out. If a truly elastic material is subjected to a cycle of stress, the stress-strain curve will be a straight line. If the material undergoes reversible plastic deformations during the cycle, the stress-strain curve will be a hysteresis loop (fig 3). The area enclosed by this loop represents the amount of energy expended during each complete stress-cycle. Specimens subjected to cycles of stress below the fatigue limit can dissipate an unlimited quantity of energy as heat without any damage (fatigue failures). In table 4 values are given for damping properties, expressed as logarithmic decrement for the hysteresis loop. It also gives values for some improved wood products, developed at the US Forest Products
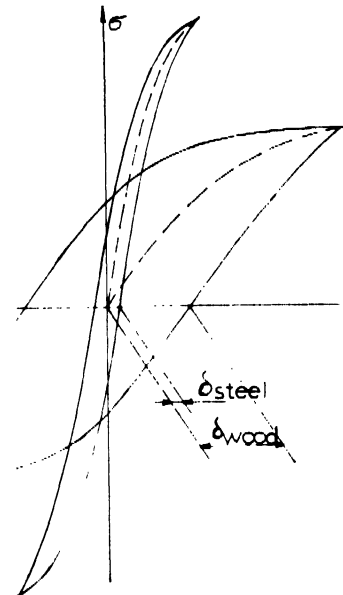
Fig 3. Damping Properties

Laboratory, primarily intended for aircraft structures. The damping properties of these refined wood products, especially the compressed wood products (Compreg), show extremely good values and indicate what levels may be reached by utilization of wood and wood products in future wooden ship design.

"Ideal" material

Values given for wood in the standard tests, bending, compression, shear etc, are valid only for "ideal" wood. "Ideal" wood is a wood material similar in properties to the small, clear specimens used in the tests. This wood is tested under standard conditions such as those international conditions proposed by FAO (1954, 1958, 1963), which are:
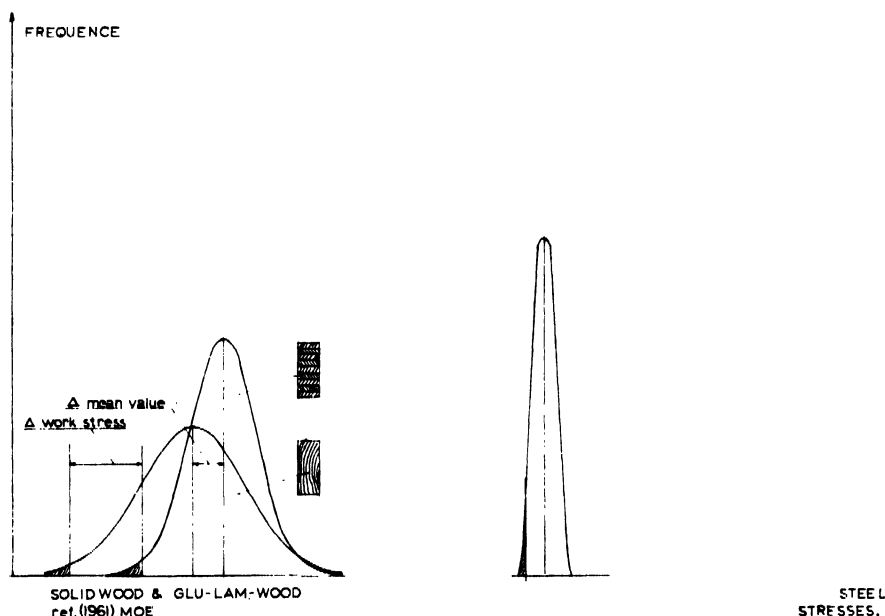
Fig 4. Variability in mechanical properties

[218]
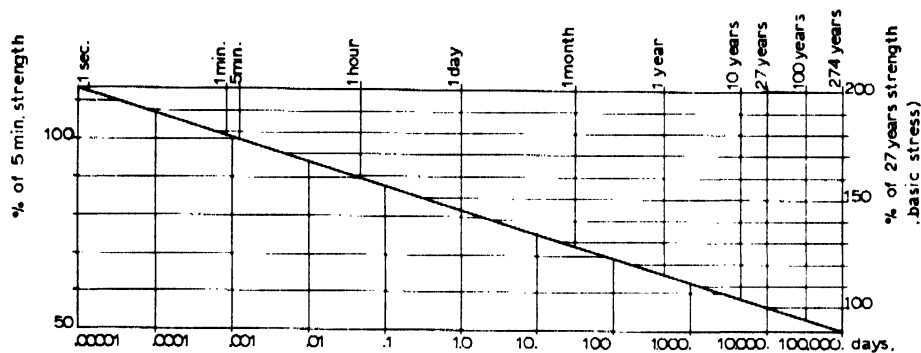
Fig 5. Load-duration/stress-relation for wood, ref: US Forest Products Lab. (1955)

Wood moisture content (1) 12 per cent
                              (2) above 30 per cent (above
                                   fibre saturation point)
Load duration   5 min
Temperature   68°F (20°C)

Factors which affect mechanical properties

Variability

Variability in mechanical properties is common to all materials. Fig 4 shows that the degree of variability, expressed as standard deviation of the frequency distribution curve for the property investigated, differs markedly with the type of material. Man-made materials can be manufactured to within narrow limits of tolerance for specified properties. The frequency distribution curve is narrow with the mean value near the approached aim. For natural materials, however, such as wood, the curves are wide. More than 95 per cent of the strength values are higher than the accepted near-minimum value, which is three-quarters of the average for wood. Thus the factor 3/4 is used to represent variability in wood (Wood, 1960). It also is remarked how the wood materials can be improved by utilizing the lamination technique (Moe, 1961).

Load duration

Wood creeps under permanent loads. For long duration use (27 years), the US Forest Products Laboratory recommends reducing design strength values to 56 per cent of standard test values. Fig 5 shows the load duration working stress curve recommended by this laboratory (Wood, 1951). The built-in overload properties are clearly seen when using the 27-year basic stress values.

Moisture content

Fig 2 shows that wood moisture content has a marked influence upon strength when wood is dried below fibre saturation point (below about 24 to 28 per cent). However, this increase need not be too seriously considered in practical design work, since checks and shakes develop during drying which either partially or completely nullify the increase. Generally, the increase in strength with drying is more marked in members of small dimension (e.g. lamellae for glue-laminate members), where internal drying stresses are of a low order of magnitude and where checks are not as important as in larger members. In the larger members, drying stresses may cause serious strength-reducing checks.

Temperature

Influence of temperature on mechanical properties need not be emphasized in design work. Although wood properties are adversly affected by temperature, the comparative effect in metal is many times greater, where internal stresses due to temperature variations may cause serious trouble due to brittle failures.

Combined factors

The relation between initial values of stress, time and temperature and between stress, time, wood moisture content (WMC) and temperature have only a minor influence under normal service conditions. The practical designer can ignore these relations without apprehension.

Mechanical properties of clear, structural components

Basic stress may be defined as the stress which can be permanently sustained with safety for an ideal structural component containing no strength reducing factors. Alexander (1949) and Armstrong (1961) give basic stress values for a wide range of structurally important wood species.

Strength reducing factors (knots, cross grain, etc.)

Definition of defect

A defect in timber is an irregularity occurring in or on wood that may lower any of its basic strength properties (Newlin, 1924). One fundamental characteristic of wood is the difference in its strength along and across the grain. Wood is about 16 times as strong in the direction of the grain as across the grain. This difference in strength with different angle of the grain accounts for the serious weakening effect of most defects.

Effect of defects on mechanical properties

Tension is affected most seriously by cross grain, knots, cross breaks and compression failures. Since the outside fibres on the convex side of beams have to sustain tensile stresses, the load capacity of a beam depends especially on the tensile strength properties of these extreme fibres.

Reduction in shear strength is due almost entirely to shakes and checks which reduce longitudinal shear

strength properties considerably. The effect of cross-grain and knots is much less in compression than in tension. The compressive strength of wood parallel with grain is six to ten times that of wood tested perpendicular to the grain. For bearing strength at an angle to the grain, the intermediate values given by Newlin (1939) should be used (Hankinson's Formulae).

Working stress values

Working stress may be defined as the stress which can be permanently sustained with safety by a structural component of a particular grade. Sunley (1961) gives working stress values for different species, graded after content of defects.

Structural grading

Stress-grading of timber was developed to save work. Each individual piece of timber is stress-graded and stamped as it leaves the saw. Stress grade classes are proposed for international standardization by FAO (1954, 1958, 1963). Grading is a useful tool for designers when designing beams and other members where stresses vary along the length and across the section; for example, in glue laminate members with lamellae of different grades in outer and inner layers.

Design stress values

Design stress may be defined as the stress which can be permanently sustained with safety by a structural component member under the particular service conditions of loading. To obtain design stress from basic stress for a particular species of a particular grade of structural timber, used to fulfil a given structural function, the procedure outlined above and described in detail by the US Forest Products Lab. (1955) or the Nav-Ships Manual Vol. III (US Bureau of Ships 1957–62) should be followed, provided great accuracy is afforded in each case.

Safety allowance for mechanical properties

No matter how accurately one calculates the inter-related strength properties and strength reducing factors, one will never have a precise estimate of all the conditions under which the wood member must be ultimately tested in service. An additional variable will be the judgement of the designer. After all calculations have been made, a "factor of safety" will arise. Wood (1960) discusses this in detail for timber structures.

PHYSICAL PROPERTIES

(Non Structural, which may affect Structural)

Fire resistance, thermal conductivity or resistance; effects of chemicals, electrical conductivity or resistance; diffusivity, absorption, swelling and shrinking; biological decay resistance (FAO, 1954).

Environments affecting physical properties

Physical: fire
Chemical: effects of sea water plus oxygen
Climatic: air moisture content, temperature, oxygen
Biological: wood-destroying organisms.

Effect of environment—relevant combinations

Fire/Fire resistance
Chemical/effect of chemicals: chemical corrosion rust,
Chemical/electric conductivity: electro chemical corrosion
Moisture/diffusivity: drying or penetration of wood
Moisture/absorption
Moisture/swelling and shrinking
Biological/decay resistance.

Generally speaking, inorganic materials are affected by physical and chemical factors, but unaffected by biological. The reverse can be said for the organic materials. Tables 5 to 8 compare and judge the first six combinations.

Biological decay

Because wood is a link in nature's life cycle, certain biological organisms attack and devour it. Their food comes from the cell wall content, either cellulose or lignin, or both, the same elements which give wood its strength (cellulose—tensile strength; lignin—compression strength).

Effect of fungal decay

Cartwright and Findlay (1958) investigated reduction in strength caused by a fungus (*Polyporus hispidus*) growing in pure culture on ash wood. They found that impact-bending properties (toughness) were rapidly affected. After only two weeks' exposure to the fungus,
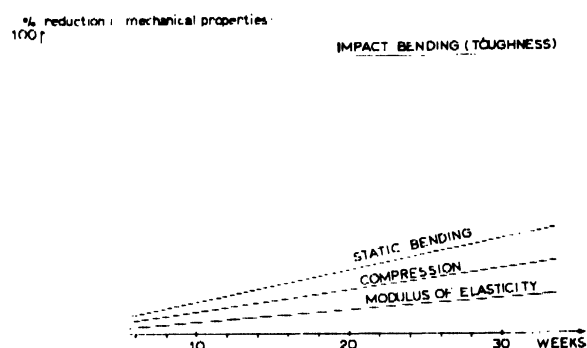
Fig 6. Reduction in mechanical properties of ash to attack by Polyporus hispidus, ref: Cartwright and Findlay (1958)

there was a 20 per cent reduction in this property. After 12 weeks, the impact bending properties had dropped to 10 per cent of their original values (fig 6). The following conclusions were drawn:

- Fungi causing brown rot, in which attack is mainly directed against the cellulose, cause a fairly rapid loss of strength
- Fungi causing white rot, in which all wood constituents are attacked, may also cause a rapid drop in toughness in certain species, but this will occur less rapidly than with brown rot
- Fungal infection works most rapidly to destroy toughness. This is followed, in approximate order of susceptibility, by losses in bending strength, compressive strength, hardness and elasticity

TABLE 5

Environmental factors (physical properties)

Classification					
Attack rate	1: unaffected	2: slightly affected	3: moderately affected	4: affected	5: highly affected
Resistance rate	1: highly resistant	2: resistant	3: moderately resistant	4: non-resistant	5: perishable
Factor of protection	1.0	0.8	0.6	0.4	0.2

TABLE 6

Fire/Fire resistance (thermal conductivity or resistance)

	Steel		Aluminium		Laminated Plastic	Wood	
	unprotected	insulated	unprotected	insulated			
Fire resistance	0.2	0.2-0.4	0.2	0.2	0.8-1.0 thick mbrs. 0.4-0.8 med. thick 0.2-0.6 thin mbrs.	1.0 0.8 0.3-0.6	large section med. thick thin mbrs.
Thermal resistance (insulation properties)	0.2	0.2	0.2		0.8-1.0	1.0	

TABLE 7

Chemical/Effect of chemicals (chemical corrosion)
Chemical/electric conductivity (electro-chemical corrosion)

	Steel		Aluminium alloy (sea water resistant)	Lamin. Plastic	Wood
	unprotected	surface-protected			
Chemical resistance (chemical corrosion, rust)	0.2	0.4-0.8	0.8-1.0	1.0	1.0
Electric conductivity (Electro-chemical corrosion)	0.2-0.8 for metals, depending on: (a) combination of dissimilar metals in underwater part of hull, (b) difference in electric potentials, (c) exposed surface areas.			1.0	1.0

TABLE 8

Moisture/diffusivity: (drying, penetration); Moisture/Absorption; Moisture/swelling and shrinking;

	Steel	Aluminium	Laminated Plastic	Wood unprotected from moisture	surface-protected: paints, sheathing	Stabilized
Diffusivity	1.0	1.0	0.9-1.0	0.2-0.8 depends on species	0.2-0.8 depends on species and efficiency of surface-protection	0.6-1.0 depends on species and efficiency of impregnation
Absorption	1.0	1.0	0.6-1.0 depends on manufacture	0.2-0.8 ditto	0.2-0.8 ditto	0.6-1.0 ditto
Swelling and shrinking	1.0	1.0	0.8-1.0	0.2-0.8 ditto	0.2-0.8 ditto	0.6-1.0 ditto
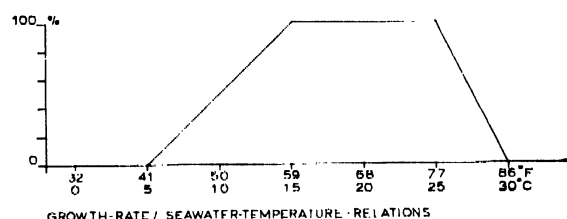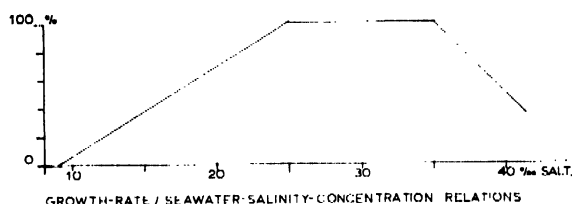
Fig 7. *Growth-rate/growth-condition-relations for marine-borer: Teredo Navalis ref: Kollmann (1951)*

Even though infected wood is hard and firm, one cannot assume its strength as unimpaired.

Growth of wood destroying organisms

Wood-destroying organisms demand the following conditions to grow: food stuff (cellulose and/or lignin in cell walls), suitable hydrogen ion concentration of food, suitable moisture content of wood, suitable temperature level, available oxygen (for marine borers: seawater). In fig 7 growth rate, as function of the above mentioned factors, for marine borer (Teredo) and in fig 8 for fungi are shown (average values).
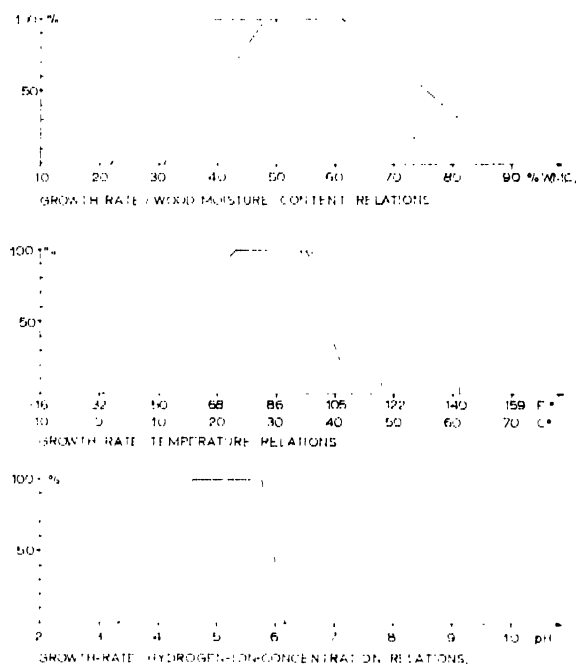
Fig 8. *Growth-rate/growth-condition relations for wood-destroying fungi ref: Cartwright and Findlay (1958)*

PROTECTION FROM BIOLOGICAL DETERIORATION

If combination of all growth factors listed above is not optimum, growth rate will be reduced or even stopped (as in winter time). If only one of these factors is removed permanently, growth cannot progress. As it is known that wood with moisture content below 20 per cent (e.g. interior wood) is too dry for growth of fungi, this fact conscientiously should be utilized in constructive protection.

Control of wood moisture content

In order to obtain a quality wood product, fast removal of water in the log is essential. The following procedure is recommended: Wood is felled in summer time when moisture content is minimum ("sapless"). Immediately after felling, the log must be sawn into lumber. Immediately after sawing, lumber must be artificially dried to a moisture content below 20 to 25 per cent (Verrall, 1949).

Until recently, winter-felled timber followed by natural seasoning was thought superior to summer felled timber followed by artificial drying. The introduction of modern wood drying techniques has reversed this. Now artificially dried summer felled timber is superior. This is because any degree of wood moisture content can be obtained in a short period and wastage due to drying defects and biological attacks during the drying period can be reduced. Artificial drying can be started with a sterilization process to kill all fungi and insects and can be completed with chemical preservation treatment.

Moisture content of wood in boats

Hirt (1944) confirms that wooden boats can be protected by controlling moisture content. With an electrical moisture meter, Hirt investigated moisture content of wood in more than 85 boats operating in fresh water. He concluded: "Information obtained indicates that the moisture content of exposed faces of most timbers in tight, well ventilated, fresh-water boats is below fibre-saturation point (24 to 28 per cent); that is, too low to permit decay even below the waterline."

Since wood absorbs water most rapidly along the grain, the critical points are:

● At stem and stern where planks join these members at the rabbet

● At butt joints in planks

● Where holes are bored perpendicular to the grain, as for fastenings, shaft tubing and sea-water connections

● Where ends of frames soak in bilge water

● Where heads of frames and beams are continually wet, due to leakage along stanchions and deck seams

It is at the above points where the use of fungi and decay resistant wood species and timbers treated with preservatives would be of most value. Plywood members in contact with water are apt to absorb moisture more rapidly than solid wood because of exposed end-grain along edges. Poor ventilation encourages a dangerously high moisture content.

When moisture content of boat timbers is above the fibre saturation point (24 to 28 per cent), the cause can be traced to one or more of the following reasons:

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- Use of wood with too high an initial moisture content (above 30 per cent)
- Leakage through seams when the ship moves in seas (European type construction, especially deficient)
- Leakage through butt joints, holes for fastenings, sea-water connections, shaft tubing or other points
- Soaking of members in poorly drained spaces
- Water condensation on cold surfaces, when air moisture content is high
- Constant high air moisture content in poorly ventilated spaces

The sources of these troubles can largely be eliminated by proper construction and provision for good ventilation during construction, service and storage.

Estimated WMC values for members

When wood is installed, its moisture content should always coincide with that expected in service to avoid open seams, loose fastenings and other factors which reduce the lifetime of wood and seriously affect ship strength. These estimated moisture content values for members at installation can be taken as (Hirt, 1944):

20 to 25 per cent for planks below the waterline
15 to 20 per cent for planks above the waterline
15 to 25 per cent for interior strength members.

Ventilation of wooden boat structures

Further preventive protection is afforded by designing wood structures to allow good ventilation of all wood surfaces. Necessary and adequate ventilation equipment is a vital part of constructive protection because it allows wood to dry. Ventilation can be afforded either by natural air (open system) (Evans, 1957) or artificially conditioned air with a fixed moisture content and temperature (closed system) (MacCallum, 1959).

TABLE 9

Natural durability of heartwood species from attack by Teredo (African conditions)

Based upon tests in Teredo infested tropic waters, with 12 · 12 in (30 × 30 cm) sections from 40 different species. McCoy Hill (1964) gives the following classification of species tested. The following rating for classification is used:

Attack rating	Resistance rating	Service expectancy (years)	Classification
Trace to slight	very resistant to resistant	8 plus	A
Slight to moderate	resistant to moderate	5–7	B
Moderate to heavy medium	moderate to slight	1½–4	C
Heavy	non-resistant	minus–1½	D

Class A	Class B
Ambligonocarpus obtusangulas	Acacia nigrescens
Brachylaena hutchnsii	Afzelia quanzensis
Erythrophleum guinrense	Burkea africana
Dialium dinklagei	Chlorophora excelsa
Dialium holtzi	Cassipourea malosana
Manilkara butugi	Juniperus procera
Manilkara propinqua	Mimusops usambarensis

Manilkara sansibarensis	Mimusops fruiticosa
Ocotea rodiaei	Olea hochstetteri
Parinari holstii	Tectona grandis
Terminalia prunoides	Trachylobium verrucossum

Class C	Class D
Brachystegia spiciformis	Albizia glabrescens
Cynometra webberi	Bombax rhodognaphalon
Eucalyptus saligna	Cephalospera usambarensis
Funtumia latifolia	Cupressus lusitanica
Ocotea usambarensis	Cupressus macrocarpa
Pygeum africanum	Entandrophragma stoltzii
Vitex keniensis	Fagaropsis angolensis
	Khaya spp
	Newtonia buchananii
	Ochroma lagopus
	Podocarpus milanjianus
	Pseudotsuga taxifolia
	Ulmus procera

TABLE 10

Natural durability of heartwood species from attack by fungi (European conditions)

Based upon tests with 2 : 2 in (5 × 5 cm) specimen in fungi infested soil, Savory (1961) gives the following classification of species. The following rating for classification is used:

Grade of durability	Expected service years	Classification
Very durable	25 plus	1
Durable	15–25	2
Moderately durable	10–15	3
Non-durable	5–10	4
Perishable	minus 5	5

Class 1

Scientific name	Common name
Dicorynia paraensis	Basralocus
Afrormosia elata	Afrormosia kokrodua
Afzelia spp	Afzelia
Lophira alata	Azobè, Ekki
Ocotea rodiaei	Greenheart
Chlorophora excelsa	Iroko
Eucalyptus spp	Jarrah, Ironbark
Mimusops hechelii	Makorè
Sarcocephalus diderrichii	Opepe
	Padauk
Eucalyptus microcorys	Tallowwood
Tectona grandis	Teak
Paratecoma peroba	Peroba do Campo

Class 2

Scientific name	Common name
Gossweilerodendron balsamiferum	Agba
Castanea sativa	Chestnut (sweet) true
Cordia goeldiana	Freijo
Guarea spp	Guarea
Swietenia macrophylla	Mahogany (Central America)
Quercus spp chiefly Q. alba	Oak (American white)
Quercus robur, Q. petraea	Oak (European)
Pinus caribaea	Pitch pine (Honduras)
Entandrophragma utile	Utile
Thuja plitaca	Western red cedar
Chamaecyparis lawsoniana	Port Orford cedar

Class 3

Scientific name	Common name
Lovoa klaineana	"African walnut"
Cistanthera papaverifera	Danta
Pseudotsuga taxifolia	Douglas fir, Oregon pine
Entandrophragma angolese	Gedu nohor
Dipterocarpus spp	Gurjun, Yang.
Anisoptera spp	Krabak
Larix decidua	Larch (European)
Khaya spp	Mahogany (African)
Quercus spp, chiefly Q. borealis	Oak (American red)
Pinus sylvestris	Redwood, Norway pine
Entandrophragma cylindricum	Sapele

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Ulmus procera	Elm (English)
Ulmus thomasi	Elm (Rock)
Ulmus americana	Elm (White)
Ulmus glabra	Elm (Wych)
Aucoumea klaineana	Okoume, Gaboon
Picea abies	Baltic spruce (whitewood)
Picea glauca	Canadian spruce
Picea sitchensis	Sitka spruce
Abies alba	Silver spruce

Class 5

Fraxinus excelsior	Ash (European)
Fagus sylvatica	Beech (European)
Betula lutea	Birch, yellow
Acer pseudoplatanus	Maple, sycamore
Gonystylus bancanus	Ramin
Ochroma lagopus	Balsa

(Sapwood of all species can be classified as perishable.)

TABLE 11

Resistance to penetration (diffusive properties)

The ease with which wood can be impregnated with preservatives is graded into four groups. Thomas (1964) gives the following list:

1. Extremely resistant: Even under prolonged pressure treatment, absorption is small and there is little or no penetration laterally and only very little into the vessels.

2. Resistant: Species are difficult to impregnate under pressure and require long periods of treatment. Lateral penetration is usually not more than $\frac{1}{8}$ to $\frac{1}{4}$ in (3.2 - 6.4 mm), but in some species penetration along the vessels is quite deep.

3. Moderately resistant: Fairly easy to treat. It is usually possible to obtain a lateral penetration of $\frac{1}{4}$ to $\frac{3}{4}$ in (6.4 to 19 mm) in two to three hours under pressure and the penetration of a large proportion of the vessels.

4. Permeable: Species can easily be penetrated completely under pressure without difficulty, and can be deeply penetrated by the open-tank process (non-pressure treatment).

Species classified after penetration ability: (heartwood only)

Class 1

Scientific name	Common name
Afrormosia elata	Afrormosia kokrodua
Guarea spp	Guarea
Chlorophora excelsa	Iroko
Khaya spp	African mahogany
Swietenia macrophylla	American mahogany
Mimusops hechelii	Makorè
Shorea spp	Red meranti
Quercus robur	Oak (European white)
Tectona grandis	Teak
Entandrophragma utile	Utile

Class 2

Gossweilerodendron balsamiferum	Agba
Pseudotsuga taxifolia	Douglas fir, Oregon pine
Ulmus glabra	Elm (Wych)
Ulmus thomasi	Elm (Rock)
Tsuga heterophylla	Western Hemlock
Dipterocarpus spp	Gurjun, Yang
Larix decidua	Larch (European and Japanese)
Triplochiton scleroxylon	Obeche
Entandrophragma cylindricum	Sapele
Picea spp	Baltic, Canadian, Sitka spruce
Thuja plicata	Western red cedar
Chamaecyparis nootkatensis	Yellow cedar

Class 3

Fraxinus excelsior	Ash (European)
Ulmus procera	Elm (English)
Nauclea diderrichii	Opepe
Araucaria angustifolia	Parana pine
Pinus caribaea	Caribbean pitch pine
Pinus strobus	Yellow pine
Chamaecyparis lawsoniana	Port Orford cedar
Pinus sylvestris	Norway pine, Redwood
Quercus borealis	Oak (American red)

Fagus sylvatica	Beech (European)
Betula lutea	Birch yellow
Acer pseudo-platanus	Maple, sycamore
Gonystylus bancanus	Ramin
Ochroma lagopus	Balsa (for core in sandwich-mbr: only)

(Sapwood of all species can be classified as permeable)

Use of heartwood

To protect the dead cells in heartwood of certain living trees from attack by biological organisms, a natural preservation with more or less effective toxic components takes place in the cell walls. The use of heartwood from such species provides certain protection.

Wood species can be chosen which have moderate to good natural biological resistance properties. Table 9 lists some wood species classified according to natural resistance to attacks by the marine borer Teredo in the tropics (McCoy-Hill, 1964). Further protection against this worm is given by sheathing of glass or nylon fibre plastic (UK, war against — 1965). Table 10 lists some natural durable species which are resistant to wood destroying fungi. Species in the higher classes should be used in combination with control of wood moisture content (Savory, 1961; Hartley, 1960; Krause, 1954; Morgan, 1962; Hillman, 1956).

Chemical preservatives

The most effective protection for moist wood is to permeate it with preservatives which, in effect, poison the food in the cell wall on which wood destroying organisms feed. For sapwood of all species non heartwood, woods formerly classified as perishable and woods for which the full cross section can be penetrated and protected, a pressure-preservative treatment is possible. This treatment will produce superior material for wooden ships of the future. The material thus obtained will be even safer to use than the natural durable species because the grade of protection afforded by treatment can be controlled. Table 11 lists wood species which can be treated easily and protected by penetration with chemical preservatives (Thomas, 1964).

JOINTS

Apart from decay, the greatest weakness in wooden structures lies in the joints (see Timber Engineering Co., 1957). In mechanical fastened joints the stress in one wood member is transmitted to another through point transmitting fastenings. Stress is naturally concentrated around these fastenings (Ichikawa, 1955). In glued joints, the opposite is true; there will be no stress concentration. Rather, stresses will flow uniformly from member to member. Homogeneous joints, therefore, are superior to point transmitting fastened joints. The best joints are the homogeneous glued joint and the worst the poor single drift bolt or round iron bars which cannot even be post-tensioned, as can be done with screwbolts (Yoshiki, 1959).

Should mechanical, rather than glued, joints be preferred, some effort should be made to approach the homogeneous joint as much as possible, to avoid the

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stress concentration by using post-tensioned screwbolts in connection with ring or grid connectors (dowels). A system of closely spaced smaller gauge fasteners such as nails, screws and spikes is even better than a few big widely spaced bolts. Gusset plates of plywood or Compreg should be used to increase the joint area available for nailing. The minimum thickness of a given metal fastening for small gauge fastenings for use in sea water will often be determined from the risk of corrosion (Baehler, 1949; Farmer, 1962; Morgan, 1962). Two metals of different electrical potential must not be used in the same structure because a circuit is established and the most electro positive metal will deteriorate (Packman, 1961). The risk of corrosion may be serious even for heavy bolts and spikes. Such metal failure may be as damaging to the structure as failure of the wood material due to fungi or marine borers. The key to better utilization of wood properties seems to be the water resistant glues.

STRUCTURAL MEMBERS

Glue-laminated members

Possible types of glued structural members include glue-laminated members, structural plywood, structural sandwich and particle boards (Curry, 1957; Erickson, 1959; US Forest Products Lab., 1955; Kollman, 1951). Some significant advantages of glued-laminated members over green solid wood members are (Freas and Selbo, 1954):

- Ease of fabricating large structural elements from standard commercial lumber sizes
- Laminations are thin enough to be seasoned readily before fabrication, giving more freedom from checks or other seasoning defects of large one-piece wood members
- Individual laminations can be dried to provide members thoroughly dried throughout, permitting the designer to make calculations on the basic strength of dry wood for dry service conditions
- Opportunity to design in accordance with strength requirements, structural elements that vary in cross section longitudinally
- Possible use of lower grade material for less highly stressed laminations without adversely affecting the structural integrity of the member
- Large laminated members may be fabricated from small pre-assembled components which may be necessitated by the non-availability of large high grade timber

Certain factors, mostly costs, are involved in producing glue-laminated members which are avoided in solid wood timbers. Some are:

- Preparation of timber for gluing and the gluing itself usually raises the cost of the final laminated product above that of solid green timbers
- A longer period is required to cut, season and laminate timber than is required to produce solid green timbers

- The laminating process requires special equipment, plant facilities and fabricating skills not needed to produce solid green timbers
- Production of glue-laminated members requires several additional operations and extra care to ensure a high quality product than solid members
- Large curved members are awkward to handle and ship by usual carriers

Freas (1956) Ketchum (1949), Moe (1961), Selbo (1957), and UK Timber Research and Development Association (1960) give more information on designing glue-laminated members. Lindblom (1947) gives a general description of manufacturing 148-ft (45-m) wooden ships with glue-laminated strength members.

Bent wood members

Bent wood may be an alternative to curved members of smaller dimensions. Of the several methods commonly used to produce curved parts of wood, bending is the most economical in material, the most advantageous for members requiring strength, and perhaps the cheapest.

Long experience has evolved practical bending techniques and it requires skilled craftsmen to apply them. Yet commercial operations often sustain serious losses because of breakage during the bending operation or the fixing process that follows. It has long been felt that far more reliable information is required about the following: criteria for selection stock; better methods of seasoning and plasticizing wood; more efficient machines; techniques for drying and fixing the bent part to the desired shape; the effect on the strength properties, before competent bending can be performed. (Pillow, 1951; MacLean, 1953; US Bureau of Ships, 1957–62). A special handbook has been issued where all problems in wood bending are dealt with (Peck, 1957).

When bending it is very important to avoid over-stressing the fibres on the convex side, which may cause

Fig 9. Load deflection curves for frame-members of same cross-section 2.0 in × 2.6 in (50 mm × 66 mm), ref: Luxford and Krone (1956). The conversions in the sketch shall be 1370 and 430 mm respectively

tension failures. On the concave side the fibres are compressed considerably, thus spoiling the initial strength of the material. Therefore, the stress/strain properties of bent wood cannot be compared with the properties of natural material in straight solid or laminated wood. On the other hand, the stress/strain properties of bent wood may not be disadvantageous if properly utilized, as these characteristics (in bending when decreasing the curvature) are very similar to those of mild steel (in tension) (fig 9). Bent wood will yield just as mild steel, and will be able to absorb several times as much energy as laminated curved members before failure for loads which tend to strengthen the members (same cross section assumed) (Luxford and Krone, 1956). This may be a useful property for bent frames for beach landing boats, as discussed by McLeod.

COMPARISON OF STRENGTH PROPERTIES OF STRAIGHT AND CURVED MEMBERS

Straight keel members

Luxford and Krone (1946) investigated strength/stiffness properties of laminated, solid and bolted keel members for a 50-ft (15-m) motor launch. The following conclusion is given in the report:

Though the bolted, scarfed member had an uncommonly slight slope of the scarf (1 in 18), the strength in bending was only about half the strength of the solid keel member with no joint. Laminated keel members with plain scarf joints of slope 1 in 12 in each lamination, sustained a maximum load in bending about 20 to 25 per cent higher than solid sections without joints. Laminated keel members with serrated scarf joints of the dimensions used, and located as in the test, were approximately the same bending strength as solid section without joints.

Curved frame members

Luxford and Krone (1956) also compared strength/stiffness properties of laminated and steam-bent frame members for a 50-ft (15-m) motor launch. If there is a choice between transverse frame members in laminated or solid bent wood, the important performance points given in the conclusion should be considered. Bent frames of the patterns tested are equalled in strength and stiffness by laminated frames whose cross sectional dimensions are each seven eighths as great as those of bent frames. Strength and stiffness of bent frames may be expected to decrease with an increase in the relative curvature (ratio of depth or radial dimension of the frame to the radius of curvature) and the factor seven eighths is not applicable to frames whose relative curvature differs greatly from that of the frames tested.

STRENGTH PROPERTIES OF COMPLETE STRUCTURES

Wooden vessels can be contemplated as large nailed laminated beams from a strength/stiffness point of view (Otsu, 1960; Takehana, 1960; Tsuchiya, 1963). Therefore an investigation of the following compound beams is of great interest. The following performances should be investigated.

Indirectly connected horizontal strakes

Harada et al. (1950) investigated the strength properties of "European-type" vessels, both experimentally and theoretically, in order to improve the longitudinal strength properties of wooden vessels built as the European type ship. The distribution of internal stresses in such a structure were calculated theoretically based upon certain approximate assumptions (Yushiki, Takehana, 1957). Harada et al. (1954) found that the critical points were the apparent slip between wooden members due to "yielding" of material round the fastenings.

Other strength investigations of members were carried out (Yoshiki, 1956). Strength/stiffness properties of double sawn frames subjected to simple bending loads were investigated analytically and experimentally. The properties were all dependent on the number and distribution of the fastenings, and yielding around the fastenings.

Strakes directly connected

In order to improve the longitudinal shear strength of a nailed laminated beam, keys and dowels may be inserted between the strakes. Harada proposed this for improvement of longitudinal strength properties of the European type vessel, and found that stiffness properties of the vessel were increased considerably. He also recommended the introduction of keys rather than closer spacing of the frames.

Granholm (1961) investigated strength/stiffness properties of nailed laminated beams and found that the properties of such a member depend on the factor "modulus of displacement" (between wooden members), which confirms Harada's investigation. The value of this factor can be determined by simple detail tests, and depends on the gauge of nails used and the hardness (specific gravity) of wood used. The factor also depends on the magnitude of the load applied. The modulus of displacement is thus not constant but decreases as the load increases, or varies inversely as the load varies in a ship structure.

Boats and other structures built up from narrow strips, edge nailed together, are another example of a compound beam, the strength/stiffness properties of which are similar to Granholm's beam(s). Shear strength properties along the strips can be improved considerably by gluing the strakes together, as stresses then will flow uniformly over the continuous glue line instead of being concentrated around the fastenings. Due to the relatively thin shell thickness, the lateral strength depends on a correct combination of curvature, shell thickness, frame distribution and scantlings, proportional to the margin member conditions. Such a boat structure in the smaller size range (up to 50 or 60 ft (15 to 18 m), might show promising possibilities as claimed by Hamlin (1954, 1959) and Pedersen (1964). Instead of nails, internal wires may be used. Goodman (1964) investigated the strength/stiffness properties of cylindrical shells built from strips and "frozen" into the desired curvature (concrete moulding form) by means of post-tensioned wires. Goodman's investigation confirms Granholm's statement, but some remarkable points should be mentioned.

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In all tests, there was an immediate relaxation of pre-stress after tensioning. It appeared that initial moisture content of the panel had a considerable influence on the magnitude of this initial relaxation. A rather surprising finding of the tests was the fact that increases in moisture content increased the stress level (tension stresses in wires) only slightly, if at all.

Beam with diagonal web-members

In order to obtain better strength/stiffness properties of large, compound beams (wooden-ship structures), Granholm (1961), Harada (1950), Hishida (1957–59), Doyle (1957) and Brosenius (1947) recommend the use of double diagonal web plates in which the shear stresses do not cause large deformations which may be damaging to the structure. (See also Lindblom, 1963).

Instead of double layer or multi layer diagonally laid planks, plywood panels may be a solution, if developable surfaces are acceptable. Plywood panels with the grain running in a diagonal direction would be advantageous. They might also easily be manufactured in longer lengths than at present and more easily scarfed in diagonal directions.

WOOD IN COMBINATION WITH OTHER MATERIALS

The following possibilities may be considered as materials for use in combination with glued laminated members and complete wood structures:

- Unidirectional glass or nylon fibre fabrics glued to outer laminations with polyester resins
- Aluminium foil between laminations
- Aluminium strips glued to outer laminations (tensile material)
- Post-tensioned stainless steel internal wires (reinforced wood)
- Sheathing or surface cover of wood for strengthening and for protection from decay and borers and, internally, to provide clean surfaces in the hold or below the waterline

Granholm (1954) describes in detail the technical possibilities of combining timber and high strength steel, that could be used in practical engineering as light weight beams and girders.

Composite ships may be made in two ways. One method is to have a rigid skeleton of steel or aluminium profiles (Hishida, 1959) and sheeting of one or several layers of wood planking, plywood panels, covered wood or plywood sheeting. The other, the rigid skeleton may be glue laminated wooden members, plywood members (built up beams or web frames) or bent members and the sheeting either of FRP, aluminium or plywood "planking" covered with fibre plastics.

TENTATIVE DESIGN PROPOSALS

Round bottom vessels 20 to 50 ft (6 to 15 m)

Ideal structure: The ideal is one piece construction without joints. An example is the moulded plywood hull as produced from the hot or cold mould process (Oehlmann, 1963), fig 10.

Construction on longitudinal frames: After erection of a skeleton of longitudinal glue-laminated frames and transverse bulkheads, the skeleton is covered with two layers of double diagonal plank sheeting, with a steep orientation of layers, and finished with a fibre-plastic cover (fig 1.7).

Construction on transverse frames: The skeleton consists of transverse glue-laminated frames and longitudinal stringers (beam shelves) along margins. The skeleton is covered with two layers of double diagonal plank sheeting, with a flat orientation of layers, and is finished with a fibre-plastic cover, (Johnson, 1953) fig 1.7.

Strip construction: Strips may be laid in one or several layers, either longitudinally or diagonally, supplemented by longitudinal members (Hamlin, 1954, 1959; Pedersen, 1964).
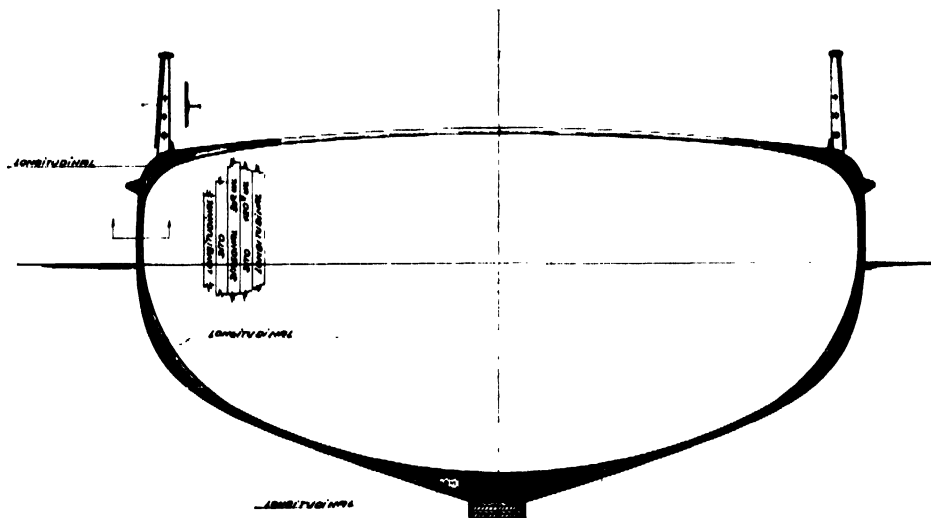
Fig 10. Glued built-up shell. (K. Oehlmann, Travemünde)

H 2
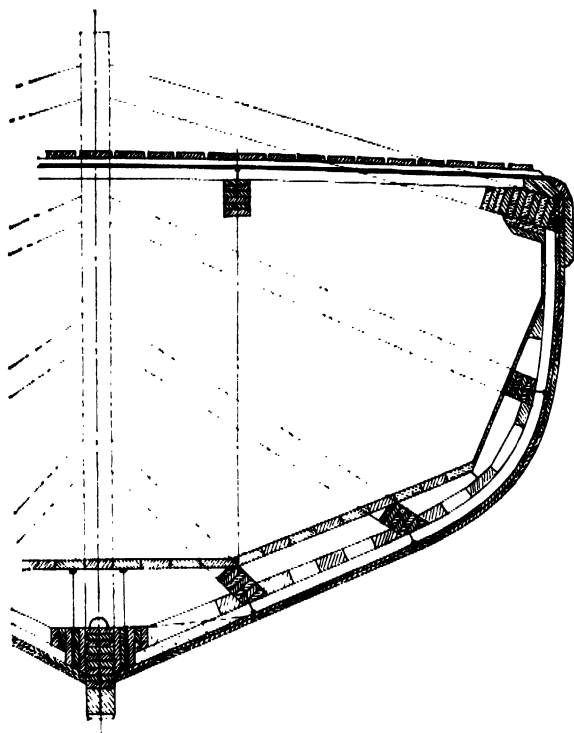
Fig 11. Longitudinal glue-laminated frames. Transverse bent-wood frames

Round bottom vessels 50 to 150 ft (15 to 45 m)

"Ideal" structure: The "ideal" is a one piece construction built up of various closely connected layers. An example is the 700-ton *Vision* built in 1850 (Murray, 1851), fig 1.3.

Construction on longitudinal frames: The skeleton consists of deep longitudinal glue-laminated frames, trans-
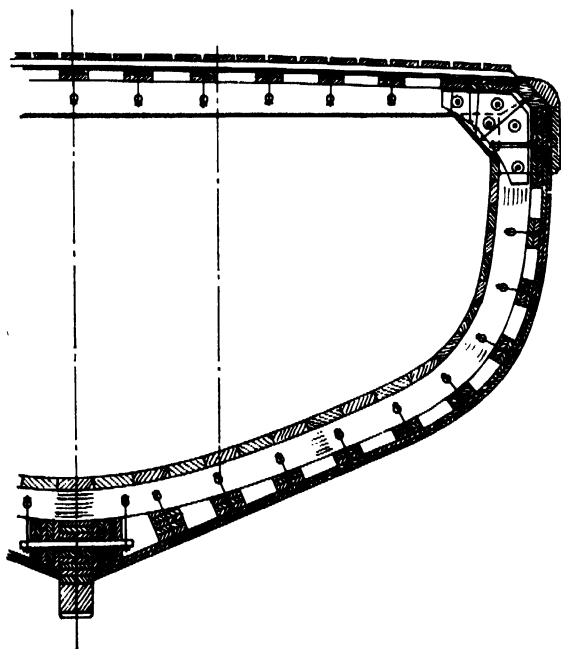
Fig 12. Transverse glue-laminated frames. Longitudinal glue-laminated stringers

verse bulkheads and web frames, and is used as a form for transverse bent frames which are closely spaced and permanently fixed to the longitudinal glue-laminated frames. It is covered with two layers of double diagonal plank sheeting at a 45° angle and is finished with a fibre-plastic cover (Isherwood, 1908; Flodin, 1919; Brosenius, 1947), fig 11.

Construction on transverse members: The skeleton consists of deep widely spaced frames and transverse bulkheads. This transverse system is covered with closely spaced longitudinal (glue-laminated) stringers of smaller cross section. Finally this skeleton is covered with two layers of double diagonal plank sheeting at a 45° angle and is finished with a fibre-plastic cover (Evans, 1957), fig 12.

Vee bottom vessels 20 to 100 ft (6 to 30 m)

The universal strength member for all sizes is the pre-assembled, built up, transverse frame and beam. The corners are assembled with plywood or Compreg gusset plates. Fastenings may be either stainless steel bolts and connectors, or closely spaced nails. The straight solid wood members should be pressure treated with chemicals for protection.
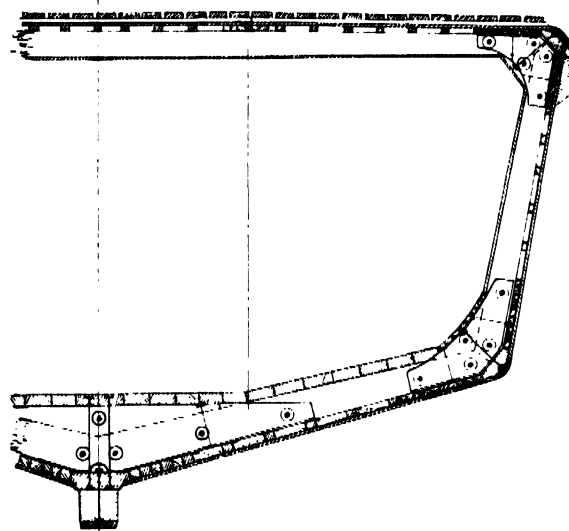
Fig 13. V-frame vessel

After erection of a skeleton of the widely spaced frame and beam members, this is covered with longitudinal, closely spaced stringers. Chines are built up from square strips to provide an adequate shear transmitting area. Finally this is covered with plywood panels, if surfaces are developable, or if not with two layers of double diagonal plank sheeting at a 45° angle. The hull is finished with a fibre-plastic cover (fig 13).

Aluminium and its Use in Fishing Boats

by C. W. Leveau

Emploi de l'aluminium dans la construction des bateaux de pêche

L'aluminium est tenace, résilient et absorbe très bien les coups. Les bateaux en aluminium résistent bien aux chocs produits par les vagues, les accostages brutaux, ou les collisions avec des épaves, car l'aluminium cède—puis revient à sa forme initiale—davantage que la plupart des autres matériaux employés en construction navale.

Certains alliages légers spéciaux possèdent une haute résistance à la corrosion marine et sont aptes au soudage, la zone de soudure conservant de bonnes propriétés physiques. Aussi les bateaux de pêche en aluminium sont-ils maintenant soudés, à l'exception de petits bâtiments à moteur hors-bord.

Les bateaux en aluminium n'ont pas besoin de peinture, et aux Etats-Unis d'Amérique la plupart ne sont pas peints. Lorsqu'on applique une couche de peinture, c'est uniquement pour des motifs d'ordre esthétique.

L'aluminium sert également à la construction des roufs de nombreux bateaux de pêche de fort tonnage à coque en acier ou en bois. Il est également très employé pour la confection des cloisonnements et revêtements de cales à poisson.

El aluminio y su aplicación en los barcos de pesca

El aluminio es duro, elástico y tiene una gran resistencia a las abolladuras. Las embarcaciones de aluminio aguantan perfectamente los golpes de mar y los choques violentos al atracar o contra derrelictos u objetos flotantes, porque este material es más flexible que la mayoría de los utilizados en la construcción naval cuando se someten a esfuerzos de choque.

Hay aleaciones marinas especiales y muy resistentes a la acción corrosiva del agua salada que al soldarlas adquieren elevadas propiedades físicas en la zona soldada; así, salvo las pequeñas embarcaciones con motor fuera de bordo, los pesqueros de aluminio se sueldan hoy día.

Los pesqueros de aluminio no necesitan pintura, y la mayoría de los utilizados en los Estados Unidos no la llevan. Si se les pinta es sólo por motivos de estética.

El aluminio se emplea también para la caseta del puente en muchos pesqueros grandes con casco de acero o madera. Para los mamparos de los ranchos y como forros de las bodegas del pescado se usa también mucho el aluminio.

ALUMINIUM is tough, resilient, and has great dent resistance. Aluminium boats stand up well when battered by slamming action of waves or the impacts of hard docking or even when colliding with debris. This is because aluminium deflects farther than most other boat-building materials when subjected to impact stress. The energy of impact is dissipated more gradually than it is in a less ductile material. Also, aluminium has a higher elastic limit than, say, the polyester laminates, hence it will absorb far more impact energy before failure.

More particularly, as compared with steel, some types

TABLE 1
Mechanical property limits for plate. Comparison chart for - H112, –H113 and –H321 tempers

Alloy and temper	Thickness inches	mm	Minimum tensile strength lb/in²	kg/cm²	Minimum yield strength lb/in²	kg/cm²	Elongation % in 2 in (50.8 mm)
5052–H112	0.250–0.499	6.4–12.7	28,000	1,970			7
	0.500–2.000	12.7–50.8	25,000	1,760			12
	2.001–3.000	50.8–76.2	25,000	1,760			16
5154–H112	0.250–0.499	6.4–12.7	32,000	2,280	18,000	1,270	8
	0.500–2.000	12.7–50.8	30,000	2,110	11,000	770	11
	2.001–3.000	50.8–76.2	30,000	2,110	11,000	770	15
5086–H112	0.250–0.499	6.4–12.7	36,000	2,540	18,000	1,270	8
	0.500–1.000	12.7–25.4	35,000	2,470	16,000	1,130	10
	1.001–2.000	25.4–50.8	35,000	2,470	14,000	990	14
	2.001–3.000	50.8–76.2	34,000	2,400	14,000	990	14
5083–H113	0.250–2.000	6.4–50.8	44,000	3,100	31,000	2,180	12
5456–H321	0.250–0.624	6.4–15.8	46,000	3,240	33,000	2,320	12
	0.625–1.250	15.8–31.8	46,000	3,240	33,000	2,320	12
	1.251–2.000	31.8–50.8	44,000	3,100	31,000	2,180	12

TABLE 2
Mechanical property limits. Sheet and plate comparison chart for –0, –H32, –H34, –H36 and –H38 tempers

Alloy and temper	Thickness inches	mm	Min tensile strength lb/in²	kg/cm²	Min yield strength lb/in²	kg/cm²	Elongation in 2 in (50.8 mm), % minimum									
							.020-.031	.032-.050	.051-.113	.114-.128	.129-.161	.162-.249	.250-.499	.500-1.000	1.001-1.500	1.501-2.000
5052-0	All		25,000	1,760			18	20	20	20	20	20	18	18	18	18
5154-0	All		30,000	2,110	11,000	775	12	14	16	18	18	18	18	18	18	18
5086-0	All		35,000	2,460	14,000	985	15	15	18	18	18	18	14	14	14	14
5083-0	.051-1.500	1.27-38.0	40,000	2,820	18,000	1,270			16	16	16	16	16	16	16	
	1.501-3.000	38.0-76.0	39,000	2,740	17,000	1,200										16
	3.001-5.000	76.0-127.0	38,000	2,670	16,000	1,130										
	5.001-7.000	127.0-178.0	37,000	2,600	15,000	1,050										
	7.001-8.000	178.0-203.0	36,000	2,530	14,000											
5456-0	.051-1.500	1.27-38.0	42,000	2,950	19,000	1,340			16	16	16	16	16	16	16	
	1.501-3.000	38.0-76.0	41,000	2,880	18,000	1,270										16
	3.001-5.000	76.0-127.0	40,000	2,820	17,000	1,200										
	5.001-7.000	127.0-178.0	39,000	2,740	16,000	1,130										
	7.001-8.000	178.0-203.0	38,000	2,670	15,000	1,050										
5052-H32	All		31,000	2,180			5	5	7	9	9	9	11	12	12	12
5154-H32	All		36,000	2,530	26,000	1,830	5	5	8	8	8	8	12	12	12	12
5086-H32	All		40,000	2,820	28,000	1,970	6	6	8	8	8	8	12	12	12	12
5083-H32	All		45,000	3,170	34,000	2,500			8	8	10	10				
5052-H34	All		34,000	2,390			4	4	6	7	7	7	10	10		
5154-H34	All		39,000	2,740	29,000	2,040	4	4	6	6	6	7	10	10		
5086-H34	All		44,000	3,100	34,000	2,500	5	5	6	6	6	6	10	10		
5083-H34	All		50,000	3,520	39,000	2,740			6	6	8	8				
5052-H36	All		37,000	2,600			3	4	4	4	4					
5154-H36	All		42,000	2,950	32,000	2,260	3	3	4	5	5					
5086-H36	All		47,000	3,310	38,000	2,680	4	4	6	6	6					
5052-H38	All		39,000	2,740			3	4	4	4						
5154-H38	All		45,000	3,170	35,000	2,460	3	3	4	5						

TABLE 3
Recommended practices for jig welding of aluminium alloys

Material thickness inches	mm	Welding position	Joint design (bevel)	Current Amps – DC	Arc voltage	Filler wire diagram inches	mm	Argon* gas flow CFH	No. of passes
3/32	2.36	Flat	None	70-110	18-22	1/32	0.76	30	1
				100-120	18-22	3/64	1.19	30	1
1/8	3.18	Flat	None	110-130	20	3/64	1.19	30	1
		Horiz./vert.	None	100-120	20	3/64	1.19	30	1
		Overhead	None	100-120	20	3/64	1.19	40	1
1/4	6.35	Flat	None/single	200-225	26-28	1/16	1.57	40	1
		Horiz./vert.	Single	170-190	26-28	1/16	1.57	45	2/3
		Overhead	Single	180-200	26-28	1/16	1.57	50	2/3
		Flat	None	220-250	28-30	1/16	1.57	80	2
3/8	9.53	Flat	Single/double	230-320	26-28	1/16	1.57	50	1/2
		Horiz./vert.	Single/double	180-235	26-28	1/16	1.57	50	3
		Overhead	Single/double	200-240	26-28	1/16	1.57	50	5
		Flat	None	260-280	28-30	1/16	1.57	80	2
1/2	12.70	Flat	Single/double	280-340	26-30	3/32	2.38	50	2/3
		Horiz./vert.	Single/double	210-250	26-30	1/16	1.57	50	3/4
		Overhead	Single/double	225-275	26-30	1/16	1.57	80	8 - 10
		Flat	None	280-320	30-32	1/16	1.57	80	2
1	25.40	Flat	Single/double	320-420	26-30	3/32	2.38	60	4 - 5
		Horiz./vert.	Single/double	225-285	26-30	1/16	1.57	60	4 - 6
		Overhead	Single/double	225-285	26-30	1/16	1.57	80	15 +
		Flat	None	390-400	35-37	1/16	1.57	80	2
2	50.80	Flat	Single/double	350-450	26-30	3/32	2.38	60	12 +
3	70.20	Flat	Single/double	350-450	26-30	3/32	2.38	60	20 +

* Gas flows for helium are slightly higher than for argon

TABLE 4
Representative mechanical properties of inert-gas metal-arc welded joints in aluminium alloys 5086 and 5083

Alloy and temper	Gauge inches mm		Tensile strength lb/in² kg/cm²		Yield strength 1/ lb/in² kg/cm²		Elongation % in 2 in (50.8 mm)	Joint efficiency % 2/	Location of fracture
			Tested with beads in place						
5086, 0	1/4	6.35	38,000	2,680	18,000	1,270	15.4	100	Parent plate, fusion line
5086, H112	1/4	6.35	38,000	2,680	19,000	1,340	14.0	100	Parent plate, fusion line
5086, H34	1/4	6.35	38,000	2,680	21,000	1,480	8.3	80	Parent plate, fusion line, weld metal
5086, H112	1/2	12.70	39,000	2,740	21,000	1,480	11.4	100	Fusion line
5086, H34	1/2	12.70	39,000	2,740	21,000	1,480	12.0	84	Fusion line
5086, H112	3/4	19.05	41,000	2,880	21,000	1,480	16.7	100	Fusion line, parent plate
			Tested with beads machined off						
5086, 0	1/4	6.35	35,000	2,470	17,000	1,200	12.5	100	Fusion line
5086, H112	1/4	6.35	37,000	2,600	17,000	1,200	14.3	94	Fusion line, weld metal
5085, H34	1/4	6.35	37,000	2,600	18,000	1,270	12.9	78	Fusion line, weld metal
5086, H112	1/2	12.70	39,000	2,740	20,000	1,410	16.5	100	Fusion line
5086, H112	3/4	19.05	39,000	2,740	20,000	1,410	16.8	100	Fusion line, weld metal
			Tested with beads in place						
5083, 0	1/4	6.35	43,000	3,030	20,000	1,410	16.2	100	Fusion line, parent plate
5083, H113	1/4	6.35	46,000	3,240	24,000	1,690	16.6	100	Parent plate
5083, H113	1/2	12.70	45,000	3,170	22,000	1,550	12.5	88	Fusion line
5083, H113	3/4	19.05	45,000	3,170	23,000	1,640	16.0	97	Fusion line
			Tested with beads machined off						
5083, 0	1/4	6.35	40,000	2,810	20,000	1.410	15.3	97	
5083, H113	1/4	6.35	42,000	2,950	22,000	1,550	14.0	91	Weld metal
5083, H113	1/2	12.70	42,000	2,950	21,000	1,480	16.3	93	Weld metal
5083, H113	3/4	19.05	42,000	2,950	21,000	1,480	18.3	90	Weld metal

1/ At 0.2% offset

2/ Based on the typical tensile strength shown in the Kaiser Aluminum Sheet and Plate Book, Second Edition 1958

of aluminium have a modulus of elasticity of about 10,000,000 lb/in² (700,000 kg/cm²) and steel about 29,000,000 lb/in² (2,000,000 kg/cm²). Thus, some aluminium plate deflects farther under a given load; the kinetic energy of impact ($\frac{1}{2}mv^2$) is absorbed as work (force × distance), as the plate deflects a greater distance than it would if it were of steel. The mean stress in the plate is thereby reduced substantially because of the increased deflection of aluminium as compared to that of steel.

The alloys recommended for building boats may be called marine aluminium, and due to practical experience and technological developments these alloys may confidently be regarded as the most modern and useful of the boat-building materials.

Tables 1 and 2 give data on such alloys that are eminently suitable and satisfactory for boat hull construction. Tables 3 and 4 give data on welding characteristics for these alloys.

The typical specifications for aluminium boats given as examples are intended as a guide only, they have been compiled from various builders of successful boats. As every design and construction problem cannot be covered or foreseen it is recommended that engineering personnel of a reputable prime aluminium producer be consulted by naval architects and boat builders for specific designs and for specific conditions before design-ing the boats and before specifying and ordering the material until experience has been gained in working with this metal.

WEIGHT—STRENGTH

Aluminium weighs about one-third as much as steel, and the aluminium marine alloys in tempers suitable for ship construction have about the same yield and tensile strengths as ordinary ship-building steel and about one-third the weight.

Aluminium–magnesium–manganese alloy 5086-H34, for example, has a typical tensile strength of 47,000 lb/in² (3,300 kg/cm²), a yield strength of 37,000 lb/in² (2,610 kg/cm²) and has excellent formability, weldability and corrosion resistance.

The tensile strength of steel used in steel-boat construction is in the range of 45,000 to 50,000 lb/in² (3,170 to 3,520 kg/cm²) with a yield strength of about 35,000 lb/in² (2,470 kg/cm²). When stretch-forming has to be done, however, a hot rolled steel is used with a yield of 24,000 to 28,000 lb/in² (1,690 to 1,970 kg/cm²). When it comes to strength to weight ratio alloy, 5,086 is 18,000 lb/in² (1,270 kg/cm²) per unit weight versus 7,000 lb/in² (493 kg/cm²) for steel and no more than 15,000 lb/in² (1,060 kg/cm²) for the highest quality mahogany (fig 1, tables 5 to 8).

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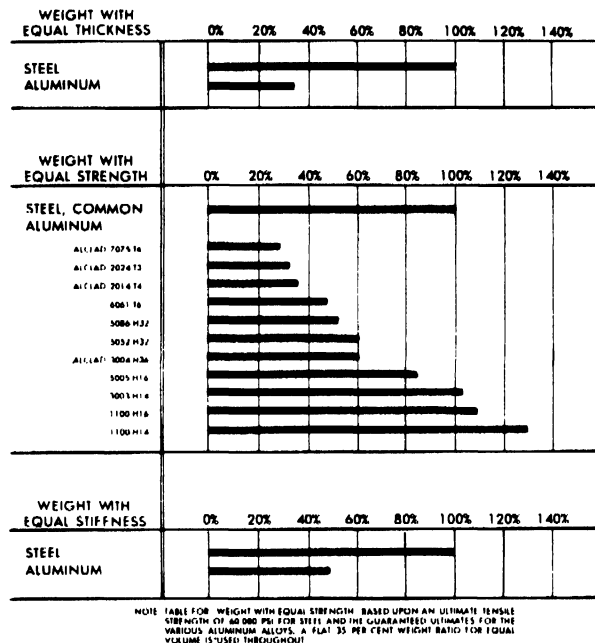
Fig 1. Weight-strength in per cent—steel-aluminium

TABLE 5
Material comparisons

Material	Weight		Ult. tensile		Yield tensile		Ult. shear		Shear to grain		Ult. bearing		Mod.of elasticity	
	lb/ft^3	kg/cm^3	lb/in^2	kg/cm^2	lb/in^2	kg/cm^2	lb/in^2	kg/cm^2	lb/in^2	kg/cm^2	lb/in^2	kg/cm^2	lb/in^2	kg/cm^2
Douglas fir	33	0.43	11,700	825	8,100	570			1,140	80	910	64 *	1.92	0.135
											7,420	522 +		
White oak	46	0.59	13,900	980	7,900	567			1,890	133	1,410	99 *	1.62	0.114
											7,040	496 +		
Sitka spruce	27	0.35	10,200	720	6,700	472			1,150	81	710	50 *	1.37	0.097
											5,610	395 +		
African mahogany	32	0.41	11,140	785	8,810	620			1,050	74	1,210	85 *	1.43	0.1005
											6,430	453 +		
Steel	490	6.30	60,000	4,230	33,000	2,320	45,000	3,170			60,000	4,230	29	2.04
Stainless steel	490	6.30	85,000	6,000	30,000	2,110	30,000	2,110					29	2.04
Wrought iron	480	6.17	48,000	3,380	26,000	1,830							28	1.97
Al-6061-T6	168	2.16	42,000	2,960	35,000	2,460	27,000	1,900			88,000	6,200	10	0.70
5052-H34	168	2.16	34,000	2,400	26,000	1,830	20,000	1,420			68,000	5,080	10.2	0.72
5154-H34	169	2.18	39,000	2,750	29,000	2,040	23,000	1,620			78,000	5,820	10.2	0.72
5086-H34	166	2.14	44,000	3,100	34,000	2,390	26,000	1,830			88,000	6,200	10.3	0.73
Evendur bronze	532	6.33	52,000	3,670	18,000	1,270	40,000	2,820					15	1.056
Monel	550	7.08	75,000	5,300	35,000	2,460							26	1.83
GRP MIL P-17549B Grade 3	100	1.28	18,000	1,270			10,000	705			21,000	1,480	1.2	0.085
RPL with grain			32,000	2,250			13,000	916					1.4	0.099
RPL across grain			21,000	1,480			14,000	987					1.1	0.077

* Perpendicular to grain

\+ Parallel to grain

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TABLE 6A
Typical mechanical properties—wrought alloys

Alloy and temper	Tension Ultimate strength lb/in² kg/cm²	Tension Yield strength lb/in² kg/cm²	Tension Elong-ation % 1/	Hardness Brinell No. 2/	Shear Ultimate strength lb/in² kg/cm²	Bearing Ultimate strength 3/ lb/in² kg/cm²	Fatigue Endurance limit 4/ lb/in² kg/cm²	Modulus Elasticity 5/ lb/in² kg/cm²
3003-H14	22,000 1,550	21,000 1,480	8	40	14,000 986	38,000 2,670	9,000 635	10.0×10^6 0.705×10^6
5050-O	21,000 1,480	8,000 563	24	36	15,000 1,060	39,000 2,750	12,000 845	10.0×10^6 0.705×10^6
5050-H32	25,000 1,760	21,000 1,480	9	46	17,000 1,200	47,000 3,310	13,000 915	10.0×10^6 0.705×10^6
5050-H34	28,000 1,970	24,000 1,690	8	53	18,000 1,270	52,000 3,660	13,000 915	10.0×10^6 0.705×10^6
5050-H36	30,000 2,110	26,000 1,830	7	58	19,000 1,340	56,000 3,950	14,000 985	10.0×10^6 0.705×10^6
5052-O	28,000 1,970	13,000 920	25	47	18,000 1,270	61,000 4,300	16,000 1,130	10.2×10^6 0.719×10^6
5052-H32	33,000 2,320	28,000 1,970	12	60	20,000 1,410	71,000 5,000	17,000 1,200	10.0×10^6 0.705×10^6
5052-H34	38,000 2,680	31,000 2,180	10	68	21,000 1,480	78,000 5,500	18,000 1,270	10.2×10^6 0.719×10^6
5052-H36	40,000 2,820	35,000 2,460	8	73	23,000 1,620	82,000 5,770	19,000 1,340	10.2×10^6 0.719×10^6
5083-O	42,000 2,960	21,000 1,480	22	73	25,000 1,760	88,000 6,200	-	10.3×10^6 0.725×10^6
5083-H32	49,000 3,450	39,000 2,740	10	-	-	-	-	10.3×10^6 0.725×10^6
5083-H34	53,000 3,730	43,000 3,030	8	-	-	-	-	10.3×10^6 0.725×10^6
5083-H113	46,000 3,240	33,000 2,320	16	84	27,000 1,900	-	23,000 1,620	10.3×10^6 0.725×10^6
5086-O	38,000 2,670	17,000 1,200	22	65	64,000 4,510	79,000 5,560	-	10.3×10^6 0.725×10^6

continued ...

1/ In 2 in (50.8 mm). 1/16 in (1.65 mm) thick specimen
2/ 1102.3 lbs (500 kg) load. 0.394 in (10 mm) ball
3/ Ultimate bearing strength with edge distance 2.0 times rivet diameter
4/ Based on 500,000,000 cycles of completely reversed stress using the R.R. Moore type of machine and specimen
5/ Average of tension and compression moduli. Compression modulus about 2 percent greater than tension modulus

TABLE 6A (continued)
Typical mechanical properties—wrought alloys

Alloy and temper	Tension Ultimate strength lb/in² kg/cm²	Tension Yield strength lb/in² kg/cm²	Tension Elong-ation % 1/	Hardness Brinell No. 2/	Shear Ultimate strength lb/in² kg/cm²	Fatigue Endurance limit 4/ lb/in² kg/cm²	Modulus Elasticity 5/ lb/in² kg/cm²
5086-H32	42,000 2,960	30,000 2,120	12	77	25,000 1,760	-	10.3×10^6 0.725×10^6
5086-H34	47,000 3,310	37,000 2,610	10	86	27,000 1,900	15,000* 1,060	10.3×10^6 0.725×10^6
5086-H112	39,000 2,750	19,000 1,340	14	68	23,000 1,640	22,000 1,550	10.3×10^6 0.725×10^6
5154-O	35,000 2,470	17,000 1,200	27	58	22,000 1,550	17,000 1,200	10.2×10^6 0.719×10^6
5154-H32	39,000 2,750	30,000 2,110	15	67	22,000 1,550	18,000 1,270	10.2×10^6 0.719×10^6
5154-H34	42,000 2,960	33,000 2,330	13	73	24,000 1,690	19,000 1,340	10.2×10^6 0.719×10^6
5154-H36	45,000 3,170	36,000 2,540	12	83	26,000 1,830	20,000 1,410	10.2×10^6 0.719×10^6
5154-H112	35,000 2,460	17,000 1,200	25	63	-	17,000 1,200	10.2×10^6 0.719×10^6
5454-O	36,000 2,540	17,000 1,200	22	62	23,000 1,620	18,000 1,270	10.2×10^6 0.719×10^6
5454-H32	40,000 2,820	30,000 2,110	10	73	24,000 1,690	18,000 1,270	10.2×10^6 0.719×10^6
5454-H34	44,000 3,100	35,000 2,470	10	81	26,000 1,830	18,000 1,270	10.2×10^6 0.719×10^6
5454-H112	36,000 2,540	18,000 1,270	18	62	23,000 1,620	18,000 1,270	10.2×10^6 0.719×10^6
5456-O	45,000 3,170	23,000 1,620	24	75	28,000 1,970	-	10.3×10^6 0.725×10^6
5456-H321	51,000 3,600	37,000 2,610	16	90	30,000 2,120	-	10.3×10^6 0.725×10^6
6061-T4	35,000 2,470	21,000 1,480	22	65	24,000 1,690	14,000 985	10.0×10^6 0.705×10^6
6061-T6	45,000 3,170	40,000 2,820	12	95	30,000 2,120	14,000 985	10.0×10^6 0.705×10^6

* Krouse reverse bending fatigue test
1/ In 2 in (50.8 mm). 1/16 in (1.65 mm) thick specimen
2/ 1102.3 lbs (500 kg) load. 0.394 in (10 mm) ball
4/ Based on 500,000,000 cycles of completely reversed stress using the R.R. Moore type of machine and specimen
5/ Average of tension and compression moduli. Compression modulus about 2 percent greater than tension modulus

TABLE 6B
Mechanical property limits—extrusions

Alloy and temper	Thickness 1/ inches	mm	in²	cm²	Strength minimum Ultimate lb/in²	kg/cm²	Yield lb/in²	kg/cm²	Elongation 2/ % in 2 in (50.8 mm) or 4 diam 3/
6061-T4	All		All		26,000	1,830	16,000	1,130	16
6061-T6	All		All		38,000	2,670	35,000	2,460	10
6063-T4	0 —0.500	0 —13.2	All		17,000	1,200	10,000	705	12
6063-T6	0 —0.124	0 —0.28	All		30,000	2,110	25,000	1,760	8
	0.125—1.000	0.30—2.54	All		30,000	2,110	25,000	1,760	10
5083-H112	All		0—32	0—265	40,000	2,820	24,000	1,690	12
5086-H111					36,000	2,540	21,000	1,480	21
5086-H112	All		All		35,000	2,460	18,000	1,270	12
5154-H112	All		All		30,000	2,110	11,000	775	12
5454-H112	All		All		31,000	2,180	12,000	845	12
5456-H112	0 —5	0 —132	0—32	0—265	42,000	2,960	19,000	1,340	12

1/ The thickness of the cross section from which the tension test specimen is taken determines the applicable mechanical properties. For material 1½ in or less in thickness, when not tested in full section, the tension test specimen is taken from the centre of the section; for material over 1½ in in thickness, the specimen is taken midway between the centre and the surface. Specimens are taken parallel to the direction of extrusion

2/ For material of such dimensions that a standard test specimen cannot be taken, or for material thinner than 0.062 in, the test for elongation is not required

3/ Diam represents specimen diameter

TABLE 7
Recommended rivet diameters

Material thickness 1/ inches	mm	Rivet diameter inches	mm
0.028 – 0.036	0.71 – 0.91	1/16	1.57
Over 0.036 – 0.048	0.91 – 1.22	3/32	2.38
Over 0.048 – 0.064	1.22 – 1.62	1/8	3.14
Over 0.064 – 0.080	1.62 – 2.30	5/32	3.96
Over 0.080 – 0.104	2.30 – 2.64	3/16	4.71
Over 0.104 – 0.128	2.64 – 3.25	1/4	6.38
Over 0.128 – 0.188	3.25 – 4.77	5/16	8.45
Over 0.188 – 0.20	4.77 – 5.08	3/8	9.50
Over 0.20 – 0.25	5.08 – 6.35	7/16	11.10
Over 0.25 – 0.30	6.35 – 7.62	1/2	12.70
Over 0.30 – 0.35	7.62 – 8.88	9/16	14.30
Over 0.35 – 0.40	8.88 – 10.02	5/8	15.90
Over 0.40 – 0.55	10.02 – 14.10	3/4	19.05
Over 0.55 – 0.70	14.10 – 17.80	7/8	22.20

1/ Thickness referred to is that of thinnest component.

Note:

The edge distance for riveting should normally be 2D (where D = rivet diameter) and never less than 1½D. With these edge distances the bearing strength of aluminium alloys may be taken as 1.8 times the tensile strength. The rivet pitch should not be less than 3D; for water-tightness the maximum is 4D or 10t (thickness of thinnest material in the joint), whichever is the smaller.

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TABLE 8
Wrought aluminium marine alloys
A. Approximate equivalents

USA Al. Ass.	Australia	Austria	Canada	France AFNOR	Germany DIN	Italy UNI	Japan JIS	Switzerland VSM	UK BS
5052	AA57S 5052	M10(2Mg)	57S	A—G2	AlMg3 (3.3525)	PAG 2.5	A2-1	Al-3Mg	N—4
5154			C54S			PAG 3.5		Al-4Mg	
5456			6211		AlMg5+Mn 3.3555	PAG5+Mn		Al-5Mg+Mn	N5/6
5083	5083		D54S		(AlMg+Mn) 3.3555		A2-7		N8
5086	5086		E45S	(A—G4)				(Al-4Mg+Mn)	N5/6
6061	AA65S		65S	A—SC+Cu +Cr	(AlMgSiCu)	PASIG+Cu +Cr	A2-4	AlSiMg.Anti +Cu corodal +Cr	H—20

The alloys given as equivalents in this table might vary considerably in their chemical composition from one country to another. Alloys not standardized in their respective countries are in parentheses.

B. Specification composition limits

Alloy	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Other Each	Other Total
5052	.45Si+Fe		.10	.10	2.2-2.8	.15-.35	.10		.05	.15
5154	Si+Fe	.45	.10	.10	3.1-3.9	.15-.35	.20	.20	.05	.15
5456	Si+Fe	.40	.10	.50-1.0	4.7-5.5	.05-.20	.25	.20	.05	.15
5083	.40	.40	.10	.30-1.0	4.0-4.9	.05-.25	.25	.15	.05	.15
5086	.40	.50	.10	.20-.7	3.5-4.5	.05-.25	.25	.15	.05	.15
6061	.40-.8	.7	.15-.40	.15	.8-1.2	.15-.35	.25	.15	.05	.15

CORROSION

It is necessary in marine applications to have good resistance to corrosion as well as immunity from stress corrosion.

Resistance to corrosion is determined experimentally by the change in mechanical properties and by measuring the depths of individual pits on test panels after prolonged periods of exposure. Such tests have shown that most aluminium alloys in sea water will undergo localized pitting to an average depth of 2 to 3 mm in one or two years. With longer exposure, corrosion continues but the rate of increase in depth diminishes with time. This has been referred to as the "self-stopping" nature of corrosion on aluminium and is considered to be due to the formation of protective corrosion products over the small pits.

When aluminium is placed in contact with other metals commonly used in marine applications, it may be attacked by galvanic corrosion. This action is much like that of a wet electric cell. Galvanic corrosion of aluminium is more severe when aluminium is coupled to copper or copper-bearing alloys—bronze, brass, monel—than when it is coupled to steel, lead or nickel. Also, galvanic corrosion of aluminium is more severe in a bimetallic couple immersed in sea water than in a couple merely exposed to marine atmosphere or immersed in fresh water.

Generally, bimetallic couples are undesirable. Through appropriate design, however, galvanic corrosion of aluminium can be prevented or minimized. The most com-
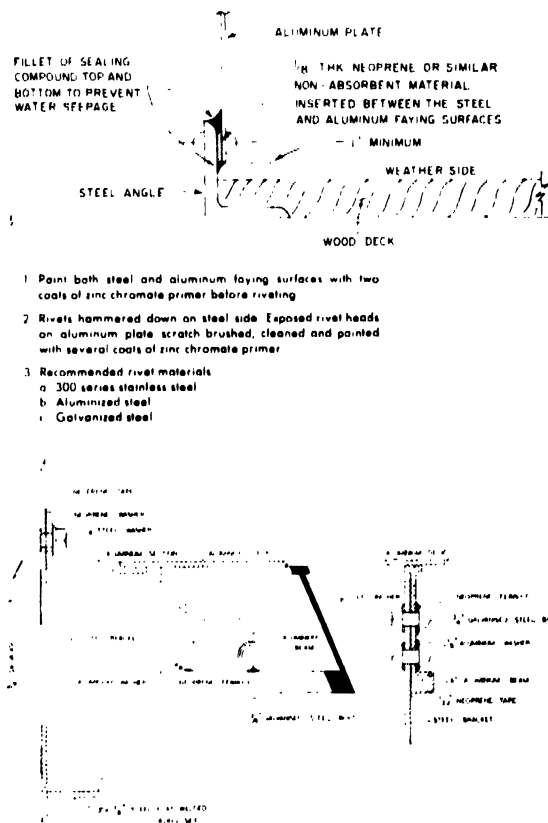
Fig 2. Details of aluminium to steel connections

M. V. CABRILLO

Anode Placement
Modified 3 14 61
Anode Material - 99.99% Zinc
(MIL-A-18001E)

Anodes attached to steel rudders with steel studs welded to rudders and steel nuts. Anodes attached to aluminum by means of 6061-T6 alloy studs welded to aluminum and type 302 stainless steel nuts. Non-hardening, aluminum pigmented calking compound used as bedding material between zinc anodes and aluminum.

Note Optimum anode placement will vary with hull and service conditions.

(A) Hull (Al) - 2 anodes
4" x 8" x 0.5"
One on each side, 2 ft out from keel and 15 ft from bow.

(B) Front Strut (Al) - 2 anodes
4" x 4" x 0.5"
One on outside surface of each strut.

(C) Shaft - One spherical anode on each shaft.

(D) Rear Struts (Al) - 4 anodes
4" x 8" x 0.5"
One on outside surface and one on inside surface of each set of struts.

(E) Rudders (Stl) - 4 anodes
5" x 10" x 0.5"
One on outside and one on inside surface of each rudder.

(F) Transom (Al) - 2 anodes
4" x 8" x 0.5

Fig 3. Anode position on aluminium boats

mon control of galvanic corrosion in bimetallic connections is accomplished by separating the interfaces between the aluminium and the dissimilar metal with gaskets, washers, sleeves and bushings of insulating materials, such as neoprene, alumalastic, fairprene, presstite and micarta. These materials prevent the flow of galvanic current necessary to sustain the attack on the aluminium (fig 2).

Painting the surfaces of both metals with zinc chromate paints will also inhibit galvanic corrosion in salt water.

Woods treated with copper-containing compounds should not be used in contact with aluminium. Wet or unseasoned wood may cause corrosion of aluminium if in direct contact. Faying surfaces between wood and aluminium should always be protected by painting the wood with a zinc chromate paint, an aluminium pigmented paint or a bitumastic paint, and by applying zinc chromate primer to the aluminium.

Some harbours and jetties have stray electrical currents in the water and in order that the aluminium will be fully protected against electrolytic action, as there could be bare spots on the hull bottom, zinc anodes are placed on the bottom, shafts, struts or rudders so the anodes will absorb the corrosive action instead of the aluminium. See chart of anode placement on the m/v *Cabrillo* (fig 3).

PAINTING

The principal reasons for painting aluminium boats are (1) to add eye-appeal and (2) to prevent fouling of the hull bottom. The inherently good corrosion resistance of aluminium is attested by long-time exposure of unpainted boats.

Painting aluminium, as with painting of other materials, requires appropriate preparation of surfaces prior to painting, the use of proper application methods and acceptable paints. Surfaces must be clean to assure good bonding. Solvent wash and either inhibited alkaline cleaners or an alcoholic-phosphoric acid cleaner are used. Further prepaint treatment is desirable. This consists of either a thin coat of zinc chromate wash primer or the application of any one of the proprietary chromate-phosphate chemical conversion coatings.

For decorative use, the same marine paints used on other materials can be applied to aluminium. The manufacturer's directions should be followed.

Selection and application of antifouling paints on aluminium requires special comment. Antifouling paints containing mercury in any form, i.e. oxide, chloride or mercuro-organic compounds, are not to be used on aluminium under any circumstances because the mercury will destroy the aluminium by forming an amalgam. Copper-containing antifouling paints can be used, provided a sufficiently thick (usually 2 to 3 coats of a compatible red lead or zinc chromate anticorrosive paint) layer of barrier paint is first applied to the aluminium. If applied directly to aluminium, these copper-containing antifouling paints may cause galvanic corrosion. A third type of antifouling paint, containing organo-tin compounds, has been recently introduced by a number of leading marine paint manufacturers for use on aluminium, steel and non-metallic materials. Exhaustive tests indicate that organo-tin-containing antifouling

paint systems are compatible with aluminium, even without intermediate barrier paints. Many organo-tin systems tested provided protection against marine fouling for a period equivalent to a normal boat season. With most organo-tin systems tested, the use of barrier paints resulted in greater protection against marine fouling under extreme fouling conditions than was provided by the same system without the barrier paint, although one vinyl system containing organo-tin was equally effective with or without barrier paint. (Summerson *et al.*, 1964.)

Restoration of the paint or repainting of an old boat requires the cleaning and preparation methods described previously. To remove old paint, organic paint removers are recommended. Removers based on caustic (alkali) are not acceptable. Light sand blasting can also be used but care should be exercised to avoid overblasting, resulting in removal of aluminium. In repair and maintaining copper antifouling bottom paints, damaged areas should be cleaned to bare metal, properly pre-treated and painted with barrier paints before applying the copper antifouling top coat. Organo-tin antifouling paints can be applied directly over a wash primer or chemical conversion coating.

Following is a step-by-step description of repainting an aluminium boat:

Other pre-treatment, fillers and paint systems than those recommended may be used, but since each component of a system must be compatible with the total system, the use of trade names has been employed in order to be specific and to ensure the required compatibility. Experience has shown that "short cuts" or deviations from the procedure can lead to unsatisfactory results. Consequently, all steps must be followed in order.

Removal of old paint

● Strip old paint with a commercial paint stripper such as Turco 4260 B or equivalent. The stripper should be applied and allowed to remain on hull for approximately one hour or until paint film is readily removable. The loosened paint can be easily removed by steam cleaning using a neutral detergent additive such as Turco Steamsall in the boiler water.

● Use a disc or belt sander or rotary wire brush (stainless steel) to remove any chemical coating pre-treatments, such as Alodine, from hull area. (As an alternative the entire hull may be sand-blasted after paint removal to remove filler compound, corrosion products, etc. Use clean sand and avoid excessive blasting.)

● Seams, crevices and pitted regions, if present, should be filled with suitable fairing compound such as Devcon's plastic aluminium filler.

Prepaint treatment

Entire hull area should be washed with a phosphoric acid-alcohol water reducible cleaner such as Turco WO 1 or equivalent. Flush thoroughly with fresh water. Allow to dry thoroughly.

Application of paint

● As soon as hull is dry, it may be spray painted with one thin coat of metal etching primer. The film thickness should not exceed 0.5 mm, with 0.3 mm desirable.

● This can be followed almost immediately with one coat of anticorrosive spray applied to a dry film thickness of approximately 1.5 mm. (Follow paint company's recommendations for thinning of paint and for drying time.)

● Follow with two coats of metallic anticorrosive.

● Follow with two coats of antifouling paint to produce a dry film thickness of 2 to 3 mm.

COSTS

Benford and Kossa (1960) stated as follows:

A steel tuna clipper, 1,200 tons displacement, power, one 1,600 hp diesel engine; to be built on the U.S. west coast.

Structural hull invoiced weight . .	302 tons	
Structural hull material cost . .	£21,500	($60,400)
Structural hull man hours per ton of steel	153	
Structural hull man hours—total .	40,200	
Total material cost of vessel, including machinery and outfit . . .	£119,000	($333,000)
Labour	£96,200	($269,600)
Overheads (80% of labour) . .	£77,000	($215,700)
Sub-total . . .	£292,200	($818,300)
Profit (10%)	£29,200	($81,800)
Insurance (1%)	£2,900	($8,200)
Total cost of steel vessel, does not include fishing gear	£324,300	($908,300)

If aluminium was used in lieu of steel for the hull and in lieu of wood for the deckhouse, the cost may be as follows:

Structural aluminium hull weight .	340,000 lb	
Structural aluminium material cost .	£54,500	($153,000)
Structural hull cost in steel . .	£21,500	($60,500)
Additional hull material cost . .	£33,000	($92,500)
Additional deckhouse in aluminium .	£500	($1,500)
Total additional material cost . .	£33,500	($94,000)

About 56% additional hull and deckhouse material cost.

An example of a complete aluminium vessel

Estimating labour cost the same for the aluminium hull as for the steel hull, the following are total costs for the aluminium tuna clipper:

Total material cost of vessel, including machinery and outfit—£119,000 + £33,500 ($333,000 + $94,000)	£152,500	($427,000)
Labour	£96,000	($269,000)
Overheads (80% of labour)	£77,000	($215,700)
Sub-total .	£325,500	($911,300)
Profit (10%) . . .	£32,500	($91,100)
Insurance (1%) . .	£3,300	($9,100)
Total cost of aluminium vessel	£361,300	($1,011,500)
Total cost of steel vessel .	£325,000	($908,300)
Additional cost of aluminium vessel	£36,300	($102,200)

About 11.5% additional cost of the complete tuna clipper.

Shipyards may argue that it is more difficult to fabricate aluminium than steel into a hull but shipyards accustomed to fabricating aluminium hulls will testify that it is easier to handle the aluminium plates as they weigh only half as much as steel plates. In addition, the welding speed for aluminium is about three times as fast as for steel, even though more pre-welding preparation is needed in order to assure clean surfaces.

The aluminium tuna clipper discussed here should cost no more than about 10 per cent more than a similar sized steel vessel.

Weight saving

There will be about a 152 tons weight saving in the aluminium hull versus the steel hull. This weight saving can be utilized in various ways: (1) to obtain more speed with the same power; (2) to reduce the size of the power plant and reduce fuel consumption and still obtain the same speed as the steel vessel; (3) increase the carrying capacity in addition to (1) or (2).

Saving on maintenance

The hull and deckhouses of an aluminium fishing vessel may be left unpainted, thus affording a tremendous saving on up-keep. The bottom may be painted with antifouling if needed.

Even if it is decided to paint the aluminium vessel there will still be a saving on maintenance over wood- and steel-hulled vessels.

ALUMINIUM APPLICATIONS TO HULL

Typical specifications for 14 to 18 ft (4.3 to 5.5 m) aluminium outboard fishing boats

(1) Welded construction

ALLOY	MATERIAL THICKNESS
Hull	
Sides: 5052-H32 to -H36	0.090 in (2.3 mm)
Bottom: Same	0.125 in (3.1 mm)
Sides: 5086-H32 or -H34 or -H112	0.090 in (2.3 mm)
Bottom: Same	0.125 in (3.1 mm)
Sides: 6061-T6	0.090 in (2.3 mm)
Bottom: Same	0.125 in (3.1 mm)
Transom	
5052-H32 to -H36	0.125 in (3.1 mm)
5086-H32 or -H34 or -H112	0.125 in (3.1 mm)
Decking	
5052-H32 to -H36	0.080 in (2 mm)
5086-H32 or -H34 or -H112	0.080 in (2 mm)
6061-T6	0.080 in (2 mm)

Framing—formed sheet
5050-H34 or -H36; 5052-H32 or -H34; 5086-H32 or -H112

Castings—for strength
Sand and permanent mould: 355-T51; 356-T51; 357

Castings—no special strength required
Sand and permanent mould: 43-F
Permanent mould: A214-F
Sand castings: F-214-F

(2) Riveted construction

ALLOY	MATERIAL THICKNESS
Hull—Transom—Decking	
505-H34 or -H36; 5052-H32 to -H36; 6061-T4 or T6	0.074 in (1.9 mm)
Seats—backed with floatation material	
Same as hull	0.040 in (1.1 mm)

Framing—extruded shapes
6061-T4; 6062-T4 or -T6; 6063-T4 or -T6

Framing—formed sheet
5050-H36; 5052-H32 or -H34; 6061-T4

Castings—for strength
Sand and permanent mould: 355-T6; 356-T6; 357
Die castings: 218; 360; Almag-35

Castings—no particular strength required
Sand castings: 43-F; F214-F
Permanent mould: A 214-F
Die castings: 13; 43; 218; 360

Rivets

Sheet alloy	For best results
5050 and 5052	6053-T61
6061	6063-T6; 6061-T6

Typical specifications for 35 ft (15.8 m) fishing boat welded aluminium construction

ALLOY	MATERIAL THICKNESS
Side plating	
5086-H32 or -H34 or -H112	0.188 to 0.250 in (4.7 to 6.3 mm)
Bottom plating	
5086-H32 or -H34 or -H112	0.219 to 0.250 in (5.6 to 6.3 mm)
Transom	
5086-H32 or -H34 or -H112	0.219 to 0.250 in (5.6 to 6.3 mm)
Decking	
5086-H32 or -H34 or -H112	0.188 to 0.250 in (4.7 to 6.3 mm)

Framing
Extrusions—5086-H113 or 6061-T4 or -T6
Formed sheet—5086-H32 or -H112

Castings—for strength

Sand and permanent mould:
355-T51; 356-T51; 357

Castings—no special strength required

Sand and permanent mould: 43-F
Permanent mould: A214-F
Sand: F-214-F

Mechanical fastenings

Use 18-8 stainless-steel fasteners for hardware to deck and hull, guardrails to hull, engine to bed, strut to hull, under-water fittings to hull.

Welding castings to sheet and plate

With high silicon casting alloys such as 43, 355, 356 and 357, use 4043 filler wire when welding to thin sheet.

The 5000 series filler alloys may be used in welding to wrought alloys in heavy sheet or plate gauges.
With 214 cast alloys, 5000 series filler alloys such as 5154, 5356, 5183 are recommended in preference to 4043.

Fuel tanks

Integral with hull—same as hull. May be clad with 7072 alloy on the fuel side if desired.

Separate tanks—Alclad 3003-H14 or Alclad 3004-H32.

Bare alloys may be protected with chemical conversion coatings of the chromate variety such as: Alodine 1200, Bonderite 721, Iridite 14-2, Turco 4178, Oakite Chromicoat.

Fresh-water tanks

Alclad 3003-H14 or Alclad 3004-H32.

Fuel piping and fittings

Alclad 6061-T61, Alclad 6063-T6, Alclad 3003-H18, Alclad 3003.

If suitable aluminium alloy or stainless-steel valves are not obtainable, use non-ferrous tubing and connect to aluminium tanks by insulated flange or stainless-steel nipples.

Fresh-water piping and fittings

Same as fuel piping and fittings.

Salt-water piping and fittings

Non-ferrous, stainless-steel or plastic is recommended.

Non-ferrous sea valves or fittings should be electrically insulated from hull. Aluminium piping and fittings: Alclad 6061-T6, Alclad 6063-T6, Alclad 3003-H18, may be used provided suitable aluminium alloy or stainless-steel or plastic valves and fittings are available

Some aluminium-hulled fishing boats in U.S.A.
(1) Gillnetters

Since 1959 some 81 aluminium gillnetters have been built for salmon fishing in Alaskan waters. Eleven of these were built by Marine Construction and Design Co., Seattle, Washington, and the balance by Matsumoto Shipyard, Vancouver, B.C., Canada (fig 4, 5, 6 and 7). Their particulars are as follows:

L—32 ft (9.5 m)
B—11 ft 6 in (3.5 m)
T—2 ft 5 in (.74 m)
Light-weight—6,000 to 7,000 lb (2,721 to 3,175 kg)
Fish-hold capacity—27,000 lb (12,254 kg) of fish, aft cockpit capacity 8,000 lb (3,628 kg) of fish

Fig 4. Gillnetters under construction

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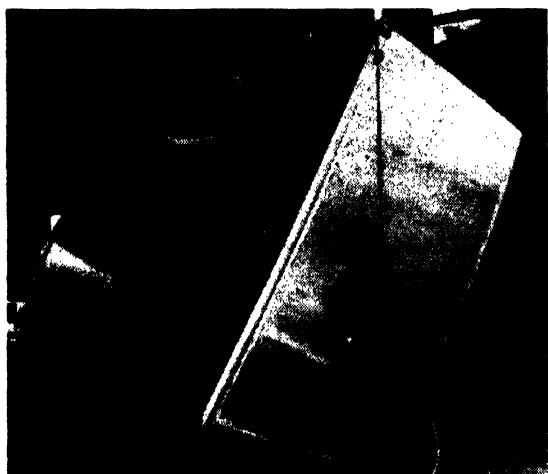
Fig 5. *Gillnetter removed from jig*
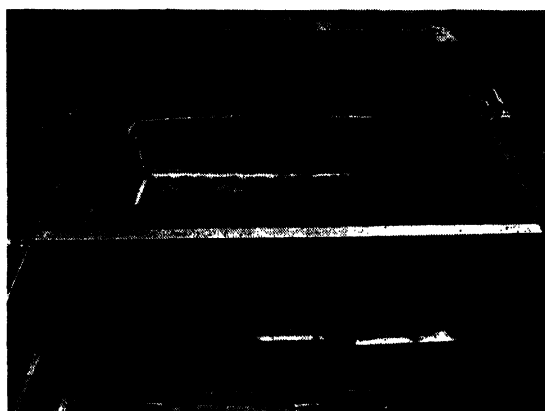
Fig 6. *Interior of a 32-ft (10.6-m) gillnetter*
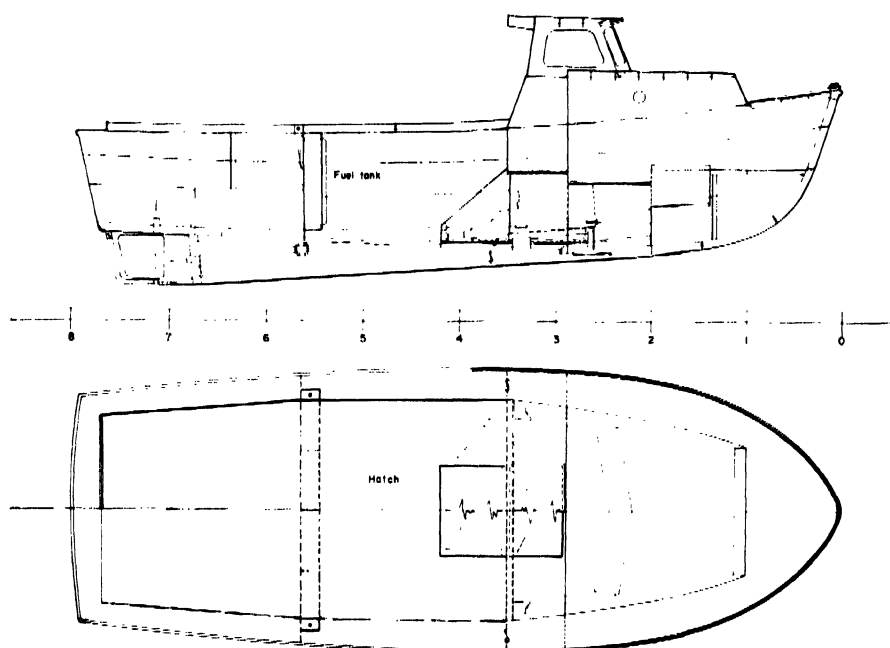
Fig 7. *Structural profile and main deck plan of a 32-ft (10.6-m) aluminium gillnetter*

Speed—15 knots

Main engine—165 hp Gray marine gas engine, engine rpm—3,400

Propeller—20 in diam. × 17 in P (510 × 430 mm)

Reduction gear—2 : 1 hydraulic

Shaft diam.—1½ in (38 mm)

Material—5083 or 5086 aluminium, depending on ship-yard; sides and bottom ¼ in (6.3 mm); bulkheads, deck and floor plates ³⁄₁₆ in (4.7 mm); cabin ⅛ in (3.2 mm). Extrusions 5083-H112 aluminium alloy.

(2) Seine skiffs

Dozens of these boats have been built of aluminium since 1959. Many of these, built by Alfab Co., Edmonds, Washington, have the following particulars:

L—17 ft 6 in (5.3 m)

B—8 ft 7 in (2.6 m)

Main engine—a variety of power plants was used

Fuel capacity—95 gal (360 l)

Material—5086 aluminium for hull plating with 6061 aluminium extrusions for framing

Others have dimensions of 18 ft 6 in × 8 ft 6 in (5.6 × 2.6 m) and 18 ft 6 in × 9 ft 6 in (5.6 × 2.9 m), some built by Kazulin-Cole Shipyards, Tacoma, Washington; and some by Marine Construction and Design Co., Seattle, Washington.

(3) Purse seiner

The *Josie J*, an all-aluminium purse seiner, was built in 1960 by the Alfab Co., Edmonds, Washington, for Mr S. A. Johnson, Seattle, for operations in Alaska and in Puget Sound. Particulars are as follows:

L—57 ft (17.4 m)

B—18 ft 6 in (5.6 m)
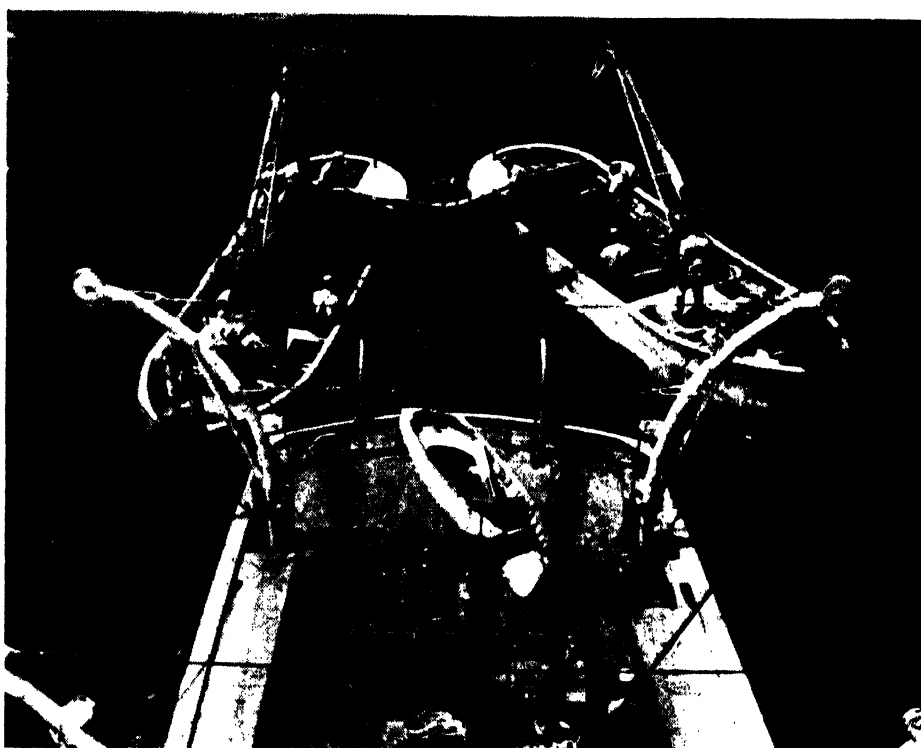
Fig 8. Aluminium menhaden seiners at work

T—7 ft 6 in (2.3 m) loaded

Weight—53,000 lb (24,000 kg) without seine, skiffs and gear

Speed—24 knots in light condition, 18 knots loaded

A similar boat in steel would have weighed about 26,500 lb (12,000 kg) more.

Material—5086 aluminium, $\frac{1}{4}$ in (6.3 mm) for shell plating; $\frac{3}{16}$ in (4.7 mm) for bulkheads; decks are $\frac{1}{4}$ in (6.3 mm) with deckhouse and upper deck $\frac{3}{16}$ in (4.7 mm).

(4) Purse seine boats for Menhaden fishing

In 1958, 78 of these boats were built by R.T.C. Boat Company, Camden, New Jersey, for Fish Products Company, Lewes, Delaware. Since that time some 150 such boats have been built, and operations range from the Virginia Coast to the Gulf of Mexico (fig 8).

These boats, L—36 ft (10.9 m), weigh 10,000 lb (4,536 kg) less than similar steel boats, a weight reduction of some 63 per cent.

Material—5052 aluminium, $\frac{3}{16}$ in (4.7 mm) for sides and $\frac{1}{4}$ in (6.3 mm) for bottom.
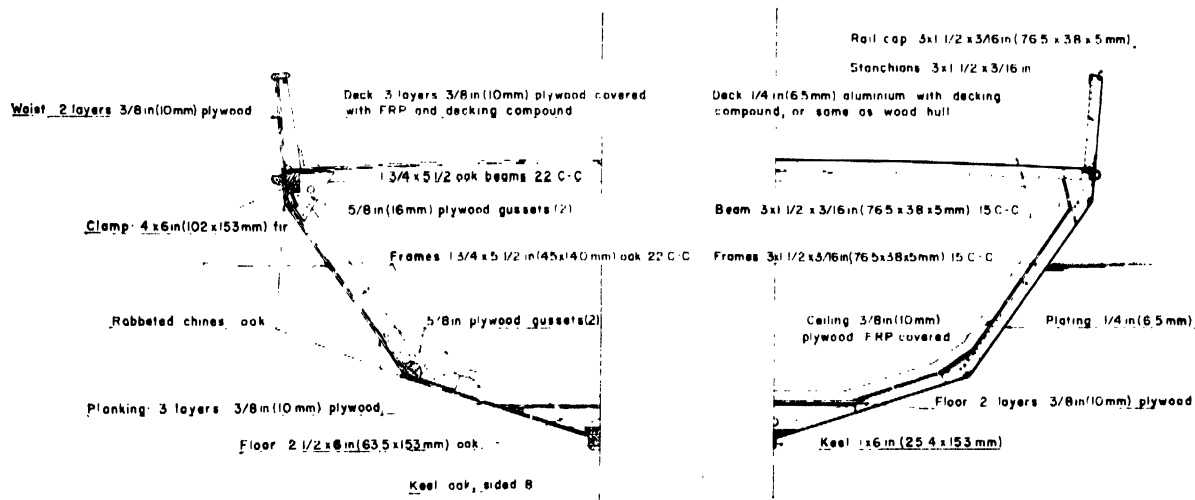
Fig 9. Midship sections of a dragger

(5) Dragger

The midship section sketches of a proposed 51 ft (15 m) dragger designed by naval architect Cyrus Hamlin, Manset, Maine, U.S.A., should be of interest.

Mr Hamlin estimates that the aluminium hull would cost 15 per cent to 20 per cent more than the wood hull, but this may be less at a yard experienced in aluminium construction. Offsetting the higher cost will be practically no maintenance of the aluminium hull, more fish-hold capacity and less weight. The hull and deck planking would total 1⅛ in (28.6 mm) in thickness versus ¼ in (6.3 mm) for aluminium and 5½ in (140 mm) deep frames and deck beams in wood versus 3 in (67 mm) in aluminium (fig 9).

The dragger is designed for either stern or side trawling. The midship section of the aluminium hull shows the ceiling, or inner fish-hold lining, to be of plywood which, of course, could be of aluminium.

(6) Crayfishing boat

Built by Engineer and Marine Services, Fremantle, Australia, in 1960 for crayfishing. Now owned and operated by Australian Aluminium Company, Sydney (fig 10, 11, 12, 13). Particulars:

L—64 ft (15.5 m)
B—17 ft 6 in (5.2 m)
D—8 ft (2.4 m)
T—4 ft 6 in (1.4 m)
Power—one 230 hp Deutz engine with 2 : 1 reduction gear
Speed—11.3 knots

Range—500 to 600 miles
Hull plating—⅜ in (8 mm)
Deck plating—³⁄₁₆ in (4.7 mm)
Frame spacing—about 18 in (.457 m)

The owners report that this vessel has been very successful and that there is a complete absence of either pitting or corrosion. The hull is left unpainted.

(7) Sport fishing boats

The *Lee Scott*, a catamaran, built in 1958 by Forster Shipyard, Terminal Island, California. Particulars:

L—45 ft (13.7 m).
B—16 ft (4.9 m)
Power—two 100 hp Gray marine gas engines with 2 : 1 reduction gears
Speed—about 17.3 knots
Material—hull plating ₇⁄₃₂ in (5.5 mm) 5086 aluminium, framing of 5083 and 5086 aluminium extrusions.

A 48 ft (14.6 m) aluminium charter sport fishing boat was built in 1960 by Jansen Machine Works, Troutdale, Oregon. Particulars:

L—48 ft (14.6 m)
B—12 ft 3 in (3.7 m)
T—2 ft 8 in (.8 m)
Speed—20 knots
Power—two 671 Gray marine diesels with 1.5 : 1 reduction gear
Material—sides and bottom ¼ in (6.3 mm) 5086-H34 aluminium plate; bulkheads, decks and cabin ₅⁄₃₂ in (4 mm); framing 6061-T6 extrusions and bar stock.

Fig 10. Cray fishing boat at sea

Fig 12. Stern framing of cray fishing boat

Fig 11. Hull plating on cray fishing boat

Fig 13. Stern tube of cray fishing boat

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Outboard rental boats used for sport fishing get severe and heavy-duty use. The Manager, Mountain Harbour Landing, Arkansas, has this to say: "We spent less than £36 ($100) total maintenance on our 100 Duracraft Pacemakers", 14 ft (4.3 m) aluminium outboard boats, "in three years of rental use". That is an average of 2s 5d (33c) per boat per year. The Manager, Crystal Springs Fishing Village, writes: "£7 ($20) was our total maintenance cost for our fleet of 106 Duracraft Pacemakers in their fifth season of use." Less than 3d (4c) per year per boat!

Rental boats are usually left unpainted; the only maintenance required, as a rule, is an occasional hosing down with fresh water, inside and out. The particulars are as follows:

L—14 ft (4.3 m)
B—4 ft 2 in (1.3 m), 4 ft 6 in (1.4 m), 5 ft 4 in (1.6 m)
D—21 in (.5 m), 22 in (.6 m), 24 in (.7 m)
Weight—135 lb (61 kg), 183 lb (83 kg), 198 lb (90 kg)
Alloy and temper of hull material—6061-T4
Thickness of hull—.063 in (1.6 mm)
Thickness of transom, deck, seats—
    .080 in (2 mm) transom
    .063 in (1.6 mm) seats
    .063 in (1.6 mm) deck
Rivets—6053-T61
Extrusions: side keels—6061-T5; spray rails, centre
    keel, cap rain—6061-T42
Capacity—745 lb (338 kg)
Power—maximum 18 hp
Speed—20 to 23 knots

ALUMINIUM FISHING BOAT APPLICATIONS OTHER THAN HULL

Fish-hold linings and pen boards

Aluminium pen boards and fish-hold linings were first installed in the United States in 1959 in the *William J. O'Brien*, a 20-year-old, 122 ft (37 m), Boston trawler. Material for the extrusions was 6063-T6 and the fish-hold lining was 5052 alloy (figs 14, 15, 16).

Similar wooden pen boards weigh 8 lb (3.6 kg) dry and up to 14½ lb (6.6 kg) wet and have to be dried out and painted several times a year. The aluminium extrusions weigh about 5 lb (2.2 kg), wet or dry, never need painting, are easy to clean and retain no odours. They also increase the cooling efficiency of the ice and decrease spoilage by allowing oxygen to reach fish stored against

Fig 14. Aluminium pen board installation
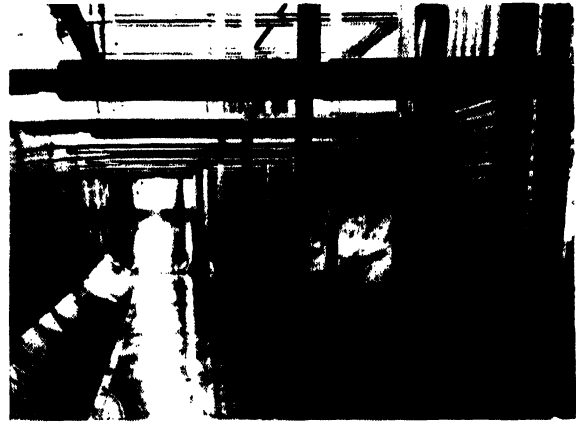
Fig 15. Aluminium pen boards and fish hold lining
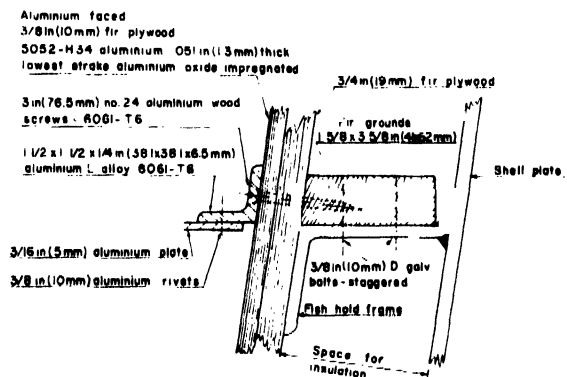
Fig 16. Pen partition details

the sides along the corrugations. The aluminium pen boards last almost indefinitely whereas the wooden boards have to be replaced frequently.

To re-line the fish hold with aluminium, the hold was stripped down to its steel hull and treated with zinc chromate. A 2 in (50 mm) layer of plastic foam was used to replace the cork. The aluminium sheets were overlapped and made watertight with an adhesive tape. The sheets were secured with aluminium screws to the underneath furrings.

Aluminium fish-hold linings and aluminium pen boards have been in use in European fishing vessels for about 17 years and have proved to be far more sanitary than wood, and have withstood corrosion and the most rigorous service conditions. Wood, on the other hand, gets water-soaked and heavy, slime accumulates in cracks and crevices which is impossible to entirely remove and clean, so that bacteria in large numbers populate the fish holds and contaminate the fish catch.

Deckhouses

Numerous steel-hulled fishing vessels and fishing research craft are built with aluminium deckhouses and pilot houses to save top-side weight and for reducing maintenance (fig 17, 18, 19).

One such craft, a 165 ft (50.3 m) research vessel, *Albatross IV*, designed by Potter, M'Arthur & Gilbert, Inc., Boston, and built for the US Bureau of Commercial Fisheries by Southern Shipbuilding Corp.,

Fig 17. Aluminium deck house

Aluminium bulkheads are also used in the main deck-house cabin of the same sheet gauges and extrusion sizes as in the bridge deckhouse and boat deckhouses.

A 99 ft 11 in (30.5 m) dragger, also designed by Potter, M'Arthur & Gilbert, Inc. and built for the Boston Fishing Co., Inc., used $\frac{3}{16}$ in (4.7 mm) 5052-H38 aluminium for deckhouse siding and roofing. Fish hold is lined with $\frac{3}{8}$ in (9.5 mm) fir plywood faced with .051 in (1.2 mm) thick 5052-H34 aluminium sheet. Pen partitions are of $\frac{3}{16}$ in (4.7 mm) 5052-H38 sheet with stiffeners of $5 \times \frac{1}{4}$ in (127 × 6.3 mm) flat bar and $1\frac{1}{2} \times 1\frac{1}{2} \times \frac{1}{4}$ in (38 × 38 × 6.3 mm) 6061-T6 extrusions.

Both of the above vessels were built to American Bureau of Shipping rules and designed to Lloyds Class A1 Fishing Service Rules.

Fig. 18. Aluminium deck house

Aluminium deckhouses can be left unpainted in order to save on maintenance, and in hot climates the aluminium deckhouses have a far cooler interior temperature due to the heat reflectivity characteristics of aluminium. Stability is enhanced by having less weight topside and carrying capacity is increased by the amount of weight saving obtained through elimination of the steel structures and substitution of aluminium. Over half of the weight can be saved in such structures.

Other ship-board applications

Funnels, radar masts and signal masts are other items made of aluminium. Although the weight is not great, due to the high position in the vessels any weight saving there is of consequence from the stability point of view. Maintenance cost savings again are of importance in these items.

The following is an example of maintenance and life obtained from a firm of British trawler operators:

Fig 19 Detail "A" of deck house shown in fig 18

ell, Louisiana, used $\frac{1}{4}$ in (6.3 mm) 5052-H34 aluium plate for the top bridge deckhouse siding and f and with $4 \times 3 \times \frac{1}{4}$ in (102 × 76 × 6.3 mm) aluminium usions for side stiffeners and $4 \times 3 \times \frac{3}{8}$ in (102 × 76 × mm) roof framing. Railing up-rights are made of in (31.7 mm) standard aluminium pipe as is the top gitudinal rail with $\frac{3}{4}$ in (19 mm) pipe for intermediate gitudinal rails. Deckhouse superstructure, on top of t deck, is made of .28 in (7 mm) aluminium plate for s and has the roof deck made of .33 in (8.3 mm) and in (7 mm) aluminium plate. Side stiffeners are $3 \times \frac{5}{16}$ in (102 × 76 × 8 mm) extru. Interior bulk-sions ds are of $\frac{3}{16}$ in (4.7 mm) sheet with $2 \times 1\frac{1}{2} \times \frac{1}{4}$ in × 30 × 6.3 mm) inverted angle extrusions. Railings on bridge deck are the same as on the tophouse roof.

	Steel funnel Average life 10 years		Aluminium funnel Est. life 20 years (after 5 years exp.)	
Initial cost . .	£50	($140)	£126	($353)
Cost of painting (steel monthly, aluminium semi-annually). .	£480	($1,344)	£160	($448)
Repairs over life .	£50	($140)	0	0
Total cost 10 years	£580	($1,624)		
Total cost 20 years	£1,160	($3,248)	£386	($801)

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Iversen and Son, A.S., Norway, has in recent produced over 30,000 fish boxes made of alu-m which are used for boxing fish at sea (fig 20). stored in this way, in a chilled hold, are reported 90 per cent suitable for filleting, and this figure, aid, is expected to reach 100 per cent. Such alu-m boxing increases hygienic conditions of trans-tion due to reduced presence of bacteria. In on there is a reduction in maintenance costs as nium boxes will last almost indefinitely. The boxes

Fig 20. Aluminium fish boxes

ade of Norwegian alloy number M 57S (similar to o. 5052) with a thickness of .08 in (2 mm) at the ınd .07 in (1.75 mm) for sides and bottom. Their ı is 2 ft 7⅞ in (810 mm), width 1 ft 6⅞ in (480 mm), : 6⅞ to 7⁵⁄₁₆ in (175 to 185 mm). The weight is ximately 11 lb (5 kg) with a volume of 15 imperial ι9 l). A wooden box would weigh approximately 22 lb (8.2 to 10 kg). The bottom features a draining ı—11 holes in each side trough and 3 holes in each o arranged that melted ice water and slime does not to the box below when stored on top of each other.

SUMMARY

ımic factors are the main reasons for using alu-m in fishing boat construction. After five years of :ing experience with aluminium gillnetters, a firm ιska, having a fleet of 41 such 32-ft boats, repre-g an investment in excess of £215,000 ($600,000) ιtremely pleased with the performance of these The representative of the firm has this to say:

"I would never put this amount of money into wood, steel, or plastic. These boats are faster, stronger and maintenance-free. True, like all boats there are bumps and dents, but the ease with which we can repair these is phenomenal. We have an Aircomatic welder with argon gas at the cannery and anything that develops we repair quicker than is possible with wood, with results as good as brand new. These boats have given us excellent service with no deterioration to the 5086 aluminium plate. Our maintenance costs on them to date have been nil. Their greater speed and carrying capacity increase their yield, fishermen being equal. Personally, I feel these make all other small fishing boats obsolete."

These boats are entirely unpainted. Sanitation in the smooth aluminium fish holds, which are easy to clean, is another obvious advantage.

There are now more than 80 aluminium gillnetters fishing for salmon in Alaskan waters, and some 230 aluminium Menhaden purse seine boats, each 36 ft (11 m), service motherships in the Gulf of Mexico and off the US east coast, and there are numerous other types of aluminium fishing boats giving excellent service.

Economic advantages

We have, then, the following economic advantages when using an aluminium fishing boat: (1) reduced mainten-ance, practically nil; (2) reduced fuel consumption per mile of travel due to lower weight; a 65 ft (19.8 m) aluminium boat, for instance, weighs about 54,000 lb (24,494 kg), 24,000 lb (9,886 kg) less than the 78,000 lb (35,380 kg) of a steel boat with the same dimensions; (3) reduced draft; (4) constant weight of the hull, no water absorption as with a wooden hull; (5) possibly better manoeuvrability due to less hull weight; (6) no dry or wet rot and no painting, caulking or puttying needed as with a wooden hull and no rust as with a steel hull; (7) greater speed with the same hp due to less weight; (8) better sanitation, keeping the fish in good marketable condition.

An aluminium hull will last almost indefinitely. An example of the lasting qualities of marine aluminium is the 55 ft (16.8 m) aluminium yacht *Diana II* built in England in 1931. In spite of severe service with the British Navy during World War II with limited and sometimes no maintenance this hull is still in excellent condition having outlasted many power plant changes. As long as proper alloys are used and care taken with bi-metallic connections during construction there is no reason why an aluminium fishing boat hull would not last almost for ever. Such a hull requires no maintenance whereas a wooden hull needs constant attention, and a steel hull needs chipping and scraping off the rust and painting and eventually there is no hull left. Teredo attack, especially in southern water, is a constant threat to a wooden hull as are dry and wet rot.

When considering smaller fishing boats used in con-junction with larger vessels the purse seine skiffs may be mentioned. Heavy, waterlogged wooden seine skiffs are difficult to take off and on the seiners, and nets and leads can get snagged on the wooden framing members that may be splintered. The lightweight aluminium seine skiffs, on the other hand, are easy to handle and their smooth and clean interior is a real asset when handling the nets. As the aluminium skiffs never need painting the upkeep is negligible and they will last almost indefinitely. Their light weight provides more speed with equal power and could make them more manoeuvrable, cuts down on fuel consumption, and if more speed is not desired a smaller power plant will provide a speed equal to the heavier wooden hulls. Also, there are no leaks in a welded aluminium hull, whereas a wooden hull develops leaks after having been out of the water for a time due to shrinkage of the hull planks, and time is required for swelling; also, puttying and caulking is often required. The aluminium hull may be launched at any time without fear of leaks and without any work on the hull.

Fig 17. Aluminium deck house

Aluminium bulkheads are also used in the main deck-house cabin of the same sheet gauges and extrusion sizes as in the bridge deckhouse and boat deckhouses.

A 99 ft 11 in (30.5 m) dragger, also designed by Potter, M'Arthur & Gilbert, Inc. and built for the Boston Fishing Co., Inc., used $\frac{3}{16}$ in (4.7 mm) 5052-H38 aluminium for deckhouse siding and roofing. Fish hold is lined with $\frac{3}{8}$ in (9.5 mm) fir plywood faced with .051 in (1.2 mm) thick 5052-H34 aluminium sheet. Pen partitions are of $\frac{3}{16}$ in (4.7 mm) 5052-H38 sheet with stiffeners of $5 \times \frac{1}{4}$ in (127 × 6.3 mm) flat bar and $1\frac{1}{2} \times 1\frac{1}{2} \times \frac{1}{4}$ in (38 × 38 × 6.3 mm) 6061-T6 extrusions.

Both of the above vessels were built to American Bureau of Shipping rules and designed to Lloyds Class A1 Fishing Service Rules.

Fig. 18. Aluminium deck house

Fig 19 Detail "A" of deck house shown in fig 18

Slidell, Louisiana, used $\frac{1}{4}$ in (6.3 mm) 5052-H34 aluminium plate for the top bridge deckhouse siding and roof and with $4 \times 3 \times \frac{1}{4}$ in (102 × 76 × 6.3 mm) aluminium extrusions for side stiffeners and $4 \times 3 \times \frac{3}{8}$ in (102 × 76 × 9.5 mm) roof framing. Railing up-rights are made of $1\frac{1}{4}$ in (31.7 mm) standard aluminium pipe as is the top longitudinal rail with $\frac{3}{4}$ in (19 mm) pipe for intermediate longitudinal rails. Deckhouse superstructure, on top of boat deck, is made of .28 in (7 mm) aluminium plate for sides and has the roof deck made of .33 in (8.3 mm) and .28 in (7 mm) aluminium plate. Side stiffeners are $4 \times 3 \times \frac{5}{16}$ in (102 × 76 × 8 mm) extru. Interior bulk-sions heads are of $\frac{3}{16}$ in (4.7 mm) sheet with $2 \times 1\frac{1}{2} \times \frac{1}{4}$ in (50 × 30 × 6.3 mm) inverted angle extrusions. Railings on the bridge deck are the same as on the tophouse roof.

Aluminium deckhouses can be left unpainted in order to save on maintenance, and in hot climates the aluminium deckhouses have a far cooler interior temperature due to the heat reflectivity characteristics of aluminium. Stability is enhanced by having less weight topside and carrying capacity is increased by the amount of weight saving obtained through elimination of the steel structures and substitution of aluminium. Over half of the weight can be saved in such structures.

Other ship-board applications

Funnels, radar masts and signal masts are other items made of aluminium. Although the weight is not great, due to the high position in the vessels any weight saving there is of consequence from the stability point of view. Maintenance cost savings again are of importance in these items.

The following is an example of maintenance and life obtained from a firm of British trawler operators:

	Steel funnel Average life 10 years		Aluminium funnel Est. life 20 years (after 5 years exp.)	
Initial cost . .	£50	($140)	£126	($353)
Cost of painting (steel monthly, aluminium semi-annually). .	£480	($1,344)	£160	($448)
Repairs over life .	£50	($140)	0	0
Total cost 10 years	£580	($1,624)		
Total cost 20 years	£1,160	($3,248)	£386	($801)

Fish boxes

Bernt Iversen and Son, A.S., Norway, has in recent years produced over 30,000 fish boxes made of aluminium which are used for boxing fish at sea (fig 20). Fish stored in this way, in a chilled hold, are reported to be 90 per cent suitable for filleting, and this figure, it is said, is expected to reach 100 per cent. Such aluminium boxing increases hygienic conditions of transportation due to reduced presence of bacteria. In addition there is a reduction in maintenance costs as aluminium boxes will last almost indefinitely. The boxes
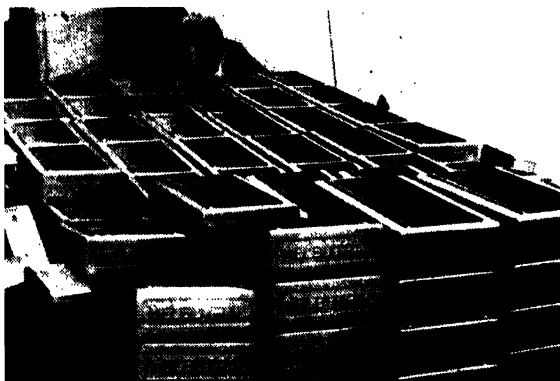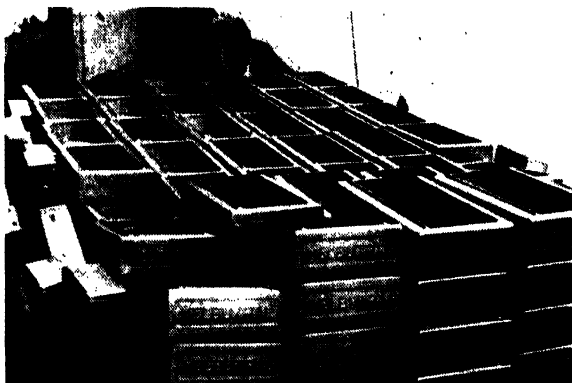

Fig 20. Aluminium fish boxes

are made of Norwegian alloy number M 57S (similar to US No. 5052) with a thickness of .08 in (2 mm) at the ends and .07 in (1.75 mm) for sides and bottom. Their length is 2 ft 7⅞ in (810 mm), width 1 ft 6⅞ in (480 mm), height 6⅞ to 7⅚ in (175 to 185 mm). The weight is approximately 11 lb (5 kg) with a volume of 15 imperial gal (69 l). A wooden box would weigh approximately 18 to 22 lb (8.2 to 10 kg). The bottom features a draining system—11 holes in each side trough and 3 holes in each end, so arranged that melted ice water and slime does not run into the box below when stored on top of each other.

SUMMARY

Economic factors are the main reasons for using aluminium in fishing boat construction. After five years of operating experience with aluminium gillnetters, a firm in Alaska, having a fleet of 41 such 32-ft boats, representing an investment in excess of £215,000 ($600,000) are extremely pleased with the performance of these boats. The representative of the firm has this to say:

● "I would never put this amount of money into wood, steel, or plastic. These boats are faster, stronger and maintenance-free. True, like all boats there are bumps and dents, but the ease with which we can repair these is phenomenal. We have an Aircomatic welder with argon gas at the cannery and anything that develops we repair quicker than is possible with wood, with results as good as brand new. These boats have given us excellent service with no deterioration to the 5086 aluminium plate. Our maintenance costs on them to date have been nil. Their greater speed and carrying capacity increase their yield, fishermen being equal. Personally, I feel these make all other small fishing boats obsolete."

These boats are entirely unpainted. Sanitation in the smooth aluminium fish holds, which are easy to clean, is another obvious advantage.

There are now more than 80 aluminium gillnetters fishing for salmon in Alaskan waters, and some 230 aluminium Menhaden purse seine boats, each 36 ft (11 m), service motherships in the Gulf of Mexico and off the US east coast, and there are numerous other types of aluminium fishing boats giving excellent service.

Economic advantages

We have, then, the following economic advantages when using an aluminium fishing boat: (1) reduced maintenance, practically nil; (2) reduced fuel consumption per mile of travel due to lower weight; a 65 ft (19.8 m) aluminium boat, for instance, weighs about 54,000 lb (24,494 kg), 24,000 lb (9,886 kg) less than the 78,000 lb (35,380 kg) of a steel boat with the same dimensions; (3) reduced draft; (4) constant weight of the hull, no water absorption as with a wooden hull; (5) possibly better manoeuvrability due to less hull weight; (6) no dry or wet rot and no painting, caulking or puttying needed as with a wooden hull and no rust as with a steel hull; (7) greater speed with the same hp due to less weight; (8) better sanitation, keeping the fish in good marketable condition.

An aluminium hull will last almost indefinitely. An example of the lasting qualities of marine aluminium is the 55 ft (16.8 m) aluminium yacht *Diana II* built in England in 1931. In spite of severe service with the British Navy during World War II with limited and sometimes no maintenance this hull is still in excellent condition having outlasted many power plant changes. As long as proper alloys are used and care taken with bimetallic connections during construction there is no reason why an aluminium fishing boat hull would not last almost for ever. Such a hull requires no maintenance whereas a wooden hull needs constant attention, and a steel hull needs chipping and scraping off the rust and painting and eventually there is no hull left. Teredo attack, especially in southern water, is a constant threat to a wooden hull as are dry and wet rot.

When considering smaller fishing boats used in conjunction with larger vessels the purse seine skiffs may be mentioned. Heavy, waterlogged wooden seine skiffs are difficult to take off and on the seiners, and nets and leads can get snagged on the wooden framing members that may be splintered. The lightweight aluminium seine skiffs, on the other hand, are easy to handle and their smooth and clean interior is a real asset when handling the nets. As the aluminium skiffs never need painting the upkeep is negligible and they will last almost indefinitely. Their light weight provides more speed with equal power and could make them more manoeuvrable, cuts down on fuel consumption, and if more speed is not desired a smaller power plant will provide a speed equal to the heavier wooden hulls. Also, there are no leaks in a welded aluminium hull, whereas a wooden hull develops leaks after having been out of the water for a time due to shrinkage of the hull planks, and time is required for swelling; also, puttying and caulking is often required. The aluminium hull may be launched at any time without fear of leaks and without any work on the hull.

All-Plastic Fishing Vessels

by Mitsuo Takehana

Bateaux de pêche en plastiques renforcés

La communication étudie, des points de vue de la technique et du coût, l'applicabilité des plastiques renforcés de fibres de verre à la construction des coques de bateaux de pêche. Il semble que les chantiers japonais de construction de bateaux de pêche puissent offrir un important débouché à ce procédé, à condition que soient effectués les travaux de recherche nécessaires. L'auteur décrit les types de bateaux de pêche pouvant être construits en plastiques renforcés.

L'étude fournit également des données sur l'échantillonnage et le coût des bateaux japonais. Il est signalé que le prix de revient des bâtiments en plastiques armés pourrait être ramené à 120 pour 100 seulement de celui des bateaux en bois. La communication s'attache aux avantages que présentent les navires en plastiques renforcés, étant donné que, par rapport au mode de construction classique, cette technique permet une énorme réduction du poids de la coque.

Embarcaciones pesqueras hechas enteramente de plástico

El trabajo describe la aplicabilidad de los plásticos reforzados con fibra de vidrio en la construcción del casco de las embarcaciones pesqueras desde el punto de vista de la tecnología y el costo. Al parecer, existe un amplio mercado potencial en las industrias de construcción de barcos pesqueros del Japón, a condición de que se realicen investigaciones adecuadas. Se indican ejemplos de los tipos de embarcaciones pesqueras que se pueden construir con dichos plásticos.

Se indican también datos sobre escantillones y costos en el Japón. Se hace notar que el costo de las embarcaciones de plástico reforzado con fibra de vidrio podría reducirse 1,2 veces en relación con el costo de las embarcaciones de madera. Este trabajo trata también de las ventajas del diseño de las embarcaciones de plástico reforzado con fibra de vidrio debido a la enorme reducción del peso del casco en comparación con la construcción corriente.

FIBREGLASS Reinforced Plastic (FRP) is no longer new in many countries as a material for naval or pleasure craft, and the demand for it is ever increasing. FRP is now unanimously recognized as the best plastic material that can be suitably used at sea. The writer intends to discuss whether FRP can play any helpful role in the modernization of about 350,000 Japanese small wooden vessels. Japan is now suffering a

Fig 1. 5 GT pole and line boat

remarkable rise in construction costs of wooden boats, aggravated by the shortage of good quality timber and lack of skilled shipwrights. This has resulted in using steel for small boats of even less than 5 GT. The change in material demands changes in hull shape, which also changes vessel performance. FRP could, therefore, well replace wood as the construction material for smaller fishing craft if its advantageous properties are fully utilized, namely, light weight, good durability, thermal qualities, decrease in vibration and corrosion. FRP should be further investigated for workability, cost and other factors.

FRP was first used about four years ago in Japanese fishing boat construction. Today the material is seen in about 300 laver-picking and 100 pearl-working boats, several pleasure fishing boats and fishing patrol boats of 32 to 43 ft (10 to 13 m). A tuna fishing vessel of 54 ft (16.5 m) length overall has recently been constructed. This is the largest vessel in use to be constructed of FRP, although several of a larger size are under trial.

The main obstacles to the full utilization of FRP for fishing boats are:

● Uncertainty about strength and durability among would-be users
● Only recently have the proper procedures been established with regard to ship form shape, method of construction and testing
● Economy in applying the material has not been analysed enough
● Technical training is needed for those going into the FRP business, as well as promotion of the material among boat owners.

Fig 2. 20 GT pole and line boat

Japanese technologists have done five years research on applying FRP to high-speed boats from 8 to 39 ft (2.5 to 12 m). Another study is under way on the application of FRP to fittings of large ships. The writer is planning a third project to remove the above-mentioned bottlenecks by promoting FRP applications in co-operation with governmental organizations, research institutes and manufacturers.

SPECIAL FEATURES OF SMALL BOATS

Table 1 shows the number of sea-going motor fishing vessels in Japan at the end of 1963. In 1964, steel boats and woooden boats increased by 522 and 3,339 respec-

Fig 3. 3 GT trawler

tively. The increase of the latter includes those converted from non-powered boats. In terms of gross tonnage, however, the steel boat has increased by approximately 63,600 GT, while wooden vessels have decreased by about 7,000 GT. This indicates that the average size of wooden vessels has decreased. Mechanization of non-powered vessels is indicated by the 2.1 per cent increase in the number of powered vessels below 5 GT. Preference for larger engines is seen in the increase of average engine output; for example, from 39 to 42 hp for the vessels between 5 to 19 GT. Japanese small fishing vessels below 50 GT can be classified into a few groups based on their economy.

Vessels under 1 GT are not engaged in active commercial fishing. Many are owned by part-time retired fisher-

men. Vessels of 3 to 5 GT have high productivity and are the core of the coastal fishery. Their main methods are small-scale trawling and pole-fishing. The vessels of 5 to 10 GT are not necessarily economical, depending on the operating waters. Some owners have replaced their boats with vessels of 20 to 30 GT. The vessels of 40 to 50 GT are highly capitalized fishing operations with larger crews.

Fig 4. 5 GT trawler

This paper will refer only to the group below 30 GT, with emphasis on those from 3 to 5 GT, including non-powered vessels such as cultivation boats and tenders.

Fig 1 to 20 provide a comparison of wooden and FRP boats, ranging from a 5-GT pole fishing boat to the largest plastic tuna vessel in Japan. In 1960 the Japanese Fisheries Agency prepared drawings of 16 kinds of small prototype wooden fishing boats, with a view to curtailing the amount of materials and the number of processes. Fig 11 and 12 are some of these drawings. FRP construction requires standardization. In the first place, various local types were selected and those which were popular over a large area were chosen. This selection was considerably difficult as it involved minimizing traditional differences in various areas. Timing was another problem as the right advice must be given at the right moment if fishermen are to accept such modification of their vessels.

NEED FOR FRP CONSTRUCTION

Table 2 shows the consumption of wood and price trends in Japan. As is shown, the domestic supply has increased only 22 per cent during the last eight years, while imported wood increased 7.5 times. The price of timber in 1963 was 2.2 times the price of general commodities. During the period, the quality of wood for boat construction has declined, resulting in quicker hull

TABLE 1: **Powered sea-going fishing vessels (as at the end of 1963)**

Type of construction or size of vessel	No. of vessels	GT	hp
Steel . . .	3,299	1,121,258.56	1,906,280
Wood . . .	189,216	788,263.74	3,108,150
Total . . .	192,515	1,909,522.30	5,014,430
Less than 5 GT .	167,684	300,174.93	1,315,237
5—9 GT . .	8,041	58,755.39	227,078
10—19 GT .	7,129	108,024.79	406,310
20 GT and over .	9,661	1,442,567.19	3,065,805

Note: Number of other fishing vessels which are not listed above are:
Non-tidal water, powered 3,600
Non-powered   202,820
Among these, 175,436 vessels are less than one GT

TABLE 2: **Consumption and price of timber in Japan**

	Consumption		Price Index	
Year	Domestic Product	Import	General Commodities	Timber
1955	38,256	2,054	343.0	509.9
1957	41,667	2,893	368.8	614.8
1959	42,827	5,705	348.3	604.1
1961	49,333	9,635	355.7	764.0
1963	46,882	15,300	356.0	786.9

Note: Product and import unit is 35,315 ft³ (1,000 m³)
      Unit of price index is average of 1934—1936
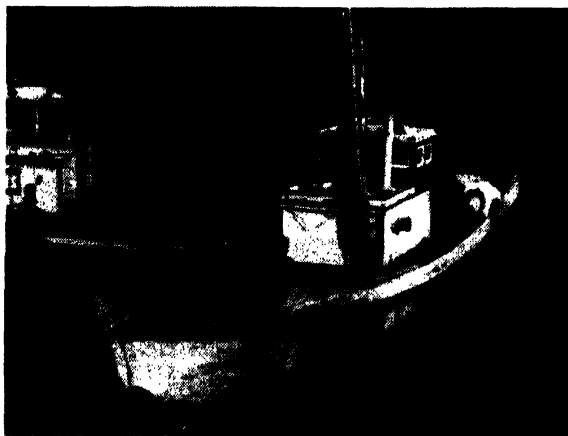
Fig 5. 2 GT trawler
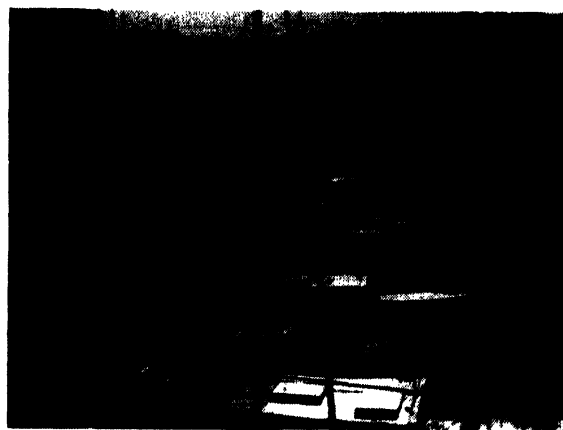
Fig 6. Shell-fish and laver boats

deterioration. At the same time, construction has become inferior as there are fewer apprentice shipwrights. This trend is seen especially in vessels below 5 GT which are built in small village shipyards. In table 3 the number of small wooden vessels remains almost unchanged because they cannot be built in steel. Table 4 shows the trend of the standard cost of a fishing boat hull. The hull construction cost of wooden fishing boats has increased by as much as 60 per cent; the cost of steel construction has

remained almost unchanged. This is due to rising wood costs, shortage of skilled shipwrights and no improvements in construction of wooden vessels. On the other hand, building techniques for steel vessels have considerably improved so that the rise of both material and labour costs are almost cancelled.

To cope with this situation, a few shipyards, which formerly built in wood, have been consolidated into one enterprise to strengthen their facilities and build steel vessels. Now 20 GT auxiliary boats for purse seining and 5 GT fish carriers are built in steel. The construction of these small steel boats is, however, outside of the existing ship-building standards of construction work, and establishment of standard regulations is needed.

Meanwhile, traditional small fishing boats are built of wood in small-scale shipyards which cannot afford additional equipment to start building steel boats. Under the circumstances, it seems advantageous for them to learn FRP construction techniques as the equipment needed is less expensive than for steel vessels.

Fig 7. Laver boat

PROBLEMS IN FRP CONSTRUCTION

The problems involved in the construction of small FRP fishing boats are:

- FRP construction does not require any joints, making it light and durable, while conventional wooden boats require joint strength, resulting in heavy structure. If FRP vessels are built on wooden boat lines, they tend to float excessively and lose balance
- As seen in fig 1 to 20, there are various hull shapes according to local requirements. It is necessary to standardize them into a few shapes taking the preceding item into account. Difficulties in building different designs of FRP vessels can be overcome by applying prefabrication techniques. This is especially true for Japanese traditional type pole-fishing vessels and trawlers. However, there is a huge number of small vessels which do not require special designs for local conditions. Examples are, laver-picking boats, pearl-cultivation boats, tenders and launches, which can be built easily by means of the female mould method. Large vessels over 39.4 ft (12 m) should be built by means of the male mould method
- Since shelters are often not large enough to accommodate many small vessels, they bump, and fenders are necessary
- Small vessels are often accommodated in shelters where there is no water at ebb tide. Many small vessels are beach-landed. Therefore, a special plastic cover on the bottom is necessary or easily replaceable false keels must be added

- FRP-built boats have significant hull deflection adversely affecting the engine and shafting. The engine bed should be wooden or wood reinforced. When reinforced by wood, attention should be paid to the different durabilities of wood and plastic

Fig 8. Laver boat in FRP

EXAMPLES

Laver* and pearl boats

For open boats such as laver-and-pearl cultivation boats, the female mould method is used, since about 100 vessels are built from one mould. It has been concluded that three types of laver-collecting boats can be FRP-built in Japan; the Ariake type (fig 8), Funabashi type (fig 10) and Toyohashi type. On the other hand, modification of existing design is needed for the pearl-boats so they can also be used as tenders. The new designs are shown in fig 13 and 14. This boat develops about 12.5 knots with a 10-hp outboard engine and two men on board. The dimensions are $L \times B \times D = 16.1 \times 5.27 \times 2.23$ ft ($4.92 \times 1.6 \times 0.68$ m), with hull weight 190 kg. Central deflection is 0.2 in (5 mm) under the bending moment of $\frac{\Delta L}{12}$, with the maximum stress rated at 355 lb/in^2 (0.25 kg/mm^2), when the distance of two hanging hooks is 11.44 ft (3.48 m). The price of this is £140 (US$390) for the hull and £130 (US$360) for the engine, totalling £270 (US$750). The weight of the hull is only 190 kg in comparison with 800 kg for a wooden boat of the same size. The heavier weight

* Note: laver is a kind of seaweed.
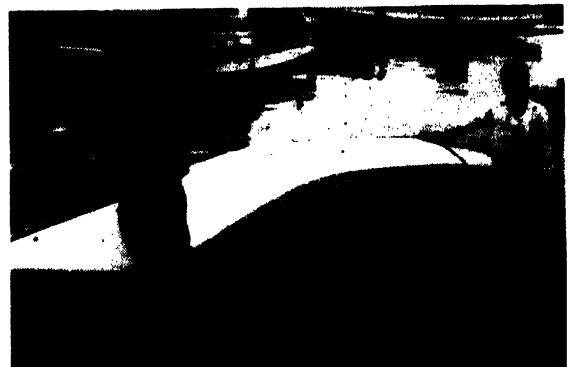
Fig 9. Laver boat in FRP

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of the wooden boat necessitates an 18-hp engine to make the same speed. A wooden boat of the same size costs £90 (US$250) for the hull plus £210 (US$585) for an 18-hp engine, totalling £300 (US $ 835).

Japanese traditional boat

The prefabrication method is applied to this type of boat without the mould. Therefore the construction procedure is the same as for wooden boats. Plates are made by attaching FRP on one side of a vinyl chloride foam plate. The plate is used as a hull plate with the FRP side out. The outside joints are sealed with FRP and the inside is coated with FRP to the required thickness. This process is difficult for double curvatured surfaces, but the Japanese-type boats have no such structure. Fig 15 and 16 show an experimental boat built by this method. Various tests, such as rolling, strength, vibration and speed, had been carried out with this boat. The dimensions are L × B × D = 18.2 × 4.25 × 1.97 ft (5.54 × 1.29 × 0.60 m). The engine is 3-hp diesel and the engine bed is made of zelkova. The deck beams and deck plates are also wood. The performance data are:

Maximum speed	5.75 knots
GM light condition	0.83 ft (0.27 m)
Rolling period	1.64 sec
Extinction coefficient	0.058
Radius of gyration	1.141 ft (0.47 m)

These data indicate that deck comfort should not differ from the same size wooden boats. This prefabrication method has been applied to several sport fishing boats of 33 ft (10 m) to 40 ft (12 m) (fig 17) in small local wooden shipbuilders who learned the FRP technique.
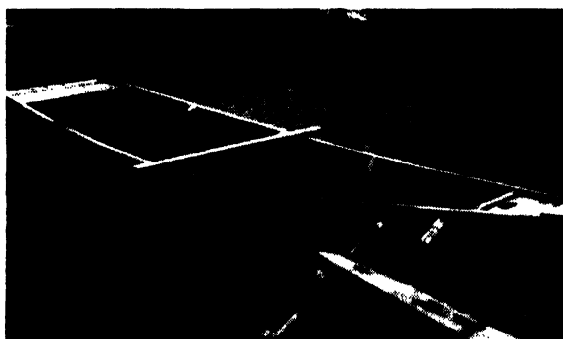
Japanese traditional sport fishing boats

Sport fishing boats built of FRP sandwich system with vinyl chloride foam plates in the middle layer by means of cage-type male mould have the following specifications:

L × B × D   41.0 × 7.9 × 3.6 ft (12.5 × 2.4 × 1.09 m)
Hull weight 2 tons
Engine   20 hp diesel
Speed   9 knots

Vibration tests of a full-scale model showed a wooden engine bed dispersed vibration. The thicknesses of FRP used are:
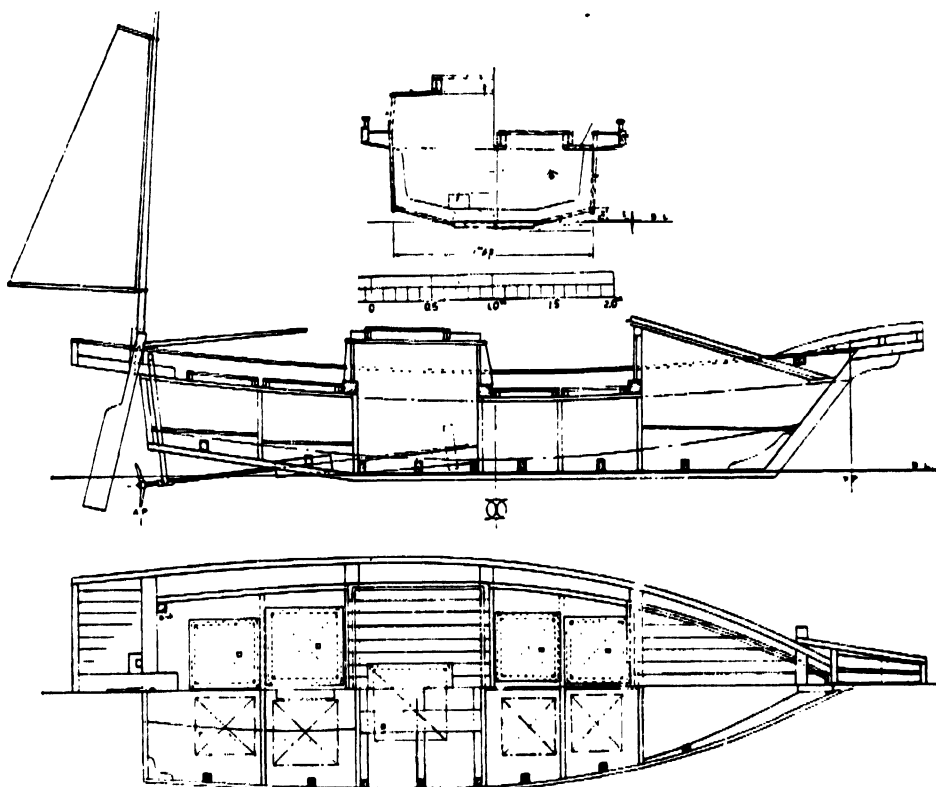
Fig 10. Laver boat

Fig 11. 1.5 GT pole and line boat
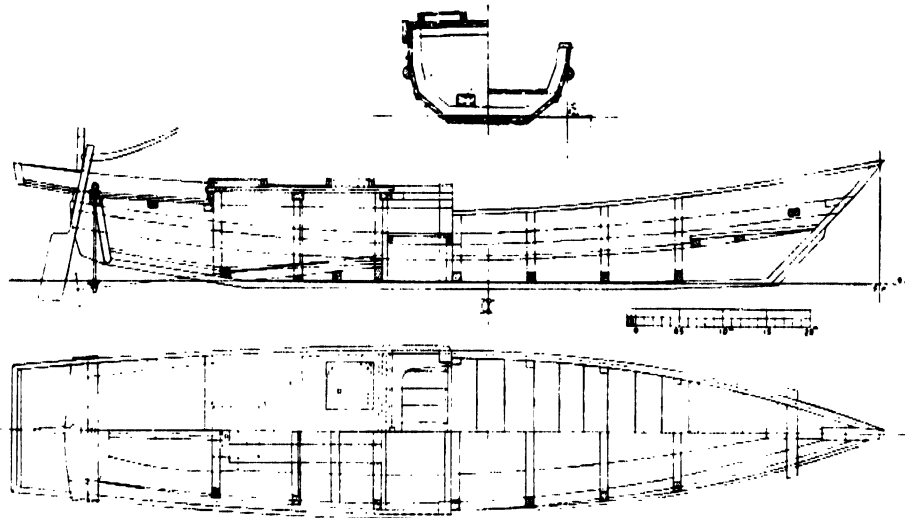
Fig 12. 2.5 GT shell-fish and laver boat

Side	0.14 + foam 0.39 + 0.09 in (3.5 + foam 10 + 3 mm)
Flat keel	0.14 + foam 0.79 + 0.09 in (3.5 + foam 20 + 3 mm)
Bilge strake	0.14 + foam 0.59 + 0.09 in (3.5 + foam 15 + 3 mm)
Deck	0.14 + foam 0.39 + 0.11 in (3.5 + foam 10 + 2.8 mm)

Tuna catcher boats

The largest FRP boat built in Japan based on the cage-type male mould method is a tuna catcher boat (fig 20). The specifications are as follows:

Length overall	54.3 ft (16.5 m)
Breadth	12.2 ft (3.70 m)
Depth	5.0 ft (1.52 m)
Main engine	120 hp diesel, 1,500 rpm

Fig 13. Multi-purpose boat in FRP

Fig 15. Sports fishing boat in FRP

Fig 14. Embarkation test of a multi-purpose boat in FRP
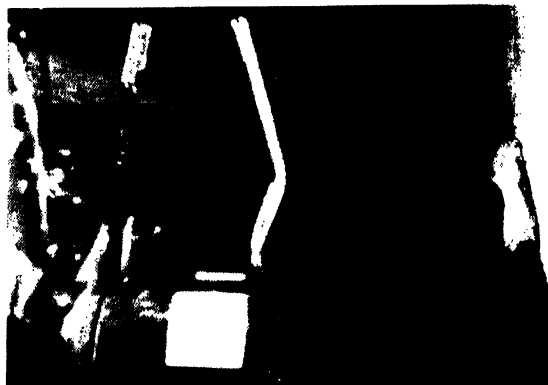
Fig 16. Engine bed of a sports fishing boat in FRP

[251]

TABLE 5: Comparison of tuna catcher boats (wood, steel and FRP)

Hull material		Steel	Double diagonal wooden hull	FRP sandwich
Length, ft (m)		49.4 (15.04)	52.5 (16.00)	49.25 (15.00)
Breadth, ft (m)		12.13 (3.70)	11.84 (3.61)	12.13 (3.70)
Depth, ft (m)		4.96 (1.51)	5.02 (1.53)	5.00 (1.52)
Cubic number ft³ (m³)		2,970 (84.0)	3,110 (88.2)	2,980 (84.4)
Fish-hold capacity, ft³ (m³)		335 (9.5)	388 (11.3)	325 (9.2)
Main engine, hp		120	90	120
Maximum speed, knots		9.1	9.4	9.7
Light load condition	Displacement, ton	18.26	19.44	12.64
	KG/D	0.93	0.80	0.90
	GM, ft (m)	4.07 (1.24)	4.30 (1.31)	4.88 (1.49)
	Freeboard, ft (m)	3.05 (0.93)	3.48 (1.06)	3.31 (1.01)
Departure condition	Displacement, ton	26.84	28.81	24.49
	KG/D	1.01	0.93	0.98
	GM, ft (m)	2.20 (0.67)	2.29 (0.70)	2.26 (0.69)
	Freeboard, ft (m)	2.49 (0.76)	2.88 (0.88)	2.52 (0.77)
Arrival condition	Displacement, ton	38.08	37.94	29.23
	KG/D	0,89	0.86	0.94
	GM, ft (m)	1.97 (0.60	1.93 (0.59)	2.13 (0.65)
	Freeboard, ft (m)	1.61 (0.49)	2.23 (0.68)	2.03 (0.62)
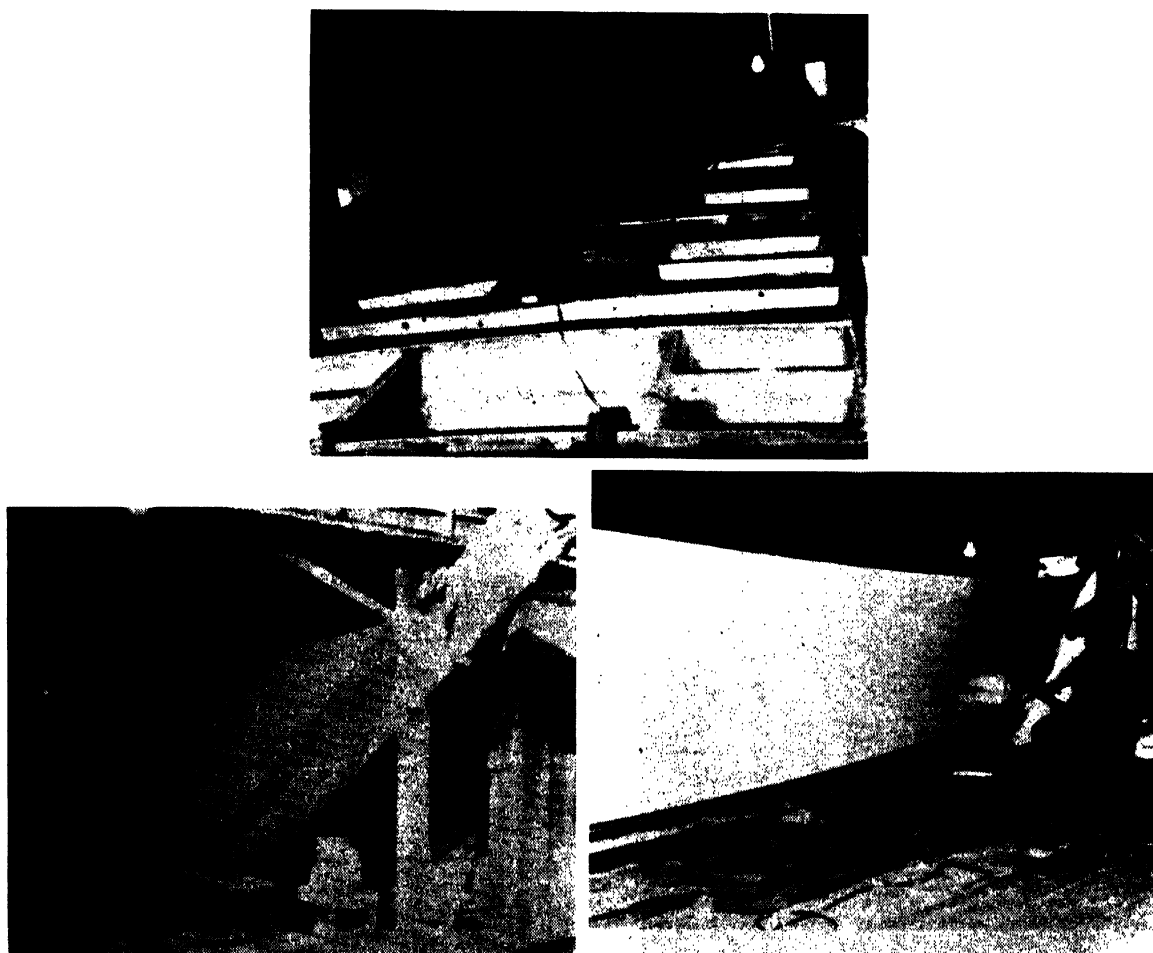
Fig 17. Aspects of a sports fishing boat construction with no mould

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Table 5 shows the comparison of wooden and steel boats. Materials used are:

Shell plate: outside—glass 6 layers 0.24 in (6 mm)
core—vinyl chloride foam 0.79 in (20 mm)
inside—glass 2 layers 0.12 in (3 mm)
Deck plate: 0.59 in (15 mm) plywood covered with two layers of glass

Scantlings of shell plates are designed to be as strong as 1.8 in (45 mm) thick cryptomeria planking, which will protect the hull against swordfish or marlin attack.

Others

A laver fertilizer boat $L \times B \times D = 24.6 \times 7.9 \times 2.78$ ft ($7.5 \times 2.4 \times 0.85$ m), weighing 1.8 tons was built with the FRP vinyl chloride foam sandwich construction. The cage-type male mould was used. Several FRP pleasure boats have been modified into fishing patrol boats in various districts.

FUTURE DEVELOPMENT

Essential research

Small localized vessels have their own traditional hull forms developed by experience of traditional fishing techniques and local sea conditions. This is particularly applicable to the size of boat which could be readily fabricated in FRP. It is difficult to introduce any drastic change of boat building materials because of tradition. The initial introduction should be in such items as work

Fig 18. Male-mould construction

boats, sampans and equipment like hatch boards, ventilators, life raft cases and fishing gear, where there is ample scope for plastic construction. The method could then be extended to other vessels as builders become more familiar with the material.

The introductory requirements are as follows:—

● The design should take full advantage of reduced hull weight and emphasis placed on stability, roll angle and damping
● Application of wooden material for engine bed, deck and other parts should be further investigated

● Instruction programmes should be arranged so that work could be easily carried out by local wooden boat builders
● The development of an effective inspection method is required
● Fatigue, wear, durability of FRP vessels should be tested by experimental boats
● Special hull forms which could only be built with FRP such as catamaran, wave form bottom, etc., likely to lead to improved performance for smaller fishing boats, should be developed

Standards and specifications

Standards should be established for work, inspection, construction and design. Simple calculable standards may be more useful than lists of scantlings for small fishing vessels which have a large variety of hull forms. Design data should show how many layers of FRP are necessary to provide the required strength and the type of reinforcement fibre to be used.

Fig 19. After launch

Economic considerations

There is a deep-rooted general conception that FRP boats are more expensive than wooden boats. The cost of FRP pleasure vessels is the same as that for plywood ones, because of mass production. An advantage of plastic construction is that the boatyard may be smaller than the conventional yard, thus reducing overhead costs.

TABLE 6: Cost of non-mould FRP boats and wooden boats (sports fishing boats)

Item	Non-mould		Wooden boat	
	FRP	Sandwich boat		
	£	$	£	$
Fibreglass	190	530	—	—
Resin (polyester)	110	310	—	—
Sandwich core (vinyl chloride foam)	100	280	—	—
Other running supplies	30	84	—	—
Timber, bolts and nails	260	730	450	1,260
Manufacturing cost	240	670	230	645
Management cost	20	56	20	55
Total	950	2,660	700	1,960

Note: Boat dimensions, $41.0 \times 6.95 \times 3.48$ ft ($12.5 \times 2.12 \times 1.06$ m)
Boat type, Japanese traditional type
Boatyard, conventional wooden boatyard

If plastic vessel fabrication becomes widespread, the cost of construction will be competitive with that of wooden boats, especially as the cost of FRP materials is decreasing while wood prices are increasing. If the demand should become large enough unskilled labour could be used, thus reducing costs even more.

The present constructional costs of FRP laver-collecting boats in a special factory are as follows:

Female mould method:

Material cost: Resin £0.2 (US$0.6) per kg
Fibreglass £0.5 (US$1.4) per kg
Polyvinyl chloride foam £1.22 (US$3.4) per kg
Others £1.20 (US$3.3) per kg

Cost of mould: Wooden mould 7 times cost of boat
FRP mould 2 times cost of boat

Cost of man/hr: About £0.4 to £0.55 (US$1.1 to $1.5) per unit process. One unit process is 2 kg of material.

However, a certain amount of material is lost during the construction. The weight of a completed boat is 120 lb

Fig 20. 54 ft (16.5 m) tuna catcher in FRP

(55 kg), and the selling price is £55 (US$153), which is much higher than the locally built wooden boat of £20 to £25 (US$56 to $70). Generally, the selling price of FRP vessels is estimated at £1 (US$2.80) per kg. The above cost is estimated on the assumption that 100 vessels are built from one mould. A choice of female, male and non-mould methods may be made to obtain economic efficiency by considering the number of vessels to be built as follows:

Female mould method	20 to 100 vessels
Male mould method	20 vessels or less
Non-mould method	1 to 10 vessels

As shown in table 5 comparing the non-mould method with conventional wooden boat construction, the FRP vessels cost 35 per cent more than wooden boats. This difference for non-mould method can be reduced to 20 per cent in the near future.

A wooden boat will last five years while FRP boats will remain in use for ten years and maintenance costs for FRP will be far lower than for wooden vessels. Therefore, the difference of building cost can be easily covered by these advantages.

There are still many problems to be solved for all-plastic fishing vessels, and the most important matters to promote FRP vessels are as follows:

● Technical know-how of FRP boats is needed among fishermen
● Advantage of FRP vessels on durability should be fully utilized
● Design of special hull form should be developed
● Proper work method, inspection method and standards should be established
● Construction costs should be lowered

When the above problems are properly solved, FRP will surely take a firm stand in the fishing boat-building industry, which is a quite large potential market for FRP.

A 110-ft Fibreglass Reinforced Plastic Trawler

by Ralph J. Della Rocca

Chalutier de 110 pieds (33,5 m) en plastique renforcé

L'intérêt croissant que suscite l'immense potentiel de production alimentaire des océans se manifeste par le besoin de nombreux chalutiers modernes améliorés quant au rayon d'action et au volume de cale. Cet objectif peut être atteint économiquement par l'emploi des intéressants matériaux de construction que constituent les plastiques renforcés de fibres de verre.

L'auteur indique comment il est possible de réaliser un chalutier de 110 pieds (33,5 m) en partant d'une récente étude approfondie concernant des dragueurs de mines états-uniens. Les plastiques renforcés présentent des avantages dans la construction des chalutiers, et l'auteur les compare aux matériaux classiques. Il traite de divers aspects de la préparation des plastiques: renforts, résines, procédés de moulage, fabrication du stratifié, ainsi que des propriétés physiques des stratifiés recommandés.

La communication étudie la réalisation de coques en plastique renforcé (panneaux simples, la coque étant munie de membrures, construction en "sandwich", construction mixte), et recommande un choix de modes de construction des coques.

En conclusion, l'auteur présente un avant-projet de chalutier de 110 pieds conforme aux règlements des sociétés de classification, avec des échantillonnages comparés pour le bois, l'acier et le plastique renforcé, et donne un résumé des caractéristiques du bâtiment.

Arrastrero de plástico de 110 pies reforzado con fibra de vidrio

El interés cada vez mayor que despierta la enorme fuente potencial de alimentos que es el mar requiere la construcción de muchos arrastreros de diseño mejorado en lo que respecta al radio de operaciones y a la capacidad de carga. Esto se puede conseguir económicamente utilizando las ventajas de construcción que representa el plástico reforzado con fibra de vidrio (PFV).

Se dan los resultados acerca de la viabilidad de un diseño de arrastrero de 110 pies, empleando como base un amplio estudio realizado para los dragaminas de Estados Unidos. Se exponen las ventajas de PFV para los arrastreros, comparándolo con otros materiales de construcción. Se examinan los refuerzos aplicables de fibra de vidrio, resinas, métodos para trazar, y construcción de laminados, incluyendo las propiedades físicas de los laminados recomendados.

Se examina la construcción de cascos utilizando el PFV, incluyendo forros y cuadernas simples de materiales mixtos o en capas, y se seleccionan y recomiendan tipos de construcciones de cascos.

Se da un diseño preliminar para un arrastrero de 110 pies basado en normas de regulación que incluyen bocetos de escantillones para madera, acero y PFV; además se resumen y comparan estas características de los barcos.

RECENTLY the vast potential food source in the sea has intensified the interests of both government and commercial organizations throughout the world to develop and expand their fishing industries, requiring, therefore, the replacement and expansion of the fishing fleets, the construction of new processing facilities, research and development to improve fish-catching equipment and processing systems and conductance of oceanographic studies to determine fish propagation and migration. Most government agencies with jurisdiction over their fishing industries are providing all or part of the necessary funds and assistance for these programmes.

In the USA, there is similar interest and the expansion of the fishing industry, particularly the replacement and addition of new fishing craft, is being given considerable attention.
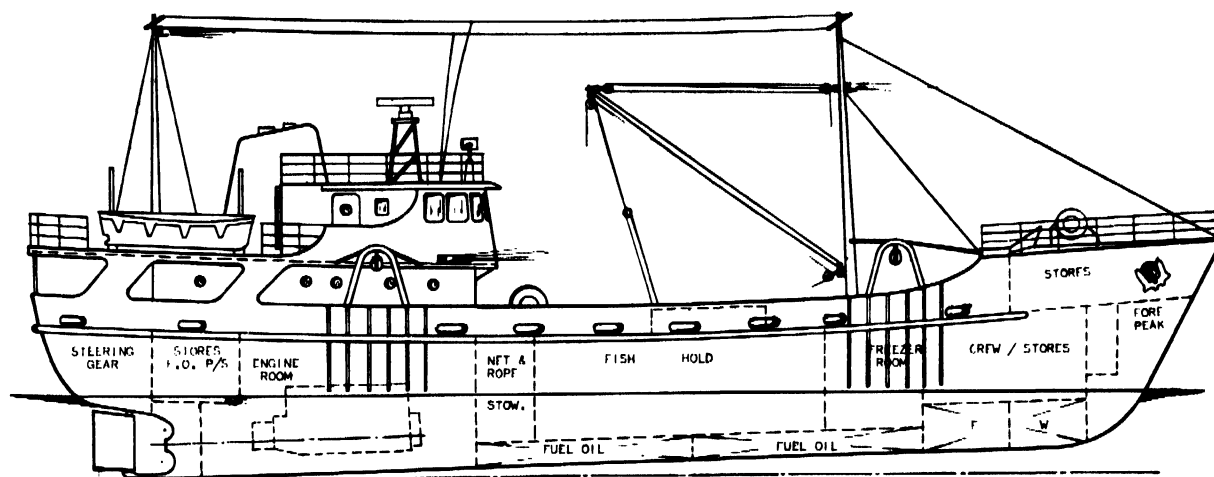
Fig 1. 110-ft side trawler

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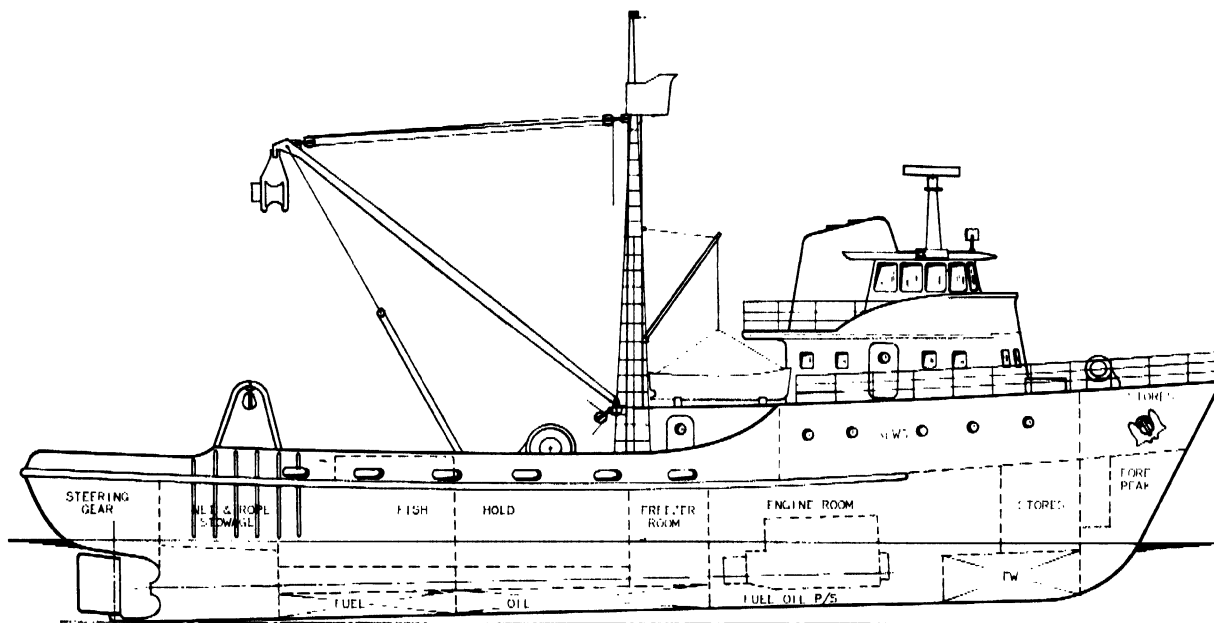
Fig 2. 110-ft stern trawler

In connection with this expansion, the author's company has conducted an independent limited study for commercial fishing boats of FRP construction. The object was to ascertain the relative characteristics of trawlers of FRP hull construction and standard wood or steel construction. The trawler was selected because of its wide use and the need to catch more fish, fish in deeper water, reduce manual labour, be easily convertible from one fishing method to another and be suitable for bad weather fishing. The 110-ft (33.6 m) length was selected as an average length for a medium-size trawler and for comparison with a similar study conducted on US Navy FRP minesweepers between 112 to 189 ft (34.2 to 57.8 m) (Spaulding and Della Rocca, 1965). One standardized hull would be used for both the side and stern-type trawlers with necessary adjustments in deckhouse and fishing equipment locations. Fig 1 and 2 illustrate the typical side and stern trawlers considered. The principal characteristics of these trawlers are:

Lwl	110 ft (33.6 m)
B	23 ft 6 in (7.19 m)
D	13 ft 6 in (4.13 m)

The results are preliminary since the hull designs were limited to the development of the midship sections, and the associated characteristics being compared were derived from Fishing Boats of the World: 2 for wood and steel hulls and from the minesweeper study for the FRP hulls.

COMPARISON OF HULL CONSTRUCTION MATERIALS

Large wooden hulls of frame and plank construction must be rigidly constructed to prevent working and leakage at fasteners, seams and joints, resulting in scantlings larger than is necessary to resist the applied loads.

Wooden construction reduces space available and water soakage can increase the weight approximately 5 per cent, thereby reducing cargo capacity. Metal water and fuel tanks further increase the hull weight. For the prevention of dry rot, space is required behind the ceiling and insulation for forced ventilation. Wooden hulls require considerable maintenance and are completely rebuilt throughout a 20-year period.

Steel hulls are heavier than wood or FRP hulls since they require a high corrosion allowance. Insulation in the fish hold must extend beyond the inside face of the frame flanges. Repairs are difficult in the fish hold as welding is not permitted on either side and the crew cannot carry out repairs. Maintenance is high because of the necessary periodic chipping and painting. Life expectancy of the original hull is 20 to 25 years.

FRP is superior to both wooden and steel hulls because of excellent durability qualities and low maintenance. Recent US Navy surveys on a submarine fairwater (N. Fried) and the US Coast Guard on a 40-ft (12.25 m) patrol craft (Cobb, Jr., 1962) has substantiated this. Time in dry dock is considerably reduced due to the one-piece hull and deck, eliminating all caulking and re-tightening or replacement of fasteners to maintain watertightness. Further, FRP hulls are not subject to accelerated weather and water exposure deterioration, dry rot, biological attack and swelling due to water soakage associated with wooden hulls. Impact damage is restricted locally, minimizing repairs. Repairs to fibreglass hulls are simple and easy, requiring less skilled labour and hence further reducing maintenance costs.

The life expectancy of FRP boats is not as yet determined due to its relatively recent development. Based on limited durability reports (N. Fried, Cobb, Jr., 1962) it appears an exceptionally long life expectancy can be predicted.

The above and the large savings in hull weight make

FRP a most suitable and preferable hull material for trawlers. Its versatility and properties far surpass other materials in providing the essential requirements for a successful design, ease of fabrication and excellent durability.

CRAFT APPLICATIONS

FRP is a proven hull material providing satisfactory service in commercial, naval and pleasure craft throughout the world. Since its first application to hull construction in 1946 in the US, over a million pleasure craft and over 2,000 US Naval craft have been built of it. Eighty per cent of all US Naval craft purchased last year are FRP construction. Its application to larger and larger hulls is rapidly progressing and the limiting size is still undetermined.

Many craft over 50 ft (15.3 m) have been constructed of FRP and provide satisfactory service. Included are the 77-ft (23.5 m) pilot boats built in Holland, 67-ft (20.5 m) power yachts built in England, 80-ft (24.5 m) passenger boat and 100-ton tanker built in Russia for river service, 52-ft (15.90 m) high speed gas turbine craft and 57-ft (17.4 m) mine-sweeper for the US Navy and a 65-ft (19.9 m) crew boat in the USA. Of greatest interest to the fishing industry is the recent construction of the 63-ft (19.3 m) stern and 74-ft (22.6 m) side FRP trawlers in South Africa (Ship and Boat Builder, 1965). This yard is contemplating the construction of a 96-ft (29.4 m) trawler and anticipates the construction of vessels up to 140-ft (42.8 m) in this material. It now has a considerable backlog of orders for large FRP fishing boats.

The results of a recent study for 112 to 189-ft (34.25 to 57.8 m) US minesweepers concluded that vessels in this size range can be satisfactorily designed and constructed with the present available materials, fabrication techniques and construction facilities.

Other applications of FRP in the marine field giving satisfactory service include funnels, deckhouses, hatch covers, reefer panelling and doors, submarine superstructures, shaft fairwaters tanks, antenna trunks, awnings, torpedo tubes, ventilation covers and buoys.

MATERIALS AND MOULDING METHODS

Since the innovation of the fabrication of reinforced plastic laminates with thermosetting resin and glass fibres, continuous research and development by the manufacturers, fabricators and government agencies have improved resin formulations, fibreglass reinforcements and moulding techniques to produce good sound structural laminates. Although there are many types and variation of basic materials and moulding techniques, this study is limited to those proven both economical and satisfactory for the construction of large hulls.

Reinforcements

New types of glass filaments with high strength and moduli properties are now available. However, due to economics and the medium strength-high rigidity requirements for most hulls, the filaments in the reinforcements for structural laminates are still of lime-alumina borosilicate glass with low alkali content, known as E-glass. This glass composition has high chemical stability and moisture resistance.

The fibreglass filaments are manufactured in parallel bundles or strands usually consisting of 204 fine filaments drawn together from a bushing without twisting. The diameter of the filaments can vary from 0.00020 to 0.00100 in (0.005 to 0.025 mm) with 0.00038 and 0.00053 in (0.0097 to 0.0135 mm) in 150's and 75's yarns* respectively, being mostly used for plastic reinforcement. These basic strands are used to make the different reinforcements such as continuous roving, chopped strand mat, cloth and woven roving.

For maximum laminate dry and wet strengths, the fibreglass filaments used in reinforcements for structural laminates are sized or finished with a coating to improve the chemical bond between the moulding resin and the glass filaments. Vinyl silane sizes or finishes such as Garan and A172 were most widely used with polyester resins for marine laminates until the recent development of a new improved type (Araton). This has improved laminate strength and other properties due to faster and more thorough wet-out of the individual filaments during moulding.

The economical reinforcements most commonly used in boat hull laminates are:

- Chopped Strand Mat of short randomly oriented fibres held together with a high solubility resin binder compatible with the moulding resins and varies in weight from ¾ to 2 oz/ft² (0.587 to 1.546 g/cm²). Mat is easy to wet out, builds up thickness rapidly but is not as strong as cloth or woven roving. It is commonly used in commercial boats for the hull and decks separately or in combination with cloth, woven roving or both. It also is widely used in both commercial and military boats in way of contacting surfaces of joints and secondary bonds including repairs, as a surface ply against the gel coat and in the bonded surfaces between the skins and cores of sandwich panels

- Woven Cloth is made of 150's or 75's (30,240 or 15,120 m/kg) yarn in a plain open weave construction with approximately equal strength in both directions weighing approximately 10 oz/yd² (70.47 g/cm²) and commonly known as "boat" cloth. Cloth is expensive and builds up thicknesses too slowly to be economical when used alone. It is used for surfacing interior areas of exposed mat or woven roving laminate to improve appearance. It is also used for repairing damaged laminates

- Woven Roving is made of flattened bundles of 140's or 75's (28,224 or 15,120 m/kg) yarn in a heavy plain weave construction with a slightly greater number of strands in the warp direction. It is available with variations in the number of strands per bundle and width-to-thickness ratio of the bundle. The 5 × 4 weave pattern weighing approximately 24 to 27 oz/yd² (169 to 190 g/cm²) is most widely used for hull and deck construction

* Refers to 15,000 and 7,500 yards of filament/pound (30,240 and 15,120 m/kg).

separately or in combination with mat. Although it is more difficult to wet out than mat, it is the most commonly used since it is strong and builds up laminate thickness rapidly and economically

The 140's and 150's (28,224 and 30,240 m/kg) yarn weights are generally specified for naval boat construction and the less expensive 75's (15,120 m/kg) yarn is used for pleasure and commercial craft. Differences in strength and other properties for these yarn weights are negligible for cloths and woven rovings of the same construction and weights.

Resins

The resins used in hull construction are limited to the thermosetting polyesters and epoxies. Although epoxy laminates have less shrinkage and slightly better physical and weathering characteristics, most hull laminates and other marine products are fabricated of polyester resins because of their versatility, ease of handling and low cost. Laminating resins must be compatible with the finish on the reinforcement to obtain the necessary bond for maximum strength and durability.

Practically all pleasure and commercial boat hull laminates are fabricated of general purpose rigid polyester resin pre-compounded by the manufacturer with a small amount up to 10 per cent maximum, of flexible polyester resin to improve the impact resistance.

Self-extinguishing or fire-retardant polyester resins, having approximately the same physical characteristics as the general purpose rigid resins, are available with slightly higher cost and weight. The small increase in cost of the completed boat is well worth the added safety.

To prevent draining (run off) of the resin when laminating the hull sides and transom structural laminates, approximately 2 to 3 per cent maximum by weight of silicon dioxide filler is blended into the polyester resin. This type of filled resin, (thixotropic) resembles a heavy oil in consistency. The fabricator can add the silicon dioxide filler to obtain the desired consistency or purchase the filled resin pre-compounded from the manufacturers.

To improve surface finish and increase durability, specially compounded gel or outer surface coats of filled resilient polyester resin are generally applied to the female mould surface prior to laying-up the structural laminate. Where colour is moulded into the outer surface, organic coloured pigments in conjunction with magnesium silicate, titanium dioxide, talc or other fillers and silicon dioxide for thixotropy are added to the resin in quantities up to approximately 20 per cent maximum with no effect on the laminate's physical properties. Some companies recommend that the resilient resin be left clear with only the silicon dioxide additive and the colour added in the subsequent layer of reinforcement for maximum protection.

To start the polymerization or the curing reaction of the polyester resin, a liquid or paste catalyst of 1 to 2 per cent by weight is mixed into the resin. The rate and conditions of the curing reaction depend on the type and amount used. The most common types used with polyester resins are cuemene hydroperoxide and methyl-ethyl-ketone peroxide.

For room temperature curing of polyester resins, without the application of heat, it is necessary to add an accelerator such as cobalt naphthanate or manganese naphthanate in combination with one of the above catalysts to start a rapid curing reaction.

When fabricating by the contact moulding method, it is necessary to provide adequate time for impregnation of the reinforcement with the resin between the completion of mixing and the hardening of the resin, and to prevent excessive exotherm during curing of thick laminates. To control this time or resin pot life, certain combinations and quantities of catalyst and accelerator are used. Normally, methyl-ethyl-ketone peroxide is combined with cobalt naphthanate to obtain a rapid cure and cuemene hydroperoxide is combined with manganese peroxide to permit a slower cure with lower exotherm. Catalyst and accelerator must never be mixed directly together, since this combination is explosive.

Core materials

Structural core materials for stiffeners and sandwich panels in hull construction are limited primarily to polyurethane foam and balsa wood. Polyurethane foam in various densities is more widely used for stiffeners and bulkhead sandwich cores and balsa wood is used for some lower hull, bulkhead and deck sandwich panels. To obtain greater bond strength the balsa wood cores are placed with the edge grain perpendicular to the face laminates. Polyvinyl chloride foam is now being used as an experimental core material in some small boats being fabricated in the US and recently in a large catamaran sailing vessel. Although service experience is very limited, it is performing satisfactorily.

Applicable military and commercial specifications as well as recommended procedures for using the basic materials described above are available from the manufacturers. Additional detailed information and descriptive discussions are presented (Gibbs and Cox, Inc. 1960 and 1962).

Moulding methods

Most FRP boat hulls are manufactured by the open mould or contact moulding method with room temperature cure. Partial or complete hulls, decks or bulkheads of sandwich construction are moulded by the vacuum bag method to obtain a good bond between the core and laminate faces. Matched die moulding is being used extensively by one US boat manufacturer for hulls up to 17 ft (5.20 m).

For larger hulls including the 110-ft (33.6 m) FRP trawler, the contact moulding method with room temperature cure is the only practical method now available. Future improvements and new innovations of moulding methods may change this.

There are a number of proven techniques used with the contact method to fabricate hulls of this size in single skin and frames or sandwich construction. For single skin and frames construction, a sectionalized wood or steel female mould is the the most practical since the entire hull, interior bulkheads and framing can be constructed while rigidly maintaining the hull in the same vertical position. For smaller hulls the female

mould may be rotated about a longitudinal axis to permit the hull laminate to be laid down on a relatively horizontal surface. Further, the female mould produces the finished exterior surface.

A male mould similar to the female mould may be used to simplify fabrication of the shell by beginning the laminate at the keel (now at the top) and continuing down the sides and transom. This technique has the disadvantages of being difficult to remove the finished hull shell from the mould, rotating it and maintaining its shape when in the inverted position to mould in the internal bulkheads and framing. Also the high cost of sanding or light sandblasting and painting the outer rough surface more than offset the advantage of moulding the shell downwards.

For a sandwich-type hull construction it is extremely important that an excellent bond be obtained between the core and face laminates. This can be accomplished, without pressure, by carefully moulding the laminate faces down on the core. However, when the core is placed on the inner or outer laminate face, pressure, preferably by vacuum bagging, is necessary to achieve a good bond.

Sandwich-type hulls have been moulded with both the female and male moulds. Similar advantages and disadvantages as for the single skin and frames hull exist with the additional cost and the problems associated with vacuum bagging large areas.

If sandwich construction is limited to a prototype or few hulls, an inexpensive wooden female or male form will be more economical. With this technique the foam core in board configuration is planked over the form and the inner or outer laminate face is applied directly on the core, depending on which type of form is used.

After the first applied laminate face is cured, the partially completed sandwich must be inverted to lay-up the laminate face on the opposite side of the core to complete the sandwich. The advantages of being able to mould-in bulkheads and framing and having a more rigid structure to rotate will occur when the female form is used.

Based on the above, the use of a female mould for fabricating either a single skin and frames or sandwich-type hull is considered to be the most practical since the entire hull and internal bulkheads and framing can be constructed without inverting a partially completed hull and having a finished outer surface.

Laminate construction

Structural fibreglass-polyester laminates may be reinforced with chopped strand mat, cloth or woven roving used individually or in combinations. Considering all other factors equal, the strength of a laminate is directly proportional to the type and amount of fibreglass reinforcement it contains. Other factors which affect strength are the resin, chemical finish on the fibreglass filaments, moulding method, fabrication techniques, quality control and experience. The most important factor in the fabrication of FRP hulls is that the manufacturer creates the structural material as well as the hull configuration. Through his experience and a quality

control system, the basic materials, the moulding method and technique, and the environmental conditions are selected to construct the laminate best suited to the application by the most economical production procedure.

The strength of FRP laminates can be varied to compare favourably with wood, steel, aluminium and other high strength materials. If necessary extremely high strength laminates of approximately 300,000 lb/in^2 (21,130 kg/cm^2) tensile strength, can be produced with special reinforcements and resins by the filament-winding process. However, to construct a large FRP trawler which will be economically and operationally competitive with wood and steel trawlers, the basic materials available now must be judiciously selected and moulded.

Therefore, the laminate selection was limited to E-type glass of mat, composite mat-woven roving or all woven roving reinforced polyester resin fabricated by the contact or hand lay-up moulding method with room temperature cure. These laminates correspond respectively to the "low", "medium" and "high" glass content laminate classification established by SNAME (Structural Plastics Task Group of the Hull Structures Committee, 1965). The physical properties given in table 1, obtained from the above classification, were used for the preliminary structural design of the FRP trawler.

The results of a comprehensive study of the effect of glass content on laminate unit weight and cost conducted for the large minesweeper hulls (Spaulding and Della Rocca, 1965) using the same basic materials and the conservative values given (Gibbs and Cox, Inc., 1962 and SNAME, 1965) indicated that, although the minimum laminate weight occurred at approximately 50 per cent glass content by weight, there is very little increase in weight between 35 and 60 per cent. This is due to the relationship between strength and density which varies with the glass content. Laminates in the low glass content range have lower strengths and densities requiring greater thicknesses and those in the high glass content range have higher strengths and densities requiring lesser thicknesses resulting in little difference in the unit weights, within the 35 to 60 per cent glass range. However, assuming the cost of the mat and woven roving reinforcement is the same, there is a significant increase in materials cost, approximately 19 per cent.

For this study, the selection of the laminate reinforcement need not depend on strength and unless a high modulus of elasticity is required for longitudinal bending deflection, the most economical within weight limitations is preferred.

The mat laminate with 25 to 30 per cent glass content may be the most economical but will have the greatest hull weight. A composite laminate of alternate plies of 2 oz/ft^2 (1.566 g/cm^2) mat and 24 to 27 oz/yd^2 (169 to 190 g/cm^2) woven roving reinforcement with an average glass content of about 35 per cent will increase the material cost approximately 5 per cent above the all mat laminate and will decrease the weight approximately 3 per cent. An all 24 to 27 oz/yd^2 (169 to 190 g/cm^2) woven roving laminate with an average glass content of about 50 per cent will increase the material cost approxi-

I 2

mately 16 per cent above the all mat laminate and will decrease the weight approximately 4 per cent.

Therefore, it appears that the all mat laminate should be selected. However, the composite mat-woven roving laminate at a 5 per cent increase in cost will reduce the weight 3 per cent, will increase the hull bending modulus approximately 30 per cent and will increase the impact resistance of the hull considerably. Further, the mat-woven roving laminate is much easier to fabricate, requires less labour due to the reduction in weight and gives excellent service with minimum maintenance and repairs. These advantages are well worth the extra cost of the basic materials which is negligible when considering the total costs.

Since both these laminates are equally attractive, the preliminary design for the FRP trawler was based on both.

It should be noted that the construction selected in the minesweeper study is the all woven roving reinforced polyester with 50 per cent glass content. This was based on both naval and navy boat contractors' experience with this standard construction, and its higher strength, moduli and impact resistance.

HULL CONSTRUCTION

Since there is much controversy as to the most appropriate material for the internal framing of large FRP hulls, various structural systems of FRP, aluminium and wood were investigated for both single skin and sandwich construction for the minesweepers (Spaulding and Della Rocca, 1965). The composite mat-woven roving polyester laminate with 35 per cent glass content was used as the fibreglass reinforced plastic material.

The following nine different framing systems were evaluated for ease of attaching framing to skin, continuity of the framing system, remaining useful volume, simplicity of framing, ease of maintenance and repairs, ease of attachment of fittings and equipment, hull thermal insulation qualities and midship sectional properties.

FRP single skin hull construction

(1) Closely spaced FRP longitudinals and widely spaced FRP transverses
(2) Closely spaced FRP transverses
(3) Closely spaced aluminium longitudinals and widely spaced aluminium transverses
(4) Closely spaced aluminium longitudinals and widely spaced FRP transverses
(5) Closely spaced FRP longitudinals and widely spaced aluminium transverses
(6) Closely spaced aluminium transverses
(7) Closely spaced wood transverses

FRP sandwich hull construction

(8) Widely spaced FRP longitudinals and FRP transverses
(9) Widely spaced aluminium longitudinals and aluminium transverses

The results of this investigation indicate that all the FRP framing systems 1, 2 with the single skin shell construction, and system 8 with the sandwich construction have many advantages over the others considered. Framing systems 1 and 2 are considered the most economical to construct, maintain and repair. Of these two, longitudinal framing system 1 is preferred since all of the longitudinals contribute to the longitudinal bending strength and stiffness of the hull and because this system is considered simpler and more economical to construct.

Framing system 8 with sandwich construction of the same laminate construction and polyurethane foam core provides excellent thermal insulation qualities, has a minimum number of frames with greater unobstructed interior areas and minimum maintenance requirements. However, it will be more difficult and costly to construct and repair. Further, sandwich construction with the thick faces and core required for these large size craft are very difficult to inspect for complete quality assurance and very difficult to locate minor damage and leakage prior to it becoming necessary to carry out extensive repairing.

Framing systems 3, 4, 5 and 9 of full or partial aluminium can provide lighter and stiffer hulls but are not recommended due to increased costs and construction time, and the difficulty to construct, maintain and repair. Further, the problem of attaching and maintaining the aluminium frames to the fibreglass laminate has not been completely resolved and previous limited experience has not been too encouraging. Also, the effect of the differences in moduli, rate of thermal expansion, etc. have not been resolved. Considerable research and development is necessary before these framing systems can be applied with complete assurance.

The closely spaced wood transverses framing system 7 is considered unacceptable and not recommended since many of the problems associated with similar aluminium systems will also apply but with far greater emphasis on maintenance. Undesirable increased hull weight above the all FRP system is another important disadvantage.

It was concluded that further investigation of the large FRP trawler would be limited to the single skin and longitudinally framed hull and sandwich constructions.

Economical studies were made of the effects of variations in framing spacing for the single skin and frames construction and the variations in the thicknesses of the faces and core for sandwich construction for a FRP minesweeper.

For the single skin and frames construction, it was concluded that in general closer spaced longitudinals and transverses will result in a lighter structure due to the associated reduction of shell thickness. However, this will increase the complexity of construction and associated fabrication costs. The effect of the variation in laminate glass content between 35 and 50 per cent was also considered and found to be inconsequential in regard to unit weight and cost of materials.

For the sandwich construction study, the laminate construction used is the same as used for the single skin and frames construction. The core material selected is polyurethane foam of 6 to 8 lb/ft³ (2.87 to 3.83 kg/m³)

density. Results indicated that the best compromise for weight and cost requires a core depth of approximately 3 to 4 in (76 to 101 mm) with approximately ⅜ in (9.5 mm) thick laminate faces. In addition to the 6 to 8 lb/ft³ (2.87 to 3.83 kg/m³) density foam, closely spaced internal vertical shear webs of similar laminate construction are considered necessary for over-all rigidity, shear strength and to resist large local impact loads.

When compared to single skin and frames, a hull of sandwich construction as considered for this study, is slightly heavier in weight and substantially more costly.

HULL STRUCTURAL DESIGNS

To ascertain hull structural configurations for evaluation of the proposed FRP trawler, preliminary structural designs were limited to the development of representative midship sections of a typical 110-ft (33.6 m) trawler of wood, steel, FRP single skin and frames and sandwich type constructions.

Specific design criteria such as water loading for the shell, decks, bulkheads, flats, etc. are not available since trawler scantlings are generally derived from previous proven designs. Where applicable, scantlings were developed in accordance with recommendations and rules established by authoritative organizations.

Wood trawler

The midship section developed for the wood trawler is illustrated in fig 3. The scantlings are based upon tables 20 and 21 of Traung (1960) and are representative of bent frame wood construction now used on the US west coast. Although specific construction details vary from country to country, the basic structural arrangement is considered typical of the majority of wooden fishing vessels of this size. No additional insulation is required in way of the fish hold because of the excellent insulation properties of the hull planking and inner ceiling.

Steel trawler

The midship section developed for the steel trawler is illustrated in fig 4. The steel scantlings given in fig 4 are derived from table 23 of Traung (1960) and are intended to satisfy the minimum requirements of both Lloyds Register of Shipping and American Bureau of Shipping Rules, 1965. Transverse framing is used throughout, with non-tight floors on each frame. All framing members and plating surfaces in the fish hold must be insulated and sheathed.

FRP trawler single skin and frames

Fig 5 illustrates the proposed fibreglass construction for a trawler of single skin and longitudinal frames
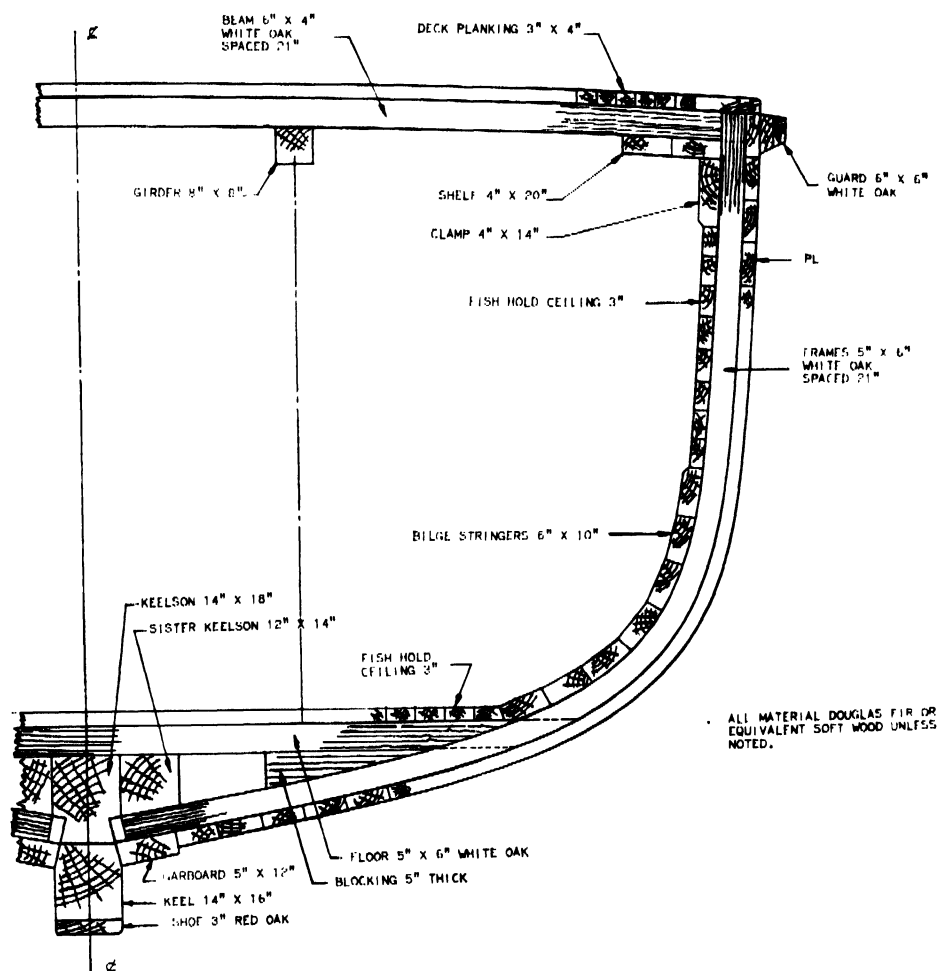
Fig 3. Midship section 110-ft wooden trawler

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BEAM 4"x3"x1/4" Γ SPACED 23"

(12.75 LBS/FT2)

GIRDER - 8"x4"x3/8" Γ

FACE OF INSULATION AND SHEATHING

1/4" PL BRACKET

GUARD 6" X 6" WHITE OAK

SIDE SHELL 5/16" (12.75 LBS/FT2)

FRAME 4"x3"x5/16" Γ SPACED 23"

5/16" FLANGED PL BRACKET

CENTER KEEL = 5/16" (12.75 LBS/FT2)

TANK TOP 1/4" (10.2 LBS/FT2)

1. ALL MATERIAL MEDIUM STEEL UNLESS NOTED.

BOTTOM SHELL 5/16" (12.75 LBS/FT2)

FLOORS & GIRDER 5/16" (12.75 LBS/FT2)

BAR KEEL 1-1/2"x6"
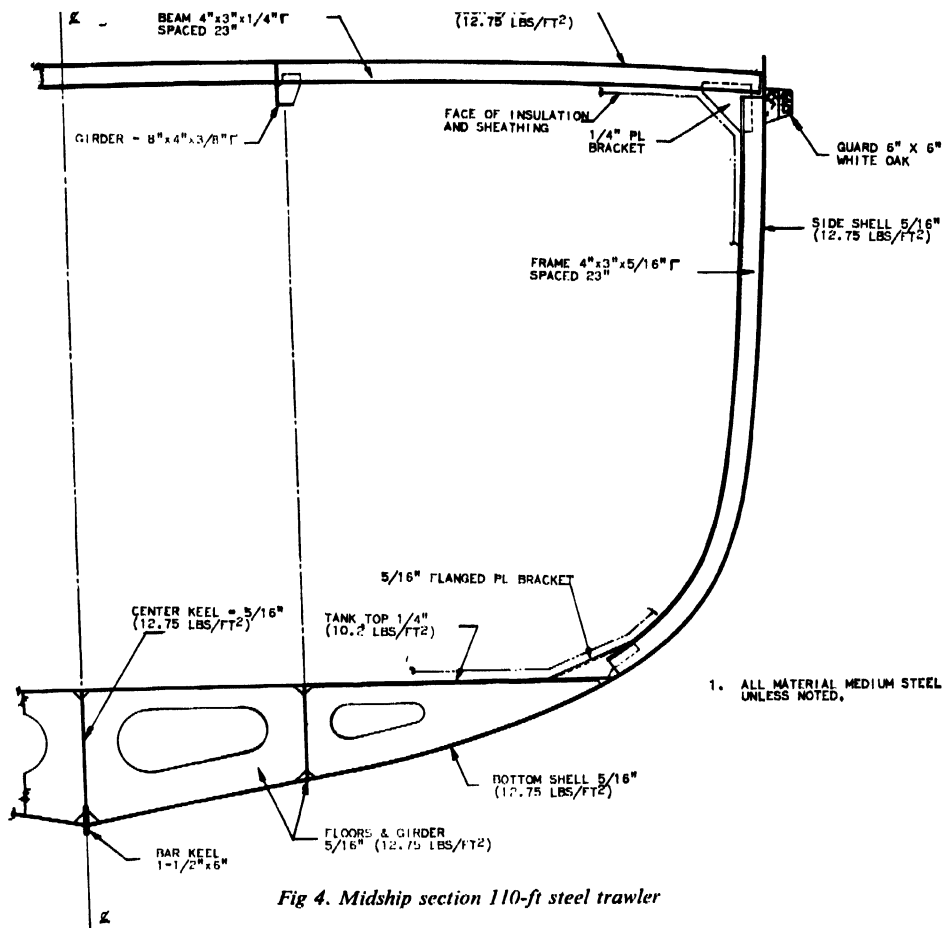
Fig 4. Midship section 110-ft steel trawler

DECK LONGITUDINALS 4" X 3" X .17" ∏ SPACED 18" O.C.

DECK .62"   STRINGER .75"

GUARD 6" X 6" WHITE OAK

8"x3"x.21" ∏ SPACED 6'-0" O.C.

FACE OF INSULATION & SHEATHING

SHEER .75"

SIDE .62"

FRAME WEBS .42" FLANGE 3" X .42" SPACED 6'-0" O.C.

LONGITUDINALS 5"x3"x.21" ∏ SPACED 18" O.C.

CENTER KEEL WEBS .70" FLANGE 5-1/2" X .70"

LONGITUDINALS 6"x3"x.21" ∏

TANK TOP PANELS 2" THICK CORE .21" TOP & BOTTOM FACES

SIDE GIRDER WEBS .50" FLANGE 5" X .50"

KEEL .94"   BOTTOM .62"

NOTES

1. LAMINATES CONSTRUCTED OF ALTERNATE PLIES OF 2 OZ/SQ. FT, MAT AND 24 - 27 OZ/SQ.YD. WOVEN ROVING.

2. ALL CORE MATERIAL POLYURETHANE FOAM OR EQUIVALENT: 2 LBS/CU FT DENSITY FOR LONGI- TUDINALS 6-8 LBS/CU FT DENSITY FOR TRANSVERSE FRAMES, LONGITUD- INAL GIRDERS, CENTER KEEL AND TANK TOP PANELS.

Fig 5. Midship section 110-ft fibreglass trawler. Single skin and frames

TABLE 1. **Physical properties of typical marine laminates***

Average values for guidance only

Physical property†	Chopped strand mat laminate Low glass content	Composite laminate‡ Medium glass content	Woven roving laminate High glass content
Per cent glass by weight	25–30	30–40	40–55
Specific gravity	1.40–1.50	1.50–1.65	1.65 1.80
Flexural strength lb/in² × 10³ kg/cm² × 10⁶	18–25 1.27–1.76	25–30 1.76–2.11	30–35 2.11–2.47
Flexural modulus lb/in² × 10⁶ kg/cm² × 10⁶	0.8–1.2 0.06–0.08	1.1–1.5 0.07–0.11	1.5–2.2 0.11–0.16
Tensile strength lb/in² × 10³ kg/cm² × 10⁶	11–15 0.77–1.06	18–25 1.27–1.76	28–32 1.97 2.25
Tensile modulus lb/in² × 10⁶ kg/cm² × 10⁶	0.9–1.2 0.06–0.08	1.0–1.4 0.07–0.10	1.5–2.0 0.11–0.14
Compressive strength lb/in² × 10³ kg/cm² × 10³	17 21 1.20–1.48	17 21 1.20 1.48	17–22 1.20–1.55
Compressive modulus lb/in² × 10⁶ kg/cm² × 10⁶	0.9–1.3 0.06–0 09	1.0 1.6 0.07–0.11	1.7–2.4 0.12–0.17
Shear strength perpendicular lb/in² × 10³ kg/cm² × 10³	10–13 0.70–0.91	11–14 0.77–0.99	13–15 0.92–1.06
Shear strength parallel lb/in² × 10³ kg/cm² × 10³	10–12 0.70–0.85	9–12 0.63–0.85	8–11 0.56–0.77
Shear modulus parallel lb/in² × 10⁶ kg/cm² × 10⁶	0.4 0.02	0.45 0.03	0.5 0.035

* Properties from short-term loading tests—wet condition. Composite and woven roving values for warp direction.
† Tested in accordance with ASTM Standard Specification or equivalent Federal Standard LP-406b.
‡ Based on typical alternate plies of 2 oz/ft² (1.566 g/cm²) mat and 24 oz/yd² (169 g/cm²) woven roving.

supported on widely spaced transverse webs. The scantlings indicated are representative of a composite reinforced laminate laid up with alternating plies of 2 oz/ft² (1.57 g/cm²) mat and 24 to 27 oz/yd² (169 to 190 g/m²) woven roving. These scantlings are based on the average physical and mechanical properties for a composite laminate of 35 per cent glass content given in table 1.

The scantlings were derived by calculating steel scantlings to the American Bureau of Shipping Rules and converting them to equivalent FRP scantlings. Plate panels were converted on the basis of providing equal stiffness, requiring steel thicknesses to be increased by the cube root of the flexural moduli. Beams and frames scantlings were converted by the direct ratio of tensile strengths.

The scantlings so derived were compared with the requirements of the new Lloyds SR 65/39 Provisional Rules being prepared for the application of FRP to fishing craft and were found to be in remarkably close agreement.

In fact, the only differences were in the main deck longitudinals and the web frame at the bilge, which are 1 in (25.4 mm) deeper than required by Lloyds. A review of the first draft of these Lloyds Rules, which are subject to revision prior to publication, indicate that they are exceptionally well compiled and in considerable detail. The scantlings given in the Rules are for an all-mat reinforced polyester laminate moulded by the contact or hand lay-up method. However, the designer is permitted to modify the scantlings where fibreglass reinforcements other than chopped strand mat are used.

In order to evaluate the effects of glass content on the weight, strength and cost of the FRP trawlers, similar calculations were made for an all-mat reinforced laminate with a glass content of approximately 25 per cent. Although this results in skin and frame laminates about 10 and 20 per cent thicker than those given in fig 5 respectively, the laminate specific gravity is reduced to about 1.42 from 1.50.

Though a nominal thickness of foam insulation would
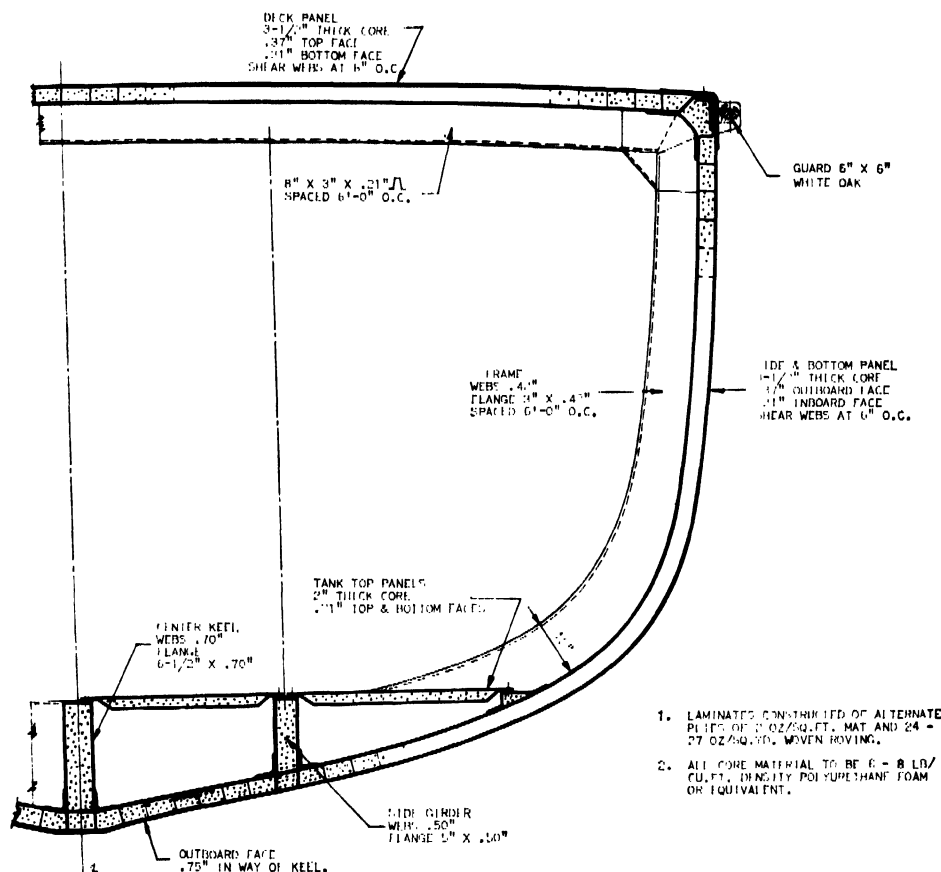
Fig 6. Midship section 110-ft fibreglass trawler. Sandwich construction

be required in the fish hold adjacent to the outer skin, the framing members will not require additional insulation since their polyurethane foam cores will be more than adequate.

FRP trawler sandwich

Fig 6 presents the alternate FRP trawler utilizing sandwich construction for the shell and deck. The design of this hull structure is based upon providing equivalent panel strength and stiffness as provided by the single skin and frames. Again, both the composite laminate of alternate plies of mat and woven roving and an all-mat laminate were considered. The all-mat panels require face thicknesses about 20 per cent greater than those in fig 6. The transverse frames are similar to those used for the single skin and frames design. Additional insulation is not required in way of the fish holds since the polyurethane core has more than adequate thermal protection.

The core material selected for the sandwich construction is a 6 to 8 lb/ft³ (2.87 to 3.83 kg/m³) density polyurethane foam or equivalent, which is required to resist local bearing loads on the face of the laminate, and to transfer the shear loads between the skin and core as well as between the individual panel and frame. In addition, it may be necessary to incorporate laminate shear webs, as shown in fig 6.

COMPARISON OF TRAWLER CHARACTERISTICS

To evaluate and compare the characteristics of the proposed FRP trawler with the equivalent wood and steel vessels, estimates of capacities, weights, costs, etc. were prepared based on the midship sections presented in fig 3, 4, 5 and 6. Additional information regarding fish gear, machinery, etc. was obtained from Traung (1960).

Table 2 compares the weight, area, stiffness and strength characteristics of the four midship sections illustrated. The weights of wooden members are based upon a specific gravity of 0.45 and 0.70 for soft and hard wood respectively, and the fibreglass laminate specific gravities are assumed to be 1.42 and 1.50 for the all-mat and composite mat-woven roving laminates respectively. The use of FRP in lieu of wood significantly reduces the weight of the primary hull structure by 43 to 53 per cent. The single skin and frames is about 10 per cent lighter than the sandwich construction and the use of the composite mat-woven roving laminate will save about 5 per cent in weight over the all-mat laminate construction. The steel and wood midship sections are approximately equal in weight.

The use of FRP construction will increase the net cross sectional area in way of the fish hold approximately 16 per cent over the wood construction, while the cor-

TABLE 2. 110-ft (35.6 m) trawler comparison of midship sections characteristics

		Wood	Steel	FRP Single skin & frames		FRP Sandwich	
				Mat	Mat-roving	Mat	Mat-roving
Weight/ft amidships*	lb	1,500	1,510	760	700	850	770
	(kg)	(680)	(685)	(345)	(318)	(386)	(349)
Weight/ft relative to wood		—	1.00	.51	.47	.57	.52
Hold area inside sheathing	ft²	200	220	230	230	234	234
	(m²)	(18.6)	(20.4)	(20.4)	(21.4)	(21.7)	(21.7)
Hold area relative to wood		---	1.10	1.15	1.15	1.17	1.17
Moment of inertia, I †	$in^4 \times 10^3$	16,660	1,242	4,173	3,641	4,285	3,590
	$(cm^4 \times 10^3)$	(686,730)	(51,230)	(171,990)	(150,140)	(176,680)	(148,000)
Modulus of elasticity, E	$lb/in^2 \times 10^6$	.85‡	30	.95	1.2	.95	1.2
	$(kg/cm^2 \times 10^6)$	(0.060)	(2.1)	(.067)	(.085)	(.067)	(.085)
EI	$lb/in^2 \times 10^{12}$	14.1	37.3	4.0	4.3	4.0	4.3
	$(kg/cm^2 \times 10^{12})$	(41.3)	(109)	(11.7)	(12.6)	(11.7)	(12.6)
Stiffness relative to wood		—	2.6	.29	.31	.29	.31
Section modulus	$in^3 \times 10^3$	190.4	13.6	46.2	40.4	47.9	40.2
	$(cm^3 \times 10^3)$	(3,121)	(242)	(757)	(663)	(785)	(659)
Stress for 2.7×10^6 ft lb Mom.,	lb/in^2	170	2,190	700	800	680	810
	(kg/cm^2)	(11.9)	(154)	(49.3)	(563)	(47.9)	(57.1)
Ultimate strength	$lb.in^2$	6,500§	60,000	14,000‖	17,000¶	14,000‖	17,000¶
	$(kg\ cm^2)$	(458)	(4,227)	(986)	(1,197)	(986)	(1,197)
Ultimate factor of safety		38	27	20	21	21	21

* Includes tank top, but neglects insulation or sheathing
† Neglects tank top, wood ceilings
‡ Actual modulus for wood, 1.7×10^6 lb/in², reduced 50 per cent for slippage of joints
§ Ultimate compressive strength of Douglas fir
‖ Ultimate tensile strength of chopped-strand mat (SNAME, 1965)
¶ Ultimate compressive strength of composite mat-roving laminate (SNAME, 1965)

responding increase for steel is about 6 per cent less, due to the necessity of insulating the tank top and framing members.

Due to the inherent flexibility of FRP, the relative hull deflection for both single skin and frames and sandwich construction will be about 3½ times that of the equivalent wood trawler, assuming twice the calculated deflection of the wood trawler to account for joint slippage, and 9 times that of a steel trawler, for equal bending moments. This flexibility will not seriously affect the performance of a trawler with machinery aft. However, with the machinery well forward, stresses due to excessive hull deflection may be induced in the propeller shaft and bearings which will have to be considered when designing. If necessary, the hull deflection can be reduced by increasing the all-mat or composite mat-woven roving laminate thicknesses or providing a laminate with a higher elastic modulus such as an all-woven roving laminate.

The stresses in the fibreglass laminate hull, though greater than those of the wood hull, are not considered significant. The fact that the safety factor for the wood hull is nearly twice that of the fibreglass hull is indicative of the relative inefficiency of wooden construction, where shell scantlings far in excess of those dictated by normal loadings are necessary to provide sufficient overall hull rigidity and tightness. The tank top has not been included in the calculations of hull stiffness or strength, since it is often discontinuous in way of the machinery spaces.

Light ship weight

Table 3 presents estimated light ship weights for the structural configurations considered. The hull structure for the wood trawler was estimated by proportioning the weight/foot amidships from table 2 to that of a similar vessel with a known hull structural weight. The steel hull structure is obtained from Fishing Boats of the World: 2 and is about 10 tons heavier than the wooden hull. Since the weight of the shell and deck of the steel and wood trawlers will be nearly identical, this 10-ton increase reflects the greater weight of the steel bulkheads, flats, deckhouses, etc.

The hull structure weight of the single skin and frames fibreglass trawlers were based both on the savings in weight/foot amidships (table 2) and the results of a similar study of a 110-ft (33.6 m) fibreglass Inshore Minesweeper (SNAME, 1965). Proportioning results of this study indicate that although the use of FRP in lieu of wood reduces the weight of the shell and decks 49 to 53 per cent amidships for the all-mat and composite mat-woven roving laminates respectively, the reduction in overall hull structural weight will be only about 38 to 41 per cent. This reflects the reduced weight savings in such items as bulkheads, flats and deckhouses.

For the sandwich construction hull, the 43 and 48 per cent reductions in weight per foot amidships relative to wood construction, table 2, are equivalent to a 34 and 38 per cent reduction in overall hull structural weight, table 3. The use of sandwich construction is seen to add about 5 tons to the hull structural weight.

These hull weights are combined in table 3 with the outfit, machinery and fish gear weights obtained from Traung (1960) and a 10 per cent margin is added to obtain the light ship weights. An additional margin of 5 per cent is included for the wood hull weight for soakage.

TABLE 3. 110-ft (33.6 m) preliminary light ship weight estimates

| | Wood | Steel | FRP Single skin & frames | | FRP Sandwich | |
			Mat	Mat-roving	Mat	Mat-roving
Hull structure—tons	120	130*	75	71	80	75
Outfit and hull Eng.—tons†	50	50	50	50	50	50
Fish gear—tons‡	7	7	7	7	7	7
Main and aux. machy—tons§	25	25	25	25	25	25
Sub total—tons	202	212	157	153	162	157
Margin—design (10 per cent)—tons	20	21	16	15	16	16
Margin—soakage (5 per cent)—tons	10					
LIGHT SHIP—tons	232	233	173	168	178	173
Hull structure relative to wood		1.05	.62	.59	.66	.62
Light ship relative to wood		1.01	.75	.72	.77	.75

* From fig 283, Traung (1960)
† From fig 284, Traung (1960)
‡ Estimate 3 per cent of light ship, Traung, (1960)
§ From fig 285 and 286, Traung (1960)

The significant weight savings resulting from the use of FRP construction can be used to increase fish-hold capacity, endurance and reduce horsepower, individually or in combination. The use of integrally-moulded fuel and water tanks in a FRP hull, instead of the independent metal tanks now used in most wooden trawlers, will permit significant increases in available tank capacity by eliminating voids adjacent to the shell and decks. The reduction in the light ship weight will cause an increase in light ship vertical centre of gravity of about 5 per cent. This is due to the reduction in hull structure weight having a centre of gravity below the overall light ship centre. Consequently stability requirements must be considered early in the preliminary design.

Light ship cost

Preliminary light ship cost estimates presented in table 4 are based upon US construction at current average wage and productivity scales. In view of the wide regional variation the costs given are approximate though the trends indicated are quite significant.

To establish a valid basis for cost comparison, it is necessary to assume that the techniques in constructing large fibreglass hulls is sufficiently advanced that all problems associated with logistics, manpower utilization, lay-up techniques, etc. have been satisfactorily resolved, and the required facilities are readily available. Present experience is very limited, and so it can be assumed that the costs derived in this study are somewhat optimistic but should stabilize to the indicated ranges as further experience is gained.

Material costs for wood and steel are derived from Traung (1960). FRP material costs are based upon the following recent prices assuming bulk purchasing:

Item	Costs UK shilling/lb	$/lb
General purpose resin (non-fire retardant)	1.75	0.245
2 oz mat (27.6 g)	3.44	0.48
24–27 oz woven roving (169–190 g)	3.52	0.49
Polyurethane foam (prefoamed boards)	7.17	1.00

The resultant single skin laminate and sandwich unit costs were increased to account for other materials (metal, wood, castings, doors, etc.). All material weights were increased 15 per cent to account for wastage, and the 10 per cent design margin in table 3 was included.

Productivity rates are very difficult to evaluate since they vary widely. For the production of a single hull, the values shown in table 4 are considered to represent average rates. The productivity value for sandwich construction of 300 to 310 man-hours/ton is tentative and reflects the slower lay-up rate of foam core material. Wage rates for fibreglass laminators vary from £0.54 to £0.895/hr ($1.50 to $2.50/hr) with £0.627 ($1.75) representing a fair average.

The costs of outfit, hull engineering, machinery and fish gear are derived from Traung (1960) and are considered constant for all structural configurations. Mould costs are based upon the FRP minesweeper study and are representative of an open sectionalized female mould for the single skin and frames hull and a less expensive open framework for the sandwich hull. Deck moulds and special scaffolding are included.

The effects on labour costs for the duplication of hulls were determined by applying a reduction factor, developed from limited US Navy and industry information, to all direct labour costs in accordance with the following list:

Hull number	Relative labour cost
1	1.00
2	.943
5	.849
25	.670

These values result in a laminating rate of 15 lb per man-hour (68 kg/hr) for the twenty-fifth hull. This is considered representative for production of FRP hulls by the contact or hand lay-up moulding method.

The costs given in table 4 are plotted in fig 7 and indicate that FRP construction will be more expensive than either wood or steel, particularly for a single hull. However, for 5 identical hulls or more, the cost of a single skin and frames fibreglass trawler will be approximately 5 per cent greater than the wood or steel. Sandwich

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TABLE 4. 110-ft (33.6 m) trawler preliminary light ship cost estimates

	Wood		Steel		FRP							
					Single skin & frames				Sandwich			
					Mat		Mat-roving		Mat		Mat-roving	
	£	$	£	$	£	$	£	$	£	$	£	$
Material cost/ton	89.6	250*	71.6	200*	293.9	820	314.3	880	419.3	1,170	444.4	1,240
Hull weight with margin—tons	132		143		83		78		88		83	
Invoiced mat'l (×1.15)†—tons	152		165		95		90		101		95	
Material cost	13,725	38,300	11,790	32,900	27,880	77,800	28,350	79,100	42,430	118,400	42,180	117,700
Man-hours/ton	160		160*		225		225		300		310	
Cost/Man-hour	1.0	2.75	1.0	2.75	0.63	1.75	0.63	1.75	0.63	1.75	0.63	1.75
Cost/Ton labour	157.7	440	157.7	440	139.8	390	139.8	390	190	530	190	540
Direct labour	20,970	58,500	22,500	62,800	11,650	33,500	10,390	30,800	16,560	46,200	16,060	44,800
Overhead—80 per cent labour	16,770	46,800	17,990	50,200	9,320	26,000	8,815	24,600	13,220	36,900	12,830	35,800
Material, labour and overhead	51,465	143,600	52,280	145,900	48,850	136,300	48,200	134,500	72,220	201,500	71,070	198,300
Profit (10 per cent)	5,160	14,400	5,230	14,600	4,875	13,600	4,840	13,500	7,240	20,200	7,095	19,800
Sub-total	56,625	158,000	57,510	160,500	53,725	149,900	58,040	148,000	79,460	221,700	78,170	218,100
Outfit, machinery, etc.*	57,950	161,700	57,950	161,700	57,950	161,700	57,950	161,700	57,950	161,700	57,950	161,700
Mould cost‡	—		—		30,460	85,000	30,460	85,000	2,500	60,000	21,500	60,000
Total—1 boat	114,575	319,700	115,460	322,200	142,140	396,600	141,460	394,700	158,910	443,400	157,620	439,800
Total—each of 5 boats	104,115	290,500	103,690	289,300	109,710	306,100	107,130	304,500	132,140	368,700	131,000	365,500
Total—each of 25 boats	90,850	253,500	90,750	253,200	95,260	265,800	94,940	264,900	117,410	327,600	116,480	325,000
Total cost relative to wood												
1 boat	—		1.01		1.24		1.23		1.39		1.38	
5 boats	—		1.00		1.06		1.05		1.27		1.26	
25 boats	—		1.00		1.05		1.04		1.29		1.28	

† Provides 15 per cent for wastage
* From Costs of Construction (Traung, 1960)
‡ Derived from FRP minesweeper study (Spaulding and Della Rocca, 1965)
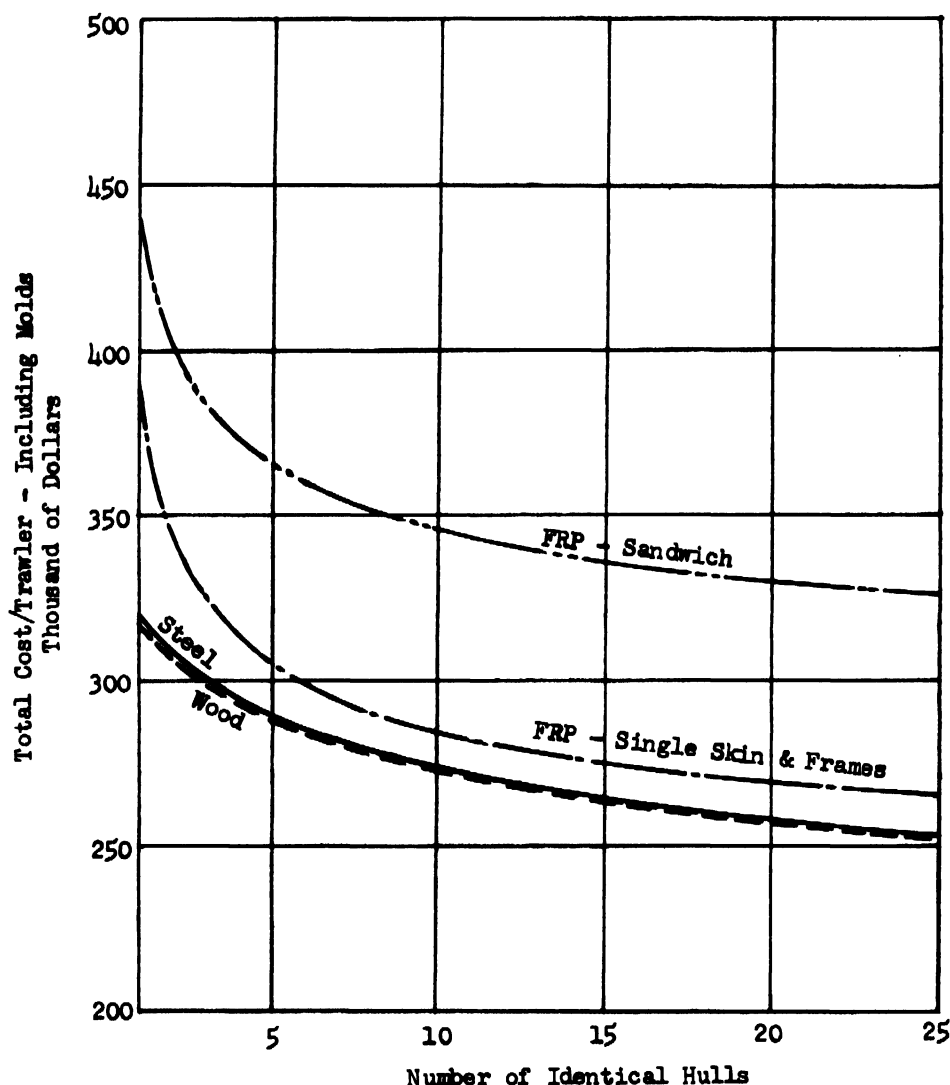
Fig 7. 110-ft trawler — Preliminary Cost estimates

construction is considerably more expensive, approximately 26 to 28 per cent.

The cost differential between the all-mat and the stronger, lighter composite mat-woven roving laminate construction is negligible. Within the accuracy of these estimates, it can be concluded that the cost of a FRP hull is relatively unaffected by glass content. Similar studies for the all-woven roving laminate used in the minesweeper study confirms this conclusion for up to 50 per cent glass content.

It is instructive to study the overall cost per pound for the hull structure. These values are shown below for a procurement level of 5 hulls:

Hull material	Cost £/lb	$/lb
Wood	0.172	0.48
Steel	0.150	0.44
FRP single skin all-mat laminate . .	0.305	0.85
FRP single skin mat-roving laminate .	0.32	0.89
FRP sandwich panel all-mat laminate .	0.40	1.12
FRP sandwich panel mat-roving laminate	0.42	1.17

This indicates that the favourable cost structure of the single skin and frames construction is directly attributable to the significant weight reduction achieved. This favourable comparison is strictly limited to a large, relatively heavy planked wood being replaced by a lighter fibreglass hull. For smaller boats, or those incorporating a laminated plywood hull, the use of FRP construction will result in a higher first cost relative to wood or steel construction.

CONCLUSIONS

FRP as a hull material for large trawlers averaging 110 ft in length is considered feasible and practicable. The reality of their construction is virtually assured in view of the South African shipyards' experience of the 63-ft and 74-ft trawlers and their anticipation of building similar vessels to 140 ft of the same material.

Considerable advantages are available over wood and steel trawlers in weight and space saving, reduced maintenance, ease of repair and excellent durability.

TABLE 5. 110-ft trawler, summary of characteristics

Characteristic	Wood	Steel	FRP*
Capacity			
Fish hold volume—ft³	6,000 (165.6 m³)	6,600 (182 m³)	6,900 (190 m³)
Tons iced fish	110	120	125
Light ship weight—tons	232	233	168–173
Maintenance	Constant	Constant	Light
Vulnerability	{ Fire, Rot, Marine Borers	Rust	Fire†
Repairs	Difficult	Moderate	Simple
Estimated cost			
1 trawler	£114,800 ($319,700)	£115,500 ($322,200)	£141,500 to 141,900 ($394,700 to 396,600)
Each of 5	£104,100 ($290,500)	£103,700 ($289,300)	£109,100 to 109,700 ($304,500 to 306,100)
Each of 25	£90,850 ($253,500)	£90,750 ($253,200)	£94,950 to 95,250 ($264,900 to 265,800)

* Fibreglass reinforced plastic single skin and frames construction
† Greater fire resistance to wood by the use of fire-retardant self-extinguishing polyester resin.

Construction costs for procurement of five or more hulls are competitive.

Results of a recent industry survey (Spaulding and Della Rocca, 1965) in the USA indicates that there are several interested organizations with adequate facilities and plastic fabrication experience in large boat and other structures, and similar interests and capabilities exist throughout the world.

At present, the single skin and frames construction with closely spaced longitudinals and widely spaced transverses, fabricated in a sectionalized female mould by the contact or hand lay-up moulding method with room temperature cure polyester resin is the most attractive.

Other important advantages of FRP trawler construction are greater cargo capacity, less vulnerable to rot, borers and corrosion and greater resistance than wood to fire damage by the use of fire-retardant or self-extinguishing resins at a slightly higher cost.

A summary of the important trawler characteristics for wood, steel and FRP single skin and frames construction is presented in table 5. Except for slightly higher cost, the FRP trawler is superior to both the wood and steel trawlers in regard to capacity, weight, maintenance, vulnerability and repair.

Fig 8 presents a proposed FRP 110-ft stern trawler which can be developed, and constructed with available basic materials in a number of shipyards with adequate facilities and experience.

The ease of forming complex shapes with this material results in a ship form with smooth flowing lines and surfaces, and should be a safe, sound ship providing many years of satisfactory service with minimum maintenance.

The opinions expressed are those of the author and should not be construed as reflecting the official views of Gibbs & Cox, Inc.
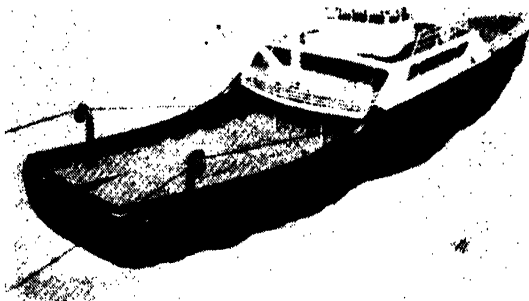

Fig 8. 110-ft fibreglass trawler

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Comparison between Plastic and Conventional Boat-building Materials

by D. Verweij

Comparaison entre le plastique renforcé et les matériaux classiques employés en construction navale

Le plastique examiné est un polyester armé de fibres de verre. Les caractéristiques de ce produit peuvent varier selon le type de renforcement adopté, mais la communication n'étudie à fond que le polyester renforcé de "mats" (feutres de verre) et de tissus de "roving".

L'auteur expose une méthode permettant de comparer les caractéristiques mécaniques, et décrit un critère judicieux de comparaison fondé sur la résistance à la traction et à la flexion et sur la rigidité.

Il rapproche ensuite le polyester armé de verre textile des matériaux traditionnellement utilisés en construction navale, pour conclure que ce stratifié soutient bien la comparaison avec les métaux et, sauf sous le rapport de la rigidité, avec divers bois.

Après avoir exposé les avantages de la construction en "sandwich" avec du polyester renforcé de fibres de verre, l'auteur étudie les propriétés mécaniques de ce matériau, qui sont jugées satisfaisantes.

Enfin, il examine le polyester armé sous l'angle de la résistance à a corrosion, de l'entretien, et de la facilité de réparation.

Comparación entre los materiales plásticos y los de tipo corriente en la construcción de embarcaciones

El material plástico utilizado es la fibra de vidrio reforzada de poliéster (FRP) y puede variarse según el tipo de refuerzo aplicado, pero solamente se examina a fondo la FRP reforzada con esterilla y mecha trenzada.

Se investiga el método de comparación de las características mecánicas y se explica el criterio correcto de comparación basado en la resistencia a la tracción, la resistencia al corte y la rigidez.

Seguidamente se comparan la FRP y los materiales corrientes para la construcción de barcos y se descubre que la FRP se puede enfrentar con ventaja con los materiales metálicos y, salvo en lo referente a la rigidez, con varias maderas.

Se expone la necesidad de la construcción con FRP en forma de capas intercaladas, estudiándose las propiedades mecánicas de este tipo de material y comprobándose que resultan favorables.

Por último se examina la durabilidad, por lo que respecta a la resistencia a la corrosión y al mantenimiento, y también la facilidad de reparación de las construcciones con FRP.

PLASTIC for the construction of fishing craft is usually fibreglass reinforced polyester (FRP) and manufactured from two components, plastic polyester resin and a reinforcement of glass fibre. Although other plastics (i.e. Epoxide resin) are worth attention, the current high price of Epoxide makes its use prohibitive for fishing vessels and most other craft.

Very soon after the initial attempt of the various shipyards and manufacturers to use FRP in 1954, it was realized that more research was required in two fields.

Basic material and its use

In the Netherlands this was largely carried out by the Plastics Research Institute of Delft which played a major part in research and the training of personnel.

Construction in FRP

The economical use of FRP for boat construction can only be achieved if the designer fully appreciates that the vessel is to be an FRP construction. The various strength characteristics that can be achieved must be utilized and the various materials forthcoming. Hence close co-operation between the Research Institute and the Technical University of Delft Shipbuilding Department was set up.

Governmental co-operation

At about the same time, when the initial results looked promising, the Netherlands Government, and especially the Navy, entered into the operation and a great number of naval vessels were built. This, in turn, enabled a great quantity of data and experience to be acquired. Pilot vessels of 78 ft (23.40 m) were built and proved successful.

International co-operation

Gradually international co-operation has been built up with firms in Japan, Hong Kong and Israel. This has avoided duplication of research and development already carried out elsewhere. In principle, also, this has led to agreement, based on experience gained in the Netherlands, to develop and build fishing vessels constructed in this medium. In 1962, an International Board to consider "Synthetic Materials for Shipbuilding" was set up, and this Board reported to the International Ship Structural Congress (ISSC) in July 1964.

TYPES OF FRP

There are various compositions for glass fibre reinforcement, such as mat, woven roving, glass fabrics, surfacing tissue and unidirectional materials (fig 1). Only mat, woven roving and unidirectional materials will be considered here.

The mechanical qualities of FRP are determined by the type as well as the amount of glass reinforcement used. Some possibilities are given in table 1. By using different combinations of amount and type of reinforce-

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Glass reinforcement	Glass %	Tensile strength		Crossbreaking strength		E modulus	
		lb/in²	kg/cm²	lb/in²	kg/cm²	lb/in²	kg/cm²
Mat	28	12,150	(850)	19,300	(1,350)	1,070,000	(75,000)
Woven roving . . :	45	31,000	(2,170)	31,500	(2,200)	1,500,000	(105,000)
Undirectional . . .	50	53,000	(3,710)	64,000	(4,480)	3,000,000	(210,000)

ment, the range of mechanical qualities can be large. The skilled designer can do so to his advantage, using different combinations of different glass reinforcement in various parts of one particular boat.
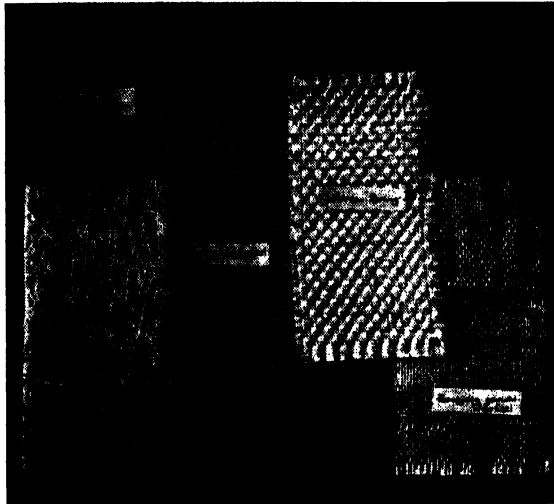
Fig 1. Types of glass reinforcements

PRINCIPLE OF COMPARISON OF MECHANICAL CHARACTERISTICS

The incorrect method

A comparison of strength to specific gravity is shown in table 2. The following statement was added to this table: "From this table it appears that FRP has the highest

TABLE 2: **Comparison of strength to specific gravity**

Material	Specific strength
Wood (Dry)	$\frac{7.5}{0.75} = 10$ lb/in² × 10³
FRP	$\frac{29}{1.5} = 19.4$
Aluminium	$\frac{32.5}{2.5} = 13$
Steel	$\frac{65}{7.5} = 8.7$

$$\text{Specific strength} = \frac{\text{Strength}}{\text{Specific gravity}}$$

specific strength". This statement is rather bold and it is an oversimplification to such an extent that it becomes partially incorrect. To get a correct insight into the qualities of various materials, we must clearly separate tensile strength, bending strength and rigidity.
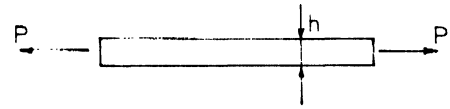
Fig 2. Beam submitted to tensile force P
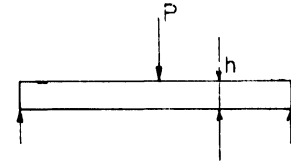
Fig 3. Beam submitted to bending force P
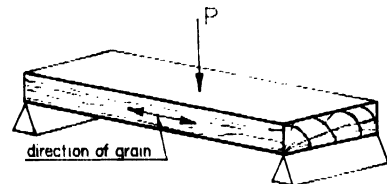
Fig 4. Wooden plate supported at right angle to grain
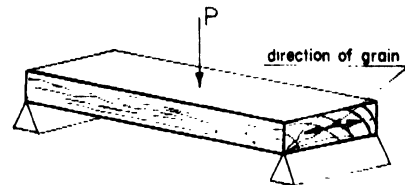
Fig 5. Wooden plate supported parallel to grain

Criterion for tensile strength

If a beam (fig 2) with unit width and thickness H is subjected to a tensile force F_t, then the tensile stress σ_t equals F_t/H. Beams of different materials are of equal weight if their thickness, H, varies in inverse ratio to their specific gravity. Therefore, the maximum tensile force which beams of equal weight but of different materials can withstand is dependent on the ratio:

$$\frac{\sigma_t}{\gamma}$$

Criterion for bending strength

The beam in fig 3 with unit width and thickness H is now subjected to a bending force F_b. This results in a bending stress:

$$\sigma_b = M; \quad M = \tfrac{1}{4}F_b l = \text{bending moment}$$
$$W = \tfrac{1}{6}H^2 = \text{modulus of section}$$

Analogous to 2, the maximum bending force which beams of equal weight can withstand is dependent on the ratio:

$$\frac{\sigma_b}{\gamma^2}$$

TABLE 3: **FRP versus steel and aluminium as regards strength and stiffness**

		FRP mat (28%)		FRP woven roving (45%)		Shipbuilding steel		Aluminium (AlMg3)	
		lb/in²	(kg/cm²)	lb/in²	(kg/cm²)	lb/in²	(kg/cm²)	lb/in²	(kg/cm²)
Specific gravity	γ	1.5		1.6		7.8		2.65	
Tensile strength	σ_t	12,150	(850)	31,000	(2,170)	64,000	(4,500)	38,000	(2,660)
Crossbreaking strength	σ_B	19,300	(1,350)	31,500	(2,200)	64,000	(4,500)	38,000	(2,660)
Modulus (Bending) E		1,070,000	(75,000)	1,500,000	(105,000)	30,000,000	(2.1×10^6)	10,000,000	(700,000)
$\sigma_t\, \gamma^{-1}$		8,100	(566)	19,350	(1,363)	8,200	(578)	14,350	(1,011)
$\sigma_B\, \gamma^{-2}$		8,580	(600)	12,250	(863)	1,050	(74)	5,410	(381)
$E\, \gamma^{-3}$		318,000	(22,250)	361,000	(25,432)	63,200	(4,452)	538,000	(37,900)
$\sigma_t\, \gamma^{-1} \times 10^2 \times 6{,}920^{-1}$		100		241		102		179	
$\sigma_B\, \gamma^{-2} \times 10^2 \times 7{,}100^{-1}$		100		144		13		64	
$E\, \gamma^{-3} \times 10^2 \times 187{,}000^{-1}$		100		114		20		170	

Criterion for rigidity

Apart from strength, we must consider stiffness. It may happen that a beam (fig 3) bends so much under a force F_b that the deflection, a, surpasses acceptable values, although the bending stress σ_b may stay within normal limits. Therefore, stiffness and strength must be dealt with separately. The deflection, a, depends on the ratio F_b/EI where $E=$ modulus of elasticity, and $I=$ moment of inertia $=\frac{1}{12} h^3$.

Analogous to 2 again, the bending force which causes beams of equal weight to deflect equally depends on the ratio:

$$E$$

Summary of criterion

For a given weight:

tensile strength proportional to $\dfrac{\sigma_t}{..}$

bending strength proportional to $\dfrac{\upsilon_b}{..2}$

rigidity proportional to $\dfrac{E}{..3}$

COMPARISON OF FRP WITH STEEL AND LIGHT ALLOY AS REGARDS STRENGTH AND RIGIDITY

In table 3, FRP, both with mat and with woven roving as reinforcement, is compared with steel and light alloy on the basis of equal weight and using the three criteria found above. With FRP mat as a basis, it follows:

FRP-woven roving is stronger than aluminium, FRP-mat and steel

FRP-woven roving is more rigid than FRP-mat and steel

Aluminium is more rigid than FRP-woven roving, FRP-mat and steel.

COMPARISON OF FRP WITH WOOD AS REGARDS STRENGTH AND RIGIDITY

General

Whereas comparison of the mechanical qualities of FRP with those of steel and aluminium was rather simple, a comparison of FRP with wood is more difficult. This is because of the following:

● Variations in mechanical qualities of various samples of the same wood can differ greatly

● The mechanical qualities of wood are greatly affected by the moisture content

TABLE 4: **FRP versus wood as regards strength and stiffness**

		FRP mat lb/in² (kg/cm²)	FRP woven roving lb/in² (kg/cm²)	Oak lb/in² (kg/cm²)	Teak lb/in² (kg/cm²)	Fir lb/in² (kg/cm²)	lb/in² (kg/cm²)
Specific gravity	γ	1.5	1.6	0.85	0.85	0.55	0.85
Tensile strength	σ_t	12,150 (850)	31,000 (2,170)	6,700 (472)	9,300 (655)	6,800 (479)	6,300 (443)
Crossbreaking strength	σ_B	19,300 (1,350)	31,500 (2,200)	6,700 (472)	9,300 (655)	6,800 (479)	6,300 (443)
Modulus (Bending) E		1,070,000 (75,000)	1,500,000 (105,000)	1,210,000 (85,240)	1,170,000 (82,427)	1,040,000 (73,268)	1,410,000 (99,334)
$\sigma_t\, \gamma^{-1}$		8,100 (566)	19,350 (1,363)	7,900 (557)	10,950 (771)	12,400 (874)	7,400 (521)
$\sigma_B\, \gamma^{-2}$		8,580 (600)	12,250 (863)	9,300 (655)	12,900 (881)	22,500 (1,585)	8,750 (616)
$E\, \gamma^{-3}$		318,000 (22,250)	361,000 (25,432)	1,980,000 (135,264)	1,920,000 (135,264)	5,900,000 (415,655)	2,310.000 (162,740)
$\sigma_t\, \gamma^{-1} \times 10^2 \times 6{,}920^{-1}$		100	241	99	135	154	92
$\sigma_B\, \gamma^{-2} \times 10^2 \times 7{,}100^{-1}$		100	144	109	69	264	103
$E\, \gamma^{-3} \times 10^2 \times 187{,}000^{-1}$		100	114	630	610	1,865	730

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● A wooden boat is not a homogenous structure, but consists of a great number of parts held together by frames and fastenings. These fastenings cause weak spots in the structure

Therefore, a comparison on the basis of laboratory-selected samples of wood bears little relation to the characteristics of the complete wood enstructure in the boat. Nevertheless, an attempt is made to compare FRP-mat and FRP-woven roving with oak, teak, fir and pitch pine (table 4). The mechanical qualities of the wood are those for wet wood, taken along the direction of the grain, i.e. for wooden beams, supported and loaded as in fig 4.

An investigation of the characteristics of wooden beams, supported as in fig 5, will give much lower values and should be considered when analysing table 4.

Conclusions from table 4

Using the same criteria as outlined previously, the conclusions are:

On the basis of equal weight, wood (in wet condition tested as in fig 4) is much more rigid than FRP and also stronger than FRP-mat. However, FRP-woven roving is stronger than wood.
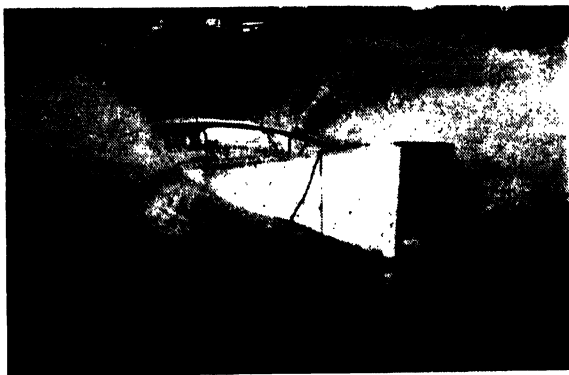
Fig 6. Drop test with FRP lifeboat

Practical examples of FRP compared with wood

The comparison of the various materials as given in tables 3, 4 and 5 is based on a comparison of beams out of the different materials.

● It is difficult, if not impossible, to compare FRP with wood solely on the basis of the tables showing mechanical characteristics, but rather with actual experience with wooden and FRP boats,

Fig 7. Pram type motor launch

which have stood up in practice, and have been built lighter than comparable wooden craft and with good results. Some examples may illustrate this

● In many countries, ships' lifeboats made of FRP have almost completely replaced former wooden, steel and aluminium boats. These FRP boats are lighter than the others, yet they are strong enough (perhaps even too strong) for their purpose. Only FRP lifeboats have to pass rigorous tests, amongst these a drop test, illustrated in fig 6. It is unthinkable that wooden lifeboats would survive such treatment

● Fig 7 shows a pram-type motor launch entirely in FRP with both mat and woven roving as reinforcement. The hull itself is about 40 per cent lighter than if made in wood

The FRP boat is stronger. In a test report, issued by police authorities after testing the prototype for some months, it was said:

". . . in shallow water, on several occasions sand and stone bottoms were hit and the boat suffered no damage. Even when running full speed and with the ebb-tide the boat ran aground on a stone jetty below the water surface which brought the boat to a sudden stop. The damage done was some scratches on the hull and a dented bilge keel. Once the boat was jammed between a bigger vessel and a mooring post which led one to expect that everything would be crushed; however, after the pressure was released, the boat returned to her old shape. If this had happened to a wooden craft, it would have been irreparably damaged, whilst a steel boat would have been dented severely."

Another proof of superiority of FRP over wooden boats can be found in the military field. A great number of armies are replacing or have replaced their wooden storm and assault boats by FRP boats. These boats can be made not only lighter for the strength required but have lower maintenance and repair costs.

FRP SANDWICH CONSTRUCTION
General

When comparing FRP with aluminium, but more especially wood, it was found that although FRP was stronger, it was less stiff. This can be overcome by adopting a sandwich-type of construction. The principle of this is illustrated in fig 8. The inner and outer skins are held apart by a core of light-weight material. For this, PVC-foam has been used with success in a great many cases. For FRP fishing craft, the rule is:

outer skin 0.3 times core thickness
inner skin 0.2 times core thickness

In theory the skins can be much thinner, but they become so vulnerable that they have little practical value.

Influence of mechanical characteristics

For the sandwich in fig 8, with facings of woven roving with specific gravity, 1.6 and PVC-foam core with specific gravity, 0.08, we find an overall specific gravity of 0.59.

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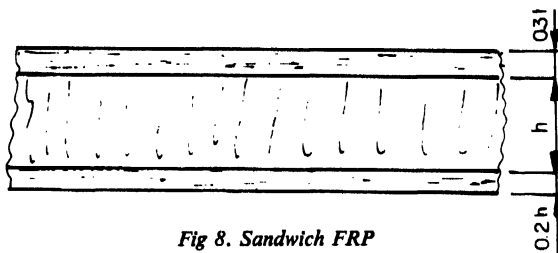
Fig 8. Sandwich FRP

So the sandwich with total thickness 1.5 H has the same weight as a solid FRP laminate with a thickness $= 1.5\,H \times 0.59/1.6 = 0.55\,H$. When calculating the moment of resistance and the moment of inertia for both the sandwich and the solid laminate, we find:

ratio sandwich: solid of modulus of section:

$$\frac{0.224\,H^2}{0.05\,H^2} = 4.5$$

ratio sandwich: solid moment of inertia:

$$\frac{0.190\,H^3}{0.014\,H^3} = 13.6$$

However, the bending strength of the sandwich as well as the modulus of elasticity are lower than those found for the solid laminate. For the sandwich in question we find:

$$6b = 15,700\ \text{lb/in}^2\ (1,100\ \text{kg/cm}^2)$$
$$E = 1,145,000\ \text{lb/in}^2\ (80,000\ \text{kg/cm}^2)$$

Therefore the

$$\frac{\text{strength sandwich FRP}}{\text{strength solid FRP}} = 4.5 \times \frac{15,700}{31,500} = 2.25$$

$$\frac{\text{Rigidity of sandwich FRP}}{\text{Rigidity of solid FRP}} = 13.6 \times \frac{1,145,000}{1,500,000} = 10.4$$

Translating this into the criteria used in tables 3 and 4 we obtain table 5.

CONCLUSION

From table 5 it is clear that the FRP sandwich is the best as regards mechanical qualities.

INFLUENCE OF WEIGHT

In the foregoing great stress has been laid on selecting a construction material with favourable relation of strength and stiffness for weight. It was found that FRP fulfils these requirements best. Weight is so important because of the following reasons:

● If a boat is heavy, then much material must be handled during construction which increases building costs

● The handling characteristics of beach-landing craft are mainly governed by the weight of the boat. Above a certain weight limit, it is impossible to handle a boat alone or with two people. For a given total weight, therefore, a boat made out of a material with a high strength : weight ratio can be larger

● It requires less power for the same speed to propel a lighter vessel, and therefore either speed may be increased or power reduced

On the other hand, it is *not* necessary for a boat to be heavy in order to be stable and to have good sea-keeping qualities.

In a report by the Towing Tank in Hamburg (Möckel, 1963), it was clearly proved that in comparing the stability of wooden pilot boats and FRP pilot boats, the lighter FRP boats were just as stable. Of course, and this is very important, the designer of FRP boats should take into account the influence on weight of the construction material, which he selects when determining length, beam, depth and freeboard as well when designing the linesplan of the boat in question.

IMPACT

All wooden construction boats are rather easily damaged by impact forces; steel and more especially aluminium get severely dented or even damaged by impact forces. Steel and aluminium are moreover weakened considerably by notches or scratches. FRP, on the other hand, shows excellent impact resistance, with FRP-woven roving by far the best. Moreover the impact resistance values are only slightly reduced by notches. This is of great practical value. Not only will a FRP boat be able to withstand rought treatment, but also a crack once started will not continue easily as is the case with steel and aluminium.

FATIGUE

All of the materials mentioned in this paper show reduction in strength if submitted for a prolonged time to alternating or constant forces. Both wood and FRP show fatigue strength after 10 million cycles of around 25 to 30 per cent of the static strength; aluminium is the same or even less good than FRP. Steel is slightly better in this respect, since it retains about 40 per cent of its strength.

For FRP sandwich constructions, a PVC-foam core may be severely weakened in case of high temperatures and is especially the case with horizontal surfaces like decks, when other core materials should be considered.

TABLE 5: **FRP versus other materials at equal weight**

Criteria	FRP mat	FRP woven roving	FRP sandwich	Steel	Aluminium	Oak	Teak	Fir	Pitch pine
Tensile strength	100	241	218	102	179	99	135	154	92
Crossbreaking strength	100	144	320	13	64	109	69	610	103
Stiffness	100	114	1,190	20	170	630	610	1,865	730

CORROSION RESISTANCE

Steel

Under salt-water conditions, steel needs continuous and excellent protection to prevent rapid corrosion. Some woods, especially those containing acids, such as oak and Douglas fir, may have a severe corrosive influence on steel.

Aluminium

Aluminium shows quite different results, depending on the type of alloy used. Some alloys show little or no corrosion in sea water. However, aluminium remains a difficult material as regards corrosion and may give quite unexpected results. If wood, treated with preservatives containing copper, comes into contact with aluminium, this will lead to rapid corrosion. Also many antifouling paints have a disastrous effect on aluminium. Ships' lifeboats have been corroded completely where supported by leather-covered chocks.

Wood

With the exception of teak, all wood should be protected by proper painting to prevent rot and decay.

FRP

FRP is not affected by sea-water, provided proper raw materials of boat-building quality have been used and have been handled with the necessary knowledge and care.

DURABILITY AND MAINTENANCE

One of the main advantages of FRP over any other material mentioned above is that it is durable, if made properly, even if unattended and without maintenance, except perhaps for a regular coat of antifouling paint.

There are several examples demonstrating this long-term durability. In a report regarding three U.S. Coast Guard boats (Cobb, 1962) results of inspection of these ten-year-old boats were most encouraging. Neither sea-water (heavily polluted in this case) nor leak oil and dirt on the inside had had any measurable effect on the laminate. Especially important was that the maintenance costs for these craft had been 80 per cent less than for comparable steel craft.

The U.S. Buships report (Alfers-Graner, 1960) on the superstructure of a U.S. submarine. After having been used for more than five years, the flexural strength was still 88 per cent and the flexural modulus 91 per cent of the original values. There was no change in hardness.

TABLE 6: Heat conductivity

	BTU/ft/ft²/hr/°F	Kg cal/m/m²/hr/°C
FRP mat . . .	0.10	0.06
FRP woven roving	0.12	0.08
PVC-foam.	0.03	0.02
Steel .	40	26.87
Aluminium	140	94.05
Oak	0.14	0.09
Teak	0.14	0.09
Fir	0.09	0.06
Pitch pine	0.14	0.09

THERMAL INSULATION

For fishing craft, proper thermal insulation can be an important requirement. Table 6 shows again that FRP, especially FRP sandwich, has excellent qualities. An illustration of the heat-insulating qualities is given in the aforementioned report (Cobb, 1962). During a serious tanker fire in the port of Houston, a FRP and a steel patrol boat were despatched to the scene of the accident. The crew of the FRP boat were able to operate closer to the intense heat and for a longer period than those on the steel boat, because of the low conductivity of the fibreglass boat. While the topside paint was scorched, the laminate did not ignite nor was it damaged.

COSTS

Prices of materials

For a fishing craft, especially if made in sandwich, the excellent thermal insulation of FRP will make it possible to reduce drastically or leave out extra thermal insulation layers. This influences building costs favourably.

Prices of materials may vary considerably according to location. Current prices in the Netherlands are given in table 7.

TABLE 7: 1965 prices of materials in the Netherlands

	Nett £/lb	£/kg	Waste %	Gross £/lb	£/kg
FRP mat .	0.104	0.229	12	0.117	0.258
FRP woven roving . .	0.122	0.269	14	0.139	0.306
FRP sandwich PVC . .	0.185	0.408	14	0.211	0.445
Steel . .	0.025	0.055	15	0.029	0.064
Aluminium .	0.154	0.340	15	0.177	0.390
Oak . .	0.034	0.075	50	0.051	0.112
Teak . .	0.137	0.302	50	0.206	0.454
Fir . . .	0.026	0.057	50	0.039	0.860
Pitch pine .	0.036	0.079	50	0.054	0.119

Taking into account, however, the differences in strength and rigidity of actual vessels, wooden construction is about 40 per cent and steel 100 per cent heavier than FRP. Table 8 gives an indication of the actual material costs for boats of different materials.

TABLE 8: Actual material costs for boats of different materials

FRP mat .	100
FRP woven roving	88
FRP sandwich .	95
Steel . .	37
Aluminium .	113
Oak . .	46
Teak . .	175
Fir . .	35
Pitch pine .	48

Labour costs

The influence of labour costs on the total price of a vessel is great. Moreover, it is to be expected that this influence will increase, since almost universally they are increasing more rapidly than the cost of materials. With FRP, especially, the labour costs are influenced by several factors:

- Number of boats required
- Type of glass reinforcement
- Solid laminate, sandwich, or both
- Degree of mechanization
- Construction details
- Finish required

In many cases the designer can have a great influence on the actual labour costs and it requires much experience to design optimum boats in this respect. In view of the great number of variables, it is impossible to make a valid comparison of labour costs of FRP with other materials.

Summary

Material costs of FRP are by no means excessive. Labour costs of FRP vary greatly depending on design and the number of boats required. Provided they can be made in sufficient quantity, experience in different countries indicates that in many cases FRP boats are not more expensive, and often cheaper, than boats of other materials.

REPAIRS

One of the outstanding advantages of FRP is that repairs can be easily carried out. To illustrate the extent to which repairs are possible, we refer to fig 9 showing a 33-ft (10 m) sailing yacht, badly damaged during a hurricane. The insurance company accepted it as a total loss on the basis of experience with wooden vessels; nevertheless, the boat was successfully repaired, as shown in fig 10, at a price of less than 10 per cent of the original value.

RANGE OF LENGTH OF VESSELS

FRP is suitable for boats up to at least 120 ft (36.6 m) in length. Lloyd's Register of Shipping takes this length as the upper limit in its present rules for construction. The largest FRP vessels built so far are 77 ft (23.4 m) in length. They are two pilot-boats (fig 11) built in the Netherlands. The largest FRP fishing craft to date have a length of 74 ft (22.6 m). These trawlers were built in South Africa. FRP can be used certainly for fishing craft up to 100 tons.

Fig 9. Damaged FRP yacht

Fig 10. Same yacht after repairing

Fig 11. FRP pilot vessel "Albatros"

BUILDING POSSIBILITIES OF FRP BOATS

Especially if boats are to be built in quantity, FRP offers great possibilities to the designer, both as regards appearance and the incorporation of special design features that influence performance (bulbous bow) without great increase in the price of the vessel.

Types of moulds

The building of FRP boats always requires a mould. When a great many boats of the same type are required, it pays to make the mould in FRP over a wooden pattern of the boat.

When a sandwich construction is adopted, a FRP mould can be advantageously used when a large series is to be built. Should only a small number be required, rather simple moulds should be considered, consisting of a number of frames, covered with narrow battens at regular intervals

Discussion: The employment of new and conventional materials in boatbuilding

BOAT YARD FACILITIES

Reid (Canada): Conveyed his congratulations on Fyson's paper, and added a few comments for further discussion.

In the case of developing countries a question arises regarding available or proposed boatbuilding facilities and whether these should be centrally located or situated around the coasts in certain strategic locations. As part of a study Reid had undertaken for the Canadian Government concerning the improvement of fishing boats in certain areas, one of the major problems that was found was the great lack of suitable boatbuilding yards of any kind.

The fishermen themselves are excellent boat builders with a high degree of personal skill and quite capable of producing the new types of vessel recommended. The problem is that these fishermen are concentrated in isolated communities, none of which in themselves could support boatyard facilities without considerable financial government aid.

The suggested alternative might be the establishment by the government of small boatbuilding facilities in certain strategic areas. These facilities should include only the essential machinery such as bandsaw, circular saw, planer, power drills, etc. The facilities should be sufficient to handle all heavy milling, leaving the light work to be done by the traditional methods. It would be an advantage that a maintenance man or instructor should be present to actually handle such equipment.

There should also be adequate stocks of any material or equipment not easily obtainable locally.

If standard vessels are to be built, then master templates for all the heavy members should be available at each location, a system found very successful in Newfoundland, where these problems occur.

Some education system in boatbuilding should be available to the fishermen, preferably in the off-season period.

Finally Reid advised to use traditional methods of construction that are easily performed by the fishermen building for themselves. He had some reservations about the wide application of glued laminate construction which may be difficult to control under adverse conditions in heat and humidity that prevail in many developing countries.

Methods of improvement?

Rasmussen (Denmark): Congratulated Fyson on an excellent paper. It is very seldom one sees this comprehensive subject treated so concisely and at the same time so completely. On the subject of steambent frames versus laminated frames: what in Fyson's opinion would be the best course to take in an area where the old double-sawn frame system is about to be discarded in favour either of steambent or laminated frames?

It appears that the technique of steambent heavy stock, for example 3 × 4 in (75 × 100 mm) or more, is a difficult one.

More details on glue types would be welcome. Has Fyson any experience on use of epoxy glues in comparison with the more well-known glues on the phenol-resorcinal and the resorcinal types. This question is specially related to the necessary pressure needed.

O'Connor (Ireland): Congratulated Fyson on a paper which does present a very good blueprint for development of boatyards in those countries which are endeavouring to improve their fishing craft.

The boatyards operated by the Irish Sea Fisheries Board have in operation a section control system such as Fyson suggests and it is found very satisfactory and can be recommended, provided the supply of materials for each section is efficiently organized.

One notable omission in Fyson's paper is some advice on the storage and installation of the boat machinery. With the long delivery times nowadays quoted by engine and machinery makers and the probable transport delays which might be experienced in the case of deliveries to countries without their own engine manufacturing concerns and, even in the case of some which have, it is a wise operator who makes provision for any such delays and therefore some advice on machinery storage would be welcome to readers.

There is no mention either of the necessity for the equipping and manning of a fitters shop to take care of the machinery installation and repair work. O'Connor suggested that some of Fyson's engineer colleagues might well add their advice on this important point for the benefit of developing countries. These additions would make this paper a comprehensive document.

Problem of using FRP

Verweij (Netherlands): Fyson's remarks that for series production co-operation between the builders and an experienced naval architect is essential, equally holds when one considers building of boats in FRP.

The naval architect then should have a thorough knowledge of the theoretical and practical problems of designing and building FRP boats.

Verweij differed with Fyson as regards the usefulness of a mixed plywood reinforced plastics construction for small craft.

Verweij's objections against such a mixed construction is that in the long run these two different materials can be separated from each other by water penetration. Especially for open fishing craft which will always have water on the inside of the hull, this composite construction will give rise to troubles.

It is better to rely on either a whole wooden or a whole fibreglass construction.

Where Fyson proposes the use of aluminium deckhouses on steel vessels, in order to save weight, corrosion must be feared. Certainly, it can be done, but one has to be very careful.

Moreover, there is a great difference in thermal expansion between steel and aluminium, with aluminium expanding twice as much. Fibreglass, however, shows the same expansion as steel and presents no corrosion difficulties.

Experience in India

Devara (India): Fyson did a splendid job in covering all aspects of boatyard facilities, organization and running of it. It richly deserves congratulations.

A few observations first by explaining the experiments made in India might be interesting. A boatyard was started in Kakinada (Andhra Pradesh) in 1959 with a production target of 5 boats (30 ft or 9 m and below). There were only a few hand tools. Later on a few power tools were added. During the second year, with a view to improving the rate of production, the workers were formed into two groups to build an equal number of boats. They were encouraged to compete with each other in early completion of the boats. This worked well in the beginning, but failed later on, as there was no incentive (say by way of bonus) for the boat-builders who did the job in a shorter time. Later on, they were grouped according to their skills and were allowed to do repeat jobs, e.g. one group in charge of keel assembly and the next in planking off and so on. This worked very well since it was coupled with increase of wages for whoever showed better efficiency in completing the same jobs.

From 1961, all materials were purchased in bulk by calling all-India tenders, and after having properly estimated the yearly requirements.

By these steps and close and constant expansion and guidance, the efficiency of the boatyard was improved. This boatyard is well known for producing teakwood (*tectona grandis*) boats at a far cheaper price compared to other parts of India, e.g. 30 ft (9 m) boats in teakwood are priced at £650 ($1,800), whereas the prices in other yards are £1,000 to £1,150 ($2,800 to $3,200) though built with non-teakwood.

A few words to the participants from developing countries:

- Please do not over-mechanize the boatyard, but use the full manpower available, so as to provide greater employment and also to reduce high overheads due to costly machinery
- Give good training to boatbuilders in all aspects, including using small power tools and time-saving jigs
- Have constant and close supervision—which often results in finding out ways and means of economizing the number of operations and cutting down wastage
- Proper planning of production programme, procurement of materials, utilization of the specialized skills of workers and close supervision of the boatyard can result in efficient and economical running

McNeely (USA): Fyson's paper will be of inestimable value in the establishment of sorely needed shore facilities in developing countries.

Australian experience with bent frames

Swinfield (Australia): With reference to Fyson's paper re "plank templates", it is submitted that the "old fashioned" half model (of as large a scale as practical) holds many virtues even today including that of "plank layout".

It is not necessary to spile every plank and if the "scaling method" of plank layout is used between, say the garboard and the bilge plank and the bilge plank and sheer plank, then most other planks can be bent around and "set" from the work bench direct on to the moulds. This of course does not include "stealers". If the designed shape of the boat precludes using the "scaling method" of plank layout then the design of the deck frame and the design of the stem could usually be so arranged that planking becomes relatively simple. Because "planking" itself is usually vulnerable to misadventure and "teredo" it should always be easy to remove and replace any plank.

Referring to the selection of stock Swinfield emphasized that all timber should be sawn with the grain running parallel with the face of the bent frame. Fyson quoted a limiting radius of four times the thickness for bending. This seems remarkably small and probably accounts for many broken frames in the "after life" of some vessels. Swinfield recalled an unusually high proportion of broken frames in fishing vessels with deep heels and in "metre class" yachts with very deep heels. The practice of bending any timber to such excess should be discouraged. If such is necessary it is much better to "deep cut" the end of the frame, subjected to the excessive bending, and so "laminate" the otherwise over-stressed timber or frame.

It might be mentioned that the method of fastening the planking to or through the bent frame should always be very carefully considered in the light of the dimensions and species of timber used in the frame.

A solid (one piece) bent frame can usually be through fastened with a "turned" or clenched copper nail; it is not absolutely necessary to roove such a frame. A light frame or one that is composed of two laminations does not always take kindly to such a procedure and invariably splits between the clenched fastenings. It is suggested that a fully rooved frame is necessary in an extreme case or an alternate arrangement of rooves and clenched nails be used.

Swinfield referred to bent frames steambent around ribbands which "run around" the vessel from mould to mould or bent frames that are bent inside ribbands, garboards and sheer strakes. Frames bent away from the vessel and left to cool for machining are rarely used in Australia. The limiting dimensions of steambent "hardwood" frames would be about $3\frac{1}{4} \times 3$ in (82×76 mm) in two laminations. Glue is not used in such construction and copper through-fastenings are invariably used. In all cases it is essential to paint the faying surfaces of all frames before applying the planking to avoid rot in the years to come.

UK methods listed

Lee (UK): Fyson is to be given full support in his warning that the establishment of a new yard or the re-equipping of an old one for the series production of boats requires a careful study of the possible demand.

The following comments reflect experience in UK:

Air drying: Most boatyards find it better to obtain prepared material from timber merchants than to undertake extensive air-drying in the boatyard.

Series production: In the building of large craft it is useful to have a platform at deck level on which light wood-working machinery is mounted. This enables the workmen to cut and prepare the timber without wasting time going down the scaffolding and to the mill.

Marine railways: Railways impose a restriction on movement whereas greasy ways on wood or metal runners enable boats to be moved with greater freedom. The space available can be used to much greater advantage particularly when there is a variety of types of boat. There is no necessity for points, etc.

Portable machinery: Portable electric saws have proved very useful as they can cut heavy timber without it being moved to a fixed circular saw, which would be expensive on labour. When the timber has been cut substantially to shape it is lighter and easier to handle.

Apprentices: Most boatyards find that although they have an extensive training programme, after they are trained the apprentices are lost to other industries.

Boiling better than steaming

Colvin (USA): Fyson's paper gives a good synopsis of the small wooden boatyard. More stress should be made on detailed lofting, regardless of the fact that it is a one-off building. Experience has always been that the more detailed the lofting, the less labour involved in the later stages of the construction.

It is becoming more difficult every year to obtain good steam-bending stock. However, it has been found that boiling rather than steaming gives a more supple timber with which to work and does not have the tendency to dry out the wood as does steaming. Also, soap and kerosene is added to the water which eases the bending as well as gives a preservative action. In the heavier frames, rather than bend over a form, Colvin normally bends a frame to ½ molding full siding, forming the two of them simultaneously and riveting the two. Rather than use the pheno-resorcinol-formaldehyde adhesives, they are using epoxies with seemingly better results. They do cure at low temperatures and are easier to spread.

Unless the yard was well-planned in the beginning, there is little that can be done to arrange the buildings in an orderly fashion to have a more or less continuous flow of material. Most yards have been expanded as necessity demanded; and, with the changes in technology and construction, and the availability of smaller tools and more efficient means of handling timber, the expansion has not necessarily been correct. One of the most difficult aspects of wooden boat construction is the necessity of having a great deal of capital invested in timber that is just drying. It has been found that carefully controlled dry kilns produce equally as good timber for boatbuilding perhaps as air-dried stock, which permits the yard to invest its capital in other things than timber. The cost of air-drying is becoming prohibitive in that ideally it should be turned at least once during drying and then baulked during the final stages where the straightness and all can be controlled to a nicety. The availability of large timbers in soft woods, i.e. Douglas fir, has altered the methods of building on the Chesapeake Bay, where hard woods are very difficult to obtain in any length or of good quality.

Technical equipment needed

The type of railway is dictated more by whether it is a building yard or a repair yard, or both. In Colvin's own yard, where they are primarily engaged in new construction, only launching ways are used and they have no railway as such. They find that steel cradles are best for launching on all types of boats from the smallest to the largest as they do not have to worry about their floating up under the hulls. With the larger vessels and the extremely heavy cradles, they secure the cradle to the hull during launching and then drop the cradle after the vessel is afloat alongside a crane, retrieving it and then greasing it ready for the next launching. For very small craft under four tons displacement, launching is via a crawler crane. They found a crawler crane to be an excellent investment in comparison to derricks and sheerlegs as it allows the installation of engines, the raising of spars and lifting heavy loads any place in the yard, including heavy keel timbers. It also can be used for pile driving and dredging, and can be barge-mounted for light salvage work. All in all, it becomes a very versatile and useful machine.

With the advent of lighter and more powerful electric engines, the portable machinery has in many instances replaced the fixed machinery, especially in the interior joiner work, decks and cabin work.

Fyson is absolutely correct, and it should be stressed, that light machinery doing heavy work is expensive in time and tools. This is a common fault with many small yards where the owners are endeavouring to save a few dollars and end up spending three times as much as one heavy-duty tool would have cost.

It is no doubt desirable to use the system proposed by Christensen in the itemization of construction. In theory, such a cost analysis is highly desirable, but in practice it becomes very difficult and an unwieldy system—unless the yard is very large and can afford the additional labour necessary to keep track of the book-keeping. A slightly simpler system is to use the main headings —i.e., backbone, framing, etc. as items, but add the total fastenings as an item, total paint as an item, etc. as these are purchased from independent suppliers, and billing is very easily posted. After the vessel is completed, a cost per unit weight of planking, or a cost per unit weight of displacement, or per ton, or any other convenient method can be used to determine the cost. For a larger vessel, the increase in machinery can be directly figured based on machinery costs as can the equipment, Item 12.

The establishment of a small yard, while it does depend on the demand for new vessels, also depends a great deal on the reputation and the ability of those operating the yard. A well-established yard in USA will sell their vessels not only several hundred miles but several thousand miles from its location, and in many instances, export their vessels, so the yard location of necessity need not be in the middle of the demand area, but in an area that is accessible to materials, labour and transportation.

Training of personnel

The undertaking of training of personnel is one of the most difficult areas of operation unless the yard is established in a long-time boatbuilding centre. It seems that it is almost as easy and as fast to train personnel from the beginning rather than try and adapt a house carpenter to boatbuilding or a professional cabinetmaker to interior joiner work. Their preconceived ideas are often the biggest bottleneck in production. In many of the high schools in USA, there are shop courses, and an enterprising employee will usually be found utilizing these facilities. In USA, it is very difficult to indenture apprentices, and individual state requirements are such that schooling must be made available to children until they reach a certain age, so that unless the enterprise is very large the cost of employing apprentices with their required schooling is prohibitive. Also, the four or five years that are required to elevate one to journeyman at low initial pay causes most people to go into other industries which offer higher pay to begin with, even though there might be little future in the work. It is perhaps true that, worldwide, one of the most difficult aspects of wooden boat construction is the training of the future builders.

Training in developing countries

Heath (Zambia): Fyson invited discussion on training in developing countries. For the interest of those considering setting up a boatbuilding programme in wood construction the following points might be worth noting.

A minimum period of 4 years experience as a carpenter has been necessary for a trainee boatbuilder, a 12 month course will produce a man suitable for employment as a helper to a more experienced boatbuilder. It has also been found that it is not necessary or desirable to train boatbuilders as in a school i.e. with theory and basic joints, etc. A year working more as an apprentice gives better results and is productive if a building programme is in progress.

It is appreciated that in a case where no boatbuilders exist at present it will be necessary to start as a school, this was

done in Zambia, but after three years it was found the school was able to switch to production. Over a five year period from scratch, 60 boatbuilders were trained. The boat types taught and built varied from dories to open motor fishing boats of 26 ft (8 m) LOA both carvel, clinker and marine plywood constructions were used.

The greatest importance is "follow up" after training, including provision of boatbuilding materials and loan schemes for fishermen, to purchase the boats built by the ex-trainees.

If these last points are not taken into consideration, at the outset of promoting an improved boat scheme for fishermen, the whole project will almost certainly fail.

Author's Reply

Fyson (FAO): Thanked Reid for his interesting comments which were certainly relevant to the earlier stages of boatyard development. His suggestions for the use of master templates is a good one and Fyson added by way of example that in Senegal, where he was responsible for boatbuilder training, they are in fact doing this. Trainees from the course form co-operatives at the end of their training period to build 42 and 52 ft (13 and 16 m) fishing boats. For this purpose, they will have the use of master templates made up in plywood.

On the question of the use of laminated or steambent frames to replace sawn frames, as mentioned by several of the contributors, Fyson considered that the choice is dependent on factors which vary from country to country, such as the experience and skill of boatbuilders and the availability of suitable timber for steambending. Where skills have been sufficiently well established in traditional methods, and close and careful supervision of the correct use of glue and clamping techniques is available, lamination can be successful, and Fyson gave as examples Ghana and Nigeria, where lamination techniques are being successfully used. A further factor in making this decision is the question of cost. Given the availability of suitable timber for steambending, then lamination will definitely be more expensive.

Fyson agreed with Verweij on the difficulty of coating planked hulls with fibreglass. However, there is another use of fibreglass, of which Fyson had some experience, in the construction of small hard chine plywood boats, less skilled labour can be used and costs cut by the use of fibreglass tape to seal the keel and chine joints.

Epoxy glues are very sensitive to humidity and for this reason Fyson did not recommend their use in tropical countries.

The idea of laminated frames constructed in a central workshop to be distributed to smaller yards is interesting, but would probably be impractical unless the boatyards were situated close together.

To Verweij, Fyson said that in most developing countries, wood is locally available, while steel and plastics must be imported. Therefore, because of exchange controls and currency problems, wood is liable to be the dominant material for some time to come.

WOOD IN FISHING VESSELS

Potter (USA): Simpson's (1960) proposals were used in his design office for the design of about 12 wooden fishing vessels ranging in size from 72 to 125 ft (22 to 38 m) LOA. Some of these were built exactly to the scantling rules and some departed from them to conform more closely to general practice. Potter, having succeeded the late Simpson, had revised his scantling figures.

Table 30 of Simpson's paper shows the smallest vessel, 68 ft (20.75 m) to be of heavier construction than the proposed scantling rule would require. The 85 ft (25.9 m) LOA vessel is built in many respects of scantlings equal to the proposed

rule, and the largest vessel, 115.86 ft (35.3 m) LOA is built quite a bit lighter than the rule would require.

Nine vessels have been used for a re-evaluation, and the trend of the comparison between actual construction and the "Suggested Standard Scantlings" shows the same thing as table 30. Therefore, the key tabulation of table 28, "Standard Frame Spacing and Plank Thickness" and fig 150 "Section Moduli of Frames" and fig 151, "Section Moduli of Deck Beams" have been revised to more nearly conform to actual contruction practice.

TABLE 1
Standard frame spacing and plank thickness

N	Frame Spacing		Plank thickness	
	Inches	mm	Inches	mm
4.00	12	305	1¼	38
4.25	13	330	1⅜	41
4.50	14	356	1¾	44
4.75	15	380	1⅞	48
5.00	16	406	2	51
5.25	17	432	2¼	54
5.50	18	457	2¼	57
5.75	18	457	2¼	57
6.00	19	483	2⅜	60
6.25	20	508	2½	64
6.50	20	508	2⅝	67
6.75	21	533	2⅝	67
7.00	21	533	2¾	70
7.25	21	533	2¾	70
7.50	22	559	2⅞	73
7.75	23	584	3	76
8.00	24	610	3	76

The new table 28 "Standard Frame Spacing and Plank Thickness", here given as table 1 shows a reduction in frame spacing beginning at N=6.50 and through to the largest size listed, N=8.00. The maximum frame spacing is reduced from 26 in (686 mm) to 24 in (610 mm). The plank thickness is reduced beginning with N=5.75 and above. The maximum plank thickness is reduced from 3½ in (89 mm) to 3 in (76 mm).

Fig 1 "Section Moduli of Frames" is Simpson's fig 147 and shows the original proposed graph line and a new one (dotted) which approaches the spots indicating values for the nine vessels investigated.
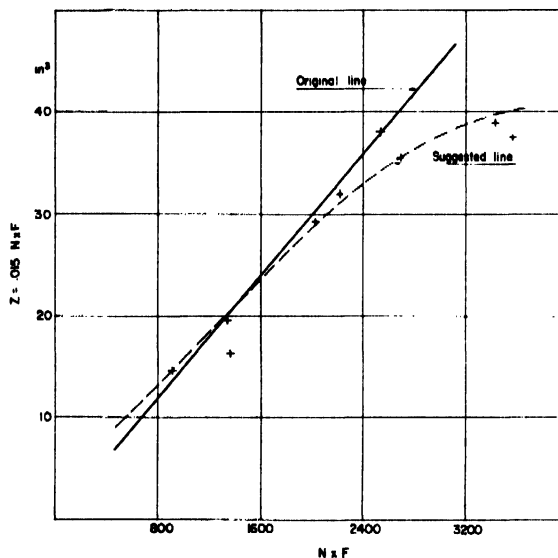

Fig 1. Section Moduli of frames

Fig 2 "Section Moduli of Deck Beams", is Simpson's fig 150 and is treated in the same way. There are two other changes suggested:

Keelsons: Sided and moulded 4×t, up to LOA = 100 ft (30.5 m)
Sided and moulded 4½×t above LOA = 100 ft (30.5 m)
Sister Keelsons: The original paper says "Not used under 90 to 95 ft (27 to 29 m.) LOA". This should read "Not used under 80 ft (24 m.) LOA."
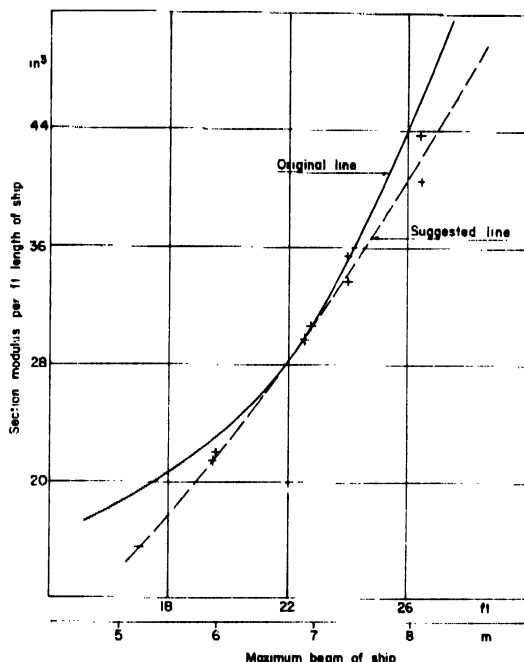

Fig 2. Section Moduli of deck beams

No other changes seem indicated up to the present. If the process of scantling design outlined in the original paper is followed, using the changes shown herewith, it is believed that the result may be a strong and durable vessel. The reason for saying "may" instead of "will" is because the best size for the various pieces of timber is only one factor leading to strength and durability. The strength qualities of each piece can vary from excellent to worthless and of course it also requires certain qualities to help insure durability and long life. Even with all these factors on the favourable side, the final result really depends on the skill and knowledge of the builders. Tight, well made joints and well placed fastenings well set up can make all the difference between a good vessel and a poor one.

Practice in USA Northwest
In the Northwest section of USA it has been generally considered that bent-frame construction is the cheapest and best in vessel sizes up to about 50 ft (15 m) length overall. In vessels of 50 to about 70 ft (15 to 21 m) LOA there have been some with bent frames and some with sawn frames. Above 70 ft (21 m) LOA practically all commercial vessels have been sawn-frame construction.

The reason for use of bent frames in this area is because good bending oak is available locally, and can be worked in sizes up to about 3½ in (89 mm) square with average shipyard skills and a minimum of equipment. Also, there is very little waste of material if the timber is suitable and well selected.

When a builder has developed a popular model the same moulds and ribbands can be used for a number of vessels, thus reducing the cost, material and time to build. The basic simplicity of making up the framing of this type, consisting of two bent pieces and a plank floor joining them over the keel, contrasts with the templating, cutting, fitting, bevelling and bolting together of perhaps 12 pieces in the average sawn frame. The bent frame, in sizes up to about 2½ in (63 mm) square, can be twisted to the required bevels.

The best bending stock in USA is known as Appalachian white oak (*Quercus alba*) and is found in a broad area inland in the mountain regions as well as along the sea coast. The coastal oak was cut off for shipbuilding and other purposes in the early years of settlement, but second growth timber has provided enough for boatbuilding needs except during accelerated building in wartime. In modern times logging machinery and transport makes this material available to the shipyard from a very wide region.

This is fortunate because only unseasoned oak from young trees is suitable for steam bending. Oak which has been seasoned before bending will very often crack after short service. In wartime large amounts of oak were shipped to building yards at a distance, and because it was unseasoned it checked very badly and a lot of it was wasted.

It might be thought that the use of unseasoned timber in a boat would be likely to cause rot. However, the steaming process seems to sterilize the material and it is not common to find rot in steambent framing.

Problem of bent frames
At times yachts built in Europe have been delivered to USA in which many of the steambent frames suffered brittle fractures. One vessel which Potter had surveyed, only two or three years old, had over fifty broken frames. He had often wondered whether the European oak (*Quercus robur*) is suitable for steam bending, or whether the examples of brittleness which have come to his attention are because these frames were bent of seasoned timber.

Each boatbuilder of experience will have developed some little variations on the usual methods of steambent framing, but the basic system is as follows:

Frames to be bent in place. From the loft layout, forms of braced planking are made to the inside of plank and set up on the keel. Ribbands or stringers (of spruce, usually) are fastened to the forms at close intervals, extending from bow to stern. This constitutes all the preliminary work prior to bending the frames.

The shipyard may order the framestock in log form which is cut to size in the yard. This is the best arrangement because the material is not dried out at all before use and also the yard has full control of the cutting. If the timber supplier is local and co-operative the frame stock may be ordered in quarter-sawed flitches, ready for the yard to complete the sawing and planing.

One of the benefits of a square frame—that is, siding and moulding equal—is that the individual pieces can be turned to put the flat of the grain parallel to the planking, which is the easiest to bend and does not tend to split from plank fastenings.

The milled framestock is then placed in a steam box where it is steamed until pliable enough, usually one hour per inch (2.5 cm) of thickness. A three inch (7.5 cm) thick frame should steam for three hours. This is where the judgment of experience makes a great difference. The man in charge of the steaming must keep tally of the frames in the box and if he is capable, the number of broken frames will be much reduced.

The steam box is usually a long watertight box with a

removable opening at one end through which the frames are inserted and removed. There are sometimes racks to support the frames and insure complete exposure, but often the frames just float in water allowed to stand about half-depth of the box. Most shipyards have a wood-fired steam boiler, using scrap wood for fuel, and the steam is introduced into the box at several points along its length and directly into the water. One yard used a discarded torpedo tube for a steam box, and also introduced a small proportion of kerosene into the steam bath.

When steamed long enough, the frame is removed from the steam box and as quickly as possible is passed over the top of the ribbands and bent into place against them. The crew doing this work must be quick to keep the frame from cooling. A series of bar or C-clamps are used to pull the frame tightly against the ribbands. At the top a sort of wrench is applied to twist the frame to the correct bevel. Usually a few blows of a mallet or heavy hammer on the upper end are required to drive the frame heel tightly in place at the keel.

Method of bending and fitting

Frames to be bent on a form and fitted cold. Equipment required is a flat bending area with either a heavy plank flooring or a cast iron grid bending slab such as is used for bending steel frames. The desired contour is chalked on the floor or grid and a series of shaped blocks or cleats are fastened down defining the bend to be made. Here is where experience counts, because the bend should be a little sharper than the finished frame, since it will tend to straighten out while cooling.

The end of the frame at the keel is where the frame stock is first secured, so usually there are two cleats or blocks on the bending flat at this point with a space for the frame between, plus a wedge. At each of the cleats there must be means of clamping or wedging the frame.

A block and tackle is rigged to hook into a loop of rope at the upper end of the frame and haul it around from the straight to the bend required.

Heavy frames tend to fail in bending from compression on the inner face of the bend and from tension on the outer face which causes cracks or slivering splits. The compression failures can be minimized by care in achieving a smooth bend with no local irregularities and by enough support from the cleats on the inner face to eliminate localized pressures.

The tension failures can be minimized by use of a steel strap with a strong square hook at one end. The strap is made the width of the frame and the hook is of fairly heavy angles or other shapes, just the right size to fit snugly over the end of the frame. In use, the hook is fitted to the end of the frame as soon as it arrives from the steam box and the strap is pulled tightly against the frame stock and nailed or strongly clamped to the frame at the end of the strap, the idea being to prevent stretching the outer fibres of the wood. The assembly of frame stock and strap is then bent around the cleats in the usual way. The use of the strap tends to increase compression within the frame stock and thus requires extra care to prevent compression failures.

The bending procedure is then as follows:

Frame stock arrives at the bending flat as hot as possible, strap is attached, heel of frame wedged into the cleats prepared for it, block and tackle attached at the other end, tackle hauled in steadily, and frame clamped or wedged to each cleat as frame meets it. All this must be done quickly but it is very important that it be done smoothly.

Once in shape the frame is allowed to cool briefly and wooden strips are then nailed across the bend like the chord of an arc to prevent straightening out, one strip before

removing from the bending flat and the strip on the other side immediately after. A pair of frames is made from each set of blocking, or more as may be needed for a group of identical vessels.

The resulting frame has no bevels, which must be cut from the material. A case could be made for using the required frame moulding without regard to the bevels. When beveled the frame will be undersize compared to the square section frame, but this will occur gradually as the frame location approaches the ends of the vessel, where it need not be so heavy. However, the usual practice is to add the bevel requirement to the moulding of the frame. This makes bending harder and increases the chances of bending failures.

Note that even in construction where the frames are bent in place against the ribbands, it is usual to "mould" the bulkhead frames on the flat as described here, thus having a flat face to the frame.

Fastening of frames

In contrast to a double sawn frame there is no question that fastenings in a bent frame are more of a problem because there is much less material to receive the fastenings and because the fibres are already stretched or compressed to some degree.

The main difference in the fastenings is that it is not practical to use drifts because the frame is too light and springy to take the heavy hammer blows. Even the use of nails for plank fastenings requires backing up the frame with a heavy iron to give sufficient inertia. The best fastenings in smaller sizes are bronze wood screws or copper rivets, and in larger sizes, through-bolts.

Fortunately, most fastenings into a bent frame are at right angles to the flat of the grain. The exception is the fastenings from floors to frames. Very often these are a series of bolts in a row, each cutting through the same layers of grain of the wood. Where it is possible, bosom floors should be used instead of the usual ones on the side of the frames, the fastenings then being through the flat of the grain.

Some years ago Potter worked on the design of a 60 ft (18.3 m) wooden vessel which carried a heavy deck load at a speed of over 20 knots in the open sea. This vessel had a bent frame construction which was similar to that shown in fig 3. While there are lot of pieces in this construction they are light and easy to handle and Potter considered the end
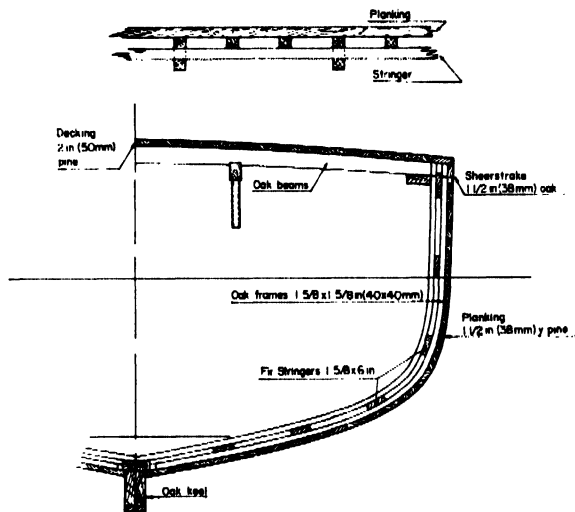

Fig 3. Proposed construction section for 60 ft vessels (beam 16 ft, depth 8 ft)

[282]

result is a very strong construction with some flexibility. The outer and inner frame stock and the spacers between the stringers are all of the same size. Because of the small cross-section of the frame stock it is easy to bend and may be easier to procure. Note that the inner frame provides a means for securing a bulkhead.

Fig 4 shows the scantling section of a small tugboat built in 1948 and still in general service as a contractor's tug. It has been used in heavy service and still is in excellent condition. The contractor tried to bend these frames against the ribbands but found they were too heavy and had to be bent on the slab, being put into the boat after cooling and "setting".

Potter's comment on Pedersen's paper was to suggest that more emphasis must be placed on the practical economic aspects of the use of wood in vessel construction, as it is not often possible to try for the refinement of structure which the paper recommends.

He was very interested in the forced drying out and he enquired whether this caused any adverse effects on the seams and butts of the ship structure?
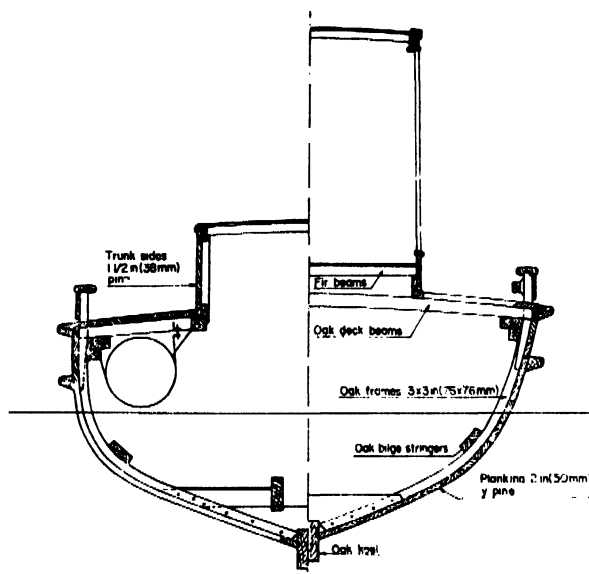

Fig 4. Construction sections for diesel powered tugboat (loa 45ft, maximum beam 13.5 ft, depth 6.5 ft)

Norway's use of wood

Ullevålseter (Norway): In Norway, more than 95 per cent of the fishing fleet of 40,000 smaller and larger vessels are wooden vessels. There has not been many essential changes in the construction and building methods. The knowledge gained in wood science has not been used to its full extent in the wooden shipbuilding field. Today's constructional methods for wooden vessels, make the biological destruction of the wood a very interesting field of study.

Due to the severe biological destruction in Norwegian wooden fishing vessels, especially by wood rotting fungi, the Agricultural College of Norway, Department of Wood Technology, was in 1958 given the problem by the Directorate of Fisheries to determine the different biological agencies and give recommendation for its prevention.

In 1960 Ullevålseter had visited 69 wooden shipbuilding yards and collected 78 samples of wood from different vessels attacked by wood rotting fungi. From an earlier survey, there were 12 samples, so the total collection amounted to 90 samples.

Besides the wood rotting fungi studies were also made on damage caused by a wood-destroying insect—*Nacerda melanura* and the marine borers *Teredo* and *Limnoria*.

The following biological agencies of destruction are therefore registered:

A. Wood—destroying insect—*Nacerda melanura*
B. Marine borers—*Teredo* and *Limnoria*.
C. Wood rotting fungi.
   1. Basidiomycetes—Wet rot
      Coniophora puteana, fig 5
      Trametes serialis, fig 6
      Lentinus lepideus
      Poria sp, fig 7
      Polyporus annosus
   2. Ascomycetes and Fungi Imperfecti, fig 8
      Phialophora fasticata
      Chloridium sp
      Trichoderma lignorum
      Penicillium sp
      and several unidentified.

There is a well established agreement among all wood scientists that the most effective preservative method for wood, against biological destruction is pressure treatment with creosote or chemical compounds. In the future, there will be used more pressure treated wood in the building and repairing

Fig 5. Typical appearance of wet rot in ships frames, caused by Coniophora Puteana

Fig 6. Typical decay in Scots Pine Timber by Trametes Serialis

of wooden vessels, but one must not forget that the main lines on which to work to solve the rot problem must be to design the vessels in such a way that one can control and keep the moisture content in the wood below the level that creates the rot danger culture condition.

This means the importance of using well seasoned timber in the building of new vessels and to practice regular moisture check when the vessel is in use or storage.

Fig 7. Large rot pocket. Rot caused by Poria *Sp*

Difficulty of drying

Since there are very limited periods of good natural climatic drying conditions in Norway, particularly in winter, autumn and spring, it is a major problem always to builders, on how to dry out new wooden materials and vessels in use. Even when heating can be introduced, this method can be both ineffective and expensive.

In addition to causing cracks and warping of the wood, very often only partial drying of the surface takes place, leaving the deep seated residual moisture in the wood. During high humidity periods, high temperature drying can even increase dampness and restrict drying, causing sweating and condensation.

In the practical field application the dehumidification technique of drying wood is important. The drying equipment is a compact unit and has the advantage of being portable. The dehumidification drying technique is based on the principles of absolute humidity moisture extraction, following and simulating the best natural climatic summer condition for drying, i.e. 65 to 75° F (18 to 24° C) at 45 to 55 per cent relative humidity, with a steady gentle breeze or air change. This technique operating in a closed area will efficiently simulate these ideal summer drying conditions all the year round, irrespective of outside climatic conditions, granting a background temperature of 65 to 75° F is created in the closed drying area. Since the drying zone is closed, little outside air change occurs so the raising of background temperature can be economically and easily created with very little heat losses. The warm air circulating over the damp wood steadily evaporates moisture from the wood into the air to a high humidity condition. This moist air is drawn back to the dehumidification unit and the moisture is condensed out of the air and absolutely extracted, then drained away. The dry air is then sent away to repeat its pick up of moisture from the wood.

The following results are obtained from practical drying test of inner shell area with a portable dehumidification unit. The main objective of the drying test was to reduce moisture content in wooden structure below danger point of rot inception and culture environment for fungi growth. Of primary consideration, this drying technique would provide the dry background (18–20 per cent m/c) necessary for a surface treatment of timber by chemical preservatives which will not penetrate wood if saturated with moisture.

Testing moisture content

The ship to be tested was a Scots pine built fishing vessel 53 ft (16 m), built 1955. The fish hold was 600 to 700 ft³ (17 to 20 m³) dripping saturated everywhere. From 3 pm September 9th, 1965, to 12 am September 11th, in 45 hours, the dehumidifying unit extracted approximately 400 lb (200 l) moisture from the hold area. The next 48 hours extracted 180 lb (90 l) moisture, which gave an ultimate moisture content of the wood of 18 to 20 per cent. The moisture content was checked with an electric moisture meter.

A low moisture content of 18 to 20 per cent is of course no limit of the drying capacity, but in drying out vessels one will not find it practical to dry to a lower moisture content because of the problem of wood shrinkage. A second guide to the control of moisture is to include in new vessels, remote metal probes in rot-dangerous hidden areas of ship structure, fig 9. The metal probes will be linked by flex wires to a central open point so that the moisture content of hidden timbers can be checked by electric moisture meter at regular intervals and the rot danger culture condition anticipated before it is too late. Much of the rotting goes on in these hidden areas, and extensive damage is done before visual indication appears. It is then too late to apply drying and preventive techniques. Some suggestions for the future would therefore be to build wooden vessels with (a) remote metal probes, fixed at all vital areas, (b) a small permanent dehumidifying unit to deal with excess moisture in critical areas and (c) the possibility to give a massive dry out with a larger dehumidifier.
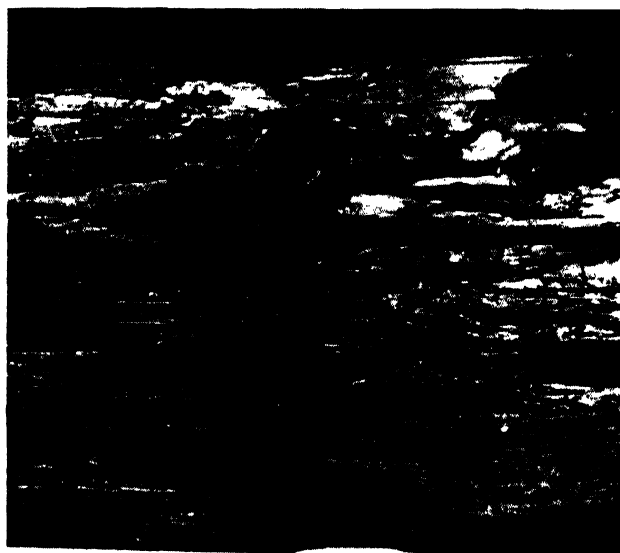
Fig 8. Soft rot, caused by Ascomycetes *and* Fungi Imperfecti *in ships planking*

The important point is, there is no other known practical method of measuring the moisture content of wood in the field, except the laboratory approach of weighing wood samples on a micro-balance. The electric moisture meter is a fair practical guide—as accurate as is possible and based on sound calibration principles. It is used widely all over the world, in the field and in laboratories. If checked, at weekly intervals as a routine, this would bring the problem far more under control. Prevention is always far more effective and economic than cure.

This should be the main objective: To know the potential danger point—the excess moisture content of timber—is

Fig 9. Fixed probe technique on wooden ships

90 per cent of the battle, for it is so much easier and quicker to dry out 5 to 10 per cent excess moisture than it is to deal with 100 per cent saturation.

Techniques for prevention

The long term approach of getting at the root of the problem, by prevention techniques during the ship building is the basic scientific principle on which to work.

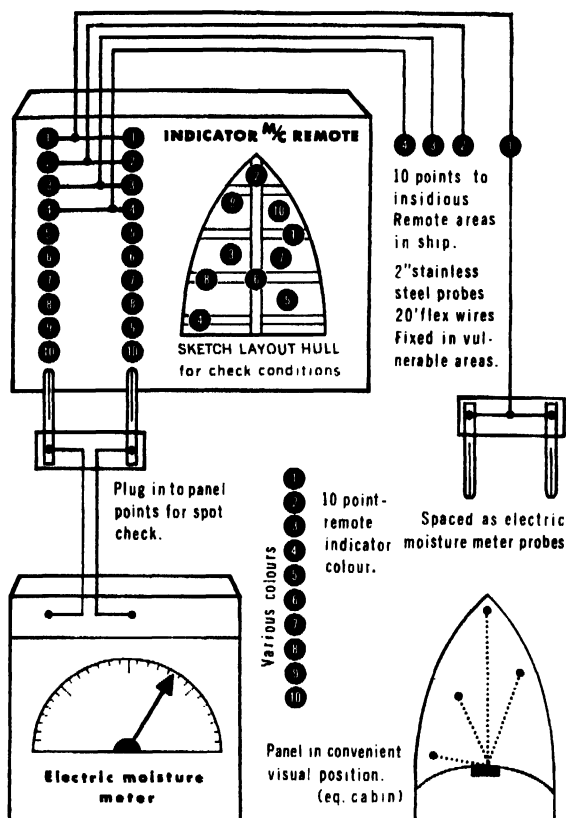Pedersen has presented a most interesting paper on wood as a building material for fishing vessels. When Pedersen gives the advantages of glued laminated members it seems likely that he was forgetting to mention one advantage of great importance and that is that each individual lamination can be pressure-treated with chemical compounds, which in the end can result in a structural element that is 100 per cent penetrated. This seems to be one of the major arguments for using glued laminated members in the future building of wooden fishing vessels and the safest way with today's knowledge to obtain increased protection against biological destruction.

In Norway there are at least two boat-yards that have taken advantage of the research carried out and are using the combination of pressure treatment and the laminating technique to give the new fishing vessels increased protection against biological destruction.

Boat-yards also are finding the combination of pressure treatment and the lamination technique competitive. A fishing vessel built of pressure treated laminated members, with all its advantages, only costs about 10 per cent more than a conventionally built vessel and 10 per cent less than a steel vessel.

Potter put forward the question of any damage being caused on the wood as, for example cracking, with the dehumidification technique of drying. To Ullevålseter's know-

ledge no extensive cracking takes place and this is one of the major advantages with the dehumidification technique compared to the common high temperature drying. This is because, with the dehumidification, one is simulating the best natural climatic summer condition for drying, i.e. 65 to 75° F (18 to 24° C) at 45 to 55 per cent relative humidity. At this low drying temperature, the wood is dried very gently and the surface tension is reduced to a minimum.

Simplicity and strength

Chapelle (USA): Pedersen has presented a very interesting paper. Wood construction has been under attack for some years on various grounds. This paper gives an answer to some of the criticisms raised against wood.

However, it seems that the proposed glue-laminated construction may be needlessly complex and, therefore, costly. The supply of timber is not so stringent in the areas known as boatbuilding centres, to require a completely laminated construction. Glue-lamination has been accused of producing brittle structures, but if such weakness exists, the method can be applied in producing built-up forms, as substitutes for large scantling timber members, without fear.

The part that might be played in timber construction, by reversing the field of study, can well be considered. This is to use simple hull forms, with a mixture of natural timber and glue-laminated construction, primarily for exploration of low cost construction.

In large wooden hulls, the procurement of heavy timber has become an increasing area of difficulty. The solution does not seem to be further gambles in experimental construction, whether plastic, sheet material, glue-lamination or complicated variations in wood construction. Composite construction; implying use of steel frames, deck beams, floors, keelsons, stem and stern liners and plate knees and stringers, with wooden planking and decking, should certainly be first explored.

This might save both cost and weight, combining the supposed advantages of both steel and wood construction. A yard experienced in wood construction could readily convert to composite construction with only a small outlay in equpment and in training help. There appears to be something wrong with the strength calculations that create the supposed need of very elaborate structures or for new materials. Few boats built reasonably well, of timber, fail in strength for engineering reasons. Rather, failure is due to rot or corrosion or some external cause (worms, accidents, etc.). The classic approach of taking structural details out of the hull and applying assumed or rationalized estimates of loading is, of course, faulty. The true loading of a boat hull is on the hull as a whole and strain gauge studies indicate how difficult it is to work out a useful estimate of probable loading in design stages. It is this complication that also leads to over-designing structure members. It was this that created so much interest in scantling tables and standards in former congresses, for these were based on trial and error over a long period, rather than on theoretical engineering.

There is no need to produce stronger hulls by new construction methods, but rather to maintain similar strength with less weight, labour and, of course, cost. This is particularly true if information is being collected for use in the underdeveloped fisheries, where capital investment must be low. Surely, this is not a commonly suitable area for the introduction of expensive, foreign materials and complicated building techniques.

In making comparisons between wood construction and other materials, there seems to be a tendency here to make general statements derogatory to standard wood construction. There are certainly serious problems in the use of timber

and there are areas where other building methods might be utilized.

However, it does not aid these other building techniques to exaggerate the shortcomings of timber construction by assigning extraordinary maintenance problems, short life, lack of scientific data or other imaginary objections to use of timber.

The decisions that must be made in deciding which technique of building is to be used, with respect to an underdeveloped fishery, are too important to be based on anything but an objective approach.

Laminated multiple-layer planking

Lindblom (Finland): Expressing appreciation of Pedersen's excellent and comprehensive study of the material "wood". Lindblom had been building wooden boats for almost 40 years, but he was really hardly fully aware of the beauty and the outstanding properties of this material until reading Pedersen's paper. He admired (and shared) Pedersen's enthusiasm for the subject. The paper contains everything a builder of wooden boats wants to know about the material he is using.

Lindblom could find no reason for criticism at all. On the contrary! In this paper, there is one statement which he would like to underline. Pedersen has, as the first person Lindblom knew of, treated wood as "engineering material", a promotion and title this material really deserves.

Lindblom's firm once, ten years ago, was perhaps the biggest wooden boatbuilders in the world—and at that time they made extensive use of laminations in as much as all the structural parts of serial built hulls (bed, frames, floors, beams, etc.) were of laminated wood. They had obtained full class approval for the lamination and construction technique by the Marine Register of USSR.

After this period, during the last five to six years, they have concentrated their attention as to wood on the problem of developing a practically (and economically) usable technique for the production of laminated multiple-layer planking (the skin only).

In this respect, there has been some success. There are in Finland about a dozen boats (fast naval gun boats, length 72 ft (22 m), displacement 50 tons, speed more than 36 knots which are in service today. These boats have intentionally been put through the most severe punishment to a degree which has resulted in broken frames etc., but the planking has endured this test. An evidence of this is the fact that for a recent repeated order the Navy specified the same laminated triple skin planking with thickness of ⅞ in (22 mm) maintained.

Some laboratory research tests aiming to obtain strength figures have been carried out and are still going on. As this material is not ready, as soon as there is more practical production results, especially as to the economy and picture of the building of round bilge hulls with multiple-layer "glue-welded" planking a paper will be prepared and published.

Lindblom would not bother to work along these lines if he were not convinced that there is a great possibility for "glue welded" wooden boats, but he was of course, as always, an optimist and has behind him a long and mostly happy marriage with wood which may influence his opinion. Only the future can give the definite answer.

Wood best but scarce

Cardoso (Portugal): Thanked Pedersen for an excellent paper on wood properties. It is said that steel (or even plastics) is much better than wood for fishing vessels of more than a certain length. The truth of such a statement is in fact depend-

ent on the economics of the locality concerned and has little to do with the strength properties of the materials concerned. Wood is indeed one of the very best materials available for boat building.

The problem is only that in Europe and North America it is becoming more and more difficult to find wood of good quality, especially of the heavy scantlings necessary for larger vessels. Also the skill of the ship's carpenter is of a high order and he has a hard trade. Consequently his pay increases steadily with time and he is more and more difficult to find in comparison with steel workers, for whom training facilities are much more readily available.

That this is indeed an economic reality is proved by the fact that, without doubt, in Portugal where the economic evolution described has not been so rapid, wood is still by far the better case for fishing vessels of under 82 ft (25 m) length.

Experience with plywood

Andersson (Sweden): After many years experience in building both wooden yachts and fishing and catcher vessels up to 700 GT in the traditional way, Andersson had, during the last ten years, been doing some development work with birch plywood.

This is especially for refrigerated cargo vessels, normal cargo vessels in the hold and for sun roofs etc. In ten years, it has replaced loose boards of pine and other species because of its better quality, labour simplification and improved strength, tightness, etc. The material has been developed to resist mildew and to have improved strength. This was achieved by using improved gluing methods. The pressure while gluing was increased from 100 to 200 lb/in^2 (7 to 14 kg/cm^2) to 270 to 350 lb/in^2 (18 to 22 kg/cm^2), which made it necessary to use new processes. On 8,000-ton refrigerated fruit carrying ships, the temperature in the cargo room is changing from 43° down to 7° F (+6° down to −22° C) and back—this is an additional test of the material.

Mildew was difficult to check. The usual preparations against mildew could not be used due to the regulations for the keeping of food stuffs. One new anti-mildew preparation showed great promise without being poisonous. This was tried on the surface of the plywood as well as mixed into the epoxy paint. Mildew started again after some years. It was then determined that the starch and sugar contained in the wood expanded to the surface; the anti-mildew combination was then also mixed into the glue used between the different plies. In this way the glue layers also prevented mildew attacks and the material became resistant throughout. A further improvement was made in that the plywood sheets were painted mechanically, by colour rollers using a pressure of 150 to 170 lb/in^2 (10 to 12 kg/cm^2). The primer was pressed into the wood fibres which resulted in good adhesion and density of the anti-mildew mixture paint. After priming, the panels were polished and further applications were made. Two paint types were used—epoxy and uretan. Both lacquers are of the hardening type.

The panels are made with grooves in all four sides, which results in a great labour simplification. The waste compared with loose boards has been reduced from 25 to 3 per cent. The time for fitting has been reduced to half. These materials are fully resistant against rot. Delaminations on any great scale have not taken place.

Plywood glued to metal

These refrigerated cargo ships have plywood surfaces for insulation and air ducts in the holds up to 185,000 ft^2 (17,000 m^2). The thicknesses used are ⅟₁₆, ⅜, ½, ¾ in (7, 9, 12, 18 mm). In addition 1 in (25 mm) is used for floors and the

top of bottom tanks. Truck transports up to 10 tons are carried on such floors.

An advantage of the material is that under a load it gives way and then returns to its original position. Compared with metal and steel, it is much more elastic and easy to fit.

During banana transportation, the humidity is about 95 per cent at 37 to 43° F (+3 to +6° C). On the return voyage, the holds are cooled down to −8° F (−22° C) in order to reduce the humidity. This happens at two to three week intervals during shipments between North America and Europe. This hard testing proves this material can very well be used for the construction of fishing vessels. Government agencies are issuing certificates at the request of builders and owners.

When gluing together with steel and other metals, tars of epoxy have proved to be a very useful material. It is free from water, contrary to other glue types. It has to be used with a hardener which can be timed to suit the type of work. For work which has to be carried out over a long period, the hardener can be fitted to take place 7 to 8 hours after the application of the glue. This epoxy tar prevents rot or the penetration of water. At scarphs and other connections the tar is penetrating so well into the material that delamination of the ply layers is prevented. The tar has good elasticity which makes it possible to glue together plywood with steel and other metals.

This method of gluing plywood with metals has been tested for a long period and is recommended as a good solution also when building fishing vessels.

Relative virtues of different materials

Thiberge (France): A number of the papers give the impression that this or that material is conclusively better than the others. The problem has two sides. Each of the materials mentioned has its own peculiar technical characteristics which naval architects and shipwrights must exploit as best they can, but the accompanying drawbacks must also be accepted in the various cases, and some attempt made to compensate for the weak points by correspondingly better hull construction.

Turning to Pedersen's paper in particular, it is so encyclo-paedic on the properties of wood that one wishes to translate them into practical applications immediately. Several successive stages must be gone through before one could hope to arrive at entirely novel structures for fishing boat hulls. In calculating the strength of the actual materials, it is not enough to understand the material itself; it is necessary also to know what stresses it must resist, potential strain patterns and places of maximum stress. Now, these incognita are too complex and too numerous, and as regards the values of the mean stresses to which the hull is subject under operational conditions—and those stresses will obviously vary in a number of ways depending on what sort of sea is running and, on the other hand, the hull strength factors and their reciprocal effect.

In the European fishing sector, the introduction of novel structures for wooden hulls means that several successive stages must be gone through and will need a certain amount of time, particularly in the sense of the time taken by users to try out under operational conditions the innovations as they are introduced. At all events, there have been new developments, as may be seen when one reviews the last ten years, for example, in the use of plywood, laminated frames and engine bed design. Obviously, not all innovations occur at the same place or in the same manner.

Pedersen remarked that scientific research on wood has been going on in all parts of the world over the past 50 years. The research and publications of the Tropical Forest Tech-

nology Centre at Nogent-sur-Marne, on, *inter alia*, a very wide range of African woods, should be mentioned in this connection.

One final remark, this time on the strength of European-type boats as evaluated by the Japanese. Otsu's safety co-efficient had the following values: 35 (compressive strength); 88 (tensile strength); 16.5 (shear strength). It is a matter of evaluating the strength of a part of the planking in respect of the stresses it is normally called upon to withstand. However, it is clear that the Japanese researches concluded that this type of construction has its weaknesses, in that the material "yielded" round the fastenings. Considering the cross checks made with French research conducted a few years later, a safety coefficient of 88 for tensile strength cannot allow for the working loose of joints. Can some light be thrown on this question?

Plastic sheating on wood

Verweij (Netherlands): Pedersen mentioned the possibility of sheathing wooden craft with fibre plastics. There are certainly cases where this method is attractive, but the use of fibre-glass for this purpose should be restricted to plywood boats. In a planked boat the working of the wood will eventually loosen or break the fibreglass skin unless this skin is very thick which results in excessive weight. For planked wooden craft nylon covering can be used successfully for instance by applying "cascover" or similar method. Regarding laminating of wood this is certainly a process well worth contemplating in some cases. However, it puts a rather heavy burden on the capacity of the workmen and is in general rather complicated in practice. He would hardly consider it of great value for developing countries.

Pressure treated pine in planking and fish hold lining

Haavaldsen (Norway): The proper preservation of wood in fishing vessels is of great economical importance. In Norway pine is used to a large extent in planking and girder. Technical experts strongly recommend the use of pressure treated material, but this has been prohibited by health authorities due to the risk of contamination. Since most of the pressure treated material contains soluble substances these can concentrate on the surfaces due to evaporation of water from wet material. So far known there is only one exception: Pine treated with Boliden K 33 salt holds after fixation only very heavy soluble substances (e.g. copper and chromearsenates). It was felt that this material could be used without any risk of arsenic poisoning. To throw light on the problem simple experiments were performed to see if toxic amounts could appear in fish contacting the Boliden K 33 impregnated pine. Small pieces of fish fillets weighing about 1 oz (approx. 28 g) were laid on either dry or presoaked small impregnated wood-blocks at a temperature of 50° F (10° C) for 48 hours. The fish fillets used were from Norwegian haddock and cod and were alternatively placed with the muscle or skin side contacting the impregnated material. Each fillet was trimmed never to exceed $\frac{5}{16}$ in (0.8 cm) in thickness. For the practical consideration there was no difference between the two ways of applying the samples, and in table 2 the values are combined. Each figure represents six samples.

TABLE 2
mg arsenic per g fish fillet

Days of pre-soaking in sea water	Cod	range	Norwegian Haddock	range
7	0.008	0.005–0.010	0.010	0.005–0.015
2	0.008	0.005–0.013	0.007	0.001–0.009
0	0.004	0.002–0.008	0.003	0.001–0.003

[287]

The samples were small and the flow of resin around knots made the surface inhomogenous in respect to preservation substance. This is the reason for the range observed. If larger samples of fish had been used, a narrower range would have been found. Neglecting this and taking the highest value found, 0.015 mg arsenic, as the base for consideration it will appear that a man eating 0.7 lb (0.3 kg) of a very thin fish fillet, the whole side of which had been in contact with Boliden K 33 impregnated pine, would have received a dose of 4.5 mg of arsenic corresponding to about 6 mg arsenic trioxide. Arsenic trioxide has been used for therapeutic purposes and Norwegian doctors prescribed it in daily doses of 15 mg. The lethal dose that can be found in the literature is between 70 and 180 mg. It will appear from this consideration that intoxication by arsenic contaminated fish under practical circumstances, where only a small part of the fish can be in contact with the fishholding material, cannot appear.

FUNGI ATTACK AND DECAY

Rasmussen (Denmark): Congratulated Pedersen on the admirable manner in which all the relevant information on wood properties has been compiled—ready for use for boat designers. However, naval architects are never satisfied regarding detailed information, and in this connection Rasmussen asked two questions:

While Scandinavian pine is said to be fairly good for pressure treatment, it is well-known that heartwood of pine cannot be pressure treated. Has Pedersen any additional information on the effect of fungi attack in actual practice on such heartwood parts of, for example, pressure treated construction elements of laminated pine.

The possible use of pressure treated beech as a shipbuilding material is also intriguing. Has Pedersen any detailed information on the use of pressure treated beech?

Research initiated

Pedersen (Denmark): In 1963 OECD arranged a meeting entitled Deterioration of Wood in the Marine Environment. The Icelandic delegation, headed by Bardarson, reported on an internal Icelandic meeting which had concluded that it was advisable to have the following co-operative work: fundamental scientific work by institutes in OECD member-countries only, and technical and practical work by wooden shipyards, associations and others interested in the problem, under the guidance of the Government authorities. The main subjects for fundamental research could be the following:

● Study of fungi causing decay in wooden boats
● Species of timber especially susceptible to decay by fungi and marine borers etc
● Effect of different treatment of wood
● Non-destructive methods for testing for decay and borers in wooden boats

The main subjects for technical and practical work could be:

● Selection of timber for wooden shipbuilding and quality certification
● Storage of timber for shipbuilding
● Practical possibilities of treatment of wood for shipbuilding (boiling, drying, impregnation etc)
● Construction details in wooden vessels, influencing the ecology of fungi and marine borers
● Practical aspects regarding repairing of wooden vessel already damaged by fungi or marine borers

In the OECD meeting, Harmsen (Myceological Laboratory, Wood Dept, Technological Institute, Copenhagen, Denmark) stated that in many cases deteriorated oak was infected before assembly (*Polyporus sulphureus* and *Stereum* spp), and in other cases the decay was due to absorption of water through leaks, condensation and/or poor ventilation (*Coniophora cerebella*). Table 3 summarizes the fungi observed in samples of different wood species. Often more than one species of fungi were found in the same boat. The table gives no information concerning the relation between attacked and sound boats, this relation may be more than 10 per cent. The expense in repair varies from a negligible amount to £3,000 ($8,500), or even sometimes more than the insurance value of the vessel. The number of motor fishing vessels in Denmark is approximately 8,300 of which about 4,300 are less than 5 GT. In Denmark 13 local mutual insurance companies insure against losses due to "fast-growing" fungi and only such attacks are covered by the insurance.

In table 4 detailed figures showing the Danish condition are given. In the period 1950-64 the insurance companies have paid a total amount of 3.2 million dkr (£160,000 or $450,000) distributed on 253 vessels repaired. Owners themselves have paid an amount approximately of 900,000 dkr (£45,000 or $125,000). Economical losses due to attacks of "slow-growing" fungi (i.e. soft rot) are assumed to be of the same magnitude and may be approximately 4 million dkr (£200,000 or $560,000). The average costs of repair of detected damages therefore may be approximately 1 million dkr

TABLE 3

Fungi observed in Danish wooden boats (mainly fishing boats) as of August 1963—219 boats

Fungus species	Pinus (pine, fir)	Picea (spruce)	Larix (larch)	Pseudotsuga (dougl. fir)	Fagus (beech)	Fraxinus (ash)	Quercus (oak)	Un-known	Total	per cent of samples
Coniophora cerebella	35	18	2	2	3	2	95	1	158	81
Polyporus sulphureus	—	—	—	—	—	—	15	—	15	7
Polyporus spp *	7	3	—	1	2	—	4	1	18	8 ⎫ 30
Polyporus sp (unidentified)	8	1	—	1	—	—	22	1	33	15 ⎭
Stereum hirsutum	—	—	—	—	1	—	24	—	25	11
Stereum frustulatum	—	—	—	—	—	—	4	—	4	2 ⎫ 18
Stereum sp	—	—	—	—	—	—	9	1	10	5 ⎭
Other species †	10	1	—	3	—	—	6	—	20	
Unidentified	13	5	—	2	—	4	20	2	44	
Soft rot	2	3	—	—	2	1	35	1	44	
Electrochemical attack	1	—	—	—	—	—	5	—	6	

* *Fomes fomentariusm, Polyporus balsameus, P.versicolor, Poria monticola, P.vaillantii, P. xantha, Trametes serialis*
† includes *Coprinus* sp, *Paxillus, Schizophyllum, Hymenochaete, Corticium, Peniophora*, blue stain fungi and moulds
Insects: *Xestobium rufovillosum*, 1 sample, oak. *Nacerdes melanura*, 1 sample, oak.

(£50,000 or $140,000) per year. The insurance value of the fishing fleet in 1962 was about 400 million dkr (£20 million or $56 million). The number of fungi-attacked vessels was

24 vessels	older than 40 years	before 1925
65 vessels	between 30–40 years	1926–1935
85 vessels	between 20–30 years	1936–1945
17 vessels	between 10–20 years	1946–1955

TABLE 4
Economical losses due to detected and repaired fungi attacks in Danish wooden fishing vessels

Year	No. of repaired vessels	Amount paid 1,000 dkr	Insurance value of fleet in million dkr	No. of vessels in fleet (>5 GT)
1950	1	20	142	··
1951	—	—	144	—
1952	2	31	160	—
1953	2	21	163	3,597
1954	2	29	167	3,590
1955	7	106	173	3,578
1956	7	55	184	3,567
1957	19	211	208	3,633
1958	27	205	234	3,682
1959	22	218	290	3,814
1960	24	290	366	3,970
1961	22	298	417	4,045
1962	43	526	438	4,060
1963	75*	1,215*	—	4,062
Total		3,216		
Owners' own risk		880	7 dkr 1 US dollar	
		4,096	=4.1 million dkr	
			20 dkr = 1 pound sterling	

*sum of non-specified attacks

Information on 62 vessels is lacking. To illustrate Harmsen's statements, fig 10 shows a great knot with white-pocket rot situated in a floor member in a vessel during construction in a Danish yard. Fig 11 is taken from Cartwright (1958) and shows an axial cut-through such a knot with white-pocket rot, caused by the fungi species *Stereum gausapatum*, which attacks dead branches on living trees.

In 1950 the Danish Ministry of Fisheries built a fishery research and inspection vessel, *Jens Vaever*, at a well-known shipyard. It was built with first-class workmanship and had tight-fitting ceilings in all cabins etc. Nine years later this vessel was condemned. The fungi (*Stereum hirsutum*) had eaten most of the longitudinal strength timbers. The fungi in question especially likes sapwood of white oak and infected sapwood must have been fitted when the vessel was built. In the shipyard, just as in most other traditional Danish yards, wood logs and even planks are placed on the ground where the risk of infection by fungi is especially high. Due to the high moisture level in newly cut timber, the wood provides a good growing substance for spores and mycelia of wood-destroying fungi, created from adjacent pieces of rotting timber lying in the yard.

Wood can be compared with meat, and the following question is relevant: "does anybody dream of placing a lump of raw meat on the ground for a week in summertime before eating it?" The next question therefore is: "why then is it permitted to use wood which has been placed on the ground and consequently infected by fungi, as a boatbuilding material?" The result may be either that human lives and material are lost for unknown reasons at sea, or the attack

Fig 10. Knot with White Pocket Rot in a floor member

Fig 11. Axial cut through a knot with White Pocket

TABLE 5
Loss of lives and material in Denmark during the period 1951-64

Loss of lives of Danish fishermen: Causes	1951	52	53	54	55	56	57	58	59	60	61	62	63	64
Suspicious: in connection with wreckage for unknown reasons	6	5	13	- -	13	15	13	13	8	1	4	21	—	---
Suspicious: unspecified reasons	2	1	3	—	--	4	3	1	1	—	1	—	---	—
Unsuspicious: specified reasons	16	20	15	21	13	12	14	15	6	13	12	14	·--	·--
Total loss of lives:	24	25	31	21	26	31	30	29	15	14	17	35[1]	15	19
Loss of Danish fishing vessels:														
Suspicious: sprung a leak for unknown reasons	2	3	6	6	1	1	2	—	2	·--	5	2	1	3
Suspicious: wrecked for unknown reasons	7	5	7	1	2	7	6	3	4	3	2	6	6	4
Unsuspicious: specified reasons	13	8	10	10	13	5	3	8	5	13	13	12	6	5
Total loss of fishing vessels:	22	16	23	17	16	13	11	11	11	16	20	20[2]	13	12

[1]Including 11 losses in connection with losses of 5 steel vessels.
[2]Including 5 losses of steel vessels.

is detected in time and repaired as shown in fig 12. As shown by Cartwright and mentioned in Pedersen's paper, even a slight attack by fungi has a serious weakening effect on impact load strength properties of wood.

In addition to being a problem of high economical importance, decay is also a problem of safety. In table 5 from the statistics issued by the Danish Ministry of Fisheries, a classification is given of losses of lives and vessels. In 1951 to 1964 128 fishermen and 97 vessels have been lost due to unspecified reasons. Some losses may be caused by attacks from wood-destroying fungi in the timber structure.

Fig 12. Fungi attacked wooden fishing vessel under repair

Icelandic investigations

Bardarson (Iceland): Owing to serious damage in wooden fishing vessels, caused by fungi, the Icelandic Government began in 1955 to assist owners of the vessels involved. Thus the Government paid compensation in the form of 90 per cent of repair cost as follows:

Year	£	US $
1955	31,300	87,613
1956	76,600	214,145
1957	188,000	527,245

When the fungi attack (mainly *Coniophora cerebella* and some *Poria* spp) was discovered in increasing number of vessels an insurance system was created by Law of 29th April 1958 and committed to the Icelandic Fishing Vessels Joint Insurance Institute.

Since the beginning of this Insurance system compensations have been paid as follows:

Year		
1958	92,500	259,782
1959	185,006	517,192
1960	73,300	205,230
1961	117,000	328,155
1962	83,000	232,234
1963	137,761	384,450
1964	247,874	691,742
1965	375,349	1,047,485
Total:	1,311,790	3,666,270

(The figures for 1965 are partly estimated.)

The figures of the years 1958 to 1965 incl. represent approximately 75 per cent of the actual repair costs, as the vessels owners have in their own risk 10 per cent and also one-third of new material for old.

The number of vessels insured against fungi-attacks has been about 600 vessels in recent years, and the insurance amount, which is based on 90 per cent of hull value and other woodwork (machinery and equipment is excluded) is about £485,000 (US $1,354,000). Until the year 1960 the approximate annual addition was about 25 new wooden fishing vessels to the fleet, worth about £250,000 (US $700,000). Since 1960 almost all new-built Icelandic fishing vessels are of steel—only a few of the smallest types are still built of wood.

In the year 1958, when the fungi-insurance began, until, and including 1962, 85 wooden vessels have been repaired after such damage, and eight have been condemned as total loss.

In the year 1963, 17 vessels were involved in fungi-attack; of these 13 vessels were repaired and four vessels condemned.

In 1964, 32 vessels were involved; of these 19 vessels were repaired and 13 vessels condemned.

In 1965, 47 vessels suffered fungi-attack; thereof 23 vessels were repaired and 24 vessels condemned.

Precautionary treatment

When repairing wooden Icelandic fishing vessels, and in new buildings care is taken to use the best available wood quality, and although not artificially dried, it is treated with fungi-destroying chemical preservatives, containing at least 5 per cent of pentachlorphenol according to request by the State Directorate of Shipping. At the same time care is taken to ventilate as far as possible the closed-in spaces where structural members are covered with ceiling, watertanks etc. Experience has shown that fungi attack is very seldom in the engine-room where dry, hot air keeps the moisture in the timber lower. Further mechanical ventilation of other parts of wooden fishing vessels and also artificial periodical drying out (dehumidification) of existing wooden vessels with repeated conservation by chemical preservatives containing pentachlorphenol is now under consideration in Iceland.

In spite of the fact that more than 90 per cent of new-built fishing vessels for Iceland are now built of steel, there are still many wooden vessels in the Icelandic fishing fleet, and the smallest ships are still built of wood.

WFA survey in UK

Sutherland (UK): A decay survey was instigated by the White Fish Authority in conjunction with Forest Products Research Laboratory and Torry Research Station, both of the Ministry of Technology, to investigate the increased incidence of decay in the fishrooms of Scottish wooden fishing vessels.

Forest Products Research Laboratory have been acting as advisors, examining specimens of decayed timber removed from fishing vessels and determining the species of fungi found.

Torry Research Station are engaged in testing the effects of a variety of wood preservatives on the quality of fish by treating fish boxes, keeping fish in the boxes, later cooking and testing the quality of the fish by means of a taste panel. The report is still awaited but it is known that rather wide differences in the results have been found.

The Authority are carrying out the field research and a large number of fishing vessels are being surveyed for signs of decay. Moisture content surveys are being carried out by drilling into the timbers with a borer or an auger and extracting cores of up to 2½ in (63 mm) long. These cores are weighed almost immediately, dried in an oven at 212° F

(100° C) for 4 hours, then reweighed. Wide divergencies of moisture content have been found in the same fishroom, and readings from 20 to 120 per cent have been recorded. Readings are also being taken before and during building to determine the exact amount of drying that takes place during building. These new vessels are to be checked periodically to record the build-up or otherwise of moisture content.

In new construction certain remedial steps have been taken, the main ones being—oak has superseded larch for ordinary beams, the deck planking is pressure-impregnated and all other wooden members of the boat are either dipped or surface treated with a wood preservative.

The use of more decay resistant timbers is being investigated and in some cases, is being tried.

The problem in the case of existing fishing vessels is more serious as the replacement of susceptible timber by more decay-resistant timber would be a long and expensive process.

It is advised that the fishroom should be dried, the paint removed and the whole of the interior timber surface treated with a wood preservative and that no repainting should take place. This treatment should be repeated at each annual overhaul.

Possible remedy for decay

Forest Products Research Laboratory have suggested a possible remedy for the decay in fishing vessels which is now being examined. A specified amount of a borax paste is applied to the larch beams. The paste diffuses into the timber, killing any incipient decay and inhibiting the timber from future attacks.

Twelve pieces of larch, 6 in (15 cm) square and 14 in (35.6 cm) long similar to that supplied to the boatyards were prepared by Forest Products Research Laboratory in the following manner. Two ⅝ in (16 mm) holes were drilled through from top to bottom and the holes packed with borax paste. One of the holes was plugged at both ends whilst the other hole was plugged only at the bottom in order to ascertain whether diffusion is more rapid with one end open to the humid atmosphere of a fishroom. The blocks which were painted with bitumen leaving the top face bare, were then fitted alongside the beams on three different fishing vessels, four to each boat, leaving the top bare surface slightly below the decking to allow the moisture to gain access to the bare face of the treated blocks. A further 12 blocks, treated in a similar manner were retained at Forest Products Research Laboratory to act as a control.

This treatment, if successful will enable vessels to be protected at a reasonable cost. A quantity of this borax paste has now been supplied by Forest Products Research Laboratory and will be tried on a number of fishing vessels. Borings will be made at regular intervals to follow the movement of the paste into the timber. A U-shaped piece of cheap timber painted all over will be fixed alongside a larch beam which has had all sealing materials, such as paint, removed. The groove will be packed with the solution. The paste is made up as follows:

	weight	parts
"Timbor" (trade name for borax powder)	5 lb	80
Water	5 lb	80
"Polycel" (wallpaper adhesive) .	1 oz	1
Ethylene glycol . . .	2 oz	2

The dry "Timbor" and "Polycel" are mixed together and then added slowly to the ethylene glycol and water, stirring the mixture all the time. The paste is ready for use about 24 hours later and should be sufficient in quantity to treat three deck beams. Approximately 1 lb of paste is required

per yard (0.5 kg per m) of beam with a section of 6×8 in (15×20 cm), which means that the groove in the U-shaped timber should be ½ to 1 in (12 to 25 mm).

It is necessary, when surface preservative treatment is to be carried out on a fishing vessel, that the timbers should be dried and all paint removed whereas with the borax treatment only a small area of paintwork requires to be removed and the wetter the timber, the quicker the diffusion.

Tentative conclusions

Some conclusions have been reached as a result of the work carried out up to the present. It appears that the larch members of the fishroom show appreciable drying while the oak members show little difference in moisture content. This is not so important as oak is more resistant to decay. Further work is required in this field to establish how often forced drying would need to be carried out to yield a cumulative effect which could be expected to reduce the overall decay hazard.

Although there is a wide range of moisture content readings in the same fishroom there is one common factor. The timber in and around the ice lockers and especially the beams above the ice locker are very wet, giving a clear indication of the detrimental effect of open ice lockers. This in itself suggests a strong argument for ice lockers to be made in the form of insulated vapour-proof boxes separated from the fishroom main timbers to allow free ventilation.

It will be seen from table 6 that the main fungal attack on the larch beams has been identified as *Coniophora cerebella* (Cellar fungus) and the main fungus identified in decayed Douglas fir is *Poria monticola*. This latter fungus is not natural to UK but is imported in the Oregon pine from North America. The spores of the fungus lie dormant in the timber but become active under suitable conditions.

The treatment of Douglas fir decking by pressure impregnation will stop the spread of the fungus from one plank to another and thence to the beams. It will not stop the internal decay within any plank that contains those spores as only sterilization and pressure impregnation would make certain of decay-free timber. Decay in oak is more severe where linings have been or are fitted to the fishroom and suitable ventilation is not present. Several cases of decay in oak were due to sapwood being present and in others red or turkey oak had been used instead of European oak. This red oak, which is no more resistant to decay than larch, is almost impossible to distinguish with the naked eye from white oak. (Pedersen (Denmark) advised a study of the guide for distinguishing red oak from white in US 1957–62, Vol I, pp 8–10).

TABLE 6

Material from 20 Scottish-built boats examined (a few samples came from sources other than the WFA). The table shows the number of boats in which decay by the fungi listed was confirmed in the timber species indicated

Timber	Conio-phora cere-bella	Poria monti-cola	P.† car-bonica	Poria sp	Un-known wood dest-royer	Ster-eum sp
Larch . .	9	3		1		
Oak . .	2				1	
Red Oak .						2
Douglas Fir .	2	9*	1	1	1	
Gurjun .					1	
Baltic Redwood .					1	

*Includes two instances where, by inference, the fungus had spread from Douglas fir to larch.
†*Poria carbonica* is like *P. monticola*, a North American fungus.

Importance of joints and scarphs

Pedersen (Denmark): As mentioned by Potter and as is well-known to all boatbuilders, the strength and stiffness of a wooden boat depends on the joints. Their strength depends on their fitting and the right distribution of proper fastenings. The moisture content must also be on the same level as in service to avoid open seams and loose fastenings. Vital details, such as keys and dowels of hard wood, placed in the scarphs to take shear, have been "forgotten" in the last decades. Boatbuilders claim that they are time-consuming to fit and therefore the cost will rise if such "refinements" are insisted upon. The result has been an increase in scantlings in individual members (when comparing Danish rules issued in 1933 and 1947). This has created an even more unfavourable ratio between strength of joints and strength of scantlings, consequently there is a general **decrease** in overall strength.

Fig 13 shows that timbers in sawn double frames formerly were connected by fastenings placed near the edges, while present-day practice only shows fastenings placed in the neutral axis of the frame members. Detailed performances showing joints of varying efficiency as found by tests should be given for the advice of the boatbuilder and scantlings should be determined accordingly.

Fig 14 shows floor/frame joints in a vessel under construction. When supplies of curved shipbuilding timber were plentiful, there was no trouble to find the right piece of timber for every curved member. Scantlings-rules were based on this. Today it is not unusual to find curved pieces sawn from straight or nearly straight timber, with cross grain as the result, thus having little strength.

Fig 15 shows a part of the frame system of a wooden vessel. In one of the timber pieces, a long shake running across the member can be seen. Fig 16 was taken in a flat-bottomed vessel (ferry). At both ends, approximately one third of vessel's length from stems, all floor members are notched down to half the rule moulding, consequently reducing the strength of this vital point on the floor element. What is the reason for demanding heavy rule scantlings outside the notches, when such strength-reducing notches are tolerated at this vital spot?

FORMER-DAY PERFORMANCE.

PRESENT DAY PERFORMANCE.

Fig 13. Double frame practice formerly and today (types and distribution of fastening and wooden keys in old type frames)

Fig 15. Shake due to cross grain in a frame member

Fig 14. Performance of frame joints in a vessel under construction

Fig 16. Floor member notched down to give place for propeller shaft

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Lamination

Hareide (Norway): Added some comments on experience of laminates in Norway. A series of experiments are at the moment in progress but not yet complete. They feel that by the correct use of laminated structures, much strength can be gained. Temperature and humidity control are essential. If not correctly laminated under right conditions, laminates are liable to disintegrate either in a short while or maybe over a long period. Machinery is important and at the moment still not satisfactory. In Norway they still use manual assembly but are experimenting with machinery.

Sinclair (UK): It would seem, from comments so far made, that the fabrication of laminated members is very difficult. This is not the truth; a well laid out shop and good supervision can provide laminations without a great deal of highly skilled labour. A slatted platform which can be used in the same way as a steel frame slab can be erected above hot water pipes supplied by an ordinary central heating boiler and pump. The glued members can be covered by tarpaulins and left to set overnight. It is not claimed that laminations are better than, only a substitute for, natural frames, beams etc. when natural wood supplies are difficult. Both can be incorporated in the same vessel.

Glue lines in laminations can easily be tested for adhesion but the real test is whether they will last for 15 to 20 years.

In't Veld (Norway): As the technical leader of a boatyard in Norway building laminated and pressure treated fishing boats for the North Atlantic, In't Veld said that it is not so simple as Sinclair said. It is not only the heating, but also and maybe more important is the moisture, which is supplied while heating for hardening and it is the moisture in the timber before glueing, temperature in working sheds, drying methods of pressure treated wood, and so on.

Another difficulty is training the workers and in Norway the skilled boatbuilders are "dying out". This is the only reason why fishing boats are made of steel. The average age of boatbuilders in his yard is 45 years, but they are now training a new generation. This boatyard has built about 400 ships since 1902 in a district where almost everyone was a boatbuilder.

To make clear the difficulties in the laminating method there have been examples of boats falling to pieces. Well, these boats were made by yards where it was believed that laminating was a simple affair, but these yards were no longer in existence. This happened at the beginning of the laminated period.

The laminations are controlled by the Norwegian Wood Council to the rules of the Norske Veritas. Everyone ordering a laminated vessel has to insist on inspection by an authoritative institution, to the rules of Norske Veritas or similar.

Traung (FAO): There was a meeting in Denmark in 1964 to consider wood for shipbuilding. It was announced that Norske Veritas had rules for laminated fishing vessels since 1955. If a boat was built in Denmark to the rules of Norske Veritas, would the boat be approved—the answers were "yes". Now Hareide indicates that he is working on some new rules for laminated wooden fishing vessels in Norway—will the Norske Veritas rules be amended?

Hareide (Norway): They are not working on new rules, they are experimenting to improve the procedure of lamination. The further purpose is to facilitate the work and give guidance to shipbuilders, thereby promoting safety and reduction of prices.

The rules of Det Norske Veritas on wooden vessels have been approved by the Norwegian Authorities, and are now under revision.

Retvig (Denmark): Denmark has no rules for lamination of fishing vessels. If any owner wishes to build with laminating, the Danish authorities will approve the vessel, if it is classed in Norske Veritas or Bureau Veritas.

If the owner wishes his vessel to be unclassed, the Danish authorities will approve the dimensions after the classification rules, as regard laminated ships. For conventionally built wooden fishing vessels the rules issued by the Danish Government are known to be near the strictest in the world and need to be revised, in order to save wood and weight. It is difficult to take the necessary steps for such revision until there will be similar rules for all the Scandinavian countries and perhaps UK and Germany, for fishing vessels operating in the same area and under same circumstances.

Scantling rules

Pedersen (Denmark): Gnanadoss (1960) compared scantlings in respect of cubic content of timber per 1 m (3.28 ft) length amidship for: Simpson's (1960) proposals; New England trawlers as built (no rules); Bureau Veritas, France; Danish Government rules; Swedish rules; Newfoundland rules; Hanson's (1960) experience data (US Pacific coast). Conclusions:

- Small and medium-sized boats are much more heavily built than would appear necessary according to Simpson's proposal
- Boats built to the Danish rules are the heaviest in the categories analysed
- Newfoundland rules lay down that where timber other than Newfoundland timber is used, it may be sided and moulded ½ in (12.7 mm) smaller if the construction is entirely of hard wood. This reduction does not appear sufficient in the larger boats
- It might be possible to evolve unit weights for the different categories of boats, which may form also a basis for estimating the total weight of the hull
- The possibility of gathering further information to cover small boats, to compare the existing scantlings and to suggest more judicious and rational use of timbers
- Gnanadoss' comparisons form a basis for comparing scantling regulations in several other countries and eventually to formulate uniform regulations
- Simpson's proposals appear a fair basis for determining the scantlings and are a fine blend of scientific knowledge with practical experience

In 1964 the Danish Wood Council in co-operation with the FAO Fishing Boat Section arranged an international meeting in Copenhagen entitled "Structural research on wooden fishing vessels". Forty participants from 15 countries agreed:

- That a non-dimensional approach based on expected strains and stresses and applicable to various methods of construction should be encouraged
- That it would appear important as a first step to decide upon common rules for defined geographical regions
- That at the same time no effort should be spared to utilize existing knowledge and rules for the intermediate establishment of a more rational rule basis. This should encourage improvement of local building practice, improving the safety and economy of vessels by better utilization of building materials
- That continuing international co-operation in establishing such rules should be encouraged by all means

- That ways and means should be found to allow for a co-ordination of individual studies in this direction to be effected, and
- That proper preservation of wood is of equal importance as the provision of suitable scantling rules

Pedersen had carried out work following the conclusions. Rules issued by the following authorities (Classification Societies and Governmental bodies) were compared:

A Bureau Veritas, 1963	A1:	double frames
	A2:	glue-laminated frames
B German Lloyd, 1964	B1:	single frames
	B2:	double-frames
	B3:	glue-laminated frames
C Danish Governmental rules, 1947	CI:	open double frames
	CII:	closed double frames
D Swedish Governmental rules, 1952	D:	double frames
E Norwegian Veritas, 1955/57	E1:	double frames
	E2:	glue-laminated frames
F White Fish Authority, Scotland, 1960	F:	single and double frames
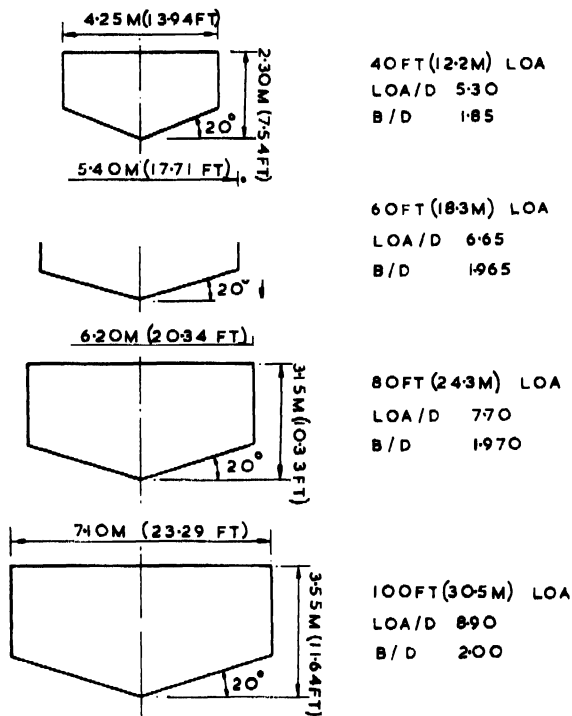
Fig 17. Midship sections of vessels

Four basic vessels of length 40, 60, 80 and 100 ft (12, 18, 24 and 30 m) LOA and same type of midship section, fig 17, were compared in respect of the following terms:

weight over strength of longitudinal and transverse strength members
utilization of material (solidity)
weight over capacity
cargo carrying efficiency (deadweight:displacement ratio).

The following assumptions were made:

1. All wood material assumed to be homogeneous and isotropic

2. No joints in longitudinal and transverse strength members
3. Only one part of a double frame was considered to be effective when calculating section modulus for double frames
4. Keel, keelson and garboard material to be concentrated at keelcorner
5. Bilgeplanks and bilgestringers to be concentrated at bilgecorners
6. Sheerstrakes, beamshelves, beamclamps and covering boards to be concentrated at the deck side corners
7. Principal dimensions determined from fig 18 (figures given in Danish rules as table 1A, page 11)
8. Section modulus for midship sectional cross area was calculated in the traditional way (1 m deck planking area is excluded for hatch opening)
9. Section modulus per 1 m floor frame and beam system was calculated from the following equation:
$$W_s = \frac{b \times h^2}{s}, \text{ where } b = \text{siding of one part, } h =$$
moulding and s = frame spacing
(Reference: Bureau Veritas rules 1963, page 15, article 5–21–45, and page 20, article 5–46–3)
10. Floor members to be considered as members lying between keel and bilge
11. Frame members to be considered as members lying between bilge and deck corner.
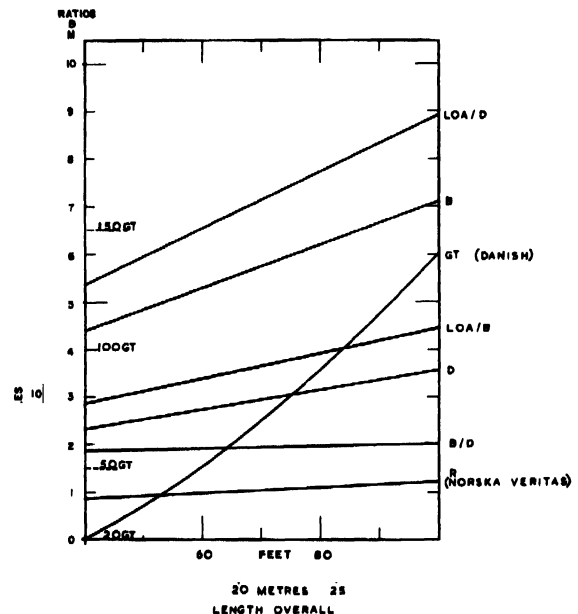
Fig 18. Principal dimensions of vessels

The results of these calculations are given in fig 19 to 26. The conclusions are:

Weight/strength of longitudinal and transverse strength members

Fig 19 shows how much longitudinal material is used to obtain the same section modulus of the mid-sec area. All rules compare very equally in this respect. The curves are downward sloping, which is surprising as it was thought that more longitudinal material was needed for the larger sizes. The longitudinal material seems to be better utilized in the larger sizes than in smaller. An explanation may be that local strength requires nearly the same thickness of hull planking for all sizes. The diverging character of the Scottish curve F in the upper size range is remarkable.
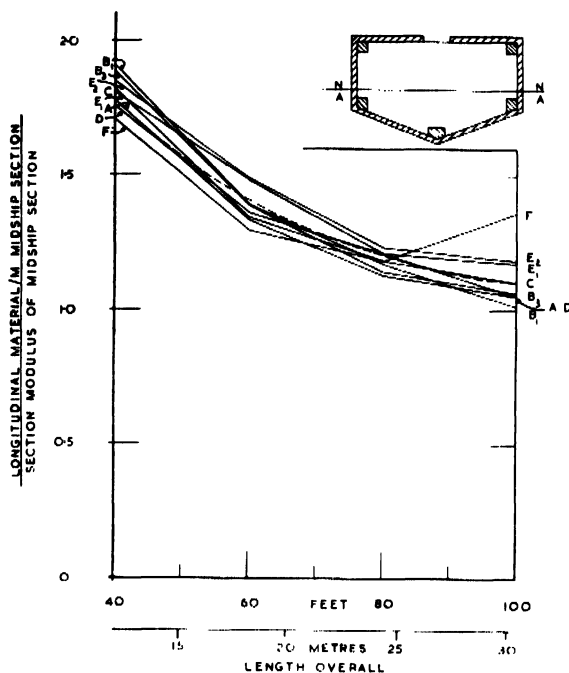
*g 19. Longitudinal material per 1 m mid-sec area: section modulus
of mid-sec area*

In fig 20 the values differ widely. Curves E₁ (Norwegian
critas) and B₂ (German Lloyd, double frames) show the
ost unfavourable values, while curves A₂ (Bureau Veritas,
u-lam frames) and B₃ (German Lloyd, glu-lam frames) show
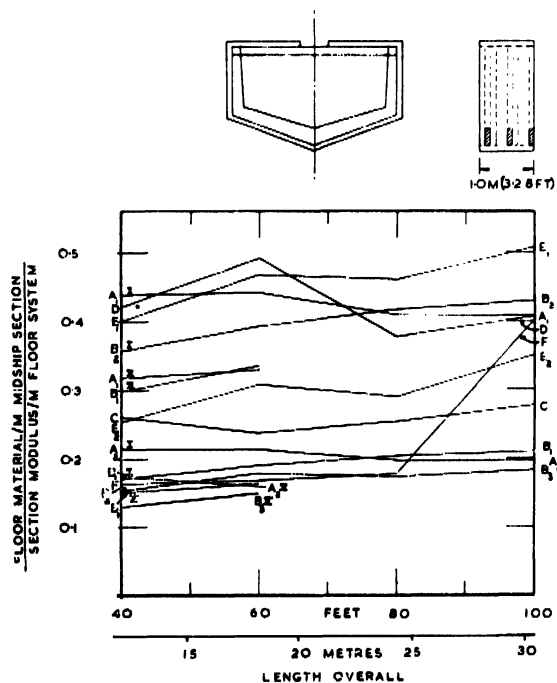e best. Danish curve C, CI and CII show intermediate
.lues.

*Fig 20. Floor material per 1 m mid-sec area: section modulus per 1 m
floor system*

In fig 21 the curve A1 (Bureau Veritas, double frames)
compares most unfavourably, and curves B₁ (German Lloyd,
single frames) and F (Scottish rules, single frames) show best
values. Danish curve C lies in the upper range of the diagram.
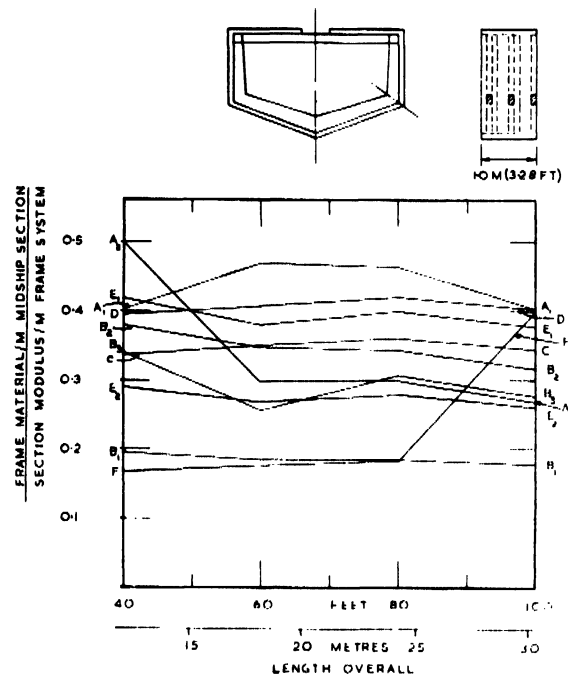
*Fig 21. Frame material per 1 m mid-sec area: section modulus per .
frame system*

The curves A₂ and A₁ (Bureau Veritas) in fig 22 show m
unfavourable values, while curves D (Swedish) and F (Scotti
show best. The Scottish curve F shows a remarkable 1
value in the 60 ft range. The Danish curve C shows
intermediate trend of all curves given.
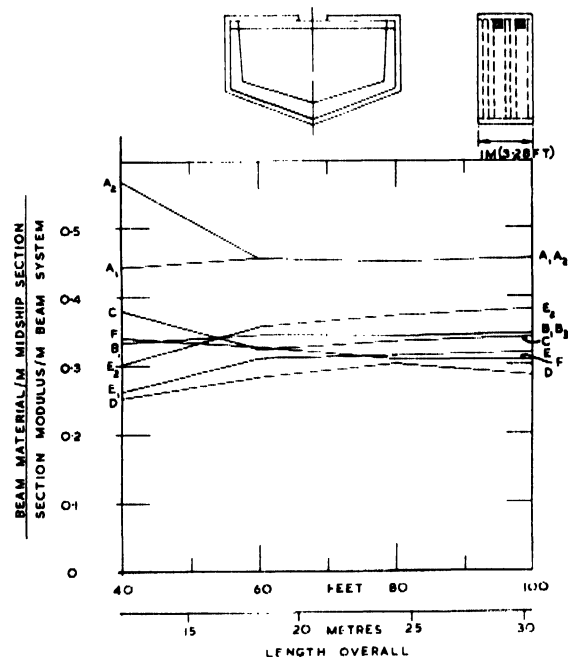
*Fig 22. Beam material per 1 m mid-sec area: section modulus per 1 m
beam system*

Utilization of material (solidity)

This is a concept used in aircraft design to compare how
well material is utilized in the same structure made in different
applications. The curves CI and CII (Danish) in fig 23 show

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most unfavourably while the curves A_2 (Bureau Veritas, glu-lam frames) and B_3 (German Lloyd, glu-lam frames) show most favourable values.
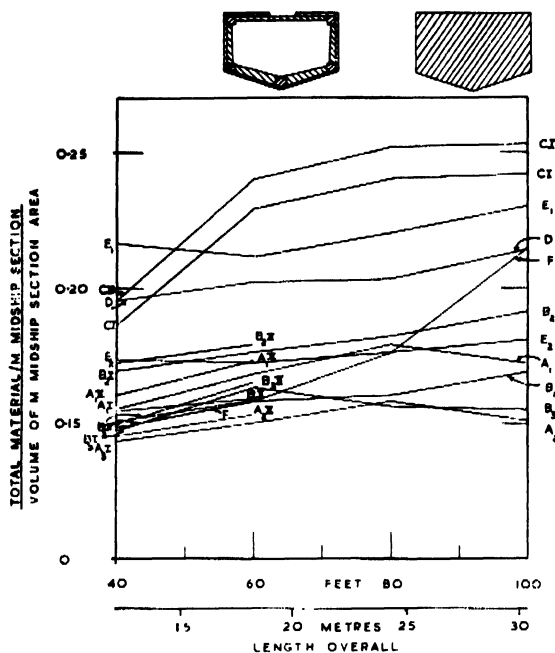
Fig 23. Total material per m structure of mid-sec area: volume of a 1 m prism with mid-sec area

Weight/capacity

Fig 24 shows how much material is used in order to obtain the same payload volume. Payload volume is a rough
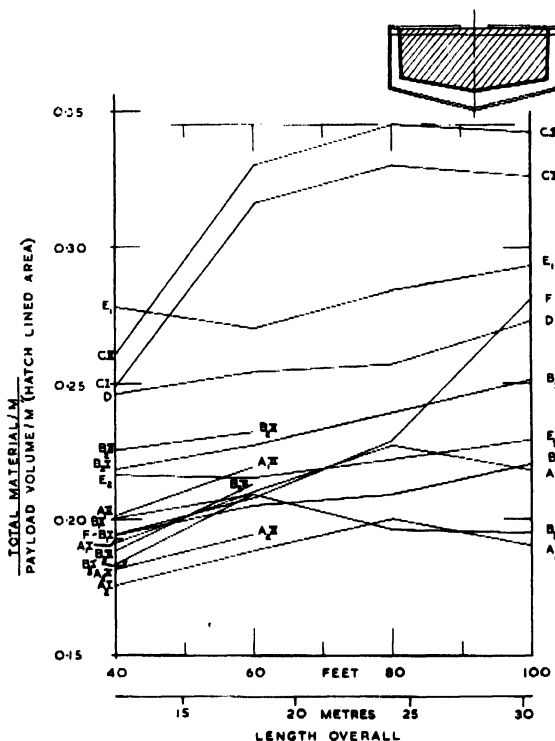
Fig 24. Total material per 1 m mid-sec area: payload volume per 1 m mid-sec area

measure for GT of the vessel. Here the curves CI and CII (Danish) compare worst, while curves B_3 and A_2 show best values.
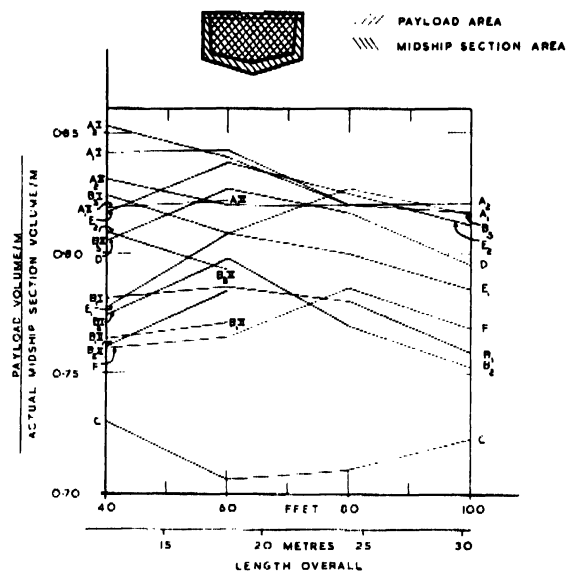
Fig 25. Payload volume per 1 m mid-sec area: actual volume per 1 m mid-sec area

Fig 25 shows roughly measure of the "tonnage factor" or GT:displacement ratio. Here the Danish curve C naturally shows the lowest values due to the great moulding of the transverse members. This, claimed to be favourable by Danish boatbuilders, is only apparently favourable because it is gained at the cost of heavy amounts of timber.
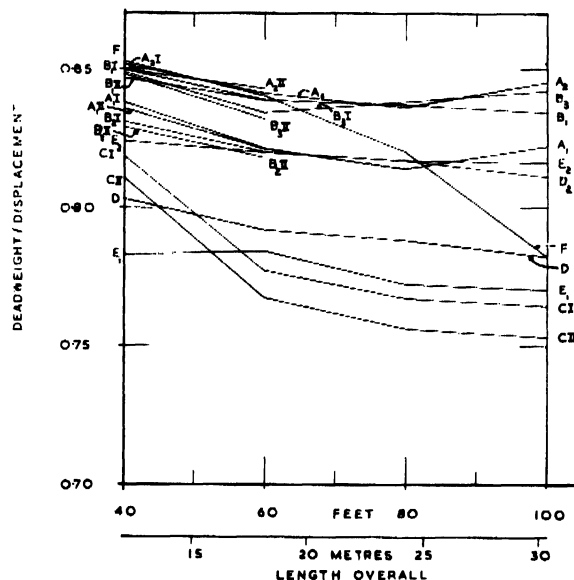
Fig 26. Deadweight: displacement ratio

Cargo carrying efficiency expressed by the term —deadweight: displacement ratio

Fig 26 indicates the cargo carrying ability or efficiency for vessels compared. As deadweight is equal to displacement minus weight of light ship, it is obvious that values approaching unity are most favourable. The curves A_2

and B_3 show most favourable values, while the curves CI and CII show most unfavourable.

The Danish rules permit two different double-frame systems, see fig 27. A fixed timber-spacing and not a fixed frame-spacing is prescribed by the rules, and it is left to the boatbuilder if he prefers open double frames with 2 in (50 mm) distance between the timber parts or closed double frames, in which the timber parts lie close together. In practice the same vessel can be either built with a greater number of relatively stronger closed double frames or a smaller number of relatively weaker open double frames. In the calculation differences occurred, as only frame spacing is used in the equation, but even greater differences than shown in the graphs exist in practice. In no other rules does this strange situation occur, although the two performances of double frames are also allowed in other rules (i.e. Norwegian Veritas).

As a general conclusion, it may be said that material seems to be utilized and distributed most efficiently in vessels built in accordance with the rules issued by Bureau Veritas 1963 and German Lloyd 1964 for vessels built from glued-laminated strength members, while the most inefficient use and distribution of material seems to be prescribed in the rules issued by the Danish authorities, 1947.

DANISH RULES:1947

TIMBER SPACING: t, fixed.
FRAME SPACING: s, vary.

NORWEGIAN VERITAS 1955

TIMBER SPACING: t, vary
FRAME SPACING: s fixed
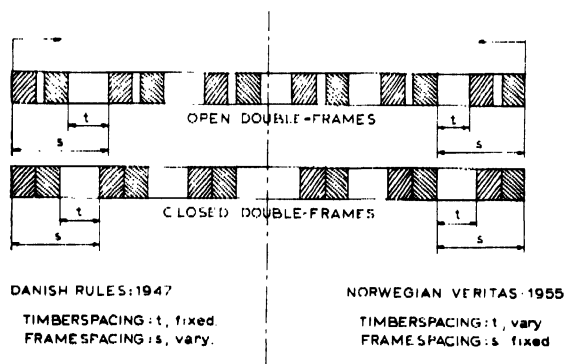
Fig 27. Frame and timber spacing in open and closed frame performances according to Danish and Norwegian rules

Boat strength basis

Sutherland (UK): Pedersen is at least a courageous man and if his tables of comparison were designed to make official bodies wake up to the discrepancies in scantling sizes in the wooden fishing fleets fishing in the same waters he succeeded in his purpose. However, it is suggested that until there is a basic strength requirement from which to work such comparisons are of little use except possibly to make those nations whose vessels are in the more favourable side of the diagrams sit back complacently and say "Well, we always knew our boats were stronger".

Can Pedersen say what the strength requirements are and if so, on what does he base his findings?

The divergence shown on each of the graphs for the Scottish scantlings are of course due to the fact that at 80 ft (24 m) the single sawn frames become double. The reason for this is that the sizes of timber required for single sawn frames are difficult if not impossible to obtain. However, it is doubtful if any fishing boat of over 80 ft (24 m) will be built of wood in the UK in the future.

Wood versus steel

Bardarson (Iceland): Congratulated Pedersen for his excellent paper. Wood has been the material mainly used for smaller Icelandic fishing vessels for centuries, and for many many

years there have been Icelandic rules for the construction of wooden vessels up to about 250 GT.

Such vessels have been built both in Iceland and abroad, the main structural members being of oak. During the last ten years time, the problem of fungi in wooden vessels, very costly repairs and the general increases in the size of Icelandic fishing vessels, has had the result that new vessels are being built more and more of steel. Many Icelandic wooden shipyards are now starting the building of all-welded steel ships instead of wood. It has been found that after the changing over there is still sufficient work for the wooden ship-builders in a small steel shipyard. Craftsmen in wood make the moulding loftwork, erection and lining up of the steel ships, and there is a considerable amount of woodwork in every steel vessel.

They have built even very small boats of steel, down to 33 ft (10 m) decked vessels, but with increase in size, all-welded steel has more advantages over wood construction. Above 80 to 100 GT the all-welded steel vessel is very much superior to the wooden vessel.

Although not believing in the future of larger wooden vessels, Bardarson again expressed his thanks to Pedersen for his excellent and very interesting paper. He was sure it will be studied carefully by everyone concerned in the building of smaller fishing vessels. He agreed with Pedersen's views that new developments in wooden shipbuilding must be found if wood is to survive the competition from other shipbuilding materials.

Kilgore (USA): In regard to metal versus wood in developing regions, attention is called to the advanced fleet built in Mexico in the past few years. The Mexicans would have had sound reason for choosing predominantly steel construction.

Wood maintenance cheaper

Hines (Canada): The consensus of opinion in Eastern Canada has always been that it is more economic to maintain steel trawlers than wooden trawlers. During the past 20 years some casual observations were made that led us to initiate a more detailed study. The casual observations led us to believe that wooden trawlers had less maintenance and fuel costs, but the detailed data have revealed that this is true only in the overall average and that the cost varied considerably from vessel to vessel and from year to year. This variation applied to steel trawlers as well.

Three wooden and three steel trawlers were studied for 1963 and 1964 and the data are given in tables 7, 8 and 9. These vessels have been selected as an average of the whole fleet. In order to make the test as fair as possible, the largest wooden vessels and the smaller steel vessels have been selected for this purpose. The best estimates would indicate that there are about 75 wooden trawlers over 100 ft (30.5 m) and 50 steel trawlers over 115 ft (35 m) in the Province of Nova Scotia. Wooden trawlers are not generally, or for that matter even rarely, built over 115 ft. This is due to the fact that it is difficult to obtain timber of sufficient structural strength to construct a wooden trawler of a greater length.

It could be well stated that the utilization of 3 wooden and 3 steel trawlers is an inadequate sample for a universe of this size; but these are the vessels which have fished a full year and under those conditions and with those stipulations which make them conducive to a comparable study of this nature.

Obviously two years of study are insufficient to arrive at any substantial conclusions, but it is the hope to continue these records for a further two or three years, at which time the concept might be validated that maintenance and fuel costs for vessels of steel and wood do not play as important a

TABLE 7

Comparative data on wooden versus steel trawlers, Nova Scotia: 1963

(Canadian $ 1 = US $ 0.93)

| | Wooden trawlers | | | | | Steel trawlers | | |
	1	2	3	Average	Average	4	5	6
Year built and average age	1950	1957	1951	10.3	9.0	1956	1952	1954
Length (ft)	115	115	115	115	134	124	137	141
Construction Costs ($)	285,948	296,156	287,528	289,877	433,333	450,000	420,000	430,000
Number of trips	30	31	26	29	27	26	27	27
Days at sea	262	266	227	252	259	265	257	255
Hours fishing	2,874	3,634	2,317	2,941	2,431	2,349	2,706	2,239
Number of crew	16–18	14–18	15–18	14–18	15–17	15–17	14–17	16–17
Landed weight (lb)	3,745,776	4,808,520	3,050,140	3,868,145	4,426,122	4,107,941	4,357,100	4,813,325
Landed value ($)	189,816	254,007	145,792	196,538	170,459	151,017	168,440	191,920
Hull repairs	9,018	8,985	9,849	9,284	11,074	7,880	10,689	14,651
Engine repairs	8,170	3,629	8,993	6,931	11,836	13,598	16,460	17,285
Marine insurance	7,364	7,967	7,369	7,567	12,045	12,824	9,862	13,449
Fuel, oil, grease	20,984	18,725	14,753	18,154	19,852	17,291	20,225	22,041
Total receipts	191,316	254,007	145,792	197,038	170,459	151,017	168,440	191,920
Total expenditures	83,020	91,276	82,615	85,637	107,178	96,509	106,372	118,653
Net cash return to labour and to capital	108,296	162,731	63,177	111,401	63,281	54,508	62,068	73,267
Net cash: crew share	72,188	97,640	52,931	74,253	63,275	55,716	61,907	72,203
boat share	36,108	65,091	10,246	37,148	6	−1,208	161	1,064
Less depreciation	−21,446	−19,232	−21,565	−20,748	−32,500	−33,750	−31,500	−32,250
Net earnings of boat	14,661	45,859	11,319	16,400	−32,494	−34,958	31,339	−31,186

TABLE 8

Comparative data on wooden versus steel trawlers, Nova Scotia: 1964

Canadian $ 1 − US $0.93)

| | Wooden trawlers | | | | | Steel trawlers | | |
	1	2	3	Average	Average	4	5	6
Year built and average age	1950	1957	1951	11.3	10.0	1956	1952	1954
Length (ft)	115	115	115	115	134	124	137	141
Construction costs ($)	285,948	296,156	287,528	289,877	433,333	450,000	420,000	430,000
Number of trips	30	30	30	30	24.6	25	24	25
Days at sea	250	265	258	258	240	246	236	238
Hours fishing	2,681	3,547	2,808	—	—	2,259	—	—
Number of crew	14–18	16–18	15–18	15–18	12–17	12–17	12–17	12–17
Landed weight (lb)	3,863,316	4,733,118	3,605,019	4,067,151	3,548,866	2,824,844	3,475,667	4,346,088
Landed value ($)	201,716	259,804	190,992	217,504	136,306	105,516	131,185	172,217
Hull repairs	9,568	9,616	11,538	10,241	8,093	6,913	7,738	9,627
Engine repairs	7,945	7,658	17,405	11,003	17,959	15,883	16,017	21,976
Marine insurance	7,364	7,967	7,368	7,566	10,665	11,281	8,675	12,139
Fuel, oil, grease	24,240	19,092	28,016	23,783	22,700	21,724	20,370	26,007
Total receipts	201,716	259,804	190,992	217,504	136,306	105,516	131,185	172,217
Total expenditures	94,090	91,335	111,522	98,982	115,387	111,379	112,017	122,765
Net cash return to labour and to capital	107,626	168,469	79,470	118,522	20,919	−5,863	19,168	49,452
Net cash: crew share	76,521	99,890	70,956	82,456	49,190	36,424	46,922	64,225
boat share	31,105	68,579	8,514	36,066	−28,271	−42,287	−27,754	−14,773
Less depreciation	−21,446	−19,232	−21,565	−20,748	−32,500	−33,750	−31,500	−32,250
Net earnings of boat	9,659	49,347	−13,051	15,318	−61,771	−76,037	−59,254	−47,023

place in costs of operation as might have been the original thinking.

Over the two-year period the average wooden trawler spent 255 days at sea, landed 3,967,648 lb (1,800 ton) of fish valued at £68,000 (C$207,021). The steel trawlers, on the average, spent 250 days at sea, landed 3,987,494 lb of fish, about the same amount, but only valued at £51,000 (C$153,382) see table 9. The higher-average landed value for the quantity landed by the wooden trawlers when compared with that of steel trawlers is accounted for mainly by the higher average prices received. The species mix was also much better for the wooden trawlers since approximately 40 per cent of catches were obtained on George's Bank for which a premium price is paid.

TABLE 9
Comparative data on wooden versus steel trawlers, Nova Scotia

(Averages for 1963 and 1964)

	Wooden trawlers			Steel trawlers		
	1963	1964	Average	Average	1963	1964
Age	10.3	11.3	10.8	9.5	9.0	10.0
Length (ft) . .	115	115	115	134	134	134
Construction costs ($)	289,877	289,877	289,877	433,333	433,333	433,333
Number of trips .	29	30	29.5	25.8	27	24.6
Days at sea . .	252	258	255	250	259	240
Hours fishing .	2,941	—	—	—	2,431	—
Number of crew .	14–18	15–18	14–18	14–17	15–17	12–17
Landed weight (lb) .	3,868,145	4,067,151	3,967,648	3,987,494	4,426,122	3,548,866
Landed value ($) .	196,538	217,504	207,021	153,382	170,459	136,306
Hull repairs .	9,284	10,241	9,762	9,583	11,074	8.093
Engine repairs . .	6,931	11,003	8.967	14,897	11,836	17,959
Marine insurance .	7,567	7,566	7,566	11,355	12,045	10,665
Fuel, oil, grease .	18,154	23,783	20,968	21,276	19,852	22,700
Total receipts . .	197,038	217,504	207,271	153,382	170,459	136,306
Total expenditures .	85,637	98,982	92,309	112,282	107,178	115,387
Net cash return to labour and capital . .	111,401	118,522	114,962	42,050	63,281	20,919
Net cash: crew share .	74,253	82,456	78,354	56,232	63,275	49,190
boat share .	37,148	36,066	36,607	14,138	6	28,271
Less depreciation .	−20,748	−20,748	−20,748	- 32,500	· 32,500	— 32,500
Net earnings of boat .	16,400	15,318	15,859	46,632	−32,494	60,771

Economic factors listed

The cost differential between the wooden and steel trawlers regarding hull repairs is negligible, as is also the case with fuel, oil and grease; on the other hand engine repairs for the steel trawlers were approximately 65 per cent higher than for the wooden trawlers, and marine insurance was 50 per cent higher for the steel trawlers (see table 8).

The main difference between wooden and steel trawlers lies in the capital investment or outlay which, on the average, was £96,000 (C$289,877) and £144,000 (C$433,333) respectively. There are no comparative figures available on the life span of wooden versus steel trawlers but there are still a few wooden trawlers in operation after 20 years of service. Most of the older wooden vessels, the Lunenburg Schooner for example, have become obsolete and are now being used for coastal freighting and other commercial operations outside the province, therefore, making it inconvenient to maintain records of their life span.

A final point concerns the general impressions of sea-kindliness which involves the period of roll and mount of pitching. In this part of the world the period of roll is restricted because the boats have to be stiff enough to take care of the icing and sea conditions. Therefore, it can be said that the boats are relatively stiff. The other factor involved concerns pitching which can cause a great deal of discomfort in heavy rigid structures without resilience.

For this reason a wooden ship has an easier motion and caters more to sea-legs. This is borne out by the fact that most of Nova Scotia's older and more reliable skippers prefer to sail in wooden ships.

Size of boat decides the material

Rebollo (Spain): Generally speaking, boats up to 82 ft (25 m) length are built of wood and larger boats of steel in Spain. In this contribution, only wooden boats (since the discussion is limited to under 100 GT) will be considered. Broadly, when a boat is built, e.g. between 62 and 82 ft (19 and 25 m) length, three of four templates offering three or four varia-

tions in beam and depth are available. Length is decided, for the most part, by the template actually chosen. The templates serve only to shape the hull and are subsequently dismantled for use with other boats. In this way the builder greatly simplifies his task and needs only two or three simple machines to work the wood. In addition to, and independent of, the shipyard, there are assembly workshops where engine, tubing, pumps etc. may also be assembled. The deck houses were formerly made of steel but in recent years some light (e.g. aluminium magnesium) alloy has been used. The plans of the deck houses are submitted for approval. Special attention is paid to how they are fastened to the deck, and to ensuring that the fastenings are strong enough. The companionways used to be made of wood but, since a number of boats were lost due to damage caused to the latter, and consequent flooding through these openings, they are now for the most part built of steel and strongly secured to the deck.

Author's reply

Pedersen (Denmark): Potter in his excellent contribution gave a clear picture of the difference between non-engineering and engineering structures. Fyson in his paper, stressed the many technical and economical advantages of series-produced vessels over those individually-built. Large-sized glue-laminated members and sheet-panels seem to fit extremely well into this pattern, especially if simple hullforms are accepted by customers. Centralized production of such standard-elements seems to be the only possibility of obtaining products of adequate quality.

Since 1939 a great deal of information on glue-laminated products has been issued by Forest Products Laboratories the world over (Wilson, 1939; Freas, 1950; Schniewind, 1964). Production of glue-laminated members, plywood, etc., demand "laboratory conditions". An exact procedure and strict schedule must be followed.

Standard running tests normally used are the block-shear, and delamination-tests. In the delamination-test, 15 to 20 years exterior conditions are simulated in order to find percentage failure of glue-line after this period. These

accelerated delamination test results are compared with long-term tests under service conditions. In Germany, Switzerland, Sweden and Norway, glue-laminated wooden structures were introduced in 1920. Although only the non-water resistant casein glues were used, these structures have now given 40 years of perfect service, even under most adverse conditions (Wilson, 1939; Selbo and Gronvold, 1963).

Ullevålseter is correct when saying that one of the major advantages of the lamination technique is, that each individual lamellae can be 100 per cent protected before assembly, resulting in a 100 per cent safe wood product. Gluing of salt-treated Norway- or Scotch-pine (*Pinus sylvestris*) gives no trouble (Selbo and Gronvold, 1956; Selbo, 1957; Truax *et al*, 1953; Selbo, 1964). Rasmussen's fear of fungi-attacks in heartwood of treated glue-laminated members is unfounded. However, if a 100 per cent protected product is wanted, species belonging to class 4 in table 2, treated with copper-chrom-arsen-salts or similar efficient preservatives should be used.

Haavaldsen's information is received with thanks, as one of the major objections against the use of copper-chromarsen-salts for wood protection in fishing vessels is now invalid.

Good average properties of laminated wood

Glued laminated wood is a refined wood product with better average properties than natural wood. Because of eliminated risk from fungi, insect and other biological attacks, less checking and shrinkage, etc., glue-laminated members will give more trouble-free service than members made from unprotected members of natural green wood. This will be especially true under adverse temperature and humidity conditions, as proved by Lindblom (1963) in arctic glue-laminated wooden-ships. A plan which could quickly raise the status of wooden boat building in developing areas, taking Greenland and Denmark as an example, can be proposed as follows: Several well-established factories for glue-laminated wood exist in Denmark. Sets of glue-laminated members and other standard elements could be shipped to Greenland and assembled there, using trained local labour. Greenland fishermen and boatbuilders could develop types and sizes of vessels suited to Greenland conditions, instead of being dependent on vessels as used and built in Denmark.

As stated by many discussers, weight of light ship should be kept as small as possible in order to increase payload. Therefore, materials with high specific strength-values should be given first priority.

When comparing scantlings of traditional wooden fishing boats on an equal weight/strength-basis, the results seem surprising. As Sutherland stated, the value of such an investigation is limited until basic strength-requirements are determined. For relative comparisons, however, the figures can be used.

As might be expected, the figures referring to glue-laminated vessels compare most favourably in respect of the ratios compared.

Hines' comparisons, based on three steel- and three traditional-built wooden vessels are valuable. Those investigations, however, do not confirm the commonly accepted thinking among naval architects that great differences in maintenance- and running-costs occur, when comparing representative vessels built from different materials. In Hines' opinion, the main difference lies in the capital investment, if the same lifetime for the vessels compared is assumed. If this conclusion is correct, vessels should be built as inexpensively as possible, regardless of materials used.

Neglect of good practices

Bardarson mentioned that traditional-built wooden boats are being replaced by steel vessels, due to very costly repairs of fungi-attacked wooden vessels. In this case maintenance-costs on wooden vessels are very high and lifetime very short. This, however, need not mean that steel is better than wood, rather that wood was used in a wrong way, i.e., placed in green condition in very compact structures where growth-conditions for wood-destroying fungi are favourable.

In all reports on fungi-attacks in wooden vessels from different countries, there seems to be a general trend, namely a rapid increase in the number of attacks in the last 10 to 20 years only. The explanation may be that vital assumptions and unwritten rules accepted formerly, have now been forgotten.

Requirements for selection, preparation, etc., of wood before installation, as given in the old rules, are only of a very general nature and interpreted in a haphazard way by the individual builders.

Due to the minimum steel plate thickness of $\frac{5}{16}$ in (7 mm) required by reason of corrosion, smaller steel-vessels are excessively heavy and consequently uneconomical. Kilgore referred to the large fleet of smaller steel vessels built in Mexico. It would be valuable to know *why* the Mexicans have chosen steel for other materials, and what their experiences are with these vessels.

Excessive weight causes waste

The important question on influence of weight upon efficiency and economy for different sizes and types of vessels should be taken up as a separate point at a future congress.

As Retvig stated, and mentioned by Rasmussen in his paper, and being well-known since the Second FAO Fishing Boat Congress in 1959, the Danish rules for wooden fishing boats demand excessively heavy scantlings, resulting in expensive and heavy boats.

Unnecessary amounts of expensive boat building timber are used. It is the fishermen in the first instance who must pay for the timber and for the transport of this unnecessary and expensive ballast, but in the end the housewives have to pay for more expensive fish.

Every year millions of kroner are wasted due to overheavy boats. Danish fishermen already have paid great bills in human lives and material due to disasters which may be traced back to undetected fungi attacks in the unprotected wood-members.

(*Editor's Note: The Danish rules for the construction of wooden fishing vessels were officially cancelled on 6 December, 1966*).

Chapelle and Thiberge remarked that a true picture on the loads acting on a hull in service is difficult to obtain. However, thanks to work being done by classification-societies, technical universities, etc., data are being collected, treated and crystallized into strength-criteria for main structural members of ship- and boat-structures, thus giving the engineer a rational design-base from which to work.

The final goal—a rational design procedure—seems to be within reach in not too many years.

ALUMINIUM AND ITS USE IN FISHING BOATS

Whittemore (USA): He had designed and constructed a group of the aluminium gillnetters referred to by Leveau. The strength to weight ratios indicated of 18,000 lb/in² (1,250 kg/cm²) for aluminium versus 7,000 lb/in² (500 kg/cm²) for a steel structure implies that the weight of an aluminium structure would be approximately 38 per cent of a steel structure. This appears to be a little optimistic since it generally has been recommended that for a welded structure, the scantlings and thicknesses of the aluminium structure

should be at least 50 per cent greater than that of the equivalent steel structure. This would result in the weight of an aluminium structure being approximately 50 to 52 per cent of the weight of a steel structure. This same ratio is indicated in fig 1 of Leveau's paper for Alloy 5086-H32.

Any shipyard with experience in construction of steel vessels which is contemplating entering the aluminium boat construction field, should proceed with caution. Aluminium does not behave the same as steel in a welded fabrication and therefore theories and practices which were used in the construction of steel hulls are not directly applicable to aluminium fabrication. For example, aluminium does not have the same shrinkage characteristics as steel when welded. A steel hull would show a great deal of distortion in the plating if all the interior framing were continuously welded, but can be kept relatively smooth by using intermittent welding. Aluminium hull structures on the other hand show little distortion when the framing is welded continuously and greater distortion when heavy intermittent welds are used. With the availability of the high-speed continuous-feed welding machines, it is possible to weld stiffeners with a small continuous bead for the same or less cost as the heavier intermittent weld of the same total strength.

The smaller continuous welds are preferred over the heavier intermittent welds in areas subject to vibration and impact loads. Serious cracking problems have developed in aluminium plating subject to vibration and impact loads when intermittent welding was used.

The cracks generally started at the ends of the intermittent welds, in the heat-affected zone. The ends of the intermittent welds form hard spots in the middle of the plating around which the plating is free to move, relatively. However, by continuously welding the stiffeners to the plating in these areas of high loads, the cracking problems were completely eliminated. Hard spots are eliminated and the reduction in strength at the heat-affected zone in the parent metal is decreased using the smaller continuous weld at a higher rate of speed.

Extruded panels prove helpful

In recent years, special extruded aluminium panels have been available from the aluminium manufacturers with the stiffeners forming an integral part of the plating. This makes an excellent structural system for a hull subject to vibration and impact loads since the intermittent welds with their hard spots and heat-affected zones are diminished. These panels have been used in vessels subject to high impact loads such as hydrofoil panels.

Hard spots of any kind are to be avoided in the hull plating. Stiffeners should not terminate in the middle of plating panels. Brackets for foundation structures should be extended to the nearest panel stiffeners. The ends of bulkhead stiffeners should not be simply welded to the shell plating or tank top plating. The ends of such stiffeners should either be stopped just short of the shell plate with a diagonal trim to permit freedom of movement or else bracketed to a shell stiffener. Brackets connecting longitudinal shell framing at bulkheads should be carried to bulkhead stiffeners or eliminated using a boundary stiffener or doubler plate at the inboard edge of the shell stiffeners.

Most of the above precautions are not necessary in steel hull structures for the type of vessels being discussed here, although some of these precautions are applied in large steel tank ships.

The 57 ft (17.4 m) all-aluminium purse seiner vessel referred to by Leveau was faster than similar size wooden and steel seiners, but nowhere near as fast as he has indicated. The vessel was originally equipped with a 470 continuous hp

engine, which is about double that normally installed in a vessel of this size and service. With a ready-for-sea displacement including normal gear and fuel of about 70 per cent of that of a similar steel vessel, the aluminium seiner achieved a speed of about 40 per cent greater than that of a normal steel vessel, as would be expected. The 24 and 18 knot speeds referred to by Leveau were what was originally hoped for prior to construction.

Where speed without cargo or draft restrictions with cargo are important, aluminium hulls are an effective answer, provided experienced aluminium repair facilities are in the operating vicinity or the owner acquires aluminium welding equipment and trains personnel to use it.

Importance of technical skill

Allen (USA): As a manufacturer of a number of aluminium boats, some of which appear in Leveau's paper, and a shipyard which has maintained most other aluminium vessels in the area, Allen did not feel that Leveau's paper gives proper significance to the problems which persist in design and construction for the elimination of cracks. Since the principal use of aluminium in small boats is in high-speed vessels, the problems are further aggravated, particularly in the stern structure which by the nature of design is usually quite flat. Builders contemplating building aluminium vessels for the first time should take advantage of the technical help offered by experienced naval architects and aluminium companies.

Aluminium should not be encouraged in areas where welding equipment and materials and skilled personnel are not readily available. The repairs of cracks is not just a matter of welding, but usually demands a revision of structure. In the stern of high speed vessels, this more often than not occurs in fuel tanks.

As a further observation of aluminium vessels, which have been in service even with knowledgable owners, there is a tendency to ignore the galvanic corrosion of dissimilar metals in mounting new fittings or changing deck machinery

With the most careful use of technical assistance and the greatest care in construction with the most qualified workmen in USA, it is not possible to insure complete elimination of cracking (sometimes in the most unexplained locations). Although almost all of aluminium boats have developed bothersome cracks, the most serious cracking problems affecting safety of vessels have occurred in wood vessels 50 to 90 ft (15 to 27 m) long, using full hold capacity aluminium sea water tanks to carry live king crabs in Alaska.

British practice cited

Lee (UK): Leveau makes a very good case for the use of aluminium alloys in fishing boats. Practice in the UK differs in respect of the following:

Antifouling composition: lead based paints are not used on aluminium structures in marine conditions as corrosion would be serious in the absence of an effective barrier.

Mechanical fastenings: stainless steel is prone to crevice corrosion when continuously immersed in sea-water. Corrosion pitting may arise, even when not immersed, from chloride contaminated moisture. Galvanic protection, e.g. electro-deposited zinc coating, is necessary.

Where aluminium alloy is joined to steel the fastening is of steel, not aluminium.

It should be noted that aluminium is subject to fungal attack in the presence of kerosene-type fuels and water. Fuel tanks at least should be suitably protected. The aluminium is pretreated with Alochrome 1200 (ICI Paints, Slough) and coated with an epoxy resin; a polysulphide rubber PR 1422

(British Paints) is used for sealing all joints and for giving an overall finishing coat.

Japanese details

Takehana (Japan): Some examples of aluminium ships built in Japan are:

1. Japanese Coast Guard Patrol Boat: *Daio* (1949)
2. same: *Arakaze* (1954), this is the first ship made of Al-Mg-Mn (A2P7)
3. Superstructures of Escort Ship: *Akebono* (1955) weight of aluminium used is 40 tons
4. Torpedo Boat No. 7, 8, 10 (1957–1962) displacement 120 tons, weight of aluminium hull 50 tons, speed 50 knots
5. Superstructures of Canadian Boxide Carrier *Sunwalker* (1957) weight of aluminium 200 tons
6. Tuna Fishing Catcher Boat (No. 8 *Akebono*) (1956)

Length overall .	51 ft (15.5 m)
Length BPP .	46 ft (14 m)
Breadth .	11.8 ft (3.6 m)
Depth .	5.25 ft (1.6 m)
Thickness of shell plating .	$\frac{3}{16}$ in (5 mm)
Thickness of deck plating .	$\frac{1}{8}$ in (3 mm)
Frame .	$0.16 \times 6 \times 1.6$ in ($4 \times 150 \times 40$ mm)
Frame spacing .	2.6 ft (0.8 m)
Deck beam .	$0.16 \times 4.7 \times 1.6$ in ($4 \times 120 \times 40$ mm)
Hull weight .	about 8 tons (corresponding weights for wood 13 tons, steel 11 tons, FRP 7.5 tons)

Recent increase in USA

MacLear (USA): From 1950 to 1960 relatively few aluminium boats were built in the USA. From 1960 to 1965 there has been a substantial increase and at present most US aluminium shipyards are at 100 per cent capacity. The early difficulties have mainly been eliminated and several yards that once built in wood or steel now construct in aluminium exclusively, or primarily. Referring to cost, the following comparisons are interesting. From the same US yard, double planked wooden construction is quoted as costing $2.50 per lb and for aluminium construction $3.00 per lb based on a completely outfitted vessel. This gives a difference in price of 20 per cent, but because of the weight saving in aluminium, the figure is more like 15 per cent.

Another quotation from Germany taking steel construction as the datum, places double planked wood cost 2 per cent higher and aluminium construction 11 per cent higher. This gap is lower than many realize. As far as fishing vessels are concerned, it must be remembered that the extra capacity and earning power might well offset the extra constructional costs.

Temperature and conductivity

Pedersen (Denmark): Aluminium has excellent electrical and heat conductivity properties, consequently poor insulation properties. (See table 6 in Verveij's paper).

Could Leveau answer the following questions:

- How much does the necessary installment of insulation material in an aluminium hull affect the building costs?
- Can an aluminium hull be safely protected from the rapid rise in temperature in the material in case of a fire, in order to avoid an early collapse of the structure?

Toullec (France): In reply to Pedersen: Since aluminium has a very high conductivity it transmits to the boat as a whole the temperature of the water, which exerts a moderating influence and one making for a high degree of comfort without a lot of insulation being necessary.

Pedersen (Denmark): What if temperatures are constant, arctic or tropic? Would it not then be necessary to insulate?

Problem of impact loadings

Nickum (USA): Typical views of deck house framing and plating would be more helpful if frame spacing had been shown. Tabular values of allowable deflection for decks, particularly of small vessels which have only personnel loads involved might also be helpful in preventing over-designing and putting in too much material. Also the data on ultimate strength of materials would be more useful to the designer of welded structures if values in the "as welded" condition were included, or at least a statement that in designing for welded structures the strength in the fully annealed condition should apply.

Recent experience in USA, particularly in the development of structure for hydrofoils which are subject to high impact loadings, show definite advantages in the use of extruded aluminium panels. These extrusions can be obtained with "T" stiffeners extruded in place on the panels. They have been obtained in widths up to 26 in (660 mm) in width. While the dies are very costly they are very definitely advantageous in reducing weight.

Fig 28 is an example of how very thin skinned sections can be used for heavy loadings by the use of haunches or elliptical fillets in the material just next to the "T" stiffeners. This particular section can take pressures up to 45 lb/in² (3.15 kg/cm²) at the yield point of the material.
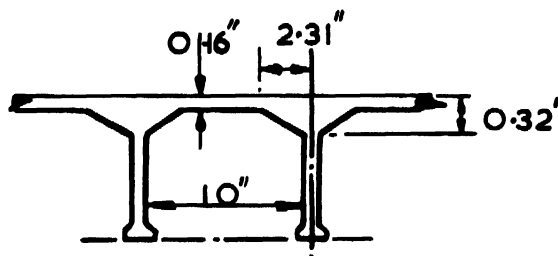
Fig 28

Nickum endorsed Allen's warning that competent people and procedures must be used for working aluminium. Shrinkage is often a serious problem to an inexperienced operator. An example is a 210 ft (64 m) vessel now under construction which shrank a total of 10½ in (270 mm) during the construction, caused by lack of allowance for shrinking and poor welding procedures.

Special care has to be taken in the layout of the framing so that the welding head can reach all parts of the structure.

Special care should also be taken in the use of aluminium to see that it is not subjected to fire. Because of its low melting point, a fire next to one of the main structural members can very seriously reduce the vessel's strength. On a Norwegian vessel which recently burned off the US Pacific Coast, no aluminium fittings, including the deck house, the funnel, the life boats and all inclined ladders, were left on one side of the ship which had been subjected to the fire.

Corrosion factor

Verweij (Netherlands): Aluminium is certainly suitable for many applications. However, especially in sea water or at

the seaside, one has to be aware of unexpected difficulties due to galvanic corrosion.

This danger will be greater if used in areas where people understand less of this corrosive action. Even with anti-fouling paints, one has to be very careful. In general, painting of aluminium requires minute attention.

Whereas impact strength of undamaged material is good, this is not the case with the notched impact resistance. Therefore, a beginning of a crack will easily go on.

In great contrast to this is the behaviour of fibreglass, where the notched impact resistance is nearly as great as the unnotched impact resistance. Also the absolute values for fibreglass are very high.

Construction of aluminium boats requires greater technical knowledge and skill than is required for any other material.

Protection from ice

Petersen (Denmark): There is another purpose for aluminium in Scandinavia and Greenland namely to preserve wooden fishing boats during navigation in icefilled waters and specially take care of the planks in the waterline belt. In former days galvanized iron sheets were used or in the oldest day copper plates. Today copper is very expensive and galvanized iron has a very short life time and it became natural to test aluminium. For boats built for fishing in Greenland, where navigation in ice is very common in several months of the year, $\frac{1}{16}$ to $\frac{3}{16}$ in (1.5 to 5 mm) aluminium plates, 1.5 ft (0.5 m) over load waterline and 1.5 ft (0.5 m) below light waterline are used. Before the sheets are fastened the planking is painted with neutral asphalt after the caulking has been finished. Galvanized 1 in (25 mm) spikes are set at a distance of about $\frac{3}{4}$ in (20 mm) along the edges.

The quality is salt water resistant aluminium with hardness $\frac{1}{2}$ H. (Al–Mg). Different firms have useable alloys. Aluminium for this purpose has a lifetime about three to four years against about two years for galvanized iron sheets.

Troup (UK): To a naval architect engaged with design of aluminium craft, Leveau's paper is of great value. When a UK shipyard first began to use aluminium, they found that they had considerable difficulty in riveting. The rivets were very easily overworked, and on some occasions the heads burst off with some startling results.

Developing countries should not use aluminium without the advice of experts. Furthermore one cannot use steel workers! They are much too heavy-handed, so if one wishes to train people to work aluminium use sheet-metal workers.

Some technical points

Leathard (UK): Aluminium has a comparatively low impact value. The value given by Leveau is measured with stresses only in one direction. It should be corrected as the value is not the same for plates stressed in two or three directions.

The section shown in fig 2 of Leveau's paper stiffener section is standard in USA. It was to a large extent used in aluminium superstructure in *Bergensfjord* built in UK. This stiffener serves a two fold purpose. It gives a better location of the welds of the stiffener to the plate and at the same time acts as a backing strip for the butt-weld of the plate. The design of aluminium structures requires expert advice. This is an example of the right way to use such a section.

Table 8 of Leveau's paper shows several different aluminium alloys. This could possibly create confusion and UK has standardized a rather small number of sea water resistant alloys.

Toullec (France): Leveau's excellent paper is worth several comments but time only permits one, concerning the essential quality of this material, namely its lightness. The fact that trawlers must have enough immersed hull surface to counterbalance the drag of the trawl seems to me to be incompatible with the reduction in underwater body needed for high speeds. Is there any information on vessels currently in operation? Careful studies should lead to a form capable of reconciling the two needs.

Nickum (USA): Concerning reducing the number of alloys, it should not be forgotten that aluminium is a much more sophisticated material than steel, for example the weldability varies between the different alloys. The alloy 54 56 is very weldable while the alloy 60 61 which has a higher strength should not be welded. It should be remembered that the alloy 54 56 has its yield strength considerably reduced when welded. When welded the strength qualities go back to the unannealed condition and one has to take these corrected figures into the strength calculation. One also has to take into consideration the welding in different axes, especially when designing close to the yield strength of the material.

Overcoming stubborn prejudices

Kilgore (USA): The aluminium producers have come into the boatbuilding and shipbuilding market aggressively only a few years ago, and have had to deal with some stubborn prejudices before they could even begin talking the virtues of their product. The first of these prejudices is the notion that aluminium corrodes in salt water. Every day one still encounters that old notion. The second is that welding aluminium is a tricky business, reserved only for highly trained technicians.

The aluminium-magnesium alloys do **not** corrode to any significant extent. Skill in welding aluminium properly does not take more training than skill in proper welding of steel. It is true that both these statements deserve some qualification. Aluminium is lower in the electromotive scale than iron, and hence more care is necessary in exposing dissimilar metals. Aluminium welding requires procedures different than for steel. But neither of these reservations adds significantly to the cost of using the product.

In comparing the two metals, people usually leave out the corrosion allowance which must be added to the required thickness of exposed steel. This varies with the environment, but after computing the thickness for strength and stiffness one always has to add enough steel so that in a given number of years sufficient thickness will remain. This is not necessary with the aluminium-magnesium alloys.

Another factor in the value of an investment is the probable salvage value at the end of useful life. The salvage value of a steel boat is at present practically nothing, even if it were in first class condition. Scrap aluminium is now bringing over £7 ($20) per ton. Still another saving is the saving in haul-outs.

Taking all factors into consideration, and not forgetting the greater operating profitability through reduced weight, the aluminium fishing vessel is generally the best bargain the fisherman can find. This is not true for those vessels where the hull is the major part of investment. But in fishing rigs of the common sizes, the hull alone represents only a part of the investment, and a long list of other items cost the same no matter what the hull may be: refrigeration system, propulsive system, steering system, ground tackle, accommodations, electronic gear, rigging and winches, navigational equipment, fire-fighting and lifesaving requirements, general stores, and the fishing gear itself.

There is one objection to aluminium: with simplified construction, even the smallest shipyard can bid on the construction of a fairly large steel hull, subject chiefly to

his ability to launch it. The reason is that for shaping and bending heat can be used instead of heavy and expensive machinery. It is quite amazing what a workman with only a torch burning liquified petroleum gas can do with a piece of steel. The labour costs a little more than power shaping, but when the job is done the yard does not have its capital tied up in costly machinery. Now one doesn't dare play a torch on an aluminium plate. So how does one make it fit?

Big potential for small craft

Colvin (USA): There is, without a doubt, a great potential for aluminium in small craft, and especially in small fishing vessels; however, in the past decade there has been a great deal of misleading information put forth to favour aluminium over steel construction. There are, of course, instances where aluminium surpasses steel, but there are many others where the high cost of aluminium construction does not compare favourably with steel, cannot be justified, and would be a detriment to progressive fishing and boatbuilding if it were forced upon the fishermen.

Leveau has been very instrumental in the USA in putting forth useful information to the naval architects for their guidance in the design of aluminium vessels. The data and cross-comparison tables that he has formulated and published on various occasions have done a great deal to ease the burden of seeking pertinent information regarding aluminium construction. However, it would be appropriate at this time to point out several items which should be carefully thought over by designers as well as builders in arriving at a solution to a given problem. For a number of years, a high corrosion resistant steel has been available in USA with a tensile strength of 70,000 lb/in² (5,000 kg/cm²) minimum and a yield point of 50,000 lb/in² (3,500 kg/cm²) minimum, with a shearing strength of 37,500 lb/in² (2,650 kg/cm²) and an endurance limit of 42,000 lb/in² (3,000 kg/cm²) against the 28,000 lb/in² (2,000 kg/cm²) of this mild steel. Basing the carbon steel on a minimum yield of 33,000 lb/in² (2,300 kg/cm²) and a working stress of 18,000 lb/in² (1,300 kg/cm²) the high strength steel with a minimum yield of 50,000 lb/in² (3,500 kg/cm²) would be 18,000 times 50,000/33,000 = 27,270 lb/in² (1,900 kg/cm²) or a ratio of yield points of 1.515 or, say, 1.50. Yet the cost of high tensile steel is only about 50 per cent more than mild steel. Since the weight ratio for tension members is inversely proportioned to the yield points of the two, then 33,000/50,000 = .66. Using high tensile only for the shell plating and decks, and assuming that the shell and decks are 68 per cent of the total hull steel, and the savings by reduced scantlings of the shell by weight is then 34 per cent net on the shell, or a hull with 78 per cent of the total weight of mild steel, a saving of 22 per cent would result, or about one-half the weight saved by the use of all-aluminium construction at an increase in cost of less than 1 per cent of the cost of mild steel.

Comparative strengths

A very thorough examination of the strength of aluminium versus steel indicates that the thickness of aluminium must be 1½ to 2 times the thickness of steel for the same stiffness or the same strength, which gives a saving, if averaged out, of 44 per cent on steel weight for mild steel and 22 per cent for the high tensile steel; yet the cost of the aluminium structure over the mild steel structure is four times as much!

Leveau has correctly shown the 56 per cent additional hull and deck house material cost, but has lumped it in with the machinery and outfit, which hides the true cost of the aluminium hull. As it is interpolated downwards into small fishing vessels of say five to 20 tons displacement where the hull cost and the machinery cost are about equal, the figures differ from those for the larger vessels. To the fisherman who is spending, say, £11,500 ($32,000) of which £5,750 ($16,000) is in the hull and £5,750 ($16,000) is in the machinery and outfit, the material cost of the steel would be roughly £715 ($2,000) and the equivalent cost of the aluminium would be £2,850 ($8,000) or a difference of £2,135 ($6,000), or 18.75 per cent of the total delivered hull cost and 37.5 per cent of the bare hull cost. Going still further, since probably borrowing the greater portion of the money involved, the additional £2,135 ($6,000) on a 10-year loan at 6 per cent simple interest would raise the figure to £3,400 ($9,600). This is indeed a very hard thing to sell, especially if the fishing operations are, as they are in many instances, on a marginal basis to begin with.

When preparing identical designs for steel and aluminium, it was found that costwise it would be advantageous to use the same engine, regardless of the hull that was built. The weight difference amounted to about 2½ tons, and yet there was less than a knot (8 per cent) difference in their cruising speeds when speed was of minor importance.

Colvin heartily concurred with Leveau that the fabrication of aluminium is certainly not any more difficult than steel, and in many instances is probably easier and simpler than in steel; however, the difference in weight becomes a very minor problem in the handling of large plates in the size of vessels under consideration.

Coatings protect against corrosion

Almost all of the classification societies at the present time will allow substantial reductions in shell plating if the shell is to be coated with the inorganic zinc silicate compounds that are now available to the marine industry. This only further reduces hull weight and at the same time indicates the effectiveness of these coatings as protection against corrosion. There are a number of companies in USA that are guaranteeing over 15 years effective corrosion resistance of these materials, and there should be no unusual maintenance problem to speak of in steel vessels. So now the maintenance difference between aluminium and steel is almost nil if both are to be painted. Even if the topsides are not painted, most certainly any vessel that remains in salt water for any period of time must have anti-fouling and must be hauled once a year in the northern climates and twice a year in southern climates for repainting. This is necessary on aluminium boats just as on the steel.

One must be very careful in the design of aluminium vessels since it is almost impossible if not impossible to achieve 100 per cent strength joints through welding as can be done very easily in steel. About the only material that can be fully welded 100 per cent is aluminium in the annealed condition. One may expect an efficiency of approximately 85 per cent with good welders. The cost of welding aluminium is much higher than the cost of welding steel as far as the deposit of weld metal is concerned; however, the speed of welding reduces the labour involved so that apparent averages in small yards seem to be about 1.2 to about 1.32 times the cost of welding in steel.

The significant applications for aluminium where the lighter weight is justified both by cost and by application is in fishholds, penboards, deck houses, and in any small boat is definitely advantageous. The aluminium becomes more economic in fishing vessels that are to be used as beach boats and are not permanently kept afloat which obviates the necessity of any painting.

One must remember, especially in small craft, that the scantlings of the steel, wood, or aluminium hulls are not based on the strength requirements of the hull so much as on the ease of working and the availability of the material. In

two experimental hulls which were based on oyster skiffs 26 ft (8 m) in length, they had a shell plating of .0747 in (1.9 mm). They proved to be extremely strong ($\frac{1}{10}$ of the deflection of the wooden hulls), were lighter in weight than the wooden counterparts, and were completely electrically welded. This would normally be about one-half the scantlings that would be considered desirable for ease of construction for a 26ft hull.

"Real handbook for users"

Lindblom (Finland) gave thanks for a most comprehensive paper—a real handbook for users of aluminium. Leveau's paper was like "a letter in the mail", unexpectedly offering aid when needed. Lindblom's firm is (probably) the only shipyard in Finland building round bilged boats in all-welded aluminium. But, of course, they have encountered a whole lot of problems, not yet solved. Nevertheless, there is a certain definitely positive quality in this material - the saving of weight.

They have built and are building fast patrol boats for Coastguard and Navy service. The bigger boats of this type are built in steel and Lindblom had in vain tried to persuade customers to use wood or light metal in lieu of steel.

This is best illustrated by an example. A steel built patrol vessel of 115 ft (36 m) in length and 130 tons displacement makes a speed of 26 knots with three 1,350 hp diesels given a total of little over 4,000 hp together. Recently made calculations indicate that if this hull were to be built of light alloy, a speed of about 24.5 knots would have been possible with only two engines of the same size, totalling 2,700 hp as against 4,000. The saving in cost would have been substantiated to say the least of it. Owing to saving in weight, one engine complete with shafting, piping, cables etc., the corresponding reduction of bunkers (fuel, lubricating oil, etc.), the use of aluminium in a case like this seems to be not only fully motivated, but in respect of money-saving imperative.

The reason why a lighter construction for hull was not accepted by the buyer is supposed to be the ice. This is, however, not correct. On a boat of this size, type and speed, the propellers are by far the most vulnerable spots and not the hull.

Lindblom had been experimenting with surface layers of Dynel-Epoxy laminate on wooden shell and the results are very encouraging and also studied the adhesion of this laminate on aluminium.

This type of laminate has a very high resistance to abrasion. How would it be to use such a laminate on aluminium hulls as protection against the abrasive tear of this ice. If possible, such a combination would greatly increase the possibility to use aluminium.

Virtues listed for small craft

Hamlin (USA): Aluminium is the best material now available from which to build small fishing vessels. It is lightweight, strong, and highly resistant to deterioration. Barring some sort of galvanic accident, an aluminium craft should last almost indefinitely. Geerd Hendel, a naval architect of Camden, Maine, USA, and a pioneer in aluminium construction, recently examined very carefully his 26 ft (8 m) aluminium sloop built before World War II. The only deterioration he could discover was in a few rivets, easily replaced, and in the faying surface between the hull and the wood fin keel where some pitting was found due to holes in the insulating bedding compound. This is a remarkable record for a boat built of less suitable alloys than those available now, and a boat which has been exposed to the constant wear and tear of charter service most of its life.

Another argument for using aluminium in fishing vessels will become increasingly strong as the demand for a higher quality of landed fish is felt by ship owners. The ability of maintaining a highly sanitary state on an aluminium craft, a non-porous material which requires no paint, is non-toxic, and will not rust, should serve increasingly as an incentive to its use.

There is a question, however, about the use of aluminium as a lining for fish holds, especially refrigerated ones. The advantages, such as cleanliness and light weight, are obvious, but it seems that the same qualities of heat transmission which are an advantage in the rest of the vessel are a disadvantage in a fish hold, since aluminium will permit the flow of heat to all parts of the fish hold lining much more rapidly than another material will. It is perhaps significant in this connection that the latest Ross stern trawler will not have an aluminium lining in its fish hold, according to news releases.

Cost must be reduced

McNeely (USA): Although Leveau's paper presented a sound economic argument for greater use of aluminium in fishing-vessel construction, considerable opposition will remain until initial costs are somewhat more competitive. The new alloys are much stronger than the layman realizes and quite resistant to salt-water corrosion. In this instance McNeely referred to aluminium otter boards used with the *Cobb* pelagic trawl and live-well tanks on Alaskan king crab boats.

Foussat (France): Marine aluminium alloys have been used in French fishing vessels since 1955. On the basis of information received from Aluminium Français, aluminium has been installed (a) on live-bait tanks and wheelhouses on tuna clippers and, (b) on trawlers, pen boards, fish-hold stanchions and other accessories. They are practically in mint condition even where they were installed as long as ten years ago. All these vessels have skiffs made of light alloys. Wheelhouses are painted, but only for appearance sake. The live-bait tanks are also painted because the fishermen think that the sardine kept inside them are better off that way. The other parts have never been painted.

The alloys used are, in accordance with standard French nomenclature, AG4 and AG5 for sheet metal and ASGM for extrusions.

The installations of the 12 vessels in question, in particular where the fish hold equipment is concerned, have proved to be hard-wearing, so able to take knocks and so easy to maintain that there can practically be no going back now.

Hygiene is the most important consideration with refrigerated fish holds with temperatures in the region of 32°F (0°C), and aluminium provides a perfect complement to the plastic cladding of the walls. These holds keep entirely odour-free.

Author's reply

Leveau (USA): In reply to Allen's remarks about the importance of elimination of cracks, Leveau stated that cracks generally are the result of vibration cycles which are different from steel, and refers to the chapter on Vibration contained in the book *Aluminum Boats* published by Kaiser Aluminum and Chemical Sales, Inc., Oakland.

To Lee's comments on UK practice, Leveau replied that when painting aluminium boats with anti-fouling compounds, barrier coats should be used as explained in all painting recommendations. Mechanical fastenings of dissimilar metals should always be protected, as shown on page 235. The drawings on page 235 also show the fastening materials, and page 239 refers to fuel and water tanks.

[305]

MacLear discussed comparison of costs and Leveau would add that the price differences quoted are approximately the same in various yards with slight differences, depending usually on the yard's experience with aluminium construction.

In reply to Pedersen's queries concerning insulation, Leveau said that aluminium hulls built in the USA are not insulated, and neither is it necessary.

Nickum had mentioned the hazard of fire, but this is a problem with most materials.

Verweij points out the problem of galvanic corrosion, but Leveau said that this can be eliminated with proper care in the separation of bi-metallic connections and in following published instructions for painting. Investigations on notch or crack propagation in aluminium are going on at various organizations. A fibreglass Coast Guard rescue boat recently came apart and sank in San Francisco Bay. Leveau had never heard of an aluminium boat coming apart.

Leveau thanked Troup for his interesting comments and agreed that expert help is needed as it is in most construction projects of whatever kind, especially in developing countries. In reply to Leathard and Toullec, he said that it is up to qualified naval architects who design the aluminium vessel to consider stress calculations and the lighter weight for the best performance.

Nickum commented on aluminium alloys and Leveau agreed that it is correct to use care in strength calculations in welded structures, and table 4 of his paper may be used as a guide. Alloy 6061 can be welded and frequently is, although the strength of the weld zone is considerably reduced.

In reply to Kilgore's comments, space did not permit Leveau to go into the matter of forming and bending aluminium plate and shapes. However, all of the major aluminium prime producers have publications dealing with this subject.

To Lindblom's comments, Leveau added that aluminium has shown remarkable resistance to ice. As a matter of fact, several outboard boats and a 27 ft (8.3 m) fire boat have been used in icebreaking operations with no damage to the aluminium shell.

To Hamlin's question, Leveau believed that aluminium fish hold linings and partitions have better ice-keeping qualities than any other materials. That is also the reason for using aluminium in the freezing compartments of domestic refrigerators.

To McNeely's comments, Leveau said that initial costs of aluminium boats are about 10 to 20 per cent above other materials, depending on the yard. However, less maintenance requirements, more speed with the same power, more carrying capacity, offset this in a short time. Note comments in the first three paragraphs of his paper.

PLASTIC FISHING BOATS

McInnes (UK): During recent years, increasing interest has been shown in the use of reinforced plastics for the hulls of fishing boats. In view of this interest, Lloyds Register have published their "Provisional Rules for the Application of Reinforced Plastics to Fishing Craft" (Lloyds Register, 1965).

These rules have been based on the experience gained with reinforced plastic commercial craft and yachts since the first boat of this material, a 56 ft (17 m) motor yacht, was completed to class in 1956. The rules cover fishing craft between 20 to 100 ft (6 to 30 m) in length, but design studies of larger boats have been carried out.

Although the rules are primarily intended for the guidance of owners and builders wishing to use this method of construction for fishing craft to be classed with the Register, they should also prove useful guidance to builders, and those

at present contemplating building-up or replacing their fishing fleets. The requirements have been presented in a simpler technical manner and contain much descriptive text with sketches of constructional detail.

Many of the problems and pitfalls experienced by moulders over the past few years are mentioned, and consequently can be avoided by the boatbuilders just starting to use this new material. One such problem dealt with is that mentioned by Takchana and by della Rocca, namely the need for a stiff bottom construction over the entire length of the propeller shafting.

Hull scantlings are given for solid single skin and for sandwich construction. Here is envisaged a thinner core material than that proposed by della Rocca, as at present there is no suitable polyurethane core material available on this side of the Atlantic.

The various types of laminations mentioned in the papers have been described in the rules, but for simplicity of presentation, the requirements are stated in terms of the general purpose chopped strand mat. If laminates of woven roving, or of composite mat-woven roving are to be used, the requirements are obtained by adjustment for the higher strength materials. In Britain similar procedures are used to those so well presented by Verweij and Lloyds will try to incorporate such correction factors when revising the rules.

A section dealing with structural and production considerations is included and draws the builder's attention to the need for careful and economic planning, in detail design as well as the fabrication procedures to be carried out on the shop floor. A note of warning is included as regards over-stretching the yard's capacity of both labour and moulding space. "Don't bite off more than you can chew" is a fairly good rule for boatyards, as the successful use of this material is directly related to maintaining simplicity and consistency.

Questions asked

If work of a high quality is to be achieved and consistently maintained, it is essential that the hulls are moulded under good conditions, and as is Lloyds' normal practice with other plastic craft, they require the hulls of fishing boats to be moulded in an approved workshop. There are a few comments:

- When boats are being lifted by hooks, it is usual to use a bending moment of WL/6 with a conservative stress of $\frac{1}{2}$ ton/in^2 (80 kg/cm^2) rather than the WL/12 value given by Takchana,

- Della Rocca mentioned the use of fire-retardant resin, but this should not be advocated as it will cause an unjustifiable increase to the material costs, with possible adverse effect on weathering characteristics. If fire retardency is desired it may be obtained by the normal methods such as the use of a fire-retarding paint,

- Could Della Rocca give us details of experience with balsa wood sandwich in vibration areas? It may be satisfactory with smoothly running engines but a bit doubtful when heavy diesels are fitted,

- In Della Rocca's paper, he relates the plastic scantlings to steel scantlings and in doing so it should be stated that deductions can be made for corrosion and for higher possible negligence,

- The involved chemistry and adding of the various ingredients to the resin mix is not as complicated as would appear. There is an increasing tendency for the moulder to use the material straight from the drum with only the addition of the catalyst, and sometimes pigment,

- The selection of the laminate construction has been dealt with at length, mostly in favour of the composite mat/woven roving. The mat laminate should not be so easily disposed of. This construction is being used in the 85 ft (26 m) South African boats under survey and is proving structurally adequate and economically sound,
- As mentioned by all authors, the designer has plenty of scope with this material and reduced scantlings can be achieved by intelligent design. Uni-directional material can be employed in the sheerstrake, deck edge and in the keel to increase the hull stiffness. Bilge keels and rubbing bands can effectivley be made into strength members,
- Can Takehana give any further information on the use of ultrasonics for the detection of delamination and for the measurement of laminate thickness?

Japanese practices

Lee (UK): Takehana's paper illustrates the difficulty of introducing a new material of construction, the full value of which is only achieved by using new concepts of design and manufacture. It is too much to expect seafarers to accept so much novelty at one time and it would be a pity if reinforced plastics attracted a bad reputation through inappropriate treatment. Takehana's approach is to be commended.

The statement that FRP vessels built on wooden boat lines are comparatively light requires qualification as the scantlings of wooden boats vary greatly and stiffening or bulk has to be worked in FRP boats far beyond the needs of strength in order to achieve an acceptable degree of rigidity.

The following information reflects experience on this matter in UK:

Boat	Wood	FRP	Composite
14 ft (4.3 m) sailing dinghy ex mast, sails and rigging	580 lb (263 kg)	370 lb (168 kg)	
27 ft (8.2 m) ship's sea boat including engine	1.77 tons	1.72 tons	1.80 tons
36 ft (11 m) ship's and harbour work boat including engine	5.3 tons	5.3 tons	
52.5 ft (16 m) harbour launch including engine	17.74 tons	14.9 tons	—

The hull shapes illustrated in Takehana's paper show sharp chines. FRP does not take kindly to such shapes as the sharp edge is resin-rich and will chip under bumping conditions. Practice in UK is to work to a radius of curvature equal to twice the thickness of the laminate. Incidentally, plane surfaces which are associated with sharp edges are not as easy to release from a female mould as are curved surfaces, the greater stiffness of which facilitates removal.

Stiffeners and bearers

As for the significant hull deflection of FRP boats, stiffening is certainly a matter which has to be considered in design. There is evidence that, with some resins and methods of manufacture the amount of deflection is progressively less with time, indicating possibly a continuing cure of the plastic.

The remarks about wooden engine-bearers are of particular importance. Wooden bearers are easier to adjust when fitting the engine or replacing the engine by another one and they absorb vibration better than do plastics bearers. Wood in way of the engine also absorbs some of the noise which might be troublesome with an all-FRP laminated structure as this material reflects and transmits noise. Nevertheless, FRP is better than metal as regards vibration and noise.

The sandwich construction described by Takehana is particularly appropriate when it is required to have a clean interior surface, free from the obstruction caused by stiffeners. The polyvinyl chloride (PVC) core, laid on sections, has also the advantage as serving as a mould. UK practice is to have a much thicker core than that. Caution is necessary with this method of construction as expanded plastics are weak in shear.

Takehana's proposal regarding an effective and reliable means of inspection is fully supported. Ultrasonic methods are showing some promise.

Regarding the remarks about fatigue, wear and durability, the UK has a 25 ft (7.6 m) FRP boat which was built in 1953 and has served for experiments in repair techniques, etc. The boat is now nearly at the end of the normal "life" of its wooden counterpart and will be kept in service for a further five years with the intention of finally testing it to destruction. The evidence is that it is superior to wood as regards durability. Experience shows that sacrificial wood is necessary for rubbers, false keel, etc. in order to safeguard against wear by abrasion. Long-term experience is awaited about the fatigue of FRP, particularly when associated with the large amounts of deflection as pointed out by the author, and this might be serious in a very long craft. It is worthy of note, however, that two FRP boats, the 36 ft (11 m) *Ilala* and 21 ft (6.4 m) *Golif* crossed the Atlantic safely, meeting some very rough seas, in the Transatlantic single-handed sailing race of 1964.

Takehana's statement that overhead costs are reduced in a boatyard concentrating on plastic construction needs qualification as extra costs arise from the temperature and humidity controls necessary when working with plastics.

Takehana does not mention the use of a spray gun in depositing FRP. This is a method which lends itself to mass production and it gives very good results.

Experiment in Zambia

Heath (Zambia): The Fishing Craft Experimental Section of the Fisheries Department of Zambia, has recently made a one-piece glass fibre mould from a marine plywood version of FAO's design BB 59—the 24 ft (7.3 m) beach boat shown in Gurtner's paper.

Two hulls have been built from this mould, using 1½ oz glass mat and polyresin, using six laminations on the bottom and five on the sides. Engine beds are 3 in (76 mm) thick hardwood, 9 ft (2.7 m) long and are bonded with glass and resin to the hull.

One boat is powered with an 8.5 hp air-cooled diesel, the other with a similar 16 hp model which has also to supply power to a line hauler.

Information is needed on:
- Effect of humidity during the laying-up process
- Effects if any of the sun in the tropics on fibreglass and resin laminates
- Is it necessary to use a gel coat - what is the advantage apart from colour? Cracked gel coats have parted from the hull
- What are the suitable plastics for petrol and fuel oil tanks, and fireproof plastics?
- Experience in setting up a fibreglass boatbuilding business in a developing country (sub-tropical). Information is needed to set up a possible co-operative enterprise to build, say 30 beach boats a year in the first instance

Rebollo (Spain): So far only a few pleasure craft have been built in plastics in Spain. In any case, the Government as a general rule does not intend to authorize the use of plastics for hull construction until rules have been drawn up regarding appropriate scantlings and standards been established for quality, strength, fire resistance and other properties of these materials.

Type of engine bearer defended

Verweij (Netherlands): Takehana points out, as was already done by Takagi and Hirasawa, that it is essential for Japan to build a large number of fibreglass fishing vessels in order to reduce maintenance costs.

In Takagi and Hirasawa's paper, it is also mentioned that the ratio $\triangle$/LBD is constantly increasing. There again, the adoption of fibreglass as building material would be favourable, since the resulting lower hull weight would tend again to reduce the ratio $\triangle$/LBD.

Thus there is not too much danger that the hulls become too light and "lose balance" as mentioned by Takehana, but, of course, one never can use the same lines plan when changing from a wooden into a fibreglass boat and stability must also be carefully investigated. Also the problems with bumping and grounding during ebb tide will not present any real difficulties.

As regards the problem of the use of wood in engine bearers, Verweij disagreed altogether that it is essential. His experience goes to diesel engines up to 310 hp. All these engines have been installed on fibreglass bearers without using wood at all, but by using box type fibreglass girders filled with foam to dampen vibration.

As regards essential research, Verweij agreed wholeheartedly with what Takehana suggests.

As for fig 11 and 12 in Takehana's paper, Verweij commented in this respect on Yokoyama's paper. In fig 5 of that paper, the calm water propulsive characteristics are given. As Yokoyama says himself, the relative rotation efficiency of the propeller is very low. This must be due to the shape of the afterbody. Maybe the building methods with wood require this, but when building this boat in fibreglass, it would be very easy and not very expensive to build a tunnel for the propeller.

This would not only improve the propulsion characteristics, but would also very effectively guard the propeller, when the boat was aground or lying ashore, without the need of some mechanism to raise the propeller under such conditions. An idea of the afterbody of the present wooden vessel and the proposal for the FRP vessel is given in fig 29.


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---- WOODEN
——— FRP
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SECTION A-A

SUGGESTED MODIFICATION FOR FRP
CONSTRUCTION TO IMPROVE
PROPULSIVE EFFICIENCY AND
PREVENT GROUNDING DAMAGE
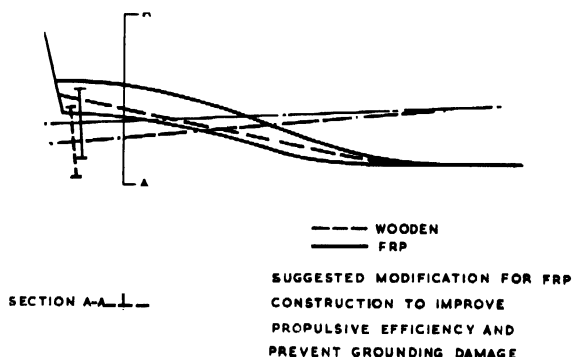
Fig 29

Synthetic FRP qualities

Kilgore (USA): Three papers have dealt with plastics construction (Takehana, Verweij, Della Rocca). Pedersen has also mentioned composite construction of wood and fibreglass. For the sake of completeness on this subject, it is suggested that reports be added on the properties of the synthetic fibre reinforced-plastics; they depend on wood for strength. The chief of these is Polypropylene, but Dynel and Dacron also show promise. Briefly the advantages are:

- Resins used with synthetic fibres stick to damp wood
- Resins are elastic
- Elongation of fibres at rupture is over 20 per cent
- Moulds are not necessary
- Mass production is not necessary for economy
- Cheapest kinds of wood are suitable for cores
- Skills in wooden boatbuilding are readily adaptable
- Resulting weight is lighter than fibreglass
- Fastenings need not be non-corrosive
- Impact properties are superior to fibreglass
- The useful life is longer than fibreglass
- The cost of one boat of composite wood-synthetic plastics is much cheaper than a single fibreglass boat

Recently the Society of Small Craft Designers (USA and Canada) has had two comprehensive papers on the synthetic fibre-reinforced plastics by Lord and Koopman, and a summary by Koopman follows below. Enough boats have been built this way to prove practicability.

US practices

Koopman (USA): Large savings are possible through the use of FRP in both large and small fishing vessels. These materials have been successfully applied to small hulls, but are seldom applied to large hulls where their benefit may be felt most.

Della Rocca stresses the weight saving in hull structure, but says little about the effect this saving has on the other elements of the hull. The use of FRP requires that an entirely new hull be designed. Full ends are no longer necessary to provide that little extra displacement. The added cross-sectional area of the hold is small. Capacity must be increased by the lengthening of the hold as well as the hull. A slight increase in the hull length will increase cost little and require no more power. The power requirements for a hull of a specified hold capacity are lower than that of todays standards. The reduction of power and full requirements make the FRP fishing trawler less costly to construct than a wood or steel vessel.

A FRP fishing trawler has the disadvantage that it must be constructed in a costly mould. It is difficult to make alterations in hull design to suit changes in fishing gear. A mould may become outdated before its cost has been defrayed.

Wood is not out of contention with FRP. Through the use of synthetic FRP wood can be used at its optimum, resulting in light, inexpensive structures. FRP has had limited success when combined with wood because of its relative rigidity. The synthetic reinforced plastics, such as Polypropylene and Dynel, however, are highly flexible. Stress concentrations are not built up by the dimensionally unstable wood.

A synthetic reinforced plastics covering serves to:
- Prevent decay
- Protect the wood from abrasion and bruising
- Unify the wood structure
- Reduce the cycling of the wood moisture content

A synthetic reinforced plastics covering does not:
- Prevent moisture from entering the wood
- Add appreciably to the structural strength because of its low modulus of elasticity

Polypropylene and Dynel reinforced polyesters and epoxies have been used successfully in the designs of Lord for over

TABLE 10

Typical properties of Polypropylene and Dynel reinforced plastics

Property											4 oz (113 g) Vectra Polypropylene	3.75 oz (106 g) Travis Dynel
Flexural Strength												
Yield	.	.	.	.	lb/in²	.	.	.			6,000–7,000	6,000–9,700
					kg/cm²	.	.	.			422–493	422–683
Ultimate	.	.	.	.	lb/in²	.	.	.			10,000	6,000–9,700
					kg/cm²	.	.	.			705	422–683
Flexural Modulus .	.	.	.	.	lb/in² · 10⁵	.	.	.			1.10–4.33	1.05–4.10
					kg/cm² × 10⁵	.	.	.			0.0775–0.306	0.0705–0.289
Elongation at rupture	.	.	.	.	Per cent	.	.	.			20	1.5–10.0
Izod impact .	.	.	.	.	ftlb/in of notch	.	.	.			18–20	0.50–0.75
					kgm/25.4 mm	.	.	.			2.5–2.77	0.07–0.104
Specific gravity	.	.	.	.	.	.	.	.			1.05–1.10	1.15–1.20

five years. The largest hull constructed with these materials is 95 ft (29 m) long. There are no indications that much larger hulls cannot economically be constructed using wood-plastic composite structure.

Polypropylene and Dynel reinforcements are used with flexible polyesters and high elongation epoxies. Use of the more conventional rigid thermosetting resins results in brittle and notch sensitive laminates. Polypropylene reinforced plastics is used for the general covering of hulls. It acts to unify the hull by preventing the shifting of the wood members, and also acts as a crack arresting covering. Though a wood core covered with polypropylene reinforced plastics may be broken, the fibrous web which results prevents complete rupture of the panel and leaking is held to a minimum. Dynel reinforced plastics is notch sensitive, but has unusually high abrasion resistance. It is ideal for docking shoes, ice guards, and other chafe gear.

Neither Dynel nor Polypropylene reinforced plastics require gel-coats as do the FRP. Dust from sanding is not irritating, and the flexibility of the fabric lends itself to easy lay-up. See table 10 for some typical properties of Polypropylene and Dynel reinforced plastics.

In fig 30 is the midship section of a synthetic reinforced plastic-wood composite trawler having the same dimensions as the hull used by Della Rocca for his studies. The section only serves as a comparative study, and many improvements can be made upon it. Panel stiffness and other local properties of the wood-plastic composite structure are superior to that of the single skin, mat-roving hull proposed by Della Rocca.

In determining the strengths of the wood a grain slope of 1/10 and a moisture content of 15 per cent was used. The frames are laminated and the planking is edge glued with high elongation epoxies. The structure is lightly tacked together with bright nails since the glued joints give unity to the structure. The bright nails will not rust once the hull is covered. The first ply of Polypropylene cloth is set in epoxy to obtain the best possible adhesion to the wood, but the rest of the covering is done with the less expensive polyesters.

Tables 10, 11 and 12 are a result of an examination of the wood-plastic composite structure. The values in these tables are intended to correspond with similar values entered into tables 2, 3 and 4 of Della Rocca's paper.
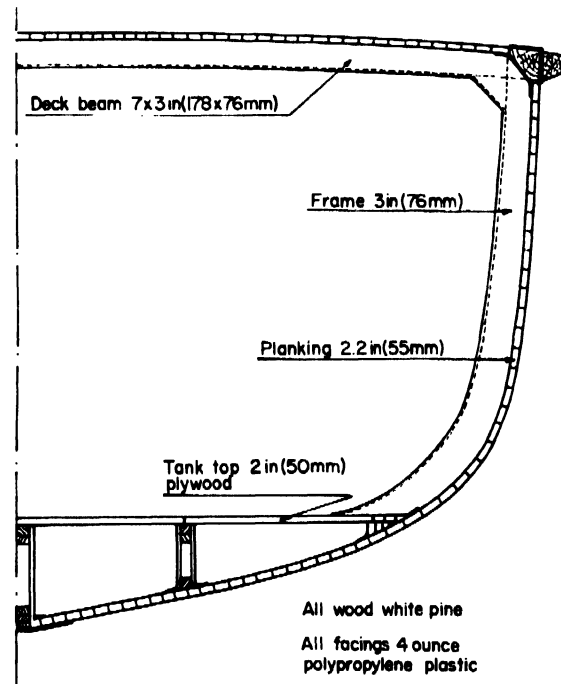
Fig 30. *Midship section of 110 ft wood and synthetic reinforced plastic composite trawler*

TABLE 11

Midship section characteristics 110 ft wood and synthetic reinforced plastic composite trawler

Weight/ft (m) amidships, lb (kg)	.	750	(1.120)
Weight/ft (m) relative to wood		.50	
Hold area inside sheathing ft³ (m³) .		237	(22)
Hold area relative to wood	.	1.19	
Inertia, in⁴–ft³ (cm⁴–m³)		62,790	(105.300)
Elastic modulus, lb/in² (kg/cm²) × 10⁶		1.10	(0.0775)
EI, lb–ft²× 10⁹ (kg–m²× 10⁹) .		69	(33.7)
Stiffness relative to wood	.	.70	
Section modulus, in²–ft (cm²–m)	.	8,372	(4.275)
Stress for 2.7× 10⁶ ft–lb (0.375× 10⁶ m–kg) mom. lb/in² (kg/cm²)	.	323	(22.8)
Ultimate strength lb/in² (kg/cm²) .	.	6,950	(490)
Safety factor on ultimate	.	22	

TABLE 12

Preliminary light ship weight 110 ft wood and synthetic reinforced plastic composite trawler

Hull, structure, tons	.	.	.	.	.	.	.	65
Sub-total, tons	.	.	.	.	.	.	.	147
Margin—design (10 per cent), tons	.	.	.	.	.	.	15
Margin—soakage (3 per cent), tons	.	.	.	.	.	4
Light ship, tons	.	.	.	.	.	.	.	166
Hull structure relative to wood	.	.	.	.	.	.	.54
Light ship relative to wood	.	.	.	.	.	.	.69

TABLE 13

Preliminary light ship cost estimates 110 ft wood and synthetic reinforced plastic composite trawler

Material cost/ton . .	£343	($960)
Hull weight with margin .	72 tons	
Invoiced material (×1.15) .	83 tons	
Material cost	£28,450	($79,680)
Manhours/ton . . .	200	
£/manhour ($/manhour) .	£0.83	($2.32)
£/tons labour ($/ton labour)	£162	($464)
Direct labour . . .	£11,940	($33,410)
Overhead, 80 per cent labour	£9,540	($26,730)
Material, labour, and overhead	£50,000	($139,820)
Profit (10 per cent) . .	£5,000	($13,980)
Sub-total	£54,700	($153,830)
Outfit, machinery, etc. .	£57,500	($161,700)
Mould cost	£—	($—)
Total, 1 boat . . .	£112,500	($315,500)
Total, each of 5 boats .	£100,000	($280,800)
Total, each of 25 boats .	£83,300	($233,500)
Total cost relative to wood:		
1 boat	.99	
5 boats	.96	
25 boats . . .	.92	

McNeely (USA): One of the more important implications of Takehana's paper is the ease with which mass production techniques might be employed to lower the cost of standard hull forms. If a reduction in the number of base hull forms could be effected then lower costs through mass production might accelerate the advancement of fishing in developing countries. What is suggested here is that it is unreasonable to have a thousand different hull designs for use in about 20 various fisheries. Standardization in FRP construction might be an important key to the development of fisheries in several sections of the world.

Netherland experience

Verweij (Netherlands): Della Rocca's paper is excellent. As regards the materials of the core it must be pointed out that excellent experiences have been obtained in the Netherlands with polyvinyl chloride (PVC) foam, which was used in deck and hull of both 50 ft (15 m) landing craft and 77 ft (23.5 m) pilot vessels. For future application, polyurethane foam may be contemplated for the deck, whilst retaining PVC for the hull core. With PVC foam, extensive research was done and amongst other things, it was found to have good durability and fatigue characteristics. Not much is known so far about the fatigue properties of polyurethane.

As regards the various types of hull construction, the systems mentioned there under (1), (2) and (8) are to be preferred over others and also that (1) is better than (2).

When dealing with sandwich construction, Della Rocca rightly points out the additional advantage obtained with excellent thermal insulation. However, Verweij did not share Della Rocca's opinion as regards the weight of a sandwich versus a solid construction. Also the new Lloyds rules arrive at lighter weight for the sandwich. This different approach may also explain greatly the higher price of the sandwich boats—Della Rocca finds.

As regards difficulties with the propeller shafting, which may arise due to hull deflection, a flexible coupling and, if necessary, a part of the shafting at midlength with a universal joint at both ends will cure the problem.

Lee (UK): One point which seems to be omitted from the remarks on reinforcement is that chopped strand mat limits "wick" action in the event of damage and thus minimizes delamination.

Mould costs similar

MacLear (USA): Complimented Takehana for his paper and noted with interest that the mould costs in Japan are very similar to those of the USA and Europe. Mould costs are often equal to the cost of the boat, if the hull alone is moulded.

If a deck mould is also made the total mould cost can be twice the cost of the finished boat, and if extensive interior mouldings are made the cost ratio can be as high as three times.

He had very much enjoyed Della Rocca's paper and did not doubt that there will be 110 ft (34 m) fibreglass trawlers in the future. He thought one should start with boats of 60 to 70 ft (18 to 21 m).

He also mentioned that he had seen fibreglass both outside and inside of a plywood boat. In the beginning he was concerned about rot. The US Coast Guard is considered to be very severe in their demands and they had tested such a 12-year-old boat and had found no deterioration. This boat was 100 ft (30.5 m) long, used for charter parties going out one to three days at a time for fishing for pleasure. The plastic boat industry has grown very fast in the USA, 50 ft (15 m) boats are laid up in two days compared with the usual one to six months for a wooden boat. The US Coast Guard and US Navy now make most of their smaller boats in FRP.

A boat owner had had a wooden 40 ft (12 m) boat and had been spending £1,000 ($3,000) a year in up-keep. He now has a fibreglass boat of the same dimension and spends £180 ($500) yearly in up-keep. This great difference seems too good to be true, but other owners agree that it is quite possible.

Finally a warning. A lot of boat yards in USA which started with fibreglass constructions have gone bankrupt. It is interesting to note that there are a great many satisfied plastic boat owners but quite a few disappointed moulders.

Timely and valuable

Colvin (USA): Takehana's paper is a very timely one with a great deal of food for thought. It is quite evident that he has found in Japan a very similar problem to that which exists in USA that is, a sharp increase in the cost of timber along with its decrease in quality, and the scarcity of skilled wooden shipwrights, and the even further scarcity of those willing to undertake the long apprenticeship to become wooden shipwrights.

It will be appreciated by all the difficulty of the Japanese Fisheries Agency in selecting the prototypes because of the vast variations not only from locality to locality, but of the various vessels within the locality. The laver and pearl boats do lend themselves to the FRP construction. However, aluminium as well as steel also lend themselves to this type of vessel. Takehana points out that steel construction is becoming more popular and this is also true in USA. The small village shipyards that already have the technical capabilities of building in wood would find the change-over into steel one of a minimal cost and very little change in technique. It would require the training of a welder, but the equipment outlay would be less than £180 ($500). This is especially true of those yards building in sizes under 50 ft (15 m) in length as a 180 amp AC/DC welder and an oxygen-acetylene cutting torch would be the only absolute requirements. While the methods of working in metal are different to those in wood, yard personnel experienced in wood construction require only a few weeks to grasp the differences in technique. Also, in oysterboats that range from 28 to 35 ft (8.5 to 10.7 m) in length, it is possible to build not only a stronger boat and a better boat but a lighter boat in steel than conventional wood planking and the same weight as plywood planking. The small shipyard, however, is not faced simply

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with whether or not they can continue to exist by building just wood or just steel; but it finds itself faced with the problem of having to use FRP and aluminium as well as steel and wood. Each has its place where it functions best. The cost change-over from wood to FRP construction would be approximately the same as for steel construction if spray equipment were purchased.

Theoretical or actual strength?

Takehana's method of building without moulds would indeed eliminate much of the initial cost that is associated with FRP construction. A point that he has brought out very clearly is the desirability for design data showing how many layers of FRP are necessary to provide the required strength along with the type of fibre to be used. While it is possible in theory to calculate this strength, the theoretical strength and the actual strength are two different values. A great deal of skill is required in the lay-up of FRP hulls if they are to have consistent integral strength and uniformity. The temperature, humidity and the human factor all affect the end result of FRP hulls. And if it is to be spread out on a wide scale through a variety of builders, then there should be a means of testing each of the hulls via a trepanized system with a sampling of at least ten spots per side. If the quality of the lay-up lacks by a certain percentage of the theoretical lay-up, then additional material would be called for. Under this system, it would make the builders more conscious of quality.

The advantage that is inherent in most Japanese fishing vessels is their simplicity of form which, in turn, gives them a dampening motion, permits rather heavy loading, still maintaining very good powering characteristics. The abandonment of the design of a traditional vessel and its replacement, while it often cures one problem, creates many more. Sometimes they even go so far as to solve and cure problems that have not even become apparent. It would seem that the solution to the small craft problem would be in the training of the small builders into all materials. Then full advantage could be taken of wood, steel, FRP and aluminium simultaneously and by the same builder.

Balancing sales with production

In USA FRP does cost more than its counterpart in wood, and that while mass production allows one to turn out a vessel in a shorter length of time, it also creates the problem of having to expand the facilities too a point where sales must keep up with the production, and ideally must exceed production. If a small yard is to mass produce, then the yard layout in woodworking tools is approximately the same as it had been in the wood boatbuilding unless, of course, they purchase the moulds from a competent pattern shop which would make their plate layout very minimal.

The actual lay-up can be done by semi-skilled workers; however, in Takehana's table 6, it is noted that the timber, bolts and nails in the non-moulded sandwich boat is 58 per cent of that of the all-wooden boat, which indicates that some skilled labour is going to be a requirement. The vessels shown in fig 11 and 12 are ideally suited for direct conversion to metal construction.

It will be interesting to see the developments in fibreglass reinforced plastics over the next few years in Japan. If the vessels can become standardized, perhaps the solution then falls entirely within the realm of FRP in small craft at least. However, if the standardization becomes impossible, then it would seem that diversification in the small yards, in gradually introducing various components of FRP will be the way to gain acceptance of the material and give the necessary time to the individual builder to develop his techniques.

Author's replies

Takehana (Japan): Answer to McInnes: The bending moment WL/12, stress 25 kg/cm² was obtained from static experiment, so in the design stage the bending moment must be taken as WL/6 with consideration to dynamic action.

Due to the recent development of ultrasonic techniques, it becomes possible to generate waves which have higher power and narrower pulse width. It has been said that flaw detection in high decrement material is impossible, but now this becomes possible.

The present applications of this high power detector are as follows:

● Detection of tumour in human body
● Detection of cracks in fire clay
● Detection of a flaw in the solid propellant in a missile

Ultrasonic waves look also promising in the non-destructive detection of cracks and delamination in FRP laminates.

Pulse width 0.05	. . 0.1 μs
Output power .	. . 10 kw
Frequency .	10 megacycles

The answer to Kilgore is: If a wooden plank is completely enclosed by synthetic fibre plastics, delamination would occur by the swelling of the wood due to the absorption of water. Should this point be solved completely, this would be the best way to save wood, make a strong and rigid ship and reduce the maintenance costs.

Answer to Colvin: Lee has also mentioned the spray gun but it appears very difficult to handle and the laminate produced is not so strong as roving cloth reinforced plastics. The raw material is also more expensive if mass production is not adopted. A more desirable piece of equipment for a plastic boatyard would be a temperature controlled workroom for cold and bad weather countries. Regarding table 6 which shows that in FRP no-mould construction, timber bolt nails are only 58 per cent of those required for wooden construction. But in using these, less skilled labour is required than for the wooden ships.

Answer to Lee: a sharp chine is not favourable in FRP construction and it is preferable to round up the sharp corners, but not to such a degree as to affect the roll-damping characteristics. To the point that polyvinyl-chloride (PVC) core is not very strong to shear, the combination of paper honeycomb and plastic foam might offer a solution.

Meeting Lloyd's rules

Della Rocca (USA): McInnes stated that the provisional Lloyd's rules envisaged a thinner core material than that proposed in his paper; as at present there is no suitable polyurethane core material available on the US side of the Atlantic. The Lloyd's rules "are exceptionally well done and in considerable detail". The proposed scantlings are in remarkably close agreement with these rules. Two methods were used to extrapolate the Lloyd's rules requirements for sandwich construction with 36 in or 3 ft (0.9 m) stiffening spacing to the 72 in or 6 ft (1.83 m) spacing used in the proposed 110 ft trawler. First, as specified by note 3 of table 2 in Lloyd's rules, where the spacing of the stiffening members differs from the basic 36 in, the section modulus is to be modified in the ratio of the spacing squared. By simple arithmetic, $(72/36)^2$, the factor for increasing the section modulus is 4. To maintain the same mat laminate thickness and weight, the 1 in (25 mm) core depth specified in table 2 was multiplied by the factor of 4 giving an equivalent core thickness of 4 in (100 mm). The second method used was to

determine the section modulus required by Lloyd's rules for a single skin laminate for 72 in (1.83 m) stiffener spacing and determining an equivalent sandwich section. Both approaches gave very close agreement and resulted in the scantlings presented, in fig 6 of the paper. The core material is not considered in the strength of the panel by Lloyd's rules and the paper.

McInnes' comment in regard to the use of fire-retardant paint as a normal method of obtaining fire retardancy is satisfactory for steel or wooden hulls. This method is not recommended for fibreglass reinforced plastic hulls since in addition to the cost of painting the outer and inner surfaces of the hull, the paint will probably peel off unless it is an expensive plastic type of paint compatible with the polyester resin. Further, the outer surface will require light sand blasting or sanding to remove the wax and mould prior to painting. If the approximate 5 per cent increase in the overall cost of the trawler is considered by some to be excessive for fire-retardancy of the entire laminate, it is then recommended that only the outer gel coat resin and the resin used with the innermost ply be fire-retardant. This will result in a superior and more durable hull requiring much less maintenance at a considerably reduced initial cost.

In reply to McInnes' request for details of experience with balsa wood sandwich panels in vibration areas where heavy diesels are fitted, Della Rocca advised the use of a balsa core sandwich panel in the bottom of a 50 ft (15.3 m) pleasure craft directly below a generator driven by twin diesels at high speeds in fairly rough weather without any detrimental effect on the sandwich panel.

The corrosion issue

Della Rocca agreed with McInnes' comment that when relating the plastic scantlings to steel scantlings, deductions can be made for corrosion. In converting the steel scantlings obtained from the American Bureau of Shipping Rules to fibreglass reinforced plastic construction for the 110 ft trawler, .08 in (2 mm) for corrosion from the 0.31 in (8 mm) steel plating was deducted prior to calculating a laminate of equivalent stiffness based on the cubed root of the ratio of the flexural moduli.

Della Rocca recommended the composite mat-woven roving laminate in lieu of the all-mat laminate for the 110 ft trawler because for a 5 per cent increase in material cost, a 3 per cent savings in weight, a 30 per cent increase in hull bending modulus and greater impact resistance will be obtained. Further, experience in the USA indicates that it is much easier and quicker to lay-up the composite mat-woven roving laminate than the all-mat laminate.

Heath requested information on specific items, the following advice is offered:

- Since the glassfibres readily absorb water prior to being laminated, excessive moisture in the moulding shop due to high humidity will accumulate on the glassfibres which prevents the resin from coming in contact with the compatible chemical finish on the glassfibres and the chemical reaction at the resin-glass interface does not occur resulting in a poor bond,
- The effect of the sun on fibreglass reinforced plastic laminates will improve the basic laminate properties until full resin cure is achieved and the properties will remain constant. However a good weather-resistant gel coat is necessary on the surface exposed to the weather to protect the basic laminate. Pigmented gel coats after a number of years will have a tendency to fade,

- A gel coat is recommended and should be reinforced with a layer of 1 oz mat minimum with the next ply of reinforcement laid-up just after the resin on this mat has begun to gel. This will prevent the peeling off of the gel coat. If the gel coat peels, the entire surface of the hull must be sanded and resurfaced with a good polyester gel coat, or an epoxy base paint,
- Polyester resins are suitable and will resist attack by petrol and fuel oil tanks but they must completely cover the fibreglass reinforcement and be fully cured. A gel coat surface will provide exceptionally good protection. The author does not know of any completely fireproof plastics. However, good fire-resistant or self-extinguishing polyester resins such as Hooker Chemical Company, Durez Division Hetron polyester resins are available,

Disadvantages of plastic-coated hull ignored

The following reply to Koopman's comments will also apply in part to Kilgore. Koopman has presented a very impressive discussion for a plastic-coated wood hull emphasizing all of the advantages and disregarding all of the disadvantages. Koopman's statement that Della Rocca had disregarded the effect of weight savings on the other elements of the hull is incorrect. Della Rocca clearly stated in the discussion on Light Ship Weight under the Comparison of Trawler Characteristics the many uses that can be made of the weight saved and particularly noted that the reduction in weight will raise the light ship vertical centre of gravity about 5 per cent requiring consideration of stability early in the preliminary design.

Koopman's proposed hull construction has limited service experience of approximately five years and has many fabrication, maintenance and durability disadvantages. The fabrication of the wood core requires temporary internal framing which becomes scrap when removed and replaced with the very expensive pre-laminated transverse frames. Maintaining the moisture content in the wood to a predetermined content during construction particularly in the warmer climates must be quite difficult. Swelling of the core and framing with possible cracking of the thin plastic skin can occur when the core begins to absorb water after launching. The application of the plastic skin to the core can be very difficult since the first layer must be placed with epoxy resin to obtain a good bond. Epoxy resins normally have high viscosities and will require diluting or considerable working to properly wet out the thin reinforcement. Excessive diluting of the resin can cause run-off of the resin resulting in dry areas at the top of the lay-up and excessive resin at the bottom. Further epoxy resins cause skin irritation and in severe cases can cause permanent skin damage unless proper precautions such as gloves, masks, etc., are taken. The following layers of reinforcement placed with polyester resins can also have problems since there is an interaction between the polyester resin and the polypropylene reinforcement causing swelling of the fibres and a weakness in the bond between the resin and fibres. Also the interaction between the polyester resin and polypropylene inhibits the hardening reaction of the resin requiring larger amounts of catalyst in order to complete the cure. Shrinkage of the semi-rigid polyester resin which is generally 4 to 8 per cent will cause locked-in stresses in polypropylene fibres and negates to a large extent their elongation which is essential for this composite material to function properly.

Analysis of cost factors

For fabrication of this sandwich hull expensive jigs or heavy lifting equipment is necessary to rotate the large hull after the outer skin is placed on the core. A substantial cradle to

properly hold the hull form is also required to prevent distortion when the hull has been turned over and the inner laminate and framing are added. This will add substantially to the fabrication costs. After lay-up of the inner skin the attachment of the internal frames to the shell will require some fastenings since a bond between the inner skin laminate and wood frame with polyester resin is probably insufficient to resist hull torsion and twisting. Since polypropylene reinforced plastic-covered hulls are flexible, heavy items such as generators and heat exchangers should not be mounted on either the bottom or light frames. Unless these heavy items can be mounted to internal decks, additional structural framing will be required t· properly support them on the hull. After completion of the hull, the outer skin must be finished by sanding the entire hull surface prior to painting. Sanding of polypropylene reinforced plastics can also be troublesome due to the resiliency of the fibres causing pulling away of the fibre, particularly if the laminate begins to heat up.

In regard to maintenance problems, experience in the flexible polyester resins has indicated that they have very poor weathering qualities and are particularly subject to degradation when exposed to a water or high humidity environment. Therefore several coats of a good protective paint is required. The thin skins can be easily damaged and pulled away from the core due to gouging from rubbing against sharp objects or dragging heavy items on the deck. Repairs will be difficult due to replacement of the wood core. Decay or rotting of the wood core will occur around bolts, screws and other through attachments to the hull. Also pinholes in the thin skins can also cause decay. Damage to the core due to impact loading can be extensive since wood will have a tendency to split along the length of the grain.

In regard to durability, although the plastic skins will provide some protection, water and some air will get into the core causing decay in some areas, particularly in high stress areas where slight cracks in the skins are unnoticeable. Under these conditions, decay may be accelerated and the expected 20-year life for wood boats may be reduced.

The greatest concern with this type of construction is that progressive failure of the wood core due to overstressing or decay cannot be determined during normal inspection and a catastrophic failure can occur without any prior indication of potential failure.

Doubtful adhesion

Verveij (Netherlands): Koopman mentioned interesting possibilities about combining wooden hulls with synthetic fibres. This can offer a good protection for the outside. It is doubtful, however, whether there will be a proper adhesion with next layers using polyester resin, if the first layer was impregnated with epoxy. In building boats with glass polyester, the mould can be made out of glass epoxy and in that case no separating agent is needed. Therefore, it may be better to try resorcinol formaldehyde glue to cover a wooden hull with synthetic fibres.

However, when comparing a FRP vessel with a wooden vessel covered with plastic on the outside, one must respect statements by experts on wooden boats such as Chapelle who admits that failure of wooden boats is caused by rot or corrosion. This rot in fishing craft usually starts from the inside rather than from the outside. The FRP boat is rotproof both inside and out. To protect the wooden boat on the inside by a plastic covering is also both complicated and costly.

Heath has a number of specific questions to which the following reply is offered:

● Humidity, if excessive, can have a detrimental effect on the cure of the resin. However, actual data are very scarce. The humidity of the air is not so important as the presence of actual water on the surface of the glass. Therefore it is important to store the glass in closed polyethylene bags preferably containing a little silicagel, in a room where the temperature does not drop below the temperature in the laminating room. Also the resin should never be lower in temperature than the laminating room and preferably a few degrees warmer. In this respect it should be borne in mind that resin which has been kept in a cool place for some time needs quite a time to take the temperature of the workshop on a warm day,

● The actual laminating should not be done in full sunlight, but under cover. In direct sunlight too much styrene can evaporate, resulting in undercure. Also the rate of cure along the object under construction may vary. However, once the FRP laminate has been properly made, even tropical sun does not have an adverse effect,

● If a gel-coat is used, not much time should elapse between the setting of this gel-coat and the start of the actual laminating, in order to obtain a stronger bond. Also the gel-coat should be kept thin. Apart from colour, the gel-coat gives a smoother surface, making cleaning easier and reducing marine growth. It can also improve weatherability,

● For fuel and petrol tanks polyester can be used, but a gel-coat is also necessary. The laminate should be completely cured. For petrol tanks an isophtalic resin is better. To Verveij's knowledge there is not a really permanent fireproof polyester resin available nowadays. Therefore he proposed to limit the use of fireproof resins to a coating in areas needing extra protection (such as engine room with petrol engines),

● Information about setting up a FRP boat-building business can be given more fully in personal correspondence. However, some general remarks in connection with FRP boatbuilding might be useful. Industrialization plays a more and more important role, and this importance will continue to grow also in developing countries. FRP lends itself eminently to this trend of industrialization. Contrary to wooden boatbuilding, mainly unskilled, though intelligent labour is required and one can learn to work with FRP in a rather short time. Basic for successful building FRP boats is a design made by someone who is an expert in this field and a clear and complete manual for the actual building of the boat, together with a detailed list of materials. The next requirement is a few people with some and preferably a good experience of working with FRP who can instruct and lead a group of unskilled labour,

The industrialization also asks for standardization, and here again FRP can help, asking for standardization itself. Finally, a certain production can be reached in FRP with lower investments than needed for this production in wood, steel or aluminium.

Several contributors have pointed out the importance of low maintenance cost of FRP as compared with other materials. This factor, having great influence on the earning power of a vessel should duly be taken into account. Of course also the initial building cost remains very important. Therefore, continuous efforts are made to reduce the building costs of FRP vessels through effective use of materials, but especially by improving production techniques. This improvement of production techniques is at this moment one of the main items which is being investigated by a Netherlands Panel

preparing a report for the 1967 International Ship Structure Congress. It is expected that the result of this study will contribute greatly to making FRP commercially attractive for cargo and fishing vessels up to about 170 ft (50 m) in length. Of course also builders of smaller vessels can benefit from these investigations.

USE OF CONCRETE

James (UK): The use of concrete in the marine field is certainly not new. Between 1917 and 1922 due to the shortage of steel during and just after World War 1 over 150,000 tons of concrete shipping was built on both sides of the Atlantic, ranging in size from 7,500 ton oil tankers to small tugs and lighters. The hull thickness on such vessels ranged from between 4 and 6 in (102 and 152 mm). A new material, a derivative of concrete has now been developed in UK in which the hull has a thickness of only $\frac{7}{8}$ in (22.2 mm). In this development all the data obtainable on concrete ship construction over the years has been utilized.

The basic raw materials are sand, cement, steel reinforcing and other special additives that give this material good properties.

Concrete boat construction requires no expensive moulds such as are required in glass-reinforced plastic boat construction and therefore one boat can be produced relatively cheaply, it not being necessary to recover expensive mould cost over a series of identical hulls.

All that is required is a suitable jig to support the keel, preferably capable of having wheels attached for easy movement and a set of wooden frames similar to wooden shams used in conventional wood boat construction. The steel reinforcement being built up around these frames. Any shape of hull may be produced in this manner. The stem mould and transom mould are removed to facilitate access to the reinforcement when the hull is cast. After the hull has been cast and is no longer "green" it is sprayed continuously with water for between 100 and 150 hours according to conditions. The other frames are then removed and the hull cleaned off internally.

During the laying-up of the reinforcement for a hull, it is not necessary to adhere to any strict temperature control, when the hull is cast, however, it is advisable to maintain a moderate temperature with a reasonable degree of humidity.

The ultimate tensile strength of this concrete material is 5,340 lb/in² (390 kg/cm²) and because a mesh reinforcement is used, it will have this tensile strength in all directions. Most boats less than 100 ft (30 m) in length are now built of wood because it is cheaper than aluminium or glass reinforced plastic. Therefore this concrete shall be compared with wood.

The tensile strength of wood is approximately 6,000 lb/in² (422 kg/cm²) along the grain and negligible across the grain, also the tensile strength of a wooden hull is diminished considerably by the fastenings and the fact that the grain often "runs out" whereas in concrete hulls there are no fastenings and the tensile strength is accordingly uniform.

The compressive strength of this concrete material without reinforcement is about 7,200 lb/in² (500 kg/cm²) after seven days and 12,225 lb/in² (860 kg/cm²) 28 days and continues to increase with age far in excess of wood. Young's modulus of elasticity for this concrete material is 1.30×10^6 lb/in² (91,400 kg/cm²).

The specific gravity of the concrete is 2.4, that of glass-reinforced plastic is 1.6, and of a wooden hull including fastenings 0.9. In spite of the weight of the material a concrete hull compares favourably in overall weight with both wooden and glass reinforced plastic hulls because a concrete hull requires no heavy internal frames or floors and a panel almost half as thick as timber is equally as strong.

Vessels shorter than 100 ft (30 m) do not have stresses upon the hull that are excessive. On a 75 ft (22.9 m) trawler displacing 110 tons the maximum stress at deck level or the bottom of the skeg, depending on whether the vessel is hogging or sagging will not exceed 1,000 lb/in² (70 kg/cm²) if the thickness of the hull is approximately $\frac{1}{2}$ in (12.7 mm) thick. Therefore, with the tensile strength of the concrete material being 5,340 lb/in² (390 kg/cm²) there is ample margin for safety.

A pertinent question is whether a concrete hull is sufficiently strong to withstand rough treatment such as abrasion against dock walls or rubbing against other craft. For such vessels concrete is immensely hard and shows great resistance to abrasion. It has distinct advantages over reinforced plastics in this sphere. Because of its greater thickness and the fact that even if the surface suffers abrasion it will not weep as is the case with a glass-reinforced plastic hull due to its internal porosity.

After exhaustive tests Lloyds Register of Shipping have intimated that they will give 100 A1 classification to a vessel with a concrete hull, also the British White Fish Authority will accept applications for grants.

A concrete hull is very strong and yet is also extremely flexible. A sample strip was tested by Lloyds Register of Shipping and the following results were obtained. Size of strip: 21.65 in (550 mm) long, 5 in (127 mm) side, and 0.65 in (16.4 mm) thick. The distance of the loading point from one support point was 8.5 in (216 mm). Normal stress levels +700 to −600 lb/in² (+49.2 to −42.2 kg/cm²). It was flexed for 2 × 10⁶ cycles without fracture.

Stiffened by metal

The concrete hull is stiffened by the insertion of metal frames spaced in accordance with the size of the hull and to these frames are attached lugs to take bulkheads, etc. James' firm has also devised a method of casting into the hull, floors and engine beds in concrete and these strengthen the main structure to a considerable degree.

Vessels constructed of this concrete material up to 40 ft (12 m) in length are slightly heavier than an equivalent vessel constructed in wood, glass-reinforced plastic or steel. Larger power-driven hulls are lighter than steel or wooden hulls and yet have the same strength and are equally rigid. It should also be noted that vessels up to 60 ft (18 m) in length can be constructed of $\frac{7}{8}$ in thick (22.2 mm) material. This thickness weighing only 11 lb/ft² (52.8 kg/m²). However, the thickness of a glass-reinforced plastic hull is greatly increased as the hull sizes increase. Thereby adding to the cost of materials.

A concrete hull is fire resistant and in this respect has considerable advantage over wooden hulls and glass-reinforced plastic hulls. Test panels have withstood 3,100°F (1,700°C) for 1½ hours with no effect on the material.

It is quite possible to construct decks and superstructure in the concrete material, using the same form as the hull skin. By doing so one produces a very strong and rigid hull due to it becoming a complete monolithic structure. On smaller vessels this is not advisable due to the weight factor.

It is not necessary to protect a concrete hull with paint, but any normal good quality marine paint will be quite adequate for decorative purposes and anti-fouling. A concrete hull requires no maintenance. It is a homogeneous structure, therefore it cannot leak, cannot corrode and is immune to marine borers. Barnacles and algae will attach themselves to a concrete hull below the water line in the same manner as a timber or metal hull, but they may be easily removed with a powerful detergent which will have no effect on the hull. Concrete cannot be attacked by marine borers and hulls built

in this material will not deteriorate as is the case of hulls built of wood where a very short life span may be expected.

A tremendous advantage of a concrete hull over other forms of hull material is that it can be so easily repaired. If a concrete hull is damaged in a collision it can be repaired in about one-tenth of the time taken to repair a wooden hull. The procedure for repairing is as follows: The damaged area is broken away until the surrounding concrete material is undamaged and solid. It should be remembered that when a hull is damaged, the damage is completely localized and is confined to the area where the impact took place. Once the broken concrete has been removed any broken mesh reinforcement is replaced and knocked back into its original position.

Simple repair kits

A suitable repair kit is supplied by the makers and the ingredients mixed in accordance with the instructions and is then applied to both the interior and the exterior of the damaged section. The exterior is left slightly rough and finally "ground off ". The hull is then painted and finished as it was before damage. Normally a repair can be effected in one ordinary working day. Whereas it is comparatively simple to repair a concrete hull even in tropical conditions, the same does not apply to glass-reinforced plastic hulls where materials if stored tend to deteriorate and it is not always possible to maintain the correct working temperatures that are all important in effecting a satisfactory repair.

Hulls built of the concrete material are relatively cheaper than wood and steel and are cheaper than reinforced plastic hulls over 30 ft (9 m) in length. The main labour involved in producing a hull is in setting up and forming of the reinforcement. Consequently larger hulls are proportionately cheaper than smaller hulls. It must also be realized that to produce a reinforced plastic hull cheaply a number of hulls have to be produced from the same mould whereas in the case of a concrete material hull it is quite possible to produce a single hull to a particular shape economically.

Above 34 ft (10.35 m) concrete hulls can compete with wooden, steel and reinforced plastic hulls. For example a 24 ft (7.3 m) hull complete with floors and engine beds is sold for £700 ($1,960), a 28 ft (8.5 m) hull complete with floors and engine beds for £800 ($2,240), a 34 ft (10.3 m) hull for £1,000 ($2,800) and a 45 ft (13.7 m) hull for £2,100 ($5,880). Concrete hulls are dry, durable and more easy to repair than hulls made from other materials. Concrete is relatively cheaper than any other form of construction.

Concrete hulls do not absorb any amount of moisture and therefore there is no risk of contamination by fish in fishing boats, moreover, it is a very good insulator having a thermal conductivity of 68.88 BTU/ft²/°F/hr (335 kcal/m²/°C/hr), consequently there is little or no risk of condensation in concrete hulls. Furthermore, such a hull is completely odourless.

Due to the built-in framing and strength inherent in the material, it is possible to obtain 11 per cent more space in a concrete material-hulled craft than in a similar sized hull constructed in any other material. It must also be stressed that concrete-hulled craft may be cast into practically any form to meet the particular requirements of the purchasers, rather than the purchasers having to accept a standard design as in reinforced plastic hulls, or prohibitive costs as in wood and steel hulls.

It has already been stated that the basic raw materials for the construction are sand and good quality cement. Both these items are usually readily available in most countries. This is, of course, of paramount importance particularly in under-developed territories and countries that lack their own steel mills and accordingly have to import the raw materials

for other forms of construction, often using valuable foreign exchange.

It is also important to note that apart from one trained technician, it is quite possible to construct vessels in this concrete using intelligent but unskilled labour.

Finally the advantages may be summarized as follows: continuous and monobloc structure, smooth surface, perfectly watertight, no maintenance costs, easily repairable, extremely strong but without losing a marked degree of elasticity.

COMPARISON OF MATERIALS

Hamlin (USA): A fairly recent complication of the shipowner's and naval architect's decision-making function is the proliferation since World War II of the materials from which fishing craft can be built. In addition to traditional steel and conventional framed and planked wood, there are aluminium, fibreglass-reinforced plastic (FRP), and various ways of using wood, such as glued strip, sheet and moulded plywood, and multi-layer parallel laminations. Furthermore, combinations of materials are becoming more commonplace, such as reinforced plastic layers over wood, aluminium structures on hulls of other materials, etc.

Many criteria are used in evaluating the various properties of a building material. One of the most important is its cost, not only the cost of construction but also the cost of annual ownership as affected by the building material, and the expected efficient life of a vessel built of the material. As a start in evaluating these cost factors fig 31 can be used.
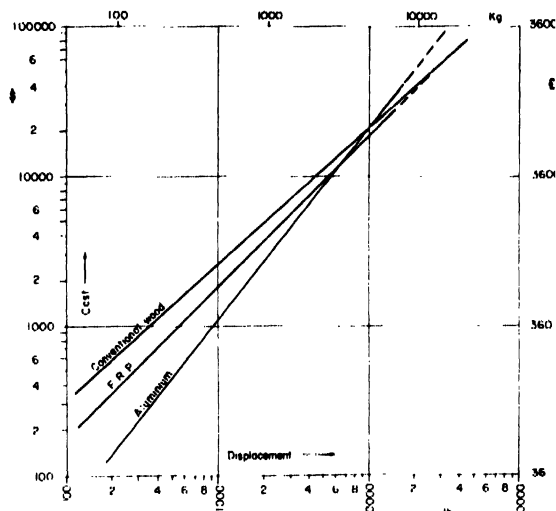
Fig 31. Construction cost versus displacement as of October 18 1965

These curves were prepared from rather haphazard data regarding the advertised cost of small and medium-sized yachts available on the USA market and no great reliance should be placed in these curves, particularly those for FRP and aluminium vessels. No attempt was made to classify them as to quality or end use, but an effort was made to equalize the basic necessities such as crew and power plants.

The curve for wooden boats has been building up over several years. It fairly represents the cost of average quality sail and power yachts built in the USA. Both the FRP and aluminium curves are based on data obtained during the 1964 New York Motor Boat Show. There were 30 points for FRP boats, nine for aluminium boats. The curves drawn could tentatively be taken as representing the cost of average stock boats of the respective materials.

There is not a great deal of difference between the selling costs of stock and custom boats. The production savings of stock boats seems to be almost wholly offset by the cost of advertising, commissions, etc., required to sell the larger production.

Even though there may be a considerable question of the validity of the curves shown on the graph they indicate the general pattern of costs with respect to building material and size. Certainly it would be interesting to see these curves refined, and also to see a companion graph of curves, based on annual cost of ownership for the various materials, against size of percent depreciation in value for each material against years of life. These three sets of curves would be invaluable in choosing the building material for a specific design.

In examining fig 31, the curves for wood and FRP seem to be in an expected relation with each other. The small wooden boat, with its multiplicity of relatively delicate components, can hardly be expected to compete in cost with the simplicity of FRP construction. The large wooden craft, on the other hand, has only a slightly greater number of parts than its small counterpart, whereas the large FRP craft is complicated by framing, cores, etc., to provide necessary strength and stiffness thus making it relatively more expensive to build.

What is surprising, at least at first glance, is the low cost of small aluminium craft relative to the other two materials. This must undoubtedly reflect the ease of building with flat plates and simple extruded sections as well as the ability to form and weld large hull sections of aluminium quickly and cheaply. Certainly the large number of aluminium gill netters on the US and Canadian West Coast, with a displacement of 6,000 to 7,000 lb (2,700 to 3,200 kg), as reported by Leveau and Brandlmayr would tend to validate the curve of aluminium costs.

The spread of the curves in fig 31 would seem to indicate a need for increased attention to shipbuilding and maintenance costs, these being a major part of any fishing operation. Perhaps the question is of sufficient importance that the FAO Fishing Vessel Section would consider establishing a Permanent Panel to raise the subject of costs from one of "by guess and by gosh" to something approaching a rigorous discipline.

Verveij (Netherlands): Although Hamlin himself already doubted the validity of fig 31, Verveij did not hesitate to call this graph misleading. Since boats of equal size (taking the total volume as the base to compare size) have different displacements if made in wood, aluminium or FRP with FRP having least weight at equal strength, one is in fact comparing boats of different sizes when using fig 31.

Lower maintenance balanced higher initial cost

Reid (Canada): As the designer of a fairly large number of moderately-sized welded steel fishing vessels over the past ten years he made the same comment to each of the authors of the FRP papers. The point is made, in all these papers, that the higher initial cost of the proposed material is more than offset by the decreased cost of maintenance in comparison to wood or steel construction. The point is made that steel requires virtually constant maintenance during its service life.

It has been common practice on the Pacific Coast of Canada and the USA to use special coatings on all external steel (except below the light waterline). This coating includes not only hull steel but deck—deck house and wheelhouse, funnel, mast, boom, deck gear and hardware.

Originally the coating consisted of sand blasting (or shot-blasting) of all mill scale followed immediately by metallizing of all sand-blasted surfaces, using either zinc, aluminium or lead to a specified depth, usually of 8 to 10 mill thickness. Since epoxy-based paints have become available, the metallized surfaces are coated with a commercial epoxy paint. In extreme cases, where inaccessible bilge spaces may occur due to hold linings, etc., these spaces have also been coated.

US Navy test results recently released indicate that zinc coatings only can be expected to give a service life of 18 to 20 years, there was no doubt of a life of 20 years or better if epoxy paint was used over the zinc.

Experience has been that these expectancies should easily be reached. The present cost in Western Canada for such coatings varies between 75 and 90 cents per square foot so treated—however, this cost is reduced by the cost of sand blasting and painting which would have to be done otherwise.

In service damage due to wire being dragged along the bilges has indicated that the metallic coatings tend to be carried into any grooves cut in the steel— again in extreme cases of surface damage it is a simple matter to wire brush or sand blast damage portions clear and recoat.

With the exception of normal maintenance costs which occur on any vessel – it is not certain that the notably higher costs of either aluminium or reinforced plastic can at present be justified by the unknown but expected lower costs of maintenance.

Paulling (USA): With the increasing difficulty of obtaining suitable shipbuilding lumber and personnel with the skills requisite to the construction of round bottom wooden boats, there will be an increasing use of sheet materials such as steel, aluminium and plywood. Its properties of strength and corrosion resistance combined with predictable and enduring connectability by welding, would make aluminium seem generally preferable to the other two. It is hoped that increasing availability of the material plus experience in its use will bring the price of aluminium construction into line with that of competing materials in the near future.

The usefulness of sheet materials for hull construction would seem to be greatest in the intermediate size range where the number of craft built to a single design is usually insufficient to justify the mould and other costs of reinforced plastic construction. Further, such craft are frequently constructed in smaller yards which are not equipped with all of the metal-forming equipment necessary for the construction of moulded metal hulls.

Fyson (FAO): Cost figures for a wooden fishing vessel to provide a comparison with figures given for aluminium and plastics can be illustrated as follows. A 52 ft (16 m) purse-seiner without fishing equipment or electronics, built in Senegal will cost approximately £14,000 ($40,000) or about £80 ($225) per m³. Further figures on cost comparison can be found in Gurtner's paper.

PART IV

ENGINEERING

Technical Experiences of Mechanization of Indigenous Small Craft

by E. R. Kvaran

Expériences sur le terrain en matière de mécanisation des petits bâtiments autochtones

L'auteur relate ses expériences personnelles dans ce domaine, en s'attachant particulièrement à l'installation de moteurs intérieurs. Selon lui, la motorisation des bateaux ne suscite aucun problème social sérieux, tout en permettant un accroissement immédiat du niveau de vie. De plus, si l'on équipe simultanément plusieurs bâtiments dans la même région, la rivalité amicale qui s'établira entre pêcheurs les aidera à surmonter leurs difficultés initiales.

L'auteur décrit l'installation de moteurs intérieurs, tubes d'étambot, etc., dans les bateaux autochtones, ainsi que les modifications devant être apportées à la coque. Vient ensuite un exposé des difficultés qui surviennent généralement sur le terrain, l'auteur préconisant, même au prix de coûts initiaux plus élevés, la facilité d'entretien et la fiabilité plutôt que la simplicité. La mise en place d'un bon service après vente constituerait également un atout précieux, et éliminerait notamment les conséquences souvent néfastes des réparations effectuées sur place dans des conditions primitives.

Experiencias técnicas en la mecanizacion de pequeñas embarcaciones exóticas

La descripción del autor se basa en su propia experiencia, particularmente en lo que se refiere a la instalación de motores internos. Arguye que la motorización de los barcos existentes no crea ningún problema social importante, sino que ofrece una mejora inmediata en el nivel de vida. Además, si en una misma región se transforman varias embarcaciones simultáneamente, la rivalidad amistosa induce a los pescadores a soportar los primeros inconvenientes.

Sigue una descripción del acoplamiento de motores internos y hélice a popa en las embarcaciones existentes, con las necesarias modificaciones del casco, explicándose las dificultades con que se tropieza normalmente en la práctica y abogándose por la facilidad de manutención y la seguridad funcional en vez de por la simplificación, aún admitiendo que el gasto inicial es más elevado. Un buen servicio del vendedor al cliente es también una enorme ventaja pues evita las defectuosas reparaciones primarias locales.

A CONSIDERABLE amount has been published on the various aspects of the mechanization of fishing craft. Many relative papers are to be found in the publications of the Fisheries Departments and Bureaus, in reports by FAO, the Colombo Plan, USAID and other international agencies, and in papers of the Indo-Pacific Fisheries Council, most of which have a limited circulation even amongst those directly concerned with the subject, while a few papers have enjoyed a wider distribution in books and in periodicals.

This paper deals with the mechanization of fishing craft both with respect to the installation of engines for propulsion and of mechanical devices for handling fishing gear. It will concern itself primarily with the installation of inboard engines in existing craft types which have not been specifically designed or developed for use with an engine.

There are still many unmechanized craft which could profitably be motorized. Many factors contribute to the retardation of their mechanization: poverty amongst fishermen is the most potent, lack of organization is another, and the formation of really effective co-operatives amongst small fishing operators for the purpose of furthering mechanization has been difficult and sporadic. Various governmental loan schemes have been very useful, but the scale on which mechanization of existing craft has proceeded is nevertheless much too small.

One of the factors has been competition from completely new mechanized boat types which, if well designed, are inevitably more efficient than the indigenous craft. This would not be a matter for concern, were it not for the fact that the introduction of new types entails a very

much greater capitalization than the motorization of existing craft, and can lead to the abandonment of usable old boats. A given investment in new boats or ships may result in increased catches as great as would result from the same investment in motorization, although this is not usually the case in a fishery which is still completely unmechanized. Motorization, on the other hand, will inevitably provide greater employment opportunities in the fishing community, and in most developing countries labour saving is not *per se* an objective at the present time and the dislocation of persons engaged in fishing can create serious problems.

Motorization of existing craft can thus often be justifiable as a preliminary step to further development. This will be true especially in cases where the motorized craft are capable of exploiting the same grounds with the same or similar methods as those proposed for the more highly developed alternate fishing method.

A number of large development schemes have been proposed for various developing countries involving investment in factory ships, large catcher vessels and expensive shore installations. As proposed, these plans inevitably show rapid capital formation and can be very attractive, at least to anyone who believes in "more jam the day after tomorrow". Due to the large capital requirements, however, such schemes are critically dependent on achieving the planned production, and fluctuations in fishing operations can result in great losses instead of handsome profits. Comparable disappointments can certainly occur in the case of motorization of existing craft, but the result then is usually that the increase in individual earnings which was hoped for is not forthcoming, or is less then expected. Provided that some reasonable

preliminary trials or investigations have been carried out, mechanization of existing craft rarely, if ever, leads to an actual operating loss, if excessive mechanical troubles can be avoided.

There may be subtle, or not so subtle, sociological reasons for favouring the mechanization of existing craft, or the introduction of new but small boat types as against launching into large-scale operations. Much has been made of the suggestion that, compared with agriculture, the fishing industry, the only other significant basic source of food, is in a very primitive state. While this may well be so from one point of view, it can be very misleading when considering the state of modern large-scale fishing enterprises. These make use of expensive and complex equipment and the operation as well as the design and selection of this equipment calls for trained specialists. In most developing countries the existing fishing community is not the place to find such specialists, nor even candidates for training. The rapid development of a large-scale fishing industry can lead to the existing fishing community being completely by-passed, with a new set of men taking over the new fishing industry. The old industry is then doomed to stagnation and eventual disintegration.

The introduction of small-scale mechanization can do much to prevent this situation from arising. Experience with engines will help to prevent antagonism toward still more advanced techniques. Even more, it will tend to limit the drift away from the existing fishery which is typical of successful fishermen and particularly of their educated sons in countries where fishing does not enjoy high social standing. When the industry can offer a place for educated and highly trained men, at least in the top levels, it will no longer be necessary for members of the younger generation to turn to medicine, law or other professions to prove their worth and to seek their rightful place in society.

MAIN TYPE OF INDIGENOUS FISHING CRAFT

Almost anything which floats and has sufficient buoyancy to carry a man can be used as a fishing craft. Anthropologists speculating on the origin of water travel usually conjure up pictures of primitive man paddling astride a log, lashing together poles or bamboos or stitching skins or bark on to a frame to create the first boats. Whatever the truth may be, these three models do represent archetypes of the most common indigenous fishing craft still in use. The log, long since scooped out and shaped to form a dug-out canoe, is often provided with one or even two outriggers for increased stability, and craft may be made from intricately shaped and jointed pieces to give greater seaworthiness and manoeuvrability. The kayaks and umiaks of the Eskimo and the American Indian canoes are perhaps the most widely publicized of the sewn boat types but various woven or stitched boats used in Africa and South-Asia are of far greater economic importance. Finally, and obviously of much later origin, are planked boats, which free the builder from the limitations of size and shape imposed by the more primitive constructions. There are no hard and clear lines of division between these four main boat types, as combinations are common. Dugouts may be enlarged by adding a planked or woven superstructure, planks may be sewn or lashed together and wooden boats may have a woven matting bottom. One has a tendency to think of non-mechanized, indigenous craft as being something primitive. In many cases this is so, but in others the craft represent a very high state of development with respect to the lines, the construction, the workmanship and suitability for the purpose for which they are intended. Even when labouring under the severe handicap of not having available metal fasteners or suitable timbers, beautiful, effective, and seaworthy craft have been developed, as in the case of the fishing boats of the Maldive Islands. Tank tests carried out for FAO on Pakistan fishing boats show that the hull form is difficult to improve on from a propulsion point of view.

The justification for mechanization lies in the economic field. No man's time is today worth so little that he can afford to depend on the vagary of the wind.

The construction of the boat will naturally affect the possibilities of mechanization and the manner in which it can best be carried out. Inboard engines, especially diesels, require reasonably rigid hulls and ones which are not too narrow, while outboards can be mounted on almost any hull form provided it is not too high. Even a bathtub has been fitted with an outboard and used as a boat to illustrate how far mechanization can be carried.

INSTALLATION OF INBOARD ENGINES

The installation of an inboard motor in an indigenous craft usually presents many more problems than does that of an outboard, as it entails at least three or four separate entities which must be reasonably harmonized if a satisfactory job is to result. The engine must be firmly mounted in the hull and the stern gear fitted in proper relationship to the engine on one hand and to the propeller location on the other. Auxiliaries such as the water inlet, the exhaust piping and silencer, air-ducting and fuel tank must be located and fixed so as to function effectively with a minimum of interference to the operations to be carried out. An engine box or house may be required and, usually, a completely new rudder, differing in design and mounting from the original.

A basic characteristic of most non-mechanized craft is shallow draft, and the first decision to be made is what to do about this problem, preferably before the engine has been purchased or selected. If the shallow draft is essential for the operation of the boat, a lifting propeller or a high-speed engine with direct drive must be used. The former is rarely satisfactory except on hulls specifically designed for it, which would of course not be the case in this instance. When a high revving propeller is used, especially close to the surface, loss of efficiency and aeration will have to be tolerated, and even so it is usual to find that the original draft is so small that even with the smallest practicable propeller some increase in draft must be accepted. This is usually brought about by reconstructing the stern of the boat, or more commonly, by adding a false keel.

Unless the installation is being carried out by a naval architect or engineer it is unlikely that any drawings will

be made and it is then easy to underestimate the size of the keel required, not to mention the angle of installation. Most indigenous craft are hauled up on a beach, regularly or occasionally. After mechanization it is often found that this is much more difficult than before and not only due to the added weight. As long as a boat has a straight keel it can be pulled up on rollers or blocks. If a false keel is added and it does not extend the full length of the bottom of the boat, there will be a "dog-leg" in the keel line, which will cause the boat to lift clear of the rollers under the middle and to drop down each time the end of the keel passes a roller. This can add surprisingly to the effort required to pull up the boat, especially with primitive equipment and on a soft surface. Lack of adequate protection for the propeller in the form of a strong skeg under it will make the problem much worse, and what was formerly a simple routine job may take on the aspects of a major undertaking.

The straight triangular-type false keel which is recommended for shallow boats will be about as deep as the diameter of the propeller, if it is to be made deep enough to provide material for a propeller or rudder-skeg and should be as long as the straight part of the bottom of the craft in the case of a dugout, or as long as the keel in the case of a framed boat. It can be tempting to reduce the size of the false keel by not allowing for the skeg, and adding one under the end of the keel, but this has the same drawbacks as fitting a short keel, namely, the keel line will not be straight and hauling up is hampered. If it is necessary to reduce the size of wood used to make the false keel, it is much better to bring it up to the level of the stern tube only and to use a separate piece above the tube, that is to split the deadwood along the shaft centreline. This will also be a big help if the boring tools available are inefficient, as is commonly the case when local craft are being fitted with engines.

Draft Problems

Shallow draft creates problems inside the boat as well as outside. If the engine must be fairly high relative to the waterline and the shaft is short, the angle of installation may be excessive. A longer shaft will not only result in lost working space but may seriously weaken the keel structure as the angle of incidence of the shaft to the keel becomes small and the hole or slot which must be cut can become quite long and detract appreciably from the strength of the keel. In this respect dugouts made from good solid trunks may be easier to mechanize than planked craft. The engine, with stationary-type mounting lugs, can be placed almost directly on the thick bottom mounted only on a wedge to give the required angle and the weakening due to the long stern tube hole is not significant.

In framed boats the distribution of the weight and vibration of the engine on to a number of frames becomes essential if subsequent stern gear troubles and hull leaks are to be avoided, and long, deep engine bearers are required. For such installations stationary-type mountings at the bottom of the crankcase are most unsatisfactory and marine-type mountings are very much preferable. Here a reduction gear which drops the pro-

peller shaft below the crankshaft centre line is also very useful in reducing the angle of installation.

Normally one would avoid bolting engine bearers through the planking, much less the engine holding down bolts. In the case of local craft this is sometimes not only unavoidable but may be desirable either to strengthen the structure or for the sake of simplicity. Take for example the case of a dug-out canoe in which an engine with a stationary-type mounting is to be installed. The engine bed can consist of a single flat wedge-shaped piece of wood, shaped to the curve of the hull on the bottom side and sloped to the required angle on top. The boat will probably require a false keel, and two extended keel bolts are sufficient to hold the bed down. Four or six engine bolts through the bed and the thick bottom complete the installation of the engine itself.

In framed and planked boats the need for long engine bearers was mentioned earlier. Such bearers will often do little real distributing of the weight unless a new system of floors is introduced at the same time and through bolting through the hull will often be the only practicable solution. In boats which have a system of heavy frames, longitudinal strengthening may be more important than adding floors, as in many such boats the planking alone supplies all the longitudinal strength, the keel being but a slightly thicker plank in the centre of the boat. When long, heavy engine bearers are introduced, excessive working of the planks from the turn of the bilge up to the gunwale may result unless stringers or longitudinal clamps are also provided. Once a boat has been mechanized it will be called upon to meet waves head on and will suffer much more slamming than it did as a sailing vessel. This is probably a more important reason for providing additional strengthening than is the vibration of the engine. If the hull is very flexible, it may retain much more of its original nature if an outboard motor is fitted, as in this case strictly local stiffening will usually suffice. If the engine is used solely as an auxiliary to sail, this problem of facing head seas will not be so important, but experience seems to show that engines never remain auxiliaries for long and, in fact, the problem becomes that of ensuring that a sail is available for emergency use.

Stern gear is usually a source of much trouble in the operation of mechanized local craft. In the first place, it may be difficult to install properly, without excessive alterations in the stern of the boat. The need for careful workmanship while installing the stern gear is usually only appreciated after repeated and costly failures. This applies not only to shaft alignment but to details such as obtaining a good fit for the stern tube, ensuring that the stern bearing flange seatings are strictly at right angles to the shaft line, and that the mounting of the bearings and the various blocks and other bits and pieces which will inevitably be required are solid enough to stand up to protracted use.

Most local craft will require a long stern tube due to the usual combination of a flat bottom, a level keel line and shallow draft, and fitting a real shaft log may be difficult. The apparent shaft log is likely to be in reality a cover for the stern tube and, in fitting this tightly to the tube to prevent leakage, it is easy to distort the tube or the

mounting of the inner bearing flange, thus paving the way for future stern gear troubles.

If beaching or shallow water operation is not contemplated, the installation can be greatly simplified by using a strut-mounted, outside bearing and eliminating the long stern tube as well as the false keel, but this will result in an extremely exposed propeller unless the bottom line of the craft has considerable curvature and comparatively more draft than is usual.

TROUBLES COMMONLY ENCOUNTERED

Mechanical troubles can lead to the failure of attempts to introduce motorization. In a typical case, the operator will be someone with no previous experience with engines, and he will usually receive a very scanty preparation for his new role. Often he will have difficulties in obtaining skilled help for his repair work, either because of a remote location or because he finds the charges of an experienced mechanic or workshop too high. (These same charges might be considered reasonable by, say, the operator of a fleet of diesel trucks.) Unless the sales agent of the engine, the government, or some other body take definite steps to assure regular servicing and moderately priced repairs, the maintenance field is almost sure to be taken over by poorly qualified persons; bicycle repair shops, for example, can blossom into fully fledged diesel repair stations over night. The net result is, of course, premature failure of the engine and exorbitant repair bills, if the engine is not abandoned altogether. This problem is a difficult one to solve, and circumstances will vary from place to place. In the first instance the onus will rest on the engine manufacturers or their export agents in selecting good representatives in the importing countries. The criteria for good agents for the purpose of dealing with small-scale fishermen may be quite different from what is required for dealing in other lines of machinery, and the possibility of having a different representative for small marine engines than for other products is worth considering. A system based on sub-agencies for this purpose can also lead to improvements in service if the sub-agents are given a fair deal by the main representatives. The practice of selling engines cheaply and making the profit on the sale of spares is particularly unfortunate when applied to motorization of fishing craft, as operating money is in chronic short supply in this business. Take for example the case of a fisherman who has been earning, say, the equivalent of £10 (US $28) per month. He borrows money for a small engine and mechanizes his craft for £400 (US $1,120). After paying all loan payments and operating expenses, including his salary, he is left with a net profit of 50 per cent per year or, say, £15 (US $42) per month. This money will most likely be used to augment his family expenditure, not to form a reserve against unexpected major breakdowns. On the assumption that his loan was obtained at reasonable rates, he would be better off if he had paid more for the engine, made smaller profits, but could be assured of cheap repairs. This point is beginning to receive recognition. In Ceylon, for example, the prices paid to engine dealers for small engines

given on loan includes provision for over £35 (US $100) for various specified free services.

Early Problems

During the early stages of motorization there were many who felt that the simplest engines possible, such as hot bulb semi-diesels would be ideal for this purpose. This has not proved to be the case, mainly because these engines need an operator adept at carrying out minor adjustments at frequent intervals, and seem to be most popular in countries with a long history of small boat mechanization, for instance, the Scandinavian countries and Japan. Full-diesels, which require little or nothing in the way of adjustments by the operator, if they are periodically serviced by a qualified maintenance man, have proved more satisfactory, but by no means trouble-free either.

The most common source of trouble in a mechanized boat is, however, probably not in the power plant at all but in the stern gear. Much of the difficulty can be attributed to poor workmanship in installing the stern gear and engine or to lack of follow-up checks during the first critical weeks. But a great deal of the trouble stems from the use of inferior or unsuitable materials or combinations of materials, leading to early corrosion and breakage. As many engine manufacturers do not make their own stern gear, problems of assessing responsibility are somewhat complex. There are numerous cases of engine makes which have operated successfully for some time and then have begun to suffer from premature stern gear failure. Such cases almost always prove to be the result of a change in the materials used by the original supplier, sometimes without the knowledge of the engine manufacturer or of his agent, if he is obtaining the gear from a different source.

The motorization of indigenous craft is by and large being carried out in tropical or sub-tropical countries. Materials which have proved satisfactory in temperate waters do not always stand up to the higher temperatures and possibly greater salinities that they will be called upon to meet under the new conditions. The rate of chemical reactions is, roughly speaking, doubled for an increase in temperature of 20°F (10°C). Operation in waters 25°F to 35°F (15°C to 20°C) warmer than the home seas will lead to corrosion rates 3 to 4 times greater, and the original reasonable life span will not be approached at all.

Poorly designed or selected propellers contribute to unsatisfactory performance. Many or most indigenous craft have lines very different from the boats considered normal by the engine manufacturer. While a few companies have taken the trouble to make a realistic propeller selection for these craft, this is the exception rather than the rule, and it has even happened that the propellers supplied (which were obtained by the engine manufacturer from an outside source) differed significantly from the manufacturer's own specifications, sufficiently so as to cause overloading and bearing failure.

Gearbox difficulties

Gearbox troubles, due to maladjustment, are all too common and unnecessary but are not to be blamed on

the engine manufacturer. The selection of undersized gear boxes, taking into account the rough treatment that they will inevitably be subjected to, is another matter. One chronic trouble with many gearboxes is that it is difficult to obtain a positive neutral position, and for some fishing operations the continuously rotating propeller is a hindrance. One of the contributing factors is that the engines are often stored for long periods under tropical conditions before being installed, and the gearbox oil becomes gummy, causing the clutch plates to stick. The simple remedy of thorough flushing is not always carried out, with the result that from the first day the fisherman suspects that he has received a defective piece of machinery. Unfortunately, however, flushing is by no means a sure-fire cure for this defect. The writer has been guilty of making his own contribution to gearbox troubles. In the interest of standardization, identical shafts were specified for engines with and without reduction gears. Due to the rigidity of the shafts even comparatively slight misalignment was sufficient to cause failure of the gearbox output shaft on the direct drive engines.

The design of the diesel engines commonly used in mechanizing small fishing craft can vary in a great number of details although there are very few fundamentally different types. A sales feature commonly overstressed is "simplicity". An engine with exposed, lubricated valve gear, no air cleaner, a wire mesh lubricating oil strainer, no flywheel cover, gravity feed fuel supply and no instruments can certainly be described as "simple", compared to an engine with a totally enclosed, force fed lubrication system with renewable filter elements, an underslung oil bath air cleaner, a fuel lift pump, lub oil pressure gauge, water cooled exhaust manifold, raised hand starter, and so on. But does this make it more desirable, particularly from the point of view of an inexperienced operator? By no means. What he wants is an engine which is easy to start, and will run for long periods with minimal attention. Most of the "complications" which over the years have been added to marine diesels are there because they contribute to these ends. They all add to the price as well as to the value of the engine and this should be given full consideration when comparing engine quotations.

In actual operation the troubles met with cover the whole range of possible faults. As experience is gained, many of the trivial ones disappear. Air locks, lack of lubrication, loose accessories, rusty chains, leaking pipe connections soon become, or should at any rate become, things of the past. Running with poorly adjusted fuel pumps or injectors, with worn bearing or pistons, with inadequate cooling water circulation, with dirty oil will go on for a much longer time and, fair or not, it is during this period that judgement will be passed on the merits of a particular brand of engine. Engines which cannot stand up to rough treatment of this nature will be found wanting, and the operators will not be prepared to accept the blame for failure if other engines can "take it" better than their own. The ability of an engine to withstand abuse, in addition to legitimate demands for long hours of continuous full throttle operation alternating perhaps with long periods of idling operation, will depend on design factors about which the operato knows nothing and cares less. On the other hand it is unlikely that he will be over-fussy about fuel economy nor, within limits, about lubricating oil consumption.

Replacements

When an engine, which is still under the manufacturer's guarantee, develops trouble of any sort, it is axiomatic that there will be disagreement between the operator and the engine agent regarding the responsibility for repairs. Most manufacturers' guarantees are really of very limited value to a fisherman in a remote area of a distant country. The usual stipulation is that the damaged parts be returned carriage paid to the factory, and that they will be replaced free of charge if the manufacturer finds that the fault is due to a defect in material or workmanship. Fortunately, many field agents, often with the approval of their principals, are more liberal and will replace and refit parts, without sending them first to the factory, in cases where they are not able to account satisfactorily for the cause of failure, without necessarily acknowledging that it was due to a factory defect.

This kind of service would again indicate that profit margins should not be too small and that it is desirable to have some sort of arbitration system worked out in advance to decide in dubious cases. Many of the initial difficulties could be minimized by proper training of the fishermen in the use of their engines. It does not seem to be fair to place this burden on the engine sales, unless it is being paid for specifically. The care and operation of engines is becoming a necessary part of the knowledge of almost any fisherman and should become a part of his general education, with such formal training as is necessary coming from a public institution of some sort. Once mechanization is well established this problem tends to take care of itself as far as small engines are concerned, as young fishermen will learn to handle engines long before they become engine owners.

There is strength in numbers. The writer feels that mechanization has a very much better chance of success if it is not attempted on too small a scale in any one given locality. The first members of any community to take to the use of engines must expect to meet opposition and, if an opportunity presents itself, ridicule. If one or two such craft are introduced they may well make a brave showing, until the first inevitable troubles appear. As the early profits are put back into repair bills the operator may be hard pressed to justify his actions to everyone who "told him so". If this happens a few times he may well be prepared to yield to majority opinion, give up, and revert to doing what every one else is doing. The situation is quite different if one or two boats are out of action while six or seven others are still earning good money. They will act as a spur and every effort will be made to get the laid-up craft back into operation as quickly as possible.

AIDS TO MECHANIZATION

Much could be done to improve the efficiency of mechanized local craft if the equipment to be installed were

especially designed for this purpose, or were made flexible enough so that it could easily be adopted to this use.

Outboard motors which can be provided with abnormal extensions fit many types of local craft much better than standard outboards, or outboards extended by 4 in (101.6 mm). At least one manufacturer has developed abnormally long motor shafts for this specific purpose, but unfortunately most manufacturers are so far not prepared to vary their production schedules to cater to this specialized market. Outboards with low propeller speeds, designed for thrust rather than speed, are also beginning to find their way into this field but again only a minority of engine manufacturers has responded to the need for development along these lines.

A true light-weight diesel outboard would find a tremendous market as far as indigenous craft are concerned, but none has appeared so far, despite some very attractive advance advertising. In the meantime inboard/outboard drives or diesels fitted to outboard drives could become very useful in this field if they were designed with local craft in mind. Operating costs are of vital importance to most operators of mechanized fishing boats, and in many cases where loans for the initial purchase are available, the operating costs take on greater significance than initial costs, and this fact creates a great demand for diesel units rather than petrol.

In many developing countries petrol is associated with luxury road transport and is heavily taxed, while diesel fuel is primarily associated with industry and public or goods transport and is consequently marketed at a much lower price. In these countries inboard engines are almost inevitably diesel, and outboards would become so also if it were to become possible. Duty-free petrol for fishermen is often advocated, but in fact this can create a very undesirable situation in countries where the price of a few gallons of petrol is worth the average daily income of a fisherman. A 30 hp engine operating at full load for 8 hr per day will require something of the order of 16 Imp gal (19 gal), (73 l) of petrol per day and with a tax rebate of, say, 1s 2d (US $0.15) per gal, this could have a black market value approaching 10s (US $1.40) per day, a sum sufficiently high to tempt the operator to stay at home whenever fishing prospects are poor or for some reason he is not keen on going out. Obviously a fisherman used to earning £10 (US $28) per month would be much more tempted than one who makes £70 (US $200), and elaborate controls would be required, especially where fishing is completely decentralized.

Installation is much easier if the engine can be installed at a large angle, even up to 15 degrees. A large angle of installation will not always solve the problem, unless the gearbox mounting is such that it does not cause difficulties in the narrow and limited space at the extreme stern. Generally speaking it is a great advantage to have all the mounting lugs or flanges on one straight line, but if it is necessary to install the engine as far aft as possible this can be a disadvantage, as the rear mounting lugs will be too low when the engine is installed at a large angle, and the engine will sit too high. A possible solution would be to have reversible mounting feet on the gear box. In the

normal position they would lie on the same line as the engine holding down lugs. When reversed the feet would be higher on the side of the gearbox. A stepped engine bearer would be used, giving adequate thickness under the gearbox feet, but still permitting a low centre line for the engine. Fig 1, (a); (b); (c).
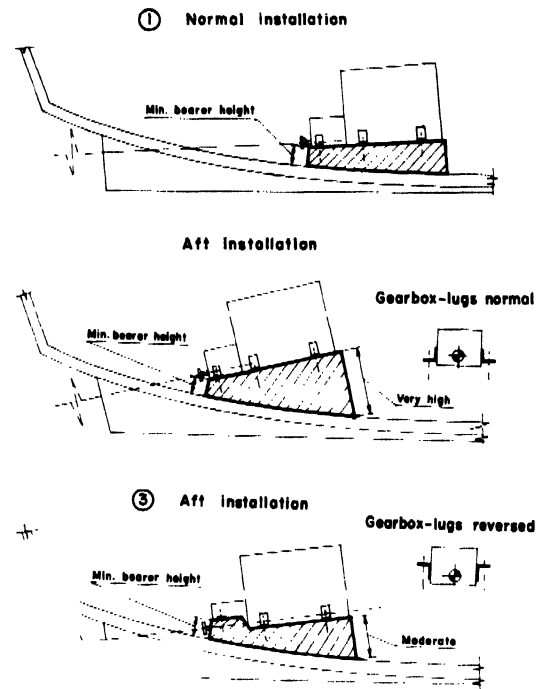
Fig 1. Use of stepped engine bearer

Improvements in lifting-type stern gear would make it much more popular. The most common source of trouble in this stern gear is the universal joint, which is usually made so that the slightest wear introduces excessive play. While universal joints of much higher quality are available for general purpose use, none appear to be obtainable for use in sea-water. The lifting mechanisms can also stand much improvement, especially with regard to ensuring proper alignment in the working position.

Life of bearings

Stern bearings which depend on water lubrication wear out much faster if the housing is not designed with water scoops to ensure positive water flow through the bearings. Diversion of part of the cooling water for this purpose has not proved too successful on various local boat types. The flow pattern around the external bearing may well prove to be such that very little, if any, of the water passes out this way and the system may not show any improvement over simply submerging the bearing. Best results have been obtained with water lubricated bearings which are mounted externally, that is, on the end of the stern tube rather than being fitted inside the tube. The reverse is true for grease lubricated bearings, which function best if the white metal is to a large

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degree inside the shaft log or deadwood, particularly if an effective oil seal and sand excluder is provided behind the white metal. Bearings with renewable white metal sleeves are much easier to maintain than bearing housings which require re-metalizing. Generous grease cups or, better still, small grease pumps for the stern bearings more than justify the slight extra cost.

In the writer's experience the most suitable stern gear for small fishing boats has a grease lubricated white metal inner bearing and a water scoop lubricated rubber outer stern bearing. For some installations the protruding outer bearing may create space difficulties, in which case an outer white metal bearing in the stern tube and grease lubricated through the stern tube would be the choice. Installation requiring a grease tube to be run through the deadwood can be troublesome, particularly if the deadwood is made up of various pieces, as may happen when a false keel has been necessary.

Even if some sort of engine box or house is provided, and often it will not be, the engine is going to be exposed to spray and a humid atmosphere and rust will form between repaintings. The use of sheet metal should, therefore, be avoided as much as possible in the designs of mountings for gauges, air cleaners, etc., as well as in these parts themselves. Screws and other fasteners should be corrosion resistant, especially the fasteners for the exhaust manifold and piping. For the same reason external threaded piping should be avoided. If a dry-type air cleaner is used it should not be one which can rust to pieces and gradually be sucked into the cylinders.

It is impossible to trace the relative importance of the various factors leading to excessive cylinder wear on small marine engines and the operator is usually blamed for having neglected his oil changes or his injectors, but a quite considerable number of worn liners and pistons can beyond a doubt be attributed to the consumption of wire mesh from cheap air cleaners.

The writer has a strong preference for the under-slung type of oil-bath air cleaner or the centrifugal oil bath despite the fact that these are somewhat bulky and that their mounting on the engine often leaves much to be desired. Automotive-type air cleaners not only tend to rust internally above the oil level but there is also a danger of the oil content being sucked into the cylinder, with drastic results in a rough sea. In any case these air cleaners only work effectively if mounted horizontally, but on most engines they take on the same inclination as the centre line of the crank shaft.

Starting ability

The most important feature of an engine from the operator's point of view is the ease with which it can be started. As far as external accessories are concerned starting will involve the cranking system, practically always by hand for smaller indigenous craft, the decompressor arrangement, and such starting aids as may be provided for the various makes of engines. Overhead hand starters are, generally speaking, the most satisfactory particularly if attached to the crankshaft rather than the camshaft. Loose starting handles which fit on to the end of the camshaft or crankshaft are the least desirable,

especially if it is necessary to build up an external support for the handle. Rigid mounting of the raised shaft is the first requirement and easy servicing of the release pawls is the next one. Effective chain tighteners will add very much to the life of the chain, and this point could stand improvement in a number of current designs. Shifting the shafts support to tighten the chain is not a very satisfactory method. Not only do the brackets tend to work loose, but there is the danger of the shaft binding if the adjustment is not carried out properly. If an idler wheel is used, it should be reasonably proportioned and firmly mounted. A spring loaded chain follower probably offers the best solution. In any case, the inclusion of a half link in the chain to permit shortening after some time would aid matters but is rarely if ever found. To prevent rotation of the raised shaft when the engine is running due to drag in the free wheel mechanism, a small friction disc is useful. The handle of the raised hand starter should be removable, as otherwise it constitutes a definite hazard at the time of stopping the engine, which may kick back as it comes up against the compression for the last time. On the other hand it is annoying if the handle falls off by itself each time it is released.

The desirable type and location of the decompressor will depend on the type of hand starter, but it should be such that starting by one man is easy. Automatic decompressors are not desirable, as the number of turns required before releasing depends too much on the strength of the operator and on the condition of the engine.

Individual decompressors for each cylinder can be useful, particularly with hand starters fitted directly to the flywheel, or in cases when one cylinder is in better condition than the others.

Of the various starting aids available, the writer has found that the most useful one is a small cup permitting the introducton of a measured quantity of lubricating and fuel oil mixture into the inlet manifold or better still into the combustion space. Self-igniting paper introduced into the combustion space can also make starting very easy, but the igniters tend to be sensitive to moisture during storage, and are usually not at hand when required. Certain slow speed engines with heavy connecting rods and cast iron pistons are provided with cups for introducing petrol during starting. While this is all right for the engines concerned, it does encourage bad habits and the operators and mechanics carry this practice over to high-speed engines where the result is bent connecting rods, or worse.

Many local craft are very narrow, which makes accessibility even more important than usual. The fact that the boat is not designed to take an engine can cause further problems. For example, it was suggested above that the foundation for the engine in a dugout can often be made of one solid piece. This will not be possible if the lubricating oil can only be drained out through a plug under the centre of the engine. Even in hulls using proper engine bearers such plugs become very inaccessible after a series of floors has been added. Drains at the front end of the crankcase are also found in converted stationary engines which must either be mounted dead level, which is

usually not possible, or the oil must be removed through the side covers. Small drain pumps would solve these problems adequately, but these are far from being standard fixtures. Lubricating oil filters, especially if built into the crankcase or sump, can be difficult to remove after the engine has been installed, and external filters often interfere with the engine bearers or floors. Sump strainers should be removable for cleaning without the necessity of dismantling the engines. Automotive or tractor-type engines modified for marine use often present particularly acute accessibility problems as it is no longer possible to drop the sump to get at the lower part of the engine.

One can naturally not expect standard production series to be radically altered to suit this one type of application but there is no doubt that a few firms specializing in, or paying attention to, this market could achieve a considerable volume of business in marine engines and accessories especially modified to meet the needs for mechanization of indigenous craft.

FAO Naval architect Erik Estlander installed the outboard (right) on a Ceylonese Kattumaran log-raft. His daughter participated in trials to convince fishermen of the safety of such an installation. An outboard motor enables the Ivory Coast fishermen (below) to reach the better fishing grounds faster. Some of the catch is shown by a member of the crew, while another removes the outboard.

Outboard Engines in Coastal Fishing

by E. Estlander and N. Fujinami

Utilisation des moteurs hors-bord pour la pêche côtière

Soixante-dix pour cent des bateaux de pêche en usage dans le monde, notamment en Asie, en Amérique du Sud et en Afrique, ne sont pas encore motorisés. Pour les bateaux de petite taille, la solution la plus facile—et fréquemment la seule possible—est la pose d'un moteur hors-bord. Les auteurs procèdent à une comparaison fondée sur des essais effectués à Ceylan, entre l'installation de moteurs intérieurs et de moteurs hors-bord, des points de vue de la fiabilité du moteur, du rendement et de l'économie. Ils énumèrent en conclusion les caractéristiques idéales d'un moteur hors-bord destiné à la pêche.

Motores fuera de bordo en la pesca costera

El 70 por ciento de las embarcaciones de pesca del mundo se halla todavía sin mecanizar, principalmente en Asia, América del Sur y Africa. El método más fácil para lograrlo en las embarcaciones pequeñas consiste en instalar motores fuera de bordo, siendo ésta frecuentemente la única solución. Se compara la instalación de motores fuera de bordo/entrobordo desde el punto de vista de la seguridad, eficiencia y economía del motor, basándose en las experiencias tenidas en Ceilán. Por último, se enumeran los requisitos de un motor ideal fuera de bordo para fines pesqueros.

THE developed fishing nations now tend to operate large highly industrialized undertakings. This is not so in many developing countries where the dense coastal population cannot be absorbed into other industries. The lack of harbours, marketing facilities capable of handling the large catch, and also the necessity to concentrate those employed in fisheries in a few large base ports rather than in the scattered villages makes heavy industrialization problematical at the present time.

Development of fishing industries should, therefore, be made step by step. There are many areas where small-boat fishing is profitable and the introduction of nylon nets and mechanized craft to such areas have made coastal fishing an important factor in the local economy.

According to the FAO Yearbook of Fishery Statistics 1962, the approximate total number of fishing vessels in the world is 1.5 million (table 1). It is assessed that one million or 70 per cent of these vessels are still un-mechanized, and these are mainly concentrated in Asia, South America and Africa. If table 1 is analysed into countries and local areas, it is obvious which regions of the world are suitable for mechanization (tables 2 to 7).

This paper deals with the mechanization of inshore fishing vessels up to 30 ft (9 m) and the advantages of outboard propulsion for such vessels.

INBOARD INSTALLATION

Until recently small craft were mechanized by light inboard diesel engines, ranging from 5 to 40 hp.

Difficulties have been encountered with inboard engines, however, partly due to the poor design of the stern gear. Even well designed stern gears suffer because of poor boatbuilding and mishandling of the boats. The main difficulties are: (a) The incorrect installation of engine beds and the shaft log, accommodating the engine and the stern gear, causing non-alignment which results in worn-out bearings and shaft. (b) Sand and other foreign material, depending on the design of the propeller bearing, may also cause bad wear. (c) Incorrect design of the stern disturbs the even flow of water to the

TABLE 1

Mechanization of fishing vessels by regions

	Total	Powered			Non-Powered
		sub-total	inboard	outboard	
Africa	94,851	(7,883)	(750)	(3,360)	(69,748)
America North	144,792	(108,604)	(975)	(1,809)	(25,500)
America South	140,230	(9,767)	(536)	(599)	(129,354)
Asia	930,251	(240,164)	(9,503)	(960)	(689,861)
Europe	228,905	(98,872)	—	—	(112,082)
Oceania	11,435	—	—	··	
Total	1,550,464	(465,290)	(11,764)	(6,728)	(1,026,545)

Note: The totals in the left-hand column are not the exact sums of the sub-total of powered boats and non-powered boats in the other columns. Similarly the sub-totals of powered boats are not the exact sum of inboard boats and outboard boats. This is because the data was incompletely reported, with some countries presenting a full breakdown and others, only over-all totals. The bracketed figures therefore have no consistency, but give a rough idea for each item. Vertical addition of the above figures does not reflect this inconsistency.
This remark also applies to tables 2 to 7. The figures of outboard engines are not well shown but considerable numbers of them are used in various countries, for example Uganda, Ceylon, Malaysia, Japan, USA etc.

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TABLE 2

Mechanization of fishing vessels in Africa

	Total	Powered			Non-Powered
		sub-total	inboard	outboard	
Dahamay	22,502	2	1	1	22,500
Ghana	10,480	2,218	268	1,950	8,262
Ivory Coast	330	180	60	120	150
Libya	416	117	74	43	299
Mauritania	25	3	3	—	22
Mauritius	1,754	180	24	156	1,574
Melilla (1961)	1,821	71	—	—	1,750
Morocco	2,552	817	—	—	1,735
Mozambique	3,805	47	47	—	3,758
Niger	168	14	14	—	154
Portuguese Guinea	116	6	—	—	110
Réunion	406	359	204	155	47
Sao Tomé and Principe	384	—	—	—	384
Senegal	6,859	874	27	847	5,985
Sierra Leone	2,660	60	20	40	2,600
South Africa	5,444	1,301	—	—	4,143
South West Africa	487	128	—	—	359
Tanganyika	5,409	37	3	34	5,372
Togo	2,898	4	—	4	2,894
Tunisia (1958)	3,652	—	—	—	
Uganda	5,900	1,450	—	—	4,450
UAR (Egypt) (1958)	13,568	—	—	—	—
Zanzibar and Pemba	3,215	15	5	10	3,200
Total	94,851	(7,883)	(750)	(3,360)	(69,748)

TABLE 3

Mechanization of fishing vessels in America, North

	Total	Powered			Non-Powered
		sub-total	inboard	outboard	
Antigua	286	81	66	15	205
Bahama Islands	1,320	70	70	—	1,250
Barbados	598	528	490	38	70
Bermuda	250	—	—	—	—
Canada (1961)	45,282	30,390	—	—	14,892
Cuba	3,471	2,660	—	—	811
Greenland (1960)	1,750	522	—	—	1,228
Grenada	610	55	50	5	555
Guatemala	29	29	29	—	—
Martinique (1960)	1,036	—	—	—	—
Mexico (1957)	8,566	—	—	—	—
Netherlands Antilles (1959)	712	—	—	—	—
Panama	251	231	—	—	20
Puerto Rico	1,300	631	160	471	669
St. Pierre and Miquelon	124	—	—	—	—
Trinidad and Tobago	1,720	1,390	110	1,280	330
USA (1961)	77,487	72,017	—	—	5,470
Total	144,792	(108,604)	(975)	(1,809)	(25,500)

TABLE 4

Mechanization of fishing vessels in America, South

	Total	Powered			Non-Powered
		sub-total	inboard	outboard	
Argentina	1,357	438	414	24	919
Brazil (1961)	119,396	3,360	—	—	116,036
British Guiana	805	421	91	330	384
Chile	5,819	1,971	—	—	3,848
Ecuador	4,960	260	—	—	4,700
Peru	1,109	—	—	—	—
Surinam	480	276	31	245	204
Venezuela (1958)	6,304	3,041	—	—	3,263
Total	140,230	(9,767)	(536)	(599)	(129,354)

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TABLE 5

Mechanization of fishing vessels in Asia

	Total	Powered			Non-Powered
		sub-total	inboard	outboard	
Aden	6,510	110	90	20	6,400
Brunei (1959)	226	—	—	—	—
Cambodia	19,113	205	135	70	18,908
Ceylon	20,701	1,557	1,557	—	19,144
Cyprus	422	346	12	334	76
China (Taiwan)	26,393	6,051	—	—	20,342
Federation of Malaya	22,109	9,770	—	—	12,339
Hong Kong	9,769	5,267	—	—	4,502
India (1961)	85,000	2,020	—	—	82,980
Indonesia (1961)	198,626	3,157	—	—	195,469
Iraq	1,820	80	30	50	1,740
Israel	392	122	—	—	270
Japan	404,035	191,899	—	—	212,136
Korea, South (1961)	42,300	5,015	—	—	37,285
Macau	2,908	176	—	—	2,732
Pakistan (1960)	30,779	2,344	—	—	30,435
Philippines	1,701	1,427	—	—	274
Portuguese India (1960)	5,095	10	—	—	5,085
Ryukyu Islands	2,744	2,059	2,059	—	685
Singapore	2,080	673	187	486	1,407
Thailand (1961)	4,966	4,443	—	—	523
Turkey	1,962	1,033	1,033	—	929
Vietnam, South	40,600	4,400	4,400	—	36,200
Total	930,251	(240,164)	(9,503)	(960)	(689,861)

TABLE 6

Mechanization of fishing vessels in Europe

	Total	Powered			Non-Powered
		sub-total	inboard	outboard	
Belgium	398	398	—	—	—
Denmark	9,398	3,872	—	—	5,526
Faeroe Islands	253	253	—	—	—
France (1960)	15,238	—	—	—	—
Germany	3,060	2,025	—	—	1,035
Greece (1959)	15,185	5,019	—	—	10,166
Iceland	2,311	—	—	—	—
Ireland (1960)	2,203	704	—	—	1,499
Italy	45,567	14,974	—	—	30,593
Malta and Gozo	402	—	—	—	—
Netherlands	2,807	1,985	—	—	822
Norway	39,746	39,682	—	—	64
Poland	1,597	1,285	—	—	312
Portugal	18,658	3,322	—	—	15,336
Spain (1960)	48,053	12,910	—	—	35,143
Sweden (1960)	10,603	2,874	—	—	7,729
United Kingdom	8,098	7,814	—	—	284
Yugoslavia	5,328	1,755	—	—	3,573
Total	228,905	(98,872)	(0)	(0)	(112,082)

TABLE 7

Mechanization of fishing vessels in Oceania

	Total	Powered			Non-Powered
		sub-total	inboard	outboard	
Australia	9,865				
New Zealand	1,570				
Total	11,435	(0)	(0)	(0)	(0)

propeller, introducing vibrations, with consequent deterioration of the aft bearing. (d) Galvanic action in copper-sheathed boats can also pose problems. (e) Fishing boats in most tropical countries have to seek shelter in river mouths and creeks where the water is so shallow that in rough seas the boats are dashed hard against the bottom when passing through breakers or over sand bars outside the entrances. This introduces strains which can cause shaft non-alignment.

If something appears amiss, especially with the stern gear, it can cause more trouble than most other components of the marine diesel unit, necessitating beaching for repair. In the operational areas, beaching arrangements are limited, and repairs a lengthy process. Beaching can result in damaged copper-sheathing and loosening of the bearing and stern tube, makes waterproofing difficult, and causes a serious loss in fishing time.

There are other problems which make the installation of inboard engines difficult; for example, in existing local boats it is often difficult to find a suitable position for the shaft through the hull, or sufficient space for the propeller, and to install proper engine beds and an effective rudder.

OUTBOARD INSTALLATION

As an answer to all these problems, the easily installed outboard engine was introduced. The outboard engine, originally developed for pleasure craft with little regard to economy, has been a tremendous success and has been produced in millions. It is simple, easy to handle, safe, light and cheap. Heavy-duty engines have been developed and tried out in the fishing industry. Outboard motorization of some small indigenous fishing boats was successful when introduced a few years ago, but it was found that the success depended a great deal on efficient engine servicing. Poorly organized servicing, sometimes during the early stages of motorization, can adversely affect results. Jamaica, Trinidad, Malaysia, Uganda and Ceylon are among the countries where outboard motorization has caught on successfully. However, the two-stroke petrol engine used in outboards today is the most uneconomical to operate of all piston engines in use, because of the high price of fuel due to heavy taxation, and a fairly high specific fuel and lubricating oil consumption.

Using cheaper fuel for outboard engines has long been considered, and paraffin as a fuel has been used by some Japanese manufacturers. Diesel engines as an alternative were tried out by others, but with insufficient success to encourage introduction to the market. The diesel design, with its high pressures, makes the powerhead heavier and more expensive, thus eliminating two of the main characteristics attributed to the petrol outboard engine—lightness and low price. It must be admitted that there is a maximum boat size in which an outboard engine can be run economically, and such a size can be found by making a comparative analysis for a particular boat equipped first with an inboard and then with an outboard engine. This limit may be indicated by the size of propellers available for outboard engines, although this situation might change in the future. Such a decision can be made more precisely between an outboard engine and a petrol or kerosene inboard engine installation. When, for example, 10 hp or less is required, it would be cheaper and more advantageous to install a small petrol or kerosene inboard engine rather than the heavier and costlier diesel.

A COMPARISON OF OUTBOARD AND INBOARD INSTALLATION

The outboard engine has so many excellent characteristics which are superior to the inboard engine that its wider use is inevitable if the right types are available on the market. These *advantages* are:

- The boat will be considerably lighter, and can therefore carry more fish and gear
- There is more space for the fishing operations
- The boat construction is simplified without the engine bed, shaft log and rudder installation
- Lower installation costs
- The cost of the engine is only a fraction of the cost of a diesel engine
- As the combination of engine and stern gear is "factory made", there is less possibility of stern gear troubles
- The boat does not have to be beached when repair work is needed on the engine, stern gear or rudder
- The fishing time lost for repairs, as in the case of inboard engines, can be reduced to almost nothing by replacing the outboard by another in a matter of minutes
- If the engine is well insulated from copper-sheathing, the chances of galvanic action may be reduced, although further study is needed to substantiate this
- The propeller acts as a rudder, which affords the boat better manoeuvrability when going through surf. With an inboard engine, the rudder is practically useless in surf when the waterflow is of the same direction and speed as that of the boat
- With outboard installation the possibilities of the craft sinking are greatly reduced because of the reduced weight of the hull and engine. The engine could also be jettisoned in an emergency. This eliminates the need of having the boat decked from a safety point of view
- The water flow to the propeller is more even than with inboard installation

On the other hand, the *disadvantages* of outboard mechanization in comparison with inboard, are as follows:

- Several types of outboard engines are run with a high compression ratio, and therefore require a high-octane fuel
- Price of fuel is sometimes exorbitant because of government tax. Several governments have, however, reduced this tax for the fishing industry
- The specific fuel consumption is twice as high
- The life of the engine is shorter
- The propeller selection is limited
- A power take-off is not yet available

TABLE 8

Comparative data for different engine installations for 27.5 ft (8.4 m) fishing boats

	Power		
	Diesel inboard 22 hp	Twin outboards 2 × 14 hp	Single outboard 14 hp
Actual fishing days per annum	200	220	220
Additional fishing days if boat is not idle for engine repairs	20	...	—
Hours per day to and from fishing grounds (28 miles)	4	4	4½
Speed knots	7	7	5.8
Fuel consumption, litre/hour	5.8	16	8
Price of fuel, incl. lubrication oil, per litre, pence (cents)	5.15 (6)	14.6 (17)	14,6 (17)
Depreciation (years)	6	3	2.5
Maintenance costs (per cent of engine value)	15	15	15
Weight saving available for cargo lb (kg)		880–1,100 (400–500)	1,100–1,320 (500–600)
Increased net carrying capacity from 50 nets to ...		65	70

TABLE 9

Initial cost of boat ready for fishing

	Diesel inboard 22 hp		Twin outboards 2 × 14 hp		Single outboard 14 hp	
	£	($)	£	($)	£	($)
Hull	615	(1,720)	615	(1,720)	615	(1,720)
Engine beds/wells	36	(100)	18	(50)	12	(30)
Rudder	28	(80)	—		—	
Installation of engine	71	(200)	...		—	
Equipment	71	(200)	71	(200)	71	(200)
Engine (including freight, handling, excluding import duty)	535	(1,500)	356	(1,000)	178	(500)
Total cost of boat	1,356	(3,800)	1,060	(2,970)	876	(2,450)
Driftnets at £8.9 ($25) each 50–65–70, plus 20–20–25 spares respectively	625	(1,750)	758	(2,125)	848	(2,375)
Total cost of boat equipped for fishing:	1,981	(5,550)	1,818	(5,095)	1,724	(4,825)

The approximate prices of boats and engines are based on costs in Ceylon in 1963

TABLE 10

Running cost (annual)

	Diesel inboard 22 hp		Twin outboards 2 × 14 hp		Single outboard 14 hp	
	£	($)	£	($)	£	($)
Annual depreciation of boat over 10 years (cost of boat minus cost of engine)	82	(230)	70	(197)	70	(195)
Annual depreciation of engines:						
diesel over 6 years	89	(250)				
twin outboards over 3 years			119	(333)		
single outboard over 2½ years					71	(200)
Annual depreciation of nets over 2 years	313	(875)	379	(1,062)	423	(1,187)
Interest of capital invested 6 per cent	119	(333)	109	(305)	103	(289)
Maintenance of boat, 10 per cent value	82	(230)	70	(197)	70	(195)
Maintenance of engines, 15 per cent value	80	(225)	54	(150)	27	(75)
Maintenance of nets, 20 per cent value	125	(350)	152	(425)	170	(475)
Cost of fuel and greasing:						
diesel, 4,640 1 at 0.06	99	(278)				
twin, 14,080 1 at 0.17			855	(239)		
single, 8,360 1 at 0.17					507	(1,420)
Salaries for 5 fishermen at:						
360 for diesel	643	(1,800)				
360 for twin			643	(1,800)		
*400 for single					714	(2,000)
	1,632	(4,571)	2,451	(6,863)	2,155	(6,036)

* Longer fishing time

The figures for the breakdown of fishing costs and salaries are based on the average results of a few fishing trips

TABLE 11

Annual income

	Diesel inboard 22 hp		Twin outboards 2 × 14 hp		Single outboard 14 hp	
	£	($)	£	($)	£	($)
Diesel fully-equipped boat 200 fishing days with 50 nets	2,285	(6,400)	—		—	
Twin outboards, 220 fishing days with 65 nets			3,270	(9,152)	—	
Single outboard, 220 fishing days with 70 nets			—		3,520	(9,856)
Running cost	1,631	(4,571)	2,451	(6,863)	2,155	(6,036)
Profit	654	(1,829)	819	(2,289)	1,365	(3,820)

The approximate average income for such a fishing boat when driftnetting is based on figures collected in Ceylon in 1962, with regard to the size and price of the catch. The catch per net is calculated at 8 lb/day (3.6 kg), and the price per lb (0.5 kg) of fish is 7 pence (8 cents), which is possibly an underestimate.

ECONOMIC CALCULATIONS

To establish the maximum economical boat size for outboard engine installation, and to compare the economy of the outboard with the inboard, it was planned to carry out tests in Ceylon with outboard engines on a 27½-ft (8.4-m) fishing boat originally designed for inboard engine. Although this has not been done, it is of interest to study the preliminary calculations based on data collected for the tests.

The main dimensions are:

Length 27 ft 6 in (8.4 m)
Beam   8 ft 4 in (2.54 m)
Engine, inboard diesel, 22 to 25 hp
Speed 7 knots

The comparative calculation in tables 8 to 11 shows this boat installed with (a) an inboard diesel, (b) twin outboard engines, and (c) a single outboard engine built into a well. The proposed fishing method is with driftnets (30 × 3 fm hung, mesh size 4 to 6 in), under conditions usually prevalent in Ceylon.

These comparative tables show that an outboard engine can compete favourably with the small diesel in boats up to 30 ft (9 m) long, mainly because of the lower weight and less space required in the boat. The lower initial investment for the outboard would be most advantageous in many countries with low financial resources.

RECOMMENDATIONS

There is no outboard perfectly suited to the fishing industry. The main reason for this is the question of economy. A fast running two-stroke petrol engine has its economical criterion in the speed and velocity of the gas in the engine. Possibly there are ways of making the power head more economical, which probably would result in an increase of vibration and noise. A question is whether or not a four-stroke engine would be more economical, without upsetting the balance of low price and small weight.

The lower part of the engine, which transfers power into efficiency (thrust) must be considered of the utmost importance when designing an engine suitable for slow running fishing boats. The diameter of the propeller has to be big, so that the thrust distributed on the disc area of the propeller is not too high. In order to acquire a better propeller efficiency, the propeller rpm should be lower than is usual on present outboard engines.

The efficiency of a propeller is determined by many factors, including the relation between shaft horse power, speed of advance and the propeller revolutions. In designing the lower part of the outboard engine, calculations should take these factors into account and theoretical speculations should be supported by practical tests.

The following characteristics, for a displacement type fishing boat, are required for the outboard engine:

● Output of 10 to 15 hp

● Two cylinders should be so arranged that the firing would be alternate. This would make hand-starting easier when the engine has to be started in the open sea and it is difficult to keep the boat still against the waves

● Recoil start rather than an ordinary straight pull rope start, which is too slow. An electric starter would only increase the breakdown risk

● The propeller should have a large diameter and low revolutions

● The propeller diameter should be suitable for heavy and badly-shaped boats but, on the other hand, the pitch should not be too large, to prevent the engine being overloaded when the boat is moving against heavy waves or is loaded

● The propeller should be so designed that it can be changed with the minimum use of tools, in order that propellers of different pitch can be easily interchanged when going to fishing grounds and returning. It would be an advantage if the propeller and fastening components could be buoyant. (The question of a controllable pitch propeller should be considered by the manufacturers.)

● The engine must be built to withstand impact wnen being unshipped and carried to a storage place, and it must be so designed that the cooling water cannot enter the cylinders if the gearbox is lifted too high

● A pipe should be fixed around the circumference of the engine, which would serve as a grip for carrying and handling and also as protection when the engine is laid on the beach

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- A petrol trap should be provided to prevent petrol flowing into the crankcase when the engine is being carried. If this is not possible, the arrangement should be to hold the engine with the carburettor face down. Otherwise starting the engine will be difficult

- The engine should be so encased and the cover lockable so that thefts of small parts are difficult

- All hot parts of the engine should be encased to prevent burns being sustained when lifting the engine from the boat

- The tiller should be long enough to permit a man on a catamaran (log-raft) or in a canoe to stand and steer the boat

- Fuel supply should be from a large tank

- The ignition should be by magneto

- The flywheel should be protected

- Where there is no space to keep tools dry, a tool box should be supplied that can be attached to the engine or screwed somewhere in the boat

- For certain fisheries, it would be an advantage to have a small generator so that fishermen can employ lights during the night. It could be arranged in combination with the magneto

- Engines must be waterproof, perhaps by encasing the engine in a waterproof tarpaulin and fixing a breathing pipe on top of the engine cover. This should be used only in bad weather conditions, or if the engine is partly protected

- Fuel consumption must be low, because petrol is often very expensive due to heavy taxation. Fuel consumption can be reduced on a two-stroke engine by using a rotary valve, which should not increase the price of the motor when mass produced. The lower unit can have a higher efficiency through good propeller design and so reduce consumption

- The engine should use only low-octane petrol

- The ratio between engine and propeller revolutions may be so high that a second gear is required to avoid making the propeller gearbox too big. In this case, a power take-off from a gearbox connected to the power head could easily be provided and would be of great advantage, for three reasons:
  (a) to drive a generator for fishing with lights
  (b) to drive a hydraulic power unit to serve a power block, net roller, line hauler, etc.
  (c) to drive a water pump to circulate water in the fish well, spray water when live-bait fishing, for bilge pumping, cleaning, etc.

- All engines should be supplied with a small bilge pump. Most fishing boats leak, and it is useful to have the pump also for cleaning purposes

- Great care must be taken to indicate when an engine may need servicing, because many owners might not be able to read, write, or make telephone calls. The organizing of engine servicing is a necessity for every fishing engine, as the fishermen usually have no experience in repair work

- It might be advantageous to manufacture certain parts of the engine in "sealed units", which could only be repaired by skilled mechanics. Many instances of engine damage have occurred when fishermen, inexperienced in maintenance, have attempted repairs

- A bracket could be supplied with the engine, for clamping on to the side of the boat

- The exhaust, if taken out over the water surface, should have a flexible exhaust pipe with a "quick snap-on" connection. When engines are installed in wells on larger boats, the exhaust pipe must be run clear of the well

- An engine installed in a well does not necessarily (depending on boat types), need an arrangement for tilting. Such arrangements are more complicated to build, and result in a much larger bottom opening than is desirable. The opening need only be large enough to provide sufficient steering clearance and avoid propeller cavitation.

CONCLUSION

The market for outboard engines for small fishing boats would seem large enough to encourage manufacturers to design units solely for this industry. To date, however, the heavy-duty outboard engine is basically still a converted pleasure boat engine.

The installation of an outboard engine in existing fishing boat hulls is not the entire answer. Fishing techniques have to be adapted to mechanized boats, marketing has to be considered, and above all efficient engine servicing has to be organized, in the initial stage with government assistance, until there are sufficient engines in the area to make private enterprise servicing an economic proposition.

In many areas, such as the large man-made reservoirs of Lake Kariba, Lake Kaptai and the big dams in India, the boats used are totally unsuitable for mechanization. Boats have been developed along coastlines, of East Africa for example, from which no fishing other than handlining can be performed. In places like Lake Victoria, Lake Chilca and Lake Nyasa in Africa, the inshore areas are over-fished, but no fishing can take place further out because the boats are unsuitable for open water. Here, boatbuilding has to be developed. When designing a small boat for such remote areas, the limited local facilities, the local timbers, the impossibility of obtaining simple items like nails, screws, bolts, not to mention woodworking tools, and, above all, the total lack of craftsmen, have to be borne in mind.

The development of small-boat fishing and the problem of motorization of existing craft has several very interesting aspects, and still demands a great deal of initiative from the manufacturer of small engines.

The Location and Shape of Engine Wells in Dug-out Canoes

by Thomas C. Gillmer and Øyvind Gulbrandsen

Emplacement et forme des puits à moteur pour pirogues monoxyles

Des points de vue économique et technique, la motorisation de certains types de petits bateaux de pêche au moyen de hors-bords installés dans un "puits" intérieur à la coque présente un grand intérêt. Les auteurs examinent les avantages et les inconvénients de cette technique dans le cas de pirogues d'Afrique occidentale se prêtant à ce type d'installation. L'étude repose sur des essais tant sur modèles réduits qu'en vraie grandeur sur des coques de forme analogue. Les résultats permettent de formuler les conclusions suivantes: (1) Le puits permet d'installer le moteur de manière plus pratique et plus rationnelle que tout autre système; (2) L'emplacement longitudinal du puits, sur le type de pirogue étudié, n'exerce pas une influence importante; (3) La forme et les dimensions de l'orifice du puits affectent de façon marquée les caractéristiques de vitesse et de puissance.

Situación y forma de las barquillas de motores en canoas de troncos

Económica y estructuralmente, tiene muchas ventajas la potenciación de ciertos tipos de pequeñas embarcaciones de pesca instalando barquillas de motores. Se examinan aquí las ventajas e inconvenientes de tales barquillas en relación con su empleo en tipos adaptables de piraguas de Africa Occidental. Este examen se basa en pruebas de ambos modelos y en canoas de escala normal de casco de forma similar. Los resultados de la prueba indican que: (1) Las barquillas de los motores proporcionan un montaje del motor más práctico y eficaz para esta adaptación que otros sistemas; (2) La situación longitudinal de la barquilla no tiene gran importancia en el tipo de embarcación probado; (3) La forma y tamaño de la abertura de la barquilla influye grandemente en las características potencia-velocidad.

RECENTLY research has been carried out to decide the best location of outboard motors other than directly on the transom. In many cases side brackets have been used but this generates a transverse moment which must be counteracted by a steering moment. This increases the overall drag and hence the power requirement. Consequently, side bracket mounting, while expedient and certainly more practical structurally, must be considered a less efficient means of propulsion than centreline mounting.

The structural limitations are of considerable importance when considering the installation of a centreline engine well. Flat-bottom skiffs are perhaps the most adaptable (Beach, 1960). In the absence of the longitudinal keel timber, a centreline well is structurally sound.

Hull configuration also imposes both structural as well as installation limitations. Round-bottom, and to a lesser extent vee-bottom craft, because of their keels and deeper sections, make well installation problematical. Notable exceptions to this are craft of monocoque or homogeneous hull structure, such as the indigenous dugout. Hull materials such as moulded reinforced plastics or pressed aluminium, particularly in the original design and building process, lend themselves to the introduction of motor wells. These materials, however have only been found advantageous in the more prosperous fishing communities. The dug-out log canoes of West Africa are traditionally propelled by paddles, often beached and launched through surf; motor propulsion would be a most significant improvement operationally, and ultimately economically.

Their shape is also easily adapted to well construction, being rather full in section which, while rounded, is rather flat in the centreline vicinity. They have straight longitudinal lines for the greater part of their length with rather full ends and a hull thickness on the bottom of 5 to 6 in (12 to 15 cm). This provides a solid base for securing the well structure, simultaneously keeping it high and thus not imposing high static water pressure.

It is significant to study the hydrodynamic phenomena surrounding the introduction of the necessary orifice through the hull shell of these structurally adapted craft and particularly the effect on resistance. In Ghana, Senegal and Dahomey this problem was resolved in testing models of the prototype craft; the tests were begun and continued (when time and facility permitted) in the towing tank in the US Naval Academy, Annapolis. In 1964 two typical somewhat similar Ghanaian canoes were acquired by FAO for power and speed tests in Dakar, Senegal.

The resistance data from the model tests has been given in its simplest form and is presented graphically on the model scale primarily because of lack of information of the full-scale conditions. These conditions are variable and so lack true conformity to the lines drawing as to make dependable P_e against speed representations of the prototype hulls most inadvisable. In addition, because of the variation of Reynold's number between the model and the prototype, the dynamics of the water flow into and around the wells introduces scaling factors which are difficult to predict from model to full scale.

It should be pointed out that any inferences and interpretations suggested must be comparative, indicating primarily tendencies and probable effects.

DESCRIPTION OF MODELS AND APPARATUS

Model 1 is of a Senegalese pirogue or canoe of 31.2 ft (9.5 m) length (model scale 1/6.35). The hull lines (fig 1) were taken from a FAO drawing made from measurements of a typical pirogue taken off at Soumbedioune in October 1962. The basic hull of this, not including the decorative stem and stern extensions or the wash or spray shields, was 28.6 ft (8.7 m) length, 4.4 ft (1.34 m) beam and the depth amidships of 1.58 ft (0.48 m). The hull has a rather extreme longitudinal curvature of the bottom (fig 2) and the sections are rather flat bottom "U" shape, of flaring sides with an angle of about 30° from the vertical.

In this model a motor well was positioned correspond-

ing to full-scale dimensions of 8.5 ft (2.6 m) aft of the midsection and was of the proportions shown in fig 3, $31\frac{1}{2} \times 13\frac{3}{4}$ in (80 × 35 cm), the same size as used in all the tests. The forward end at the bottom of this well forms the forward half of the opening through which the lower unit of the outboard engine and propeller projects. In fig 3 it is shown with perimeters that rake back at an angle of 45° with the longitudinal axis of the hull. This forward end of the well is fixed and is actually a portion of the bottom of the hull. The after part of the well bottom is an adjustable hatch, fitted with hinges at its after edge. When closed, this hatch is nearly flush with the bottom and allows a smaller opening to exist of the shape shown (fig 3). The purpose of the hatch is to enable the engine to be tilted for protection when beaching or approaching
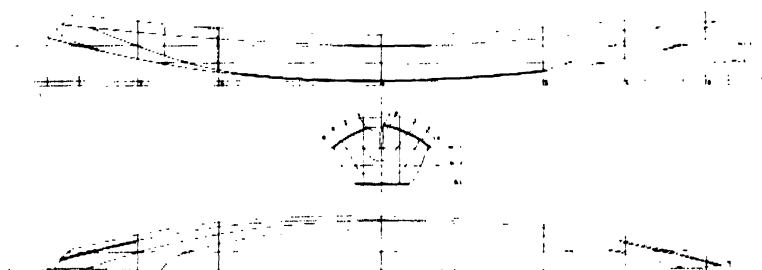
FIG 1   HULL LINES, SENEGAL PIROGUE, USNA MODEL 1

FIG 2   SENEGAL PIROGUE, USNA MODEL 1
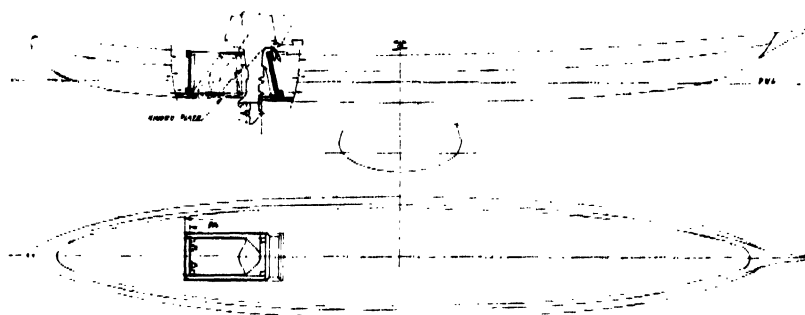
FIG 3   BASIC WELL CONSTRUCTION
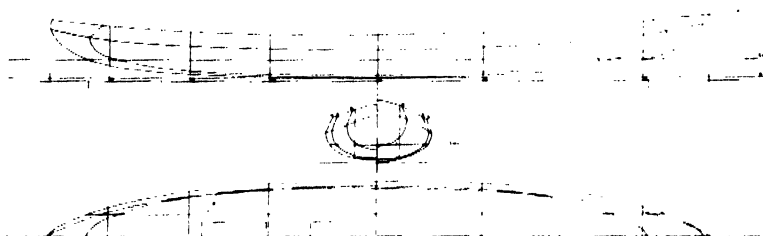
FIG 4   HULL LINES, GHANA CANOE, USNA MODEL 2

[335]
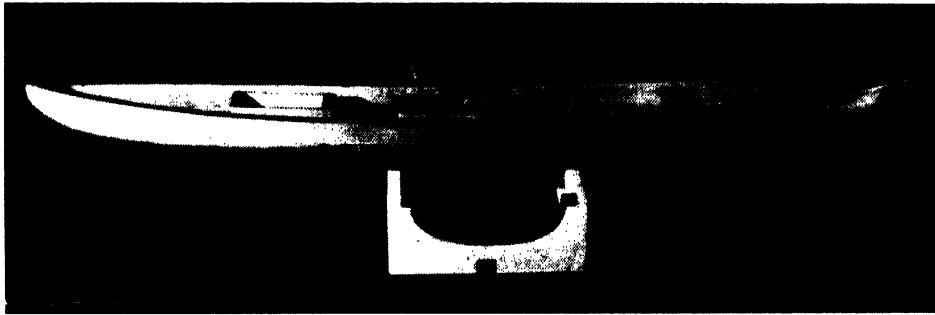
Fig 5. *Ghana canoe, USNA Model 2*
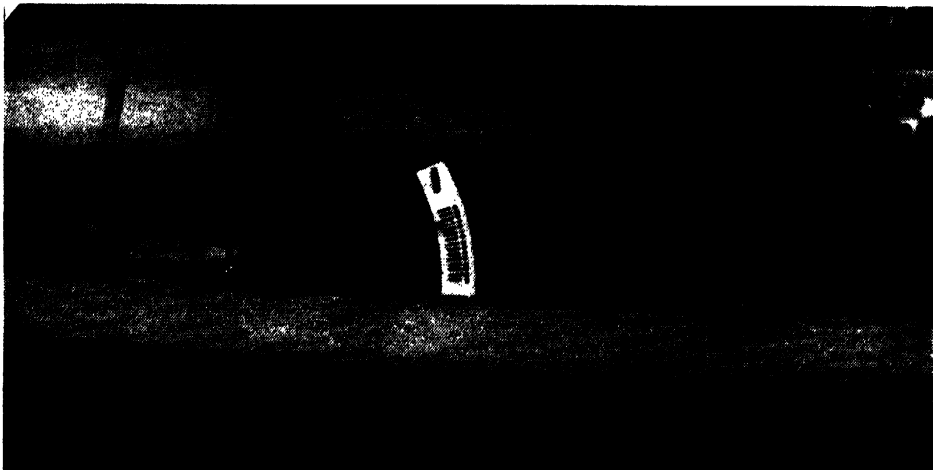
Fig 6. *Water level gauge in Model 2*

Fig 7. *Ghana canoe rigged for towing*

the bottom. The angular position of this hatch affects the hydrodynamic characteristics of the hull, as will be described.

Model 2 is of a Ghanaian canoe of 32.8 ft (10 m) length (model scale 1/6.5). The hull lines (fig 4) were taken from a FAO drawing reconstructed from measurements of a typical Ghanaian canoe taken off at Seme, Dahomey, in April 1963. The basic hull of this canoe, exclusive of stem elongations, was 29.5 ft (9 m) length, 4.85 ft (1.48 m)

beam and a depth amidships of 2 ft (0.6 m). It does not have as much bottom curvature longitudinally as the Senegalese canoe and is of a round bilge section which, in the bottom, is fairly flat amidships. The ends are quite full and "apple cheeked" (fig 5). The motor well was installed in this model of the same dimensions as described, in a first location 4.9 ft (1.5 m) aft of the midsection, and later in a second location with the forward edge of the well amidships. The wells were both fitted with the same hinged hatch in the bottom. In the model wells a gauge

was installed that registered water level variations to 0.01 in (fig 6). The models were ballasted and trimmed to an operating displacement of approximately equivalent to 1,800 lb (820 kg) full size.

They were finished with several coats of exterior grade varnish and hand rubbed to a smooth, dull surface. Turbulence stimulators were fitted since the tests were to take place in the Reynold's number range in and below the transition at flow region.

During the tests of model 2 a dye jet tube was fitted ahead of the well opening for flow studies. High-speed cinematograph cameras were used in connection with these studies but the quality of the film precludes reproduction. Fig 7 shows the model of the Ghanaian canoe, ballasted and attached to the carriage for towing.

MODEL TEST PROCEDURES

It was decided to use the standard-shaped motor well (fig 3) in two locations and test a range of hatch closure angles for various speeds to determine the speed against resistance and speed against water level curves. These tests were carried out, first with the Ghanaian canoe, model 2, with various hatch closure angles from 0° to 90° at 30° intervals. The same procedure was followed for the Senegalese canoe, model 1. The water level tests were conducted after the resistance tests. Before the motor well position was changed to another location and the tests repeated, a dye tube was incorporated to stream dye aft in line with the well for observation of the flow characteristics in the vicinity of the well opening. This was observed and photographed.

EXPERIMENTAL RESULTS AND DISCUSSION

Model tests

A naked hull test was made before cutting any motor well in the model of the Ghanaian canoe, model 2. These test results were compared with the results with the well installed and the hinged hatch in the closed position (fig 3). The results for these two conditions showed no significant difference indicating that the aperture, formed by the hatch and the shaped closure ends, produced so little additional disturbance of the flow that it was not measurable. The inference here is that this is a most efficiently-shaped aperture, producing practically no disturbance of water flow, and this was substantiated in the visual dye-stream observations. Referring to the test curves of resistance against speed-length ratio (fig 8) it can be seen that there is a considerable difference in resistance with the hinged closure hatch fully open and closed. It was observed in the water level tests in the wells that when the hatch plate is fully open (at 90°) there was considerable turbulence in the well with water entry into the hull and extreme fluctuations in water level at the upper speeds. It became necessary under these conditions to seal the top of the well temporarily. The additional drag produced by the fully-opened well might be compared to an appendage drag with a proportional flat plate or projected area similar to the after face of the well. The flow conditions are, of course, not similar but the effect and nature of the flow may be comparable.
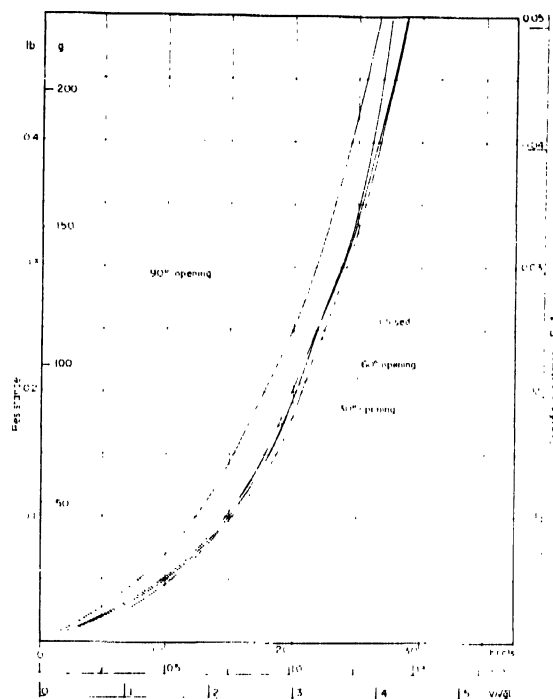
Fig 8. Speed/Resistance, Model 2, Well 1

The tests with the closure plate at angles of 30 and 60° respectively show resistance values of similar but not identical quantities and indicate that resistance increases with hatch angle at some significant values. At medium speeds there is a junction of data (approximately $V/\sqrt{L} = 1.0$) where the angle of the closure plate between 30° and 60° makes very little difference. At upper speed length ratios ($V/\sqrt{L} = 1.5$) there is no apparent change of resistance from the closed position up to 30°.

From the direction that the 60° plate angle curve appears to be taking at these higher speeds, it would be possible to say that an impact resistance against the face of the plate is building up. This is borne out further by the tests of water level where observations show turbulence developing in the well at these speeds with the plate at 60°. While no tests were conducted with hinged plate at angles between 60° and 90°, it would be reasonable to predict that the well turbulence would develop at decreasingly lower speeds with increase in plate angle. This would indicate increasing resistance until the limit with the fully-open hatch was reached.

With the well relocated in the second position, near but aft of the midsection (fig 4) the tests as in the initial well location were repeated. The indications shown for this condition (fig 9) are in general slightly more favourable. The resistance curves for the various plate angles are of similar nature when compared with the results of the same series with the first well position. They show small quantitative decreases in resistance at most speeds in the operating range. In most cases these incremental values, particularly at small plate angles, are so small as not to be of general significance.

Model 1, the Senegalese pirogue, was tested with the well as shown in fig 1. It is interesting that the basic

Fig 9. Speed/Resistance, Model 2, Well 2
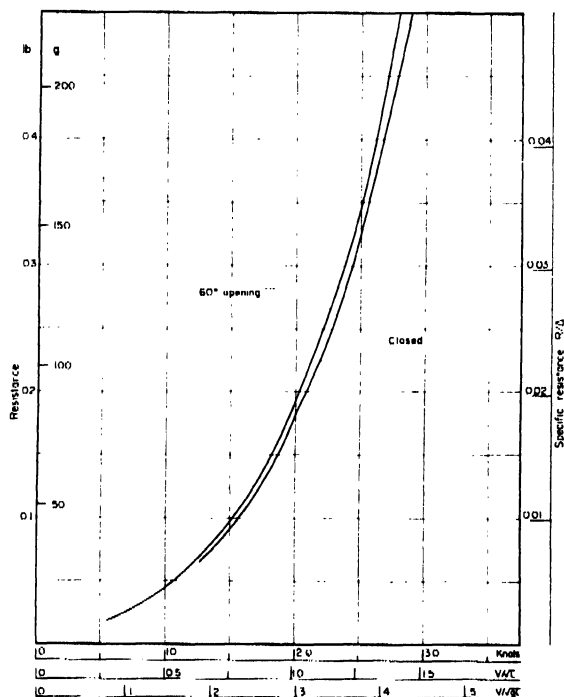
Fig 10. Speed/Resistance, Model 1

resistance curve with no well installed shows a more steeply rising curve for this flat-sectioned hull from a lower resistance value (fig 10) than model 2. In the speed range of $V/\sqrt{L}=1.0$ a specific resistance (R/Δ) of .012 is given while in model 2 (Ghanaian canoe) for the same speed, $R/\Delta=.017$ is recorded. However, the excessive longitudinal curvature of this hull rapidly increases the resistance at the more critical hull speed values near 1.3 speed-length ratio. An exceedingly deep hull-generated wave was quite apparent at this speed.

The open well test of model 1 shows less increase in resistance than model 2. There is also a marked closing of the curves as the speed increases. This is quite obviously due to the previously observed build-up in an excessive amount of wave resistance. At speed-length ratios of 1.2 to 1.25 the wave contour along the hull conforms closely to the contour of the bottom of the hull, indicating a lower pressure differential at amidships. This would produce a reduction in the drag effect of the open well, reducing it to lesser proportions in the high-speed range. As the curves indicate, at these higher speeds there is little or no change in resistance between fully-open and closed well. It must be pointed out that this phenomenon should not be generalized to include other types of hull with more conventional bottom shape or less longitudinal slope in the after bottom.

During the preliminary tests of both models it was observed that they had very poor directional stability characteristics. Model 1 actually became self-broaching when at speeds greater than $V/\sqrt{L}=1.00$. This condition was noted while checking simple behaviour characteristics where the models were towed from their centre of floatation. Using a special towing bracket which allowed the three directions of angular freedom, this instability
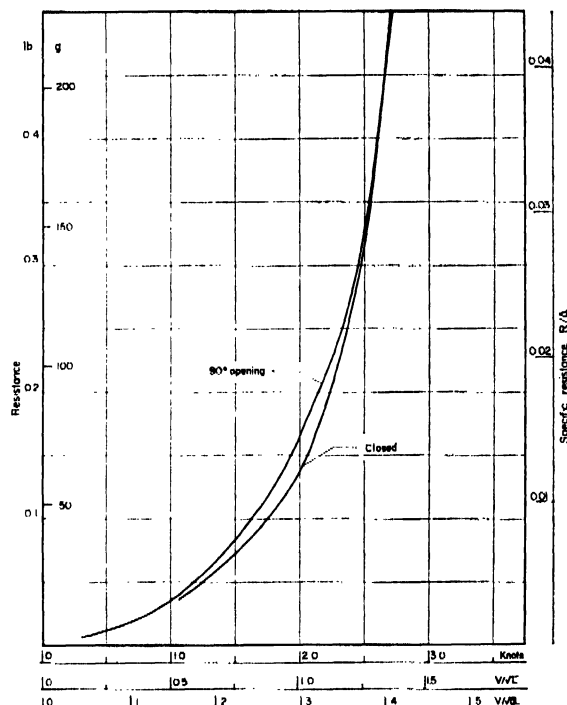
was most apparent at speed-length ratios over 1.00 and was in all cases noted after the steady state was reached and not during acceleration or deceleration. Model 1 was repeatedly swamped under these conditions. Similar steering behaviour has been observed subsequently in the full-scale tests.

The tests of static water levels in the model's engine wells were made for the total range of speeds (fig 11). These pressure head levels, together with the indicated turbulence, have been noted and also their relation to the resistance results. It should be pointed out that the water level differentials were extremely small and of generally inconclusive significance except to relate the hull-generated wave level. In the case of the fixed aperture at closed plate 0° angle the indicated well level followed the external
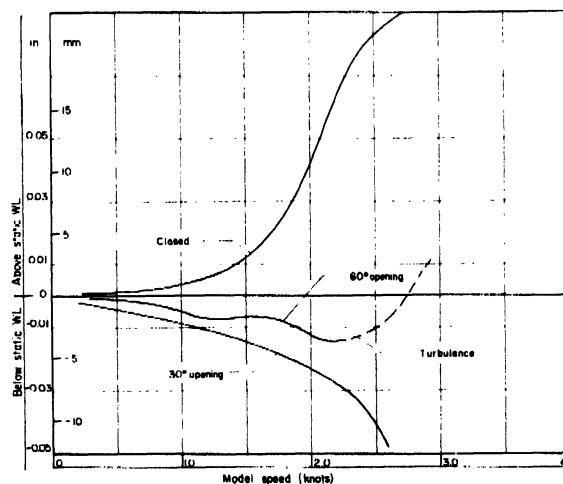
Fig 11. Water level/Speed, for various hatch openings, Model 2

[338]
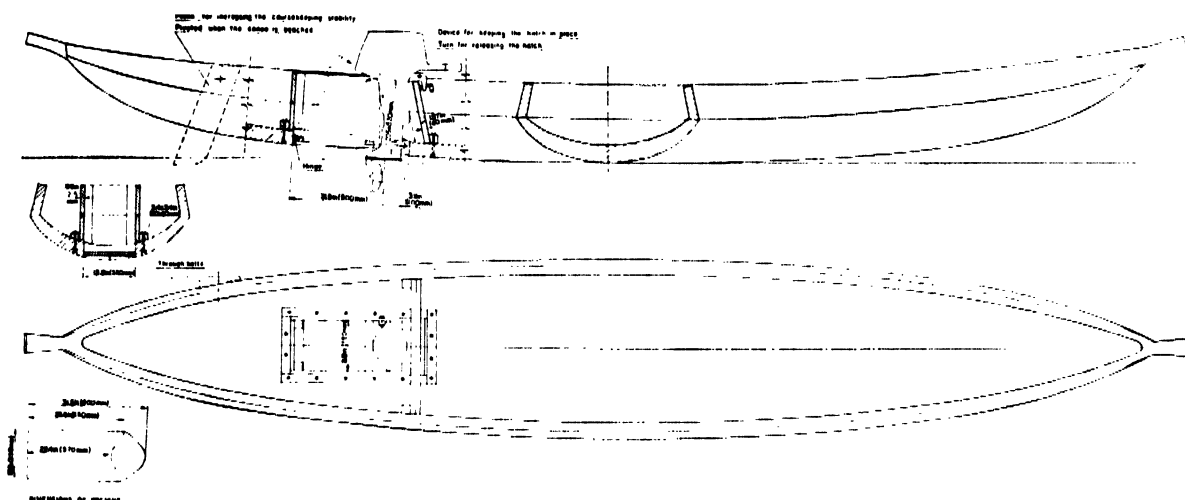
Fig 12. Ghana canoe, outboard-motor installation, position 1

water level (hull wave) very closely. Such a condition suggests those to be found by installation of a pitot static tube.

Canoe tests (full-scale)

The full-scale tests were carried out in the port of Dakar with two Ghanaian canoes of the same main dimensions:

Loa	26 ft (8 m)
Maximum beam	4 ft (1.25 m)
Dry weight	772 lb (350 kg)

There were however differences in the longitudinal

Fig 13. Wells cut through canoe A (Note thickness of hull)

shape of the canoes, canoe A having more longitudinal curvature on the bottom than canoe B.

The first thing to be decided was the dimensions of the opening to be cut in the bottom of the canoes. After discussions with Mr. A. Collart, FAO Fisheries Expert in Dahomey, who is well experienced with canoes, it was agreed that lifting the motor vertically before grounding, as done in Senegal, was an unsatisfactory solution. The opening should be long enough to permit tilting the motor. The largest motor considered for the canoe was 18 hp and the dimensions of the opening were based on this motor size with a propeller diameter of approximately $9\frac{1}{2}$ in (24 cm). The width of the opening was $13\frac{3}{4}$ in (35 cm) to give reasonable steering angles. Only longshaft motors were considered practical and gave a dimension of $20\frac{1}{2}$ in (52 cm) from the top of the transverse bulkhead to the underside of the bottom. There are on the market motors with larger propeller-diameters for higher efficiency, and for these motors the length of the opening has to be increased. A propeller of 13 in (33 cm) diameter would require an opening of 35.5 in (90 cm) length.

To reduce the resistance of the well, it was evident that the opening had to be partially closed in some way. Several possibilities were considered, but the one shown in fig 12 and 14 was selected because of its efficiency and simplicity. This consists of a hatch with a hinge, flush with the bottom at the aft end. This hinge can be very simple, just a steel rod fastened on each side to the top of the hatch and turning in holes bored in the side of the canoe. Stops must be placed on the sides of the opening forward to prevent the hatch from dropping through. Under speed, the water pressure pushes the hatch up. A device as indicated in fig 12 will prevent this but still enable the hatch to be quickly released when approaching the beach. If by accident the motor should hit the bottom while crossing the bar it can tilt freely and thus major damage will be avoided.

The first tests were of two different well positions. In position 1 the forward bulkhead of the well was placed about one-third of the overall length from the aft end in canoe A. Fig 12 shows this position and fig 14 shows position 2 further aft, which was tried on canoe B. The

Fig 14. Ghana canoe, outboard-motor installation, position 2
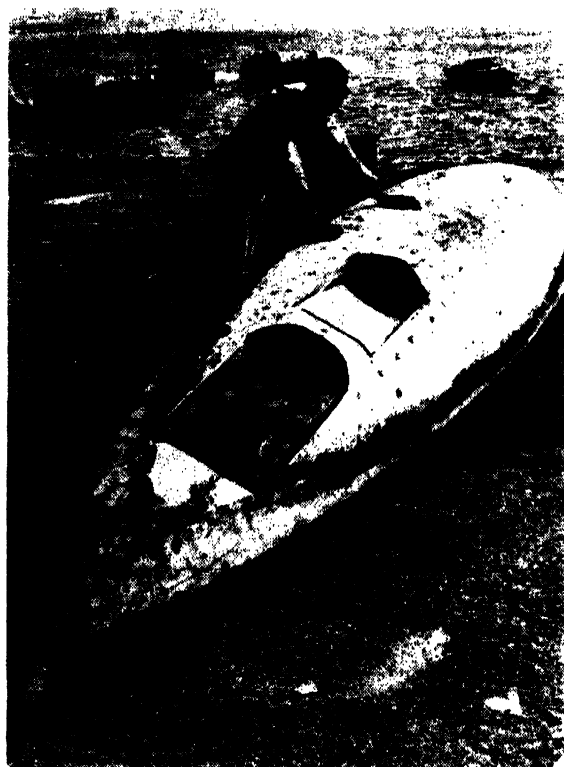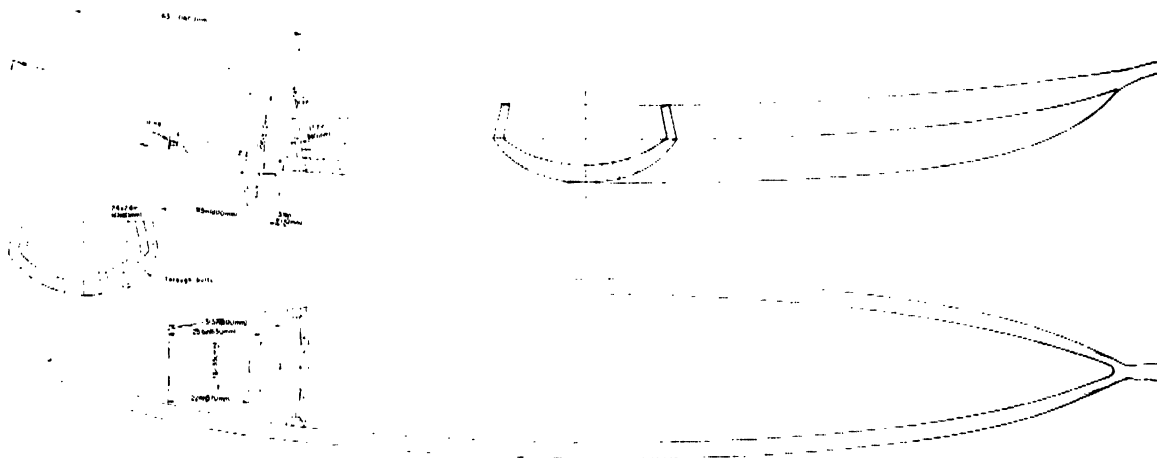
drawings also indicate the construction methods. In canoe A a box was built around the opening; $2\frac{1}{2} \times 2\frac{1}{2}$ in (6×6 cm) pieces were through-bolted to the bottom of the canoe and the sides of the well nailed to these. Canvas strips soaked in thick paint were placed in the joints to render them watertight. The aft well position in canoe B permits simplification by placing just one transverse bulkhead forward of the opening for motor attachment.

Tests results

The motor used during all the tests was developing a nominal 14 hp at 4,800 rpm. Initially both canoes were tested with the motor fitted on the side as normally used, then the wells were installed as shown in fig 15. All the trials were in the Port of Dakar under favourable wind and sea conditions.

Speed was measured by stop-watch between two fixed points 4,690 ft (1,430 m) apart, at least once in each direction at each throttle setting.

Fig 15. Well installations. Canoe A with installation position 1 to the right, and canoe B with installation position 2 to the left

Fig 16. Resistance dynamometer

[340]

Motor rpm was determined by a vibration tacho-meter and **fuel consumption** by an electronic apparatus giving an accuracy of 0.1 gal/hr.

The thrust measurements were made with the apparatus shown in fig 16. It consists essentially of a hydraulic cylinder with a piston placed between the lower unit of the engine and the transom. The propeller thrust is thus directly tramsmitted through the piston to the fluid in the cylinder which in turn registers the resulting pressure through a trans-mission line to a calibrated pressure gauge.

$$T = A \times P \times \frac{h_c}{h_p}$$

where: T = thrust (kg)

A = piston area (cm²)

P = pressure at gauge (kg/cm²)

h_c = distance of piston axis from engine pivot (m)

h_p = distance of propeller axis from engine pivot (m)

This device can be applied to any hull powered with an outboard motor and offers easy measurement. The test results for the two canoes are given in table 1.

It will be noted that by placing the motor in a well, the speed increased no less than 1.1 knots for canoe A and 1.2 knots for canoe B. An additional advantage is more adequate protection for the motor and less spray being thrown into the boat. The tests show beyond doubt that the more complicated well installation gives higher performance.

Fig 18. Fuel consumption, Ghana canoe A

The difference in maximum speeds of canoes A and B can be attributed to difference in shape; the flatter bot-tomed canoe B has a much better performance at higher speed-length ratios. A direct comparison between the two different well positions, therefore, was not possible.

Extensive trials were made with canoe A in order to determine fuel consumption, revolutions and thrust at different speeds. Fig 18 gives the fuel consumption and the rpm of the motor at two different loadings. The thrust curve is shown in fig 17. By adding 440 lb (200 kg) the top speed dropped 1.1 knots and the fuel consumption per nautical mile, increased 15 per cent.

In order to get a comparison between the two differ-ent well positions, 1 and 2, it was decided to try them on the same canoe. Canoe A was chosen for these tests because its form is most representative of the Ghanaian canoe (fig 12 and 13). It was also decided to get a com-parison between the well and the transom installation. During the tests of the latter (the end of the canoe was cut off and the motor fixed on a transom), the well-openings were plugged with polystyrene blocks shaped to the form of the bottom of the canoe. Table 2 gives an impression of the four different motor installations tested, as shown in fig 19. These tests were performed after the motor had been used for some rough beach-landing trials and there-fore it was not in the same condition as during the first tests. The top speed of the canoe with the motor in the well, position 1, dropped from 9.3 knots to 7.8 knots.

Fig 17. Speed/thrust curve, Ghana canoe, A

TABLE 1: The speed for maximum throttle

Motor side mounted			Motor in well		
Type Canoe	rpm	Speed in knots	Well type	rpm	Speed in knots
A	4,650	8.2	1	4,850	9.3
B	4,700	8.5	2	5,000	9.7

TABLE 2: General impression of the installation

	Speed in knots	Cost of installation	Loss of space	Steering	Protection of motor
Side-mounted motor	7.0	10	10	6	4
Motor in well, Position 1	7.9	3	7	8	10
Motor in well, Position II	7.8	6	8	9	9
Motor on transom	8.1	7	9	10	5

This is, however, of rather small importance since we are more interested in comparing the different installations than the absolute top-speed.

The speed for maximum throttle is shown in table 1. It will be noted that, with the exception of the side-mounted motor, the difference in speed is not great. The best in this group is the transom installation, with a speed
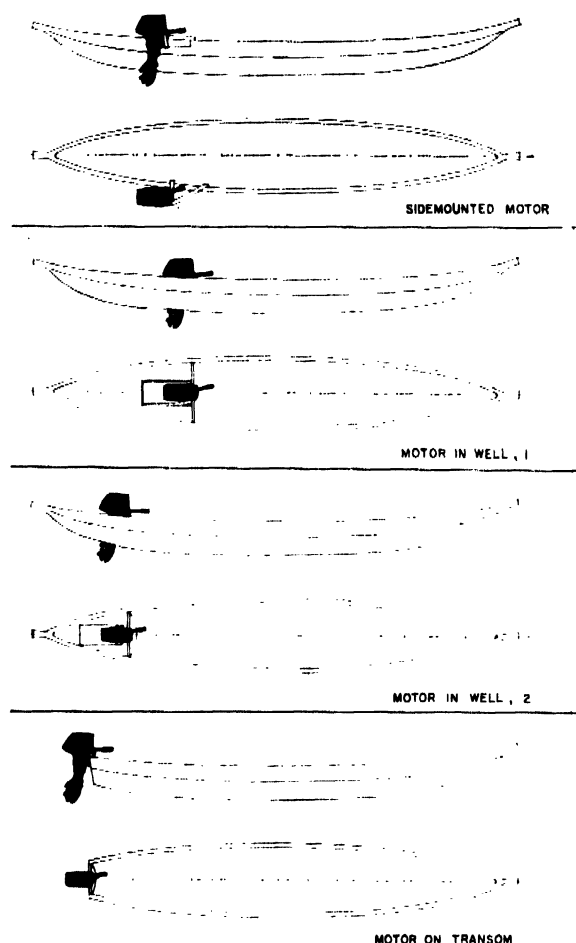
Fig 19. Different ways of motor installation

of 8.1 knots; the worst, the motor in a well, position 2, with a speed of 7.8 knots.

One significant observation for both canoes with the motor in the well or on the transom was their bad course-keeping stability. Especially with the motor in the forward well position, the canoe was tender on the helm. A reasonable explanation for this is the lack of lateral-plane aft caused by the large curvature of the bottom. The steering problem can be solved by fixing a roughly streamlined plank aft on the side of the canoe, as indicated in fig 12. When approaching the beach, it can be pivoted. It is also possible to add a keel on the canoe, but this should be placed so far aft so as not to interfere with the handling on the beach.

Under speed the propeller creates a suction which reduces the amount of water in the well. In the well, position 1, the water depth at rest was 6.25 in (16 cm), and this was reduced to 2.4 in (6 cm) at speed. In the well, position 2, there was little water both at rest and at speed. The wells were also tried without a hatch to cover the opening and this introduced much turbulent water into the well. The drop in speed, without hatch, was 0.6 knots for position 1 and 0.4 knots for position 2.

The choice of a certain type of installation must be based on many factors beside the speed: cost of installation, loss of space, steering and protection of the motor from spray. These qualities are not measurable, but table 2 is based on the general impression of the different installations during the tests.

Beach landing must also be considered. On landing, the catch is first unloaded, but the bigger canoes are still too heavy to be dragged up the beach. Five to ten men hold each end of the canoe and start turning it, using the lever principle. The men are alternately lifting and pressing down the ends, thereby changing the centre of rotation, as shown in fig 20. In this way, the canoe is "walked"
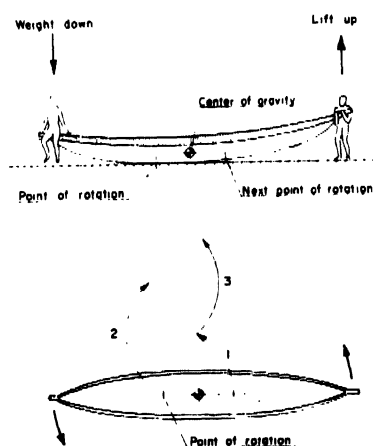
Fig 20. Method of moving a canoe on the beach

up the beach. Cutting off one end of the canoe to install a motor on a transom will, therefore, make the handling on the beach more difficult.

Crossing the surf is, from an operational point of view, the most critical period. To date, in Ghana, the motor has always been placed on the side of the canoe which makes it very exposed to breaking waves. The fishermen

[342]

therefore take off the motor and put it inside the canoe before paddling through the surf. In Senegal the motor is always installed in a well and consequently has much better protection. The motor is used also when crossing the breakers and is lifted up just before grounding. The steering is not done however with the motor, but by the master fisherman sitting far aft with a paddle. The reason for this seems to be tradition. The motor has taken over the work of the paddlers, but the master still prefers his steering position aft. This works well in open sea but, no doubt, steering with the motor gives a more positive control when going through the breakers.

The full-scale values show thrust values through speed-length ratio values of 1.2 to 2.4. Relating model and full-scale data is an interesting procedure because reliable full-scale test speed-power data is rarely available. The comparative speed-power values were reduced from full
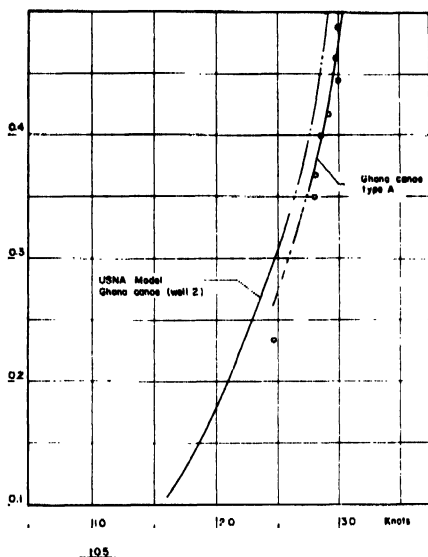
Fig 21. Ship model correlation

scale to model dimensions in this case. Fig 21 attempts to show an extension of the model test values to points reduced from the full-scale tests on the Ghanaian canoe 1 with engine in well position 1 at full load, 1,880 lb or 850 kg (3 men + 200 kg) which most closely corresponds to the model displacement.

CONCLUSIONS AND RECOMMENDATIONS

The speed-resistance curves substantiate the results of power requirements for the various well openings.
Summary of the model test results:

- In all well positions, the best condition was with least aperture opening

- As the angle of the hinged plate was increased, the measured resistance increased in both models

- Model 1 different plate angles at higher speeds show no appreciable change in resistance

- The change in well position in the Ghanaian canoe to midships results in a very small improvement in resistance characteristics

The model test results also verified the poor directional qualities of the canoes. In connection with the small improvement in powering the amidship well location with a conventional outboard motor, a rudder would be required because of a lack of a turning couple. The additional drag of a rudder would appoximately offset the powering advantage, resulting in a dubious net improvement.

As suggested from full-scale trials the addition of a fin or skeg would be most helpful. Such an addition for operation from the beach in surf would at least offer an additional safety factor while detracting a small amount from the powering characteristics. To summarize specifically the differences between the two models tested:

Model 1 (Senegal pirogue)
- Well aperture results in comparatively small increased resistance with the maximum occurring at $V/\sqrt{L} = 1.0$ to 1.1 and then diminishing to zero
- At higher speeds the wave-making resistance of this hull increased excessively with the wave contour producing a diminished to negligible effect of the well opening

Model 2 (Ghanaian canoe)
- The opened well shows a relatively large increased resistance throughout the entire speed range which is manifested when the hinged plate is open at angles greater than 60°
- With the hinged plate at angles of less than 60° there is comparatively small increase in resistance and this decreases with plate angle. The small aperture existing when the hinged plate is closed results in no measurable increase in resistance over that produced when the hull has no aperture at all

To correlate the model tests to the full-scale tests at this stage is rather difficult, but some correlation is apparent.

Primarily, the evidence of poor directional capabilities was discovered. Secondly, in the limited ranges of speed where model and actual canoe's data overlapped there is good evidence of similar results. Finally, in the full-scale Ghanaian canoe, there was a speed reduction of 10 per cent between fully-opened well and the "closed hatch" (0° plate angle) condition. This corresponds to the results shown in the model tests. It must be remembered that:

- The full-scale canoes have an undetermined roughness coefficient that could be determined only with more detailed data over the lower and medium speed ranges
- The "scaling-up" of model resistance values, taken at higher speeds ($V/\sqrt{L} = 1.5$), is frequently unreliable
- The model and actual canoes were not of identical geometric form but only "similar"
- The well locations of the model and actual canoe corresponded in only one instance
- The effect of the propeller operating below the well aperture changes the flow character of the water in the vicinity and increases turbulence aft of the well. This in turn will produce differing resistance coefficients

However, it is not extremely important that exact correlation between model and prototype be searched for, but rather trends, performance characteristics of a similar nature and data that agree generally. In these tests it is more significant and important that one series of tests is a displaced extension of the other. In this respect the model tests, together with the full-scale canoe tests, provide a thorough and extensive investigation.

The model tests generally substantiated the full-scale tests, showing that variation in longitudinal well location does not have a marked effect on the powering characteristics. It might additionally be suggested that further study of such longitudinal locations could result in an optimization of steering capabilities.

Generally, it may be concluded from both full-scale tests and model tests that motor well installations produce some deterioration in the powered performance and speed characteristics, but these effects are not significantly large. In any case, when considering other types of transient motor installation together with various operational factors (see table 2), the motor well installation is superior to any other, as applied to these West African canoes. The final choice of motor well is, of course, dependent upon the nature of the practical working conditions. There seems to be very little difference shown in tests between the full-scale position 1 and position 2 or the model tests with different longitudinal locations. The more significant factor is the use of the hinged hatch plate with the well installation, and the importance of keeping this hatch closed, or nearly so, in operation.

Jamaican dugout canoe with transom stern to accommodate an outboard. Compare with Thomas's paper p. 432.

Engine Types and Machinery Installations

by Curt Borgenstam

Moteurs et appareils auxiliaires

La gamme de groupes propulsifs dont disposent aujourd'hui les pêcheurs peut aisément désorienter par sa variété, depuis le classique moteur marin jusqu'au moteur d'automobile léger et à grande vitesse.
L'auteur commence par exposer les conditions requises d'un appareil propulsif pour bateau de pêche: puissance de traction, hélice à grand diamètre et à petit pas, rapport poids/puissance pouvant aller de 25 à 35 kg/ch, faible longueur, possibilité de fonctionner durant de longues périodes entre deux révisions, et de se prêter à d'importants travaux d'entretien à bord. Il examine les avantages et les inconvénients des semi-diesels, des diesels et des moteurs à essence, et traite ensuite de divers aspects particuliers de l'installation: carlingage et montage du moteur, pose de l'inverseur, du réducteur et de l'arbre. L'auteur décrit les systèmes d'échappement du type "sec" et à injection d'eau, ainsi que les systèmes de graissage par carter sec et par carter classique. Il étudie divers dispositifs de refroidissement: pompe classique à piston, pompe à engrenages, pompe centrifuge, refroidissement direct par eau de mer, et systèmes indirects tels que le "refroidisseur de quille". Il expose un agencement des organes d'alimentation réduisant au minimum le risque d'incendie, et mentionne certaines précautions à prendre contre le feu. L'auteur étudie les auxiliaires de bord (prise de force pour treuil ou autre équipement de pont, génératrices de courant, moteurs auxiliaires) et l'emploi de l'hélice à pas variable. Il traite pour terminer des divers types de commandes et d'appareils de contrôle et de leur agencement.

Tipos de motores e instalaciones mecánicas

El surtido de instalaciones de fuerza de que se dispone actualmente constituye una rica y asombrosa variación de diferentes tipos de motor que van desde el clásico motor marino a los motores ligeros de gran velocidad, para automóviles. El autor expone en primer lugar los requisitos especiales del motor de una embarcación pesquera: fuerza de tracción; hélice de paso pequeño y gran diámetro; relación entre peso y potencia hasta 60 u 80 libras/cv (25 a 35 kg/cv); poca longitud; largos períodos de funcionamiento entre las revisiones; posibilidades para un considerable mantenimiento a bordo. Se examinan las ventajas e inconvenientes de los motores de bola incandescente, diesel y de gasolina. Se mencionan factores especiales de la instalación: soporte o bancada del motor, colocación del cambio de marcha, engranaje reductor y eje motor. Se describen sistemas de escape de descarga en seco y en húmedo y sistemas de lubricación con colector de aceite secos y húmedos. Se examinan varios sistemas de refrigeración: bomba normal de pistón, bomba de engranaje; bombas centrífugas; sistema directo de refrigeración por agua de mar; sistemas indirectos tales como el refrigerador de quilla. Se describe la instalación de un sistema de combustible que reduce al mínimo el peligro de incendio, así como ciertas precauciones contra los incendios. El autor examina la instalación del equipo auxiliar, tal como el dispositivo para accionar la maquinilla y artes de cubierta, sistema eléctrico, motores auxiliares y uso de la hélice de paso variable. Se mencionan los tipos, diseño y distribución de los mandos del motor y de los instrumentos.

IN the Scandinavian countries the fishing fleets were mechanized at a very early stage. At that time, this process could be based largely on engines and machinery components which were designed and built specifically for their marine purpose. The machinery was created from necessity and took a classic form which so well answered the requirements that little cause existed for detailed research and study of its salient features.

Now fishing fleets elsewhere are facing the same problem of mechanization, but the situation is quite different. It is no longer possible to develop and build engines or equipment for a limited market. Units designed and built for other purposes must often be adapted and modified to suit the marine requirements. The general trend towards higher performance has also necessitated the introduction of a more refined and more complicated technique. This has not been gained at the cost of reliability. On the contrary, reliability and ease of handling have improved immensely. However, this is true only if the operator understands engine maintenance and has a proper place, tools and spare parts for it.

A similar process has taken place in the field of motor boats for naval, commercial and pleasure use. The following account is mainly based on the author's experience from this branch of technology and from installation and service of engines in Swedish west coast fishing vessels.

INSTALLED POWER

For a pleasure craft the required power is determined by the desired top speed, the cruising speed and the hull resistance at these speeds. For planing craft the position and magnitude of the hump in the resistance curve at the transition from displacement to planing condition must also be considered.

For a fishing vessel, however, the required engine power is also largely dictated by the demand for pulling power during fishing. This is the difference between the available propeller thrust and the resistance of the hull. Both vary with the speed, and it is valuable to know both these curves plotted against speed. They can be based on model tests and/or calculation, but many small boat projects cannot carry the cost of either. In such a case the designer must resort to rules of thumb plus experience. Results from towing tests have also been published and it is often possible to calculate the resistance by using the data from a similar hull.

The available propeller thrust increases with diminishing speed. At zero speed the thrust can be about 50 to 60 per cent higher than at full speed. Among other factors, the rate of increase is influenced by the pitch ratio in such a way that a larger diameter and a smaller pitch, within reasonable limits, improves the pulling power at low speed with some sacrifice of top speed.

The propeller characteristics alone are not decisive since the power and torque delivered by the engine also varies with speed.

A controllable pitch propeller can improve on the thrust curve because engine speed can be kept constant so that full engine power is available regardless of the towing speed.

This is in fact the most important, but often overlooked, advantage of the controllable pitch propeller, which is sometimes considered as just an alternative to a reverse gear (fig 1).
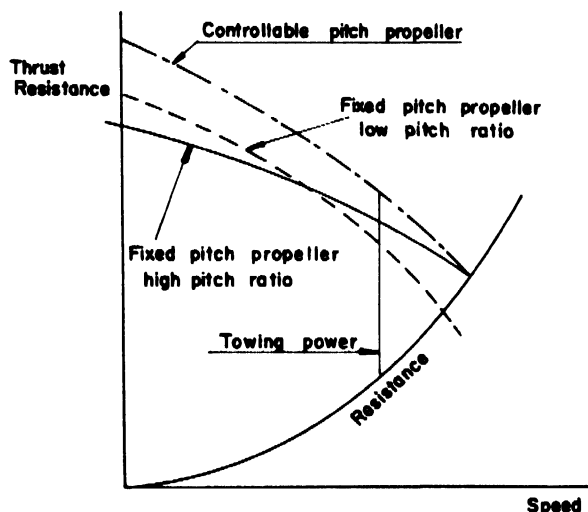
Fig 1. Towing characteristics with fixed and controllable pitch propellers

If the propeller is designed to absorb full engine power at full speed, the thrust at bollard condition will suffer from lack of engine power, because the engine can then only reach about 60 per cent of its full speed with a corresponding fall-off in output. On the other hand, if the propeller is designed for bollard condition, it can give a a high thrust at zero and low ship speed, but it will not be able to absorb the full engine power at full speed. The engine must then be throttled back to avoid over-revving with a corresponding loss of thrust and performance under free-running conditions.

To design a fixed pitch propeller for top speed usually is less advantageous mainly because most fishing craft have a very steep resistance curve at higher speed. To push the speed above 8 to 11 knots (depending on the size and length of the boat) requires a great increase of power. This is certainly the case when putting a motor into one of the older types of fishing boats, which usually have such convex buttock lines in the afterbody that they will squat considerably if high engine power is applied. A more modern design, with a good "run" aft, especially those with a transom stern, will not suffer from this to the same extent. The demand for more speed increase is better met by improvements in hull form than by power increases.

It must also be borne in mind that higher engine power not only means higher cost, weight and bulk, but also greater stresses due to vibration and propeller thrust.

The minimum installed power should be determined by

the propeller thrust required for towing of the fishing gear for safe manoeuvring and to keep pace and course in wind and sea. The shape and lines of the hull have a great influence on the characteristics of the vessel in this respect, and also the proportion of lateral plane to the aerodynamics of the body above the waterline.

GENERAL REQUIREMENTS OF FISHING VESSEL ENGINES

Weight

The weight requirements are moderate for fishing boat engines. Up to 60 to 80 lb/hp (25 to 35 kg/hp) is an adequate weight/horsepower ratio. Modern diesels of industrial, marine or automotive type offer no problem in this respect nor does, of course, the petrol engine.

Size

It is important that the installation is short, as the engine has to compete with the fish hold for the length available. This applies not only to the engine itself but includes also the whole of the drive shaft line with thrust bearing, shaft seal, propeller mechanism, reduction and reverse gear. If the engine is fitted with power take-off at the front end for the deck machinery or windlass, this must also be built as short as possible

Athwart ships, sufficient room is required for easy access to all components which have to be serviced on board.

Height is seldom critical in small open boats. However, it must be possible to lift the whole engine out, especially if it is an automotive type which requires periodic workshop overhaul.

Vibration

In fishing boat engines there is no pronounced requirement to strive for extreme quietness or vibration-free running. Elastic mounting is seldom regarded as necessary.

Running characteristics

A fishing boat engine must often run for long periods at very little load. The combustion even at low load must be sufficiently clean to prevent excessive carbon deposits to be built up. Sales pamphlets never have anything to say about the behaviour of the engine at part load. Price per horsepower is often regarded as the most efficient sales argument. As engines are designed and built to be sold, it is natural if the part load characteristics are often sacrificed or overlooked to attain favourable top power figures in the brochure.

The degree of utilization is usually very high. Some fishing boats are run for more than 4,000 hours a year, e.g. 55 per cent of the total time. For this reason the time between overhauls must be long. For 4,000 hours the engine must function without servicing other than cleaning the filters and injectors, valve clearance adjustment and other minor operations. A top overhaul can possibly be accepted, entailing cylinder head removal, decarbonizing and grinding of valves.

In this respect the requirements are quite different

from those in the pleasure boat field. Here running periods of more than a few hundred hours a year are exceptional.

Overhaul

Regarding overhaul work, the general trend points towards all major overhauls being conducted by workshops ashore, suitably equipped for the purpose with tools, spares and trained personnel. The traditional requirement of a marine engine to enable complete stripping and repair on board was long ago dropped in the pleasure boat field. This means in practice that automotive engine types with underslung bearings are readily accepted. It is this new concept that has made possible the low price, thanks to mass production, the low weight and high specific output of modern pleasure boat engines.

Even if the same trend has made itself felt in the fishing boat field, the conditions are very different. Shore workshops are often remote, especially in less industrialized countries. The organization of the fishing is also such that it is desirable that repair and maintenance of the engines can be carried out entirely on board. If this is the case, the engine design must be carefully studied so that the vital service points can also remain accessible in the actual installation on board.

HOT BULB ENGINES

When the fishing fleets of the Scandinavian countries were motorized the mechanization was largely based on the use of hot bulb engines. A great number of manufacturers concentrated their efforts on this type of engine which in many respects was eminently suited for fishing vessels. It soon got a well-deserved reputation for reliability and it also had other merits. It was not very demanding in the quality or filtration of the fuel, thanks to its ignition system and the low injection pressure which made the pumps and nozzles less sensitive to wear and dirt. It was so heavily dimensioned that it could stand corrosion as well as a certain amount of neglect and maltreatment without mechanical protests.

The hot bulb engine has found a good market as a marine and industrial engine in several remote countries where its simple, rugged construction and low demand on workshop support have been highly appreciated. In more industrialized countries, however, sales have receded in favour of diesel engines, mainly as a result of the demand for higher power and less bulk and weight. The manual work and service of the hot bulb engine is also a heavy and dirty job and does not satisfy modern standards.

Another objection against the hot bulb engine for marine use has been the necessity to preheat the bulbs with blowlamps, which means a certain fire hazard. Scandinavian fishermen have been used to this procedure for many decades but in many other areas the handling of blow torches on board a wooden boat must be regarded as rather dangerous. Modern hot bulb engines have electrical preheating systems but, in spite of this and other detail improvements, the engine is seldom competitive compared with other types.

DIESEL

For smaller fishing boats the most common replacement for the hot bulb engine is the diesel. In the lower power bracket, up to about 25 hp, slow or medium-speed engines are available, designed and built for industrial or marine use. There are quite a few Swedish makes (e.g. Bolinder), some Norwegian (e.g. Sabb and Marna), and several British and Italian. This class of engine is simple in design. Most are built to enable overhaul on board and often so slow running (800 to 1,200 rpm) that they can be directly coupled to the propeller in a small fishing boat. One installation difficulty for the engines of industrial type is often that the mounting feet are placed rather low, which suits a stationary bedplate but is less adaptable to engine bearers in a boat.

In the higher power bracket, above about 25 hp and up to about 300 hp, the market is mainly dominated by automotive-type diesels. In most cases the marine engine is made up by "marinizing" an existing basic automotive engine, which is fitted with reverse gear, see-water pump, heat exchanger and a water-cooled exhaust manifold. With few exceptions even the "pure" marine engines have much resemblance to automotive engines and generally follow their standard in layout and construction.

The main advantage of this system is that the engine can be very cheap for the power it gives, thanks to mass production methods that can be employed for the large series of the automotive industry. The marine service can also benefit from the experience gained from the automotive field. Availability of spare parts should be better and the network of service depots and agents more efficient than for a pure marine engine made in small numbers.

Generally speaking, experience with the automotive engine at sea is positive, but attention must be drawn to some characteristics which are often overlooked by the boat designer and user. The auto engine usually affords less accessibility for service and overhaul on board than marine engines. The auto engine's crankshaft is invariably carried in underslung main bearings in the cylinder block. This gives a compact, sturdy, light and cheap design which is desirable for a vehicle engine installed for accessibility from underneath. In a boat, however, con-rod and main bearings cannot be got at without lifting the whole engine out. A few engines are fitted with crankcase doors either on the block or on the oil sump, but these are usually rather narrow and difficult to work through.

Overhaul or repair of bearings with the engine on board is hardly recommended for auto engines. They have lead bronze bearings and hardened crankshaft journals, and in the case of bearing seizure the source of failure and the amount of damage to shaft and the other bearings is usually such that the engine should be treated in a proper workshop. The moving parts are also highly loaded and require an exactness and cleanliness in their fitting that can seldom be guaranteed on board. The bearing cap bolts must, for instance, be tightened with a torque wrench or by measuring the elongation, which is difficult to do in the cramped space on board.

Another class of engine which has recently been developed is the auxiliary engine for sailing boats. These

have one or two cylinders and a power of about 10 to 20 hp. They are rather high revving and are largely based on automotive practice but their dimensions and equipment are dictated by their marine use. Naturally, a sailing yacht engine must be very compact to enable it to be hidden below the deck. Their lower half and mounting feet are also designed to permit installation far aft and in a narrow space, that is, conditions very similar to those in a small fishing boat. It seems that this type of engine deserves more interest from the designers of smaller fishing craft.

PETROL ENGINES

Because of the low weight and small dimensions the petrol engine is the natural choice for an outboard motor, which in turn might lend itself better to adoption in existing small fishing boats than the inboard engine. There seems to be a demand for a diesel outboard motor, but as far as is known there is only one such on the market. This is natural, for the overwhelming number of outboard motor customers are the pleasure boat owners and for this application, low weight and silent, smooth running is much more important than low consumption and cheap fuel.

For inboard installations in fishing boats the petrol engine can seldom compete with the modern diesel. Its main advantages are low weight, little noise and vibration, but none of these is any great problem in a low-powered fishing boat. It is sometimes argued that handling and maintenance are understood and learned more easily by people used to motor car engines. However, in coastal areas ripe for mechanization of fishing craft the vehicles with which mechanics and workshops first come in contact are usually commercial vehicles which are fitted with diesel engines more often than not.

One advantage of the petrol engine is that it can be stripped down to its smallest part and reassembled without a clean workshop being available. The injection pump and injectors of a diesel, on the other hand, require the utmost cleanliness and care due to their small clearances and passages which are not found anywhere in the petrol engine or its systems.

Another advantage of the petrol engine is that it is easier to start by hand cranking due to its lower compression ratio.

It is cheaper in first cost, which is, however, outweighed after some time of operation by its higher consumption and fuel cost

The fire risk is higher. This can efficiently be kept under control by proper installations and restriction on the use of open fire and smoking on board. However, such conditions certainly do not prevail in primitive fishing boats.

A great drawback of the petrol engine in small open boats is the ignition system which is sensitive to moisture, dampness and water spray.

There are very few inboard petrol engines being built today as pure marine engines. Most of the available types are marinized automotive engines. From a maintenance point of view they must be treated like the high-speed diesels.

ENGINE BEARERS

The purpose of the engine bearers is to support and distribute the engine weight and the stresses set up by thrust, torque and vibration to such a proportion of the hull structure that there is no risk of excessive distortion or damage even when running at full power in a heavy sea. The classic type of marine engine was supported by surfaces along the sides of the bedplate running the whole length of the engine and resting against the top surface of the engine bearers. These were made to fit the support surfaces of the engine.

Modern engines usually have no such support surfaces but the weight is taken by four or six feet. This allows more freedom in the shape of the bearers, which have to be built up only to meet the feet. However, they must still be solid enough to distribute the load from the engine. They must extend for a considerable distance fore and aft of the engine and should be connected to the longitudinal bottom hull stringers. This is of particular importance in the aft part, for flexing of this part of the bottom can upset the shaft line and cause bending stresses in the shaft, couplings and gearbox. The bearers should not end too abruptly. A discontinuity in the strength can give rise to stress concentrations.

For the design of the bearers it is important to study

Transverse piece
of round iron
inserted in holes
in bearer
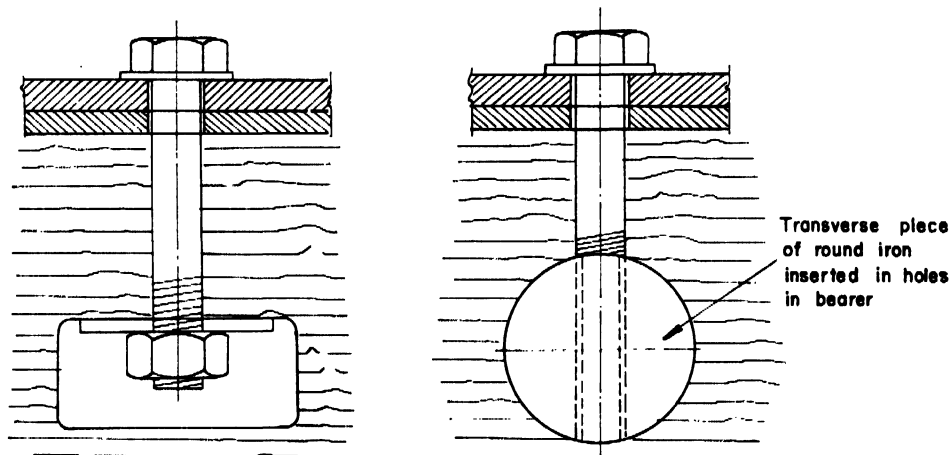
Fig 2. Alternative arrangements of engine holding down bolts in wooden bearers

the bottom half of the engine. Many modern engines have their starter motors, generators, oil filters and other parts placed rather low. It must be ascertained that all such parts are accessible for maintenance and not blocked by the engine bearers.

The same care must be applied to the gearbox. Oil coolers and oil pumps are sometimes placed low in the oil sump and require space for withdrawal in case of failure.

So-called "french screws" or "coach screws" should not be used for the engine mounting as these have to be unscrewed from the wood bearers each time the engine is lifted out of the boat. It might have been acceptable with the old-type engines where at least the bedplate spent its whole life mounted on board. Instead, the holding down bolts should be through-bolts or possibly french screws with their heads sawn off and threaded top ends (fig 2).

Under the engine feet there should be generous metal pads to prevent the feet from being pressed into the wood surface.

It is a great advantage if the engine feet are adjustable. Especially if the engine is placed far aft, it is preferable if the aft feet can be placed higher than the front ones. Otherwise the bearers might be of dangerously low section in the aft critical part. Adjustable feet can also greatly facilitate the lining up of the engine.

Another way of saving time of lining up is to use wedge-shaped rectangular washers under the feet with oblong holes (fig 3).
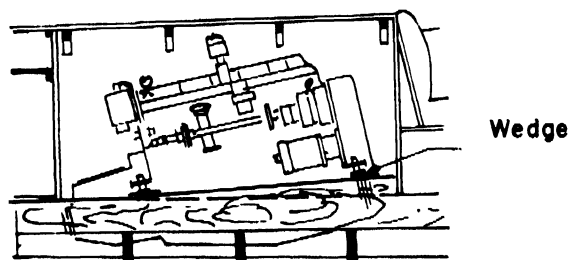
Fig 3. Wedged inserts under holding down bolts can facilitate alignment

REVERSE GEAR

If the boat has a fixed pitch propeller the engine must be fitted with a reverse gear. This contains two clutches: one for forward, one for stern drive. Several types of clutches are used: conical with or without linings, multiplate or brake band types. A common fault with many gearboxes is that one of the clutches does not disengage completely with the lever in neutral. The result is that the propeller turns a little. This can be accepted in a pleasure boat but can often be a nuisance in a fishing boat during handling of nets and lines.

Mechanical reverse gears have a manual adjustment to compensate the linkage for the wear of the clutches. It is important that instructions are given on how to make this adjustment, for in many cases the mechanism is so designed that increased wear results in a rapid increase of clutch pressure. This in turn increases the risk of clutch slip, which increases the rate of wear, etc. Clutch

slip also gives rise to friction heat with risk of distortion and damage to clutch plates.

In gearboxes of more advanced design the clutches are compressed by oil pressure delivered by a separate oil pump. No adjustment is needed in this case.

The reverse gear train is often of planetary type, either with helical or conical gears. In the "twin disc" system there are two separate gear trains for ahead and astern, both in constant mesh and connected to the drive shaft via two separate clutches. This type of reverse gear is usually made with a reduction in each gear train. In the aforementioned type the reduction gear is mechanically separate, even if it is flanged to the reverse gearbox.

The gearbox is often lubricated by the engine system, which has the advantage that only one oil level has to be checked and that no separate oil pump is needed. It means, however, that the gearbox is fed with oil contaminated by carbon from the combustion and that the engine is lubricated with oil which might contain abrasives from the wear of the gearbox clutches.

A separate oil system for the gearbox is to be preferred also for the reason that a proper grade and quality of oil can be selected for the gearbox, differently from the engine.

REDUCTION GEAR

The best propeller efficiency is obtained at a shaftspeed which does not necessarily coincide with the crank shaft speed of the engine. It is usually lower. It is not always possible, or even advisable, to design for maximum propeller efficiency. Limitations of draught can, for instance, favour a smaller, fast-running propeller with a sacrifice in efficiency. But in many cases a reduction gear is needed to enable an acceptable combination of engine and propeller speed.

The reduction gear can be incorporated in the reverse gear or it can be flanged to its housing. In a few cases it is separate from the engine and reverse gear. The most usual design has only two helical gears but planetary reduction gears can be built smaller and lighter, especially for higher reduction ratios.

The efficiency of the reduction gear can be of the order of 95 to 98 per cent, that is, a loss of 2 to 5 per cent of the engine power has to be taken into account. Contrary to the loss in a reverse gear this is continuous, and the corresponding heat loss must usually be taken care of by an oil cooler incorporated in the sump or separately mounted.

SHAFT LINE

The propeller shaft can be made of steel or bronze, but in modern motor yachts, where a small diameter and long life is essential, the shaft is generally of either stainless steel or monel. Monel is a bronze alloy with a high nickel content, which is very resistant to salt-water corrosion and fatigue stresses.

In pleasure craft, the shaft is nowadays almost invariably carried in rubber bearings. These have proved to have a long life and abrasive dirt is either flushed through or bedded in without harming the shaft journal. Thanks to their resilience, a small inaccuracy in lining up can also be tolerated.

The rubber bearings are water-lubricated, and it is important that the water supply is generous. Water scoops are a good help and their resistance is no problem in a slow vessel. A worn rubber bush cannot, of course, be repaired but must be replaced. In remote areas the old-type white metal lined bronze bush might have the advantage of being repairable with local means without a spare part supply.

A stuffing box is fitted to the front end of the stern pipe. There are several types of very efficient rubber seals but all have the disadvantage that the shaft has to be dismounted and withdrawn if the rubber seal must be replaced. For practical reasons the old type of seal with packing material of greased yarn compressed by a gland nut is preferred.

In modern yachts it is common practice not to attach the stuffing box directly to the stern pipe, but to connect it via a piece of flexible rubber hose with hose clamps (fig 4). This ensures that the stuffing box is
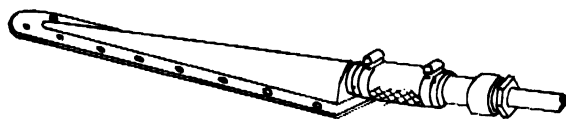
Fig 4. Stern tube with flexibly mounted stuffing box

concentric with the shaft even if the lining up is not absolutely perfect and also that the box follows the movements of the shaft. In such installations where the engine is flexibly mounted, a directly-coupled propeller shaft can be accepted, although the layout is theoretically wrong, providing the stuffing box is sufficiently free to move. Watertightness depends on the tightness of the rubber hose. It is thus essential that the hose is a close fit, that it enters over the pipe a distance at least its diameter and that the hose clamps are double, of first-class quality and well tightened.

The propeller thrust is usually taken up by a thrust bearing in the gearbox of a solidly mounted engine. In a theoretically correct elastic mounting the engine must be "fully-floating". This means that there must be an intermediate cardan shaft with two couplings, either rubber couplings or universal joints. Some plants actually run with the universal joints transmitting the propeller thrust. This is the case in a class of Swedish Coast Guard transport ships (3 × 210 hp) but the normal arrangement is to use a separate thrust bearing and fit a spline on the cardan shaft. This is the ideal solution but unfortunately it is also the most expensive and takes up much valuable longitudinal space.

Even if the engine is solidly mounted, as is generally the case in a fishing boat, a flexible coupling on the output shaft is of value, preferably one which can take axial loads. A rubber coupling can take a certain amount of angularity and also some misalignment. The manufacturer usually claims permissible values.

EXHAUST SYSTEM

The exhaust manifold on the engine and the exhaust pipe cannot benefit from any air flow cooling such as in a motor-car installation. In a boat they must be cooled with water. An important part of the marinizing of an automotive engine is therefore the replacement of the standard exhaust manifold with a water-jacketed manifold, usually of cast iron. Some marine engines have exhaust manifolds of cast aluminium. This can give rise to trouble and leakage on longer units because of the difference in heat deformation of the aluminium manifold and the cast iron cylinder head. If the short pipes between exhaust ports and manifold are not water-cooled they should be lagged with asbestos.

The exhaust pipe can be of the "dry" or "wet" type. A dry exhaust system is water-jacketed and cooled by the cooling water leaving the engine and passing in the jacket between the inner and outer pipe. Unless self-draining, the jacket must have a drain cock at the lowest point.

In a wet system the cooling water is injected in the exhaust pipe and cools the exhaust gases directly. It should be noted that the vaporizing of the water might expand more than the contraction of the cooled exhaust gas, so that a certain back pressure can be expected. However, the system is cheaper, simpler and at the same time has a good silencing effect. For these reasons it is more common than the dry system.

The injection of the water into the pipe must take place at a point where it is absolutely safe from being sucked backwards into the engine. The first part of the pipe is water-jacketed and the water injection is arranged after a downwards bend of the pipe.

The exhaust pipes are made of stainless steel or galvanized steel. Petrol engines can have pipes of copper, but for diesel the copper can become corroded by the sulphur content of the exhaust gases, especially with a wet system.

If the engine is flexibly mounted the exhaust pipe must also have a flexible connection, made of a heat-resistant hose or twin bellows. This part is uncooled and must be insulated with asbestos.

A modern system is to make the whole pipe of rubber hose, which works well if the water spray in the hose is sufficient.

There must be ample clearance all around the exhaust pipe so that no inflammable material can catch fire or get overheated by radiation.

LUBRICATION SYSTEM

It has often been claimed that a true marine engine must have a dry sump lubrication system (fig 5). This means
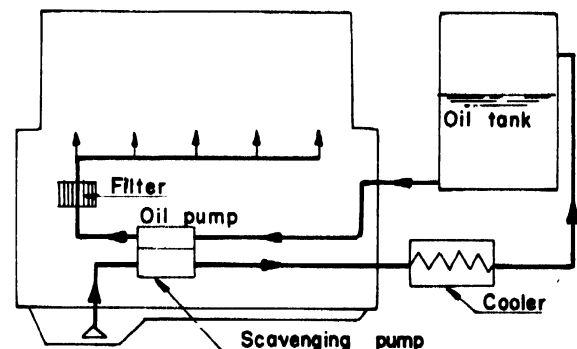
Fig 5. Dry sump lubricating system

that there is a separate oil tank and that the engine is fitted with two pumps: a pressure pump to feed oil from the tank to the lubrication system, and a scavenge pump to suck the oil from the sump and back to the tank. The scavenge pump must have slightly larger capacity to ensure that the sump is not overfilled. In practice it will pump oil, plus a certain quantity of air, which is then separated in the tank. On its way back from the engine the oil may have to pass an oil cooler.

The dry sump system is used on most larger marine engines. The wet sump system is used on most small engines and all automotive engines, even in their marinized versions (fig 6). In this case the oil sump is also the
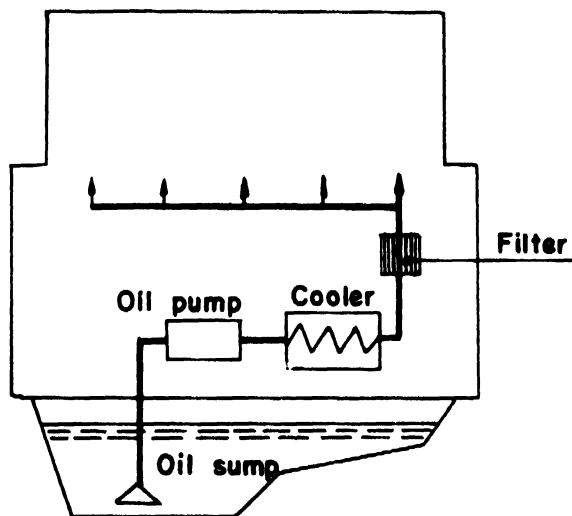
Fig 6. Wet sump lubricating system

oil tank and there is only one pump sucking oil from the bottom of the sump to the lubrication system. The oil cooler, if any, is placed in the feed line from the pump, not on the return side as in the dry sump system.

One advantage claimed for the dry sump system is that there is less risk of air introduction through movements and rolling in a seaway. Another advantage is that the oil sump is less bulky, so that the engine can be more easily accommodated in the boat.

In practice, the risk of the oil splashing in the wet sump and of aeration of the oil is not very great. Regarding space requirements, usually the fly-wheel is the lowest part and governs the position of the engine on board. The wet sump system works well but when an automotive engine is marinized it should be noted that it must often be inclined up to 5° to 15°. In some cases the sump must be redesigned, the suction pipe repositioned from the pump to the lowest part and the oil dipstick re-marked to compensate for this. An oil cooler might have to be introduced because the sump is not cooled by the air flow as in a motor-car.

In an automotive installation the oil is easily drained directly from the oil plug into a well or tank. In a boat the oil plug is very inaccessible, and even if there is a tray under the engine, this is seldom large enough to permit drainage of the whole oil quantity in the boat. Also from a fire risk point of view, it is not recommendable to

drain the oil down into the bilge or into the engine tray. For this reason a marine engine must be fitted with a separate hand-operated drain pump. If the reverse gear has a separate oil sump the drain pump can also be connected to this with three-way cocks, or it can be fitted with a separate drain pump on larger units.

The crankcase is usually fitted with a funnel or trunk to ventilate the oil fumes. In a marine installation where the engine is placed in a manned engine room or inside a cabin these fumes can be very unpleasant, especially if the engine is worn so that combustion gases and pressure can blow past the pistons. To prevent this the funnel can be connected to the air intake, so that the crankcase is kept under a certain vacuum and excess oil fumes are drawn into the intake air. For supercharged engines this system is not readily adaptable as most manufacturers of superchargers are anxious to get as clean air as possible to their impellers, and indeed deposits on the impeller vanes can have a very bad effect on their efficiency.

COOLING SYSTEM

The cooling of a marine engine might at first sight seem very simple since there is the whole sea full of water for cooling. In fact there are several factors which complicate matters considerably.

At high speed a suitably formed scoop might be all that is needed to feed sea water to the cooling system, but with the exception of pure racing boats a marine installation needs a pump (fig 7). Many types of pumps
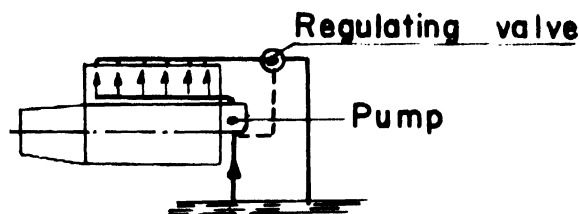
Fig 7. Salt-water cooling

are found on marine engines but most have their different limitations. The piston pump is the classic type, which has the advantage on a reversible engine that it works in both directions of rotation. However, it is rather heavy and clumsy and its valves need a great deal of attention in order not to become inoperative due to corrosion, sand, weed or dirt.

The gear-type pump has also been very common. It is simple and has no moving parts other than two gear wheels with a coarse pitch. However, grit and sand can cause rapid wear of gears and housing and its capacity is dependent on a tight fit between these. A rubber coating on the gear wheels can increase their life but a separate drive gear train between the wheels is then needed, whereby its simplicity is lost.

The centrifugal pump is simple and reliable but its capacity is often found to be too dependent on the engine speed of operation as the delivered pressure varies with the square of the impeller tip speed. A positive displacement pump is generally preferred.

Among these it seems that the vane type with a flexible rubber impeller has captured the market in the last ten years for small and medium-size marine engines. The radial vanes deflect against a half-moon-shaped cam in the housing, and once a suitable material for the impeller was found it seemed that this type of pump met the demand very well. It has been widely employed both as salt-water pump and bilge pump. It must always run wet. Dry friction will cause rapid wear of the impeller. To eliminate this risk with a bilge pump it is fitted with a clutch and it is advisable to blend a continuous small water flow into it from the water-cooling system. A worn impeller can easily be replaced, but here again is an item dependent on a proper spare part supply and which cannot be repaired with local resources.

On the intake side of the salt-water system there should be a strainer so arranged that it can be removed and cleaned with the boat afloat when the sea-water cock is closed. Still better is a twin system to permit cleaning of one strainer with the other in operation.

The water temperature is regulated by hand or thermostat. A temperature as high as 165° to 175° F (75° to 80° C) is aimed at as this has a very beneficial effect in keeping cylinder wear down. The hand cock or thermostat is so arranged that a varying proportion of the water is by-passed to the outlet side. A thermostat in the sea-water system will be corroded rather soon and must often be replaced but the mass-produced types are very cheap (fig 8).
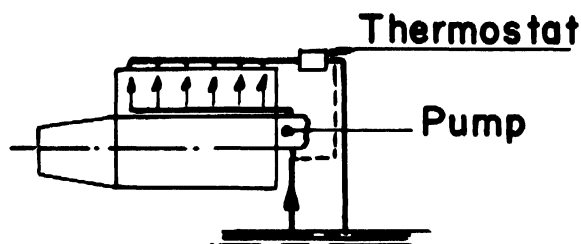
Fig 8. Salt-water cooling with thermostat

The direct sea-water cooling system will cause corrosion in the cylinder block and head. On heavier engines where the dimensions are generous this is accepted. The unfortunate thing is that the rate of corrosion increases with the water temperature which should be kept high to diminish cylinder wear.

This problem is eliminated by using indirect cooling, which has gained ground more and more, first on the automotive types with their thinner cylinder walls, but also on other types. The salt water is led through a heat exchanger to cool the circulating fresh water. The design of the freshwater pump and the thermostat can be taken over directly from the corresponding automotive engine and will seldom give any trouble (fig 9). Most manufacturers of small engines have preferred to mount the heat exchanger directly on the engine, combined with a header tank. This facilitates the installation of the engine and ensures that the layout and execution of the cooling system is kept under control by the manufacturer. The system usually works well but the design of the heat exchanger must be rather compact to allow accommodation on the engine. This often leads to
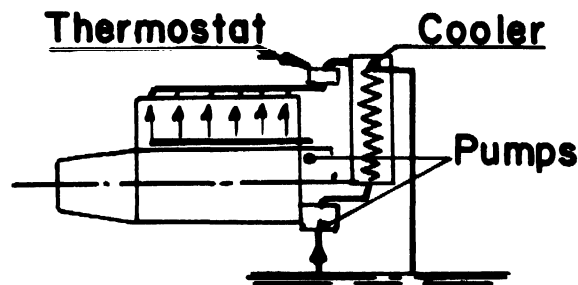
Fig 9. Freshwater cooling

cooling elements with narrow passages, which can be clogged and are difficult or impossible to clean. If the boat is expected to operate in dirty water, in rivers for instance, it may therefore be better to accept a larger heat exchanger with wide and straight tubes. This must then often be mounted separately, preferably below the floors.

A very simple form of indirect cooling is the keel cooler. In this case the heat exchanger consists of a pipe or a bundle of pipes placed on the outside of the boat bottom. The fresh water circulates through the pipes and is cooled directly by the water flowing around them. One disadvantage is that the outboard cooler is exposed to mechanical damage in case of grounding or beaching or hitting a floating object. Engine manufacturers have been rather sceptical about the outboard cooling system for this reason and also because the design and execution is entirely in the hands of the local boatbuilder, often too far from their control.

Even with a freshwater cooling system a certain corrosion can occur in the engine. Manufacturers sometimes recommend the use of rain water, but a very simple and good method is to add a small percentage of soluble oil to the water system.

FUEL SYSTEM AND TANK INSTALLATION

The quality of the fuel system is of utmost importance in a marine installation. Many engine failures and even catastrophes can be traced to a faulty or badly maintained fuel system. A leaking fuel system means a potential fire risk, which is one of the worst dangers on board.

In one litre of fuel there is more energy stored than in half a ton of dynamite, but still there is little danger so long as the fuel is kept in the tank and in the system, because it has no contact with oxygen. The important thing is to prevent it from leaking.

Welded steel is used for the tank. Copper is not recommended because of the sulphur content of the fuel. The tanks should be tested with a hydraulic pressure to check the tightness. It is a good rule to avoid flat plates as much as possible, as these are more prone to vibration and cracks.

The filler cap must be so placed that excess fuel is discharged overboard and not into the boat if the tank is overfilled by accident during refuelling. The filling funnel should end above deck, never below deck, for during filling the fuel vapours will otherwise flow out of the mouth and down into the bilge. Fuel vapour is heavier than air.

To facilitate the discharge of fuel vapours there should be a vent pipe from the tank to the boat's side.

Rules for the dimensioning and design are found in the recommendations of several organizations; for instance, the Swedish Boatyard Association.

It should be possible to remove the tank completely for repair or cleaning without having to cut out a piece of the deck or superstructure.

The fuel pipe should be led from the bottom of the tank up through its top. This is the safest system. If the line is taken down from the lowest part of the tank there must be a good quality cock valve directly fitted to the tank. A dished sludge trap with a drain plug should be arranged below the fuel pipe and in the tank bottom.

The pipes must be well clamped to prevent vibration. It is recommended to fit rubber between the clamp and the copper pipe to eliminate the risk of wear and corrosion in the pipe. The part closest to the engine should be flexible, either with a bend or a hose. The hose should be of synthetic rubber, not of plastic which can age and lose its elasticity

A fuel filter should be fitted in the line. It is always good to have a double system so that one filter can be cleaned without stopping the engine. Most diesels have such a twin filter either fitted on the engine or as part of the delivery.

FIRE EXTINGUISHING SYSTEM

Considering the often catastrophic effect of a fire on board it is surprising how many boats are running without any fire-extinguishing equipment or with defective equipment. Assistance is usually distant, and in practically all cases one is left to do what one can to save ship and life with the resources on board. In case of a fire in the fuel there is little to be done with water. It might just make things worse by spreading the fire.

The risk of fire is diminished first by a well laid out and well executed fuel tank and electrical installation. It is also important to keep the installation in order, to check the systems regularly, look for leaks, loose contacts, worn insulation and other defects.

Open fire must also be used with great care. Many disasters have occurred and many lives have been lost because careless smokers throw burning matches, glowing ashes and tobacco around.

In case of a fire it is important to act quickly and to have something to act with. A main rule is to prevent air access. A piece of canvas, a blanket or even a cap or jacket thrown over the fire might be of good help, and better still if it is first soaked in water.

A portable fire extinguisher should be placed close to the helmsman and one in the engine room if it is manned. The portable extinguishers are of short duration as they must be light, so it is good to have several.

In larger boats there should also be a fixed system of carbon dioxide bottles which can be discharged in the engine room and the tank room by pulling a handle at the helm. Before this is done the engine room must be evacuated and the hatches should be closed to prevent air access.

It can also be of benefit if the fuel cocks can be shut off remotely from the bridge by pulling a handle so that no fuel can leak out and make the fire worse. This is seldom seen on yachts or fishing boats, but such a system is used on the fast motor torpedo boats of the Swedish Navy.

AUXILIARY MACHINERY

In larger fishing craft fitted with a trawl winch, this is often driven by the engine via a front power take-off. The classic system consisted simply of a flat belt pulley on the front end of the crankshaft driving another pulley on the trawl winch shaft. It was brought into action by tensioning the flat belt with the aid of a movable jockey-pulley.

This simple system unfortunately does not fit well on modern engines and is now being superseded by more refined systems. The modern engines run too fast to permit a direct belt drive. The multi-cylinder engines also require great attention to the problem of torsional vibration, with the result that an elastic coupling might have to be introduced in the transmission. In some automotive engines the front end of the crankshaft is not at all designed for a power take-off.

The clutch, reduction gear and elastic coupling all add to the installed length of the plant, so that a certain design effort must be made to make the layout as short as possible.
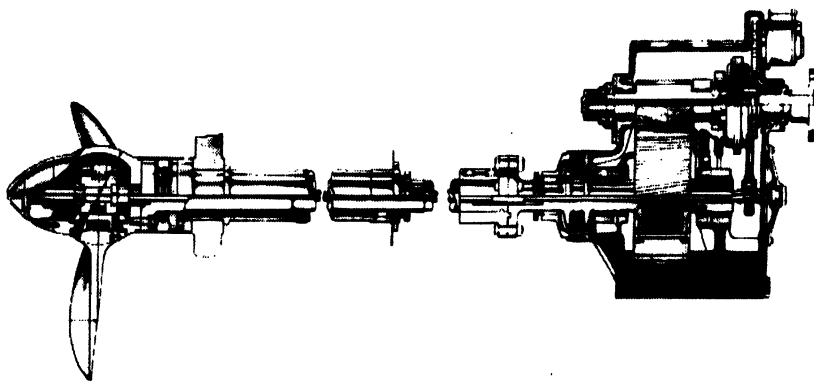
Fig 10. A compact combination of oil operated clutch, reduction gear, controllable pitch propeller control mechanism and thrust block.

TABLE 2

Transmission	Component Cost	Installation Cost	Operating Cost	Maintenance Cost	Weight	Control	Safety
Mechanical	1	3	2	4	2	4	4
Electric	4	4	1	3	4	1	3
Pneumatic	2	1	4	2	3	3	2
Hydraulic	3	2	3	1	1	2	1

power hoist, topping lift and vangs for handling the pots.

While not strictly deck machinery, the pumps that sardine and herring seiners frequently have for transferring the catch from purse seine to boat and from boat to processing plant, serve the same function as winches and brailing nets.

One deck machine not listed in table 1, but carried on almost all fishing boats, is an anchor windlass, now generally power-driven on larger boats.

POWER FOR DECK MACHINERY

Power to drive deck machinery can be supplied by either the propulsion or auxiliary engines. In vessels of less than 100 GT the power source is generally the propulsion engine.

The main types of transmission are:

- Mechanical
- Electrical
- Pneumatic
- Hydraulic

Each has advantages and shortcomings with respect to cost, weight, control precision, safety and maintenance. Table 2 gives an estimated relative comparison of those systems, 1 being the most and 4 the least advantageous. This comparison is not absolute but it does indicate a favourable position for hydraulic drives.

HYDRAULIC TRANSMISSION
Systems

Hydraulic systems and equipment applied to fishing vessels are adaptations from other industries. Lerch (1964) describes the two basic hydraulic systems, that is, the closed loop, sometimes called "hydrostatic", and the open loop. These systems are discussed below in general terms. The symbols used in the accompanying diagrams are the so-called JIC (US Joint Industry Conference) symbols (Lerch, 1964).

Closed loop system

The usual characteristic of the closed loop system (fig 1) is one pump and one motor in a circuit, where the pump discharge goes directly to the motor inlet and the motor outlet returns directly to the pump suction. It is possible for one pump to supply oil to several motors and cylinders in series, but all would have a common speed depending on the displacement of the pump. The pump has a variable displacement which controls both speed and direction of motor rotation.

This system was developed to provide alternatively rapid movement and precise control of large guns, both in coast defence and on warships. The system provided variable speed and load, using constant speed electric motors for prime movers. This eliminated the need for frequent starts of these motors whose size and number

Fig 1. Typical closed loop circuit
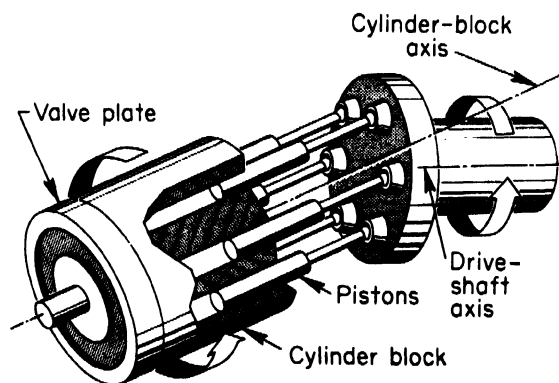
Fig 2. Schematic arrangement of axial type piston pump or motor

with each gun or turret was such to tax the power supply with high starting currents.

The military requirement of compact size for the amount of power transmitted caused the development of high pressure systems, generally about 3,000 lb/in² (211 kg/cm²).

A variation of the system is used in electro-hydraulic steering gears of larger ships, where rams replace the motor in the closed loop.

The high pressure of the usual closed loop system requires the use of piston-type machines. Fig 2 and 3 show schematically two common piston devices which can be either pumps or motors. In fig 2 as both the cylinder block and the drive shaft rotate together, the pistons move in and out of their cylinders. Ports in the
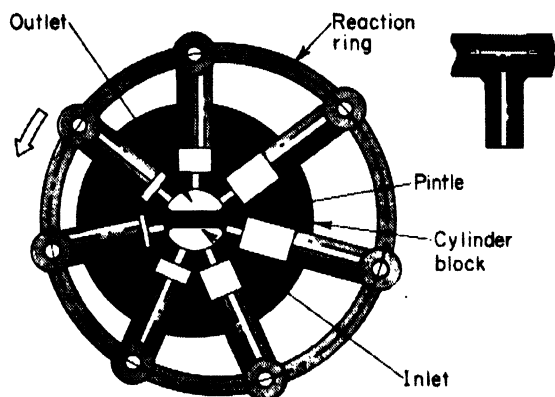
Fig 3. Schematic arrangement of radial type piston pump or motor

valve plate admit fluid while the pistons move outward and discharge fluid while the pistons move inward. In fig 3, similar functions are performed as the cylinder block rotates and the pistons are guided by the reaction ring placed eccentrically with respect to the drive shaft. Where these devices are used as pumps, their displacement is varied respectively by changing the angle between the drive shaft axis and the axis of the cylinder barrel, and changing the eccentricity of the rotating pump body relative to the circular reaction ring.

A common feature of the high pressure piston equipment is that they are designed for positive pressure only in the cylinders. Vacuum tends to collapse the springs holding the pistons against the wobble plate or reaction ring so that running any length of time with a vacuum will destroy the equipment. This restricts the closed loop system with piston equipment to machinery where large overhauling forces will not occur which can generate a vacuum in either pump or motor. The circuit usually is fitted with a constant displacement supercharging pump of small capacity to make up leakage and to maintain a positive pressure on the suction side of the main pump and on the motor when it is overhauled.

Fig 1 shows also the supercharging pump and circuit combined with a relief valve circuit which relieves or

"cushions" inertia pressures introduced to the circuit when starting and stopping heavy motor loads.

Some vane-type, variable displacement pumps are on the market which can be used effectively in closed loop systems with the same degree of control possible with piston-type pumps. However, since this type of pump is not internally balanced hydrostatically as are most vane pumps, which will be discussed later, the system pressure must be low, generally below about 1,000 lb/in² (70 kg/cm²) to avoid excessive wear.

The closed loop system has limited application to fishing vessels under 100 GT. Most piston equipment is designed to transmit powers greater than necessary for the deck machinery on these boats. Also the precision required for this type of equipment makes the cost prohibitive. The requirements for a pump for each hydraulically powered deck machine increase the cost over a system where one pump can supply several motors.

Open loop systems

The characteristic of the open loop is that a pump takes oil from a tank at atmospheric pressure and raises it to some operating pressure for delivery to one or more motors or cylinders. The oil leaving the motors or cylinders returns to the tank, again at atmospheric pressure. Two basic loops can be used, one at constant pressure and the other at constant volume.

In the constant pressure loop, the pump delivers oil to a header whose pressure is controlled by a regulator. The motors and cylinders receive oil from the header through control valves and flow regulators to control their direction and speed. The simplest circuit arrangement, fig 4a, has a constant displacement pump with a relief valve to control pressure. For illustration, this circuit includes three driven devices: (1) a motor requiring direction control, but no speed control, (2) a cylinder with speed regulation, and subject to overhauling forces, and (3) a motor with one direction rotation having speed adjustment, but not subject to overhauling. Note that the speed regulating controls are shown in series with the motor and cylinder. Where overhauling is a problem, the pressure compensated flow control valve is in the return branch so the pressure in the cylinder (or motor) is always positive, thereby eliminating air leakage into the circuit through shaft seals, and reducing the risk of cavitation in the hydraulic fluid. If overhauling is not a problem, the flow control can be placed in either the supply or the return line with equal effect. While not shown in fig 4, by-pass speed controls, discussed below with the constant volume loop, could be used but only if located between the direction control valve and the motor. Another feature, not shown but perhaps necessary where driving a high inertia load, is a cushion valve similar to that in fig 1 located between the direction valve and the motor (or cylinder).

Since the pump shown in fig 4a must always deliver its volume at rated pressure even when no motors are running, it wastes power. The sudden drop in pressure through the relief valve converts the pressure energy into heat which is lost to the system. Two refinements can improve the efficiency by reducing the energy loss when

4a - SINGLE FIXED
DISPLACEMENT PUMP

4b - DOUBLE FIXED
DISPLACEMENT PUMPS

4c - VARIABLE DISPLACEMENT
PUMP, PRESSURE
CONTROLLED SERVO
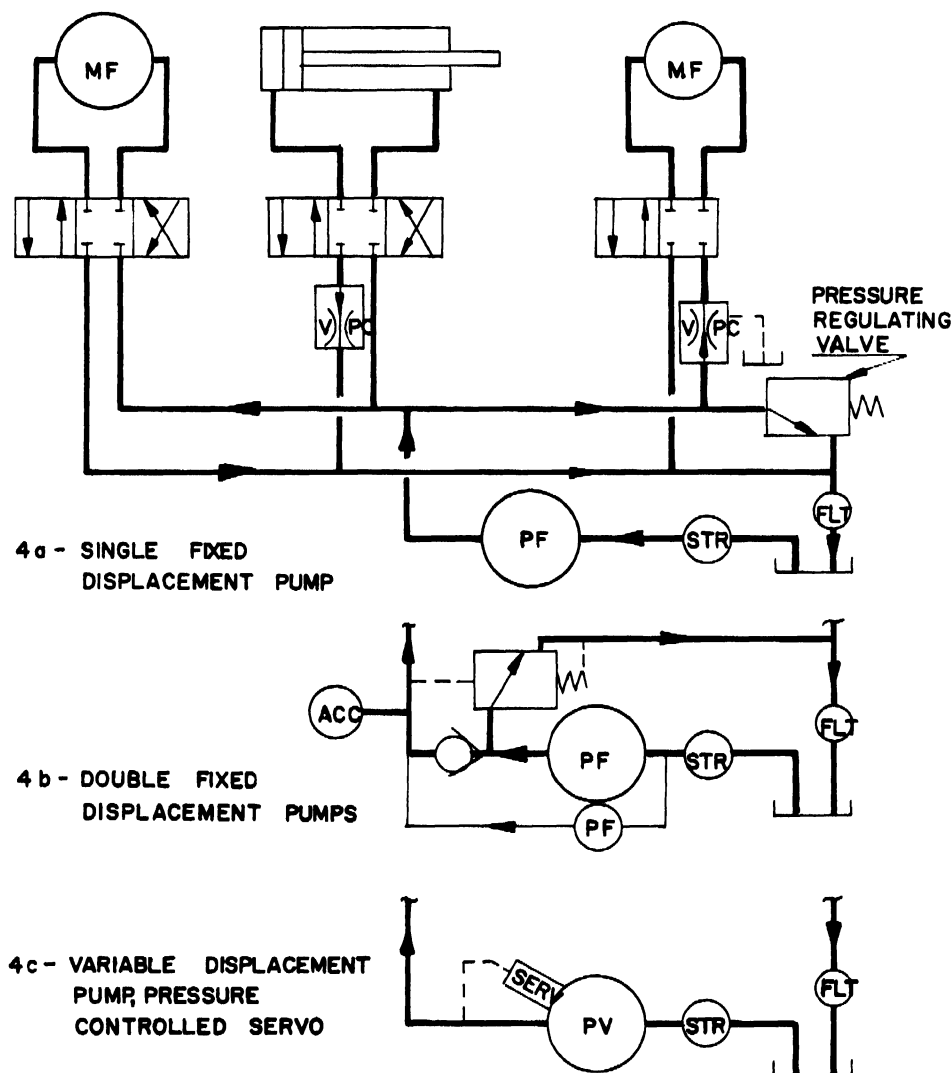
Fig 4. Typical open loop, constant pressure circuit

motors are not running. Fig 4b shows the constant pressure loop supplied by two pumps, one larger than the other. At zero and small demands, the small pump maintains pressure and the large pump circulates oil with small pressure change. The only losses at zero demand are friction in the larger pump and those from the pressure drop of smaller pump flow. The second refinement shown in fig 4c is to use a variable displacement pump similar to that used with a closed loop system, with its displacement controlled by the header pressure. Thus at zero demand, the pump stroke provides only enough flow to accommodate system leakage and, as demand increases, displacement and flow increase to maintain constant system pressure.

Fig 5 shows a typical constant volume loop, also called an open centre series loop. The pump circulates all the oil through the control valves in series. At zero power demand, the only energy loss is the pump and fluid friction in the system as the pump develops only the pressure required to circulate the oil. As one or more control valves are moved to require power, the pump develops

only that additional pressure necessary to overcome the load on the driven machine.

Since all the pump flow must circulate through the system at all times, various schemes can be provided to control motor speed where a motor displacement is less than the pump displacement, and to regulate individual motor speed over a large range. Fig 5 also shows several of these schemes as they might be applied to the constant volume loop, although in normal practice fewer devices would be connected in one loop.

The various typical drives perform as described below. For sake of illustration, all drives are shown as reversing motors, although the control of cylinders is similar. Also, for simplicity, no cushion valves are shown whereas these would be required in services with large inertia loads or in circuits with large oil flow.

(a) This motor is connected simply for reversing with constant speed in each direction, and represents the vast majority of installations appropriate for fishing boats.

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BRAKE VALVE

D.

C.

B.

A.

E.

F.

G.

THROTTLING
VALVE

MF

PF

FLT

STR
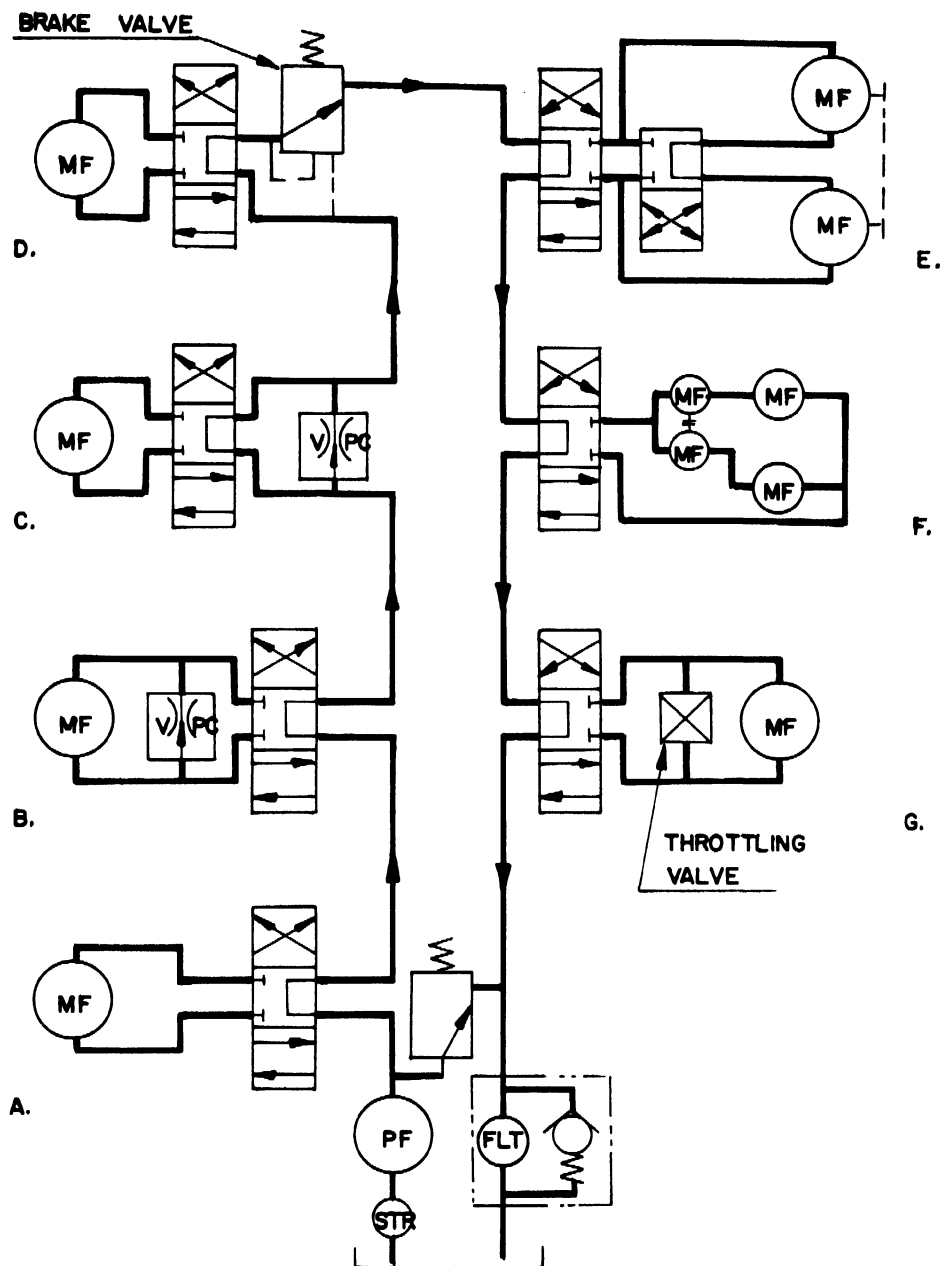
Fig 5. Typical open loop, constant volume circuit
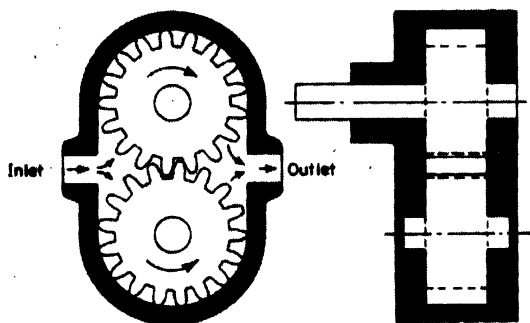
Fig 6. Schematic arrangement of external gear pump or motor
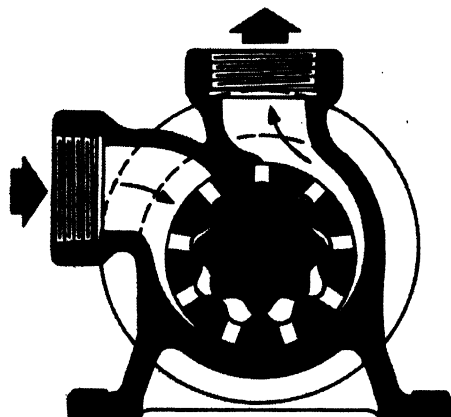
Fig 7. Schematic arrangement of internal gear pump or motor

[359]

(b) The addition of a pressure compensated adjustable flow control valve in parallel with the motor, between it and the reversing valve, by-passes a fixed amount of oil with one valve position but not with the other. Thus an adjustable reduced motor speed occurs in one direction but full speed in the other.

(c) The flow control valve in the position shown regulates motor speed below maximum rpm in both directions of rotation.

(d) The motor speed and direction control is essentially the same as (a). In normal operation, the counterbalance and brake valve is held open by the supply pressure in the external pilot. Pressure required to open the valve is about ⅕ that required by the internal pilot. In the event that a load overhauls the motor so that loop pressure drops below the pilot setting, the valve tries to close until the direct discharge pressure from the motor can open it. This acts as a brake on the motor and its speed will decrease to that at which the external pilot will again open the brake valve. Ultimately, equilibrium occurs whereby the motor will accept the overhauling load at a speed proportional to the load's magnitude.

As shown, the valve acts as a brake for both directions of motor rotation.

If braking in one direction only is required, the brake valve can be located between the direction control valve and the motor.

(e) This is a two-speed arrangement where two identical motors, mechanically connected, drive a common load. An additional valve directs the flow so the motors are in series, as shown, for full speed, and in parallel for half speed. Fig 10 shows a motor where the circuit can be changed from series to parallel internally.

(f) Here two separate motors are controlled together, so that they can drive separate machines at proportional speeds irrespective of the load imposed on either one. The added mechanically coupled motors shown, divide the total oil flow into two paths, the volume of each depending on the displacement of the motor through which it passes. If the pressure increases in one path because of the final motor's load, the flow divider becomes a "motor pump" which transfers energy from the unloaded path to the overloaded first path. All the while, both final motors turn at their original proportional speeds.

(g) This control arrangement is a variation of (b) and (c). It adds a simple globe valve to by-pass the motor. Fully opened, the motor does not run. As the valve is closed, the motor speed increases to maximum when the valve is fully closed. This scheme is used to start a motor smoothly and only incidentally to control speed. The arrangements shown in (b) and (c) provide better speed control, as the amount of oil by-passed is constant, irrespective of pressure drop across the motor.

For fishing boat applications, the various open loop hydraulic systems are most advantageous. The equipment used in these systems is generally simple and rugged in construction, and mostly the same as that in general industrial use.
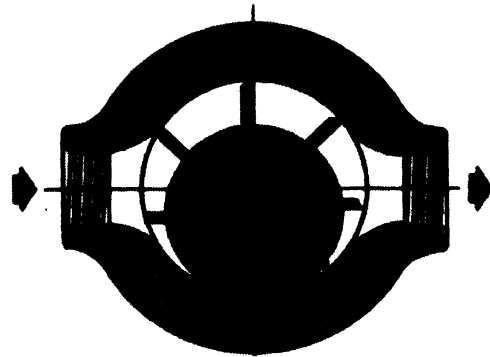
Fig 8. Schematic arrangement of vane pump or motor

Pumps and motors

The normal pumps and motors are positive displacement devices and will operate at pressures up to 2,000 lb/in^2 (140 kg/cm^2). Fig 6 to 9 show schematically the following common devices.

External gear pump, fig 6
Internal gear pump, fig 7
Vane pump with unbalanced rotor, fig 8
Vane pump with balanced rotor, fig 9
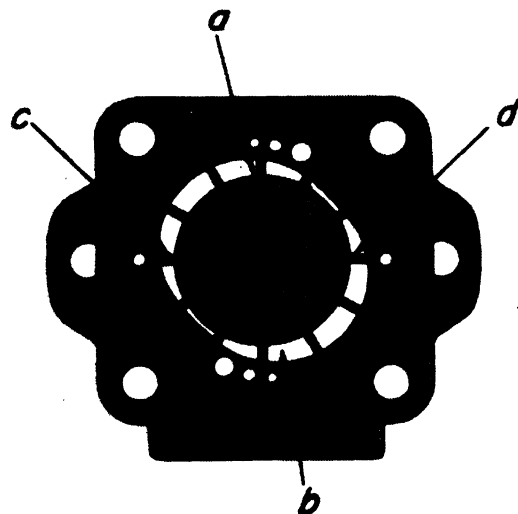
Fig 9. Schematic arrangement of balanced type vane pump or motor

Generally these devices can be used as motors as well as pumps. Their construction permits them to operate with a vacuum occasionally without major damage.

The gear pumps and motors are the simplest, having the least moving parts. However, they are not hydro-statically balanced, which adds to bearing and tooth

friction, and decreased efficiency at the higher pressures. The maximum pressure for good efficiency is about 1,500 lb/in^2 (105 kg/cm^2). The gear devices generate noise because of the abrupt displacement of oil where the gear teeth mesh.

Vane devices, particularly with hydrostatically balanced pumps and motors, have several advantages, despite the complications of more moving parts, in that side thrust is balanced so bearing loads are nominal. In fig 9, fluid enters through ports in the end covers at "a" and "b", and discharges through similar ports at "c" and "d". Most small devices have the ports connected internally so that incoming fluid divides equally and then joins after passing through. A variation of this is shown in fig 10, which is a two-speed, balanced vane-type motor, with self contained direction, speed control and cushion

Fig 11. Three drum trawl and seine winch driven by two-speed motor shown in fig 10

Fig 10. Open view of two-speed balanced vane motor with mounted control valves for series or parallel flow
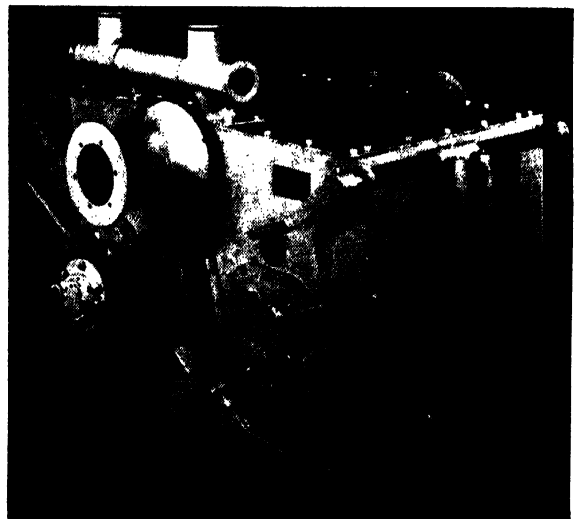
Fig 12. Two drum trawl winch with gypsies for purse seining

valves. Referring again to fig 9, at low speed, the fluid divides and enters ports "a" and "b" simultaneously, and then rejoins after passing through ports "c" and "d". At high speed, all fluid enters port "a", leaves through port "c", re-enters through port "b", and finally leaves through port "d". This motor accomplishes in one unit the circuit shown in fig 5e.

Vane pressure on the body is independent of fluid pressure so that friction and efficiency are nearly constant for a given speed. This feature permits the balanced rotor vane devices to run efficiently at pressures up to about 2,000 lb/in^2 (140 kg/cm^2). Because of the side thrust of the unbalanced rotor vane devices, their maximum operating pressure for best efficiency is limited to about 1,000 lb/in^2 (70 kg/cm^2).

HYDRAULICS FOR SMALL FISHING BOATS
Typical deck machinery
How hydraulics have been applied to some of the deck machinery mentioned earlier is illustrated in fig 11 to 18.

Fig 13. Three drum trawl and seine winch with separate long-line hauler

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Fig 11 shows a typical trawl winch with three drums, two for either the trawl warps or purse lines, and a third for brailing or cargo. In addition, it has two gypsies and a wildcat for the anchor. This winch is driven by a hydraulic motor similar to that shown in fig 10.

Fig 12 shows a winch for a smaller boat, typical of the west coast of North America. This is intended principally for stern trawling, but can be used for purse seining, using the two gypsies shown. Fig 13 is a similar winch, except that it has a third drum and a separately powered longline hauler, making it more versatile for a "combination" boat. Each winch is driven by a single, balanced

and the driven trolling gurdy. A similar arrangement is on the other side of the boat. The propulsion engine drives a single pump to supply the motors.

Fig 18 shows a seine skiff that works with the purse seiner whose winch is shown in fig 14. Note the small power block.

In developed fisheries, the advantages of hydraulically powered deck machinery have been utilized down to the smallest boats, even to seine skiffs with purse seiners. The devices used generally provide enough pulling power to enable one man to do the work of several, or allow him to pull in his fish faster than he can manually.

Fig 14. Purse seine winch

Fig 15. Longline hauler

vane-type hydraulic motor with roller chain speed reducer.

Fig 14 shows a purse winch, using the two gypsies for the purse lines or other duties. The piping in the background is part of the supply, return, and controls for the winch and for the power block this boat also carries.

Fig 15 illustrates a longline hauler and power gypsy used on many Scandinavian fishing boats. It is driven by a slow-speed, direct-drive balanced vane motor mounted in the base.

Fig 16 and 17 show two ways of powering a trolling gurdy. Fig 16 shows a mechanical clutch and drive with belts and counter shaft from the propulsion engine. The speed and direction of the gurdy, both port and starboard, are controlled by the "retired" automotive transmission on the right. Fig 17 shows a gear-type hydraulic motor

Fig 16. Trolling gurdy driven through automotive transmission

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Hydraulic deck machinery for fisheries of developing countries

Deck machinery similar to that described above would be advantageous to fishermen in developing countries. A gypsy, longline hauler, trolling gurdy, or one of various net rollers, capable of pulling about 450 lb (200 kg) at about 100 ft per minute (0.5 m/sec) would greatly improve the fishing efficiency, and hydraulic power offers a convenient driving method.

Fig 17. Trolling gurdy driven by hydraulic motor

Prime mover

A propulsion engine, even as small as 5 hp could be used to drive a hydraulic pump. Where no engine has been installed the labour saving with hydraulic deck machinery may justify installation of a propulsion engine, especially if cheap second-hand automotive engines are available for conversion. An alternative, where no propulsion engine exists, is a small engine of about 3 to 5 hp. Single cylinder, air-cooled petrol engines of this size are available at a cost, in the order of £35 ($100) in U.S.A.

Fig 18. Purse seine skiff with hydraulic power block

Hydraulic components

A simple open system with operating pressure of about 1,000 lb/in^2 (70 kg/cm^2) permits the choice of a wide variety of equipment, pipe and hoses in the power range up to about the 5 hp. The circuit for such a system is shown in fig 19. An automotive power steering unit is ideally suited. It is designed to be belt driven from an engine power take off, and is complete with its own oil reservoir, strainer and flow control valve. The direction control valve can be of a size and quality used on earth-moving machinery such as road graders and light bulldozers.

The principal advantage of hydraulic power transmission is that the driven equipment may be remotely located from the power source. This advantage can be extended further by having a single hydraulic motor with control valve and sufficient hose to allow moving the motor from one fishing device to another as the season
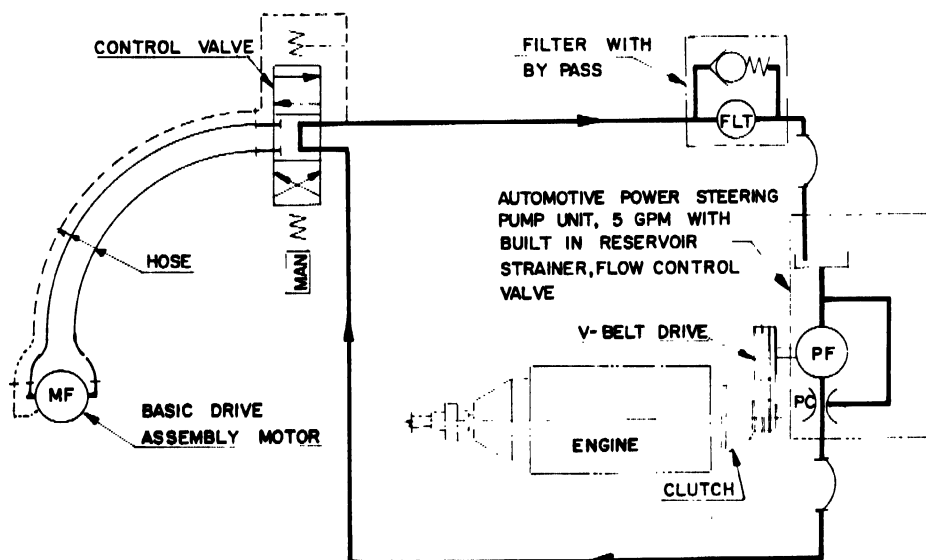
Fig 19. Hydraulic circuit for proposed basic power unit
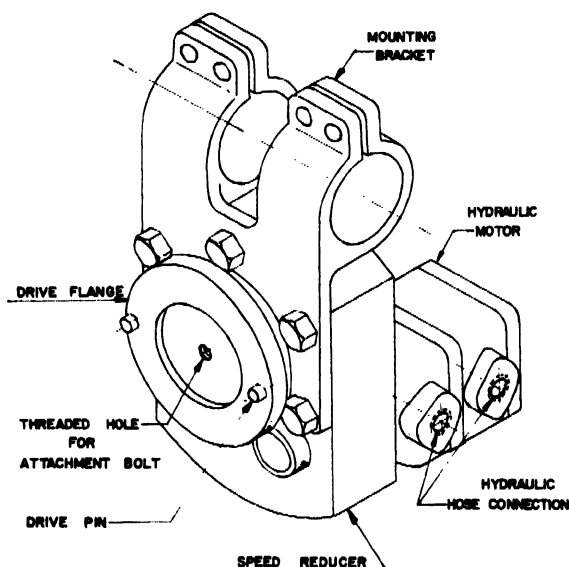
Fig 20. Basic drive assembly

and fishing techniques vary. Fig 20 to 23 illustrate typical applications that might be used.

Basic drive

The basic drive assembly consists of the hydraulic motor, a reduction gear with a drive flange and a mounting bracket. This is shown in fig 20.

The driving flange is the only visible rotating part of the assembly. Bearing in mind simplicity of construction pins of sufficient size are fitted in the flange which are in line with holes to be provided in the attachment flange of each fishing device. A bolt is inserted through the hub of the flange, which, when tightened, will press the driven flange firmly against the face of the driving flange. The studs transmit the torque from the driving flange to the driven flange. The driving flange has a $\frac{3}{16}$-in (5-mm) recess which fits a pilot in the driven flange in order to maintain axial alignment. Two clamps, which form part of the mounting bracket, can be placed over a 3-in (76 mm) pipe post ($3\frac{1}{2}$ in (84 mm) outside diameter) either in the vertical or horizontal position and rotated to suit the needs for the method of fishing pursued.

As the working area on a small vessel is located most likely aft, the socket support for the pipe post or for a davit would be placed on either port or starboard. The hydraulic control valve as well as the terminus for the hydraulic flexible hoses would be placed in the vicinity of the socket for accessibility during operation. A sufficient length of hose should be employed to permit shifting the basic drive assembly into any desired position. The supporting pipe of the horizontal design could be turned in the deck socket and positioned in the most favourable place by pins. It should be placed facing outboard or inboard for a beam net work or facing fore
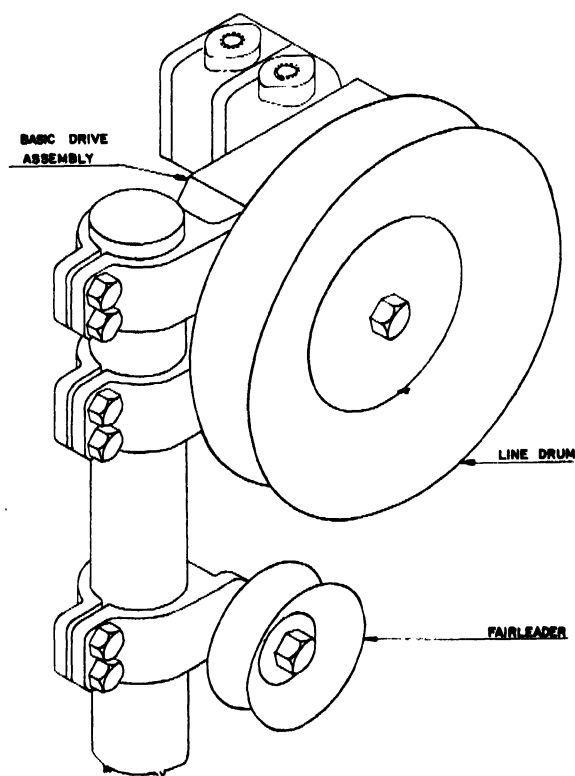
Fig 22. Basic drive assembly with longline hauler—mounted on vertical post

Fig 21. Basic drive assembly with gypsy—mounted on vertical post

and aft for fishing operation over the stern. A series of holes should be drilled in the pipe to suit the various possible positions.

A design of this type limits the line pull to 450 lb (200 kg). Nevertheless this gear has power available to replace several men under normal operational requirements.

Typical applications:

- Power gypsy, in fig 21

- Longline hauler, fig 22
  Consisting of two parts: the rope-winding pulley and a fairleader pulley. The entire assembly can be rotated to any position to suit the immediate requirements

- Net sheave, fig 23
  The design permits the net to be placed over the sheave if clamped to a davit, as illustrated in fig 23. If centreline suspension of the net sheave is desired, a simple yoke can be provided above the assembly

- Net reel. Power supply to a net reel on a gillnetter can be accomplished by the installation of a basic drive assembly with a roller chain drive to reduce the speed of the net reel to acceptable limits. The high-speed sprocket would bolt to the driving flange in the same manner as other devices

The estimated cost of a basic drive assembly, as shown in fig 20, and the hydraulic components with 100 ft (30 m) of hose and end fittings, as shown in fig 19, is £215 ($600) based on U.S.A. manufacture. The costs of the various attachments, supports and installation aboard a boat would be added to this cost.

While the basic drive as described has a high-speed motor and an industrial type speed reducer, no reason exists to prevent the use of a lower speed hydraulic motor with the driving plate mounted directly to its output shaft. It is important that a standard driving flange and a standard mounting bracket be adopted so that manufacturers throughout the world could build the basic
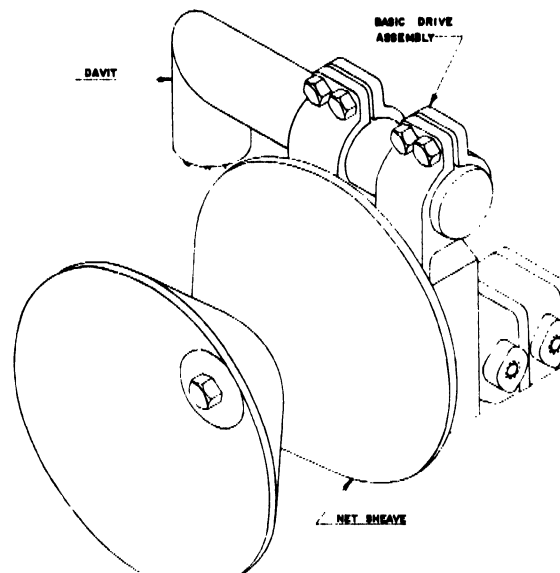
Fig 23. Basic drive assembly with net sheave—mounted on davit

drive assemblies, and the various attachments, with assurance that the assemblies would fit.

STANDARD GRAPHICAL SYMBOLS

(from ASA-732.10)

Basic symbols can be combined in any form desired. No attempt is made to show all combinations.

LINES AND LINE FUNCTIONS	
LINE, WORKING	
LINE, PILOT (L>20W)	
LINE, DRAIN (L<5W)	
CONNECTOR (DOT TO BE 5X WIDTH OF LINES)	
LINE, FLEXIBLE	
LINE, JOINING	
LINE, PASSING	
DIRECTON OF FLOW	
LINE TO RESERVOIR ABOVE FLUID LEVEL BELOW FLUID LEVEL	
LINE TO VENTED MANIFOLD	
PLUG OR PLUGGED CONNECTION	
TESTING STATION (GAGE CONNECTION)	
POWER TAKEOFF (HYD.)	
RESTRICTION, FIXED	
RESTRICTION, VARIABLE	

PUMPS	
PUMP, SINGLE, FIXED DISPLACEMENT	PF
PUMP, SINGLE, VARIABLE, DISPLACEMENT	PV

MOTORS AND CYLINDERS	
MOTOR, ROTARY, FIXED DISPLACEMENT	MF
MOTOR, ROTARY, VARIABLE DISPLACEMENT	MV
MOTOR, OSCILLATING	MO
CYLINDER, SINGLE ACTING	
CYINDER, DOUBLE ACTING SINGLE END ROD DOUBLE END ROD	

MISCELLANEOUS UNITS	
ROTATING SHAFT (ARROW IN FRONT OF SHAFT)	
COMPONENT ENCLOSURE	
RESERVOIR	
PRESSURE GAGE	
OTHER * Insert appropriate letter combinations and add appropriate symbols to indicate shafts or connecting flow lines.	

ACC	ACCUMULATOR
ELEC MOT	ELECTRIC MOTOR
ENG	ENGINE
FLT	FILTER
FM	FLOW METER
HE	HEAT EXCHANGER
INT	INTENSIFIER
PS	PRESSURE SWITCH
STR	STRAINER
TACH	TACHOMETER

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VALVES AND BASIC SYMBOLS	
VALVE, CHECK	
VALVE, MANUAL SHUTOFF	
VALVE, MAXIMUM PRESSURE (RELIEF)	
VALVE, BASIC SYMBOL SINGLE FLOW PATH IS MODIFIED.	
VALVE, BASIC SYMBOL MULTIPLE FLOW PATHS ARE CHANGED	
VALVE, SINGLE FLOW PATH, NORMALLY CLOSED	
VALVE, SINGLE FLOW PATH, NORMALLY OPEN	
VALVE, MULTIPLE FLOW PATHS, BLOCKED	
VALVE, MULTIPLE FLOW PATHS, OPEN (ARROWS DENOTE DIRECTION OF FLOW)	
VALVE, SPECIAL (IDENTIFY AND CONNECT ALL LINES)	

VALVE EXAMPLES	
VALVE, RELIEF REMOTELY OPERATED (UNLOADING VALVE)	
VALVE, DECELERATION NORMALLY OPEN	
VALVE, SEQUENCE, DIRECTLY OPERATED	
VALVE, PRESSURE REDUCING	

VALVE EXAMPLES (CONT.)

VALVE, COUNTERBALANCE WITH INTEGRAL CHECK
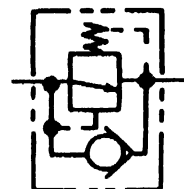
VALVE, FLOW-RATE CONTROL, VARIABLE, PRESSURE COMPENSATED
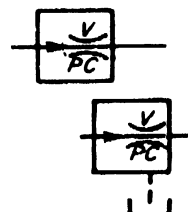
VALVE, DIRECTIONAL, 2 POSITION 3 CONNECTION

VALVE, DIRECTIONAL, 3 POSITION 4 CONNECTION OPEN CENTER

VALVE, DIRECTIONAL, 3 POSITION 4 CONNECTION CLOSED CENTER
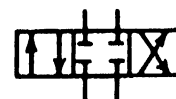
METHODS OF CONTROL

SPRING

PILOT OPERATED

PILOT OPERATED, DIFFERENTIAL AREA
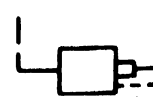
OTHER

* Insert appropriate letter combinations and add connecting flow lines.

CENT	CENTRIFUGAL
COMP	COMPENSATOR
CYL	CYLINDER
DET	DETENT
ELEC MOT	ELECTRIC MOTOR
HYD MOT	HYDRAULIC MOTOR
MAN	MANUAL
MECH	MECHANICAL
SERV	SERVO
SOL	SOLENOID
SOL PLT	SOLENOID CONTROLLED, PILOT OPERATED
THRM	THERMAL

SAMPLE COMPOSITE SYMBOLS

PUMP, DOUBLE, WITH ELECTRIC MOTOR
ONE FIXED DISPLACEMENT
ONE VARIABLE DISPLACEMENT WITH
COMPENSATOR CONTROL
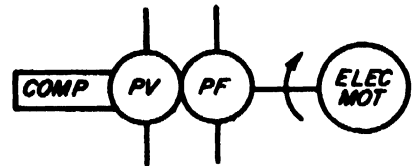
PUMP, DOUBLE, WITH IN-BUILT CHECK,
RELIEF AND UNLOADING VALVES.
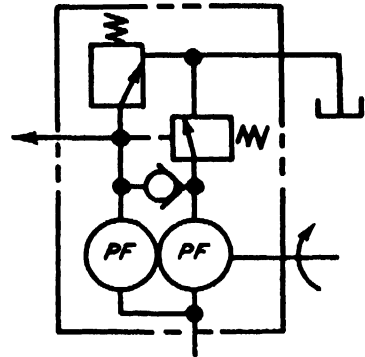
VALVE, PRESSURE COMPENSATED VARIABLE
FLOW-RATE CONTROL WITH
MAXIMUM PRESSURE CONTROL

VALVE, RELIEF AND REPLENISHING
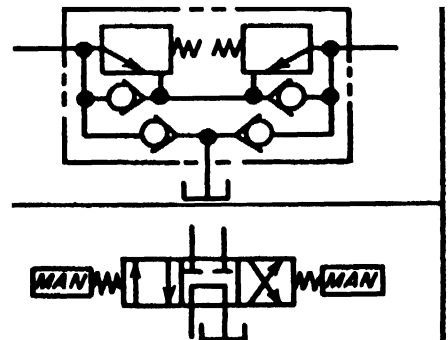
VALVE, 4-WAY, MANUALLY CONTROLLED,
SPRING CENTERED.
(PORTING AT CENTER IS P TO T
WITH CYLINDER PORTS BLOCKED)
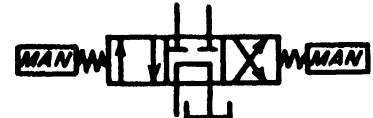
                                    SIMPLIFIED
                                    SYMBOL
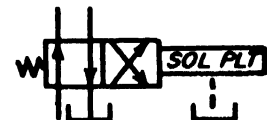
VALVE, 4-WAY
SOLENOID CONTROLLED,
PILOT OPERATED,
SPRING OFFSET

                                    COMPOUND
                                    SYMBOL
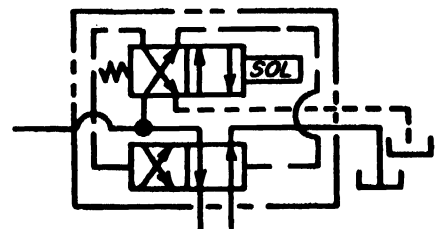
VALVE, 4-WAY, SOLENOID CONTROLLED,
PILOT OPERATED, NO SPRING
(ONE PORT PLUGGED)
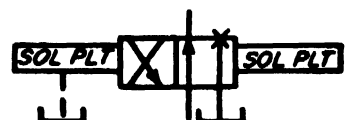
Refrigeration Facilities in Small Fishing Boats

by Seigoro Chigusa

Installations de réfrigération à bord des petits bateaux

L'auteur fait un bref historique de l'évolution des petits bâtiments de pêche japonais, en exposant les facteurs économiques ayant joué dans l'adoption d'installations modernes de réfrigération. Il passe en revue les installations et méthodes d'entreposage frigorifique pour des bâtiments d'une jauge brute allant de 20 à 100 tonneaux. On étudie plus particulièrement l'influence, sur les besoins en matière d'installations frigorifiques, des facteurs suivants: durée des sorties, volume des captures et espèces pêchées (et, partant, capacité des cales à poisson), température d'entreposage nécessaire à une bonne conservation, types d'isolations, utilisation en alternance des cales pour le poisson et pour le mazout, matériel frigorifique et fluides frigorigènes, et automatisation intégrale du dispositif de congélation. Enfin, des tableaux et illustrations sont consacrés à l'équipement frigorifique et à l'agencement des cales de navires de divers déplacements.

La refrigeración en las pequeñas embarcaciones

Se hace un breve historial de la evolución de las pequeñas embarcaciones pesqueras japonesas, con la explicación de los factores económicos que intervienen en la instalación de frigoríficos modernos. Se analizan instalaciones y métodos adecuados de almacenamiento para barcos de 20 a 100 toneladas brutas, haciéndose referencia a los efectos resultantes de los siguientes factores: travesía, tallas y especies capturadas (y, en consecuencia, la capacidad de las bodegas de pescado), temperatura para una buena conservación, tipos de aislamientos, utilización de las bodegas alternativamente para pescado y carburante, frigoríficos y refrigerantes y sistemas de almacenamiento totalmente automáticos. Por último se exponen grabados de instalaciones generales de refrigeración de bodegas y sus diversas disposiciones para barcos de distintos desplazamientos.

THE first refrigerating facilities in Japanese fishing boats were installed on *Yuryo Maru*, a fish carrier, in 1907. Since then, Japan has gained valuable experience in the installation.

In pre-war days, Japanese fisheries mostly operated in the coastal waters of the islands, with the exception of Northern Pacific fishing or whaling expeditions. There was no pelagic fishing, which requires longer voyages, and so the refrigerators installed in fishing boats were not fully utilized, and some of them were even removed.

After World War II, Japanese fisheries were extended from the exhausted coastal waters to offshore or pelagic waters to secure marine sources of protein and to stabilize the nation's nutrition. According to the expansion of fishing grounds and the increase in operating periods, refrigerators have become essential.

The modern Japanese refrigerated fishing fleet needed steady progress in techniques and national economic support to be developed.

This paper describes refrigerators installed in vessels of 20 GT to 100 GT, and furnishes information about their design and construction for possible use in other countries.

TYPES OF STORAGE

In general, for maintaining freshness of fish catch aboard, the following three methods are used:

(1) Storage with ice (refrigerators may be used in addition)
(2) Storage in chilled sea water (chilled sea water is produced by means of ice or refrigerator)
(3) Storage in frozen condition by means of refrigerator

Method 1 and Method 2 have been used from pre-refrigeration days and, depending on operating periods, species of fish and location of fishing grounds, do not necessarily need refrigerators. It is to be noted that there are limits on storing temperature and volume of ice to be taken aboard.

Initially, if with the introduction of refrigeration no ice was used in Method 1, it was not satisfactory and the freshness of the fish deteriorated. Nowadays, it is generally agreed that in the case of Method 2, even if refrigerators are used, a minimum amount of 60–70 per cent of the ice necessary for cooling without a refrigerator is necessary. The reason is that inadequate circulation of cold air in the fish holds does not achieve uniform cooling of fish near the cooling pipes and centre of the holds, and also ice performs the following functions which are essential for securing freshness:

- Pre-cooling of fish
- Washing by melted ice
- Acting as pads between fish in holds
- Uniform temperature of individual fish

When it is difficult to obtain ample ice, Method 2 by means of a refrigerator or Method 3 must be adopted.

Table 1 shows in brief the methods of storage of fish and the limit of storing days.

Generally speaking, the two methods without refrigerator in table 1 are applied to popular commercial fish, such as mackerel-pike, mackerel and cod, so that more hold space can be occupied by actual fish and the methods with refrigerator are applied to high grade fish such as prawn and tuna.

TABLE 1

Method of storing		Limit of storing days	
Method	Refrigerator	Tuna & skip-jack long liner	Two-boat trawler
(1) Storage with ice	without	40	30
	with	60	40
(2) Storage in chilled sea water	without	30	20
„	with	40	30
(3) Storage in frozen condition by means of refrigerator	with	over 60	over 40

Table 2 shows that even small vessels use refrigerators according to the length of a trip and methods of storage.

Tuna catchers of about 20 GT engaged in mother-ship operations make daily trips. As the supply of ice from the mother-ship is not usually sufficient, the catchers use Method 2 by means of a refrigerator, or Method 3. Such methods of storage for day trips may not seem necessary but they were important for pre-cooling fish before transferring it to the mother-ship.

TABLE 2

Kind of boat	Size of boat (GT)	Fish catch per trip (tons)	Operating period (days)	Storing method refrigeration plus
Tuna long-liner	20		one day	ice or only refrigeration
„	40–50	30–35	30–40	ice
„	95–100	60–75	50–70	ice or only refrigeration
Two-boat trawler	90	30–40	20–30	ice

As shown in table 2, tuna longliners of 40 to 50 GT and two-boat trawlers of about 90 GT are using Method 1 because of their limited operating period of 30 to 40 days but bigger tuna boats, 95 to 110 GT, are obliged to use Method 3 because of their 50 to 70 days operating period.

It is the general trend in Japan to use more refrigerators on small vessels. In fact, Method 1 was preferred in the past because it allowed more space in the fish hold and also the product had a better market price but nowadays, because of the improvement in storing techniques and longer trips, refrigerators are becoming more and more popular.

STORING CAPACITY BY TYPE OF STORAGE

The fish catch storable per unit volume of fish hold varies greatly with species of fish and storage method. Method 2 gives a storage ratio of 47 to 50 lb/ft³ (750 to 800 kg/m³) and is popular for mackerel and mackerel-pike. Method 1 for tuna can feasibly store 32 to 37 lb/ft³ (520 to 600 kg/m³), and Method 3 26 to 32 lb/ft³ (420 to 520 kg/m³) in bulk, respectively. Regarding two-boat trawlers in which fish is packed with ice in boxes and also refrigerated, the storing capacity is only 22 to 28 lb/ft³ (360 to 450 kg/m³).

In Method 3 the enlarged engine room space, because of the enlargement of the freezing chamber or related facilities, reduces the capacity of fish holds. When the fish hold is sub-divided into compartments the original capacity will be slightly more reduced. However, if other methods are adopted, the freshness of the fish is greatly affected because of the length of the trip.

DAY'S CATCH, SIZE OF COMPARTMENT AND CAPACITY OF REFRIGERATOR

The catch of a small tuna boat or two-boat trawler is approximately 2 to 5 tons per day. Hence, the ideal capacity of the hold should be 700 to 1,000 ft³ (20 to 30 m³) (10 to 15 tons) which should be filled in 5 to 6 days; a multi-compartment hold reduces the total amount of fish stored and should be avoided as far as possible.

The size of the compartment for Method 1 should be decided by taking account of the following:

● When the capacity of the compartment is large it takes a long time to fill and requires frequent opening which causes oscillations in temperature

● Poor cool-air circulation makes it difficult to maintain the freshness of the catch at the compartment's centre

In the case of Method 1, therefore, it is essential to place cooling pipes adjacent to the movable partitioning boards at the centre of the compartment. Method 3 is not yet popular among small vessels and it is only installed in a few vessels of 99 GT. Aiming to lower the centre of gravity of the hull, these vessels have working rooms on the upper deck under the bridge deck, preparation rooms below the working rooms and one or two freezing chambers on both sides of the preparation rooms.

STORING TEMPERATURE AND OPERATING PERIOD

The temperature of Method 1 without refrigerator is 32°F (0°C) for fish in contact with ice, and 37.5 to 50°F (3 to 10°C) elsewhere. When refrigeration is used the temperature can be lowered but care should be taken that the fish are not frozen. The storing temperature of fish by Method 3 is generally 0°F (−18°C), up to an operating period of a month, −4 to −9.5°F (−20 to −23°C) for 2 to 3 months, −13 to −18.5°F (−25 to −28°C) for 3 to 5 months, and −20°F (−29°C) and below for more than 6 months. Table 3 shows the storing temperature of fish in small fishing boats.

TABLE 3

Kind of boat	Size of boat (GT)	Storage time by days	Storing method	Storage temperature
Tuna boat	40–50	30–40	(1)	0 to − 1°C (32 to 30°F)
„	95–110	50–70	(3)	− 20 to − 23°C (− 4 to − 9.5°F)
Two-boat trawler	90	20–30	(1)	+ 3 to 0°C (37.5 to 32°F)

It shows that the storing temperature of fish by Method 3 in tuna boats less than 100 GT is −4 to −9.5°F (−20 to −23°C); this is due to their operating period of about two months but the storing temperature of larger tuna boats over 200 GT is −22 to −29°F (−30 to −34°C). With such low temperatures fish can maintain good quality after de-freezing, and the product is equally well accepted as the product of Method 1.

SPECIAL CARE FOR REFRIGERATORS USED FOR BOTH METHODS

Refrigerators used for Method 3 need to have a very large capacity compared with those used for Method 1 to freeze the fish rapidly and maintain the temperature in fish holds as low as possible. When the refrigerating machinery is used for Method 3 only, there will be no difficulties but if the same machinery is used for Method 1 either at the same time or alternatively the fish will sometimes be over-frozen and the quality reduced. The following are preventive measures against such situations:

● Control of refrigerating machinery capacity

When a compressor for Method 3 is used for Method 1, its capacity must be reduced by an unloading device.

● Control of evaporating temperature by pressure regulator

When a compressor capacity is too big or one compressor has to maintain two different temperatures, for Method 3 and Method 1, the suction pressure of the compressor must be lowered by the regulator as the evaporating temperature is proportional to the suction pressure and big differences between the temperature of the cooling pipes (evaporating temperature) and of the fish holds must be avoided, otherwise the fish placed near cooling pipes will be over-cooled, and slow freezing will begin.

● Insulation of bulkhead between fish holds for Method 3 and Method 1

When one of two adjoining fish holds is used for Method 3 and the other one for Method 1, the quality of fish in the hold for Method 1 may be seriously damaged because of over-cooling or slow freezing by the effect of the low temperature of the hold for Method 3. Insulation of the common bulkhead has to be very efficient.

● Piping arrangement

In general, over-cooling of fish holds is not a problem for Method 3 and it is natural that when the highest temperature in the holds is lowered to the required degree the temperatures around the cooling pipes will drop by 5½ to 7°F (3 to 4°C). This drop in the temperature must definitely be avoided for Method 1 because partial over-cooling or slow-freezing is not permissible for this method. The piping which is used for both Method 1 and Method 3 must be arranged having the correct

pitch on the ceiling, wall and bottom of fish holds and be divided into suitable arrangements in order to make the hold temperature as uniform as possible.

CAPACITY OF REFRIGERATOR AND INSULATION

Initially carbonized cork boards were used for insulation but were not popular because of the danger of rotting in wooden boats and a reduction in hold capacity in steel boats. Furthermore, when refrigerating apparatus was initially installed, grid coils and their sparring were thought to be a substitute for cork insulation boards and the number of boards was reduced. This was not found to be practical.

TABLE 4

Location		Method 1 −2 to −2°C (28.3 to 35.6°F)	Method 3 −18 to −23°C (0 to 9.5°F)	Method 3 −25 to −30°C (−13 to −22°F)
		in (mm)	in (mm)	in (mm)
Ceiling		3.9 (100)	5.8 (150)	7.8 (200)
Side wall		3.9 (100)	5.8 (150)	6.8 (175)
Bottom		1.9–2.9 (50–75)	3.9–4.9 (100–125)	5.8 (150)
Bulkhead	Fore	3.9 (100)	5.8 (150)	6.8 (175)
	Eng. Room	3.9–5.8 (100–150)	6.8–7.8 (175–200)	7.8–8.8 (200–225)
	Inter hold	1.9 (50)	2.9–3.9 (75–100)	3.9–4.9 (100–125)

Note: Insulation materials are foamed plastic.

Regarding the cooling pipes installed in wooden boats, there was a fear that the deflection of the wooden hull might produce breaks in the pipes but this was overcome by good piping arrangements and practically no faults occurred.

The insulation thickness of existing fishing boats is shown in table 4.

The refrigeration capacity is usually designed on the assumption that the refrigerator operates for about 12 to 18 hours per day under the temperature conditions shown in table 4. The values in table 5 are actually used considering such factors as heat gain by the frequent opening of the hatches, and use of pre-cooling before refrigerating.

TABLE 5

Kind of boat	Size of boat GT	Kind of storage	Capacity and number of refrigerator
Two-boat trawler	90	Method 1	2 to 3 RT × 1 set
Tuna boat	39–47	,,	3 to 5 ,, × 1 set
,,	96–99	,,	5 to 9 ,, × 1 set
,,	99–111	Method 3	13 to 17,, × 2 set*
,,	20	Method 2	2 to 3 ,, × 1 set

Note: * includes one set for freezing.

HOLDS ALTERNATIVELY USED FOR FISH THEN FUEL OIL

Fishing boats now require more fuel oil aboard than previously with the expansion of fishing grounds and longer total voyage time but when their constructed oil tanks are enlarged, their fish-hold capacity must be reduced. Formerly, fuel oil was taken in drums or vinyl tanks in the fish hold on the outward voyage but now it is taken into the hold itself and fish carried back in it. This eliminates overcoming unexpected difficulties, damage of vinyl tanks, etc. After the fuel oil is consumed, the fish holds are cleaned to receive the fish. The wooden ceiling plank in fish holds was often made oiltight for storing fuel oil but it was rather difficult to prevent oil from permeating the insulation boards. Plastic structure and resin paint are now successfully used in some tanks for this purpose.

Nowadays most fishing boats have a watertight metal ceiling (steel or aluminium alloy) on which the cooling piping is arranged. This metal ceiling, however, previously caused an enormous heat gain due to its direct connection with the frames through metal supports, i.e. angle bars, but this is now eliminated as insulated materials are used as supports, etc.

ARRANGEMENT IN ENGINE ROOM

It is essential that the engine room space should be minimized for maximum fish-hold capacity. To this end small fishing boats less than 50 GT are provided with no generators or electric motors and their main engines are used as a direct power source for all necessary equipment, while larger fishing boats of 100 GT have been provided with AC motors or hydraulic motors.
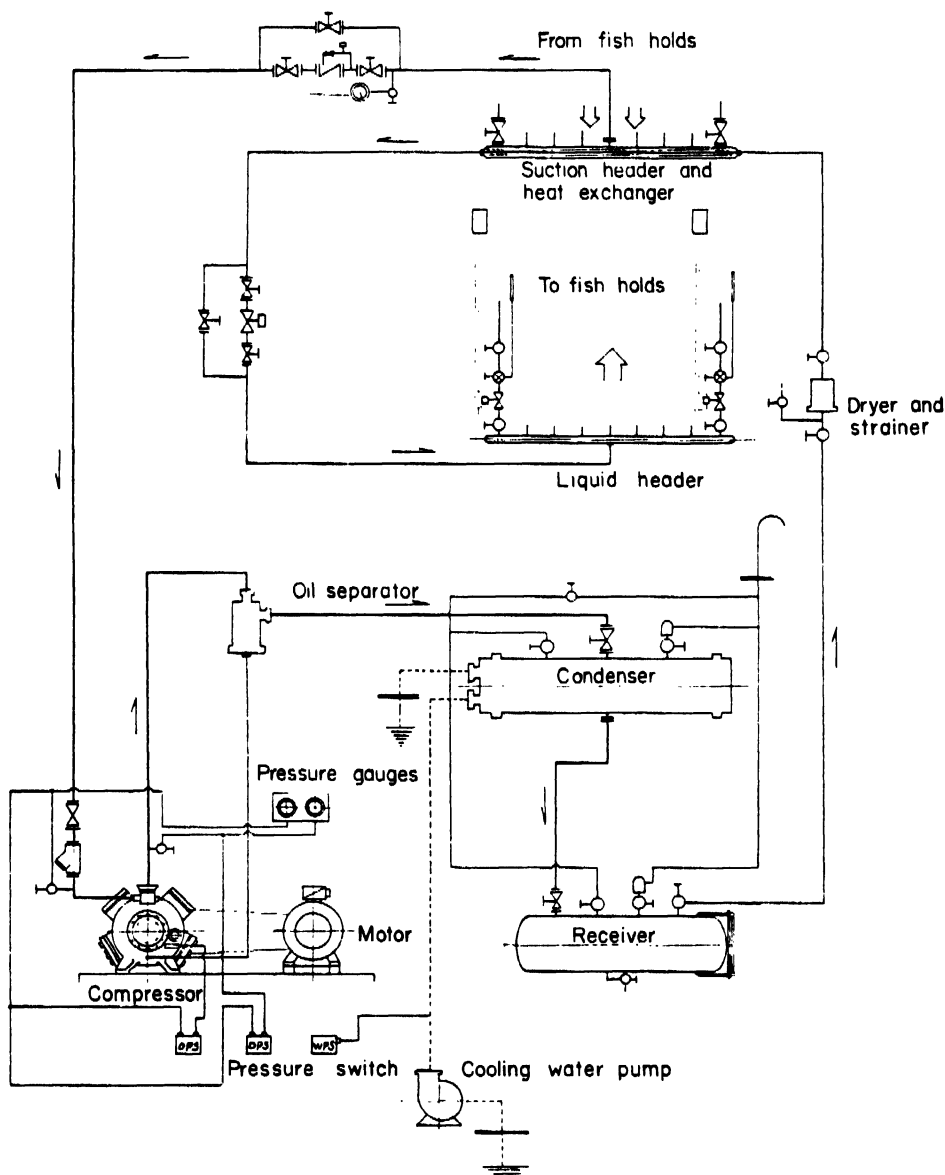
Fig 1. R-12 piping diagram
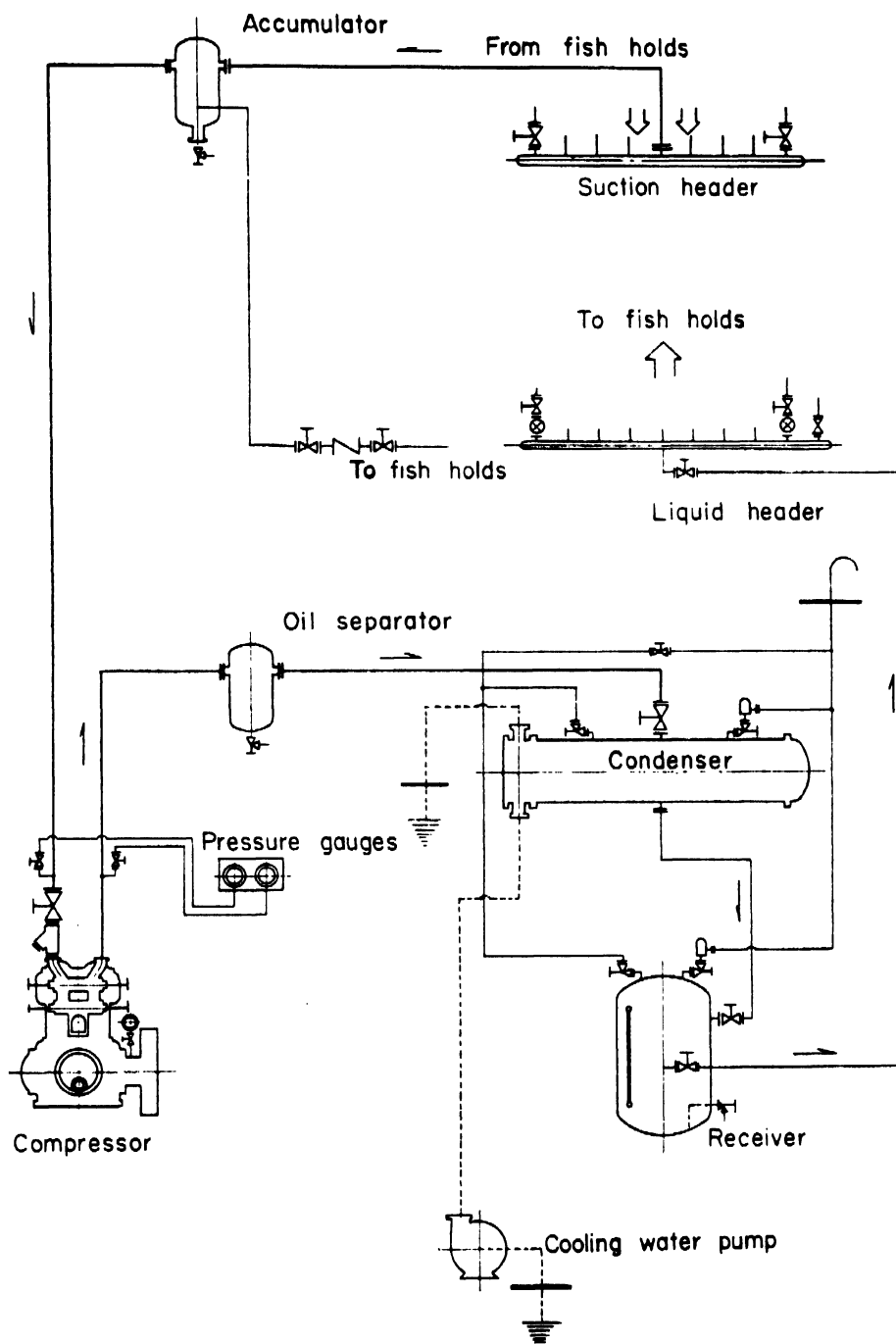
Fig 2. Ammonia piping diagram for storage by crushed ice

Refrigerating facilities are fitted forward in the engine room or on the upper deck, and the expansion valve panel and the suction header, etc., on the fore bulkhead of the engine room, the condenser at the top of the port or starboard side, and the receiver (horizontal or vertical type) underneath the condenser. Since these items are cramped in small fishing boats, every precaution must be taken against dangers by, say, automation or non-manual control using compact units.

REFRIGERANTS

The refrigerant used is mostly ammonia, Fron accounting for only 20 per cent. Ammonia is mainly used because of the following:

(a) Low cost
(b) Higher efficiency in high-capacity refrigerating facilities
(c) Gas leaks easily found

(b) above indicates that ammonia is best for flooded systems or refrigerant recurrence systems used in refrigerating facilities of large capacity. Fron is colourless and odourless, which causes difficulty in locating a leak until, arrival at fishing grounds. Fron refrigerants have the advantage in small fishing boats or school boats in respect of safety, easy automation and compactness and weight of units and therefore small boats using Method 1 will more frequently have Fron refrigerants.

Compressors of a reciprocating type with a range of rpm from 400 to 1,400 and compressors of a rotary type can be used for both ammonia and Fron. The condenser in most cases is of horizontal shell and tube type which has solid-drawn steel tubes (galvanized on the surface in contact with water) for ammonia and albrac or Low-fin tubes for Fron for good durability and reduction of weight and compactness.

Recently, to reduce engine-room space, a square-type condenser was manufactured and installed on the upper deck.

AUTOMATION SYSTEM

Most refrigerating facilities previously installed were manually controlled and ineffective. The thermometers in a hold did not necessarily indicate the correct temperatures in all parts of the hold. So in Method 1 the temperature was controlled by checking the volume and temperature of the bilge. At first it is difficult to obtain correct temperature adjustment for good preservation and only experience solves this, but this difficulty would be eliminated by automatic control. Automation of refrigerating facilities commenced with an automatic expansion valve for facilities using Fron, and later high-speed multi-cylinder compressors, also safe or protective equipment such as the dual pressure switch (DPS), oil protection switch (OPS), water pressure switch (WPS). Now automatic expansion valves and evaporating pressure regulators (EPR) have been adopted for ammonia facilities. Fully automatic R-12-type refrigerating facilities (non-manual) having all essential equipment,
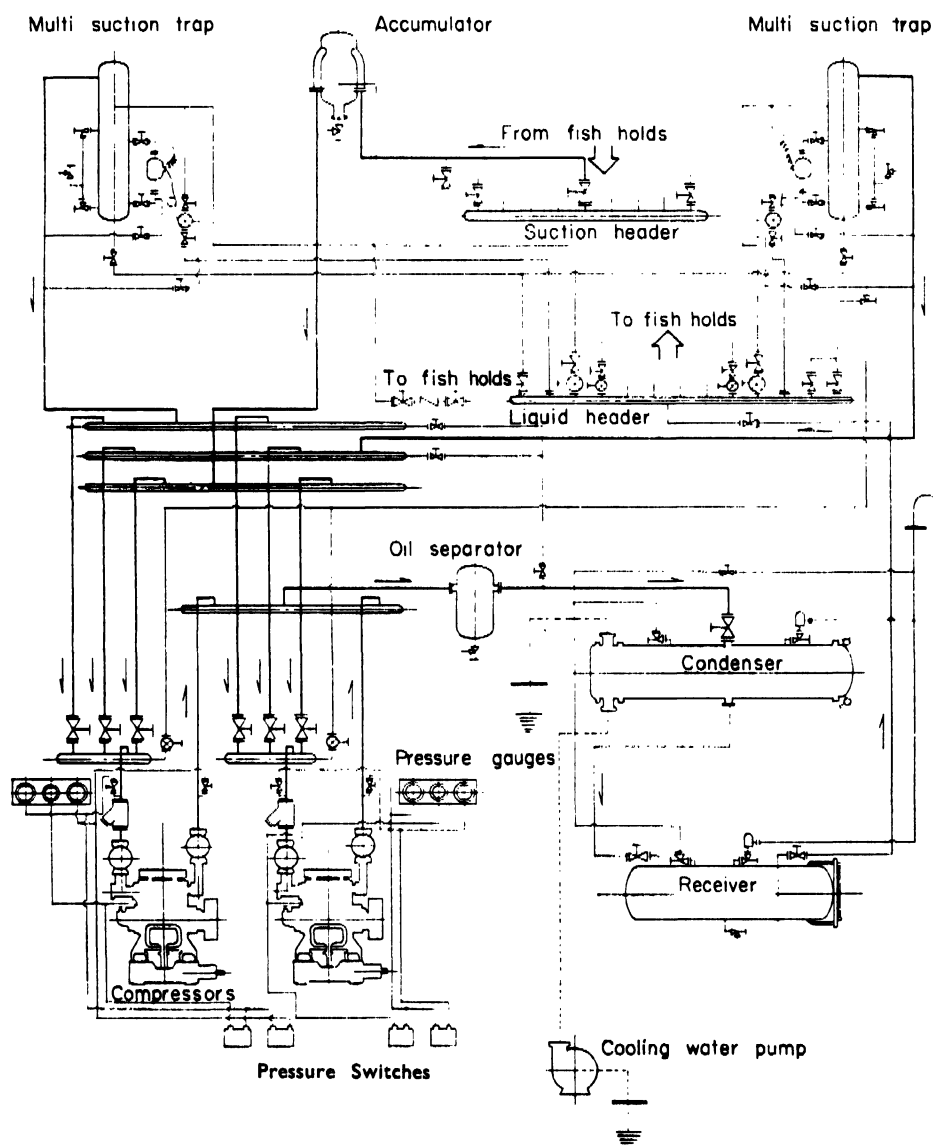
Fig 3. Ammonia piping diagram for freezing

i.e. thermostat and magnetic valve, DPS, OPS and EPR, are being contemplated for use in two-boat trawlers. Automatic control of facilities will eliminate over-cooling around the cooling pipe and slow freezing in Method 1.

Fishing operations and treatment of fish always required considerable manpower, and labour saving aboard has recently come under consideration due to the difficulty of obtaining fishermen. Many labour-saving methods, like the adoption of conveyor belt systems in the process of freezing, are being utilized.

General arrangement plans of refrigerating facilities are shown in fig 1, 2 and 3.

SPECIFICATIONS OF REFRIGERATING PLANTS

Typical examples of refrigerating plants for Japanese fishing vessels of 20 to 100 GT are shown as follows:

1. 20-GT tuna catcher (Method 2)

Lpp 51.18 to 52.50 ft (15.60 to 16.0 m)
B   11.48 ,, 12.14 ft (3.50 ., 3.70 m)
T_1 4.72 ., 5.25 ft (1.44 ., 1.60 m)
GT 19 to 20 tons
Speed about 9 knots
Fish-hold capacity 353 to 495 ft³ (10 to 14 m³) (2 subdivisions)
Storing t 0°C (32°F)

NH_3 compressor **Reciprocative Type**
3.27 in diam ×0.276 in L ×2 cylinders ×450 rpm ×31,620 BTU/hr ×5 hp ×1 set (83 mm diam ×70 mm L ×2 cylinders ×450 rpm ×7,968 kg cal/hr ×5 hp ×1 set)

Rotary Type

NRL—5 ×1,300 rpm ×4,160 BTU/hr ×5 hp ×1 set
(NRL—5 ×1,300 rpm ×10,624 kg cal/hr ×5 hp ×1set)
NH_3 condenser 14.96 in diam ×34.25 in L ×35.52 ft² to 14.96 in diam ×47.24 in L ×49.51 ft² ×1 set
    (380 mm diam ×870 mm L ×3.30 m² to 380 mm diam ×1,200 mm L ×4.60 m² ×1 set)
Cooling water pump 176.6 cu ft/hr ×29.5 ft h to 247.2 cu ft/hr ×26.20 ft h
    (5 m³/hr ×9 m h to 7 m³/hr ×8 m h)
NH_3 receiver 10.5 in diam ×31.5 in L ×55.12 lb to 12.52 in diam ×33.46 in L ×77.16 lb ×1 set
    (267 mm diam ×800 mm L ×25 kg to 318 mm diam × 850 mm L ×35 kg ×1 set)
Oil separator 6.50 in diam × 17.72 in h to 8.50 in diam × 24.80 in h ×1 set
    (165 mm diam × 450 mm h to 216 mm diam × 630 mm h ×1 set)
Liquid separator 6.50 in diam 17.72 in h ×1 set
    (165 mm diam ×450 mm h ×1 set)
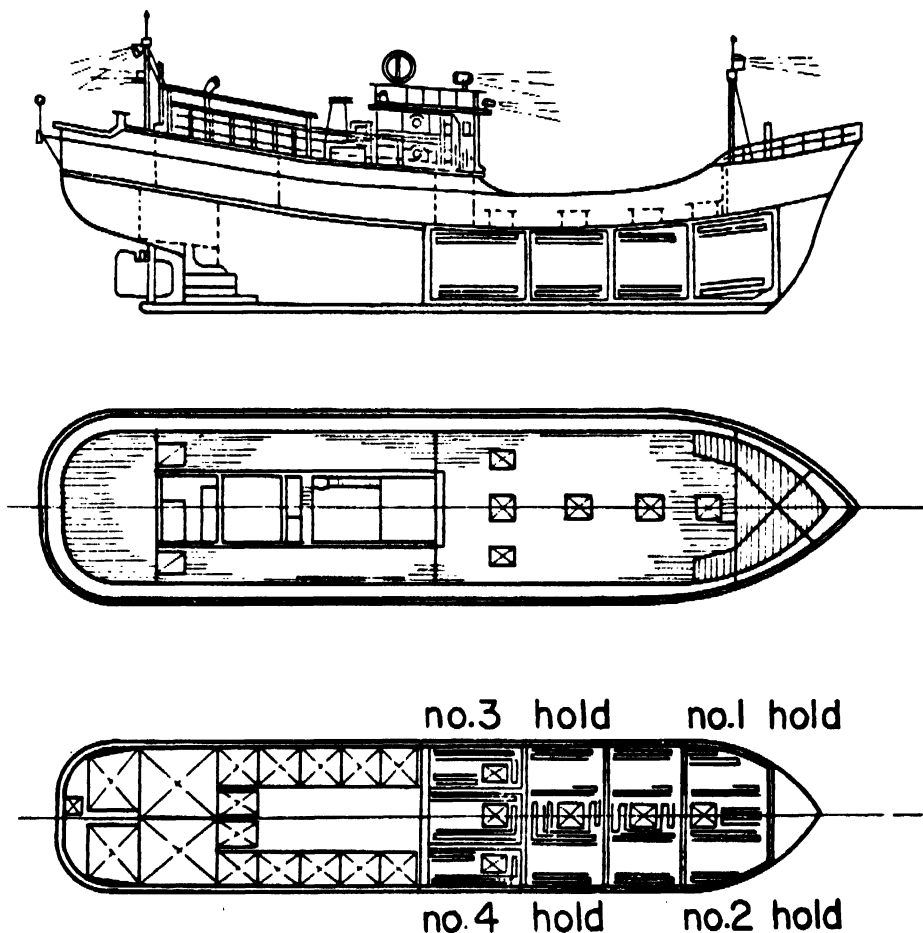
Fig 4. General arrangement of tuna longliner 39 GT

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Cooler, Shell and tube type: 12.52 in diam × 39.37 in
L × 40.90 ft² × 1 set
(318 mm diam × 1,000 mm L × 3.80 m² × 1 set)
L-shape section coil type: 1.34 in diam × 721.8 ft
951.4 ft (2 series)
(34 mm diam × 220 m to 290 m (2 series)

Circular pump 459.1 ft³/hr × 32.81 ft h to 706.3 ft³/hr ×
65.62 ft h × 1 set
(13 m³/hr × 10 m h to 20 m³/hr × 20 m h × 1 set)

2. 40 to 50-GT tuna longliner (Method 1), fig 4

Lpp 64.90 to 65.30 ft (19.78 to 19.90 m)
B 14.40 „ 15.09 ft (4.39 „ 4.60 m)
T₁ 6.69 „ 6.90 ft (2.04 „ 2.10 m)
GT 39 to 47 tons
hp 180 to 250
Speed about 8 knots
Fish-hold capacity 1413 to 1765 ft³ (40 to 50 m³)
(6 subdivisions)
Storing t 0 to −2°C (32 to 28.4°F)

NH₃ compressor 3.50 in diam × 3.50 in L × 2 cylinders ×
400 rpm × 41,500 BTU/hr × 7.5 hp × 1 set
(89 mm diam × 89 mm L × 2 cylinders ×
400 rpm × 10,458 kg cal/hr × 7.5 hp × 1
set)

or 3.94 in diam × 3.00 in L × 2 cylinders ×
600 rpm × 67,850 BTU/hr × 10.0 hp × 1
set
(100 mm diam × 76 mm L × 2 cylinders
× 600 r.p.m. × 17,098 kg cal/hr × 10.0
hp × 1 set)

NH₃ condenser 14.96 in diam × 34.25 in L × 35.5 ft² to
14.96 in diam × 59.06 in diam × 61.9
ft² × 1 set
(380 mm diam × 870 mm L × 3.3 m² to
380 mm diam × 1,500 mm L × 5.75 m²
× 1 set)

Cooling water pump 247.2 ft³/hr × 42 ft h × 1 set
(7 m³/hr × 13 m h × 1 set)

NH₃ receiver 18.90 in diam × 27.56 in L × 147.70 lb × 1
set
(480 mm diam × 700 mm L × 67 kg × 1 set)

Oil separator 8.50 in diam × 23.62 in h × 1 set
(216 mm diam × 600 mm h × 1 set)

Liquid separator 8.50 in diam × 23.62 in h × 1 set
(216 mm diam × 600 mm h × 1 set)

Cooling coil 1.07 in diam × 1,968 ft L (6 series)
(27.2 mm diam × 600 m L) (6 series)

3. 90-GT tuna boat trawler (Method 1)

Lpp 88.58 ft (27.00 m)
B 17.40 ft (5.30 m)
T₁ 8.60 ft (2.62 m)
GT 90 tons
hp 340
Speed 9 knots
Fish-hold capacity 2,825 to 3,885 ft³ (80 to 110 m³)
(5 subdivisions)
Storing t 0 to + 3°C (32°F to 37.4°F)

R-12 compressor 2.28 in diam × 1.77 in diam × 3 cylin-
ders × 1,500 rpm × 31,620 BTU/hr
× 5 h.p. × 1 set
(58 mm diam × 45 mm L × 3 cylinders ×
1,500 rpm × 7,968 kg cal/hr × 5 hp ×
1 set)

or NRL—5 × 1,720 rpm × 31,620 BTU/
hr × 7.5 hp × 1 set
(NRL—5 × 1,720 rpm × 2.4 RT × 7.5
hp × 1 set)

R-12 condenser 10.51 in diam × 29.53 in L × 45.2 ft² × 1
set
(267 mm diam × 750 mm L × 4.2 m² × 1
set)

Cooling water pump 247.2 ft³/hr × 42.6 ft h × 1 set
(7 m³/hr × 13 m h × 1 set)

R-12 receiver 10.51 in diam × 47.24 in L × 176.4 lb × 1 set
(267 mm diam × 1,200 mm L × 80 kg × 1
set)

Oil separator 5.91 in diam × 16.14 in h—8.50 in diam ×
24.80 in h × 1 set
(150 mm diam × 410 mm h—216 mm diam
× 630 mm h × 1 set)

Cooling coil 1.34 in diam × 1,968 ft L (5 series)
(34 mm diam × 600 m L (5 series)

4. 95-GT salmon and trout drift-netter (Method 1)

Lpp 86.94 ft (26.50 m)
B 18.70 ft (5.70 m)
T₁ 8.53 ft (2.60 m)
GT 96 tons
hp 350 to 440
Speed 9 knots
Fish-hold capacity 3,355 to 3,885 ft³ (95 to 110 m³)
(5 to 6 subdivisions)
Storing t 0°C (32°F)

NH₃ compressor 3.94 in diam × 3.94 in L × 2 cylinders ×
400 rpm × 59,288 BTU/hr × 10 hp ×
1 set
(100 mm diam × 100 mm L × 2 cylin-
ders × 400 rpm × 14,940 kg cal/hr
× 10 hp × 1 set)

NH₃ condenser 8.90 in diam × 59.05 in L × 61.9 ft² × 1 set
(480 mm diam × 1,500 mm L × 5.75 m² ×
1 set)

Cooling-water pump 247.2 ft³hr × 42.6 ft h × 1 set
(7 m³/hr × 13 m h × 1 set)

NH₃ receiver 13.78 in diam × 70.87 in L × 198.4 lb × 1 set
(350 mm diam × 1,800 mm L × 90 kg × 1
set)

Oil separator 8.50 in diam × 23.62 in h × 1 set
(216 mm diam × 600 mm h × 1 set)

Liquid separator 8.50 in diam × 23.62 in h × 1 set
(216 mm diam × 600 mm h × 1 set)

Cooling coil 1.34 in diam × 3,280 to 3,937 ft L (10–12
series) 34 mm diam × 1,000 to 1,200 m L
(10–12 series)
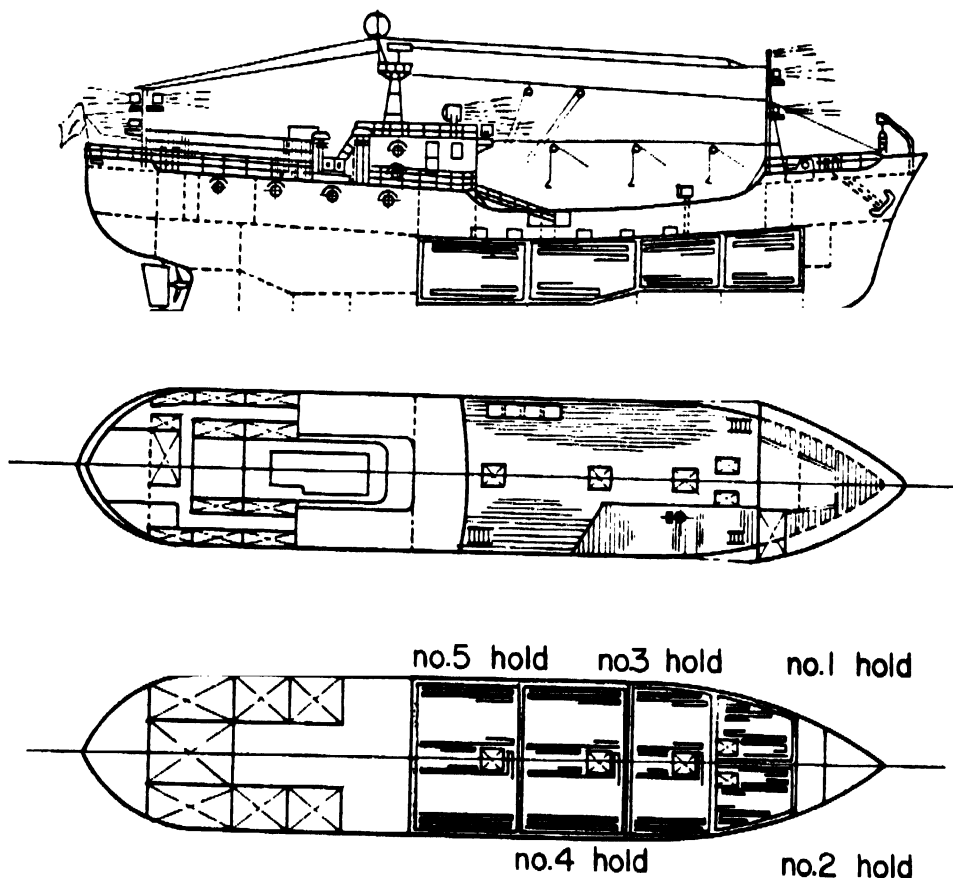
Fig 5. General arrangement of tuna longliner 99 GT

5. 100-GT tuna longliner (Method 1), fig 5

Lpp   88.58 ft (27.00 m)
B   19.03 ft (5.80 m)
T_1 8.69 ft (2.65 m)
GT   99
hp   350 to 430
Speed 9 knots
Fish-hold capacity 3,531 to 4,591 ft^3 (100 to 130 m^3)
(5 to 6 subdivisions)

NH$_3$ compressor 5.0 in diam ×4.02 in L×2 cylinders ×
           500 rpm ×118,575 BTU/hr ×20 hp ×
           1 set
           (127 mm diam × 102 mm L ×2 cylinders
           ×500 rpm ×29,880 kg cal/hr ×20 hp
           ×1 set)

NH$_3$ condenser 22.44 in diam ×59.06 in L×98.0 ft^2 ×1
           set
           (570 mm diam ×1,500 mm L ×9.1 m^2 ×1
           set)

Cooling water pump 459 ft^3/hr ×45.9 ft h
           (13 m^3/hr ×14 m h ×1 set)

NH$_3$ receiver 18.80 in diam ×43.31 in L ×231.5 lb ×1 set
           (480 mm diam ×1,100 mm L ×105 kg ×1
           set)

Oil separator 8.50 in diam ×23.62 in h ×1 set
           (216 mm diam ×600 mm h ×1 set)

Liquid separator 10.51 in diam ×29.53 in h ×1 set
           (267 mm diam ×750 mm h ×1 set)
Cooling coil 1.34 in diam ×3,937 to 4,265 ft L (8–9 series)
           (25 mm diam ×1,200 to 1,300 m L (8–9
           series)

6. 100-GT tuna longliner (Method 3), fig 6

Lpp   89.80 ft (27.37 m)
B   21.65 ft (6.00 m)
T_1 8.86 ft (2.70 m)
GT   99 to 111
hp   400 to 450
Speed 9 knots
Fish-hold capacity 3,002 to 3,178 ft^3 (85 to 90 m^3)
(1 to 4 subdivisions)
Freezing capacity 2 to 4 tons/24 hr (2 rooms)
Storing t fish-hold −20 to −23°C (−4 to −9.4°F)
           freezing −30°C (−22°F)

NH$_3$ compressor 3.74 in diam ×3.00 in L×4 cylinders ×
           1,150 rpm ×231,880 BTU/hr ×30 hp ×
           2 sets
           (95 mm diam ×76 mm L×4 cylinders
           ×1,150 rpm ×58,430 kg cal/hr ×30 hp
           ×2 sets)

NH$_3$ condenser 26.0 in diam ×94.50 m L×230.3 ft^2 ×1
           set
           (660 mm diam ×2,400 mm L ×21.4 m^2 ×
           set)

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Working room

Freezing room   no.3 hold   no.1 hold

no.4 hold   no.2 hold
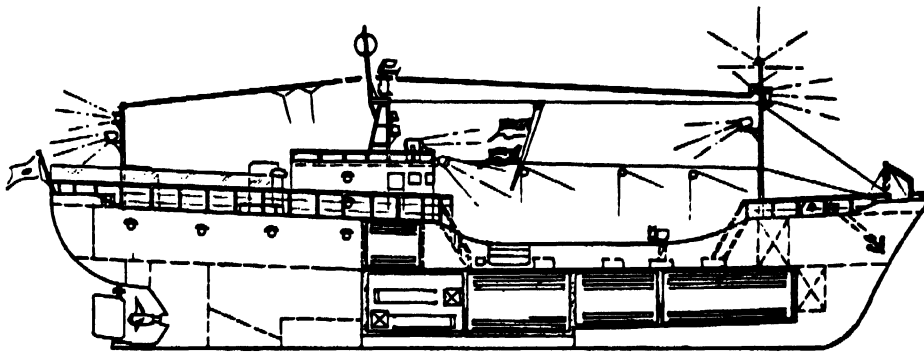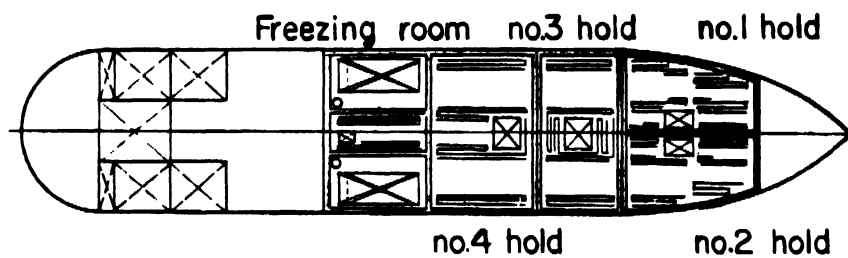
Fig 6. General arrangement of tuna longliner 111 GT

Cooling water pump 1,059 ft³/hr × 42.7 ft h × 1 set
    (30 m³/hr × 13 m h × 1 set)

NH₃ receiver 23.6 in diam × 86.6 in L × 771.6 lb × 1 set
    (600 mm diam × 2,200 mm L × 350 kg × 1
    set)

Oil separator 12.5 in diam × 35.4 in h × 1 set
    (318 mm diam × 900 mm h × 1 set)

Liquid separator for fish hold 12.5 in diam × 35.4 in h × 1
    set
    (318 mm diam × 900 mm
    h × 1 set)

for freezing 8.5 in diam × 70.1 in h × 2
    sets
    (216 mm diam × 1,780 mm
    h × 2 sets)

Cooling coil for fish hold 1.68 in diam × 1,968 ft L
    (5 series)
    (42.7 mm diam × 600 m L
    (5 series)

for freezing 1.68 in diam × 2,624.6 ft L
    (4 series)
    (42.7 mm diam × 800 m L
    (4 series)

Discussion: The application of contemporary engineering techniques to fishing craft

MECHANIZING INDIGENOUS CRAFT

Høgsgaard (Denmark): Denmark began mechanization by using four-stroke hot bulb engines while in Sweden two-stroke hot bulb engines were adopted. Sweden made the better choice, so when larger sizes came into use, the Danes changed to the Swedish system. The Swedes used water injection. It is very important that engines can run a long time at low speeds. The combustion chamber is usually made in two halves like a ball. The Swedes used injection at the top of the combustion chamber. The injection on full-power was direct and concentrated. At low speeds, fuel is sprayed to the sides of the bulb. In Denmark the atomizer is installed on the side and this gives excellent results.

Borgenstam has given an excellent paper, but Høgsgaard did not recommend blow-lamps. Sulphur cartridges should be used instead for starting. Høgsgaard would like to add that low-compression engines are not necessarily dirty. He considered that in Denmark they had arrived at an excellent result with their low-pressure oil engines. This is the most uncomplicated engine type ever manufactured and is very useful in countries where not sufficient trained people are available.

Developments in India

Gnanadoss (India): Kvaran had observed that competition from completely new mechanized boat types had tended to slow down the process of mechanization of existing craft. This is not to be taken as a general feature. In India, mechanization of fishing craft started with indigenous fishing craft after World War II, and modern, well-designed boats were introduced about ten years later. Today they have nearly 4,000 indigenous fishing boats mechanized in India and more and more existing craft are being mechanized every year.

These craft are well advanced from the point of view of design, and also well adapted for the type of fishing they are engaged in. Most important of all, they could so easily take an inboard engine to provide the motive power which is in fact the only aid the fisherman needs for his method of fishing. The low building costs of these existing craft also contribute a good deal to this development. Therefore, it follows that mechanization of existing craft is not a preliminary step to favour development, as Kvaran has put it, but is the final step itself—as far as these boats and the fishing they are meant to exploit are concerned. It should, however, be stressed, that these boats are essentially inshore fishing boats.

The real problem in India is the matter of proper powering of these boats. In most cases, these boats have been considerably overpowered. The psychology of the fisherman being the same the world over, whenever the fisherman has the choice of the engine, he tries to install an engine which is more powerful than what his friend's boat has—to satisfy his pride and to get that imaginary extra knot—which he seldom does. This psychology has, to some extent, been taken advantage of by some engine salesmen, which of course has not done much good to the fishermen.

One of the disheartening aspects of mechanization in India is the after-sales service by the engine supplier. In many instances, such a facility does not exist at all, and even if it does, the benefit of such service is meant to go more to the engine supplier himself than to the fishermen.

It is needless to emphasize that the service mechanic should be a person who can identify himself completely with the fisherman, go out to sea with him and share his experiences in full. There have been instances of service mechanics who could not even withstand the motion of boats while in the harbour and have demanded that the boat be put on hard ground if the engine has to be attended to.

Although hundreds of engines of four or five different makes have been sold in India, Gnanadoss had yet to come across any one engine supplier who attempted to come closer to the fisherman by providing him with a simple instruction manual which the fisherman can read and understand.

Strong demand in Tanzania

Chipepo (Tanzania): There is a great demand for outboard and inboard motors in Tanzania, East Africa.

The traditional double chine boats, called Ka Rua, are the ones mainly built there by the local carpenters. The length of these craft is less than 40 ft (12.2 m), using one main sail. The rigging of the sails has been learned from the Arabs. They are driven by the wind. Both large and small types of these craft use the same means of sailing. Some of these boats are good if they are mechanized by outboard or inboard engines for the larger ones. Prototype boats have been developed by the Ministry of Agriculture in 1961. It took three years to arouse the fishermen's interest in modern craft.

Later the fishermen were given loans to enable them to buy the new types of small craft. These craft are built by 12 apprentices and are 24 ft (7.3 m) in length and powered by 10 hp outboard motors. Eventually, some of the first-mentioned sailing boats will be mechanized. The experience gained by other developing countries and the information on experiments conducted elsewhere will be of much benefit to Tanzania when outboard and inboard mechanization is started.

Earnings must increase

Sapre (India): Kvaran and Borgenstam have given very useful information. Kvaran has stated that labour-saving is not in itself an objective. This is not clearly understood. When a boat is motorized, the owner has to increase his earnings by various ways like going out to sea for a longer time, using more gear, etc. However, it may not always be possible to increase his earnings sufficiently and in such an event he may prefer to reduce one of his crew to increase the earnings per head. This is more so when a new boat is built and the engine is installed. With rising costs of boat-building materials and engines, the use of labour-saving devices appears essential. It would have been advantageous if winch installation would also have been covered along with the engine installation.

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No mention has been made about spares. It is very essential to provide for spares, especially if the engine is an imported one. Sapre agreed with Kvaran's remarks about difficulties with stern gear when it is not manufactured by engine makers. Kvaran has correctly emphasized the unsuitability of some materials in tropical waters, even though they may be suitable in temperate waters. In a few cases, the fishermen lost their propellers, as the propeller shaft and nut were not made of proper material. The remarks about hand-starting of engines are useful.

Borgenstam has covered various aspects with regard to marinization of automotive engines. In India a few engines of "land type" are being marinized and the various points stated by Borgenstam on marinizing should be of benefit.

McNeely (USA): Kvaran pointed out the need to do more than just sell an engine or other equipment. One must also provide training, repair facilities and periodic maintenance checks. This is an excellent paper with invaluable hints for anyone connected with mechanization of indigenous small craft in developing countries.

Borgenstam's paper with its thorough discussion of problems in the introduction of mechanization to small craft in developing countries is valuable for its presentation of the relationship of social preferences in the selection of size and type of engines, controls, propellers and fuel systems. He gave hope that a current transition period between ignorance and familiarity with modern mechanisms will solve some of the problems.

Skilled maintenance essential

Lyon Dean (UK): Mentioned the importance of the training of those who are to look after the engines. Dean underlined what Gnanadoss had said on this point, which is a problem not only for developing countries. Any new mechanical development on a fishing vessel tends to be looked upon with suspicion by fishermen. The advantage of this new mechanical equipment can be nullified by very minor failure.

Therefore, if one is to have new mechanical equipment accepted readily, one must ensure that the operator at sea is trained in its use and its maintenance. Engineers on fishing vessels should be trained to a comparable level with merchant marine engineers.

A comprehensive spare part service should be available in local engineering shops and repairs carried out by men who have been fully trained by the makers in major servicing. This will be even more important when going into diesel electric machinery.

Useful experience from Ireland

O'Connor (Ireland): Kvaran's paper gave a very adequate account of the many problems facing development officers in many countries. Kvaran has, in enumerating all the difficulties which can arise in engineering indigenous craft, made a very good case for concentration by developing countries on the establishment of suitable designs for motorization. O'Connor suggested for Kvaran's consideration that the successful scheme adopted in Ireland for the replacement of the manually propelled "curragh" of lath and canvas by a planked open boat of 26 ft (8 m) or 3 GT (weight 1 ton) powered by an 8.5 hp air-cooled diesel with 2 : 1 reverse gear on propeller, and financed mainly by a grant and low interest loan scheme might be suitable for copying. These small craft in Ireland are operated mainly by part-time fishermen on pot fishing, drift netting and even trawling and are to be found very widely scattered on general rocky West Coast of Ireland. They can be beached satisfactorily in not too difficult a manner and kept in safety during severe weather, which has a habit of occurring without much warning on the Atlantic shore. If he were Kvaran, O'Connor would concentrate on outboards for small craft motorization if hulls were not designed for inboard engines and would expect fewer headaches as a result. This problem was dealt with in Ireland by the organization of a fleet inspection and maintenance scheme, operated by his Board and designed to improve standards and thus protect state investment.

Kvaran mentioned the problem of maintenance. This Irish maintenance scheme was successful and there is now much greater interest in the machinery and its care, so much so that the Board no longer does the work and limits itself to the free inspection of both engines and hulls. Report is given to a skipper giving advice as to the work necessary and if he so requests, the work is inspected after completion also. Simultaneous with the maintenance programme, interest was aroused among local garages and machine shops in marine engine repair and maintenance, as many of these had experienced diesel fitters who were, on inspection, found quite capable of carrying out this work and are now doing so, thus replacing the Board's service satisfactorily, it having initially brought the machinery to a reasonable condition.

It was found, however, that it became necessary to give special attention to those operators of the smaller size craft who lay their boats up for the winter. Proper steps were not being taken to ensure the well-being of the engines. For this reason a programme of special visits has been commenced by the diesel engineer at lay-up time, to these owners to show them exactly how the lay-up should be done and special advisory leaflets have been prepared and distributed.

Economic points

Mendis (Ceylon): Estlander and Fujinami point out that the fishing economy is affected by the number of nets and the number of days that a fisherman can operate, and they give a figure of 65 nets which can be shot quickly enough, but take a long time to haul. Sixty-five nets would be 7,800 ft (2,400 m) long and at a hauling speed of 20 ft (6 m) per minute, this would take 6½ hours hauling time. A heavy catch of fish or change in wind direction also puts a limit to the number of nets that one should chance shooting.

A 17½ ft (5.3 m) boat with 10 hp outboard and two men working from 10–15 nets has now become very popular in Ceylon.

Ferrer (Philippines): Considering the mechanization of indigenous boats and the acute lack of capital, the engines must be inexpensive. The dugouts in the Philippines are now using 5 to 10 hp four-stroke air-cooled engines. The stern tubes and fittings are manufactured locally at a cost of about £7 ($20) and the engines are very reliable ones costing about £45 to £90 ($125 to $250) per unit. This price is very reasonable and within the reach of the fisherman. These engines are those normally used, even though they do not have the refinements of self-starting and reversing gears. Some 4,000 units are now in use with very satisfactory performance.

Progress in Japan

Yokoi (Japan): The total number of fishing boats in Japan has been slightly decreased from about 400,000 in 1954 to about 380,000 in 1963. However, the motorization of these fishing boats has been considerably advanced year by year. In 1954 the powered fishing boats occupied only 34 per cent of total numbers, but in 1963 it was increased to 51 per cent. It should especially be noted that the number of powered fishing boats over 5 GT had not been increased but under 5 GT the number has increased 1.54 times during this period. Only 28 per cent of fishing boats under 5 GT were motorized in 1954, but in
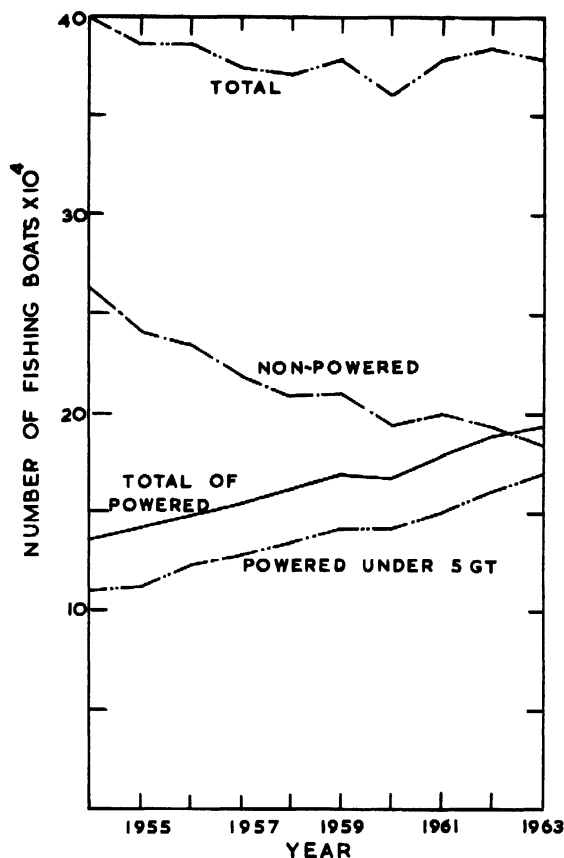
Fig 1. Motorization in Japan

Fig 2. Motorization under 50 GT

1963 the figure was raised up to 45 per cent. The number and percentage of powered and non-powered boats under 5 GT is shown in fig 1; fig 2 indicates engine types for the powered boats over the past ten years.

Tables 1 and 2 show the progress of mechanization and types of engines used for various sizes of vessels.

From table 2 it is clearly seen that diesel engines play the most important role in mechanization of small craft in Japan.

Over 80 per cent of fishing boats of 1 to 5 GT are motorized and this percentage is increasing year by year. For the power source of the boats, use of diesels is being increased and it is assumed that most of the boats will be powered by diesels in the near future. Generally speaking, the size of power required

for fishing boats varies according to the fishing method and place, and it is difficult to obtain exact relation between size of boat and engine power. Fig 3 shows the relation between the gross tonnage of boats and hp range of diesels and the speed of the boat obtained under the condition, based on the statistics of existing vessels in Japan. It is normal for these vessels that the range of L/B is 4 to 5 and L/T is 8 to 11. Average main dimensions, engine output and speed obtained for various sizes of Japanese vessels are shown in table 3.

A few examples of principal particulars of diesel engines

TABLE 1

Progress of mechanization of various sizes of vessels

	Grand total	Under 1 GT	1–3 GT	3–5 GT
Total	350,258 (100%)	202,063 (100%)	120,649 (100%)	27,546 (100%)
Non-powered	182,574 (52.0%)	158,223 (78.5%)	20,791 (17.0%)	3,560 (13.0%)
Powered	167,684 (48.0%)	43,840 (21.5%)	99,858 (83.0%)	23,986 (87.0%)

TABLE 2

Types of engines used for various sizes of vessels

	Grand total	Under 1 GT	1–3 GT	3–5 GT
Diesel	107,757 (64.0%)	20,296 (46.1%)	70,551 (71.0%)	16,910 (70.0%)
Hot bulb	11,201 (6.7%)	384 (0.9%)	4,768 (4.4%)	6,049 (25.0%)
Electric ignition	48,726 (29.3%)	23,160 (53.0%)	24,539 (24.6%)	1,027 (5.0%)

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TABLE 3
Average main dimensions, output and speed of various sizes of vessels

			Under 1 GT	1–2 GT	2–3 GT	3–5 GT
Length	. . . .	ft	16.4–21.3	21.3–36.2	27.9–31.2	31.2–36.1
		m	5.0–6.5	6.5–8.0	8.5–9.5	9.5–11.0
Breadth	. . . .	ft	3.3–3.9	4.3–5.3	5.6–6.2	6.2–7.2
		m	1.0–1.2	1.3–1.6	1.7–1.9	1.9–2.2
Depth	. . . .	ft	1.6–2.3	2.0–2.6	2.3–3.0	3.0–3.3
		m	0.5–0.7	0.6–0.8	0.7–0.9	0.9–1.0
Engine output	. . . . . .	hp	3–5	6–10	10–15	15–25
Engine weight	. . . . . .	lb	220–440	440–550	550–880	880–1190
		kg	100–200	220–250	250–400	400–540
Speed	. . . .	knots	4.5–5.0	5.0–5.5	5.5–6.5	6.5–8.0

TABLE 4
Specifications of diesel engines (vertical type)

Item	Unit	Under 1 GT	1–2 GT	2–3 GT	3–5 GT
Cooling system		Sea water	Sea water	Sea water	Sea water
Cylinder arrangement		Vertical	Vertical	Vertical	Vertical
No. of cylinders		3	2	2	1
Cylinder bore	in	3.7	3.7	3.3	3.3
	mm	95	95	85	95
Stroke	in	4.5	4.5	3.9	4.5
	mm	115	115	100	115
Stroke volume	in^3	149	99	69	50
	cm^3	2,445	1,630	1,135	815
Output	hp	24	16	11	7
No. of revolutions of crank shaft . . .	rpm	1,600	1,600	1,650	1,400
No. of revolutions of propeller shaft . . .	rpm	870	870	708	805
Break mean pressure	lb/in^2	78.2	78.2	75.1	78.2
	kg/cm^2	5.52	5.52	5.29	5.52
Piston speed	ft/sec	20.1	20.1	18.0	17.6
	m/sec	6.14	6.14	5.5	5.37
Dry weight (including stern gear) . . .	lb	1,057	814	550	506
	kg	480	370	250	230
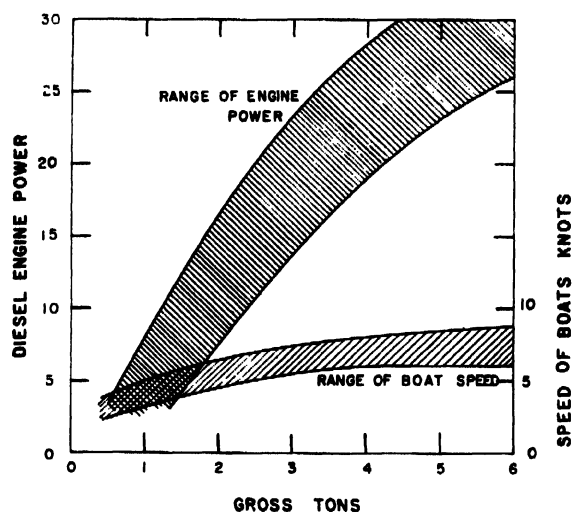
Fig. 3. Size, speed and hp of boats

are shown in table 4, according to the sizes of vessels installed with them, and an installation arrangement of such an engine is shown in fig 4.

These engines are designed for less expensive production, easy handling, long durability low maintenance cost and comparatively light weight.

The motorization of fishing boats under 1 GT is far behind. In 1963, approximately 80 per cent of them were not powered. There were a few types of vertical water-cooled diesels for this size of vessel. Easy handling, easy starting by hand, light weight, low fuel consumption, long durability and low maintenance costs are the most important factors indispensable to this size of engine.

The modification of horizontal water-cooled diesels for agriculture and industrial use into marine diesels has already been taken up. For this, the rpm is reduced and a reversing gear added. The power takeoff has been connected to the propeller shaft through the reversing clutch as the power takeoff runs at half speed of crank shaft. The stern shaft is equipped with the lifting device in most cases, which is convenient in shallow waters.
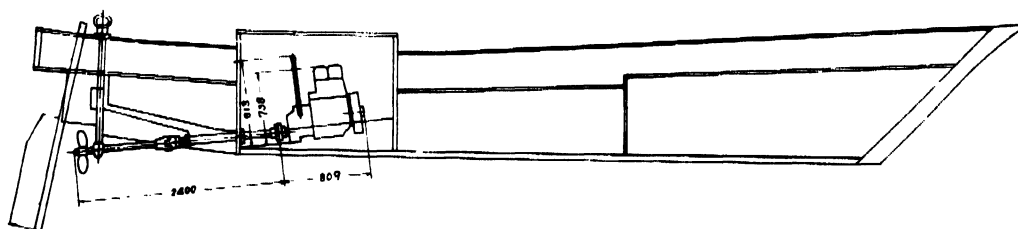
Fig 4. Layout of 2 to 3 GT boat with 4 hp horizontal diesel

Technical details

Modified engines are equipped with cooling water pump instead of evaporating cooling with a hopper tank provided with land-use horizontal diesels. The fuel oil tank is usually integral with the engine body for the land-use horizontal diesels, but this has been so modified that the tank can also easily be installed separate from the engine body. Fig 5 shows the installation drawing. The specification of the engine is referred to in the first and second columns of table 5.

These diesels have comparatively small height and can be installed under the working deck and keep good stability. Since the engines are compact, less space is required. At present, over 10,000 sets of this type of engines have been used, forming about 23 per cent of the powered boats under 1 GT.

A special arrangement has been made to install small horizontal agricultural diesels. This particular application has been successfully made in Vietnam. The Vietnamese indigenous fishing boats are called "bamboo bottomed" junks. The hull is made of bamboo-knitted basket and detachable wooden deck is fitted. It is difficult to install the conventional marine engine in such a unique boat. Therefore, a special outboard engine with combination of compact, light rigid agricultural diesel and stern gear devices has been successfully developed. These engines are the same as the engines which have been used for pumping water, polishing rice, running fibre decorticator and so on in the country (fig 6).

The engine hopper is provided with the device to protect overflow of the cooling water. The stern gear device is driven

TABLE 5
Specification of small diesel engine (for under 1 GT boats)

	Unit	(1)	(2)	(3)	(4)
Cooling system		Sea water	Sea water	Sea water	Air
Cylinder arrangement		Horizontal	Horizontal	Horizontal	Vertical
No. of cylinders		1	1	1	1
Cylinder bore	in	2.8	3.3	2.6	2.6
	mm	70	85	65	65
Stroke	in	3.1	3.9	3.0	2.8
	mm	80	100	75	72
Output	hp	3	4	3	3
Stroke volume	in³	19	35	15	15
	cm³	308	567	249	239
No. of revolutions of crank shaft . . .	rpm	1,800	1,500	2,000	2,600
No. of revolutions of propeller shaft . . .	rpm	900	750	1,000	1,300
Brake mean pressure	lb/in²	69	60	77	62
	kg/cm²	4.87	4.23	5.43	4.35
Piston speed	ft/sec	16.4	15.7	16.4	20.4
	m/sec	5.0	4,8	5.0	6.24
Dry weight (including stern gear) . . .	lb	286	440	207	148
	kg	130	200	94	67
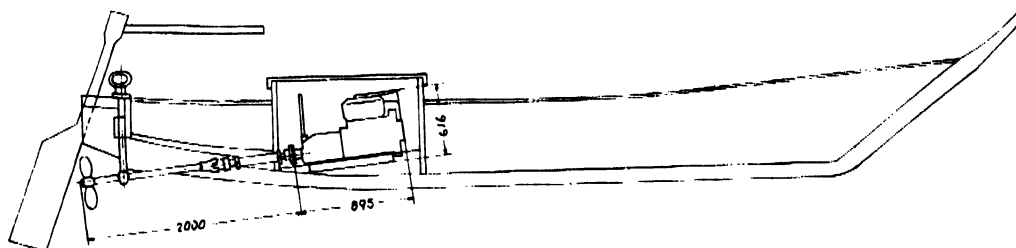
Fig 5. Layout of 0.8 to 1.5 GT boat with 4 hp horizontal diesel
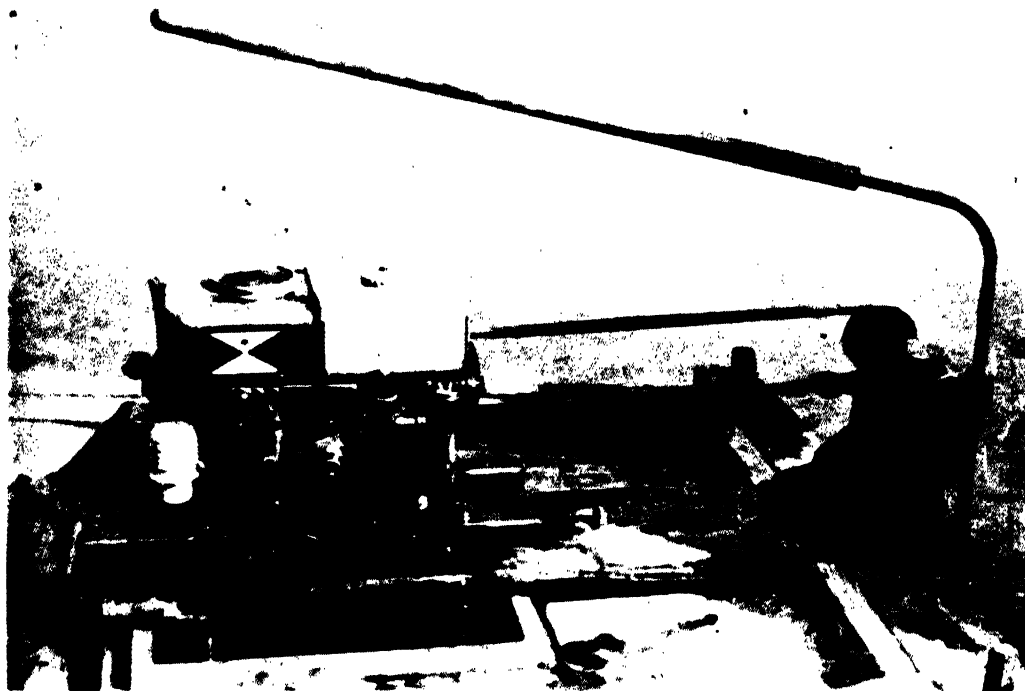
Fig 6. A 3 hp horizontal diesel installed on deck

by a V-belt and the reduction of the propeller speed is adjusted by the pulley ratio. It is equipped with lifting device and clutch gear which provides positions of forward, neutral and reverse. This special engine has all the necessary function for operation of the boat. The engine and stern gear can easily be installed or detached respectively with only four bolts. At present these engines have the types of 3, 3.5, 4.5, 5, 6 and 8 hp. For reference, the specification of the 3 hp engine is shown in column (3) of table 5 and fig 7 indicates installation drawings of the engine with the "bamboo bottomed" junk.

Some types of small fishing boats are constructed with very thin board, therefore, it is indispensable to install lighter
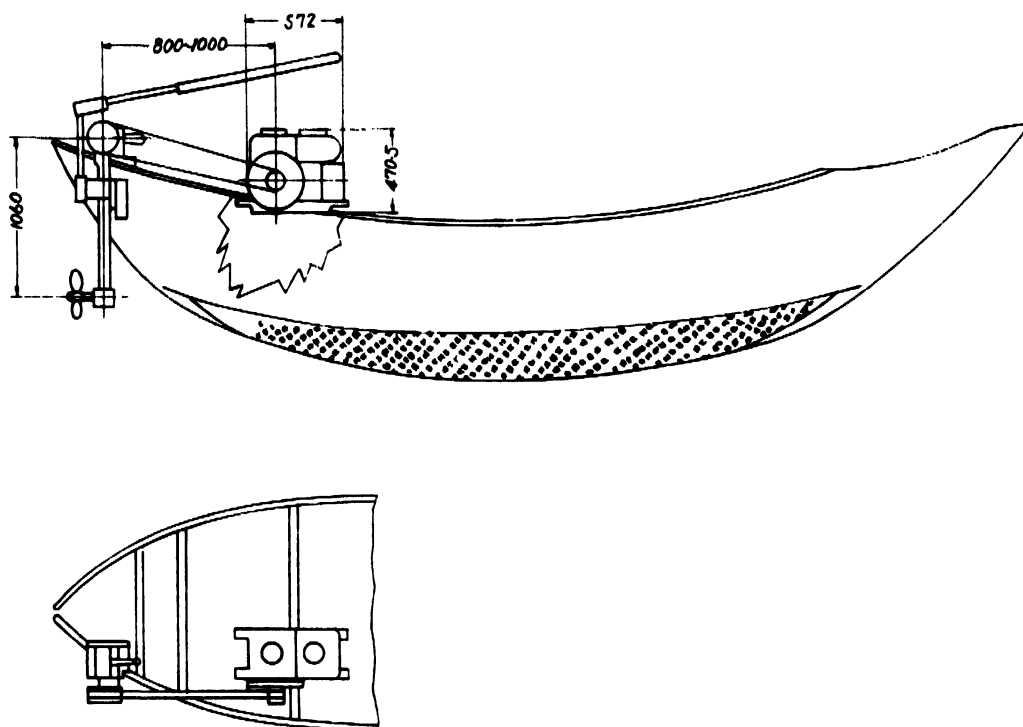
Fig 7. Layout of 2 to 14 GT Vietnamese fishing boat with 3 hp horizontal diesel

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diesel engines on such boats. For instance, the aforementioned horizontal diesel engine of 3 hp weighs 210 lb (95 kg), including stern gear, which might be a little too heavy for the small boats, depending on the construction of hull. Taking this into consideration, the undermentioned engines have been developed for inboard installation.

The modified air-cooled diesel develops 3 hp and weighs about 148 lb (67 kg) including reversing clutch with reduction gear. The air-cooled diesels were originally designed for land use and have been used for powering agricultural two-wheel hand tractors, portable generators, air compressors, winches, etc. And with adaptation of reversing clutch with reduction gear, these engines have been developed into marine diesels; they are cheaper due to mass production and have the characteristic of easy handling, rigid construction and lower maintenance cost. The power of the engines is taken off from the crankshaft and is connected to the propeller shaft through the reversing clutch with reduction gear. The reversing clutch with reduction gear is of simple cone type.

in sheltered water, 1 hp per 1 ft (0.3 m) of boat length;
in open sea 2 hp per 1 ft (0.3 m) of boat length;
for shrimping 1½ hp per 1 ft (0.3 m) of boat length.

The Government is anxious to obtain bigger boats in order to develop lobster, shrimping fisheries and middle-water trawling.

Propeller noise

Margetts (UK): The question is: does noise from the propeller frighten fish? Mechanization has been profitable and, with unchanged fishing gear, ships have progressed from the use of sail, which is silent, through steam engines to noisy motor boats, but still the catches have kept increasing. So it can be said that noise has not had a very bad effect.

Fish can hear and their range of hearing is somewhat similar to that of human beings. They are most sensitive to low-frequency noises. Their ability to detect direction is, however, poor. A steadily-increasing noise, e.g. from an

Fig 8. Layout of 0.5 to 1.1 GT boat with 3 hp air-cooled diesel

The installation of the 3 hp engine is shown in fig 8. The specification of this engine appears in column (4) of table 5. About 2,000 sets or more of the air-cooled marine diesels have been in use in Japan, Okinawa and South-East Asian countries for the last one or two years.

Caribbean practice

Plosso (Trinidad and Tobago): Good fishing grounds surround his islands. This has attracted over 200 Japanese longliners fishing for tuna and large numbers of fishing boats from Formosa and the USA fishing for shrimp. Although the population is one million and there are 74 fishing centres there are no fishing harbours. There are about 2,400 pirogues propelled by outboards of about six different types and 600 shell boats powered by inboard engines. The outboard motor on the pirogue must be carried from the water to the fisherman's home daily and should therefore be light. The 600 shell boats are 35–40 ft (10.7–12.2 m) long and are used for shrimping.

Maintenance and servicing are important requirements. Therefore most fishermen have two outboard motors, so that if one should fail, the other may be used while the other is repaired. The distance to the repair shops is sometimes as much as 20 to 30 miles, therefore the outboard is preferred because it is much easier to transport an outboard engine to the depot than tow the boat with the inboard engine to the repair shop. The average catches of pirogues engaged in trolling and handlining is 60 to 80 lb (27 to 32 kg) per day and 300 to 500 lb (135 to 230 kg) when gillnetting. The fishermen are encouraged by the Government by a duty rebate on gasoline and diesel oil, a loan for buying a boat or engine and on engines and no import duty imposed on vessels over 35 ft (10.7 m) in length and on engines and special equipment on fishing vessels. As a general guide for engine installation, the fishery authority recommends the following:

advancing trawler, probably does not affect the fish, but a sudden noise will frighten them perhaps causing them to scatter. In some methods of fishing such as ring netting, the crew are careful to make as little noise as possible.

Trawl warps split up shoals of pelagic fish and steaming ships disperse fish near the surface, but this is probably due to sight rather than sound. It is likely that in dirty water propeller cavitation will not affect fish much because it cannot be seen, and that in clear water it is only one of a number of things that fish will see, so that, in general, propeller cavitation will not be an important factor in frightening fish.

There are, however, many species of fish and wide ranges to both their condition and the condition of their environment so that the sort of generalization given here must be accepted as such.

Traung (FAO): When fishing for tuna with live bait in Australian waters, it has been noticed that steel ships catch rather less than wooden ones. Ships with their engines aft catch rather less than those with their engines forward because fishing is done aft, and if the auxiliary engine is near deck level rather than below the water level, so much the better. It seems that vibrations aft are especially liable to reduce the catch.

Nickum (USA): In the first steel tuna clipper in the USA, it was considered whether the hull noise would frighten the fish. Douglas Fir chocks were placed under the engine and there was no problem because of the steel hull construction. As has been pointed out by Traung, generators are normally placed on the upper deck, but in many USA tuna clipper boats they are placed in the engine room, with no noise difficulties although it must be said the engine rooms are forward, away from the fishing area.

There is a great difference in tropical and temperate conditions as far as equipment and machinery is concerned. Even

though the machinery may be designed to operate at 85° F (30° C) water temperature, they do not always function well. Heat transfer rates must be closely watched and also excessive corrosion. An example of this is a 10,000 tons fish factory vessel whose ammonia condensers had ⅝ in diameter tubes which after four months were so fouled that it required the entire freezing capacity of the plant just to hold the temperatures in the storage hold.

OUTBOARD AND INBOARD ENGINES

Selman (UK): In recent years FAO has done much to encourage the mechanization of small indigenous craft through the medium of outboard petrol engines. They were probably right in doing so, since it can be shown that such engines can be used to propel the most primitive and inexpensive of all craft; a solid log.

However, in Selman's opinion, outboard petrol engines have little advantage except their first cost which might approximate a half to a third of a comparable diesel inboard engine. However, since so many outboards are primarily designed for relatively high speeds of the order of 20 knots and have a very small propeller, full revolutions are seldom achieved in small indigenous craft capable of speeds of the order of 5, 6 or 7 knots and it is by no means unusual for the potential thrust to be reduced to about a quarter of what is possible, if a much larger propeller running at much lower speeds could be adopted. Some few firms do in fact fit 4 : 1 reduction gears and larger propeller more suitable for small commercial craft but these of necessity cost more.

Selman hoped everybody concerned would be quick to adopt the next step which he saw as simplified by soundly designed craft of a more serviceable and conventional type, propelled by the cheapest of all inboard diesels, the small air-cooled. The high cost of petrol and frequent servicing required
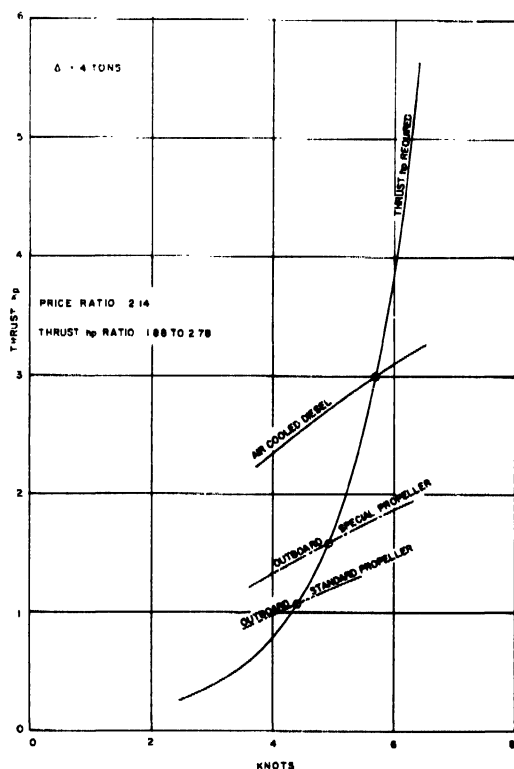
Fig 9. Performance of a 25 ft craft
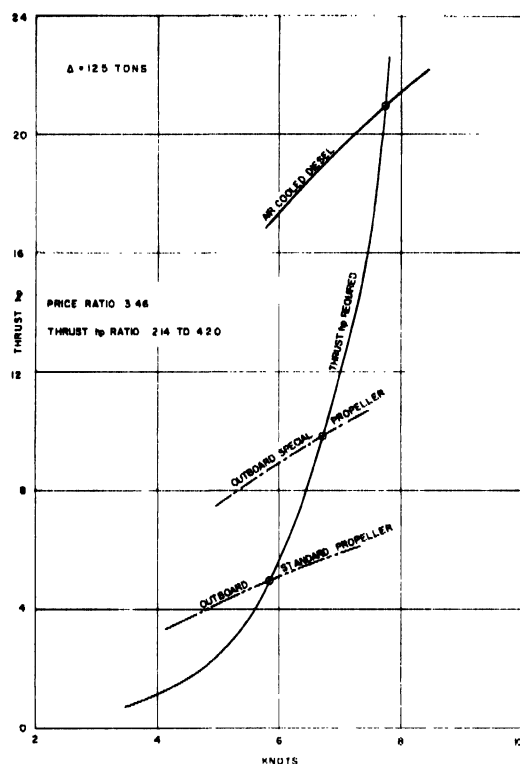
Fig 10. Performance of a 36 ft craft

by the high-speed petrol outboard will, Selman felt, cause some disillusionment to native fishermen unless progress can be quickly made towards more sophisticated craft.

Reference had been made to diesel outboards and Selman remembered examining a 40 hp engine of this type made by a British firm and exhibited at a Boat Show some four or five years ago, but which never went into production. Such engines would prove too heavy for the transom of most small craft and produce an undesirable trim. Consider the advantages of a small air-cooled engine. There is little to go wrong—there are no water pumps, pipes or heat exchangers and in cold climates there is nothing to freeze up, the fuel cost is nominal and at 2,000-odd revolutions, very low maintenance.

A comparison made of the performance of a hypothetical 36 ft (11 m) craft weighing 12.4 tons shows that a 40 hp air-cooled engine fitted with a 2 : 1 reverse reduction gear was capable of only 5.9 knots for the same nominal power, and if the propeller pitch be modified to absorb the whole of the power available, 6.7 knots became possible.

Actually in the three alternatives the thrust hp was 21, 5 and 9.8 which shows that although the diesel would probably cost from twice to three and a half times the price of the outboard, the diesel cost £41 ($115) per thrust hp, whereas the outboard cost could vary between £50 and £26 ($140 and $73) when the reliability life and running cost of the outboard is taken into account probably of the order of 2 or 3 : 1. More attention should be paid to the use of diesel engines since mechanization has proved worth while. A similar comparison has been made for a 25 ft craft and details of both are shown in fig 9 and 10 and table 6.

Not designed for fishing work

Gulbrandsen (FAO): In any discussion of outboard and inboard motors, it must be remembered that the present type of outboards used in fishing boats is to a large extent a

TABLE 6

Comparison of economics of outboard with inboard air-cooled diesels

Boat L ft	Δ. tons	Type	Engine characteristics hp	rpm	Price	Performance with standard propeller Propeller designed for knots	Propeller Diam. in	Pitch	Actual speed knots	rpm	hp devel- oped
25	4	out-board	6.0	4,500	£115 ($322)	10	6.4	3.94	4.43	3,650	4.38 (1.08 thrust hp)
25	4	air cooled diesel	6.5	2,000	£245 ($690)	5.7	16.2	4.45	5.7	2,000:2	6.5
36	12.5	out-board	40	4,500	£250 ($700)	20	8.96	4.07	5.9	3,100	27.5 (5 thrust hp)
36	12.5	air cooled diesel	48	2,000	£866 ($2,430)	7.75	20.1	13.56	7.75	2,000:2	48

Performance with special propeller Boat L ft	Type	Propeller Diam. in	Pitch	Actual speed knots	rpm	hp devel- oped	Thrust hp
25	out-board	6.4	3.33	4.94	4,500	6.0	1.6
25	air cooled diesel	—	- -	—	—	--	3.0
36	out-board	8.96	4.94	6.70	4,500	40	9.8
36	air cooled diesel	—	---		—	---	21

For 25 ft boat price per hp for air-cooled diesel is 1.96 times outboard but only 13 per cent dearer per thrust hp under best conditions for outboard.

For 36 ft boat price per hp for air-cooled diesel is 2.88 times price outboard but only 62 per cent dearer per thrust hp under best conditions.

Running costs of outboard likely to be 3 times that of air-cooled diesel.

Note: cost for air cooled-engine includes stern gear, shaft stern tube and propeller.

converted pleasure boat engine and not fitted for the job. To be fair, one must compare the best type of inboard diesels with the best type of outboard gasoline motor suitable for heavy fishing boats. That means a sturdy engine fitted with a slow-running, large-diameter propeller. This importance of low-propeller revolution has been clearly pointed out by Traung (1960c, 1964). Since then, there have appeared on the market some motors following this suggestion. Gulbrandsen had the opportunity to test two identical motors of 18 hp, but with largely different propeller-revolutions and propeller diameter on a 21 ft (6.4 m) beach-landing boat with a displacement of 1.1 tons.

Fig 11 shows the result of the tests. Above 6.3 knots, that means for the higher thrust, engine A with the large-diameter propeller, is clearly the most efficient. At full throttle, it gives half a knot more speed than engine B. With a heavier displacement, the difference would have been even greater. The fuel consumption curve shows the bad economy to run the engine at full throttle. The resistance of the boat increases sharply above a speed-length ratio of 1.4. Reducing the throttle in this range has little influence on the speed, but cuts drastically on the fuel consumption. If, for engine A, the throttle is reduced so that the boat makes half a knot less speed, the fuel consumption drops from 1.36 to 0.88 Imp gal/hr (6.2 to 4 l/hr), a saving of 35 per cent. Tests with other outboard engines showed that the same speed reduction meant a saving of 25 to 30 per cent in fuel consumption.

These are figures that really count. Applied to the comparison between outboards and inboard motors on a 27 ft (8.2 m) boat—as appeared in the paper by Estlander/ Fujinami—it means that the figure of 1.75 Imp gal/hr (8 l/hr)

quoted as the fuel consumption of a 14 hp motor can easily be reduced by 25 per cent, that is to say to 1.32 Imp gal/hr (6 l/hr) by using the right motor-propeller combination. This gives £130 ($360) less in yearly running costs for the single outboard alternative and a corresponding 26 per cent increase of profit.

It's shocking how little attention some outboard dealers pay to adopting the right propeller for the boat. Gulbrandsen had seen an example of nearly a thousand outboards being sold to native fishermen in a West-African country without any check on the performance when mounted on the canoe. The pitch of the propeller was too big, and all the engines were working far below the operating range recommended by the factory. There is no excuse for carelessness like this. With an outboard it is a very simple operation to try different propellers, measure the rpm with a vibrator tachometer and select the propeller giving the rpm recommended by the factory.

The fisherman who wants to buy an outboard for his heavy displacement boat, should keep the following well in mind:

● Select an engine with a big gear reduction and a large diameter propeller
● Ask the dealer to test the engine on the boat, measuring the rotation per minute, to insure that the motor is working in the rpm range recommended by the factory
● When going to and from the fishing grounds, remember that reducing the throttle so that the engine works at approximately 500 rpm lower than maximum, means a great saving in fuel consumption and an increased life of the engine

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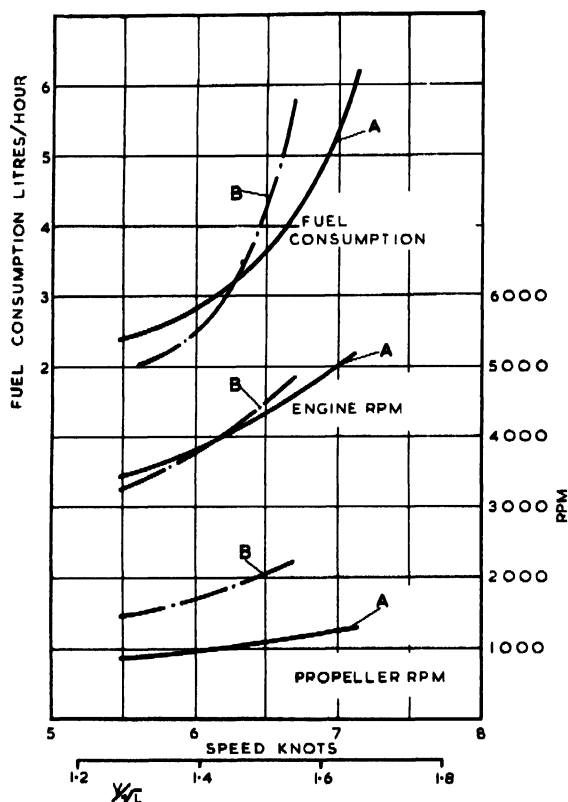
Fig 11. Results of tests on two 18 hp motors with differing propeller revolutions and diameters

A buyer of an outboard for a fishing boat should pay just as much attention to the gear ratio and the propeller diameter and pitch as to the labelled horsepower. He should test the motor on the boat, measuring the rotation per minute to ensure that the motor is working in the rpm range recommended by the factory. Only in that way can he be sure that the thirsty horses in his engine are doing their job.

Importance of canoe catch

Gurtner (FAO): In table 2 of the Estlander/Fujinami paper, the figures quoted for canoe mechanization in Senegal need an adjustment, in as much as the total number of canoes in service is about 5,500, of which approximately 2,500 to 3,000 are mechanized with outboard motors. These canoes account for about 90 per cent of the annual catch of the country, which in turn amounts to about 90,000 tons. The conditions under which this outboard mechanized fishery works are almost identical to the ones mentioned by Stoneman. Mechanizing of Senegal's canoes with outboard motors began before FAO was materially involved in assisting other countries in similar work. This is an indication that not only FAO but also other people consider outboard mechanization to be generally beneficial to canoe fisheries.

One important reason why this is so can be found in an inherent structural weakness of dug-out canoes. The section in the stern of the canoes, which would normally take the stern tube if an inboard engine were installed, consists almost entirely of heart wood of very low strength. Apart from making it difficult to fix a stern tube in this section, vibration set up by a stern tube would probably destroy the dug-out canoe very quickly.

Tito (Belgium): Estlander's paper is important and many problems can be solved if his advice is followed. Each type of

engine has its purpose and sometimes an outboard is the only reasonable answer, but one should naturally use the inboard diesel where it is more economical. In the year 1907, a four-stroke engine with a driveshaft over the stern was first introduced by a Frenchman.

Traung (FAO): Yes, outboard *versus* inboard is not really a correct way to pose the problem. It is really *when* outboards and *when* inboards, because sometimes one has to use outboards and sometimes inboards. Experienced technicians can be of much help to investigate special cases and give advice.

Problems with outboards

Stoneman (Uganda): General observations on outboards in use in Uganda:

● Of some 6,000 fishing boats and canoes in Uganda up to 30 ft (9 m) long, 1,500 are powered by outboards between 5 to 20 hp. Annual catch is worth £2.8 million ($8 million)

● The reason for overwhelming numbers of outboards primarily, they are cheap and simple. Craft are beached each night. Operation life of motors is two to three years, after which the engines are thrown away. Many owners have two motors, one in use, one under repair

● Almost all maintenance is by unskilled and heavy-handed ex-cycle repairers

● There are many failings with the engines. Nuts and bolts vibrate loose. Propeller blades get knocked off. Power head casings break. Lower ends drop off. Recoil starters pull out. Water pumps fail. Manufacturers say this is due to poor operators and poor maintenance. This is true, *but* this situation cannot be changed for many years. If the men cannot be trained to use the engines correctly, engine manufacturers must produce engines which can stand this kind of abuse. This can be done

● The above principle should be applied to much of the previous discussion and to assist the developing countries. It is no use suggesting ideal solutions to the problems if it is clear that they will never be implemented. Designers must find out by personal experience what is within our power and design their product accordingly

Nickum (USA): A word to outboard manufacturers. There is a need for heavy-duty motors and better hydrodynamic qualities around the shaft strut and propeller. Lower efficiency can sometimes be accepted in pleasure boats use, but for larger installations and commercial use more work should be done on efficiency of flow around the shaft.

Specialized types developed

Watase (Japan): Before 1957, there was little demand for outboards in Japan, except for racing outboards. Accordingly, the outboard industry consisted of mainly small enterprises which manufactured small quantities of racing outboards. Since 1958 the demand, thanks to motorization of fishing boats and the leisure boom, has increased. As a result one large enterprise after another pushed into the field of outboards and gradually the expansion of production scale was done.

Total production of outboards in Japan was 2,900 units in 1957. In 1964 it was 17,800 units. The percentage of increase of production showed over 600 per cent in 1964, compared with 1957. This is because the motorization of fishing boats was urged according to the modernization of fishing in Japan. Therefore, the main range and majority of outboards in Japan is lower power motors, that is, below 10 hp.

One outboard runs on kerosene and is suitable for the conditions of fishing village economy. The development of

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such kerosene engines became a main factor to show the marvellous increase of production, and also this kerosene engine is enjoying a good reputation in overseas' markets.

Experience in Zambia

Heath (Zambia): Estlander and Fujinami's paper is a very useful reference for the planning of work in developing countries. He made a few points on the experience of the use of several hundred outboards in Zambia. His remarks were extracted from the report of the marine engine instructor to Zambia. It has been found in the central African lakes of Zambia that the multi-cylinder outboard of 10 hp and over are far too uneconomical both for reasons of fuel cost, 37 per cent of the earnings as compared to 21 per cent for the 5 hp model, and also because of mechanical failure. They had decided not to pursue the large outboards further, but of changing to 8½ hp inboard air-cooled diesels. The lower-powered simple types of outboards are satisfactory. Their main weakness is in the bottom gear. The advent of nylon nets with great fibre strength has caused the oil seals to be pushed in with a consequent loss of gear box oil when nets become wrapped round the propeller shaft. This is a common enough occurrence at night, when passing over hundreds of surface-set nets. Non-adjustable carburetor jets are very necessary, for incorrect adjustment of jets with a petrol-oil lubrication system can cause complete failure of the engine.

The Government had subsidized the mechanical maintenance for two years before the decision was made to depart from outboards of over 10 hp. Heath suggested that when engines of 10 hp and up are required, it might be better to consider new boats designed for inboard engines with outboard drives. Gillmer and Gulbrandsen's paper will help considerably in experimental work using wells, but using inboard engines instead of outboards.

Valuable tests recorded

Fraser (FAO): The tests Gulbrandsen undertook under such primitive conditions were quite an achievement. He sent also back to Rome some more tests carried out with four different outboards, transom installed on a plastic multi-purpose boat designed by Estlander to be used as a beachboat. The measurements as in Gulbrandsen's paper were motor revolutions, fuel consumption and speed. The engines were labelled "heavy-duty" by the makers. Well, even without any deep investigation it was obvious that one motor was vastly superior to the other three in these specific conditions, and it was significant that none of the motors, even the best one, was capable of reaching the actual design revolutions. The consumption speed curves at the low displacement of about 1.1 ton indicated that speeds were somewhere between 6½ and 7 knots.

Now, referring to the consumption: taking the best motor, as compared with the other three; at 6½ knots the consumption of the best engine was 0.78 Imp gal/hr (3.6 l/hr) and the next one was 0.93 Imp gal/hr (4.2 l/hr) a difference of some 16 per cent. At 7 knots it was 1.19 Imp gal/hr (5.4 l/hr) for the best against 1.26 Imp gal/hr (5.8 l/hr) for the next, a difference of something like 20 per cent. In countries like Western Europe and developed ones, this doesn't seem perhaps very significant, but it should be remembered that these motors are to be used in areas where the financial resources are extremely limited and that fishing projects are just trying to get off the ground, and this kind of thing would be completely disastrous, especially with the very high cost of fuel.

The actual motor units themselves were very similar, so a close inspection of the propeller design was made to find the differences. A 15 per cent reduction of the total hp was assumed to take place between the engines and the propellers. A range

of wake speeds was assumed to find the wake speed to carry out really reasonable analysis, but when these were plotted on the B_p-delta charts, for the .5 and .65 blade area ratios, only one intersection was obtained and that for the best motor between the pitch diameter ratio line and the B_p-delta curve. A resort was made to apparent slip against advance coefficient. This was quite significant but it roughly came to the slip values varied from .2 to .7 for the same design and the K values for all the advance coefficients were from .44 to .54 over a range tested for the reasonably propulsion units, and .34 and .40 on the ones that didn't appear so good. As these coefficients are based on the speed of the boat itself and not on the wake speed, there would be a further reduction of 20 per cent on this. It doesn't matter what kind of efficiency charts one would use, one would get absolutely ridiculous efficiencies for these propellers. The best one has the largest propeller diameter. Therefore to decrease the B_p in order to get into a reasonable efficiency area, the only logical change would be reduce the revolutions.

This has been said many many times by many many people but it is still ignored for some reason or other. To satisfy the design conditions for which these particular propellers were designed, it is estimated that the actual speed of the vessel should be something like 15 knots or more, which is nothing like to 6 the 8 knots that they were designed for. Better propeller designs, particularly at lower revolutions, maybe somewhere around 1,000 rpm range, should be made for this particular type of heavy-duty work. Selman has argued for inboard installations because of the superior propeller efficiencies, so the outboard people know what they are up against. It is not for pleasure that these developing countries fish—perhaps it is a matter of survival and heavy-duty outboards can help make this survival possible.

Difficult conditions met

Borgenstam (Sweden): Estlander's and Fujinami's paper gives a vivid impression of the difficult conditions under which outboards have to operate in fishing boats and of the many respects in which existing engines fail to meet the specific demands of the fishing. Their list of requirements in the Recommendation chapter will certainly be interesting reading to engine makers. However, it must be realized that the overwhelming demand for outboards comes from the pleasure boat owners and also that the outboard is a pronounced mass product, which has been subjected to extensive standardization and rationalizing both in design and manufacture. It is then natural that the design development has been dictated almost entirely by the pleasure craft demand. As far as the upper part of the outboard (engine head) is concerned, the fisherman can benefit from the modern pleasure boat development. Engines have become lighter, more efficiently enclosed, better protected against water and spray, easier to start and handle. Also their flexibility and reliability have been enormously improved in the last ten years.

For the lower part, however, the situation is the opposite. Bronze gear housings with generous dimensions have given way to die cast aluminium housings with highly stressed gears and a good streamlining which is of little value at low speed. Small high-revving aluminium propellers have replaced the big slow-running bronze propellers in order to suit the demands of the 20–35 knots speed range at which most pleasure craft are used.

For these reasons there seems little reason to try to influence the makers to modify the engine head, but there is good reason to encourage the makers to develop special lower units for the fishing requirements. The cost will be appreciably higher, but the outboard is still so competitive in price and has so many

other advantages for small boats, that the effort might well be worthwhile.

Some adverse points

Vibrans (USA): As has already been pointed out four factors stand against the outboard:

1. In the present state of development, its fuel economy is not very good
2. The two-cycle engines require a mixture of lubricating oil and gasoline which is inconvenient to mix, and if not in the proper proportions can affect engine performance and life
3. The propeller speed is too high for fishing
4. The aluminium alloy in the underwater units is short-lived with continuous immersion in salt water

Van Donkelaar (Belgium): Commented on Vibran's statement concerning corrosion on outboard motors. Certain makes have been poor in this respect. However, now many outboards are superior to other means of propulsion. Aluminium dye castings get a chrome-conversion coating and motors are washed with a special process using dionized water. Engines after this treatment have stood up to at least 1,000 hours of salt spraying testing.

Further comment on Stoneman's remarks of engine life. No engine in the world is so badly treated as an outboard. These engines are often used at full throttle far too often during long periods of running. At 80 per cent of its power, the motor would almost double its life. Therefore an arrangement at the throttle control, giving the operator a positive "feel" when entering the high fuel consumption speed, would be desirable.

On economy of outboards in the last few years, much research has been done on this and modern engines have improved carburation and better ignition timing. The fuel economy comes close to that of a four-stroke engine.

There is also current research on the hydrodynamic properties of lower units and propellers. Nylon propellers have been tried but found to have less efficiency than traditional propellers, probably because of flexing of the blades.

Placing the outboard

Kvaran (FAO): The main problem with the installation of an outboard is to decide where to place the motor rather than how to do so. Generally speaking, the logical location is at the stern, but in the case of many local craft this mounting is not feasible. Excessive overhang and freeboard, coupled with flimsy construction may make it impossible to fit the engine there. In small canoes, the trim can be disturbed too much by the weight of the engine and operator if they are located too far aft.

In surf boats or boats operating in rough seas, stern mounting may result in the propeller being lifted clear of the water or close to the surface when meeting waves, causing trouble due to shearpin breakage, premature failure of the propeller bonding to the shock absorber and to excessive airation of the propeller. Airation is due to air being sucked into the propeller stream when the propeller breaks surface or comes close to doing so, and can result in almost complete loss of thrust for many seconds at a time. This is obviously an undesirable condition for a craft struggling against breakers, doubly so, if the outboard is also depended on for steering.

Relocating the engine farther forward does not always provide a solution to the airation problem, and can indeed aggravate it if the propeller is close to the hull. In such cases the solution must be found by submerging the propeller deeper or running the propeller at a slower speed. Both these solutions may mean that the engine originally selected will have to be replaced by one with a longer shaft extension, a lower rpm or a greater reduction ratio.

Stern mounting of an outboard may be unacceptable on aesthetical grounds. In double-ended dug-out canoes, for example, there is often a substantial block of wood at the bow and stern which is not cut away from the inside, as doing so would only create a small narrow slot in the prow or stern, and by slicing off the stern block one can make a small transom, which can easily be extended upwards by a crossboard which would take the motor clamp. Very few owners are prepared to mutilate their canoes in this manner, any more than the owner of a pure bred collie or pointer would agree to docking his dog's tail.

Side mounting

Next to stern mounting, side mounting is the most popular way of fitting motors to unorthodox hull shapes. This can be done by mounting the motor itself sideways, with the clamps more or less in a fore-and-aft position, or by erecting a cross piece athwartships on which the motor is hung. The former method is suitable for motors which can be swivelled completely around, but in its simplest form many involve using the motor permanently tilted to a side, which is undesirable for an engine-mounted fuel tank and for some types of carburettors. The farther aft the engine is the easier steering will be. On an outrigger, mounting the engine on the outrigger side of the hull will also aid steering considerably. This may not always be acceptable to the fishermen, however, if it interferes with the operation of fishing gear.

The sensitivity of the steering to the motor location depends on the inherent course holding qualities of the craft. Keel boats are much less sensitive in this respect than dug-outs or raft type craft. Power poles or long tails are outboards which have a long shaft directly driven from the engine crank shaft, without the usual angle drive of conventional outboards. These engines have proved extremely useful on many types of river and backwater craft, but steering difficulties make them hard to handle on dug-outs and rafts even when mounted at the stern, the craft tending to stay on their original course, moving sideways instead of responding to the tiller.

One of the advantages of outboards is that they need not alter the essential nature of the craft on to which they are fitted. The Ceylon oru, an outrigger-type dug-out with built-up sides illustrates this point. The oru is a sailing boat designed for a large spread of canvas on a very narrow hull, the outrigger serving as a counterbalance while sailing is always kept on the windward side. At high speed the outrigger may be lifted clear of the water and is then weighted down by a man balancing on the outrigger poles or on the outrigger itself. As the outrigger is permanently fastened to the main hull, it is necessary to reverse the fore and aft ends when tacking, in order that the outrigger remains to the windward. If an engine is installed at one end of such a craft, it will at times be at the stern and at times at the bow. The installation of an inboard engine calls for a rudder mounting as well, because the original steering oar does not function properly once a propeller has been installed. This means that the craft has completely lost its reversible character and can be sailed on one tack only.

A special problem

At first it appeared that installation of an outboard amidships would provide the ideal solution; the engine could be reversed or swivelled as required and the motor could act as an auxiliary regardless of which end was forward. Again practical difficulties appeared and the steering was so bad with the engine mounted amidships that keeping on course required continuous and strenuous efforts on the part of the helmsman.

The final solution was to mount the engine near one end and sacrifice the possibility of using the engine when sailing with the motor at the bow. Two engines would provide a complete solution—it is not practicable to shift one engine from one mounting to another at sea in these long, narrow boats—but in actual practice it was found that the engine is used almost entirely as an alternative propulsion, rather than as an auxiliary to the sail.

Catamarans and teppams, rafts consisting of four to five logs lashed together, are another example of craft which retain their essential character when fitted with outboards. In this case, the desirable features are extremely low freeboard to minimize drift when fishing with a short string of drift nets, and the ability to pass over shallow reefs and land on a rough shore or in heavy surf. Retractable propellers have so far at least not been able to meet the requirements nearly so easily as outboards, but further developments in inboard and outboard drives may change this situation.

Outboards have been mounted in wells in the boat, but this installation calls for careful consideration of the location and design of the well, as the flow pattern and pressure distribution under the boat is very variable, and is disturbed by the presence of the well of the motor. The main advantages of a well are ease of handling the motor, freedom from obstruction on the gunwale and good submergence of the propeller. If the outboard is to be retractable by tilting, the well tends to become long and reduces the space in what is normally a cramped boat to begin with. As the well is central, it lends itself somewhat more readily to use in dug-outs than in craft built up on a central keel.

Variations of outboards

Vibrans (USA): Another type of drive should be considered. This is a small single-cylinder four-stroke air-cooled engine with V-belt drive to the propeller shaft. This engine type is used on lawn mowers and is available in size up to about 20 hp. Under much misuse they still continue to survive and operate reliably. Fuel tank, exhaust silencer and pipe are all engine mounted, and as such should be suitable for small open boat installation. The V-belt drive with sheaves will give necessary reduction and also tolerate a measure of misalignment. Stepped cone sheaves could be provided to permit change of propeller speed whenever it was required to suit some particular operating condition. Vibrans suggested consideration of this type of mechanization for such craft as the canoes from Ghana. The inboard/outboard Z-type installation tried on a Ghana canoe was impressive, but represented more power and cost than can be justified. With the installation of the small air-cooled engine as described, no well need be provided. With the V-belt drive much flexibility is possible. The cost of the entire installation of a 5 hp air-cooled engine, driveshaft and propeller would be under £100 ($300).

Traung (FAO): In Thailand, a four-stroke engine is used to direct drive the propeller as explained earlier by Kvaran. It is called the "long-tail" engine. The engine is mounted inboard on a swivel mounting, while the propeller shaft protrudes over the stern and into the water. Installations may be from 5 to 30 hp and they are ideally suited for the mechanization of long canoes. Kvaran's plan to introduce this type of installation in Ceylon never materialized, but if it had, it might have given the outboard manufacturers a fright. Power units cost only about £70 ($200).

Noel (UK): A type of "long-tail" engine as referred to by Traung was produced until quite recently by a maker of lawn mowers in UK. It was about 3 hp and cost between £30 to £40 ($85 to $110). If persuaded, they might take up such manufacture again.

Author's reply

Fujinami (FAO): There have been so many interesting comments on Estlander's and his paper that he wanted to classify them into a few groups.

Selman, Kvaran, Fraser and Gulbrandsen mentioned the unsuitable size and rpm of the propeller and the need of heavy-duty outboards. Fujinami agreed with these comments. The pleasure boat was the origin of this engine and initially one had to accept what was offered, but this must be radically changed in the future.

Mendis, Kvaran, Plosso and Gurtner commented on the difficulties of mechanization due to the construction of indigenous craft in developing countries. Twenty years ago when Fujinami started to work with the Japanese fisheries he was shocked by the small size of the individual boats he had to deal with. Some eight years ago, when he joined FAO, the same situation occurred. One must have very clear ideas of what types of vessels are used in developing countries. There is a limit of vessel size and engine output for outboard mechanization. Where a very large hp is required, an inboard would be more advantageous, and to do this the whole design of the boat must be changed and this is not easy because of the lack of technicians and craftsmen. The outboard is the first step in mechanization and most vessels in these papers are in this stage. When the second step is accepted, as mentioned, plastic construction would be a good idea especially in tropical conditions.

The third group of people, namely Selman, Vibrans, Heath, Stoneman and Ferrer, commented on economy of outboard installation. The economics of outboards compared with inboard engines are a matter of the size and shape of the vessels, the availability of persons with mechanical knowledge and also of convenient maintenance especially in respect of the tests between the fishing station and the maintenance shop. In this respect, the outboard has considerable advantages in that it can be more readily transported. Another point of favour of outboard installation rather than inboard is the lower initial costs, which are probably more within the reach of the fishermen.

A fourth group, namely Vibrans, Noel and Plosso, commented on inboard-outboard engines. The idea of an inboard-outboard with an extended shaft is widely used and is a reasonable proposition. This gives hints to inboard engine makers how to improve their engines so that they can be installed on indigenous craft.

Fujinami was glad to hear that Tito—being a representative of the makers—considers this paper a useful guide to outboard mechanization based on the long experience of Estlander in this field.

PROBLEMS WITH INBOARD ENGINES

O'Meallain (Ireland): Engine manufacturers have not fully appreciated the necessity for their:

- advising objectively on suitability of installation, taking into account the size and purpose of a vessel
- co-operating in the collection and analysis of data to enable satisfactory advice to be given. Fishermen lack the time to collect data, and even large fishing enterprises could find the burden of doing so quite onerous. Engine manufacturers should endeavour to assist in this

Measures should be taken frequently to check alignment. More instances of faulty alignment may exist than is generally realized, resulting in undue wear and even in serious mechanical breakdown. A suggestion, which he had made many years ago that more use should be made of flexible coupling did not

at the time find a ready welcome from some engine manufacturers, who raised questions about critical speeds.

Regular inspection of engines and mechanical equipment should be carried out. It is understandable that fishermen do not like to put their boats out of service more than absolutely necessary, but where the state has a financial interest in fishing fleets by way of loan schemes or otherwise, some form of compulsory inspection could be introduced. The fisherman soon comes to recognize the advantages of timely inspection by expert personnel.

Importance of inspection

Rebollo (Spain): Referring to O'Meallain's statement, where he had expressed the opinion that engine inspections should be made compulsory, Rebollo said that in Spain a complete inspection is compulsory for all merchant craft, including fishing boats every four years, and this covers an inspection of the engines, whether or not State subsidies were obtained for the construction of the craft. In addition, a less detailed inspection is conducted each year. Where fishing craft are concerned, the inspection is carried out at a time of the year best suited to the owner of the boat in question. The inspection includes testing of the engine and of all fire-fighting, life-saving and other equipment, as well as an examination of the condition of the hull, to ascertain whether these comply with the standards laid down by the Government.

Apart from engines coupled direct to the propeller, there is a growing tendency to instal engines with hydraulically-operated reduction and reversing gear which, in addition to making for lighter engines, offer greater propeller efficiency. In either case, what attracts fishing boat owners is the improved handling, with bridge-mounted controls. One system that has not yet gained popularity in Spain, however, is the use of controllable pitch propeller. It is not sufficiently understood that the improved propeller performance in every case makes for lower fuel consumption or higher speed or towing power. Advantages such as those listed have to be bought with higher installation and maintenance costs. There has not been sufficient experience of the economics of this system, although there is no doubt that it represents a technical advance.

Stiff Japanese standard

Oguri (Japan): The requirements for engines for fishing boats designed for various fishing methods along the Japanese coastline are quite hard and severe in many respects. For instance, in certain fishing, rather a high speed is required. But on the other hand, in other cases it is necessary to have either a strong pulling force or the possibility to operate the boat for a long time at a low speed and with light loads. Furthermore, even at a temperature of 32°F (0°C) it is always required to start the engine without a cartridge or heating plug.

In addition to these requirements, it is naturally indispensable to reduce the running costs of the engine and this is the reason why heavy oil is mainly used for diesels for small fishing boats in Japan. Since the capacity and durability of engines depend to a great extent on the fuel used, it is important as well to study how to improve fuel. In Japan they had been keeping close co-operation with oil producers and had been trying to find good but cheap fuel for fishing boats. Of course, fuel cost is to a certain extent connected with the tax problem too.

Oguri believed that this fuel problem is as important as the manufacturing of less expensive and durable engines and if one succeeds to discover economical fuel, that will very much reduce the running cost of boats.

Tyrrell (Ireland): Two-stroke engines possess many desirable features for fishing vessels, but Irish experience of two-stroke diesels up to 600 hp in fishing vessels and coasters is that no

one is efficiently scavenged; all require a great deal more maintenance and cleaning than four-stroke types. One particular eight-cylinder engine has to have a piston drawn in rotation for cleaning after every passage.

It has been said by some authorities that the provision of exhaust valves on two-stroke engines would ensure much cleaner running, and it would be of considerable interest to hear the views of the makers of such engines on this apparently difficult problem.

Valuable points listed

Sinclair (UK): Borgenstam's paper will especially help developing countries. He commented:

- Design is based on free running because this is the easiest proof of contract conditions
- Insufficient stress is made of troubles associated with electrical systems of petrol engines. If small engines are being considered, magneto ignition may be the best solution but fuel cost differential in UK at least is not great
- Supply of local material and lack of trained metal workers dictates that wooden engine bearers are used —wood bearers require that frequent alignment of stern gear is carried out. It follows that wherever possible, metal bearers should be incorporated
- Access to machinery by cutting bearers is depreciated because frequently bearers materially contribute to structural fore and aft strength. If manufacturers produce engines with inaccessible parts, their products should not be incorporated in fishing vessels
- Installation must be in accordance with good engineering practice. Holding down bolts (not "French" or coach screws) should be a close fit in feet. Steel liners should be used on wood bearers and jacking and locking arrangements incorporated in the engine. This greatly facilitates maintenance alignments
- Flexible mountings are advantageous but they demand flexible couplings to shaft and to all engine connections and they tend to lead to the acceptance of misalignment with consequent bad results
- For shafting, monel is mentioned with particular regard to anti-corrosive properties. Borgenstam had omitted to mention its greater strength characteristics which enable smaller shafting, stern tube, etc., to be used with therefore practically no increase in cost over the usual mild steel or bronze shafting. This is good to bear in mind on up-rated re-engining or first installation because a smaller stern post can be successfully utilized
- On lubrication for wet sump engines, the angle of installation is not always the same as the running angle and this must be borne in mind. Dipsticks must be graduated for the angle used
- Exhaust for diesel installation can be of rubber (reinforced), water injected. Material cost is high but cheaper labour cost more than balances it out
- No mention of air-cooled engines is made. They are extremely easy to instal with no water system or hull perforations. Adequate air supply and exhaust is a paramount requirement. Air-cooled engines have been worked successfully in tropical areas
- Fresh water cooling is preferred because of corrosion in the engine by salt. Keel coolers are simplest and don't take room in the engine room. If bilge keels are fitted, they provide adequate protection and in any case damage can be met by emergency salt water in the system. Strainers should be in a standpipe and capable of clearing without shutting the seacock

- The term "corrosion" used in the text under "Cooling" presumably includes cavitation and erosion and whilst soluble oil additives help to cure this, installers can help by ensuring fair runs of pipes without variations in bore, or restrictors, and thus preventing at least some aeration
- In the fuel system no mention is made of a fuel return system for diesel engines. This must be adequate and in the range of engines under consideration full bore equivalent to the suction pipes is recommended
- In controls, no mention is made of "stop". This should always be led to the control position for emergency use
- No mention is made of multi-engine installations. It may be that some maintenance problems in developing countries may be solved by maintenance by replacement with all major maintenance work carried out ashore
- No mention is made also of the use of V-drives. Reduction gears are accepted as normal and many naval architects could find the use of V-drives of assistance in minimizing engine room space and in keeping the CG aft
- Water can be a reasonable and easily accessible fire-fighting medium

Scottish experience

Sutherland (UK): Congratulated Borgenstam and Kvaran on their papers. With the new and improved methods of fishing, the hp requirements of the Scottish Inshore Fishing Fleet has doubled and, in some cases tripled during an approximate period of ten years, and it is unfortunate that they have no definite data on which to base the hp requirements for any particular vessel working with modern fishing gear and using modern techniques. Some excellent work has been carried out by Hatfield and it is hoped that such work will be continued.

These increases in hp have presented certain problems and Sutherland confined himself to the problem of engine bearers and the methods used in Scotland to overcome this difficulty. About ten years ago, it was found that considerable trouble with the alignment of engines was due to several causes, these being as follows:

- Engine bearers were too short
- Engine bearers were insufficiently supported
- Drive bolts were being used to attach the bearers to the sawn frames
- Coach screws (or French screws) were used as engine-holding-down bolts
- The practice of some engine manufacturers in having the reverse reduction gear box feet on a much lower plane than those attached to the engine, which involved the cutting down of the wooden bearers until the gearbox feet were almost resting on the frames

To correct these faults and also keep the probable increase in hp in mind, the following regulations were made: Engine bearers of oak had to be checked over every frame and had to have a minimum length of two and a half times the distance between the forward holding-down bolts and the gearbox coupling. The bearers had to be screw-bolted through the frames before the hull planking was fitted and side and centre oak chocks, fastened to the bearers by angle irons and through bolts had also to be fitted. The side chocks, which also formed the supports for the flooring were to be fitted at every second frame and a minimum of two centre chocks were required. The engine bearers, due to the new required length, projected into the fishroom for about five or six frame spaces, but due to the inclination of the engine, these bearers could be reduced in height to the level of the flooring in the fishroom with no great impairment in strength.

Placing of bearers

In vessels of over 70 ft (21 m), these engine bearers are generally carried as far forward as possible, acting as sister keelsons to the centre keelson. However, with the more rapid increase in engine hp in the last two or three years, it has been found that a much stronger and more permanent job can be done in steel. In the smaller craft up to 36 ft (11 m), steel H beams are mounted directly on to the floors and in the medium size range 40 to 60 ft (12 to 18 m), the H beams are mounted on to oak bearers of greatly reduced depth. In the larger size of vessels in the 70 to 80 ft (21 to 24 m) range, steel bearers are fabricated on to a longitudinal base plate through-fastened to the frames. Transverse plate brackets are welded to the fabricated engine seats and through-bolted to the frames.

In the three years since fitting steel bearers, there has been a marked reduction in shaft and stern tube troubles and vibration has been definitely reduced.

Referring to the different levels of the mounting feet on engines, the manufacturers were approached and asked to alter the design of the gearbox and, probably due to the fact that this amendment would not affect the design of the engine itself, built mainly as an automotive engine, the necessary alteration in design was made.

Referring to the last sentence in the chapter on engine bearers of Borgenstam's paper, where he suggests the use of wedge-shaped rectangular washers with oblong holes to assist in lining up, it is common practice in the UK for the engine-mounting feet to have an extra screwed hole fitted in which jacking screws can be fitted.

Coping with fire

Turning to the chapter on fire extinguishing, these items have now, of course, been covered in the UK by the new fire fighting regulations which came into force on 26 May 1965.

Sutherland would add one other potential danger to Borgenstam's list: where sight glasses are fitted to the fuel tanks, self-closing cocks should be fitted to ensure that the contents of the tanks cannot run into the bilges in case of accidental fracture of the sight glass. Again, where a smothering gas system is used, a battery-driven fan with the control switch in the wheelhouse should be fitted to the engine room to assist in clearing the gas after the fire has been extinguished.

Referring to Kvaran's paper, Sutherland could understand the difficulties which faced Kvaran and would like to pay tribute to him for his excellent work in Ceylon. In Sutherland's opinion, one of the greatest troubles experienced in giving technical aid to the fishermen in developing countries is the lack of trained service engineers in these countries. It has been Sutherland's experience that modern fishing boats built to FAO designs had been lying on the beaches around India for lack of spares and maintenance and, in many cases in which spares were unavailable, cannibalization had taken place nullifying much of the good work done by FAO experts in the field.

Dickson had stressed the importance of training fishermen in the developing countries and Sutherland endorsed this view, although they obviously had different objects in mind. Sutherland would like to see more training colleges for service engineers and maintenance men and for training fishermen in the running care and maintenance of his engine.

As an illustration of this lack, Sutherland found that several fishermen in a fishing village in India had removed the rubber outer stern bearing in recently-acquired fishing boats. On questioning it was found that due to misalignment of the engine shafting, the inner packing of the stern tube had worn

and water began to pour into the boat. The local service engineer (from the nearest garage) had advised removal of the outer rubber bearing *"because it let the water in"*. His cure was then to hammer in a rough-cut soft wooden bush which immediately swelled on to the shaft and required renewal every three or four weeks. Sutherland had not decided whether this service man was inexperienced, or whether he was a very good business man.

Timing of overhauls

Campion (UK): Congratulated Borgenstam on his comprehensive paper. The boats of the Scottish herring fleet are between 50 and 80 ft (15 to 24 m) in length with engines ranging from 90 to 320 hp. (One boat of 75 ft (23 m) had 380 hp.) The majority of these engines are of 150 hp or more and maximum rpm are between 900 and 1,800. They are in the main, marine versions of automotive types.

Borgenstam had suggested that, where boats are logging as much as 4,000 hours annually, a top overhaul can possibly be accepted in the first year's running. Experience with Scottish herring boats had shown that with new engines, logging similar hours annually, it is seldom necessary to lift the cylinder head before two years, and then only for checking piston clearances and liner wear. Cylinder lines are renewed on average after five or six years, but longer periods are quite common. The normal procedure is to lift the head at two years and depending on the wear readings, either annually or every two years thereafter.

The incident of crankshaft or main bearing failure is very small and there is therefore seldom need to strip the engine. In such circumstances, underslung crankshafts are quite acceptable. Serious engine failures can often be attributed to neglect by the motor mechanic on board to properly carry out the engine manufacturer's running instructions regarding oil changes, etc. In developing countries, and for that matter in developed countries, too much attention cannot be paid to training the operators in the proper running of the engine. Where boats are owned by fishermen who work on them, most of the shares are usually held by the skipper, but a small share is often given to the motor mechanic, and this gives him some incentive to look after the engine, which is in fact his own property.

A point not mentioned by Borgenstam is the need for an adequate air supply to the engine room. The importance of proper ventilation cannot be overstressed and this is particularly important with turbo-charged engines. In fact, some makers specify that a separate trunked supply shall be led to the air intake. The aim should be to cool the engine room as uniformly as possible and to achieve this, care should be taken to avoid short circuits and to ensure that the hot air can escape. A supply should be led to a position near the floor plates, well away from the exhaust so that the cold air will sweep up across the engine. Better results can often be achieved with electrically-driven fans which, in case of fire, can be switched on or off from outside the engine room. One British engine manufacturer includes electric vent fans as part of the standard engine equipment.

Economize weight and space

Grønningsaeter (Norway): More economy in weight and space is of importance to the operator of medium- and high-powered smaller types of fishing vessels, whether concerning the main powerplant or the auxiliary. It would be desirable if a suitable propulsion unit, capable of taking advantage of the foreseen improved gas turbine, could be developed. Two likely ways of doing this is to improve the weight/power/rpm properties of an electrical propulsion motor, and/or to improve and enlarge the high-pressure hydraulic motor as a propulsion unit.

A propulsion unit consisting of a high pressure hydraulic motor capable of taking its power from a direct gas turbine-driven pump of 300 hp is now being studied in Sweden. The 300 rpm propulsion units is estimated to weigh some 1,100 lb (500 kg). A gas turbine of similar horsepower weighs about 90 to 100 lb (40 to 50 kg). If and when gas turbines become more fuel-saving, such a unit would be an economizer in space and weight and could be tucked away on and under the rudder flat and in the forepeak.

As for auxiliaries, Grønningsaeter was thinking of intermittent requirements, the example of the electric power industry could be followed with advantage on trawlers even today.

A gas turbine with a hydraulic pump of high pressure would be instantly available and provide flexible power for the winch or if electric transmission is used also for booster power for deep-freezing units in shorter spells. Such units now have an overhauling frequency of 4,000 hours and would thus be troublefree for several years as booster power. They will also be savers of space and weight in the engine room.

Grønningsaeter had been a captain of a ship with diesel electric installations for ten years. The installation was designed in USA and built in the UK. During all that time he never carried an electrician on board and had no regrets for not having done so.

Value of air-cooling

Rawlings (UK): Congratulated Kvaran and Borgenstam on having a vivid awareness of the many problems associated with the engineering of small fishing craft, particularly indigenous vessels. Many people do not fully appreciate how much more difficult it is to correctly engine small craft rather than the larger types of vessel. This is because of the much narrower margins within which it is necessary to work—margins of weight distribution, stability, trim, deck space and cargo space without, of course, forgetting performance. In the two papers under discussion, account has been taken only of what might be called conventional engines and methods. In countries where small-scale mechanization must be undertaken, particularly where the craft are of the indigenous type and where one must therefore presume that fewer of the traditional biases exist, there seems little justification for perpetuating the older types of machinery without first of all examining the possibility of the new. Rawlings was referring particularly to air-cooled engines, of which he could speak without prejudice since his company manufactures identical versions of air-cooled and water-cooled engines of similar powers. The pros and cons of conventional water-cooling methods are dealt with very fully by Kvaran and Borgenstam, i.e. direct cooling, indirect cooling (or freshwater cooling) and keel cooling, but the small type of high-speed air-cooled marine diesel engine, below about 120 hp, is here to stay. The smaller types of such an engine could be fitted successfully in most of the craft with which Kvaran is presumably concerned. To mention only four points in favour of the air-cooled engines, these are:

● Because of its in-built controlled cooling system, it very quickly reaches and maintains its maximum and most efficient thermal running condition, thus lessening wear rates and opening-up periods

● Overall maintenance is already well proved to be considerably less than with an equivalent water-cooled engine

● Corrosion is non-existent

- Provided the makers' installation recommendations are sought and followed, then the whole of the machinery installation can be done more cheaply

In conclusion, some of the most successful air-cooled installations have been applied to many fishing craft operating in tropical waters and in developing countries. This is only because the natural ventilation is made suitable and the combined cooling and exhaust gas outlet is effectively placed. That is not to say that some of the earlier tropical installations did other than present difficulties, but by experience in modifications that were subsequently made, then considerable headway has been achieved in the vessels that followed during the past two to two and a half years. These vessels are now completely successful. Even more can be achieved in this direction, just as soon as the owners, the naval architects and the engineers can get together at the very beginning of a project.

Low speeds have merit

Akasaka (Japan): Borgenstam stated "in the higher power bracket, above about 25 hp and up to about 300 hp, the market is dominated by automotive-type diesels". Akasaka wanted to comment on the situation in Japan. For fishing boats in the range of 200 to 300 hp they commonly use four-cycle engines having 350 to 450 rpm, piston speeds of 16 to 20 ft/sec (5 to 6 m/sec) and effective mean pressures of 115 to 170 lb/in^2 (8 to 12 kg/cm^2). This kind of engine is exported to Korea, Formosa and South-East Asian countries.

This is because of the reason that low-speed engines have many advantages in operation and maintenance costs, durability and reliability, etc. These features match quite well the situation of the earlier mentioned countries. Akasaka thought there should be similar situations in other parts of the world. Further he pointed out that by raising the mean pressure values the dimension of low-speed engines will become smaller. In Japan they are trying to follow this line and expect very positive results.

Menace of the status symbol

Loevinsohn (Canada): Borgenstam must be complimented on a very interesting paper to which Loevinsohn would like to add two thoughts:

The first refers to the matter of uneconomical hp ratings which were referred to by several authors of the papers on Techno-Socio-Economic Boat Problems and also during the subsequent discussion. Many have been very concerned about the dangers to individual owners and the fishing industry as a whole, resulting from engine power choices dictated not by actual needs, but by a desire to outdo others. When the engine power choice becomes a status symbol, the economic health of the industry is clearly threatened.

Loevinsohn could not absolve all naval architects, ship-builders and engine suppliers from too easy an acquiescence to unjustified demands for higher power ratings, and would like to add his plea, directed especially at friends in the engine industry, for sound economic thinking and greater responsibility on the part of the sales organizations. This also applies, of course, to a realistic engine selection with respect to engine speeds for given applications. Peak ratings are frequently quoted with unfortunate results, where only continuous ratings should be used and when owners say that they want horses and not ponies, there is clearly room for improvement.

The second point refers to the matter of air cooling, Loevinsohn was somewhat taken aback that nothing was said about the high state of development of air-cooled diesel engines at a conference which emphasizes smaller fishing vessels. Especially for the developing countries this is a very important matter. Borgenstam dealt quite thoroughly with the many problems

associated with liquid cooling systems. He might have added that a very high percentage of engine repairs and breakdowns can be blamed on cooling troubles, either the ones he referred to or simply incorrect handling of valves or faulty cooling system maintenance.

Some assured benefits

An air-cooled engine does require care in the design stage of the vessel, so that adequate air is brought in for cooling and the discharged cooling air carried away without risking a "cooling air short-circuit". Where noise control is of significance, it can normally be accomplished easily at low cost, but it must be properly planned. But once this has been done—and ignorance of or indifference to these two points may be blamed for the occasional unhappy experience despite the use of high-quality engines, one can offer the owners:

- Engines without pumps, piping, valves, heat-exchangers or keel coolers. No more cooling system maintenance problems
- Freedom from overheating on the one hand and freeze-up on the other. No more cracked blocks or warped heads
- Elimination of the danger of clogged cooling water intakes and of cooling system corrosion
- More rapid attainment of ideal operating temperature and therefore much lower wear. 20,000 and 30,000 operating hours before top overhaul are quite frequent, even on very small engines
- Easy accessibility and replacement of pistons, rings, cylinders, etc., from the top, without raising the engine or dropping the oilpan and without having to remove large head castings
- Excellent behaviour under partial-load conditions, with the higher operating temperatures counteracting carbon accumulation
- The possibility of operating the engine when the boat is *not* in the water
- The availability of warm, clean, uncontaminated discharged cooling air for heating the wheelhouse or accommodation

Kettering, the great American inventor, said "What you leave off won't give you any trouble" and this most emphatically applies to even the best liquid cooling system.

Reliable, high-quality air-cooled diesel engines are available not, as indicated by a previous contributor, only up to around 100 hp, but actually up to 250 hp at the continuous rating for heavy-duty marine applications, at a weight per hp of as little as 12.6 lb (5.7 kg). The smallest models run at 2,500 rpm; from 20 to 60 hp they run at 2,000 rpm and the larger models run at 1,800 rpm for main propulsion applications.

In view of the excellent service these air-cooled marine diesel engines have given as propulsion engines in the Canadian Arctic as well as in the tropics, Loevinsohn would like to express the hope that the next technical meeting on fishing boats will deal extensively with this subject, which is of enormous interest to all those who are searching for reliable, simple, high-performance and economical power plants which combine these usually mutually exclusive attributes to the advantage of owners who are prepared to look ahead without prejudice.

While Loevinsohn stressed particularly the use of air-cooled diesel engines for propulsion of fishing vessels, including their obvious advantage for right-angle drive units, such as the widely used "Schottel" drives, they can, of course, be used to equal advantage for driving winches, hydraulic pumps, generators and other auxiliaries.

In conclusion, Loevinsohn said that the very interesting

remarks of Høgsgaard with reference to the difficulties experienced with two-cycle engines, forced to operate for longer periods under partial load conditions, should receive the most careful attention of all those concerned with the selection of power plants which are not only low in first cost and compact in design but, above all, absolutely safe in operation under all foreseeable conditions and economical in long-term operation. Overall economy does, of course, not consist of fuel economy only. Anything which increases maintenance requirements and repair frequency is bound to reduce the time the vessel will be engaged in its prime activity, i.e. fishing, and should, accordingly, be considered unattractive for use in fishing vessels.

High speed and diminishing returns

Selman (UK): Borgenstam has emphasized the folly of overpowering small fishing boats; to use a phrase the pursuit of higher speed follows a law of diminishing returns. The temptation to seek higher speed is real, since a speed of just over 7 knots for a 36 ft (11 m) craft in terms of miles per gallon of fuel, represents the higher limit beyond which it seldom pays to go. Contemporary practice with large trawlers where speed is generally of greater importance than with small craft confirms this. Even 7 knots may be considered too high when it is realized that a drop of half a knot may reduce the power requirement by 40 per cent. At such speeds, weight is not of paramount importance, but such parameters as prismatic coefficient and angle of entrance determine power requirement which may vary as much as 30 per cent between forms of same dimensions and weight.

As Borgenstam so rightly said, only a controllable pitch propeller can provide the total power available in all conditions, since free-running and trawling speeds require a different pitch, but a word of warning here; the largest efficiency diameter should be used and the operator should be aware of the manufacturer's natural inclination to sell him with a standard diameter.

One limitation of a diesel is its inability to run slower than a third of its maximum revolutions and here the use of a controllable pitch propeller will not only remove this but give control of speed in all circumstances from maximum to zero. Precautions are required to ensure that it is not possible in any circumstances by increasing pitch to overload the engine.

In recent years, all engine designers have endeavoured to increase revolutions and by reducing torque reduce weight and size of engines. The danger is obvious and so little advance in piston speed has occurred, and as revolutions have increased, so stroke has decreased resulting in the square or under square engine.

Selman did not share the importance that Borgenstam attached to length of engine, if this meant reducing water jackets and the over-shortening of power take-offs or skimping reverse gears.

To avoid vibration

Borgenstam dismissed vibration in a sentence but much can be done to avoid its incidence. It is always an unpleasant phenomenon when it occurs. For instance, Selman would always hesitate to associate a four-cylinder engine with a four-bladed propeller or a three-bladed propeller with a three- or six-cylinder engine. More attention should be paid to the fore and aft position of the propeller in the aperture and the very thick deadwoods commonly employed in wooden craft make it desirable to place the propeller further aft than in the case of a metal craft. In Selman's opinion the minimum distance should be twice the thickness of the deadwood or a propeller radius whichever is the larger and that the deadwood should be tapered to an inclusive angle of 40 degrees. If these

precautions are neglected then there is a real danger of vibration and reduction of revolutions attainable at full power.

In Selman's opinion, all engines should have an honest smoke-free maximum rating at which the engine can run continuously without nursing. Apart from outboard engines, Selman did not argue the relative advantages of petrol and diesel engines, since few today would consider the use of the petrol engine. The outboard engine which has figured so large in FAO policy is not mentioned by Borgenstam.

Borgenstam says "bearers have to be built up only to meet the feet". Selman holds the opinion that all wooden craft should have engine bearers which are only part of continuous fore and aft girders which extend the whole length of the boat and to which the floors are attached. Should the engine be placed so far aft that the immediate engine beds have little depth, these should be secured to the sides of the deeper continuous fore and afters. Such an arrangement is seldom adopted and more often than not the engine beds are no longer than the engine itself. The engine is generally the heaviest single unit in the boat and deserves better support than usually accorded it. Some wooden Swedish craft have steel engine beds built as an integral whole to steel floors. As Borgenstam says, most small engines have four to six feet and holding-down bolts, and even if oak bearers are used for supporting the engine, frequent realignment will be required unless the bearers are surfaced by a steel plate to compensate for the deficient bearing strength of timber.

Most manufacturers of marine engines quote a horsepower which if described as bhp or shp is the horsepower at the output shaft, since the engines are tested complete with reverse and reduction gear.

While admitting the merits of monel, Selman could not imagine any fisherman paying for this expensive material especially since classification societies require such low stresses for bronze shafts. Selman regretted that his experience was contrary to that of Borgenstam in that rubber stern tube bearings are seldom used. Selman wished Borgenstam's were true. Their lubrication, in Selman's opinion, can best be achieved by attaching the discharge from the engines salt water pump to the forward end of the tube.

Borgenstam's comments under the Exhaust System heading are, Selman thought, unduly influenced by naval service practice. For instance, a dry exhaust pipe for a fisherman would surely not mean a jacketed one. Selman had never succeeded in persuading owners of luxury yachts to adopt such and accept the expense in spite of the fact that fires in accommodation are frequently caused by overheated exhaust pipes. Likewise aluminium jacketed exhaust manifolds can, Selman thought, be dismissed. If a silencer is adopted, this should not be of the absorbent type in the case of a diesel, as such will inevitably accumulate oil and catch fire. A silencer similar to the Maxim and a wet exhaust is more practical and efficient, but probably still too expensive.

Pumps for sumps

Selman agreed with Borgenstam that a small engine suitable for an open boat should preferably have a wet sump and if fresh-water cooled, a combined heat exchanger and header tank mounted on the engine. If, however, any sort of closed engine room is part of the design, then there is much to be said for a dry sump, especially for long periods of continuous service together with separate header tank, oil cooler and heat exchanger. The engine room space will lend itself to a clean and simple layout; all pipe runs can be clearly seen and removed from the engine. Salt water cooling has a history of trouble, cracked cylinders and corroded liners, and should not be accepted.

Gear type pumps are in general the most efficient if

properly designed for the salt water system, a centrifugal for the fresh water system. Since the raw water pump is the Achille's heel of a marine engine, it is natural that the rubber-vaned impellor type should find general favour. It is cheap and expendable, but if left idle for any length of time, the impeller vanes on the cam side develop a permanent set and must be replaced.

For boats operating in muddy water, Selman regarded keel or tank cooling as essential, otherwise if a fine gauge filter is used, this may need cleaning every few hours, or if a coarse strainer is used, then the heat exchanger silts up, and in either case, short term neglect may crack cylinders. Twin strainers are essential allowing one to be cleaned while underway. If keel coolers are damaged, it is not disastrous if these are fractured, but in any case, it is not difficult to provide sufficient protection either by the centre or bilge keels.

The difference between a petrol and diesel engine is not sufficiently defined for fuel tank installation. When Selman designed and constructed petrol-driven naval craft, the practice of syphon feed from tank to engine was commonly adopted as a precaution against a fuel pipe being shot away. This works fine when an engine has a carburettor which frees all air and vapour but would be disastrous if petrol injection should be adopted. The same would, in Selman's opinion, adversely affect a diesel.

With fire extinguisher systems here again most of the comment is inapplicable to diesels. Most of the precautions mentioned, Selman had in the past used with good effect and would only add that the rigid removal of all unnecessary clutter of inflammable material and bilges cleared of oil would do much to isolate any fire aboard. A clean ship is a good fire insurance.

Engine room ventilation

Nothing has been said about engine room ventilation, Selman regarded a sufficient supply of fresh cool air as important as a good fuel supply and from his experience the provision of this is perhaps the commonest fault in small boat design, whether in an engine room of a larger craft or closed cover in an open boat.

In an engine room, two large vents should provide inlets for fresh air at the after end of the engine room and be lead up from a low level adjacent to the air intake to an unobstructed position on deck. In addition, two vents of similar size should be sited at the forward end of the engine room and continue from a high deck head level to a protected point above the deck. If diameter of vents is restricted, then fans should be used. Likewise the box casing over an engine should provide an adequate inlet adjacent to the engine's air intake, taking this latter to the top of the casing if possible and providing an ample number of holes along the casing top for discharge of hot air.

Borgenstam omitted reference to outboard petrol engines which are now used to propel traditional and sometimes primitive craft. Their lightness and high speed has reduced their first cost to a minimum but Selman surmised that their maintenance is expensive, their service life short and their fuel cost excessive. It has been said if a poor fisherman can only afford the cheapest, it is no use offering him something more efficient. However, their adoption has brought a measure of prosperity and Selman suggested due consideration now be given to the merits of the cheapest form of diesel, namely the air-cooled engine to which Borgenstam has not referred. The air-cooled engine is free of all water pump troubles and needs no heat exchangers. It is usually a wet sump type and is more simple an engine than an outboard and although dearer, is more economical and robust.

One basic precaution governs its performance, namely to make sure that the hot air discharge is not sucked back into the inlet fan. Some engine makers provide in their literature comprehensive guidance how this can be simply achieved, whether the engine be installed in an open boat or in a large vessel. Normal ventilation precautions and provision for air intakes should be followed as for petrol or diesels of the water-cooled variety, but the hot air discharge must be ducted away to the atmosphere. Great numbers of these engines are in service in all parts of the world from the tropics to the Arctic, where freedom from the troubles of frozen jacket water is a boon.

Responsibility of suppliers

Devara (India): He observed in Dakar, Senegal, that suppliers of marine engines are taking full responsibility for alignment work, fitting various connections and giving a trial run. This is a working procedure which can well be followed by all marine manufacturers and their agents, in their own interests. The engine suppliers must arrange for periodical checking of engine maintenance and also make service facilities available within easy reach of all the users. This goes a long way in establishing a good name, but also better business for engine suppliers.

Corrosion through rubber contacts

Verweij (Netherlands): Borgenstam mentioned stainless steel as a suitable material for the propeller shaft. Verweij had some bad experience with stainless steel shafts used in combination with a rubber sternbearing. The portion of the shaft which came into contact with this rubber bearing started to corrode rapidly. In general, stainless steel is only stainless as long as it is polished. In way of the rubber bearing, especially if there is sand in the water the polished surface is attacked and can corrode. Verweij had had many favourable experiences with propeller shafts of Tobin bronze. This material is much less expensive than monel and shows excellent mechanical characteristics.

If possible he would always adopt flexible mountings of engines since this reduces vibration drastically and makes life aboard much more comfortable. Fishermen will surely appreciate this.

Verweij agreed with Borgenstam that a completely flexible system, i.e. rubber stern bearing, flexibly mounted gland, flexible coupling and flexibly mounted engine, can, in practice, be quite successful. However, there are several requirements to be fulfilled:

- The flexible coupling must be of a type which can absorb the thrust with the boat going both ahead or astern
- The flexible mounts of the engine must be rather stiff so as to prevent too great movements of the engine
- The engine seating, or rather the whole afterbody of the ship, should be stiff enough
- The propeller shaft should be reasonably well aligned by using a fixed coupling first which is replaced by the flexible coupling after having aligned shafts and engine

Many modern engines require good accessibility to their lower part. With wooden engine bearers this may present a problem. However, to expect engine builders to alter their designs in such a way that no access to the bottom of the engine is needed seems rather optimistic. In the case of boats built of FRP, there are no problems in this case. With a proper choice of the glass reinforcement of the bearers and especially by using a sufficient quantity of unidirectional reinforcement in the upper part, the bearers can be made in such a way that a maximum accessibility of the engine is obtained and yet be
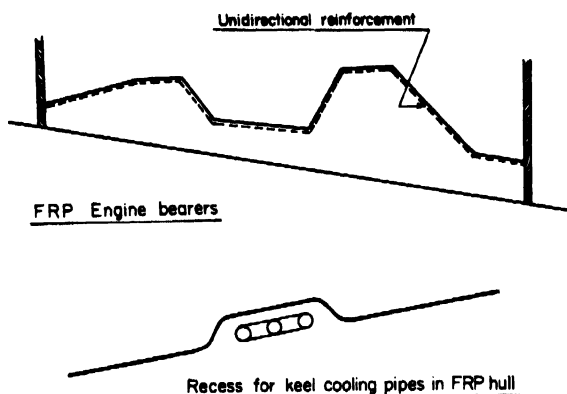
Fig 12. Engine bearers and keel cooling system of FRP boats

strong enough. See fig 12. With a boat made of FRP, it is quite easy to get a much better prevention of damage by placing the cooling pipes in a recess in the hull as per sketch.

Multi-engine installations

Lindgren (Sweden): During the last decades, the nearly explosion-like growth of road transport has made available for other fields prime movers of various kinds, manufactured in large series and offering a well-developed spare parts and service network. The advantages of these engines obviously lead to using two or more of them in parallel in cases where the hp requirement cannot be met by a single one. However, the idea of multiple-engine installations is, by no means, a new one. In a paper delivered before the Institution of Mechanical Engineers in 1933, Ricardo (1933) proposed a diesel-electric main propulsion arrangement, composed of about 75 small, high-speed diesels in the 100 hp bracket. Most of the papers presented at the symposium organized in Grimsby in 1962 by the Internal Combustion Engines Group of the Institution of Mechanical Engineers on the use of high-speed diesels in deep-sea fishing vessels, devoted some space to the problems connected with multi-engine installations.

As regards the high-speed diesel of the automotive type as such, Borgenstam has pointed out certain advantages, viz. the low initial cost per hp and the widely spread network of spare parts depots and service workshops, which though originally built for road transport can be used as well for the marinized engines.

The long production series of the modern high-speed diesels make it economically possible to invest great sums in research and development, to secure increased reliability and economy in service as well as in accurate machine tools, jigs and fixtures, permitting close manufacturing tolerances to be kept, which in turn lead to improved engine performance and a complete interchangeability of spare parts without hand fitting. The latter should be of a special value in the less industrialized countries.

Borgenstam has pointed out certain properties of the high-speed diesel in connection with service and overhaul. In the road transport business, regular maintenance and eventually "overhaul by replacement" is by now a recognized method. Lindgren liked to emphasize particularly that the same method should also be applied to the same type of engine used for marine purposes. If properly applied, it should reduce the length of time during which the vessel is held up in port while the engines are being serviced; it would also reduce the cost of labour by transferring most of the work to a well-organized factory.

Economy of replacement technique

However, if, instead of overhauling the engines on board ship, the system of replacing those due for overhaul by factory-reconditioned units is to give all the expected advantages, the installation itself must be made accordingly. It means that all the attachments, couplings, etc., of the engines, should be as easily disconnectable as possible, the necessary dismantling of the adjoining equipment should be reduced to the very minimum and, last but not least, ample openings and the necessary lifting gear should be provided in the ship itself. A standardization of the ancillary equipment would of course also help in introducing and in running the system. Lindgren believed that a still closer collaboration on the above points between the engine manufacturers and the shipbuilders would be of great value.

He fully agreed with Borgenstam's statement that the crankshaft and its bearings should not be overhauled or repaired on board; thus it may seem to be of no great importance whether the oil pan can be lowered or not. Incidentally, after a possible seizure, the replacement of, say, one piston and the corresponding cylinder liner can be performed with the engine on its bearers, if the oil pan can be sufficiently lowered. Lindgren was confident that in several cases this can be attained once the boat designers are aware of the problem.

The advantages of the high-speed diesels over the low-speed engines as regards reduced first cost, bulk, weight, etc., in single engine installations, also hold good for multi-engine installations in higher hp brackets, even when the arrangement for transmission of power from the engines to the single propeller shaft are taken into consideration. Another argument in favour of the high-speed multi-engine installation is the varying load demand on the propulsion machinery in a fishing vessel. When full power is not needed, one or more of the engines can be disengaged and stopped, allowing the other engines to operate closer to the ideal load, efficiency and temperature conditions. Furthermore, they could then be arranged to cope separately with the independent demands of the propeller, winch and other auxiliary loads. If one engine should break down, it would be disengaged, possibly by automatic devices, and the vessel would still have power to carry on at somewhat reduced speed.

Transmission of power

When choosing a system for transmitting power from the engines to the single propeller shaft a variety of transmission possibilities are possible. The mechanical types range from mechanically- or hydraulically-operated gearboxes with flexible or fluid couplings, to the simplest of them all, the belt drive. The mechanically independent drives can be either diesel-electric or diesel-hydraulic.

Diesel-electric propulsion has the advantage of flexibility in installation and in use; it allows the diesels, generators and propulsion motors to be located in the best suitable way for the working arrangements on board ship. The fact that the system has not been, as yet, put to a greater use is due, no doubt, to the high initial cost involved, as compared with other systems. This drawback still remains, but as ships become more and more complicated, their auxiliary load amounting gradually to a higher percentage of the propulsive load, the cost gap may in time get narrower. Another factor which must be taken into consideration, especially in the less industrialized countries, is the still higher scarcity of experienced electricians than of diesel mechanics. Furthermore, there are certain dangers involved in the use of high currents, at least in wooden ships, where earthing arrangements are rather unsatisfactory.

The hydraulic transmission of propulsion power offers the same flexibility as the electric system and lends itself well to multiple engine installations. If successfully integrated with all the auxiliary drives on board, it may well be considered for future use; the idea has been extensively discussed for some years now, but for the time being, it has not gained any acceptance. That may be due to the high initial cost, or to a low average efficiency, or again to the fact that apparently there are as yet no hydraulic pumps and motors of really suitable capacity and speed available on the market. With the rapid progress taking place within the technology of hydraulics, the diesel-hydraulic transmission for multi-engined vessels may well be a reality in a not too distant future.

The established transmission system for multi-engine installations is to have a mechanical gearbox with mechanically or hydraulically operated clutches to engage or disengage the engines, and a speed reduction from a comparatively high engine speed to a propeller speed giving a fair propeller efficiency. The gears must be machined with utmost accuracy in order to avoid excessive noise, and they become rather expensive, in any case when more than two engines are concerned.

Torsional vibrations can cause difficulties, and on that account rigid couplings cannot generally be used between the engines and the gear. To isolate completely the engines from the gear, thus avoiding practically transmission of torsional vibrations, hydraulic couplings have been used in the drive train from the engine to the gear; if of the variable fill type, they would also allow disconnection of the engine and may thus obviate the need for separate clutches.

With the advent of couplings, using rubber as the flexible and damping element, a new, less expensive medium has become available for limitation of the torsional vibrations to acceptable intensity. Provided that the dynamic torsional stiffness of the flexible coupling is chosen in the right way to make the unavoidable criticals fall outside the intended speed range of the machinery, a thing which can generally be accomplished with the units available on the market, all experience shows that the system well satisfies the demands on a marine propulsion machinery.

V-belt transmissions

In Sweden, for about 15 years, V-belt transmissions have been in extensive use in three- and four-engine ferries; those transmissions have done very well, the belt life being 30,000 to 40,000 hours. A ferry which was put into service in June 1965 has a propulsion machinery consisting of six high-speed diesels, driving a single-propeller shaft by V-belt transmissions. A fair number of tugboats and fishing vessels with twin-engine machinery are also in service.

Previously, such V-belt transmissions were rather bulky, due, in those days, to the limited transmission capacity of the belts, their comparatively large cross section and the attending restrictions on the minimum pulley diameter. However, with the introduction of the modern high-capacity V-belts, the transmission capacity per belt has been increased, while the width of the belt and the minimum pulley diameter has been reduced; all these factors contribute to a less bulky transmission. At the same time, the belts are resistant to oil and water and specially prepared to prevent sparks from the generated static electricity. If, after an initial service period of 25 to 50 hours, the belts are re-tensioned, in accordance with the recommendation of the belt manufacturers, the correct tension of the belt will be maintained for an astonishingly long time.

A straight V-belt drive consists normally of a driving pulley with a diameter of 8 to 10 in (200 to 250 mm), from which a propeller shaft is driven with a reduction of about 5 : 1. Thus, the driven pulley on the propeller shaft will have a diameter of 40 to 50 in (1,000 to 1,250 mm) and its application causes sometimes certain difficulties on installation. In such cases, V-belt drives with only a slight speed reduction, or no reduction at all, have been used in conjunction with a reduction gear, driving the propeller shaft. That of course infers that the inherent simplicity of a straight V-belt drive has been lost to some extent.

The flexibility of the V-belts has the same effect as the flexible coupling in the gear drives and isolates the engines effectively, so that no dangerous torsional vibrations appear. In order to distribute evenly the load over all the belts, the pulley grooves must be manufactured to close tolerances, and the V-belt lengths, in each belt set, must also be matched to close tolerance; however, nowadays all this is well known amongst the manufacturers concerned. From the installation point of view, it is important that the pulley shafts are closely parallel and that they are maintained as such when the belt tension is adjusted.

Flat and combination belts

Instead of V-belts, in some cases, flat belts have also been used, viz. a type of belt consisting of a high-strength load-carrying nylon member, combined with friction layers of chrome leather. Like the modern V-belts, they are oil-resistant and do not generate static electricity. They can be glued on board to the length required, thus allowing them independent lengths, free from the existing standards; this can certainly be of an installational advantage. If originally tensioned in accordance with the recommendations of the manufacturers, they are not supposed to need re-tensioning while in service.

Lately, a belt combining the characteristics of flat and V-belt has also been in use. It is composed of an uninterrupted high strength member of synthetic cords across its entire width, built into a single endless synthetic rubber belt, with a series of parallel longitudinal V-ribs forming its driving face. In this way the difficulty of matching the belt length in a V-belt set has been by-passed.

Both the latter belt types have about the same qualities as the modern V-belt, regarding power transmission capacity, small pulleys, isolation of torsional vibrations, etc.

In a multiple-engine drive, irrespective of the type of transmission, whether gear or belts, certain attention must be paid to the load distribution between the engines involved. The governor, which is normally installed on a high-speed diesel and which well fulfills its duties in a single-engine installation, may have to be specially adjusted to give trouble-free service in a multi-engine installation. Such an adjustment, once the need for it has been recognized, can easily be carried out by an experienced diesel equipment workshop. Furthermore, the engine control equipment on board must be built, having the even load distribution in mind, that is to say, a certain movement of the engine control lever on the bridge must be accompanied by equal movements of the governor levers of all the engines involved.

Some teething troubles

The high-speed diesels of the automotive type, in their marine version, have been experiencing some "teething troubles" in their use a propulsion machinery in multiple-engine installations; however, it is only fair to say that the difficulties concerned have not actually affected the basic engine as such. On the other hand, the "marine" equipment has, to some extent, been affected in so far as its resistance to sea water is concerned. However, the bulk of the operational disturbances can be attributed to the inadequate instructions

covering the properties of the new equipment and issued by the engine and equipment manufacturers to the building yards, as well as to the equally inadequate directions received by the crews, or simply to the inobservance by them of the said directions.

Overrating of the amount of misalignment a flexible coupling or a belt transmission can put up with, underrating of the demands upon the engine control equipment to bring about an even load distribution and a good co-operation between the engines, negligence in the piping work giving uneven cooling water distribution from the common intake to the engines, or finally in the ventilation of the machine room causing a too high ambient temperature, are some of the installation deficiencies which have given rise to service disturbances. Prolonged running with really high torque, at speeds as low as 800 rpm (possible on using a controllable pitch propeller) with a turbo-charged engine, provided with a turbo-charger matched for a speed range from 1,500 rpm and upwards, is an operational defect, which has caused engine trouble. On the other hand, there are engines of the same type which have given a virtually trouble-free service as propulsion engines in fishing and canal boats, during more than 20,000 hours without need for a main overhaul. It can then be stated, without fear of contradiction, that when properly installed, regularly maintained and appropriately run, a high-speed diesel of the automotive type will give excellent results in service afloat both in single and multiple engine installations.

Exhaust systems

Kilgore (USA): Borgenstam stated that wet systems are more common than dry. This is simple when the engine is aft. In the USA, Mexico and Canada, however, the forward location is much preferred for small boats, because of the fisherman's desire for deck space in the stern. The only feasible wet exhaust is then out the side, but this obviously will not work unless it is extremely expensive. The result is that the wet system is rarely seen.

Kilgore believed that the record will show more cases of carbon monoxide poisoning from wet systems than from dry. There may be no better reason for this than the greater length inside the boat of the wet exhaust pipe and its location through poorly ventilated spaces. In any case, this danger is very serious with gas engines.

Borgenstam's remark about excessive power cannot be too much emphasized. Although this is not a new observation, naval architects continue to call it to attention, but all over the world the engines in small craft continue to become more and more monstrous. This has come about:

- Because of the availability of cheap, high speed, low torque, heat wasting automotive engines
- Because of man's compulsion to go faster

This is going to be especially debilitating in countries where fish bring low prices and oil costs dearly. It is necessary to continue crying in the wilderness, whether or not it will do any good.

Cooling systems

Montalvo (Peru): Borgenstam mentioned an external engine cooling system, namely the keel cooler and went on to say that engine manufacturers are not entirely happy about this, since neither the layout nor the execution of the cooling system is under their control and also by reason of the mechanical drawbacks of tubing fitted on to the outside of the hull.

As regards the three methods of engine cooling used in Peru, the following remarks are pertinent:

- The conventional method gives rise to the following problems:
  the maintenance of sea-water pump, tubing and heat exchanger is fouled by the abundant scales rubbed off the anchovy caught in the net;
  heating, sometimes up to seizing point, of the engine, due to failure of the cooling system, especially as a result of repeated damage to the impellers;
  the high content of hydrogen sulphide in Peruvian waters, due partly to the presence of anchovy waste, which renders pump, tubing and exchanger maintenance a tiresome business
- Keel coolers mounted as an integral part of the hull have obviated the disadvantages of the conventional type, but have in their turn given rise to a serious problem—the formation of oxides at inaccessible points
- Externally mounted keel coolers have solved the problem: there is no pump, no heat exchanger, and no trouble from scales, oxides, or other sources.

Tubing requirement is in the ratio of .5 ft^2 (0.046 m^2) surface area per engine hp; the material used is 70 per cent coppernickel. The drawbacks of the system, such as the galvanic action of the coppernickel, have been overcome by the application of protective anodes, and no mechanical troubles arise. About 1,000 Peruvian fishing boats use this system, with excellent results. The trend is to instal keell coolers on all boats, even up to 500 hp ratings.

Bryner (USA): In answer to Montalvo's query re oxidation of coolers built into skin of steel hulls, he stated that the use of a corrosion inhibitor in the cooling water can eliminate deterioration within the water passages in closed cooling systems. Most engine manufacturers will be glad to recommend the best type of inhibitor for use with their engines.

Fire fighting

Thomson (UK): Regretted having to be quite at variance with one point in an otherwise good paper. Referring to fire extinguishing Borgenstam said "In the case of a fire on the fuel, there is little to be done with water. It might just make things worse by spreading the fire". Indeed it might, but there is quite a lot that can be done by the intelligent use of water. Some time ago, Thomson was confronted with the task of extinguishing a small fire on diesel oil on an open tray, the fire covering an area of some 15 ft^2 (1.4 m^2). Using a 2-gal (10 l) portable water extinguisher with the nozzle at "spray" setting, Thomson swept this fire off the tray in about 10 sec. Some time later, he tackled a larger oil fire. This time the fire area would be about 250 ft^2 (23 m^2), over a layer of diesel oil on water with flames rising 20 ft (6 m) or so above its surface. After sweeping the surface of this fire very vigorously with a strong horizontal spray for about 30 sec the flames were extinguished.

Yet again Thomson had the experience of extinguishing an oil fire from above the flames. Positioned in a totally dark "tween decks", he played a spray nozzle through a hatchway and, in about 15 sec, extinguished the flames, emanating from a large tray of burning oil in the space 10 ft (3 m) below, which were emerging through the hatchway.

His point was this: there are several effective ways of extinguishing an oil fire. It may, however, be too late to blanket the flames with fabric as suggested by Borgenstam; the handiest small portable extinguisher may be at the seat of the fire or be too small for the size of the fire; there is just the possibility that a CO$_2$ gas system may be ineffectually applied. It would be a great pity if fishermen were restrained from using the millions of gallons of water around them by a

warning that it was unsuitable for oil fires. Water is, in general, associated with fire-fighting and this is a psychological factor. On small vessels a hand pump with which a fisherman is familiar is, perhaps more likely to be maintained in good working condition than extinguishers or a system with which practice is seldom likely to be gained.

Provided emphasis is placed on the need for a spray and a shrouding action in application, there is no need to rule out the use of water. Thomson's experiences were acquired under a system of fire-fighting training which is in operation in the UK for officers of the merchant navy.

Townsend (USA): Borgenstam's paper presented a fine summary of practical features of the mechanical installations aboard fishing vessels, and is one of the few papers that touches on fire prevention and extinguishing; accordingly, it is felt that it is not only in order, but necessary, to suggest that the efforts of the US National Fire Protection Association (USA) be mentioned as very appropriate reference material not only for this paper, but for all those designing, building or inspecting fishing vessels.

Specifically, NFPA Publication No. 302 (Motor Craft, 1964) treats with fuel tanks and systems, exhaust and cooling systems, electrical installations, fire extinguishing equipment, lightning protection, cooking, heating and auxiliary appliances and operation and maintenance.

Rules in Norway

Strande (Norway): In connection with the implementation of the SOLAS 1960 it was found desirable also to set up new rules influenced by the new convention requirements, for the fire-fighting and fire protection of fishing vessels. These rules apply to vessels of all sizes and are principally divided into three parts, viz. one for vessels of 500 GT and above, the second covering vessels less than 500 and above 25 GT and the last covering vessels less than 25 GT.

The rules for vessels of 500 GT and above have in the first place all requirements for the materials of hull, superstructure, watertight bulkheads, engine and boiler casings, deck and deck houses. They are to be built of steel or equivalent material.

The partition bulkheads, doors in alley ways, staircases, etc., must be built of fire-retarding material. Paints and deck coverings must be of certain fire-retarding types. Regarding the fire-fighting equipment all vessels of 500 GT and above must have two separate fire pumps and vessels above 1,000 GT are in addition required to have an independent emergency fire pump placed outside the engine room.

There are specific requirements for the capacity of pumps, the fire line, valves, hoses, types of nozzles, sprayers, etc. An international coupling for shore connection to the fire line has also to be fitted. The engine and boiler room must be protected by a permanent fire extinguishing system that can either be a fog nozzle arrangement in connection with a separate automatic independently-driven pump or a total flooding system with carbon dioxide (CO_2). There must in addition be fire hoses and portable fire extinguishers in engine and boiler rooms. It might be mentioned that there are certain requirements to shut off valves in fuel lines and fire dampers in ventilation channels as well as emergency stops of ventilation fans and fuel pumps.

In the accommodation, the rules have specific requirements to number of fire valves with hoses and portable fire extinguishers. Portable equipment such as breathing apparatus, safety lamps, electrical drill, life line and fire axes must also be on board.

The rules give definite instructions regarding fire drill and maintenance of the fire-fighting equipment. Drawings showing the fire equipment, means of escape, fire alarms, description of the fire-fighting systems, position of portable fire extinguishers, fire hoses, etc., have to be put up in a central position on board. The rules for vessels of 500 GT and above are principally up to the standards of the SOLAS 1960 with respect to fire fighting, except that there are no requirements for permanent fire extinguishing systems in the cargo holds.

Insulation requirements

The rules for vessels less than 500 but above 25 GT have certain specifications as regards insulation of engine and boiler rooms, galleys, etc., if the vessels are built of wood. Regarding materials in the accommodation, paints and deck coverings the rules are practically the same as those for the larger vessels.

As some of the smaller vessels may be built of wood, the rules contain more details concerning insulation of heaters and stoves, funnels and exhaust pipes.

Vessels of less than 500 GT must have at least one independent fire pump, but for vessels less than 100 GT this pump may be driven by the main engine and for vessels between 50 and 25 GT equivalent fire-fighting equipment may be accepted in lieu of power-driven pump. There are in the same way as for the larger vessels requirements to the fire lines, hoses, valves, nozzles and sprayers. There must be at least one valve attached in the engine room. Vessels of less than 200 GT may have this valve placed at the entrance to the engine room. If there is a separate auxiliary engine room, for example, in connection with the preservation of the catch, extra fire valves must be fitted. Requirements to fuel shut-off valve, fire dampers in ventilation channels, emergency stops are as for the larger vessels. Portable extinguishers and fire axes have to be placed in engine room and accommodation. Number, type and size are specified.

The rules for fire fighting on vessels of less than 25 GT are common for fishing vessels and other small vessels except those required to have passenger certificates. The rules have as for the larger vessel requirements regarding insulation of engine room, heaters and stoves, funnels and exhaust pipes.

There are specific and separate rules for installation of gas stoves and cookers using propane or other light hydrocarbons as fuel on board. Such equipment is extensively used in smaller vessels, but the rules must of course be complied with by all vessels using such devices. Vessels of less than 25 GT are required to have at least one fire extinguisher of 13 lb (6 kg) if the vessel is decked. If the vessel is not decked, an extinguisher may be required. An adequate number of fire buckets is to be on board. The above fire regulations came into force on 26th May 1965.

Stern tubes

Breekveldt (New Zealand): A fishing boat with the engine room forward requires a long shafting arrangement. If the stern tube is kept to a minimum length, the stuffing box will be located in the fishhold or (more favourably) in another designated space aft of the fishhold. The bare part of the shaft below the insulation of the hold must be covered over somehow. Maintenance of the shaft and attention to the stuffing box can prove difficult with the short stern tube.

Breekveldt had had experience with long stern tubes in steel vessels. The stern tube is extending below the fishhold to the aft bulkhead of the engine room. The stuffing box is now located in the engine room, facilitating regular attention. The long span between the stern bearing and the stuffing box usually requires an intermediate bearing. The long stern tube is therefore underbroken and a box-type container is constructed which is linked up (oiltight) with the fore and aft parts
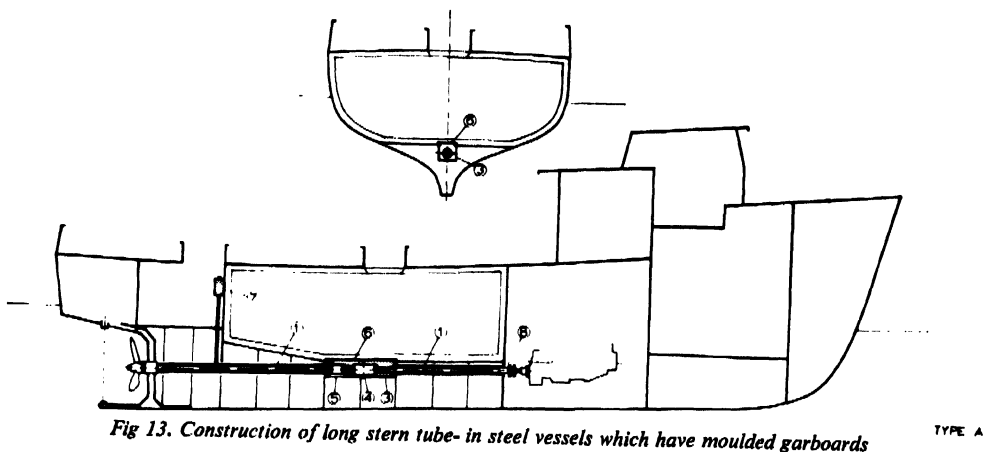
Fig 13. Construction of long stern tube- in steel vessels which have moulded garboards   TYPE A
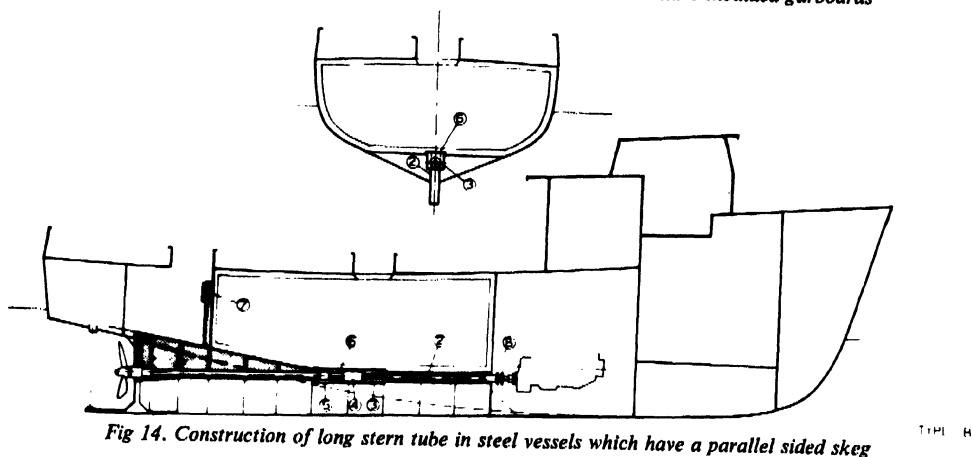
Fig 14. Construction of long stern tube in steel vessels which have a parallel sided skeg   TYPE B
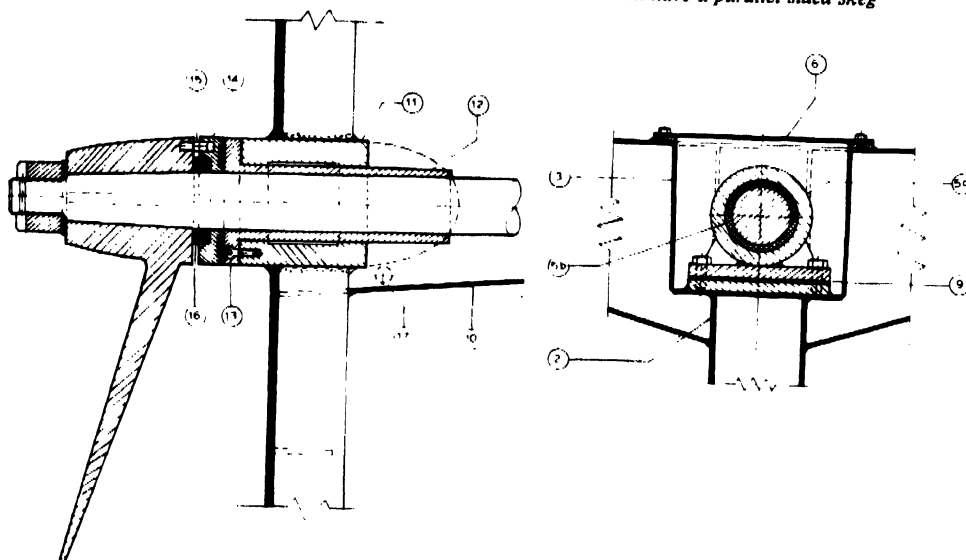
Fig 15. Detail arrangement of propeller and propeller shaft in steel vessels which have a parallel sided skeg

Key to fig 13, 14, and 15

1) Stern tube
2) Extended skeg
3) Box to accommodate the intermediate bearing and shaft coupling
4) Shaft coupling
5) Intermediate bearing
5a) Bearing housing
5b) Bearing material (ferrobestos)
6) Inspection lid
7) Header tank for stern gear oil
8) Stuffing box

9) Shimming between baseplate of intermediate bearing and foundation plate
10) Oiltight partition in skeg
11) Boss of stern frame
12) Stern bearing (bronze)
13) Fastening screw for bearing (stainless steel)
14) Sealing ring (bronze with white metal facing)
15) Driving pin (stainless steel)
16) Soft rubber ring
17) Drainplug

of the stern tube. An inspection plate is mounted on the top of this box. The lubrication of the bearings is by means of oil and to this end the whole tube and box are filled and fed by a small header tank. This tank is mounted just below the deck in either the engine room or the aftpeak space. A sealing ring is fitted between the propeller and stern boss. The arrangement is shown in fig 13.

In boats up to an overall length of 47 ft (14.3 m) it has been possible to employ shafts of 20 ft (6 m) length or shorter. The maximum available stock length of shafts is usually 20 ft (6 m). In boats with an overall length of between 47 ft (14.3 m) and 52 ft (15.9 m), it still proved worthwhile to especially import full length shafts. In longer vessels with the engine room forward, it became necessary to incorporate a coupling which because of its size must also be located in the box-like structure used for the intermediate bearing.

In boats which do not have moulded garboards, but which have a parallel-sided skeg, it was found easier to extend the skeg inside the hull and utilize the top part of the skeg as stern tube. A fully oiltight division is then welded just below the shaft line. Care must be taken that the transverse floor-plates are matched with similar plates inside the skeg and that these are welded appropriately to cope with transverse stresses.

Shafts with diameters up to 3.5 in (90 mm) and without liners, can be accommodated satisfactorily inside a skeg with an internal width of 6 in (150 mm). It is just possible to locate an intermediate bearing inside this width, but it is of course necessary to put the fastening flanges of the inspection plate outwards from the skeg.

If a coupling is necessary, then one must resort to a similar box as previously described. In this arrangement the whole top of the skeg is oilfilled. It is illustrated in fig 14 and parts of it are detailed in fig 15. The photographs in fig 16 and 17 show this type of arrangement for a 60 ft (18 m) vessel before the framing is completed.
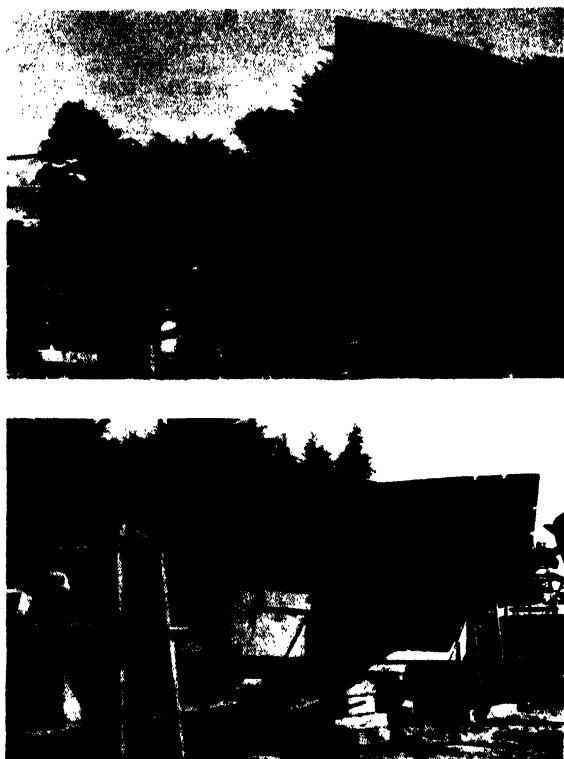
Fig 16 & 17. A long stern tube boat under construction

Just before the closing of the top part of the skeg, all slag, dirt and loose rust must be removed. Before filling up with oil and going into operation of the vessel, the tube is flushed out. A drainplug must therefore be provided on the lower end near the boss. See fig 15. The oil-lubricated stern gear arrangements have given trouble-free service. Breekveldt's experience dated back seven years, but there is every indication that at least ten years can be expected without maintenance, other than the normal attention to the stuffing box and the yearly oil changes.

A suitable oil seal at the propeller end is a bronze ring with white metal facing which is driven by three stainless steel pins. These pins are tapped into the propeller boss. The sealing ring can slide over these pins in fore and aft direction and is pressed against a flange which is part of the stern bearing. Pressure is applied by a 1 × 0.75 in (25 × 18 mm) soft rubber ring which is given 0.19 in (5 mm) compression during assembling. There must be room for the rubber to expand in the other direction and therefore the housing of the sealing ring must be chamfered. The rubber ring is cut from sheet rubber 1 in (25 mm) thick.

Oil grooves in the bearing surfaces and the face of the sealing ring provide the required lubrication. The oil used is water soluble oil of grade 30. A suction pipe from which the oil can be occasionally pumped out is advisable so that maintenance of this kind is independent of the slipping of the vessel.

The intermediate bearing is better made up, to save space. It can consist of a bronze or ferrobestos bush in a housing of mild steel heavy wall tube welded to a fastening flange. See fig 15. The material of the shaft most frequently used in conjunction with this arrangement has been mild steel. It is virtually not exposed to the sea water.

If in one length, the shaft itself can be used (before the tapers are cut) for the boring and facing of the boss and reinforcing plate in the engine room bulkhead (to take the stuffing box). For this procedure the intermediate bearing is first located in its true position to provide the necessary support during this operation.

Fixed-pitch propellers

Bryner (USA): Experience in working with builders of traditional fishing boats has shown the desirability of some sort of guidelines for the determination of minimum propeller sizes which are required to produce consistently acceptable results. Propellers are all too frequently selected without proper relationship to factors governing performance requirements. Those who are technically qualified to make propeller calculations are often consulted after the hull nears completion and shaft centreline, propeller aperture size and hull clearance are irrevocably fixed. When these conditions occur, and the largest propeller which can be fitted is too small, technical competence is often incapable of circumventing the inadequacies created by these limitations without resorting to costly reconstruction of the hull. Without hull correction, a propeller, which is too small to operate effectively, must be employed. This type of performance limitation penalizes the boat owner for as long as corrections are not made. He pays for a larger engine than resulting performance requires. He pays for fuel and maintenance at a rate for high brake hp input while getting low effective hp output. He continues to lose revenue so long as trip time required to bring home any given quantity of fish is longer than it needs to be.

The current trend in powering fishing boats points towards increased power. It is, therefore, becoming more important to achieve the proper matching of engine and propeller to produce required results. The following system provides a

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simplified method for determining minimum propeller requirements for any combination of shaft power between 20 and 1,200 hp and speed of advance (V_a) 0 to 30 knots, disc area ratios (DAR) from 0.30 to 0.90.

First it is necessary to establish the shp which will be employed and the proper V_a value for the hull. V_a should always be selected for the speed at which the most important work is to be done where full power is applied. Methods for determining V_a are available to many. Where such data is not available, the following conversion factors may be applied to boat speed for a rough approximation of V_a.

	Single screw	Twin screw
Fine hull	0.85	0.92
Moderate hull	0.82	0.89
Full hull	0.78	0.85
Very full hull	0.73	0.80
Planing hull	0.92	0.94

Estimated boat speed in knots for which the propeller requirements are to be established, must be multiplied by the appropriate factor. The result gives V_a to be used in the nomographs.

Once V_a is established, it is only necessary to connect a straight line from shp to V_a in fig 18 to determine developed blade area required to adequately carry the load. The blade area required is read directly on the centre scale.
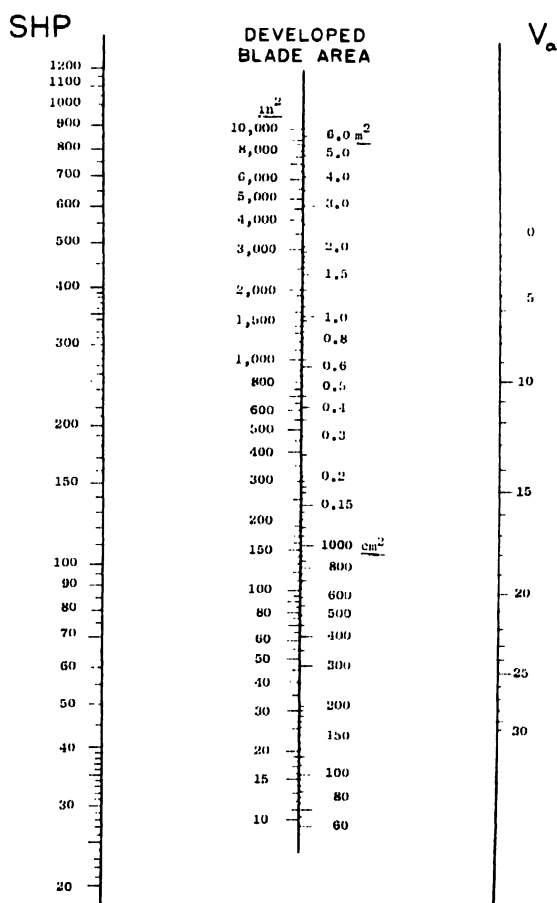
Fig 18. Nomograph for the determination of minimum blade area when shp and V_a are known. To use, connect the selected values for shp and V_a with a straight line. Read blade area where this line intersects centre scale.
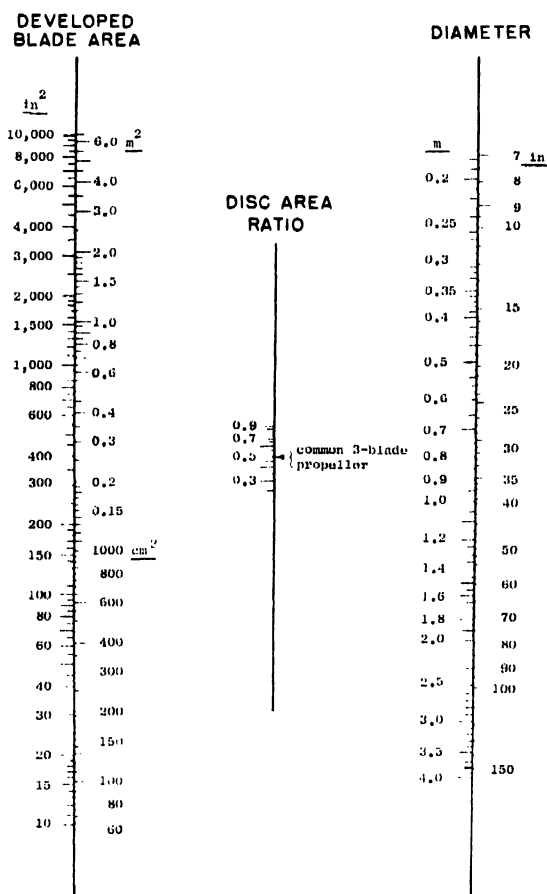
Fig 19. Nomograph for the determination of minimum diameter when blade area and disc area ratio are known, or, alternatively, for determination of disc area ratio when blade area and diameter are known. To use, connect a straight line from the determined value of blade area, through the selected value for disc area ratio, to the diameter scale. Alternatively, connect a straight line between blade area and diameter, then read disc area ratio where the line intersects this scale.

The value for blade area is then carried to the second nomograph (fig 19) to determine required propeller diameter, based on disc area ratio to be used. Here, a straight line is extended from the correct point on the blade area scale, through a selected disc area ratio. This line will intersect the diameter scale to indicate the minimum diameter for the disc area ratio which will provide the minimum required blade area.

Commonly used disc area ratios are 0.50 for many three-blade propellers, 0.55 to 0.68 for common four-blade propellers. Where diameters become too large for using common propeller types, a straight line may be connected from blade area to diameter, to determine the required disc area ratio. This will usually need to be done where special propellers are required.

The next step, after determining propeller diameter, is to determine propeller rpm. The nomograph (fig 20) for this determination bears a familiar resemblance to that often used incorrectly to determine propeller diameter from shp and rpm. When used to determine diameter, the result does not indicate whether this diameter is capable of handling the load. For this reason it should be used last to determine rpm, after the diameter and blade area requirements are established.

To use this nomograph, a straight line is run from the proper point on the shp scale through a point on the diameter scale corresponding to the selected diameter. This line will

intersect the rpm scale to read directly a nominal rpm for three-blade and four-blade propellers.

The nominal rpm, determined by this nomograph, will tolerate a rather wide range of variance. The indicated rpm value can usually be varied from a 10 per cent increase to 25 per cent reduction in rotative speed and still produce an acceptable propeller. The smaller "plus" tolerance avoids approaching excessive tip speeds, while the wide range makes it possible to adjust rpm to accept commercially available standard reduction gear ratios.

SHP   RPM

DIAMETER   3-BLADE   4-BLADE

```
                    in     m                100 --
                                                      100
                   150          4.0
 1200                           3.5          150
 1000                                                 150
  800                           3.0
  600              100          2.5          200 --
  500               90                                200
  400               80          2.0
  300               70                       300
                    60          1.5                   300
  200
  150               50                       400
                                                      400
  100               40          1.0          500 --
   80                           0.9          600 --
   60               30          0.8          700        600
   50                           0.7          800        700
   40               25          0.6          900        800
   30                                        1000       900
                    20          0.5                     1000
   20
                    15          0.4
                                             1500
                                0.3                    1500
                    10          0.25         2000 --
                     9                                 2000
                     8          0.2
                     7                       3000 --
                                                       3000
                                             4000 --
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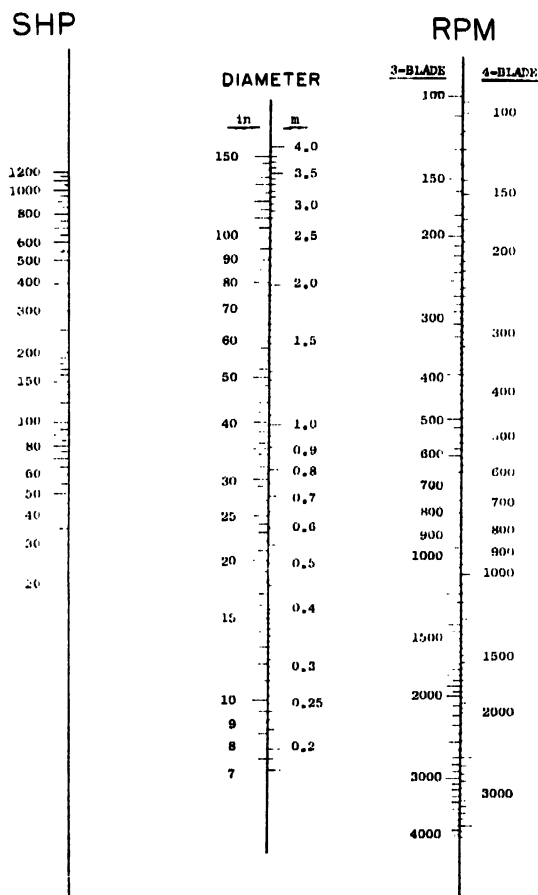
Fig 20. Nomograph for determination of propeller rpm when shaft hp and propeller diameter are known. To use, connect values for shp and propeller diameter with a straight line. Read rpm on either the three-blade or four-blade propeller scale according to the number of blades used. Rpm obtained may be increased up to 10 per cent, or reduced up to 25 per cent to adjust propeller speed to standard engine speeds and standard reduction gear ratios.

Once diameter and rpm are determined, a builder is able to provide an aperture for a propeller which will provide, at least, reasonably good performance. Increased performance, above this established minimum, can nearly always be obtained by increasing propeller diameter. It is only necessary to make the adjustment on the third nomograph (fig 20) and reduce nominal rpm by an appropriate amount.

It must be kept in mind that blade area is required to carry the load, but it is diameter which determines how efficiently the propeller will work. Propeller diameters, larger than the minimum determined by this system, will nearly always produce higher efficiencies.

Checking the system, involving many examples over a wide variety of conditions, has demonstrated the practicability of its use. Calculations by other methods bear out the basic correctness of this system. It requires the employment of a person technically qualified to calculate the final selection of a propeller, but the builder and the boat owner can now be assured that such a person is provided with dimensional limits which are adequate to provide favourable conditions for good performance.

Company thanked

Traung (FAO): Bryner's nomographs are very interesting and Traung would like to convey the thanks of the naval architects to Bryner's company for his latest addition enabling simple propeller selection to be made. The propeller calculator issued by Bryner's firm some five or six years ago has been extremely helpful in this field.

One of the reasons why several naval architects have difficulties in matching their hulls with the engines is that they have no instrument with which to easily measure the hp of the engine. Marine engineers are able to measure hp by means of strain gauges, exhaust gas temperatures, etc. But what naval architects need is a simple instrument with which the fishermen can easily determine the number of hp he is taking out of the engine. FAO has tried several fuel flow-meters but it was common that they never worked. However, even on small aeroplanes there are flow-meters where one can read exactly what power is being used, for example, during take-off. Why do not marine engine manufacturers make such an instrument?

Bryner (USA): In answer to Traung he said that his company and he himself had investigated the possibility of using flow-meters of the instant flow-rate reading type. It was found that these do exist, but they are sensitive to fuel viscosity. They are, therefore, accurate only if fuel viscosity through the meter can be controlled. Viscosity of fuels used and variations in fuel temperature, due to operating and storage conditions, makes this impractical at this time. Research is in progress. Gasoline viscosity is quite constant over normal temperature ranges and such meters are available for use with gasoline engines.

To measure engine power

Hatfield (UK): Rough methods of measuring engine power *in situ* are by fuel rack position and by engine temperature, but where an accuracy better than ± 10 per cent is required, it has been found necessary to measure power by fitting electrical strain gauges to the propeller shaft.

Engine makers, or at least the bigger firms, can do this with the aid of their own electronic engineers, for the cost of materials and wages only. Smaller firms can commission one of a number of specialist firms to strain gauge propeller shafts, at a cost of somewhere near £200 ($580) per ship. The read-out equipment could be purchased at a cost of about £125 ($350) to be used indefinitely on any ship.

A system such as this, on a normal uncalibrated shaft, would give an accuracy guaranteed better than ± 4 per cent, provided the shaft diameter were measured accurately and the material specification were known. Instruments to read fuel flow direct are available on the UK and American market.

Since there seems to be a demand for it, the White Fish Authority will publish a technical bulletin on strain gauge torsionmeters, giving full technical details and naming appropriate manufacturers.

Controllable pitch propellers

Itazawa (Japan): Was very much impressed to see that most of the Swedish fishing boats had controllable pitch propellers. The use of the controllable pitch propellor to a great extent

leads to the automation of fishing boats minimizing crew, increasing efficiency and improving labour conditions.

In Japan it was quite seldom ten years ago that controllable pitch propellers were used. However, thanks to the suggestion of Fujinami, the number of boats with these propellers has rapidly increased. Now the advantages are highly estimated among people concerned. Itazawa hoped that the further study to combine the main engine in a most efficient way with the reduction gear and the controllable pitch propeller will surely bring down the operation cost of fishing boats.

Campion (UK): Where power requirements for fishing are low, as in herring drifting and ring netting, the free-running requirements govern the power of the engine fitted and a fixed pitch propeller designed to give its best performance at high speed is no doubt the best answer. However, increasing interest is being shown by Scottish fishermen in pair trawling for herring, and although there is some difference in opinion regarding the engine power necessary for this type of fishing, indications are that considerably more power than is necessary for free-running will be required for pair trawling, particularly if this method of fishing is to be pursued in water over 60 fm (110 m) for more than a very few months each year. There, surely, is a good argument for fitting controllable pitch propellers. Although generally accepted in Scandinavia, they have not proved popular with Scottish inshore fishermen. However, some recently completed boats have been fitted with controllable pitch propellers and, once their operation is understood, owner/skippers are realizing their value.

CP propellers essential

Høgsgaard (Denmark): In Scandinavia the controllable pitch propeller has been considered for a very long time one of the essentials to the fishing boat propulsion system and such a propeller was exhibited in Sweden as far back as 1904.

The fixed pitch propeller is rarely used and can be compared with the controllable pitch propeller, as say a car engine with one gear as against an infinite number of easily changeable gears. With a controllable pitch propeller, it is possible to set the correct pitch for any condition at revolutions and hp most suitable for the engine. This means that good efficiency can be obtained in the widely different conditions prevalent in fishing procedure, i.e. trawling or free-running.

In adverse conditions in the North Atlantic, the general procedure is to turn the stern of the vessel into the oncoming seas with the propeller idling. Should these conditions exist for a long period for a ship with a fixed pitch propeller then difficulties can arise with the engines on account of the very low rpm. These can lead to engine stop so that the ship is transversed and will be wrecked. With a controllable pitch propeller, the pitch could have been reduced and the engine operated with such rpm that it could be kept running as long as there is fuel in the tanks.

Noel (UK): He had once been instrumental in testing a 13 in (330 mm) diameter nylon propeller on an 18 ft (5.5 m) lobster boat, working from the beach and being driven on to stony shingle, many times a day in the summer when carrying trippers. After 12 months' use it was still unmarked.

Nylon propellers

Høgsgaard (Denmark): The first nylon propeller in the world was made in Denmark for use for a Swedish outboard motor. Tests were carried out with this motor in water in which there was much drift-wood. The propeller suffered no damage. The boat was run on to a stone beach and again there was no damage to the propeller.

It is a difficult operation to cast nylon and it should be done at pressure of 1,300 lb/in^2 (90 kg/cm^2). The best dyes for

casting are of manganese bronze. Early castings were foun to have negligible moisture content. A better strength an flexibility are obtained when the moisture content is highe Høgsgaard had also tried treating in a hot oil bath to improv flexibility. However, a yellow skin which formed on the surfac of the nylon caused surface cracking which produced brittle ness and fracture. Nylon propellers have been used in quantit on German amphibious cars. However, for marine use, it i necessary to have a new type of nylon with more flexibilit and higher tensile strength before continuing production.

Manoeuvring

Bruce (Sweden): Manoeuvrability is a very important topic However, the field is enormous and it is only possible to trea a small portion, limiting the discussion to controllable pitcl propellers and hydraulic steering gears. In order to save time and even more to create safety, the possibility of rapic manoeuvres is very important and must be well considerec when planning an installation. Just as important is tha manoeuvrability should be available under all conditions at any speed of the boat and propeller. The two requirement call for rather big pumps and oil pressures high enough tc guarantee the manoeuvres.

Turning for a while to propellers only, it is not practical tc have a big pump working at full pressure all the time, creating a high oil temperature and wasting fuel oil. To avoid that, various methods have come into use. One method used quite frequently consists in having a servo-valve with negative overlap, that is the lands of the valve spool are ground in such a manner that when the valve is in mid-position, oil can leak through the valve from pump to tank and thus the pump pressure will be exactly what is needed to hold the propeller in place. Unfortunately the pitch can change a considerable amount, should the torque on the blades for any reason change direction and an unstable propeller can also start fluttering.

One system developed and used by one propeller maker, employs two pumps, different in size and a special valve. This valve in fact is a combination of two valves with different ways of acting. In mid-position the valve gives free passage from the big pump to tank, whereas the passage for the little pump is closed. The positive overlap for the little pump is about 1/250 in (0.1 mm) in each direction and for the big pump 0.12 in (3 mm). For fine adjustments and slow manoeuvres only the little pump comes into action, while big pump still idling. In neutral position, the piston of the servo cylinder is locked without backlash. When a quick manoeuvre is nearly finished, the speed of the piston slows down and the piston creeps to the final position, only moved by the little pump and no overriding can occur.

Most fishing boats have still the bridge control for engine governor and propeller separate, but there is a trend to combine them to a one lever system in order to facilitate the work for the captain. One must remember that the one lever system is dangerous for the engine unless there is some kind of load control. Some engines can give the maximum torque for a wide range of rpm. For those engines it is simple to arrange an alarm system giving a warning when full torque is used below a predetermined engine speed. But the system is not an automatic pitch adjustment.

If the engine is equipped with a hydraulic governor with load control pilot valve, a not too complicated method to adjust the pitch automatically to suit the engine can be used. But here the simple hydraulic system for propeller manoeuvring with negative overlap can cause hunting so that the engine speed rapidly moves up and down. The two-pump system has given excellent results as the slow final pitch adjustment and the lack of backlash give the engine governor a possibility to work in a satisfactory manner.

A fishing boat should have a quick acting steering gear for all intricate manoeuvres, but a quick steering gear is a nuisance when steaming, unless the steering gear is arranged for sympathetic steering. This means that it should act like power steering on a truck, and move slowly or rapidly, according to circumstances. Unfortunately that type of steering gear costs more, but it puts much less strain on the helmsman.

The majority of steering gears give below and up to two by 45 degrees rudder movement. However, it has been shown that it is a great advantage to use bigger rudder angles, when manoeuvring at zero and near zero speed. Rudder angles of 65 to 70 degrees have been in use a long time for river cargo ships and a number of captains of harbour tugboats praise the bigger rudder angles. For fishing boats they are in use in Holland and Norway and the least that can be said is that they give full satisfaction.

Two engines tried

MacLear (USA): Recently a 60 ft (18 m) open boat had installed two outboard motors, one in the bow and one in the stern. This was done for manoeuvrability and reliability. On trials it did 14 knots and the manoeuvrability was excellent. Referring to the extended shaft outboard, the normal extension is some 7 in (18 cm) but he had on odd occasions had to add up to six extensions. In order to keep the extended outboard from bending and causing gear wear, he had to support the stock in three directions with wire.

Many devices used

Wanzer (USA): A cursory count of the references to the need for better manoeuvrability and manoeuvring devices contained in a single FAO document (Traung and Fujinami, 1961) discloses that 37 individuals mentioned the matter at least 83 times. Innumerable publications confirm interest in manoeuvring and positioning equipment.

Several manoeuvring units are in wide use today, each offering peculiar advantages in special situations. Bow thrusters with or without controllable pitch propellers, nozzle rudders, active rudders, vertical-axis propellers, hydrojets and steerable right-angle drive units, are some of the schemes already employed. But, despite the fact that thousands of installations of all sorts have been made, there is a paucity of reliable published trial data which depict performance under service conditions.

Obviously, if main propulsion, steering and manoeuvring capabilities can be combined in a single unit completely controllable from the wheelhouse, eliminating the need for the usual steering engines, rudders, tailshafts and struts, and without costly sacrifice in performance, so much the better. The purpose of this contribution is to present hitherto unpublished trial data on right-angle drive units.

Right-angle drive units are not new. During the past quarter-century over 6,000 units, ranging in size from 40 to over 1,000 hp, have been built and put into world-wide service. Recent applications include those made in the research vessels *Prospector*, *Rockeater*, *Discoverer* (drilling rig), *Caldrill*, *Cuss I*, *Eureka*, *Monob I*, *Albatross IV*, *Josiah Williard Gibbs*, *Surveyor*, *Redwood*, *Oceanographer* and *Discoverer* (survey ship).

Japanese techniques

Osaka Shipbuilding Company, of Osaka, Japan, builds about ten tugs each year. A variety of propulsion systems has been used to meet particular requirements. Tugs have been built with controllable pitch propellers and spade rudders, with controllable pitch propellers and nozzle rudders, with vertical-axis propellers and with steerable right-angle drive
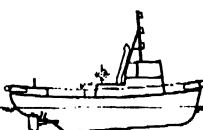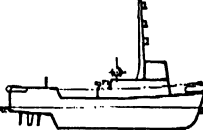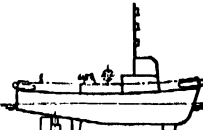
Type of Propulsion	Controllable-Pitch Propellers and Twin Spade Rudders	Controllable-Pitch Propellers and Kort Rudders	Voith-Schneider Propellers	Right-angle drive units (Harbormasters) and Kort Nozzles
General Outline				
Relative size of tug	Big	Big	Medium	Small
Approximate Engine RPM	400	400	500 - 600	750
Thrust (Pulling) Towing Thrust Power / Main Engine SHP	25.3 - 27.5 lb /SHP (11.5 - 12.5 kg /SHP)	30.8 - 35.2 lb /SHP (14.0 - 16.0 kg /SHP)	22.0 - 24.2 lb /SHP (10.0 - 11.0 kg /SHP)	33.0 - 37.4 lb/ SHP (15.0 - 17.0 kg /SHP)
Towing Force When Backing, As a Percentage of Ahead Towing Force	30%	30 - 60%	90%	100%
Time Required for an Emergency Stop, in Seconds	39	20	18	10
Time Required From Full Ahead To Full Astern, in Seconds	10	10	7	7.5
Arc Over Which Steering Force Can Be Exerted, in Degrees	70°	70°	360°	360°
Steering Time Over Full Arc Listed Above, in Seconds	15 - 30	15 - 30	15	15
Time Required for 360° Turn, in Seconds	65 - 70	45 - 50	35 - 45	20 - 25
Turning Radius in Hull Lengths (L)	3 - 5L	1.5 - 2.0L	1.0 - 1.3L	1.0 - 1.3L

Fig 21. Comparative twin screw tugboat performance

units and nozzles. Complete sea trials have been conducted for the first ship of each type built, plus less extensive trials of sister ships, all intended to supplement and confirm model test data used as the basis of design and specifications.

From actual experience the shipbuilders have tabulated the comparative data shown in fig 21. Only two right-angle drive unit-equipped tugboats—*Seiho Maru* and *Yuho Maru*—have been built to date, but otherwise fig 21 reflects wide experience.

Outline drawings of *Seiho Maru* are shown in fig 22. Her dimensions are given in table 7. Model tests were conducted at Osaka University. Fig 23 was taken on 10th October 1964, while she was conducting turning trials. Kort nozzles and four-bladed fixed-pitch propellers were manufactured and installed by the shipbuilders. Four-cycle, single-acting, turbo-

charged 500 hp 750 rpm diesels were installed. Fig 24 is photograph of *Seiho Maru* while building, showing th complete installation.

The propulsive force of each drive unit can be directed ε any desired angle. The two propellers can be operated eith∈ simultaneously or independently from a one-man contr∈ stand in the wheelhouse.

Fig 24. Stern view of Seiho Maru

Trials of *Seiho Maru* were held off Kobe Port, Japan, on 10th October 1964. The weather was fine, sea condition calm. wind light and a depth of water on the trial course about 50 ft (15 m). More recently, less comprehensive trials of *Yuho Maru* were held in the same area, whose limited trial data confirm the results of *Seiho Maru* trials.

Ahead and astern bollard pull tests were conducted at the builders' fitting-out quay (please see table 8). The weather was cloudy and the sea calm. An adverse wind, about two points on the longitudinal centre-line of the tug, at a speed of about 9.7 knots (5 m/s) may have affected measured performance. During the tests, *Seiho Maru* was trimmed 10 in (0.25 m) by the stern and her mean draft was 11 ft 4⅝ in (3.47 m), corresponding to a displacement of 163.3 tons (166 ton).

INBOARD PROFILE

UNDER DECK ARRANGEMENT

STERN VIEW

Fig 22. Propulsion layout of Seiho Maru

Fig 23. Turning trial of Seiho Maru

TABLE 7
Coastal tug *Seiho Maru*
Dimensions

Length overall	65 ft 9⅝ in (20.05 m)
Length between perpendiculars . .	63 ft 11¾ in (19.5 m)
Breadth (moulded)	26 ft 3 in (8.0 m)
Breadth at waterline	25 ft 8⅝ in (7.84 m)
Depth (moulded)	9 ft 6⅛ in (2.9 m)
Draft (moulded), designed . .	5 ft 10⅞ in (1.8 m)
Draft (maximum), designed . .	11 ft 3⅞ in (3.45 m)
Displacement	162.4 tons (165 ton)
Displacement, light . . .	142.7 tons (145 ton)
Gross tonnage	99.64
Net tonnage	31.56

Accommodation

Officers	2
Crew	4
Spare	1
Total	7

Coefficients, etc.

Midship section	0.845
Block	0.580
Prismatic	0.686
Waterplane	0.816
Tons/inch immersion . . .	3.199 (1.28 ton/cm)
Wetted surface area . . .	2214.4 ft² (205.8 m²)
Propeller immersion . . .	193.1% diameter

TABLE 8

Bollard pull tests

Engine order	Mean propeller rpm	Total hp	Rope tension	Bollard pull
1/4 ahead	187.8	286.1	14,333 lb (6,500 kg)	50.1 lb/hp (22.8 kg/hp)
2/4 ahead	233.4	505.0	22,271 lb (10,100 kg)	44.1 lb/hp (20.1 kg/hp)
3/4 ahead	263.9	722.2	30,539 lb (13,850 kg)	42.3 lb/hp (19.2 kg/hp)
4/4 ahead	297.1	1,021.4	38,588 lb (17,500 kg)	37.8 lb/hp (17.2 kg/hp)
Overload	304.4	1,103.9	40,793 lb (18,500 kg)	37.0 lb/hp (16.8 kg/hp)
4/4 astern	297.0	1,038.5	37,044 lb (16,800 kg)	35.7 lb/hp (16.2 kg/hp)

TABLE 9

Speed trials

Engine order	Average total hp	Average propeller rpm	Average speed (knots)	Speed–Length ratio $V/\sqrt{L}$
1/4 ahead	192.4	194.2	6.935	0.867
2/4 ahead	385.3	251.3	8.576	1.072
3/4 ahead	554.6	289.8	9.733	1.217
4/4 ahead	756.9	316.3	10.473	1.309
Overload	818.0	325.5	10.694	1.337
2/4 astern	371.8	251.4	8.671	1.084

TABLE 10

Turning trials

Helm angle	35°		60°		90°		90°	
			Initial 360° turn				Steady turning	
	Right	Left	Right	Left	Right	Left	Right	Left
Time required to complete right-angle drive unit positioning, in sec	9.5	14.3	8.6	5.9	5.7	6.3	—	—
Elapsed time to complete a 360° turn, in sec.	33.6	40.2	25.0	28.8	27.3	25.4	21.3	20.6
Maximum heel recorded, in degrees	9 (P)	8 (S)	8 (S)	6 (P & S)	8(S)	8(P)	6 (S)	6 (P)

To determine the minimum speed obtainable with both engines operating ahead at the lowest engine speed, each of two sets of observers made ten measurements of the time required to transverse a distance of 44.72 ft (13.63 m). Under these conditions, the *Seiho Maru* averaged 3.07 knots with a total of 31 shaft hp, the mean propeller rpm being 91.8. Lower ship speeds could obviously have been obtained with both engines running by rotating one unit so as to oppose the thrust of the other and adjusting propeller rpm to suit desires.

Other speed trials were made over a course of 4,642.6 ft (1,415 m) at a mean draft of 11 ft 3½ in (3.442 m), with a 1 ft 1¼ in (0.338 m) trim by the stern. Displacement was 161.4 tons (164.0 ton). Runs in opposite directions were averaged for all ahead speeds in order to cancel out wind and current effects. A single measurement was made of speed astern, with an adverse current and a favouring wind. Table 9 summarizes speed trial results.

Trials were made of several different methods of stopping. On one test, with the tug making full-speed ahead, main engines were ordered stopped and the drive unit kept in the ahead position. *Seiho Maru* came to a stop in 104.8 sec, travelling about 460 ft (about 140 m). On a second test, both units were turned through 180 degrees, the engines continuing to make rpm. *Seiho Maru* was dead in the water in 9.6 sec, having run about 66 ft (about 20 m). A final test was made with the tug at three-quarters-speed ahead (680 engine rpm). With engines continuing to run at the same speed, the two units were turned 90 degrees (abeam) in opposite directions, to oppose each other's thrust. *Seiho Maru* came to a stop in 10.1 sec, with the same run of about 66 ft (about 20 m).

Turning trials were made to starboard and to port at full engine speed (750 rpm), using drive unit helm angles of 35, 60 and 90 degrees, both units being used simultaneously for steering. In many multiple installations, especially when less stringent turning requirements prevail, a single unit is used for steering, and speed along course over the ground is not so severely reduced during the turning manoeuvre. The results of turning trials are reported in table 10.

Author's replies

Borgenstam (Sweden): The discussion has confirmed that to solve the problem of mechanization of fishing vessels in remote countries, it is not possible just to copy the existing machinery plants. Conditions vary widely and even in developed countries, one is undergoing a revolution in technical respect. Old traditional ideas are being revised. Opinions vary as to what the ultimate solution will be.

In the long run it seems that the marinized automotive engine will most probably capture the market in the power bracket below about 300 hp. This will take some time because its successful operation requires a land-based service organization to be built up and the philosophy of repair by replacement to be established in the minds of ship designers and users. The engine makers must assist to this purpose and they must not expect too much from the side of the fishermen themselves, who are seldom trained in this way of thinking. Naval architects must also become better acquainted with the characteristics of the automotive engine and design so that it can be properly maintained and also removed from the engine room completely when necessary. Machinery installations in fishing craft have hitherto mostly been influenced by conventional shipbuilding standards, but should also benefit from

the experience gained in the pleasure craft field. The future, whatever the outcome, will certainly be most interesting to all concerned with these questions.

Answering Traung: torquemeters for measuring of shaft power are available and can be employed for experimental purposes. Flowmeters in the fuel lines have been used in Swedish MTB's as an additional check on the actual engine output and have given good service.

Replying to Sinclair: Proper alignment of shafting is easy enough, but as a matter of experience, correct alignment would in practice seem to be the exception rather than the rule. An elastic coupling is no excuse for misalignment but can save the plant from expensive failures in case of misalignments or movements of the hull. Such couplings are usually considered only for an elastically-mounted engine, but they are a recommendable safety device also when the engine is on solid mountings.

Rubber exhaust pipes have been used in pleasure boats with positive result, but of course it requires a wet system. Keel cooling can often work with good result, but the reason why engine manufacturers do not seem to favour them is that they do not have control over their dimensioning and installation.

To Campion on the question of life between overhauls: while many engines might run for four to five years without any need of replacement, it is quite often necessary to make a major repair or overhaul after much shorter period of operation. Selman and several other speakers have had bad experience of rubber shaft bearings and would rather favour white metal-lined bronze bushes. Rubber bearings are used extensively in Sweden, both in pleasure boats and in naval craft and have given good service. In remote countries their replaceability might be less good, whereas a white metal bearing can more easily be repaired with local resources.

HYDRAULIC DECK MACHINERY

Nakajima (Japan): Congratulated Vibrans and Bruttinger on their paper. Nakajima designed hydraulic coupling and vulcan gear about 20 years ago and so he was very interested in the development of hydraulics for fishing boats. During the last 15 years, he has been studying this subject as a member of a fishing machinery committee of the Japan Machinery Association and he was pleased to see that the installation of hydraulic equipment on fishing boats has remarkably increased. He is specialized in the hydraulic equipment for tuna liners and salmon boats, which were placed in practical use about six years ago.

Equipment requires special control depending on fishing gear, weather and fish conditions and the way of operating boats. Nakajima is also studying the automatic regulation system for speed and tension control, especially about absorbing overtension or shock caused by longline. The auto-tension system today available is not sufficient and should be improved to prevent the flow out of fishing gear and saving crew labour. Regarding the pressure of hydraulic equipment which has been very much discussed, he thought it has to be judged case by case, considering economy, safety and maintenance, etc. For boats less than 100 GT it is recommendable to use hydraulic equipment not only for deck machinery but also for propellers, and that will, he believed, raise the fishing efficiency as well as that of operating boats.

Colvin (USA): Vibrans' and Bruttinger's paper is extremely important for the development of hydraulic deck machinery. It would seem that an area where hydraulic deck machinery could be advantageous would be in those localities where sailing vessels are still the prime vessel used for fishing. On the Chesapeake Bay, the oyster dredges in Maryland are operated from automobile engines as are the crab dredges on the lower end of the Bay. This is primarily due to the unlimited supply of wrecked automobiles. In areas where automobiles are scarce, it would seem that with the small prime movers, an economical hydraulic system could be used for a very minimal cost. Colvin wondered if Vibrans and Bruttinger had any occasion to investigate a small compact unit such as this for use aboard sailing vessels.

Hydrostatic system?

Hatfield (UK): Complimented Vibrans and Bruttinger on a very useful survey of hydraulic deck machinery. However, he was surprised that they think so little of the possibilities of the closed loop high pressure, or hydrostatic system in view of its great advantages in efficiency, compactness and control flexibility.

He quoted: "The closed loop system has limited application to vessels under 100 GT. Most piston equipment is designed to transmit powers greater than necessary for these boats. Also the precision required for this type of equipment makes the cost prohibitive. The requirements for a pump for each hydraulically-powered deck machine increases the cost over a system where one pump can supply several motors." This statement completely ignores a whole field of work done by Firth of NEL in the UK, and its subsequent wide commercialization.

Regarding cost, this is of course dependent on availability and would certainly be high if units had to be especially produced. But it so happens that at least two firms produce a whole range of high-pressure commercial pumps and motors, of powers and torques ideally suited to powering the winch of any 40 to 80 ft (12 to 24 m) seiner or trawler. These units are so cheap that the complete hydraulic system including tank, pipes, controls, boost pump, etc., is actually cheaper than the present mechanical array of shafts, belts and gears. Hatfield much preferred not to speak except in cases where he could show hard facts arising from service experience. This is not so in this case, as the UK has been slow in applying hydraulic to its fishing industry, to its own detriment.

However, the above-mentioned system is at present being designed by the White Fish Authority into a 70 ft (21 m) seine netter with a view to early sea trials. Hatfield thought that will be found well worthwhile.

Some comparative experiences

Lerch (USA): Vibrans and Bruttinger have provided a very interesting comparison between various transmission systems for hauling fishing gear on small vessels. Most small vessels have relatively little choice in the selection of transmission systems because of such factors as location of the driving device, local practice, local supply of materials as contrasted with imported systems (sometimes under heavy financial penalties imposed by duties) and/or lack of maintenance and repair facilities.

It had been Lerch's experience that the transmission of relatively high hp such as driving a main fishing winch, when the transmission system is simple and direct, is least expensive in installation and operating cost for mechanical system consisting of chains, sprockets and line shaft or leather belts and shafting. However, as soon as one attempts to drive remotely-located equipment, such as auxiliary winches, vang winches, anchor winches, portable devices such as powered blocks or net haulers, a mechanical system may not only become extremely more expensive but, in such cases as portable equipment, completely impractical. Lerch agreed wholeheartedly with Vibrans and Bruttinger concerning safety and control—both of which are superior and much less costly with hydraulics over other practical solutions for small fishing boats.

TABLE 11
Comparison of various power sources

Power source	Average weight/hp	Proportions in³/hp	£/hp	$/hp
Crew (long periods) (£355 or $1,000/year) . .	1,800	250,000	4,300	12,000
Crew (30 min) (£355 or $1,000/year) . . .	300	62,500	715	2,000
High-speed diesels	27	350 400	18	50
1,800 rpm electric motors	25	1,500	9–16	25–45
Low-pressure hydraulic motors	11	800	14	40
Air motors—to 10 hp	8	315	33	95
Medium-pressure hydraulic motors				
low hp (to 10)	2	15	4	10
high hp (to 60)	1	7	1	4

TABLE 12
Comparison of air and hydraulic winch drives (winch: worm gear, 36 : 1 reduction)

Driving motor	Air	Hydraulic
Motor weight	72 lb (32.7 kg)	21 lb (9.5 kg)
Motor cost	£210 ($580)	£47 ($131)
Valve cost	£37 ($105)	£9 ($24.50)
Rated hp	6.2	7.8
Dimensions (approx.) . . .	15 · 10 · 13 ft	6 · 4 · 5 ft
	(380 · 250 · 330 mm)	(150 · 100 · 125 mm)

Table 11 compares the approximate weight, size and cost of various power sources found on small fishing vessels and is offered somewhat as an extension of Vibrans' and Bruttinger's table 2. Comparisons of relative values are subject to a great deal of individual controversy based on the reader's personal experience and availability of materials. They do, however, help to illustrate the desirability and general economical superiority of hydraulic systems for the transmission of medium powers, say from 5 to 50 hp, for powering miscellaneous gear on fishing vessels.

On a rolling fishing vessel most deck-mounted gear operates under water at one time or another. Hydraulic motors have proved to be the most satisfactory drives for rotating equipment which will operate fully submerged. These can be close-coupled to the machinery with watertight gaskets and thus exclude all water from any rotating parts.

A comparison of air and hydraulically powered winches is shown in fig 25 and 26 and table 12. Fig 25 is an air-powered winch for mounting on an oil tanker where air was available and explosion hazards existed. This is a modification of a standard hydraulically driven winch, fig 26, shown installed on a new tuna purse seine vessel and used for vanging the main boom. It can be seen that the hydraulic drive is simpler and more compact, and correspondingly less expensive.

Fig 26. Two hydraulically powered winches on a tuna purse seiner

McNeely (USA): Vibrans and Bruttinger have graphically illustrated principles of modern hydraulics as related to fishing vessels. Their paper will make excellent reference material. The obvious intricacies portrayed in the paper might, however, discourage rather than encourage the greater use of hydraulics for fear of costly failure of delicate equipment. Modern hydraulic engineering has provided excellent equipment with a history of trouble-free operation. Documentation is needed of the reliability and ease of use by inexperienced fishermen.

Practical evolution on tuna vessels

Izui (Japan): During the past 40 years the improvement in performance of tuna longline haulers has been most remark-

Fig 25. An air powered winch for mounting on an oil tanker where air is available and explosion hazards exist

[411]

able from four-stage-speed-control type to no-stage-speed-control type, from driving shaft type to hydraulic type. Japanese-type line haulers have been used in Formosa, Korea, Hawaii, Africa and South America.

A 100 years ago the longline fishing boats in Japan were not more than 6 ft (1.8 m) in width, the fishing gear being four or five sets of line with 15 or 16 fish-hooks, operating in coastal water two to three miles from shore. Fishing boats became larger at the end of the nineteenth century and operated in water 30 to 40 miles offshore. The introduction of powered fishing boats in 1907 invited a marked progress in the fishing boat building and related fishing techniques, which in turn opened a way for unlimited expansion of the tuna longline fishery.

In the old days the storage of tuna was either salting or drying. The introduction of ice enabled the fishing operation to stretch longer and also made possible the transportation of tuna a longer distance. And the use of refrigerating machine aboard fishing boats made it far profitable for tuna fishing. In the early days of tuna longline fishing the loss of many fishing boats at sea was inevitable because there was no navigating instrument and weather forecasting was made only by experience and sense. And of course there was no wireless. A young widow of fishermen who never returned, stood on shore praying to God that he was alive somewhere and would return some day, brought tears to many onlookers, and once the tuna longline fishing was called "widow-making fishing". A line hauler for tuna was invented in 1923 to improve such

hard working conditions of fishermen. The specifications and principal particulars for the standard line haulers are shown in tables 13, 14 and fig 27.
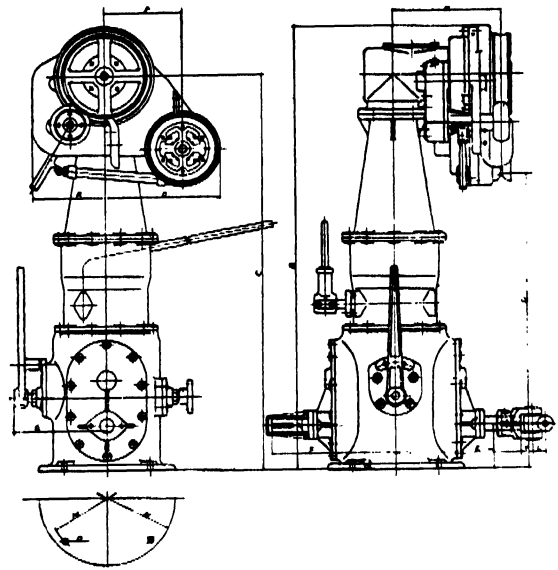
Fig 27. A standard line hauler

TABLE 13

Specification

Model	Type	Height in (mm)	Weight lb (kg)	Shaft rpm	Winding speed ft/min (m/min)	Required hp	Boat size
Special	6	59.2 (1,504)	885 (402)	250	high 690 (210) low 460 (140)	10	Over 90 GT
Large (standard)	4	55.3 (1,406)	620 (282)	250	high 590 (180) low 384 (120)	7.5	Over 30 GT
Large (lower)	3	49.5 (1,258)	616 (280)	250	high 590 (180) low 394 (120)	7.5	Over 20 GT
Medium	2	45.5 (1.155)	407 (185)	230	25 (75)	5	Over 10 GT
Small.	1	32.0 (812)	233 (106)	200	21 (63)	2	Less than 10 GT

TABLE 14

Particulars (units: in (mm))

Type	A	B	C	D	E	F	G	H	I
6	14.0 (356)	59.2 (1504)	52.7 (1337)	39.4 (1000)	16.7 (425)	16.7 (425)	12.0 (305)	1.75 (44.4)	6.0 (152)
4	13.3 (338)	55.3 (1406)	49.3 (1250)	38.8 (985)	14.4 (367)	14.0 (357)	10.2 (260)	1.5 (38.2)	4.5 (114)
3	13.3 (338)	49.5 (1258)	43.4 (1102)	33.0 (837)	14.4 (367)	14.0 (357)	10.2 (260)	1.5 (38.2)	4.5 (114)
2	10.5 (268)	45.5 (1155)	40.5 (1028)	31.1 (790)	13.5 (342)	7.2 (184)	9.4 (238)	1.1 (28.0)	4.0 (127)
1	8.3 (210)	32.0 (812)	28.1 (714)	19.4 (493)	11.3 (286)	6.0 (162)	7.8 (198)	1.0 (25.4)	4.5 (114)

Type	J	K	L	M	N	O	P	Q	R
6	1.3 (32)	1.2 (30)	0.98 (25)	16.0 (406)	18.0 (457)	6.2 (157)	10.2 (260)	15.2 (286)	9.5 (240)
4	0.98 (25)	0.98 (25)	0.86 (22)	13.8 (350)	16.0 (406)	6.2 (157)	8.5 (216)	13.2 (33.5)	9.4 (238)
3	0.98 (25)	0.98 (25)	0.86 (22)	13.8 (250)	16.0 (406)	6.2 (157)	8.5 (216)	13.2 (33.5)	9.4 (239)
2	0.98 (25)	0.86 (22)	0.98 (25)	13.8 (250)	15.5 (294)	6.2 (157)	6.5 (165)	10.0 (264)	7.0 (178)
	0.75 (19)	0.86 (22)	0.98 (25)	11.0 (279)	12.5 (318)	0.5 (12.7)	5.1 (130)	8.0 (201)	5.9 (150)

[412]

TABLE 15
Particulars of pumps and motors for No. 6 type line hauler

Particulars	High pressure		Low pressure	
	Oil pump	Oil motor	Oil pump	Oil motor
Type	Plunger	Plunger	Vane	Vane
Rpm	1,450	Up to 400	370	Up to 330
Pressure	2,100 lb/in^2 (150 kg/cm^2)	2,100 lb/in^2 (150 kg/cm^2)	284–355 lb/in^2 (20–25 kg/cm^2)	284–355 lb/in^2 (20 25 kg/cm^2)
Delivery volume	14 ft^3/min (0.4 m^3/min)	27 ft^3/min (0.75 m^3/min)	11.2 ft^3/min (0.315 m^3/min)	—
Input and torque	10–15 hp	280 lb ft (39 kg m)	10–15 hp	130–190 lb ft (18·26 kg m)
Diameter of suction and delivery . .	0.75 in (19 mm)	0.51 in (13 mm)	2 in (50 mm)	2 in (50 mm)
Weight	60 lb (27 kg)	110 lb (50 kg)	308 lb (140 kg)	264 lb (120 kg)
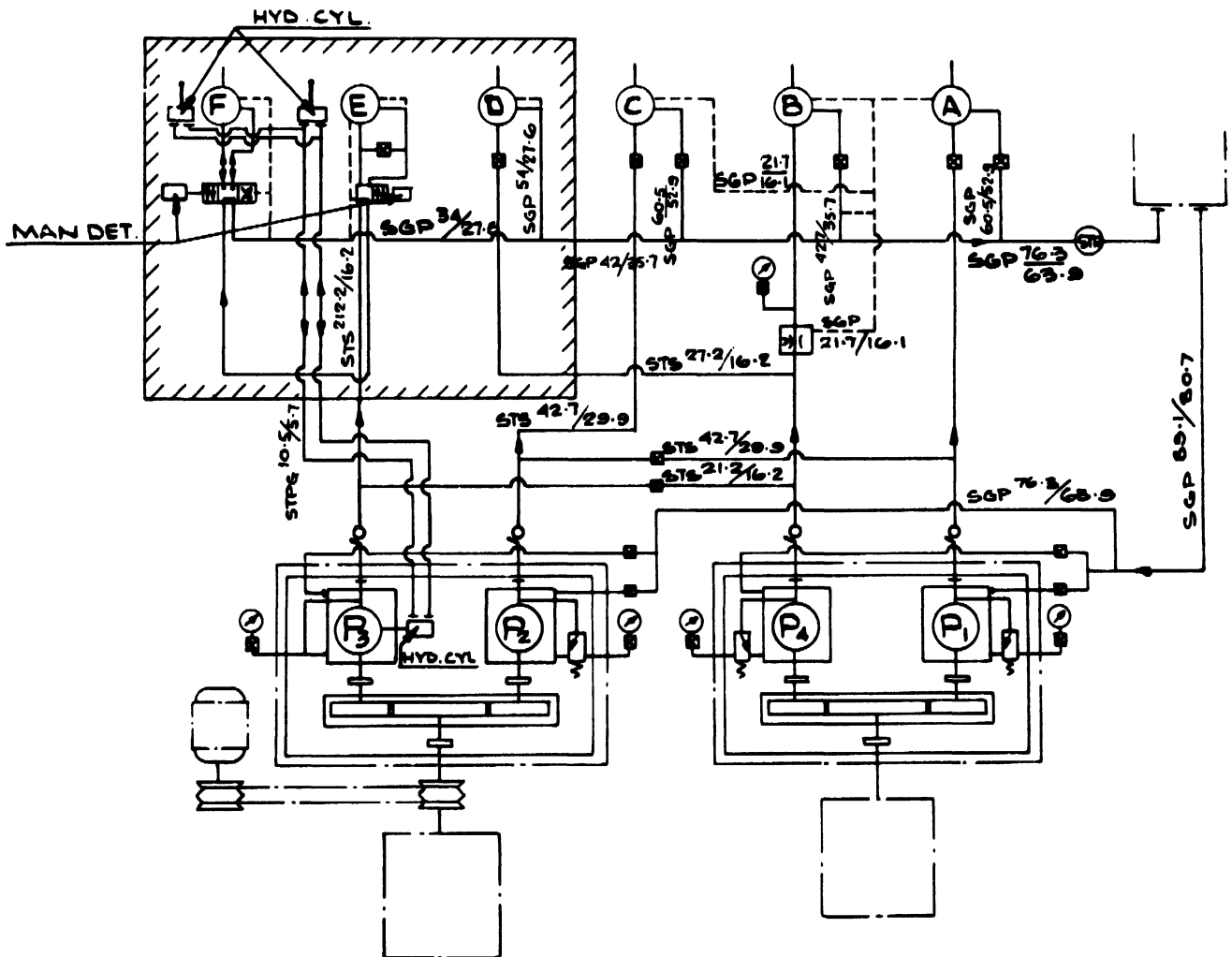
Fig 28. High pressure type hydraulic line hauler

When a line hauler is driven mechanically, by the main engine, it cannot be operated at the right rpm as the rpm of the main engine is subject to the change in boat speed. Lack of deck space causes difficulties, and therefore the main engine driving system has been changed to driving by motor installed in electric motor room, then, again it has been changed to electric motor-direct drive system. In the case of direct-motor drive, planetary gear or chain reduction gear is installed for reduction of rpm.

Hydraulic line hauler is classified into three categories: high pressure type (more than 1,700 lb/in^2 (120 kg/cm^2)) (table 15, fig 28), medium pressure type (around 1,100 lb/in^2 (80 kg/cm^2)) and low pressure type (less than 700 lb/in^2 (50 kg/cm^2)) (table 15, fig 29) by the characteristics of hydraulic pump and motor. A hydraulic line hauler can change its speed quickly or be stopped by friction clutch against the resistance of waves or fish or entangled long line.

Fig 28 shows the piping arrangement of this system as used
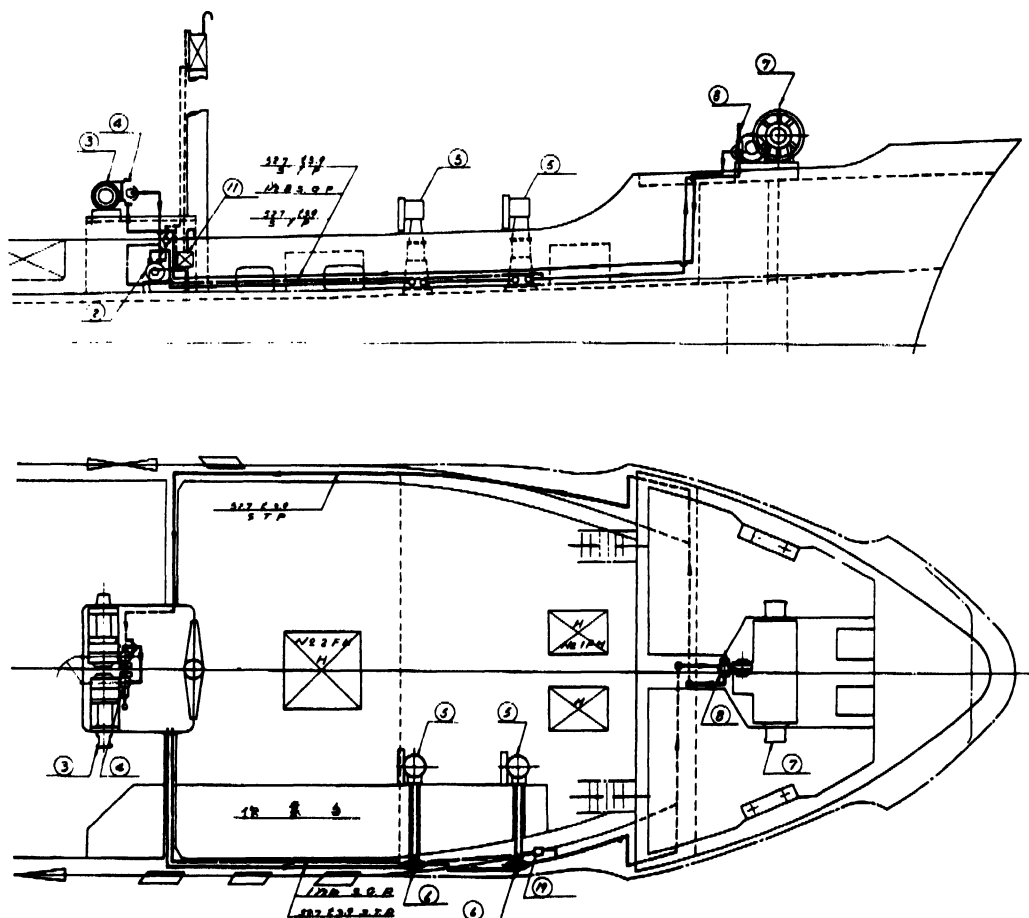
Fig 29. Layout and specifications of low pressure hydraulic line hauler

1. 15kw electric motor for hydraulic pump
2. 350 rpm hydraulic pump
3.4. .08t × 92 ft/min (28m/min) hydraulic cargo winch

5.6. 830 ft/min (252 m/min) 300 rpm hydraulic line hauler
7.8. 3.5t × 36 ft/min (11m/min) hydraulic windlass and 1 t × 39 ft/min (12 m/min) winch

in *Shinnan Maru* No. 21 (111 GT). During the navigation it does not require the operation of auxiliary engine and during loading and unloading only the auxiliary engine will suffice. Moreover, it can be driven by pump either from the main or auxiliary engine and a small variation of rpm of the main engine can be adjusted by discharge control valve that it is possible to maintain the rpm of generator and refrigerator constantly.

The float-line hauler is installed to pick up the float line and the hauling speed is 280 ft/min (86.4 m/min), hauling load is 1,750 lb (800 kg) and electric motor 2 hp, 220 V, 1,900 rpm. The fish-hauling machine is designed to haul fish easily. The hauling speed is 95 ft/min (28 m/min) and hauling load is 1,100 lb (500 kg). This can be used as a windlass for small tuna fishing boats. Branch line hauling roller can be doubly attached to roller of line hauler, making possible the hauling of the branch line at the same speed as the main line.

Baby haulers used

Baby haulers are used for small coastal fishing boats of 1 to 5 GT in which two fishermen operate with 50 baskets (one basket = 623 ft (190 m)) or four fishermen with 70 baskets and line is hauled at 165 ft/min (50 m/min). In the case of 50 baskets, it requires an hour for casting and three hours for hauling. The machine weight is 62 lb (28 kg).

The raising of hauling speed as much as possible to shorten the working hours is desirable. At present the number of long-line baskets has increased to 400 to 450 per boat with the total length of long line being over 54 nautical miles (100 km). The hauling speed is 200 ft/min (60 m/min) for the small type and 650 to 820 ft/min (200 to 250 m/min) for the large type. The hauling speed has to be lowered in accordance with the conditions of sea and fishing gear and angling ratio. As the number of revolutions is fixed in the electric motor direct-driven type, four-stage-reduction type and, later, no-stage-speed-change type have been designed. A very slow speed is necessary when lines are entangled. A sliding operation of friction clutch is needed, but further on higher resistance material for clutch disc and durable reduction gear structure is desirable. The hauling speed should be so designed that it does not give too much on long line and it can control slowing and accelerating, depending on the movement of fish caught.

Hydraulic operation of line haulers makes possible the change of hauling speed easily and ensures a proper speed, so a great progress has been witnessed in the last several years. In the hydraulic, there is a problem of high and low pressure, but it should be judged from the standpoint of dependability and safety, economy, maintenance of efficiency, convenience in handling and installing and reduction in labour and working hours. Because the operating speed of fishing machinery is so slow, a major portion thereof is of low speed type. However, with the development of geared engine, the trend is towards a higher speed.

The main line is stretched a little below the sea surface and

it is subject to the heavy moving load by the resistance from branch buoy lines, by the weight and amount of hooked fish, as well as by the pitching, rolling motion and speed of the boat. In order to haul the line safely with minimum tension and to select line hauling angle for minimum resistance, research on automatic operation of boats and automatic disposal of buoy lines and branch lines are necessary.

Productivity can be ensured by maximum catch with minimum labour. The line-hauling operation for tuna takes 8 to 12 hours and often it requires as long as 18 hours from line casting to hauling. The navigation during this period is not so easy. Unskilled navigation often invites loss, cut or entanglement of line and the search of missing line and straightening of entangled lines give a heavy burden on fishermen.

Problem on small craft

Dugon (UK): On small fishing boats it is not often possible to instal an electrically operated capstan or winch, as there is insufficient generating capacity. The alternative drive for deck machinery is mechanical or hydraulic. The control available with a fixed or variable delivery pump system gives excellent control, from "inching" to full speed in either direction, and is comparable to that obtained by electric drives.

For economic reasons on small fishing boats, fixed delivery pumps are normally used and as the hauling speed of the main engine does not usually vary, this economic hydraulic system is the best choice for this size of boat.

The basic power unit as illustrated at fig 19 of Vibrans' paper is believed to be economical, and simple and cheap to instal.

However, if a standard automotive power steering unit is used, this has certain limitations as to speed and drive, especially with slow revving engines and the flow of hydraulic fluid limits the size of winch or capstan which can be driven from such a pump unit.

On small fishing vessels using hydraulic trawl winches it is of great assistance to the fisherman to have an adjustable relief valve and possibly a pressure gauge so that the maximum pull of the winch can be adjusted to suit the type of fishing and the state of the warps and nets.

Author's reply

Vibrans (USA): Three previous papers on hydraulics have been presented at FAO meetings. These are: Hydraulic Deck Equipment (Huse, 1955), Hydraulic Deck Equipment for Research Vessels (Huse, 1961) and The Application of Hydraulic Power to Fishing Gear (Lerch, 1964). The two first give a thorough description of Scandinavian low pressure systems developed for fishing boats and the last describes the higher pressure system using equipment typical of that found in numerous industrial applications. Both discuss fisheries in Europe and America.

Aside from reviewing known hydraulic techniques, Vibrans wished together with his co-author, to contribute an idea useful to developing fisheries and this prompted the scheme of the basic drive unit adaptable to several driven devices. It was felt that an inexpensive drive could be made from a standard industrial, shaft-mounted speed reducer with hydraulic motor, close coupled to the input and a driving plate mounted on the output.

Hatfield supported the closed loop or hydrostatic system for deck machinery power and Vibrans agreed with the desirability of variable displacement pumps in providing a system with infinite speed control. Under current circumstances, he believed his statement correct about the much higher cost of closed loop hydraulic system for the deck machinery power needed on fishing boats under 100 GT. He was acquainted with some excellent high torque, slow speed, fixed displace-

ment piston-type motors, which are competitive in cost to vane motors of equal output. Except in a properly designed (and expensive) closed loop system these piston motors cannot be used where overhauling might occur. The resulting vacuum in the pump would hold the pistons away from the driving cam, allowing the motor to run away, perhaps damaging the motor components.

Lerch's comments were valuable, especially table 11 comparing the costs of supply "muscle" to fishing operations. This material adds some useful data to this paper. While agreeing with most of Dugon's comments, Vibrans believed the basic system described in the paper did not need provision for manual pressure adjustment or a pressure gauge. The operator of small deck machinery is interested only in "does it work".

The virtue of the automotive power steering pump aside from its low cost, is its almost uniform delivery irrespective of input rpm. Manual adjustment is not necessary as the built-in flow control valve automatically recirculates the fluid pumped in excess of the rated quantity. The curves in fig 30 illustrate typical performance of a popular US built automotive steering unit which is a type suited to the basic system.
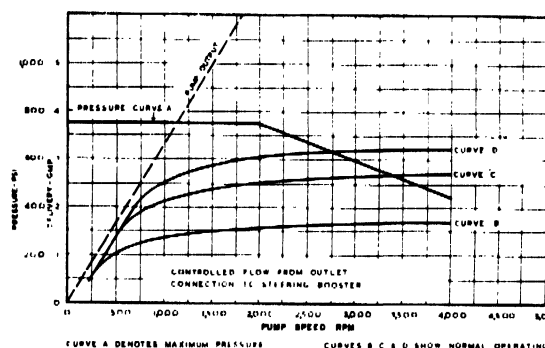
Fig 30. Typical composite delivery characteristics

FISH KEEPING ON SMALL CRAFT

Ranken (Spain): The main purpose of every fishing vessel is to land the maximum quantity of fish with the minimum expenditure of labour and commanding the best possible price. The vessel must therefore be built not only to catch fish as efficiently as possible, but also to preserve its quality in a state as close as possible to that at the time of death.

Fish handling on board large vessels has been revolutionized in the past 20 years by the introduction of the shelter deck stern trawler, in which fish preparation and processing can be completely separated from the catching operations, net handling, mending, etc. This separation, however, becomes increasingly difficult the smaller the size of the vessel, and the best that is possible is to provide as much working space as possible in the hope of achieving a fair measure of segregation of the catch from the gear.

In the smallest vessels, no fish preparation is done on board since labour is insufficient and the time at sea is in any case very short. Some measure of preparation and washing is however done, depending on variety, the larger the vessel and longer the voyage. In all handling of fish in the fresh state, the maximum amount of care possible should be taken over hygiene and in this respect the boat designers have their part to play in using hygienic materials like aluminium alloys and in providing liberal supplies of clean sea water for washing the fish and the working spaces. Good and unobstructed drainage is also important to avoid accumulations of decaying material.

Equal attention to hygiene is necessary in the fish holds and aluminium alloys for stanchions, pound boards and linings are undoubtedly a worthwhile investment. Where boxing is used, aluminium boxes are probably more durable than plastic ones, although there has been good experience with the latter in some French ports. The possibility of using aluminium for chilled water tanks is also worth considering, though steel tanks are satisfactory if properly cleaned and preserved between voyages.

Importance of ice

The primary method of preserving fresh fish is in melting ice and the proportion required varies from about 50 per cent by weight in the Arctic distant water fisheries to 100 per cent in tropical waters. The quantity of ice required can be reduced by improved insulation of the fishroom to reduce the rate of heat leakage, with or without the assistance of a small refrigerating plant to remove this heat. The actual cooling of the fish must however be done by the ice, which also provides melt water to keep the fish surfaces clean and moist. With good icing it is possible to obtain even fish temperatures between 32 and 34° F (0 and 1.1° C), and some fish will reach an equilibrium at about 31° F ($-$0.5° C). For white fish the maximum time in ice is about 16 days and the figures given by Chigusa presumably apply only to tuna and similar varieties.

If sufficient cooling is done by refrigeration to assist the ice, some freezing will certainly occur. This may be acceptable as in the Portuguese fisheries, where so-called "superchilling" to 28.4° F ($-$2° C) is standard practice and allows Mauritanian ash to be landed in good condition certainly up to 25 days old and perhaps up to 35 days. This method, however, requires more refrigeration than would be acceptable in most very small boats and is not therefore considered applicable to vessels below about 130 ft (40 m). Where superchilling is not acceptable, the cooling system must be arranged to avoid contact between the fish and the cold pipes, since the latter must of necessity work at temperatures far below the freezing point of fish. Normal practice has been to use grids on the deckhead only with, in some older steam vessels, further grids buried in the insulation of the bulkhead adjacent to the boiler room. In part-freezer vessels, such as *Lord Nelson*, no trouble has been experienced with freezing of wet fish adjacent to the frozen fish hold, since the fish is always properly iced.

A difference in practice

The stowage rates given by Chigusa do not correspond with British practice where 32 lb/ft³ (510 kg/m³) is standard for bulking on account of the high proportion of ice used. On the other hand the normal figure for chilled sea water is 45 lb/ft³ (720 kg/m³). However, it is thought that Chigusa's figure of 32 to 37 lb/ft³ (510 to 600 kg/m³) for tuna is preferable for brine freezing to the normal US figure of 45 to 50 lb/ft³ (720 to 800 kg/m³); this latter figure is also quoted by Doke and Chigusa (1960).

Chilled sea water is of course a well proven method in the USA and Canadian West Coast salmon and halibut fisheries up to about 16 days and Chigusa confirmed its suitability for tuna. The method has not found much application elsewhere, presumably due to the ready availability of cheap ice from shore as compared with the comparatively large refrigeration plant needed on board to cool the sea water and fish. Hygiene is also a considerable problem.

In all vessels the hatch sizes should be kept as small as possible to reduce the inflow of warm air, but large enough for the rapid discharge of the fish without damage. Some designs of small vessels are bad in this respect making preservation difficult.

In some small ships the refrigerating compressors have been coupled to or belt-driven from the main engine, sometimes using a magnetic coupling, thermostatically controlled. Other vessels have used electric motors obtaining power from a battery. There may well be cases where a thermostatically controlled hydraulic drive obtaining pressure from a pump driven by the main engine would be attractive, especially if the pump also drove the winch and perhaps other auxiliaries.

For wet fishing vessels there appears to be very little in favour of using ammonia as the refrigerant and Refrigerant 12 seems a better and safer choice. The problem of leaks can be largely overcome and for the most part smaller compressors can be used running at higher speeds. No difficulty is experienced with Refrigerant 12 condensers and other items may also be easier.

Varied methods for different fish

Freezing on board small vessels is limited to certain fisheries and the methods used depend on the varieties of fish involved. Brine freezing is limited to tuna, sardines and possibly shrimps. Blast freezers occupy too much space in relation to hold capacity, but so-called sharp freezers are possible in some cases, such as lobster and tuna boats. Plate freezers especially of the vertical type may well be the best choice in small ships to save space. Frozen produce will last almost indefinitely at $-$13° F ($-$25° C) or below, but higher temperatures are not recommended for any variety even for short-term storage.

If freezing is adopted it should be the aim to land a product which, on thawing, competes fully with really fresh fish. This is now easy with modern methods, but careful handling and even temperatures are still essential at all stages.

The cooling surfaces quoted by Kazama (in his paper on tuna longliners in the last section of this book) from the Japanese Government Fishing Boat Inspection Regulation for semi-blast freezers appear very small in relation to the cooling loads stated, unless much higher heat transfer coefficients are achieved than one would normally expect; the cooling loads themselves do however appear very high in relation to freezing capacity. On the other hand, the surfaces specified for the holds seem unduly high in relation to cooling load; the loads themselves are also high unless a lot of product cooling is done in the hold. It would be valuable to have Kazama's comments on these points.

It is interesting to hear that Japanese owners still continue to prefer ammonia to the safer refrigerants. This is in line with USSR, Polish, USA, Greek, Italian and other experience. It would be valuable to have Kazama's or Chigusa's comments on whether there have been any accidents with ammonia and directly attributable to it. A recent explosion in a small Spanish fishing vessel caused initially by a serious leak followed by an electrical spark, draws attention once again to the hazards, especially as a fatality resulted.

West European experience is now centred on Refrigerant 12 or Refrigerant 22 systems, often with pump circulation through the freezers, and sometimes combined with brine in the holds of the larger vessels. Two small ships now building for octopus freezing employ Refrigerant 22 pump circulation through the holds as well as through the freezers.

With a few notable exceptions like tuna, shrimps, lobster and octopus, freezing at sea does not appear to be an economic proposition in small vessels much below about 130 ft (40 m), on account of the large amount of space occupied by the refrigerating machinery to the detriment of hold capacity.

Brine or blast freezing?

Gianesi (Italy): Kazama's paper posed the question of which freezing system—salt brine or air blast—is to be preferred on

FREEZERS PRECOOLING

7'-6" (2.28m)

8'-2" (2.50m)

15'-9" (4.80m)

30   30   40   45   50   55   60   65   70   75   80   85

12'-4" (3.75m) FREEZER 1

12'-4" (3.75m) FREEZER 2

PRECOOLING ROOM

25'-11" (7.90m)

27'-11" (8.50 m)   31'-2" (9.50 m)

35'-1" (10.70m)

HOLD NO I

88'-6" (27.00M)
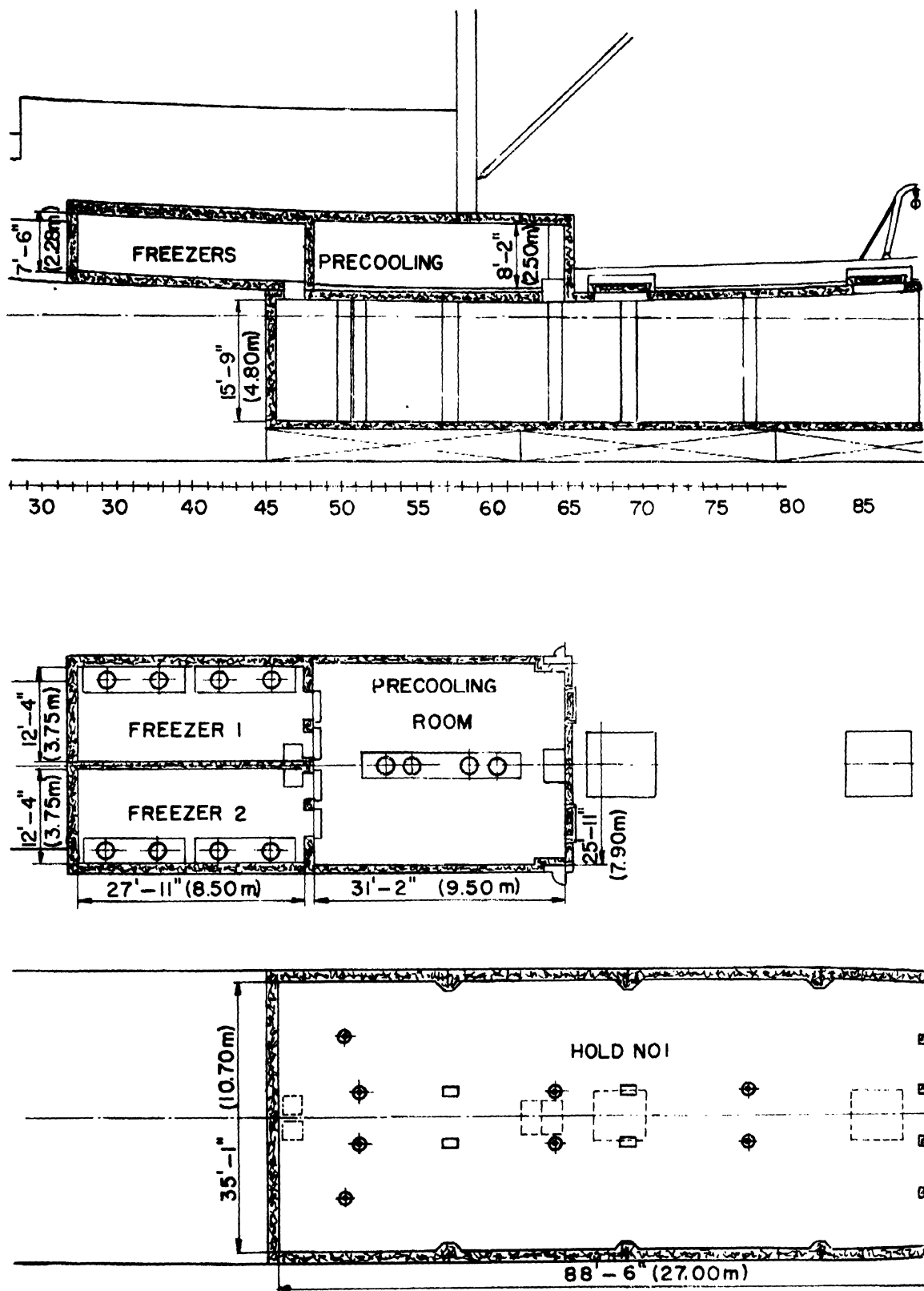
Fig 31. Layout of pre-cooling room, freezing room and fish hold

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board of tuna longliners, both from the point of view of the product's quality as well as regarding the necessity of reducing manual labour. There is no doubt that the increasing market requirements, together with the experienced reduction of the catching rate and consequent increase in the length of fishing trips and expenses, bring to a paramount importance the necessity of reducing manual labour on board and of obtaining the best frozen product.

As reported by Kazama, freezing by brine immersion is a simple process and requires little work, but it is not considered the best system from the point of view of quality and market price; with this system there is no way of substantial improvements without a corresponding increase of processing expenses for protecting the product.

The more frequently used semi-air blast freezing system on shelves gives better quality products but requires a heavy manpower. This system with the increasing claims of crews could create some organization difficulties. However, at present the answer to Kazama's question can be given by the results obtained in the manpower savings and product quality by the air-blast freezing plant that was installed some time ago on *Marefish* of 1,650 GT.

The installations on the *Marefish* were conceived according to its operational requirements as mothership, with a freezing capacity of 40 tons daily of tuna; they can, however, be proportioned without any difficulty for smaller capacities as well as for medium-sized tuna longliners of 500 tons. They consist (fig 31) of a pre-cooling room on the working deck, of two (or more) blast freezers following the pre-cooling room, of a conveying system of the tuna to be frozen from the pre-cooling room to the freezers and from there to the hatches of the holds and finally of a two-stage refrigerating plant capable of obtaining freezing temperatures of $-40°$ to $-50°$ F ($-40°$ to $-45°$ C).

It is a peculiarity of the system that the tuna are pre-cooled and frozen in air streams which allow a radical reduction of labour and, more important, a substantial improvement of the product's quality. In fact, the complete process from the time the tuna beheaded and gutted are brought in the pre-cooling room until the moment they are unloaded in the refrigerated holds, they move suspended on rails, thus reducing the number of people required to operate the process. It also eliminates heavy work and the tiring necessity to load and unload the tuna on the shelves: the latter are eliminated and replaced by low temperature air coolers; the freezers are free of the present heavy structures, thus being much cleaner and clearer; the refrigerant charge is reduced and defrosting is easier.

The said system is particularly suitable for longliners; tuna are hung singularly or in groups, depending on the size. The hanging system is very simple and does not bring any damage to the fish or alteration to the skin. Tuna is frozen round and uniformly and it was noted that its meat was clearer, a thing which is appreciated on the market. This is obviously due to the fact that products are processed in a vertical position.

The space required by the freezers is not larger than necessary with a semi-air blast system on the basis of equal daily capacity. The volume of the *Marefish* freezers is about 9,000 ft³ (250 m³) against the 11,200 ft³ (317 m³) indicated for the same capacity in table 4 in Kazama's paper.

An ante-room or pre-cooling room is necessary, but not strictly of the dimensions shown in fig 26 of Kazama's paper. Its size should be proportioned to the average catch rate and should give enough space for the rails providing the necessity to allow an easy conveyance to the freezer and a quick unloading in the holds.

The described freezing system reaches its final working temperatures of $-40°$ to $-50°$ F ($-40°$ to $-45°$ C), i.e. well lower than the ones usually reached with the semi-air blast system and requires a well calculated air flow which could result bigger than the one usually applied in the shelves. However, regarding working temperatures, Kazama seems to agree, too, that also in the semi-air blast systems, lower temperatures should be obtained to improve the quality of frozen tuna products. Obviously, these temperatures require thicker insulations and a two-stage refrigeration plant.

There are no difficulties both on the installation and operational points of view to realize these plants with ammonia or Freon 22 systems, if requested.

Fig 32 shows the *Marefish* compressor room. Besides, the two-stage system has a higher efficiency which offsets the larger ventilating power eventually required.

Fig 32. Compressor room of Marefish

Freezing times do not present substantial differences with the semi-air blast freezers (Gianesi, 1963) and depend obviously on the size of tuna. For example, with tuna of 175/220 lb (80/100 kg) freezing times were 18/20 hr on products not pre-cooled and 12/14 hr on pre-cooled ones, which substantially agrees with theoretical calculations (Levy, 1958).

It has been noted that a well proportioned pre-cooling room assures to the installation a production flexibility which could be appreciated in case of unusual loading conditions. Therefore, it could be said that the experiments and the fishing trips made to date have proved the reliability of the described freezing system, both as regards labour reduction as well as the quality of the product obtained which was truly appreciated on the market. As a result, some new fishing vessels and a new group of tuna longliners of 600 GT (see fig 33), presently being built with refrigerating plants in Italy, will be equipped with the said freezing system.

Ando (Japan): Thanked Gianesi for his discussion. The explanation about two-stage systems of freezing applied in 1,650 GT ships is very useful to shipbuilders in Japan, especially applying to middle tuna ships such as 600 GT is very interesting and Ando hoped Gianesi will show him the details of the ship.
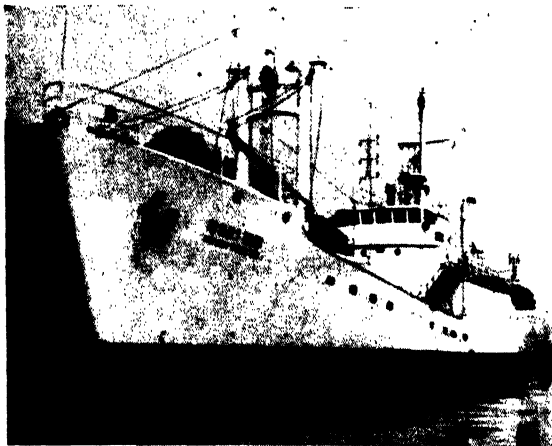
Fig 33. One of the new 600 GT tuna longliners equipped with air-blast freezer systems

Well established Canadian method

Harrison (Canada): The use of refrigerated sea water as a cooling medium for salmon has become well established in British Columbia in the transportation of salmon from the fishing grounds to the canneries. The vessels so equipped are known locally as "packers" and the sole function is to transport or "pack" the fish from collecting points on the grounds to the canneries. This change has come very suddenly. The technique was experimented with on a commercial scale in 1955. However, it was not until 1961, with the conversion of the vessel *Western Express* that the usefulness of this system was commercially demonstrated. This vessel established a pattern for all future installations in so far as the refrigeration and mechanical equipment is concerned.

Refrigerated sea water is primarily a substitute for ice. The means of employing it is extremely simple. The fish are held in watertight tanks built into the vessel. The tanks are flooded with sea water and the sea water is recirculated through heat exchangers maintaining a temperature within 1° F (0.5° C) of the freezing point of sea water. The water is not normally changed throughout the holding period.

Although there are some improvements in quality of fish possible with this technique over the best of icing practices, its main advantage lies in the rapid application of refrigeration to large quantities of fish. Loads of the order of .5 million lb (225 tons) may be taken aboard in a single day by a crew of six men. Because this is its main advantage, the technique has found little other application in the British Columbia fishing industry. It has been used successfully in the halibut fishery, but here the problems of the more sophisticated equipment offset any other practical gains.

The use of this system will perhaps always be restricted to applications where the main problem is the immediate refrigeration of large quantities of fish. It is now used in the California sardine fishery, the US Atlantic Menhaden fishery and in the US tuna fishery, where refrigerated sea water has always been the first, or chilling, stage of brine freezing.

The packer is capable of carrying from 150,000 to 500,000 lb (70 to 225 tons) of fish. The vessels have all been conversions of former small naval craft. All are of wooden construction. The holds are divided in three to six tanks. Longitudinal bulkheads are avoided because of difficulties in unloading narrow tanks, however, they became mandatory in larger vessels.

Equipment described

The first step in tank construction is the rearrangement of piping, wiring and mechanical apparatus in the hold, to either make future access unnecessary, or available via removable access panels. Bituminous paints are applied to all existing structure. Framing follows this preparation. It is in general simply the application of furring strips to the complete hold to clear boltheads, brackets and piping; and to provide nailing surface for all plywood edges.

Vertical bulkheads are installed usually framed up from 2 × 8 in (50 × 200 mm) studs with cross blocking to provide nailing surface. Laminated solid bulkheads have also been used, built up from 2 × 4 in (50 × 100 mm) material. Although more material is required, lower grades can be used. With this construction the problem of nailing surface is simply solved and a substantial saving of hold volume results.

Plywood is next applied usually in two layers of marine grade Douglas fir plywood in ⅜ or ½ in (10 or 12 mm) thickness depending on curvatures encountered. The reverse sides of the first layer are pre-painted and set in with bedding compounds. The sheets are then nailed to the framing with galvanized nails. The second layer of plywood is glued to the first with urea-formaldehyde glue. All butt joints are staggered with relation to those of the first layer. Special attention is paid to the gluing of joints. Nailing of this layer is with monel or everdure ring-nails. Fibreglass and polyester resin is applied to all corners and in many installations the whole plywood surface. Where fibreglass has not been used, thiokol paints have been used as the final coating. Both treatments have given excellent results to date.

Before dealing with refrigeration equipment, the requirements of the refrigeration system will be set out. First, the task at hand is the cooling of large quantities of fish from high temperature, 70° F (21° C) to near the freezing point of sea water, 28.5° F (−2° C). It is necessary and difficult, to think of cooling and not the maintaining of low temperature as the refrigerations task. The quantity of refrigeration required for cooling is about 20 times that required for the daily maintenance of temperature.

Because of this comparatively small refrigeration load for offsetting the heat leak, insulation is dispensed with as the cost and complications of insulating wooden vessels, so as not to encourage rot, are not warranted. Neither is there any need to insulate to limit temperature fluctuation; as the thermal inertia of the large mass of fish and water is so great that in practice, temperature rise of a tank at holding temperature would be only about 1° F (0.5° C) per 24 hours with the refrigeration not operating. The ratio of refrigeration capacity to fish carrying capacity has become established at about one ton of refrigeration to four tons of fish. The other requirements of the refrigeration system are that it be compact, simple to operate and dependable.

Source of power

High speed, lightweight diesels have been used as the source of motive power for all installations for many reasons. First, perhaps, is that diesel fuel is already aboard for the main engine. Engines of the size required here, about 50 hp, are common, cheap and compact for their size. The engineers on these vessels are quite familiar with diesels whereas electric motors which are usually employed in marine refrigeration are outside of their competence. Efficiency is also a consideration as opposed to electric drive, not in so far as fuel costs are concerned, but because of the cost of equipment, whereby a diesel driving an alternator would have to be much larger to offset the losses in a motor generator system. The power characteristics of diesel lend themselves to this application, as they can provide high starting torque and cope with overloads of a few hours' duration.

The mechanical and refrigeration equipment selections and arrangement have become almost standardized for both

refrigerated sea water and brine spray freezing or combination applications. The heart of the unit is the compressor which is V-belt driven from the diesel, the only other mechanical units are the sea water circulating pump and the condenser cooling water pump.

The compressor is a four-cylinder, 1,800 rpm, 30-ton unit. It was most fortunate for this development that compressors of this type had been developed for the needs of the air-conditioning industry, just prior to it. The machines give a very high refrigeration output for their size and were designed primarily for operating in the same temperature range. Their general use in air conditioning has also made them and their replacement parts readily available. In the same way, servicing facilities and personnel are to be found in cities everywhere. This type of compressor is equipped for either V-belt pulley or axial drive, most units being driven by V-belts. V-belt drives permit a greater choice of location in ships' engine rooms. This factor is important with ships in British Columbia. Most installations have been in existing vessels where little space is not already occupied. In new constructions here it has been equally important as the emphasis in design has been for a maximum hold space, leaving a minimum engine room to accommodate an ever-increasing array of equipment. Although the V-belt drive is not insensitive to misalignment, it is less critical than with an axial drive. This is perhaps unimportant in the initial installation. However, it is a factor in realignment later following repairs or moving of the equipment which may be done at sea or by less skilled workers.

Specially designed chiller

The chiller used to cool the sea water had been designed expressly for this service by Harrison and his collaborators at the Vancouver Technological Station of the Fisheries Research Board of Canada. It is basically a dry expansion shell and tube heat exchanger of the type now commonly used in air conditioning, but with important changes for this service. Here it must operate with the refrigerant in the tubes, below the freezing point, and cool water to freezing point, while entering at a temperature only $1°$ F ($0.5°$ C) above freezing. Furthermore the exchanger must pass water heavily contaminated with blood, slime, scales and other debris.

In the installation described, the chiller is comprised of seven identical elements. Each element has a 10 ft × 6 in (3 m × 150 mm) diameter shell of polythene pipe. This material was selected for its low cost, availability, resistance to sea water corrosion and its ability to yield without rupture should the heat exchanger inadvertently freeze up. The tube bundle consists of twenty-four ⅝ in (16 mm) diameter copper tubes arranged in six refrigerant circuits of four 9.5 ft (2.9 m) tubes each connected by U bends. The spacing between tubes is ⅜ in (9.5 mm). Semi-circular baffles of sheet brass are spaced at 6 in (150 mm) intervals.

All refrigerant connections are made at one end of the chiller to enable removal of the shell without disconnecting refrigerant lines.

It should be noted that copper tubes have been used here, despite not being highly regarded as a heat exchanger tube material for marine service. The original of these chiller elements is still in service after ten years. It appears that the low temperature accounts for the resistance to sea water corrosion.

Each chiller element has one thermal expansion valve with a six-orifice distributor for metering refrigerant circuits. Refrigerant isolating valves have been used on each chiller element for the purpose of isolating a faulty chiller from the system. The system will operate quite well with one or even two chillers not operating. However, experience has shown the chillers to be more reliable than the valves; and it is believed

that any future installation should be without isolating valves on individual chiller elements.

The chillers are racked horizontally one above the other, usually on an outside deck house bulkhead. Sea water connections between the chillers and inlet and outlet manifolds are made with automobile radiator hose and clamps to provide the required union.

Circulating pump

The circulating pump used is a 3-in (75 mm) all iron open impeller centrifugal pump delivering 500 gal/min (415 Imp gal/min, 1,900 l/min) at 40 ft (12 m) head using 10 hp. The pump is located when possible below the level of the tanks to eliminate priming problems. When this is not possible, hand-operated diaphragm primers are used.

Where possible pumps are V-belt driven from the compressor engine without a clutch. This economical arrangement is dependable and foolproof as the pump will always be in operation when the compressor is operating. Where such a drive cannot be used because of engine room limitations, electric drives are employed. Vertical electric pumps are used as they simplify making suction connections at the lowest possible level in the ship and require a minimum of floor space.

Starting point of the circulation system is the suction screen in the hold. This must be very substantial to withstand the pressure of the fish and the total surface must be very large since it is blocked off by the fish themselves, leaving a very small proportion in operation. They are located across the corners of floor and bulkhead in most cases or covering a floor gutter, or both if possible. About 1 ft^2 per 1,000 lb (0.1 m^2 per 500 kg) of fish capacity is required.

A section of screen is also extended from the main screen up a vertical bulkhead to provide a suction pressure relief and water bypass to guarantee water flow to the chillers in event of blockage. This is necessary as the vacuum which can be induced by the pump can give even greater pressures on the screens than the effect of the weight of fish. Screen material is usually galvanized, expanded metal from 12 gauge stock with ¾ in (19 mm) nominal mesh. Supporting of the screen must be adequate to support the drained weight of the tank full of fish.

Some trouble with screens

Screens have been the only source of serious trouble in refrigerated sea water systems. One solution is to arrange for the reversing of circulation, that is from bottom to top. Unfortunately, it is necessary to have top to bottom circulation to permit operation with part full tanks which is practised during loading in protected waters. Reversible piping is too costly except for small vessels, where it has been used with good results.

A new technique has been tried in the past year with excellent results. Suction screen was applied to one vertical bulkhead only, covering the whole bulkhead except for about 3 ft (0.9 m) at the bottom. Water is admitted through a perforated distributor pipe along the bottom of the tank. In this system, the effect is that the fish will plug this screen forcing the flow up through the fish and over the top, then through the screen and down the bulkhead to the pump suction pipe. The water does not short circuit through the screen as might be expected and temperatures throughout the tank have been uniform.

The major consideration in piping is sanitation. All piping should be arranged to eliminate pockets where debris can accumulate and the circuit should be such that all lines can be flushed overboard from the sea cock. This is not always

possible because access for valves is sometimes only in the engine room, necessitating lines to the tank which cannot be flushed. Provision should also be made for valving all piping into a closed loop and providing for the injection of cleaning and disinfecting materials which can be circulated in the sea water cooling and distribution system. In this way, heavy concentrations of these materials can be used, which can search out the crevices in the system.

Polythene pipe is preferred regarding corrosion, sanitation and thermal conductivity. However, as most piping is exposed to mechanical damage, little can be used, thus galvanized iron pipe becomes the usual material. Butterfly valves are preferred for all sea water valving, because of their compactness, clean lines and simple operation.

Pipes and filters

Filters should be employed in the system to protect the chiller from debris. As the space between chiller tubes is $\frac{3}{8}$ in (9.5 mm) filter mesh must not exceed this. About 5 to 10 ft^2 (0.5 to 1 m^2) of filter screen must be used. Arrangement must be made for backflushing overboard by means of reverse flow valving or by reversing the screen.

A marine, cleanable, shell and tube condenser is used. Tubes are cupro-nickel. Water passes through the tubes, which can be cleaned by removal of the water heads. The outside or refrigerant side of the tubes is finned, resulting in a very compact condenser, dimensions being 8 in (200 mm) diameter by 9 ft (2.75 m) long. This represents one of the major advantages of the use of freon refrigerants over ammonia in marine applications.

A straight centrifugal pump is used where no problem of priming is encountered. Where a self-priming pump is used, rotary, rubber-impeller pumps have been used with excellent results. Water requirements are about 70 gal/min (60 Imp gal/min, 265 l/min) at 40 ft (12 m) head. The preferred drive for condenser pumps is directly by V-belt from the diesel. In this way cooling water through the condenser is started ahead of engagement of the compressor, clearing the condenser of warm water. Electric motors are used where a remote location of the pump is desirable.

Manual rather than automatic control is employed. As the refrigeration system tends to operate for long periods of time under only gradually changing conditions of load, automatic operation is not desirable. Temperature is maintained by the manual starting and stopping of the compressor. The only operation required during running is control of condenser water to maintain condenser refrigerant pressure within the required limits. This is done by throttling waterflow from a centrifugal pump, or by-passing water round the condenser in the case of rotary pumps.

Automatic alarm devices are employed to warn of low refrigerant suction pressure, high refrigerant condensing pressure, low compressor oil pressure and high pump sea water pressure. These are preferably tied to the engine oil pressure and cooling water temperature alarms and shut down. Signal lights are employed to indicate the cause of shutdown. In this way, temperature of the sea water is automatically, although indirectly, controlled in so far as reaching the low temperature is concerned. The restarting of the equipment when again required is always a manual operation.

This same equipment is used without changes of any kind in the brine spray freezing of tuna. The only differences in operation being that the sea water is fortified with salt to permit its being cooled to about 20° F (−7° C) and the brine inlet is arranged to provide a spray throughout the hold by means of perforated piping on the deckhead. Units of this size have been found satisfactory for vessels carrying about 120 tons of tuna.

This equipment is well suited to fishing vessels as there is no refrigeration equipment located in the holds and the compactness of the equipment presents few problems in locating it in the vessel. Recently much of new construction of larger fishing vessels in British Columbia has been of vessels with this equipment for use as combination refrigerated sea water packers and brine spray freezers.

McNeely (USA): Chigusa has contributed a most valuable paper which will be useful to small boat operators throughout the world, in particular those in tropical or semi-tropical latitudes. Refrigerated small vessels might be feasible, however, only when high-valued fish, such as tuna, are taken.

Sapre (India): In Gujarat State, India, most of the prime fish caught is sent to Bombay which is about 200 miles by sea. The fish is sent in iced condition by fish carrier vessels which have insulated fish holds. It is likely that refrigerated holds may be needed in the future.

Chigusa's paper explains various refrigeration systems in small fishing boats. It would be very useful if the type and voltage of electric supply used is given. It is also essential to know the costs of the refrigeration units, particularly in respect of 20- and 40-ton vessels.

Catch, transport and market

Waterman (UK): A fishing vessel has three duties to perform:

- To convey crew and gear safely, speedily and in comfort from port to the fishing grounds and back again
- To make the task of working the chosen gear as easy and efficient as possible
- To store and transport the catch from the grounds to the port

This last function is as important as the first two, and cannot be divorced from them when the vessel is being planned. In developing countries fishermen and craftsmen are learning new skills. More often than not, the picture that is conjured up is one of warm water, blazing hot sun, primitive communications and distant markets; it is essential to bear in mind the quality of the catch and its preservation from the moment that a new fishery or a new vessel is first conceived.

Preservation is not solely the province of those who are fish technologists; care of the catch is very much the concern of every naval architect, builder and vessel owner. Questions such as "how much insulation, if any?", "what method of storage?", "what refrigeration system?", "shall I carry ice?" must all at least be posed and, in most cases answered before a single line is drawn and certainly before the keel of a boat is laid.

On the method of handling and storage and the means of preservation, this will depend on not only the equipment of the vessel, but also the basic specifications of the ship itself; proper division of available space between engine room and revenue-earning capacity; power demand of chilling or freezing plant, form of the hull to make the best use of the space available; shape and size of hatches for efficient stowage and discharge, etc.

What materials are most suitable for fishroom construction, what mechanical handling aids are justified, how big must the vessel be before refinements of this kind are economically justifiable? How long do trout, tilapia or turtles keep in ice compared with their shelf life at 80° F (27° C) in the shade? How much space will they occupy?

It is not good enough for a prospective vessel owner to pick a method of preservation with a pin and then for the builder to think up a little something that might do.

Waterman wanted to quote from a typical, but apocryphal letter: "Dear Sir, I am recently purchasing a magnificent new

fishing vessel. I shall catch plenty big tuna and want to put in ship a freezing plant, cold store and offal reduction plant; please advise me on best equipment to buy for very good keeping of fish. P.S. My boat is 40 ft (12 m) long and has a very fine sail." This letter is not so ridiculous as it sounds, and at least the writer had the initiative to ask for advice before plunging recklessly.

Seriously though, Waterman wanted to appeal for more co-operation, at a very early stage, in all fishery development, between designers, builders, engineers, operators and fisheries technologists, so that vessels are built to fulfil their three functions as efficiently as possible; there is no need for high-speed, soundly-built offal producers. After all, someone's got to eat that fish caught, and although good quality may not always mean more money, it usually helps!

Spanish experience

Gueroult (France): Chigusa's interesting paper stated that fish can be kept fresh in chilled water as much as 30 days. Trials on the Spanish and African coasts point to a period of approximately eight days. Thus these are results from experimental findings in two widely differing cases. The length of trip and operational range of a fishing boat are governed by the time the catch will keep. The specifications of a boat are so dependent on the range that there must be an agreement on the matter of "keeping time" so that there must be an explanation of the differences they record. It is possible that cold-water and tropical fish do not keep for the same length of time.

Nickum (USA): Referring to Chigusa's paper, the fish capacity is given at 32 to 37 lb/ft^3 (510 to 600 kg/m^3). The storage capacity for tuna in the USA is somewhat more of the order of 50 lb/ft^3 (800 kg/m^3). But this may be because the product goes straight to the canneries and fish appearance is not vital.

Fujinami (FAO): Gueroult mentioned that the duration of a trip to be able to preserve fish is quite different in Europe and Japan. In Europe the maximum duration is eight days in comparison to 30/40 days for Japanese tuna boats, and this may be because of the difference of quality of fish required in the market.

The Japanese market requires extremely high-quality fish, especially tuna fish, as they wish to eat it raw. In Rome, it is often difficult to find high-quality tuna to eat raw.

Fujinami had discussed the matter which Chigusa and they could not understand why such a big difference of possible duration is possible. This problem should be further studied to find the real reasons.

Author's reply

Chigusa (Japan): Long voyage is necessary for Japanese fishing vessels because the fishing grounds are distant and it is difficult to understand for Japanese, why the duration of a fishing trip of European fishing vessels is so short. If a freezing hold and a normal refrigerated hold exists together, fish in the normal refrigerated hold are half frozen and deteriorated. The hold used for both fuel oil and fish can be cleaned easily by washing the hold with sea water so that it can be used as a fish hold after being used as a fuel tank. Fish can be kept fresh for 40 days in chilled sea water.

PART V

DESIGN OF SMALL BOATS

Developable Hull Surfaces

by Ullmann Kilgore

Surfaces de coque développables

Du point de vue tant de l'économie d'utilisation que du rendement, les bateaux de pêche modernes doivent être à coque métallique, mais ce mode de construction demande un outillage coûteux et entraîne de gros frais de main-d'oeuvre, à moins que la surface de la coque ne soit développable. La communication expose, au moyen de théorèmes originaux, les propriétés fondamentales des surfaces développables, en vue d'établir des méthodes graphiques simples. Celles-ci sont valables en principe pour toutes les surfaces développables, et ne dépendent pas de la nature particulière de telle ou telle catégorie de surfaces.

Superficies desarrollables de cascos

A efectos de economía y eficacia las embarcaciones pesqueras modernas deben construirse de materiales de chapa, pero tal construcción exige herramientas y mano de obra costosas, a menos que el casco sea desarrollable. En este trabajo, se exponen las propiedades fundamentales de las superficies desarrollables demostradas por teoremas matemáticos originales, con el fin de proporcionar métodos gráficos sencillos. Estos métodos son aplicables en general a todas las superficies desarrollables y no dependen de la naturaleza especial de las distintas clases de superficies.

THE heavy capital investment in engines, rigging and gear, characterizing the modern fishing craft, is not compatible with the uncertain quality or unpredictable life of a wooden hull. The engineer's (and the banker's) demand for predictable performance discourages the construction of wooden hulls even where durable woods have not become expensive or unobtainable. The hull of continuous, homogeneous, testable sheet material is inherently stronger and lighter than the structure of small pieces of wood. If a skin of sheet material can be designed for low labour cost in construction, simple tools, and economy in repair, its engineering superiority and eventual economic advantage make it at once preferable to planks.

To enjoy the initial advantage of low labour cost in construction and repair, the skin must be developable. Construction must not demand expensive tools nor rare skills. At the same time, the hydrodynamic performance of the hull must be competitive with that of the best shape possible in wood construction. While a large number of model tests have shown that hard-chined hulls can be designed to have not significantly higher resistance than round-bottom hulls, the designer must be able to control the shape within close limits. He must be able to produce a hull of predetermined appearance and characteristics, and must not be forced to accept whatever happens when the material bends. Hence his knowledge of the medium of his art must be intimate and certain.

As ordinarily practised, the method of matching developable surfaces to acceptable curves is a tedious procedure. The method is based on the notion that any developable surface must be either conical or cylindrical, that any one of several cone-cylinder combinations will fit if only they can be found, and that the task is the simple one of trying a succession of surfaces until one is found to fit approximately. The exact fit cannot be found in this manner and so the designer's usual solution is to alter the original curves to fit the surfaces haphazardly accepted. He cuts the suit to fit the cloth. Preliminary design becomes only a rough approximation. Rather

than exactly choosing volumes, centres, parameters and desired forms for hydrodynamic and aesthetic reasons, the designer determines the results after the drafting is finished, then either accepts what chance has provided or starts over again.

A method for direct generation of developable surfaces from given beginnings is therefore needed. In hull design, these beginnings must consist of pairs of space curves: chine and profile outline of intersection of hull with centre-line, chine and deck edge, or two chines. The location and shape of these curves, it is presumed, are chosen carefully to suit displacement, appearance, and hydrodynamic efficiency. The method should provide surfaces to fit these curves, rather than to require alteration of the curves to fit surfaces. This is to say that the boundary curves adopted at the beginning of design should appear as much as possible unaltered in the finished drawing. Furthermore, the required method should be based on universal properties of developable surfaces, since the draughtsman cannot know in advance whether or not the surface to fit his curves is conical, cylindrical, convolute, or whatever.

FUNDAMENTAL PRINCIPLES

A draughtsman is not required to be a mathematician. He must trust, nevertheless, the validity of the methods he is using, and the command of his skill will be enhanced if he understands why his methods are valid. The graphical methods derived from the following theoretical considerations could be executed without having read this section; however, it might be profitable to consider at least the definitions and theorems. Some of the theorems on developable surfaces are impossible to handle by Euclidian geometry, and so resort is made to methods of differential geometry.

Ruled surface

Definition: A ruled surface is the locus of a line, called a generator, whose direction is determined by successive values of a parameter, moving continuously along a

curve (a directrix) and intersecting that directrix at an angle other than zero.

Tangency

Definition: If a plane T and a surface S coinciding at a point P, have a common normal through P, then T is said to be tangential to S at P. By extension, if T and S coincide at a succession of points determining a curve C (or a line) and if the common normals to T and S at each of these points on C are all parallel, then T is said to be tangential to S along C. It is evident that the normals to S and T will also be normal to C and to all other curves or lines in either S or T that touch C.

Developable surface

Definition: A developable surface is a ruled surface having the same tangential plane on one and the same generator (Kreysig).

Remarks—deductions from definitions

From the definition of a ruled surface, it is evident that the directrix must lie in the surface. From the definitions of tangency and that of a developable surface, we observe that each plane tangential to the surface must also be tangential to the directrix, or for that matter to any other curves in the surface that intersect the generators. A corollary observation is that if a plane be laid tangential to a developable surface at any point, its tangency will be along a line. This line is sometimes called an element of the surface, but it is preferable to call it a ruling of the surface, thus emphasizing the membership of developable surfaces in the larger class of ruled surfaces. The continuity of these rulings shows that a developable surface may be brought into isometric correspondence with a plane, meaning that every dimension of the surface may be mapped directly on a single plane. Such a surface may be described algebraically by writing the equation of a one-parameter family of planes, excluding planes parallel to each other. Graphically, the surface may be described by drawing a directrix and a sufficient number of rulings (generators). Where more than one space curve is known to lie in the surface, any one or all can be used as a directrix. Planes tangential to a surface will be tangential to these curves. It is known axiomatically that any plane may be rendered graphically by two intersecting lines or by two parallel lines.

Existence of a developable surface

Remarks: Given two space curves, C and D, the possibility of constructing a developable surface containing both curves is the first step. Many ruled surfaces containing both curves may exist, but no developable surface may be possible. The only theorem providing a test for the existence of a developable surface containing C and D is very involved, and no simple statement is available to provide an easy test. If in each projection of C and D on the planes of a Cartesian system, their curvatures have constantly the same sign, then the existence of the desired developable surface is obvious by inspection, but this is not a necessary condition. The draughtsman must rely on experience and sometimes on trial.

Uniqueness

Theorem 1: **If two space curves lie in any developable surface, they lie in one and only one such surface**

The proof of this theorem is as follows: Let C and D, having arc lengths s and σ respectively, be two space curves of allowable type, i.e. such as may lie in some (at least one) developable surface. We eliminate the trivial case of lines or points and agree that C and D are not coplanar. Adopt the hypothesis that the theorem is not true, i.e. more than one developable surface does exist containing both C and D.

At a point P_1 on C construct a plane T_1, tangential to C, and let T_1 be tangential to D at Q_1, which is possible by the hypothesis that C and D lie in at least one developable surface. A line from P_1 to Q_1 will now lie in T_1. Denote the unit direction of this line by $\hat{e}(P_1, Q_1)$. Let the unit tangent vectors to C and D be $\hat{t}_C$ and $\hat{t}_D$. Now if the unit normal to T_1 is $\hat{n}_1$,

$$\hat{t}_C(P_1) \times \hat{e}(P_1, Q_1) = \hat{n}_1 = \hat{t}_D(Q_1) \times \hat{e}(P_1, Q_1)$$

Moving along D a distance $\Delta\sigma$ from Q_1, suppose another plane T_2 is tangential to D at Q_2, and suppose T_2 tangential to C at P_1. This is possible under the hypothesis that C and D lie in more than one developable surface. The normal to T_2 is $\hat{n}_2$. Now

$$\hat{t}_C(P_1) \times \hat{e}(P_1, Q_2) = \hat{n}_2 = \hat{t}_D(Q_2) \times \hat{e}(P_1, Q_2)$$

But, since both T_1 and T_2 are tangential by hypothesis to C at P_1,

$$\hat{n}_1 \times \hat{n}_2 = \hat{t}_C(P_1)$$

This, however, is equivalent to the statement that

$$\hat{t}_C(P_1) \times \hat{e}(P_1, Q_1) \times \hat{t}_D(Q_1) \times \hat{e}(P_1, Q_2) = \hat{t}_C(P_1) = \hat{t}_C(P_1) \times \hat{e}(P_1, Q_2) \times \hat{t}_D(Q_1) \times \hat{e}(P_1, Q_1),$$

which is absurd and this completes the proof.

Parallelism of tangents to parallel plane curves

Theorem 2: **If two or more plane curves in S, a developable surface, are determined by the intersection of S with two or more parallel planes, none of which contains any ruling of S, the tangents to all such plane curves at their respective intersections with any ruling of S are parallel**

The proof of this theorem is as follows: Let parallel planes R_1 and R_2 . . . R_n intersect S, a developable surface, in the allowable manner, cutting plane curves D_1 . . . D_n. If S is continuous, it may have a tangential plane T_i along any ruling L_i, and in S every curve D_j having a point on L_i has a tangent lying in T_i. The plane curves D_1 . . . D_n cut in S by R_1 . . . R_n have such tangents, t_{1i} . . . t_{ni}, at their intersections with L_i. Now both t_{1i} and t_{2i} lie in T_i, but they also lie respectively in R_1 and R_2 and thus are identical with the lines of intersection of a plane T_i with two parallel planes. Consequently they must appear parallel in every view.

Dimensions of co-ordinates

Remarks: It is well known from the theory of conformal mapping that, after a function has been transformed to a

new co-ordinate system, the results of operations performed in the new system may be mapped back into the original system without loss of the same validity that would have prevailed if the operations had all been performed in the original system. In particular, if the original system is simple Cartesian and if the transformed system is no more than a linear transformation of one dimension in the co-ordinate system, the effect is similar to that of looking at the drawing through spectacles which distort distances along one axis.

Approximations

Remarks: The essential procedure in graphically describing a developable surface is to describe the planes that lie tangential to the surface. In many cases these tangential planes can be located directly and exactly, but in others the exact location becomes so laborious that approximation becomes preferable. For this purpose we take advantage of the similarity between a short segment of a ship's curve and its osculating circle: a tangent to the curve at the midpoint of a short segment will be parallel to the chord between the ends of the segment. Thus if a plane intersects a curve at two points not far apart, the plane when rotated slightly will be tangential midway between the two points.

GRAPHICAL APPLICATION OF FUNDAMENTAL THEOREMS

In the foregoing section some of the fundamental properties of all developable surfaces have been enumerated. They will now be used for practical drawing development. The important properties are as follows:

●　A developable surface may be depicted graphically by drawing the family of planes that are tangential to it
●　Any tangential plane to the surface is also tangential to any curve lying in the surface and intersecting the line of tangency, or ruling
●　Any plane found to be tangential to the surface at any point is unique

These properties, as far as drawing is concerned, suggest the following constructional approaches:

●　Planes tangential to the surface should be found
●　These planes are best found by using given curves already known to line in the desired surface, such as chine, sheer and profile centre-line outline
●　If any plane can be found to be tangential at a particular point, it is the unique plane tangential at that point and may be used with confidence.

The best means of illustration is a practical example, so the following gives the general procedure for the development of planes applicable to a line drawing of a vessel with the following particulars.

Lwl	.	.	.	.	39.5 ft (12 m)
Δ	.	.	.	.	15.57 tons
C_p	.	.	.	.	0.59
FB	.	.	.	.	0.53 Lwl

A preliminary hull design is drawn meeting these requirements, and with straight line sections (fig 1).
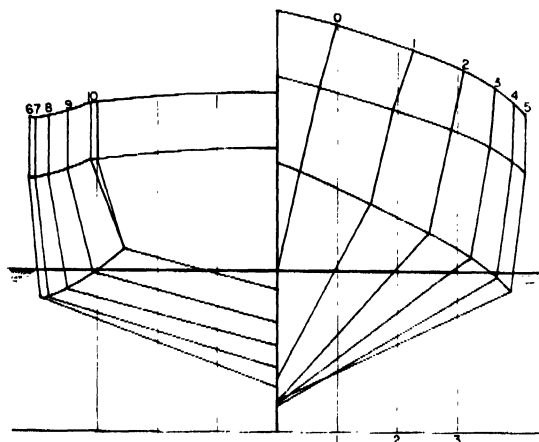
Fig 1. The preliminary body plan

Sheet materials can hardly ever be applied to a hull of straight line sections and so these sections must become suitably curved. The designer, with practice, will learn how to make allowances for this curvature in the preliminary design stage, so as finally to give the required hull parameters.

The sides of the boat above the chine are not as easy to develop as the bottom below it. In fig 2 the hull drawing has been laid out foreshortened longitudinally in half breadth and profile. This is done as the main method of constructional drawing and consists of locating various points by drawing tangents to curves at these points.

The side surface of the boat above the chine is obviously contained by two required curves, the sheer and chine lines, but some doubt exists at present whether a developable surface can be fitted to the straight stem line. As the sheer and chine lines are not simple curves, we cannot develop the surface by the more simple method that will be utilized on the bottom. The approach used is that a tangent is drawn to one curve and the plane generated is then swung until it comes into tangency with the other known curve. This is not difficult, as is shown below:

●　Take a point P at the bow on the chine and in both the half breadth and profile draw the tangents to the chine line passing through P
●　From this tangent draw any line AB intersecting the sheer line in B at a reasonable intersection angle in profile and half breadth view
●　At suitable short intervals from this line, i.e. at C and E, draw the same lines parallel to AB in the profile and the half beam
●　At the intersection of the lines through C and E and the sheer line in the half breadth view are the points D and F
●　Transfer these points to the profile giving curve BDF
●　Define the point Q where the curve BDF cuts the sheer line
●　Take the point P at the midpoint of BQ
●　Join P and P' giving the line of tangency (ruling) of the plane PAB with the side surface of the vessel

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An explanation of the above is as follows: The line ACE is the tangent to the chine line at P in both views. Therefore PAB gives a plane that is tangential to the chine and cuts the sheer line. If in profile this plane cuts the sheer line again at a second point adjacent to B, the plane must be almost tangential to the sheer line. To find this second point, we suppose the sheer line in the half breadth to be the edge view of a cylinder. This cylinder cuts the plane PAB and because AB, CD and EF lie in the plane PAB, the cylinder must cut them in the points B, D and F and these lie, as already stated, on the sheer line in half breadth. Therefore the curve BDF in profile shows the intersection of the cylinder with plane PAB and coincides with the sheer line at B and the second point Q.

Now, if PAB is rotated about PA it would become completely tangential to the sheer line approximately at the midpoint of BC at P' (osculating circle). The line PP' is therefore a line of tangency of a plane with the surface of the boat.

Another similar operation is illustrated farther aft. This time the initial tangent line is taken on the edge of deck rather than on the chine. The sequence is the same as before: beginning at P, a tangent line to A; from A, on the tangent line, to B on the chine; parallel lines CD and EF to the chine in half breadth plane. In profile, the

lines are drawn initially from C and E parallel to AB without knowing where D and F occur on them. The locations of D and F in the profile view must be located by projecting them upwards from the lines in the half breadth view. The curve BDF is the intersection of a cylindrical surface (of which the chine in this case is the edge view in half breadth) with plane PAB. This curve intersects the chine at B and F, and therefore a slight rotation of PAB will bring it into tangency about midway between B and F, at P'. The line PP' is a line of tangency of a plane with the surface of the boat, shown as ruling number 9.

The rest of the rulings on the side surface, shown in heavy lines and numbered 1 through 13, were obtained by the same manner. Finding all of them took the author two hours. The draughtsman must acquire a feeling for the surface he is working on. Once he visualizes it, the work is rapid and economical. It should be noted that development of the planes was commenced in the half breadth view. It could have been started in the profile view, letting the sheer or chine in that view represent the edge view of the cylinder, but then the cylinder would have intersected the plane almost perpendicularly, and the curve of intersection when projected on half breadth would not be so well defined. With experience, the draughtsman will select the view where the plane will be
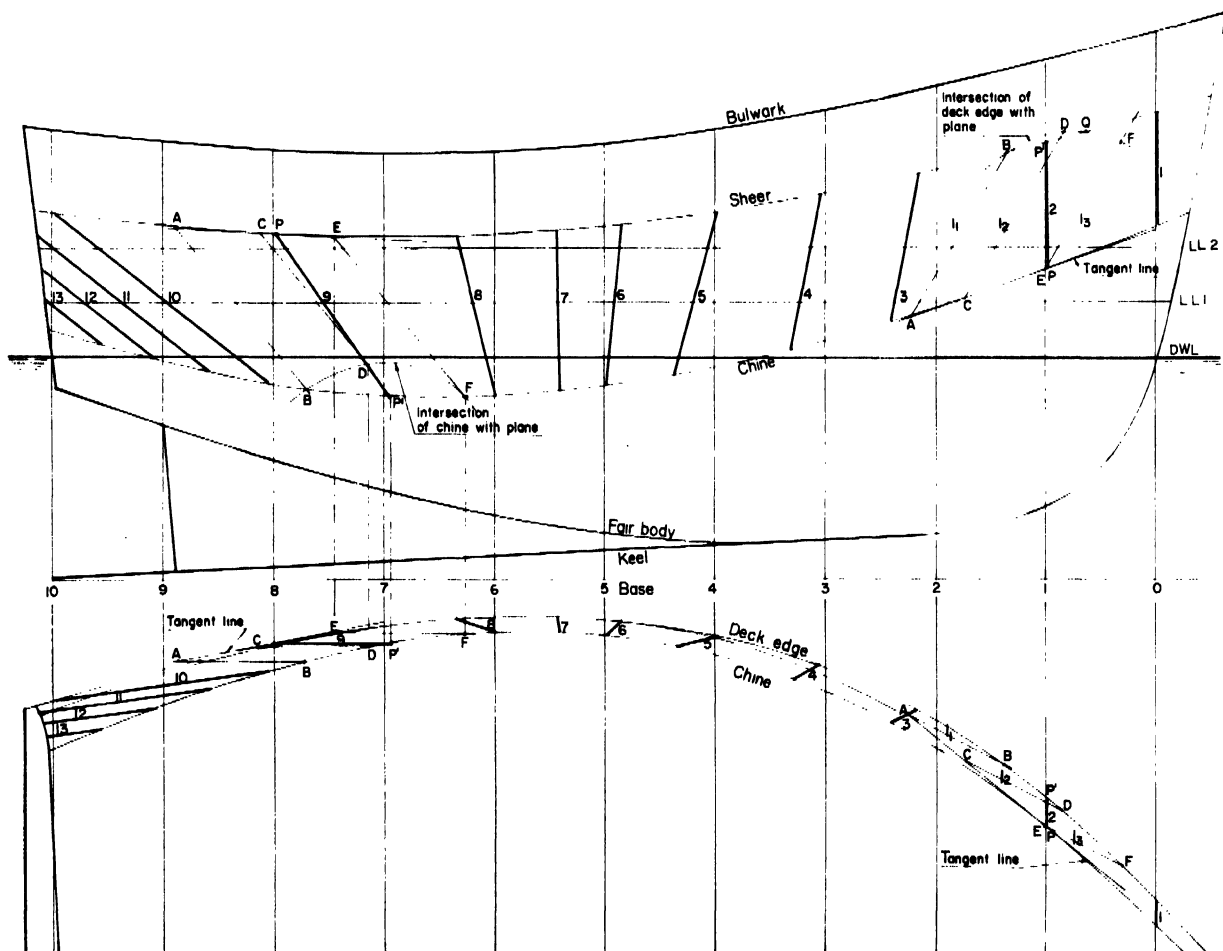
Fig 2. Development of sides

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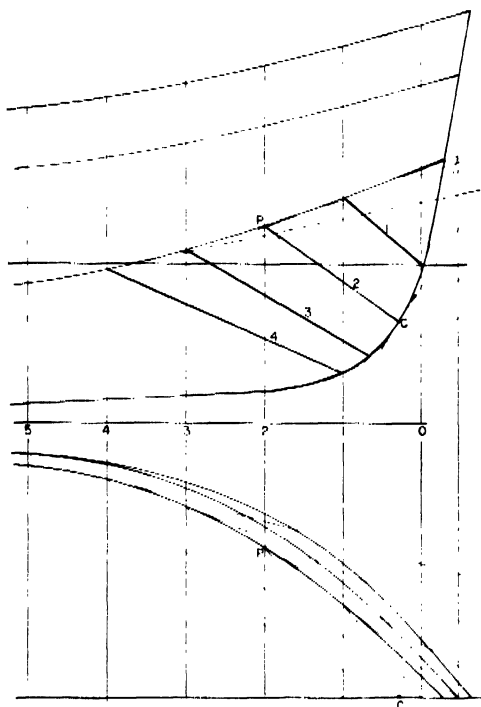
Fig 3. Development of bottom by intersecting tangents

intersected at the most acute angle for commencement. Sometimes the two points of intersection of the plane with the given line will be too far apart, in which case it will be necessary to refine the accuracy by drawing a new plane closer to the point of tangency. It is always advisable to keep superfluous lines off the main drawing; lay a piece of tracing paper over the drawing and do all the construction on that. Do not waste time or add to the work by erasing and working on a blurred drawing.

Development of the bottom is much simpler because the centre-line curve lies entirely within a plane. Because of the foreshortening of the drawing, the resultant curvature of the lines makes points of tangency easier to find. The development of the surface near the bow is shown in fig 3. Ruling 2 is used as the example. The graphical construction is as follows:

- In half breadth draw tangent to chine line at *P* and project it forward to intersect with the centre-line plane at *A*
- Transfer the point *P* to the profile and draw the tangent to the profile chine line through *P*
- Transfer point *A* from half breadth to extended tangent line through *P* in profile giving the point *B*
- Through *B* draw tangent line to bow profile obtaining point *C*, giving the plane *PBC*

The explanation is as follows: The intersection of the tangent with the centre-line at *A* in the half breadth must be in the same plane as the point *B* in profile. The line from *B* locates *C* and is tangential to stem profile. So the tangential plane is complete in *PBC*, because it is the plane tangential to two curves lying in a developable surface. Line *PC* is the unique line of tangency of *PBC* with the surface. Hence *PC* is ruling number 2. Rulings number 1, 3 and 4 are determined by the same method.

Beyond Station 4, a tangent to the chine will run off the drawing-board before it intersects the centre-line, so that from this point a third method of development must be employed. The method used is as follows (fig 4):

- Draw a line parallel with the centre-line tangential to the chine line giving the point *P* in the half breadth
- Transfer this point to the profile and draw the tangent to the chine line through *P*
- Still in profile, draw a line parallel to this tangent line to the chine, but tangential to the centre-line outline giving the point *A*
- Join *PA* which is the ruling of the surface number 5

This is based on the theorem of parallel tangents already stated. Therefore, by the theorem, the tangent to the chine at a ruling of the surface through *P*, in the profile view, will be parallel to the centre-line outline curve at the intersection of that ruling with the centre-line outline.

Now referring to fig 1, note that bottom sections 8, 9 and 10 are parallel in the body plan. They are also parallel in all other views, and therefore they define a cylindrical surface. Hence we do not have to develop the bottom abaft Station 8: this is already done.

To obtain the rulings 6 to 9, the following procedure is adopted:

- Transfer the buttock lines 1, 2 and 3 to the profile by using the height intersection from the body sections, for sections 8, 9 and 10. Transfer the intersections of the buttocks and rulings 1, 2, 3, 4 and 5 in the half breadth to the profile. Fit a spline to these points precisely, and draw the buttock lines in profile

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Fig 4. Use of parallel tangents
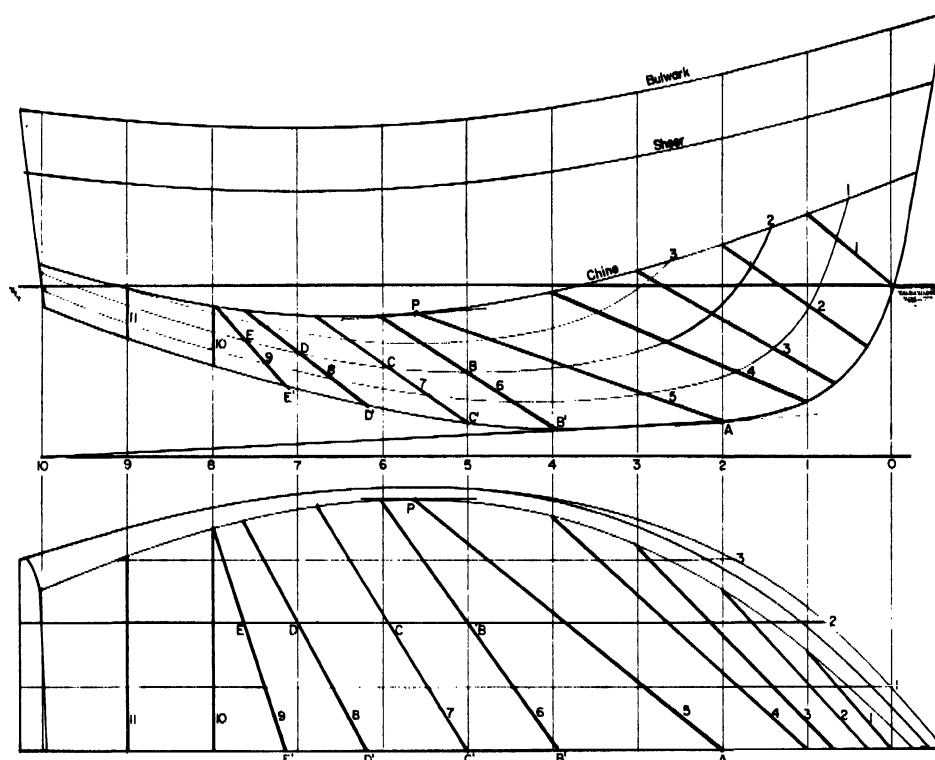
● Draw parallel tangents to the buttocks and centre-line profile line in profile, the points of tangency give the rulings

● Check all points lie on straight lines in both views. This gives the points *BB'*, etc., and the rulings 6, 7 and 8

This again is dependent on the parallel tangent theorem as buttocks and centre-line profile represent parallel planes. The gap between Station 8 and ruling number 5 is considerable, but the spline is held on at least three points at each side of the gap. It will pretty accurately describe the only fair line that can be drawn between these points. The balance of the bottom, abaft Station 8, of course, has already been found to consist of straight, parallel frames.

Developing the bottom requires half an hour. If it had been necessary, the same method could have been used on the bottom as on the sides, but faster and more accurate methods were available. The final lines are shown in the body plan, fig 5. This was obtained by transferring the new buttock lines on the stations from the profile and halfbeam shown in fig 4. The sections in the sides of the forward part of the boat are so nearly straight that the very slight curvature in them cannot be shown with the small scale on which these drawings were done. Almost any material, metal or otherwise, will have sufficient plasticity to accommodate slight deformation. The development of the bulwarks is not shown. In this case the top of rail is drawn at a constant distance from the deck, and the bulwarks could be rapidly and accurately developed by the method of parallel tangents, since over short distances the sheer and bulwark lines in profile can be considered straight lines.

Fig 5. Final body plan
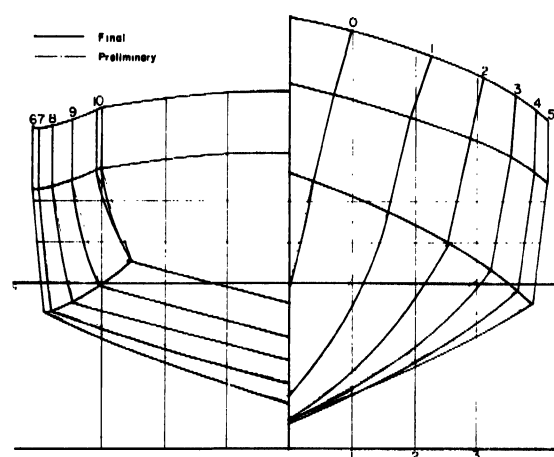
The displacement, prismatic coefficient and the position of the longitudinal centre of buoyancy have been altered, though not a great deal. If the exact specified particulars are desired, the designer should make provision in the preliminary plan for these predictable changes. The lines of chine, sheer and outline are exactly the same as originally proposed.

APPLICATION OF FUNDAMENTALS IN CONSTRUCTION

The early automobiles were equipped with whip sockets. Structures are still designed for reinforced concrete as if they were to be built of masonry and the frames of boats as if they were to be planked with wood. In the

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case of steel or aluminium hulls with developable surfaces, at least the ancient notion that a boat is supposed to have a backbone and ribs like any other real animal would be best forgotten.

A metal hull with developable surfaces can be built almost entirely with straight frame members. It is true that hardly any of these members will be perpendicular to the keel, but there is no engineering reason why a stiffener on a plate should be perpendicular to its landings if it is firmly fixed. Welding has ended any practical reason for right angles. A hard-chined boat can be built with no forming or bending required on any part except chine bars, stem bars and perhaps deck beams (even these can be longitudinal). Although chine bars are often omitted when perpendicular or longitudinal framing is used, they would be necessary for landing of canted frames.

Such hulls require the minimum of lofting and template making. They require no expensive furnaces nor heavy tools. High skill in metal working is not needed. A shipwright and a welder will do a perfect job. The appearance and the efficiency of their product will depend solely on the art and skill of the designer in working with a special medium, for the design of developable surfaces is not merely a matter of knowing how to fit surfaces to curves. Just as the sculptor trained for stone is not sure of success in wood, so the naval architect accustomed to traditional methods is not necessarily sure of success with developable surfaces before he has mastered his medium.

CONCLUSION

In the development of the hull here used as an example, no presuppositions were made as to the nature of the surfaces. It was not supposed that the surfaces were conical, nor of any particular class. True, a part of the bottom at the stern was seen to be cylindrical, but this was not a presupposition. We have spent no time hunting for some apex of some unknown and undefinable cone which probably was non-existant. Most boat surfaces are convolute and hence have no apex.

The properties exploited are those applicable to all developable surfaces. If the proofs of these properties are anywhere deficient in mathematical rigour, they can be defended by the assertion that their inadequacy in practical work is an extremely remote possibility and are certain enough for the naval architect to use them with confidence.

Dug-out Canoes and other Indigenous Small Craft

by A. J. Thomas

Pirogues monoxyles et autres embarcations autochtones

L'auteur apporte des données historiques et sociologiques permettant au lecteur de bien comprendre les divers facteurs d'ordre technique, social et économique qui interviennent dans tout effort de mécanisation des pirogues monoxyles et autres embarcations autochtones. Il est procédé à une comparaison d'ordre général entre la mécanisation des bateaux indigènes actuels et l'introduction de bâtiments modernes perfectionnés dans des sociétés primitives. Après avoir passé en revue les inconvénients et les avantages des bateaux autochtones, l'auteur présente des directives générales pour leur mécanisation, illustrées par plusieurs exemples concrets.

Las piraguas monóxilas y otras pequeñas embarcaciones indígenas

Una exposición de los antecedentes históricos y sociales de estas embarcaciones sirve de introducción al trabajo y conduce al lector a través de una completa apreciación de los diversos factores técnicos, sociales y económicos inherentes a todo intento de mecanización. Se establece una comparación general entre la mecanización de las actuales embarcaciones indígenas y la introducción de otras modernas y mejor acabadas, en las comunidades más primitivas. Se enumeran y analizan las ventajas e inconvenientes de las embarcaciones indígenas y se ofrecen, por último, orientaciones generales para su mecanización, ilustradas con varios ejemplos prácticos ya realizados.

A great deal of study has been undertaken by naval architects, marine engineers and other technicians, of fishing craft of the types and sizes used in developed countries. During the past decade FAO has also undertaken a number of missions to developing countries in order to improve the designs of fishing vessels, with the result that a large number of improved boats has been built and much valuable experience has been gained. In contrast to this, very little attention has been given to the considerable numbers of varying types of small fishing craft which are mostly used by fishermen in developing countries, although it is believed that these craft greatly out-numbered the larger craft in the fisheries of developed countries. In the past, there was a tendency among technicians accustomed to larger craft, to regard these small craft as "relics of the past" without a full appreciation of the social, economic, technological and other factors involved.

Whilst one of the long-term solutions to the problem of increasing production of fish in many developing countries may be found in a fleet of well-designed diesel-powered fishing boats, such a programme is often beyond the resources of many developing nations. Moreover, since there is mounting evidence that the outboard engine is playing a significant part in increasing the mobility of small craft and thus expanding the productivity of the small-boat fishermen, it is believed that a re-examination of the problem is justified, bearing in mind that, among other things, the outboard engine possesses the lowest weight-for-horse-power ratio of any kind of marine power and that the outboard-engine horsepower costs less than diesel horsepower.

HISTORICAL BACKGROUND OF INDIGENOUS SMALL CRAFT

Whilst it is not intended, except where appropriate, to examine the early historical background surrounding the development of the various types of small craft operated in many developing countries, it is nevertheless true to say that large numbers of these craft were developed out of the historical and sometimes geographical circumstances surrounding the countries in which they are found. Very often, therefore, they are intimately associated with the traditional art of the country and thus involve the implications of long tradition. Moreover, their existence is also often related to the socio-economic condition of the fishermen. It is against this background that a critical analysis of these craft should be undertaken. This implies that in trying initially to improve the productivity of the vast numbers of small-boat fishermen to be found in developing countries, it is necessary that attention should be given to two main considerations. These are: (a) whether the traditional craft whose behaviour, economics and functional adaptability are so well understood by the fishermen should be replaced by a more modern design whose behaviour and economics under certain given conditions are understood by the designer or other technician (but not by the fishermen) or (b) whether improvements which would not seriously alter the behaviour or functional adaptability of the traditional craft, but would increase its efficiency, should be undertaken. In order to answer either question it is necessary that close examination should be made of the social, economic, technological and other factors involved in the operations of these small craft.

DISADVANTAGES OF INDIGENOUS SMALL CRAFT

Generally speaking, these small, open craft possess serious and often unalterable limitations but they also possess many advantages and it is believed that their limitations can often be out-weighed by the advantages. The following are some of the limitations which characterize these small craft:

- They are open and therefore not adaptable to sleeping or cooking arrangements
- The crew are exposed to sun and rain
- Not adaptable to the use of large and heavy fishing gear
- Not usually adaptable to most kinds of mechanically operated fishing equipment
- Many, especially dug-out canoes, are much less durable than plank-built wooden craft since, in the case of the latter, planks can be replaced when necessary. The life of the former depends on the wood from which it is constructed
- Operations are sometimes limited by weather conditions that would not affect larger, decked craft
- Not normally adaptable to automatic bailing equipment
- Being open, they must usually return to base daily
- Fish-holding capacity is very limited

ADVANTAGES OF INDIGENOUS SMALL CRAFT

On the other hand the following are some of the advantages of these craft:

- The total capitalization for equipping them for fishing is low and the capitalization per worker is correspondingly low. This is important in developing countries with limited capital resources. In Jamaica, a dug-out canoe of 28 ft L × 5 ft B (8.6 × 1.5 m) fitted with an 18 hp outboard engine and using mobile fish traps and hook and line, might represent a total capital outlay of £450 (US$1,260). If a crew of four is required, the capitalization per worker would be approximately £113 (US$316). The gross turnover can be calculated at £1,000 (US$2,800) per annum or an average of £250 (US$700) per worker per annum. With a slightly larger craft and a correspondingly higher total and per-worker capitalization, the gross turnover may be twice as good. The gross income will vary according to the skill of the fishermen, the biological condition of the fisheries and other factors. This income should be compared with the average income per capita of the population in comparable employment in the country. In Gambia, a part dug-out, part planked canoe of 28 ft L × 5.5 ft B (8.6 × 1.7 m) fitted with a 5½ hp outboard engine and using beach seine, represents a total capitalization of £230 (US$644). With a crew of six the capitalization per worker is £38 (US$106). The gross turnover is calculated at £800 (US$2,240) per annum or an average earning of £133 (US$372) per worker per annum. This is considerably higher than the annual earning of the average farmer in Gambia. The estimated income per capita of the population is estimated as under £30 (US$84). It should be emphasized, however, that in both examples given, division of earnings is not allocated evenly as between the boat/engine/net owner and the crew. The former retains a much higher proportion than that paid to individual members of the crew as payment of fuel and as compensation

for having provided the boat, the engine and sometimes the gear
- These craft require no harbour or special installations, often a financial strain upon the resources of developing countries, but are hauled up the beaches along the coast
- Fishermen often live in the proximity of the coast adjacent to berthing areas and therefore remain in rural surroundings instead of invading towns and causing housing and other social problems
- Dispersal of small boats along the coast enables widespread fish supplies, often without the additional cost of road transport increasing the cost of distribution
- Require no slipways for servicing and are therefore inexpensive to maintain. Dug-out canoes require no caulking
- Local skills and often local materials are used in their construction, thus providing local employment
- The cost of small boats is very often within the means of individual fishermen, satisfy their pride of ownership and desire for self-employment. The limited capital involved permits large numbers of fishermen to eventually become boat/engine owners
- Large numbers of small boats enable fishing platforms to be dispersed over wide areas. This is of special advantage where fish are widely dispersed in small shoals
- In many countries the construction of small boats is such that they remain afloat when capsized. Thus, in the mind of the fisherman, his small boat is his "life raft"
- As planing craft, small boats are able to operate in very shallow water areas
- Constitute a cheap form of water-transport through shallow creeks and rivers in the absence of roads, the construction of which often places a strain upon the resources of many developing countries, or where the economic justification for construction of roads is in doubt
- Are often indispensable in places inundated by floods
- Can be propelled by oars in cases of engine failure
- Construction of these small wooden craft requires no centralized boat-yard or expensive equipment. They are often constructed on the sea-beach
- Are adaptable to various types of fishing gear, e.g. hook and line, longline, multiple-trolling rig, gillnet, cast net, beach seine, fish traps and small shrimp trawl
- When not in operation, they require no hurricane shelter in areas which are subject to such phenomena. In such an emergency they can be weighted with sand or hauled into a safe area
- Very often large numbers in a given country can be adapted to an outboard engine, that is an inexpensive "mobile" engine and does not require installation of engine-bed, stern tube, etc
- Since generally they are taken out of the water daily, much of the damage to which they would otherwise be subjected through marine borers is avoided

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- The hull can be constructed by hollowing it out of a tree trunk as is the case in Jamaica, Ghana and certain other parts of Africa, wholly out of planks or part out of a tree trunk and part of planks as in Senegal and Gambia in West Africa and elsewhere
- Well-constructed small boats when motorized can attain good operational range. In Jamaica, dug-out canoes, which have been adapted to motorization and improved in size as a result of mechanical propulsion, often undertake round trips of 120 miles at right angles to the coast
- Enable fishermen, long accustomed to daily contact with family and friends, to maintain this tradition

EXAMPLES OF IMPROVEMENTS IN INDIGENOUS SMALL CRAFT

An example of the improvement in the mobility of small craft and the consequent improvement in the economic and social status of the fishermen, without seriously altering the structure of the traditional craft, its behaviour or functional adaptability, is provided by the case covers an area much larger than the hole. It is strengthened by a false thwart resting (unlike the other main thwarts) on top of the built-up keel. The forward section of the box extends through the hole in the keel to its full depth whilst the sides and after sections of the box rest on the top of the built-up keel. The engine is clamped on to the forward sections of the box with the steering/throttle handle pointing toward the bow. The propeller is thus under the boat. One disadvantage, where the hole is too small to permit the tilting of the engine shaft out of the water, is that the engine must be removed before launching and landing in order to avoid damage to the propeller.

Another example of the adaptation is provided in the case of the dug-out canoe in Jamaica. The Jamaican canoe is hollowed out of the trunk of the "silk cotton" and less frequently out of the trunk of the "guango", both of which grow there. It has been constructed in Jamaica for many centuries originally by the indigenous people, the Arawak Indians. It was also used by the warlike Carib Indians as a means of transport as they moved from island to island in the capture of the Lesser Antilles and from there to make raids upon the Arawak Indians in
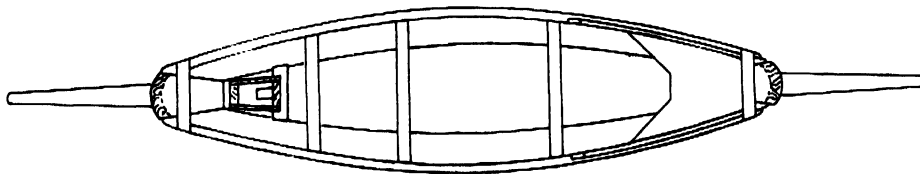
Fig 1. Senegalese/Gambian canoe showing well constructed inside the craft to hold the outboard engine

Fig 2. Traditional Jamaican dug-out canoe showing shape of bow and stern before introduction of mechanical power

of the Senegalese, and to much more limited extent in the case of the Gambian canoe operating on the Atlantic coast, both of which are structurally similar. In both cases the outboard engine has been adapted to the craft.

This craft can be briefly described as partly dug-out and partly planked. The dug-out portion represents the keel which is of heavy hardwood, the height of which is raised by the addition of one and sometimes two planks of lighter wood slanting outwards. The height and width are further increased by planks of light wood, still slanting further outwards and overlapping the top of the built-up keel. This results in a flange along the full length of the outer sides of the craft. The structure is supported by thwarts extending from one gunwale to the other and covered by a capping. In order to adapt the outboard engine to the craft, a well has been constructed inside. This has been accomplished by cutting, near the stern, a rectangular hole through the keel and constructing a rectangular box directly above the hole, (fig 1). This box

Jamaica before Christopher Columbus had discovered and taken possession of it. In early times this craft varied greatly in size. Some were constructed for one person only, whilst others were made to carry forty, fifty or more. Columbus saw one in Jamaica, 92 ft L × 8 ft B (29 × 2.5 m) (Black, 1958).

Traditionally, the Jamaican canoe was constructed with bow and stern fine somewhat similar in shape to the Montague whaler used by the British Navy (fig 2) and was propelled by sails and oars. Generally, in more modern times the length of the canoes ranged to about 28 ft (8.6 m), most being below that length. The extreme width rarely, if ever, exceeded 4 ft (1.2 m).

In the initial stages in attempting to improve the status of the fishermen, it was considered inadvisable to remove them from their small traditional craft but rather to improve its mobility and operational range and reduce the fatigue to which the oar-pulling fishermen were subjected. The reasons for adapting the outboards as a

"mobile" unit to the craft are discussed elsewhere (Thomas, 1960). It was determined that the outboard could be attached most appropriately to the stern of the canoe and some crude adaptations were made to accommodate the engine. This led to the consideration of a transom stern. But due to the texture of the silk cotton wood, it was decided that hardwood would be more resistant to the weight and the vibration of the engine. A transom stern of hardwood was therefore adapted (fig 3). This was constructed of a thick plank and moulded to fit

fishermen and builders of change and progress. As a direct result of the influence of mechanical propulsion, the structure of the Jamaican canoe was modified to embrace the conventional lines of a more modern fishing boat (fig 3). It thus became more suitable for planing speeds. The freedom from dependence upon man and wind power resulted in the construction of canoes of greater dimensions, use of improved fishing gear and techniques which were not possible before the introduction of mechanical power. The cumulative results of the improvements, the

Fig 3. Showing transom stern being a modification in shape of hull as a result of introduction of outboard power

between the sides of the canoe in such a manner as to be flush with the stern end. The adapted transom board was fastened and further strengthened by means of a strong metal bar fitted just below the gunwale and passing from one side of the canoe to the other near the transom. Sometimes "knees" of metal, bolted to the transom and the outer sides of the canoe near to the gunwales, added further strength to the adapted transom.

The adaptation described was successful and resulted in the transom stern, to accommodate the outboard engine, becoming a permanent feature in the construction of canoes. This was regarded as a mental acceptance by the

programmes of training of fishermen and making credit facilities available to them from public funds are described elsewhere (Thomas, 1960).

It may be of interest to state a further development from the improvements described. Private Jamaican financial and engineering interests have established in Jamaica a factory which constructs the improved type of canoe from fibreglass. The bilge of this craft is fitted with styrofoam to ensure floatation when capsized. Thus, a new industry has been created to the benefit of the economy of Jamaica.

Fishing Boats for Developing Fisheries

by P. Gurtner

Types de bateaux destinés aux pays dont les pêches sont en voie de développement

La communication passe en revue l'activité de la FAO durant les 15 dernières années en matière de conception des bateaux de pêche; elle est illustrée par 32 dessins représentant divers types de petits bâtiments en bois, utilisés principalement en Extrême Orient et en Afrique.

L'auteur fournit des données sur les plans et les performances, ainsi que des renseignements connexes: résultats d'essais au bassin, essais de modèles en vraie grandeur, prédictions de la puissance effective, établies au moyen d'un ordinateur, poids, et coûts. Il signale que l'on dispose de très peu de renseignements sur les bateaux de petite taille, et exprime l'espoir que les données fournies ici encouragent le rassemblement et l'interprétation d'une documentation complémentaire. Dans un bref résumé de l'expérience de la FAO sont examinées les mesures recommandées en vue d'une expansion cohérente des flottilles de pêche côtière dans les pays où l'industrie halieutique est en voie de développement.

Embarcaciones de pesca para las pesquerías en vías de desarrollo

Se examinan las actividades de la FAO en el desarrollo de diseño de embarcaciones de pesca durante los quince años últimos; 32 dibujos ilustran numerosos tipos de pequeñas embarcaciones pesqueras de madera, principalmente en el Lejano Oriente y Africa.

Se dan los datos de diseño y comportamiento así como información afín sobre los resultados de las pruebas en el canal hidrodinámico, ensayos a escala normal y predicciones de las calculadoras sobre la potencia efectiva, pesos y costos. Se pone de relieve la limitadísima información de que se dispone acerca de las pequeñas embarcaciones; los datos presentados deben actuar como estímulo para un nuevo acopio e interpretación de tales datos. Las medidas recomendadas para el desarrollo integrado de las flotas de bajura en las pesquerías en desarrollo figuran en un corto resumen de las experiencias obtenidas por la FAO en esta esfera.

MANY countries in Africa, Asia and Latin America have made considerable development efforts during the last 15 years to create larger, more efficient inshore fishing fleets. This necessitated technical assistance from outside to overcome the lack of qualified and experienced technical personnel required for an effective development of fishing boats, gear, fishing methods and disposal of catches.

FAO has been actively assisting countries requesting specialized assistance in the field of fishing boat design. Table 1 lists the main boat development projects undertaken by FAO. These projects generally have followed a similar pattern, initially in obtaining detailed knowledge of local boats engaged in fishing, then simultaneously trying to improve on these boats by introducing small changes in hull form and construction, and more efficient fishing gear and methods, and finally by developing new boat designs, specifically suited to local fishing requirements and the capabilities of local boatbuilding industries. Parallel with the improvement of local boat types and the introduction of new types, it was often necessary to conduct training courses for local fisheries officers and boatbuilders. The obvious aim of such schemes was to ensure that the work of a technical assistance mission would be continued under the guidance of local personnel, once the mission itself had concluded its operation.

Similar development work was undertaken in many cases by governments without direct foreign assistance, and in other cases bilateral aid missions have contributed by providing material aid and/or expert assistance in the field of fishing boat construction.

Fig 1 to 23 and 25 to 32 show a number of boat designs developed by FAO naval architects serving on technical assistance projects during the 15-year period, while fig 24 and 33 represent two noteworthy examples of unassisted government work. It is not the purpose of this paper to report in detail how each of the projects was planned and executed; the reports issued by FAO and based on the work of the project staff contain the relevant details on policy and administrative matters. It is intended to show some examples of what has been achieved. It should be noted that technical assistance work is often conducted under very trying conditions, and that the naval architect charged with the task of developing modern boat designs for a fishery that often has evolved directly from the dug-out to the fully mechanized modern fishing vessel, faces very different obstacles from those encountered by his colleagues in highly developed countries.

Very little factual information exists—apart from design particulars—regarding the boats presented. This is very unfortunate, but is explained by the fact that the designers of these boats rarely had the possibility of closely following the construction of the boats and later their performance under operational conditions. It is hoped that in the future it will be possible to collect and disseminate more information on weights, stability and performance of boats introduced in developing fisheries nations. This information would greatly facilitate the work of boat designers who suffer from an immense lack of applicable reference material in such countries.

Apart from the account of FAO's work this paper should be considered as a stimulus to greater future efforts in collecting reliable data on boat construction and performance as an aid to designers.

PRESENTATION OF BOAT DESIGNS

The following boats are shown with representative drawings, and table 2 gives their main particulars:

TABLE 1
Main boat development projects undertaken by FAO experts

Country	Expert	Subject	Year(s)	FAO Report No
Turkey	H.I. Chapelle	Survey of existing fleet and design of new types	1956/57	706
West Pakistan	H. Magnusson	Survey of local fleet	1953	403
	C.S. Ohlsson	Design of modern vessels based on local types	1953	403
India	P.B. Ziener	Survey of existing boats, mechanisation introduction of modern designs	1953/58	945
	K.K. Rasmussen	as Ziener	1956/57	945
	P. Gurtner	Introduction of modern designs, training organisation of fishing boat service	1958/61	1096, 1535
	A. Sutherland	Organization of marine engineering service, training	1961/62	1710
Ceylon	E. Kvaran	Mechanization, organization of marine engineering service, training	1953/65	1518
	E. Estlander	Outboard mechanization, boatbuilding	1959/62 1965	2004 2217
	P. Knoops	Introduction of modern designs (emphasis on steel vessels)	1963/65	
Thailand	P.S. Hatfield	Study of local fleet, introduction of modern trawler design	1963	1846
Sénégal	P. Gurtner	Introduction of modern boat types, boatbuilding traing	1962/64	in prep.
	J.F. Fyson	Boatbuilding training	1962/65	in prep.
	Ø. Gulbrandsen	Boat design and construction	1964/65	
Nigeria	R. Anderson C.S. Ohlsson	Study of boatbuilding possibilities Lake Chad	1963	1711
	J.F. Fyson	Short term investigation of boat building possibilities	1965	in prep.
Peru/Ecuador	P. Knoops	Research vessel construction	1961/63	
West Indies	K.K. Rasmussen	Introduction of modern boat design	1960/61	1409

24 ft (7.3 m) beach landing boat BB–59 (fig 1)
Developed specifically for limited surf landing operations in India. Extensive tests were conducted with different designs and BB–59 embodies the conclusions (FAO Reports Nos 945, 1096, 1535). The boat proved successful on subsequent trials, but no further attempts were made in India to introduce this type in large numbers. Considerable interest was shown in the design in USA and Latin America as a consequence of its publication in *Fishing Boats of the World: 2.*

25 ft (7.6 m) open fishing boat (fig 2 and 3)
The third version in the development of a small, open boat for inshore fishing in India, this design followed

earlier types of 24 ft (7.3 m) and 25 ft (7.6 m). About 150 boats were built and operate mainly for gillnet fishing and shrimp trawling (FAO Reports Nos 945, 1096, 1535).

27 ft (8 m) fishing boat E26 (fig 4 and 5)
This boat was developed in Ceylon for inshore fishing with gillnets. Many boats were built during the last few years and they continue to be an important part of the fleet (FAO Report No. 2217).

30 ft (9.15 m) open fishing boat (fig 6 and 7)
The lines and construction drawing in fig 6 show the boat as originally conceived. It served as an inshore

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boat for gillnet fishing, with considerably larger capacity than the 24 ft (7.3 m) and 25 ft (7.6 m) boats; its construction was simple and complied with local practice. The same basic boat was later produced in a half-decked version, fig 7, for trawling and gillnetting. Subsequently, the lines were redrawn with increased sheer forward, rake to the keel, and beam, and boats of this type are now being built as fully decked, small trawlers throughout South India. It is estimated that about 450 boats of this type are in operation (FAO Reports Nos 945, 1096).

32 ft (9.75 m) fishing boat E32 (fig 8)

Designed recently for longlining operations in Ceylon, this is a further example in the development chain from very small, open to fully decked, mechanized boats (FAO Report No. 2217). One boat to this design has been built in Uganda.

32 ft (9.75 m) shrimp trawler (fig 9 to 11)

The small shrimp trawler shown marked the end of a development started in 1956 on the Indian east coast. Only one boat was built to the original drawings. Subsequent 32 ft (9.75 m) models were constructed mainly in Kerala on the west coast where about 45 of these boats are fishing now (FAO Reports Nos 945, 1096, 1535). The original idea of developing a 32 ft (9.75 m) multi-purpose boat was dropped, but the boat presented here was the result.

32 ft (9.75 m) fishing boat (fig 12 and 13)

The success of the 32 ft (9.75 m) shrimp trawlers in Kerala created considerable interest in a boat of similar dimensions, but specifically suited for fishing methods other than trawling. New lines were drawn, giving the boat a more marked forefoot, essential for drifting. An aft engine installation was chosen to suit line and gillnet fishing. The boom in shrimping on the Indian west coast caused the original interest in this design to fade; on the east coast it was considered to be too costly for the line and gillnet fisheries.

36 ft (11 m) shrimp trawler (fig 14 to 16)

The development of the shrimp processing industry in Kerala in 1959 to 1960 created a demand for a larger shrimp trawler to supply the freezing and canning plants. Originally it was felt that a boat of about 40 ft (12.2 m) would be required (FAO Report No 1096). Later it was found that the 36 ft (11 m) design would meet the requirements of the industry and would allow a better utilization of the vessel on the nearby Cochin shrimping grounds. Some 15 to 20 boats of this type now operate along the Kerala and Mysore coast. The boat is as yet too expensive for the fisherman-owner. Processing firms, operating with a large profit margin because of the high world market price, find it possible to invest in these boats.

38 ft (11.6 m) trawler (fig 17)

In Ceylon an FAO naval architect proposed this design of a chine hull to investigate the possibility of reducing the excessively high building costs. It now appears that no wooden vessel of this type will be constructed. The

design is being reissued for steel construction in view of the increasing building capacity for steel vessels in Ceylon. The layout of the boat is similar to that of fig 15 with the exception of the fish hold, which will be arranged for carrying live bait for tuna fishing. The hold space will be sub-divided into tanks with pumping facilities for circulating sea water, and for storing of fish in chilled sea water.

42 ft (12.8 m) fishing boat (fig 18 and 19)

This originated as a vessel to be used for resources assessment off the coast of Orissa State in eastern India. The design should be well suited as a small trawler for commercial operations, for both stern or side trawling. Several boats of this type were built in Orissa during 1964 and 1965 but no records of their performance are yet available.

42.6 ft (13 m) handline fishing boat (fig 20 and 21)

This is an example of the introduction of a new boat into a fishery previously entirely conducted from canoes. No intermediate development steps were taken. To facilitate this large change a training course for boatbuilders was organized before the boat could be introduced. The drawings show the second, improved version of a handline fishing boat introduced in Senegal. It is noteworthy that boatbuilders could be trained from house carpenter stock in as short a period as about a year. Two boats were built during the first course, while two more 42.6 ft (13 m) boats and one 52.5 ft (16 m) purse seiner (fig 30 and 31) are under construction with the second and third group of trainees. It is estimated that henceforth some 10 to 15 boats will be built annually.

42.6 ft (13 m) trawler (fig 22)

The success of the handline fishing boat (fig 20 and 21) sparked considerable interest in small boat development in Senegal and the same lines were used for the construction of a prototype trawler. The boat will be primarily used for shrimp trawling and for training fishermen at the Dakar school of fisheries.

42.6 ft (13 m) seiner (fig 23)

One of the first design development projects undertaken by FAO concerned the survey of the then existing Turkish fishing fleet and the preparation of a number of designs of improved local type boats such as the 42.6 ft (13 m) seiner shown. It is conceived for construction to local building standards by established boatyards. It does not therefore depart substantially in shape and outward appearance from traditional types. The construction, however, is considerably altered and modernized.

39.5 ft (12 m) shrimp trawler (fig 24)

This constitutes a noteworthy example of the development of a modern, mechanized inshore fishing vessel in Taiwan. It is a combination of the traditional Taiwanese/Japanese boat and the modern USA west coast combination boat. The stern shape is a concession to the local builders who traditionally build flat cruiser sterns,

TABLE 2

Main particulars of boats presented in fig 1 to 33

Data item		NB-59 INDIA fig 1	25 ft INDIA fig 2/3	E 26 CEYLON fig 4/5	30 ft INDIA fig 6/7	E 32 CEYLON fig 8	32 ft MkIV INDIA fig 9/11	32 ft MkI INDIA fig 12/13	36 ft MkIII INDIA fig 14/16	38 ft CEYLON fig 17
Loa	ft	24	25	27.5	30	32.12	32	32	36	38.08
	m	7.32	7.63	8.39	9.12	9.8	9.76	9.76	10.97	11.63
Lwl	ft	20.37	23	24.75	28	31.33	28.17	29.25	33.25	35.1
	m	6.2	7.02	7.54	8.52	9.55	8.58	8.89	10.13	10.71
B max	ft	7.54	7.17	8.33	8.17	9.75	9.5	9.5	11.5	12
	m	2.3	2.18	2.54	2.48	2.97	2.9	2.9	3.5	3.66
Dwl	ft	6.08	7	7.5	7.58	8.5	9.38	9.38	10.83	11.79
	m	1.85	2.13	2.29	2.31	2.59	2.86	2.86	3.31	3.6
D	ft	3.25 abt.	3.55	4	4.08	4.58	4.17	4.13	5.35	5.38
	m	.99	1.08	1.22	1.24	1.43	1.27	1.26	1.64	1.64
d mean	ft	1.33	1.67	1.67	2	2.17	2.5	2.5	3.25	3.67
	m	.56	.51	.51	.61	.66	.76	.76	.99	1.12
d max aft	ft	1.83	2.5	2.25	2.83	3	3.5	3.25	4.42	5
	m	.56	.76	.69	.86	.92	1.07	.99	1.35	1.53
F min	ft	1.8 abt.	1.75	2.25	2.08	1.08	1.5	1.5	2	1.71
	m	.55	.53	.69	.63	.33	.46	.46	.61	.52
∇wl	cu ft	△ light	98	114	161	217	255	262	428	621
	cu m	abt. 1.3 tons	2.77	3.22	4.56	6.14	7.24	7.43	12.22	17.55
Fishhold capacity	cu ft	-	-	not specified	-	-	130	200	240	350
	cu m						3.7	5.7	6.8	9.9
Pb	hp	10 – 15	10 – 15	15 – 20	20 – 30	24	40	30	60 – 70	50 – 70
Engine make		Parsons	Petter Bukh Yanmar	Lister Petter	Petter Lister Bukh Yanmar	Lister	Petter Ruston Perkins	Ruston Kirloskar	Lister Ruston	Bukh
Fuel oil	Imp gal	10 abt.	10	not specified	not specified	not specified	117	100	220	265
	l	45	45				530	450	1000	1200
Fresh water	Imp gal	-	-	-	-	not specified	29	25	60	133
	l						130	115	270	600
Insulation		-	insulated fish box	part of hold space	-	-	expanded plastic foam	expanded plastic foam recommended	expanded plastic foam	not specified
Accommodation		-	-	-	-	-	-	-	2 – 3	4
Deck machinery		-	-	Vertical gurdy	Trawl winch vert. gurdy mech. drive	Vertical line-hauler	Trawl winch mech. drive	Vert. gurdy mech. drive	Trawl winch mech. drive	Trawl winch mech. drive
Purpose		Beach fishing (surf landing)	Gillnet Shrimp trawl	Gillnet	Trawl Gillnet	Longline Gillnet	Shrimp trawl	Gillnet	Shrimp trawl	Trawl

while the layout is modern and well suited to shrimp or bottom fish trawling in limited depths of water around the island of Taiwan. The design is by a Taiwanese naval architect on the staff of the Provincial Directorate of Fisheries in Taipei.

49 ft (15 m) trawler-drifter (fig 25 to 27)

The design was produced under the guidance of an FAO naval architect by a participant at a training centre directed by FAO for small boat design in India. At the time it filled the gap between traditional boat types and modern off-shore trawlers in the states of Gujarat and Maharastra on the Indian west coast, where an important continental shelf exists off the major distribution centres of Veraval and Bombay. The boat is of heavy construction suitable for locally grown timbers—and some hulls were built in 1961 to 1963 by a co-operative boatyard at Satpati. The cost of the vessels was too high (£8,600–$24,000) to make them suitable for independent skipper/owners, but those built are very successfully operated by the state directorates of fishery in Gujarat and Bombay and a fishermen's co-operative.

TABLE 2—continued

Data item		42 ft INDIA fig 18/19	13 m SENEGAL fig 20/21	13 m TURKEY fig 23	12 m TAIWAN fig 24	49 ft INDIA fig 25/27	16 m THAILAND fig 28/29	16 m SENEGAL fig 30/31	18 m TURKEY fig 32	66 ft HONG KONG fig 33
Loa	ft	42	42.6	43.2	44.33	49	52.32	52.33	60.55	66
	m	12.8	13	13.18	13.5	14.94	15.95	16	18.48	20.1
Lwl	ft	38.38	39.35	38.9	40.33	45	47.92	48.71	53	59.5
	m	11.7	12	11.87	12.3	13.72	14.61	14.85	16.16	18.15
B max	ft	13	12.47	12.6	12.75	13.5	13.05	15.42	18.37	20
	m	3.96	3.8	3.84	3.89	4.11	3.98	4.7	5.6	6.1
Bwl	ft	12.92	12.14	11.29	12.75	13.12	12.35	15.42	16.7	20
	m	3.94	3.7	3.44	3.89	4	3.77	4.7	5.08	6.1
D	ft	6.42	5.74	5.11	5.57	6.27	6.62	8.2	7.21	8
	m	1.96	1.75	1.56	1.7	1.92	2.05	2.5	2.2	2.44
d mean	ft	4	3.61	3.15	4.29	4.25	3.96	5.5	4.16	5.5
	m	1.22	1.1	.96	1.3	1.3	1.2	1.68	1.27	1.68
d max aft	ft	5	4.92	4.26	5.75	5.33	5.44	6.63	6.07	7
	m	1.52	1.5	1.3	1.76	1.63	1.66	2.02	1.85	2.13
F min	ft	2.25	1.97	1.87	1.46	1.75	2.65	2.38	2.1	2.5
	m	.68	.6	.57	.44	.53	.81	.75	.64	.76
∇wl	cu ft	780	670	654	1130 abt. 32	1050	1093	1395	1490	2700
	cu m	22.1	19	18.55		29.7	31	49.2	42.1	76.5
Fishhold capacity	cu ft	180	423	not specified	285 abt. 8	520	918	805	565 abt. 16	700
	cu m	5.1	12			14.7	26	22.8		19.8
Pb	hp	90	60 – 75	30 – 50	60	80 – 100	90	120 – 150	150 – 200	200
Engine make		Kelvin T3	Baudouin DK	Deuts	Yanmar Daiya	Lister Kelvin T3	Cummins	Baudouin DK	Deuts	Gardner
Fuel oil	Imp gal	340	310	132	660 abt. 3000	440	670	970	440 abt. 2000	2200 abt. 10000
	l	1530	1400	600		2000	3040	4400		
Fresh water	Imp gal	110	88	61	185	150	83.5	286	220 abt. 1000	440 abt. 2000
	l	500	400	275	850	680	380	1300		
Insulation		expanded plastic foam	expanded plastic foam	–	Deckhead Sides only	expanded plastic foam	Bulkheads expanded plastic foam	expanded plastic foam	–	expanded plastic foam
Accommodation		6	6	2	6	6	7	11	2 – 4	6
Deck machinery		Trawl winch vert. gurdy mech. drive	Winch or gurdy possible	Warping drums	Trawl winch mech. drive	Trawl winch vert. gurdy mech. drive	Trawl winch (combination)	Purse winch Power block hydr. drive	Trawl winch mech. drive	Trawl winch mech. drive
Purpose		Trawl Gillnet Research	Handline	Seining	Trawl	Trawl Gillnet	Trawl Purse seine	Purse seine	Trawl	Trawl

52.5 ft (16 m) stern trawler (fig 28 and 29)
Designed by an FAO naval architect on duty in Thailand in 1961, boats of this type should prove a valuable addition to the Thai inshore trawler fleet. While the scantlings are comparatively light, they are heavier than those of present built boats and that has prevented the design from being built.

52.5 ft (16 m) purse seiner (fig 30 and 31)
When the success of the first boatbuilding training course in Senegal became apparent, the Government Fisheries Service decided, in consultation with the FAO naval architect and boatbuilder, that the second course should build a larger boat suitable for the sardine fishery off the coast of Senegal. Limitations imposed by the capacity of the yard restricted the vessel to 52.5 ft (16 m) length overall. The prototype of this boat is now nearing completion and is scheduled to be commissioned early in 1967. It will serve as demonstration and training vessel under an FAO master fisherman. The boat is designed to operate a sardine purse seine with an hydraulic purse winch and a power block. The catch will be stored in four insulated tanks in chilled sea water.

59 ft (18 m) trawler (fig 32)

Similar to the boat shown in fig 23, this design was prepared by an FAO naval architect in Turkey in 1957 with the same objectives in view as for the 42.6 ft (13 m) seiner.

66 ft (20 m) trawler (fig 33)

This represents the final link in a long development chain in Hong Kong. It is hoped that this boat will finally convince the Hong Kong fishermen of the advantages of modern designs over the traditional 'junk'. It is a single boat otter trawler and should play a major role in changing the trawl fishery from an inshore to an offshore one, to supply more and higher quality fish to the insatiable Hong Kong market. The design was prepared by a Chinese naval architect on the staff of the Hong Kong Department of Fisheries. The first boat to this design is now under construction for a private fisherman aided by a Government subsidy scheme; therefore, no trial results are available.

PERFORMANCE

Current work undertaken by Doust and Traung (page 123 and 139) in utilizing computer techniques for the prediction of ship resistance for smaller vessels made it possible to investigate the applicability of these techniques to performance prediction for some of the boats shown in fig 1 to 33. Table 3 gives the parameters for these boats.

It was found that the regression equation now available for this work could only be applied with accuracy for three of the selected boats (fig 18, 20 and 25). The parameters of the others were outside the range of the initial parameter data, and the results of an investigation outside this range might well be incorrect. Fig 34 shows the three EHP predictions obtained from the computer and a comparison with model test results and full scale

trial results for the 49 ft (15 m) trawler/drifter (fig 25) and the 42.6 ft (13 m) handline fishing boat (fig 20) respectively. No comparison material is available as yet for the 42 ft (12.8 m) fishing boat (fig 18).

49 ft (15 m) trawler/drifter

The original Kharagpur model test results were corrected at NPL to make them comparable to the values obtained from the computer programme. This involved re-calculating the model test results to the same basis of infinite water and to allow for the effect of blockage due to the use of very small models. The agreement between computed and measured results is good, and in line with general experience when using these techniques.

42.6 ft (13 m) handline fishing boat

In the lower speed ranges the computed EHP bears little relation to the EHP obtained from full scale trials. From about $V/\sqrt{L}=1.175$ upwards the trend of the curves is similar. The trial EHP values are based on an assumed efficiency of 50 per cent and are furthermore subject to error due to the difficulty of correctly evaluating BHP at different engine rpm. It has been found from other efforts to determine BHP from fuel consumption measurements that this gave too high values at low engine loading, and it is felt that full scale trial results would only be reliable and comparable to computed EHP if based on torsion meter readings. The correlation is further complicated by the fact that the trial EHP applies to $L/V^{\frac{1}{3}} = 4.97$ while the computed EHP applies to 4.45.

The main conclusions that can be drawn from the comparison are:

● An extensive programme of model testing is required to extend to very small boats the range of applicability of the regression equation used

TABLE 3

Design parameters for computer analysis

	L	$\triangle$	$\dfrac{L}{\nabla^{1/3}}$	$\dfrac{L}{B}$	$\dfrac{B}{T}$	Cm	Cp	LCB	$\tfrac{1}{2}\propto_e^{\,\circ}$	$\tfrac{1}{2}\propto_r^{\,\circ}$	$\propto^{\circ}$BS	Trim
32 ft CEYLON fig 8	28.90	3.60	5.89	3.73	4.70	.534	.639	−2.09	22	54	9	0.026
32 ft INDIA fig 9	28.167	7.23	4.45	3.00	3.75	.675	.569	−3.59	22	51	14.5	0.036
36 ft INDIA fig 14	33.25	11.9	4.45	3.07	3.30	.606	.581	−1.65	25.5	52	15	0.040
42 ft INDIA fig 18	38.38	23.1	4.08	2.97	3.23	.677	.602	−1.75	29	57	18	0.039
13 m SENEGAL fig 20	39.37	19.65	4.45	3.20	3.24	.670	.552	−1.50	26	40	16	0.043
49 ft INDIA fig 25	45.00	30.1	4.43	3.41	3.10	.700	.595	−1.19	25	55	17	0.038
16 m THAILAND fig 28	47.93	31.2	4.65	3.88	3.14	.790	.578	−3.17	20	53	12	0.042
16 m SENEGAL fig 30	46.26	38.15	4.2	3.03	3.26	.694	.580	−2.61	24	57	16	0.069
66 ft HONG KONG fig 33	59.5	77.2	4.28	2.98	3.64	.732	.563	+0.24	22	47	15	0.037

LINES

3.77 ft (1.149 m)

Sheer

Chine

24.0 ft (7.315 m)

Sheer

Chine

Feet
Scale Metres
1   2   3   4   5
0.5   1.0   1.5

LAYOUT

WT compartment

Fuel

Engine under

WT compartment

Feet
Scale Metres
1 2 3 4 5 6 7 8
0.5   15   2   2.5
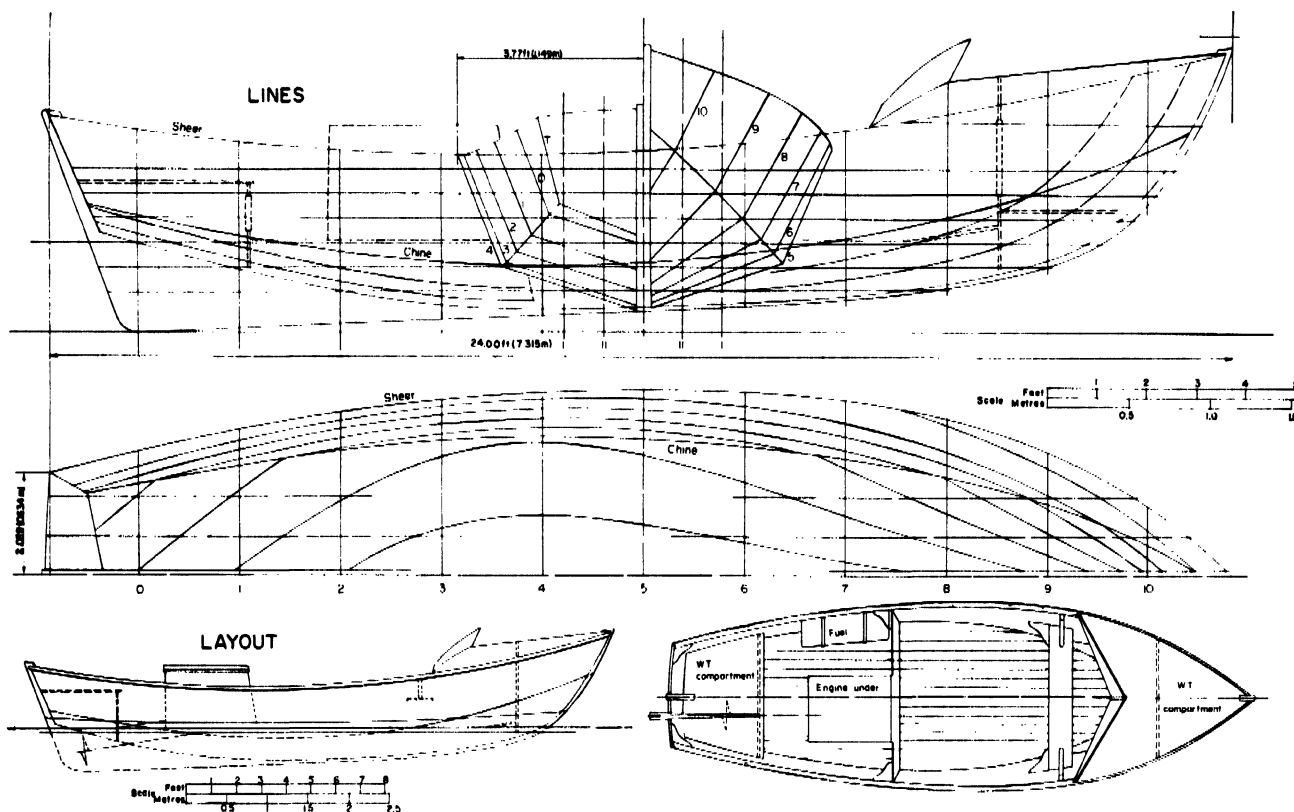
Fig 1. 24 ft (7.3 m) beach/surf boat

Loa 25.0 ft (7.62 m)

3 ft 7 in (1.09 m)

Transom

WL

Load flowline

Buttock II

Rabbet

Baseline

Lwl 23 ft (7.0 m)

Feet
Scale Metres
1   2   3   4
0.5   1.0   1.5

Sheer
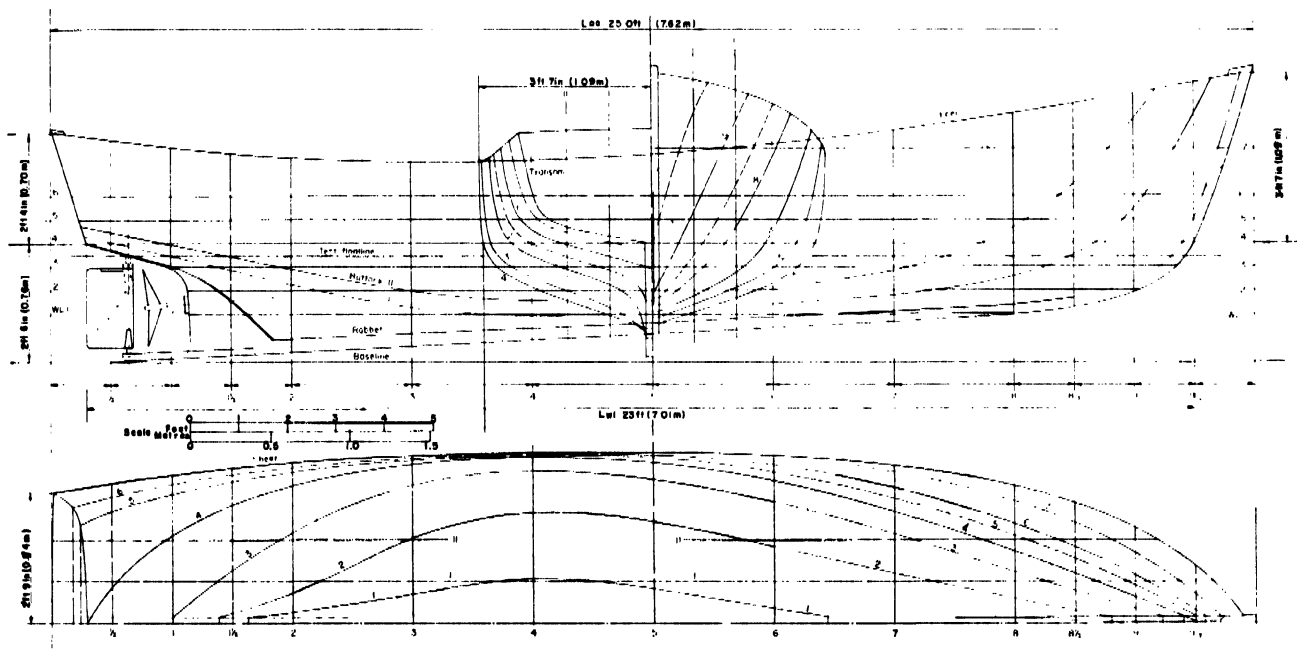
Fig 2. 25 ft (7.6 m) open fishing boat
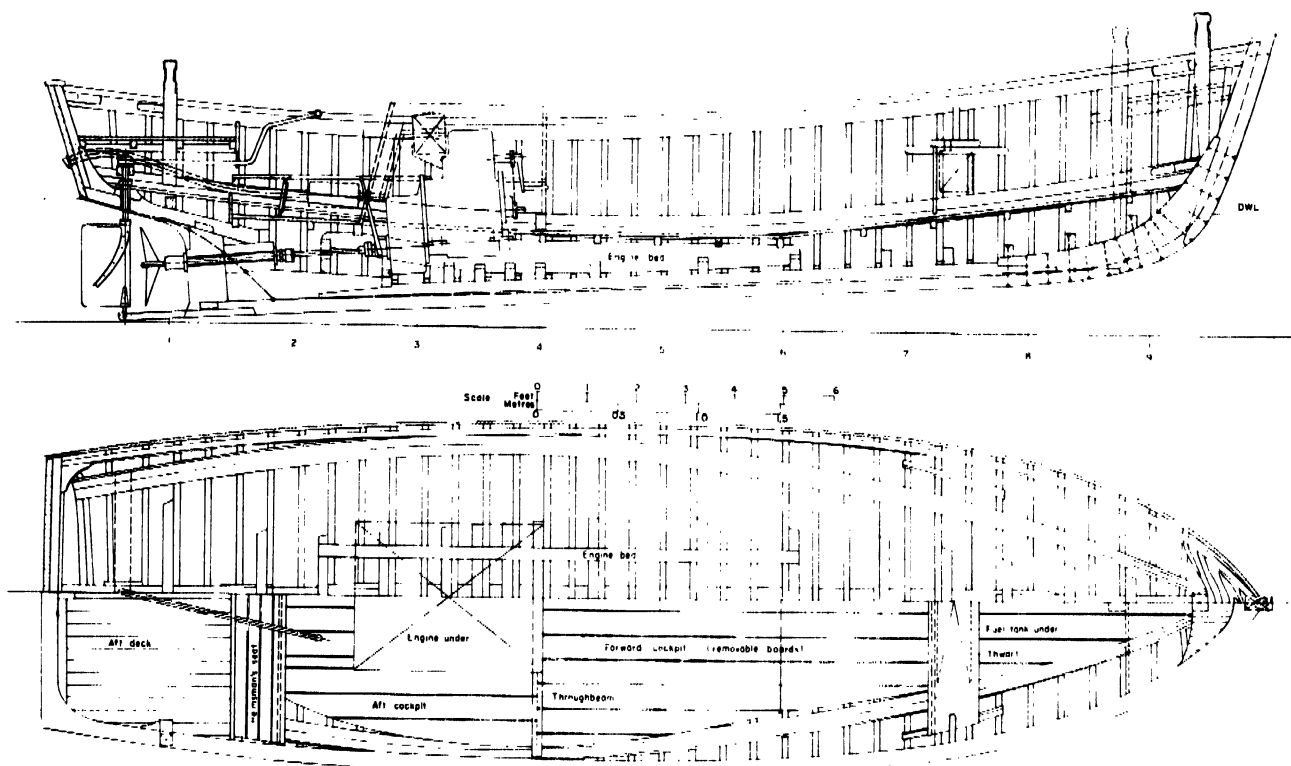
Fig 3. 25 ft (7.6 m) open fishing boat
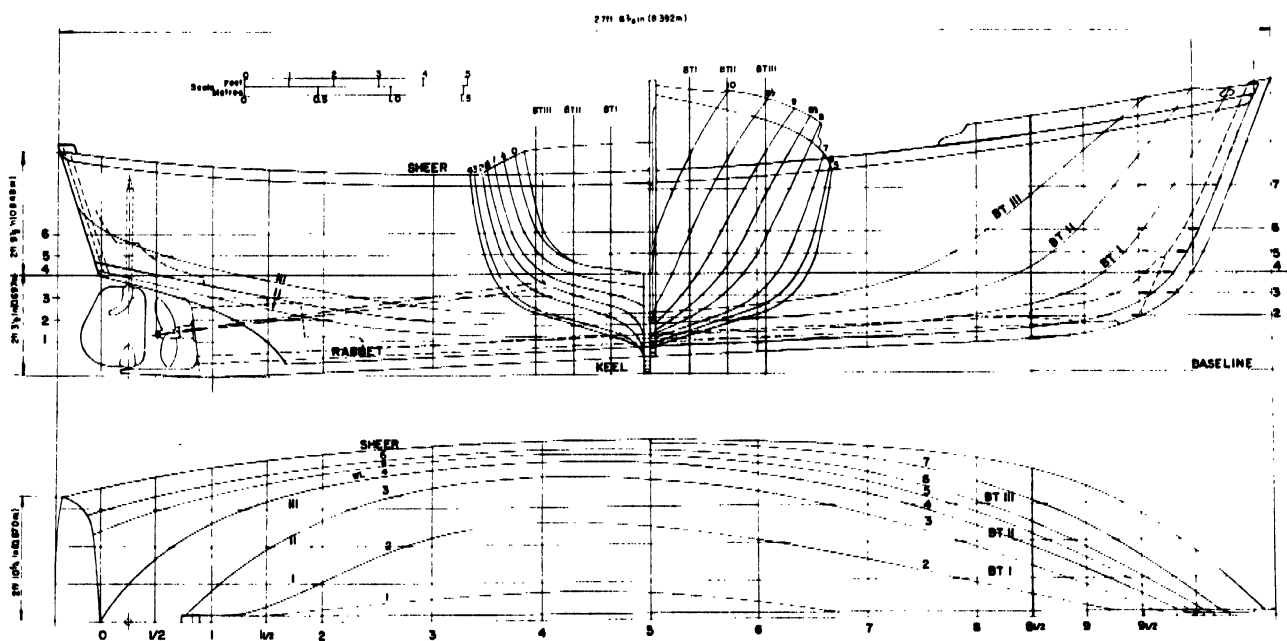
Fig 4. 27 ft (8 m) fishing boat E 26
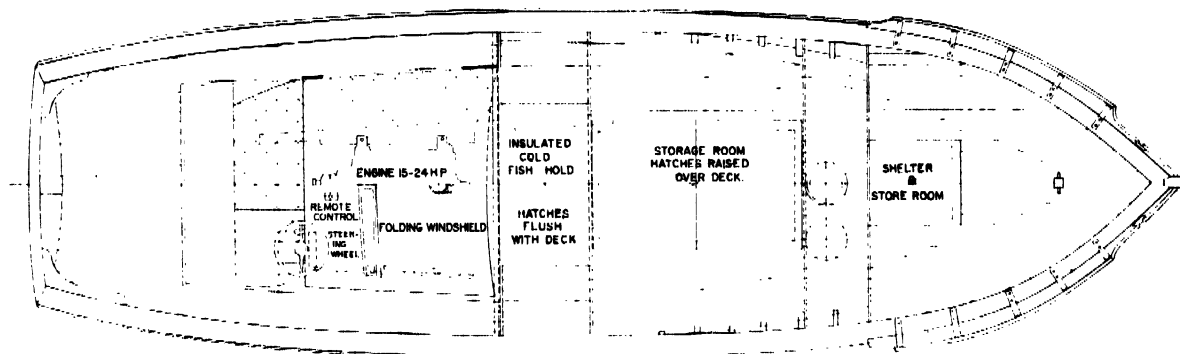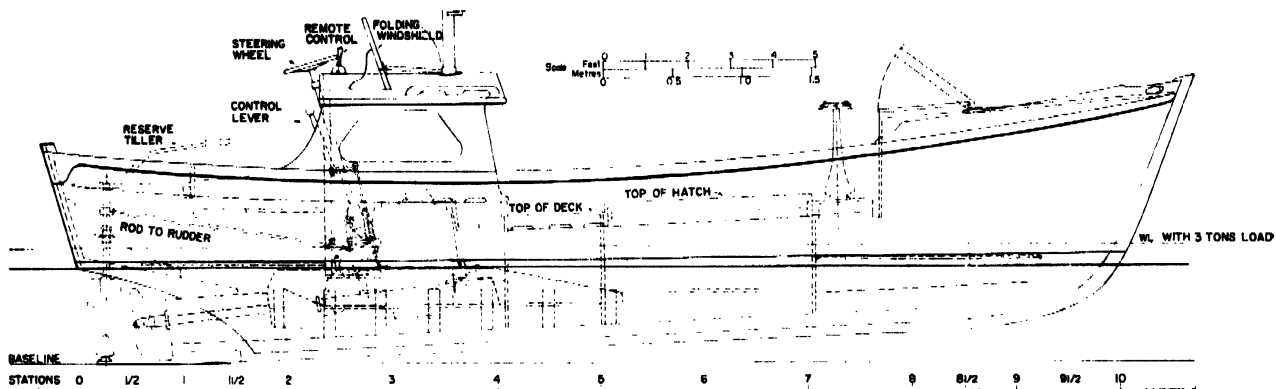
Fig 5. 27 ft (8 m) fishing boat E 26
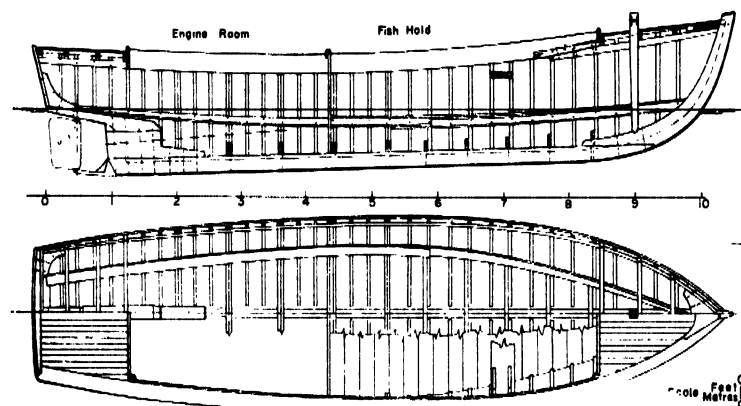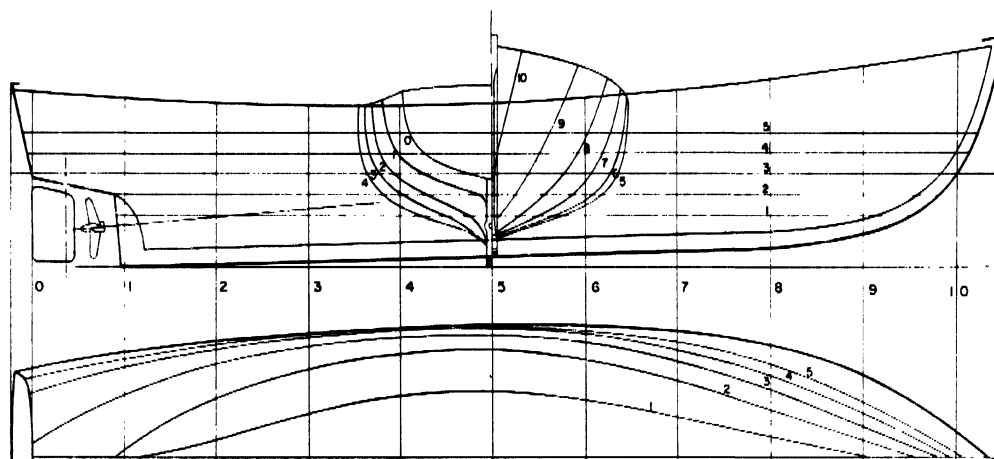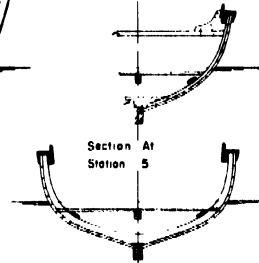
Fig 6. 30 ft (9.14 m) Madras fishing boat
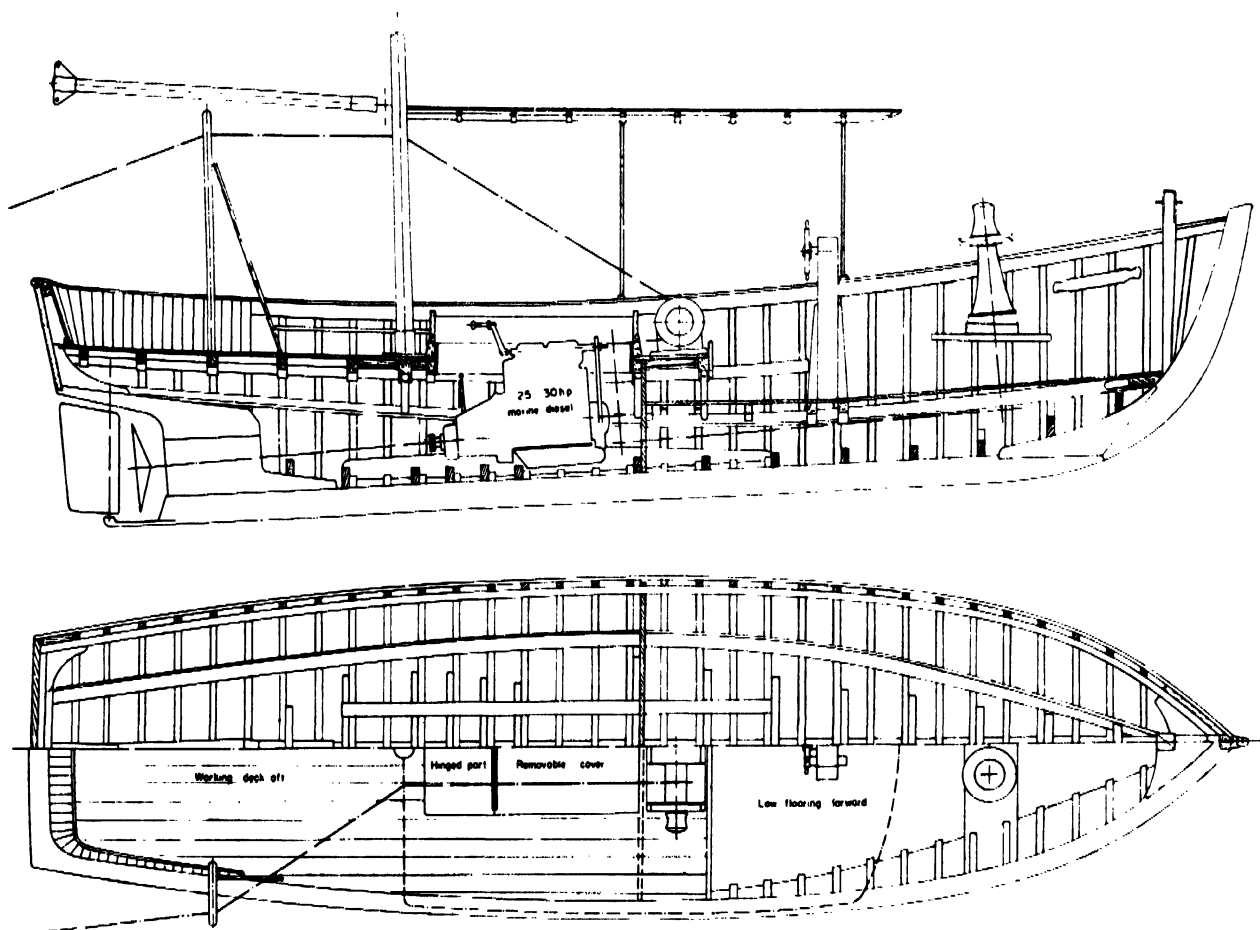
Fig 7. 30 ft (9.14 m) fishing boat. Layout as trawler/gillnetter

25 30hp
marine diesel

Working deck aft

Hinged part   Removable cover

Low flooring forward

Fig 8. 32 ft (9.75 m) fishing boat E 32

Fig 9. 32 ft (9.75 m) trawler Mk IV

Scale
Feet
Meters

0   2   4   6   8
0   0.5   1.0   1.5   2.0   2.5

Steering

Fishhold

Engine room

Shaft tunnel

Fig 10. 32 ft (9.75 m) trawler Mk IV

Fig 11. 32 ft (9.75 m) trawler Mk IV

Fig 12. 32 ft (9.75 m) fishing boat Mk I

Scale Feet
Metres

0		2		4		6		8		10
0		0.5	1.0		1.5	2.0		2.5		3.0

PROFILE

0   1   2   3   4   5   6   7   8   9   10

DECK

Batteries
Fuel. oil
Fish hold
Engine room
f w
Store
Chains
Steering
Hot air.
Service tank
Transmission
Fuel

UNDER DECK

Fig 13. 32 ft (9.75 m) fishing boat Mk I

Fig 14. 36 ft (11 m) shrimp trawler Mk III

Fig 15(a). 36 ft (11 m) shrimp trawler Mk III

14ft 6in (4.42m)   3ft 6in (1.07m)

15ft 6in (4.72m)

4ft (1.22m)

4ft (1.22m)

[453]

Scale
Feet
Metres

0   1   2   4   6   8   10

0   0.5   1.0   1.5   2.0   2.5   3.0

0   1   2   3   4   5   6   7   8   9   10

| Steering, fuel tanks | Fish hold | Engine room | Cabin, chains |
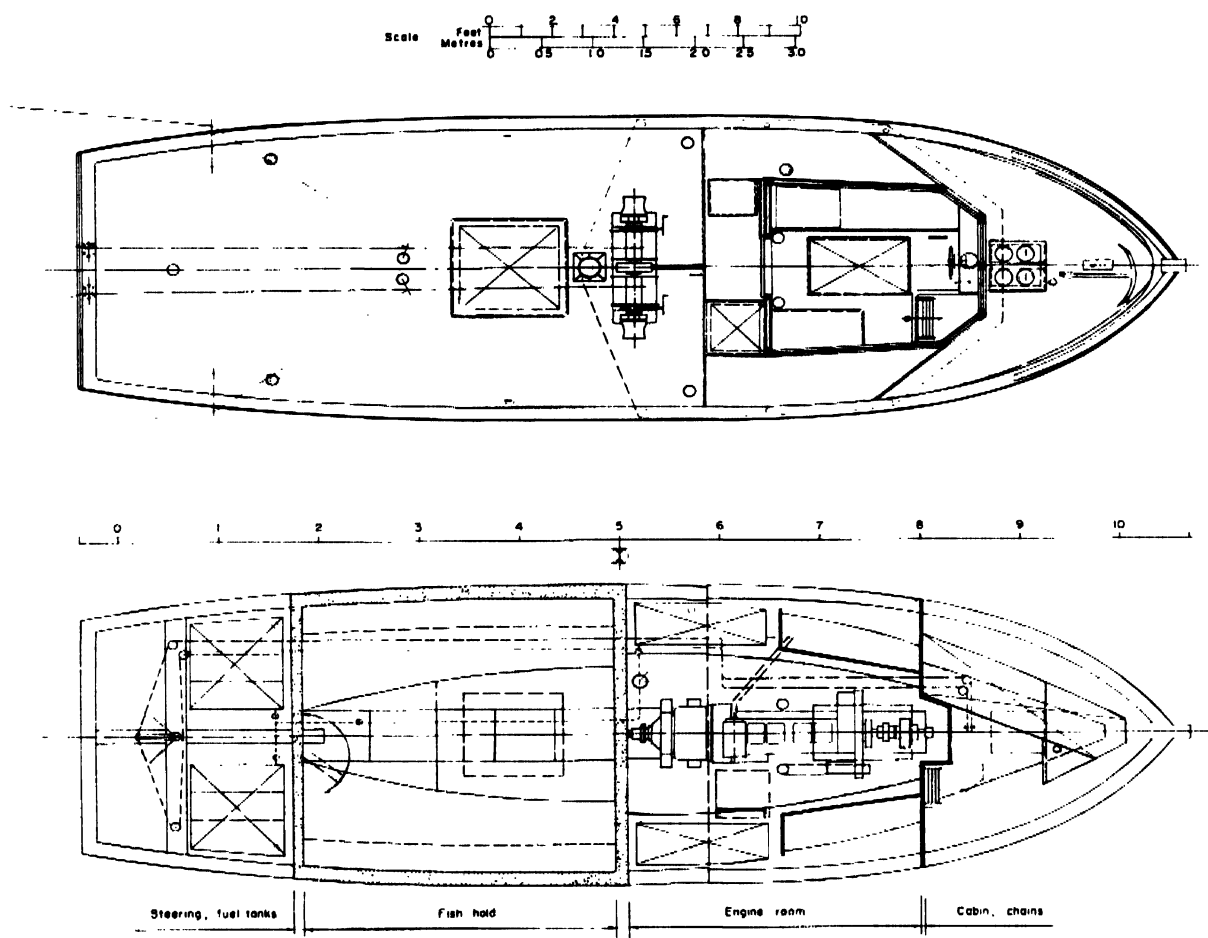
Fig 15(b). Plan arrangement of 36 ft (11 m) shrimp trawler Mk III. Scale also applies to fig 15(a)

[454]

Fig 16. 36 ft (11 m) shrimp trawler Mk III

[455]

Fig 17. 38 ft (11.6 m) trawler—Ceylon

Fig 18. 42 ft (13 m) fishing vessel

456]

R/T aerial

1½ tons lifting tackle
(1525 kg)

Winch

Gurdy

Profile

Hinged platform

m winch

Bottle rack

R/T

Echo

Desk

Hatch

Hatch

Berth

Galley

Raised deck

Deck layout

Scale Feet
Metres

0 2 4 6 8 10 12

0   1.0   2.0   3.0   4.0

Under deck

66gal

106gal

(200 l)

(300 l)

(530 l)

4·4 gal

Store

Insulated hold

4 Men

Locker

Store

Main engine

Steering

Locker

Chains

Fig 19. 42 ft (13 m) fishing vessel

[457]

Fig 20. 42 ft (13 m) handline boat—Senegal Mk II/III
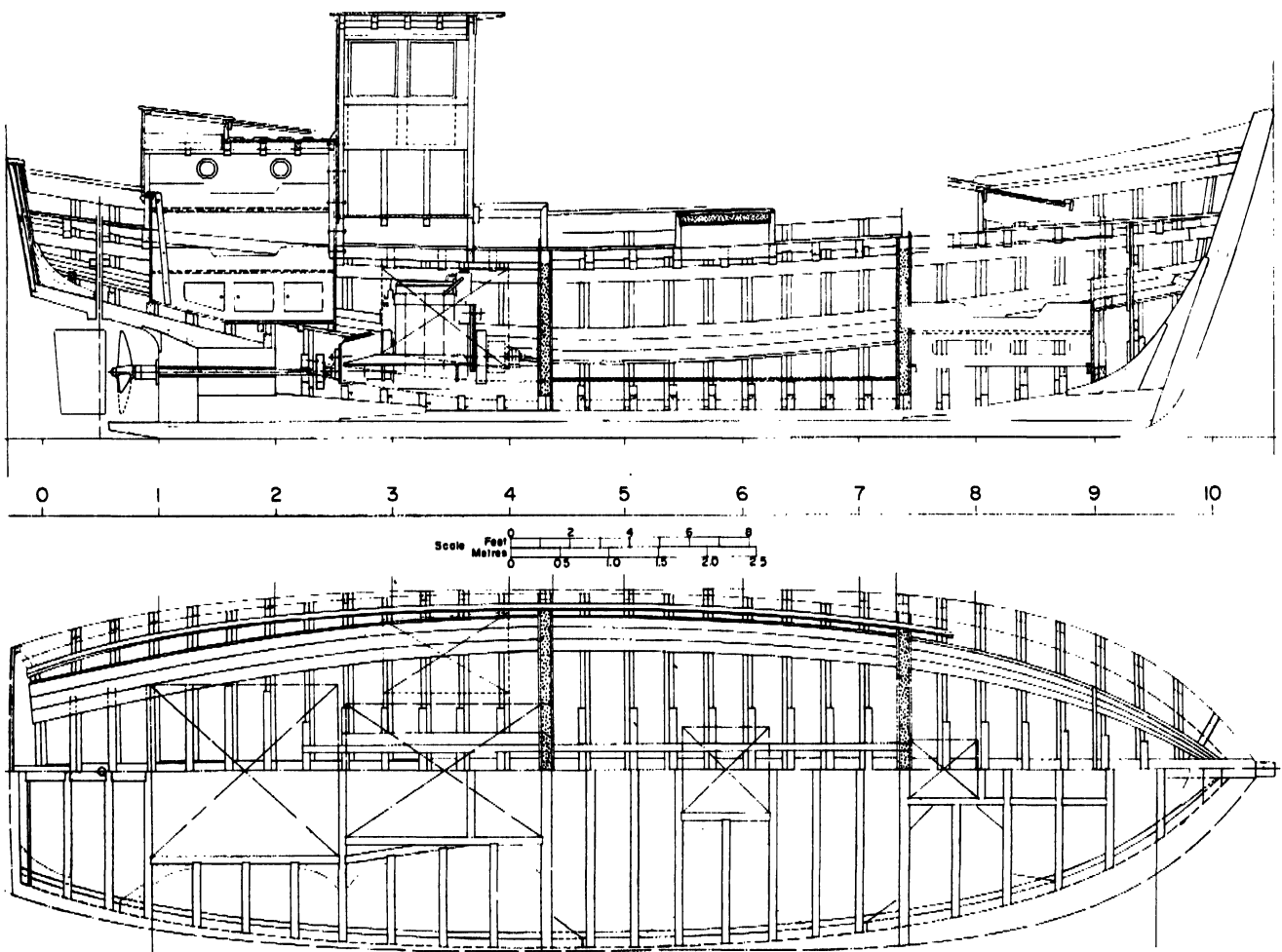
Fig 21. 42 ft (13 m) handline boat—Senegal Mk III

[458]
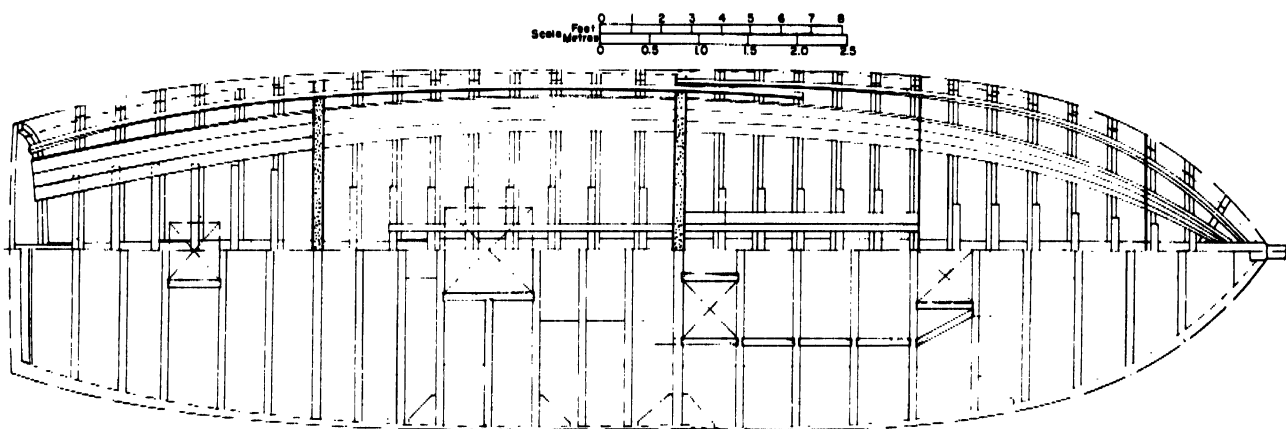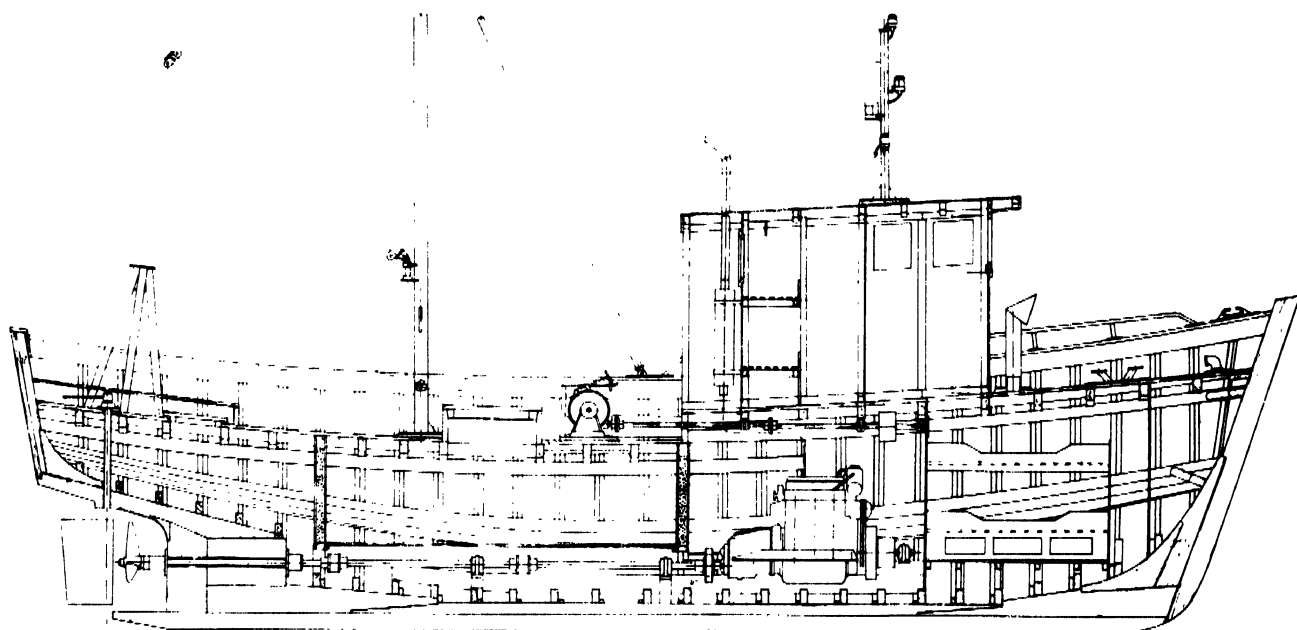
Fig 22. 42 ft (13 m) trawler—Senegal Mk II/III

[459]
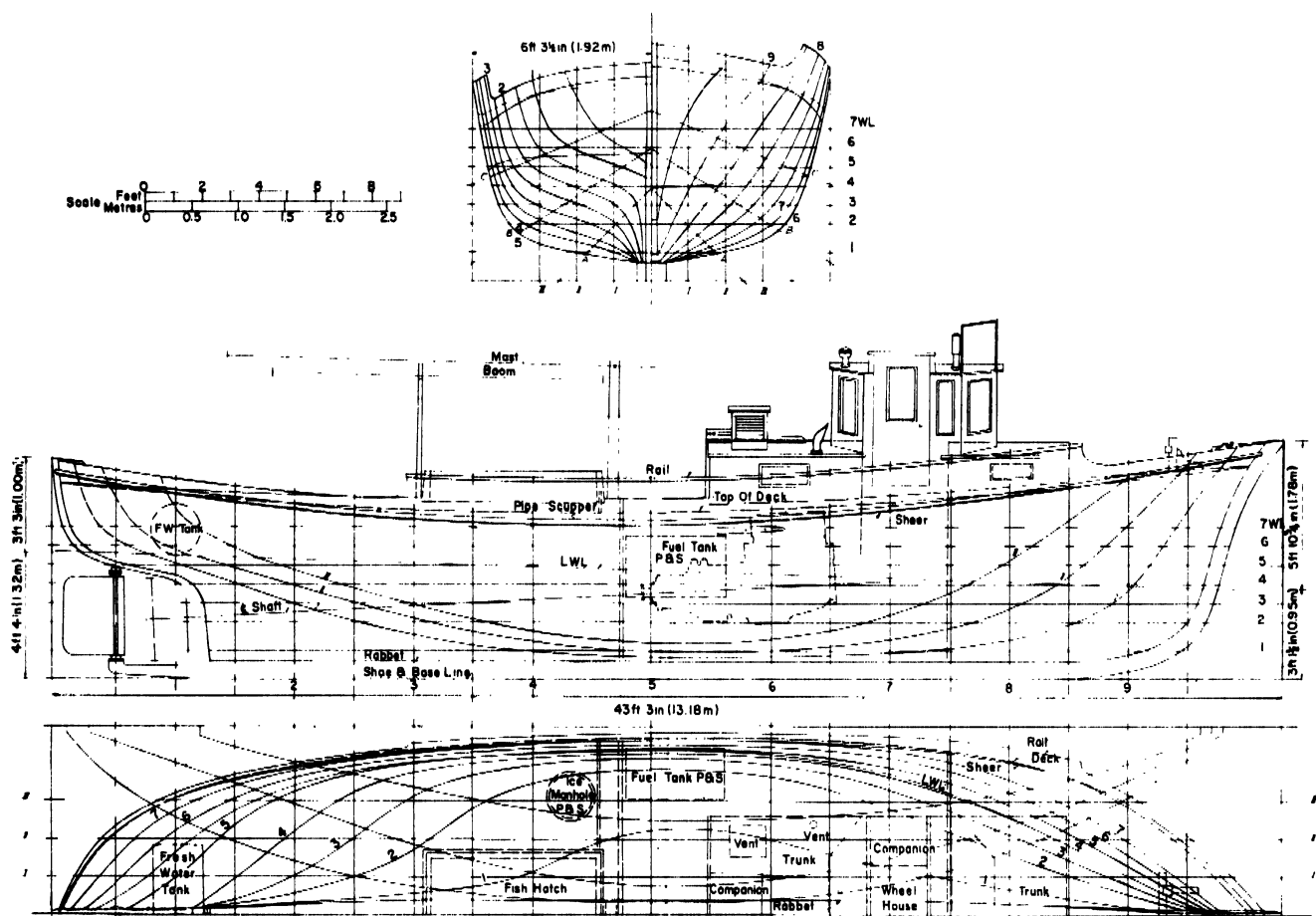
Fig 23. 42 ft (13 m.) seiner—Turkey
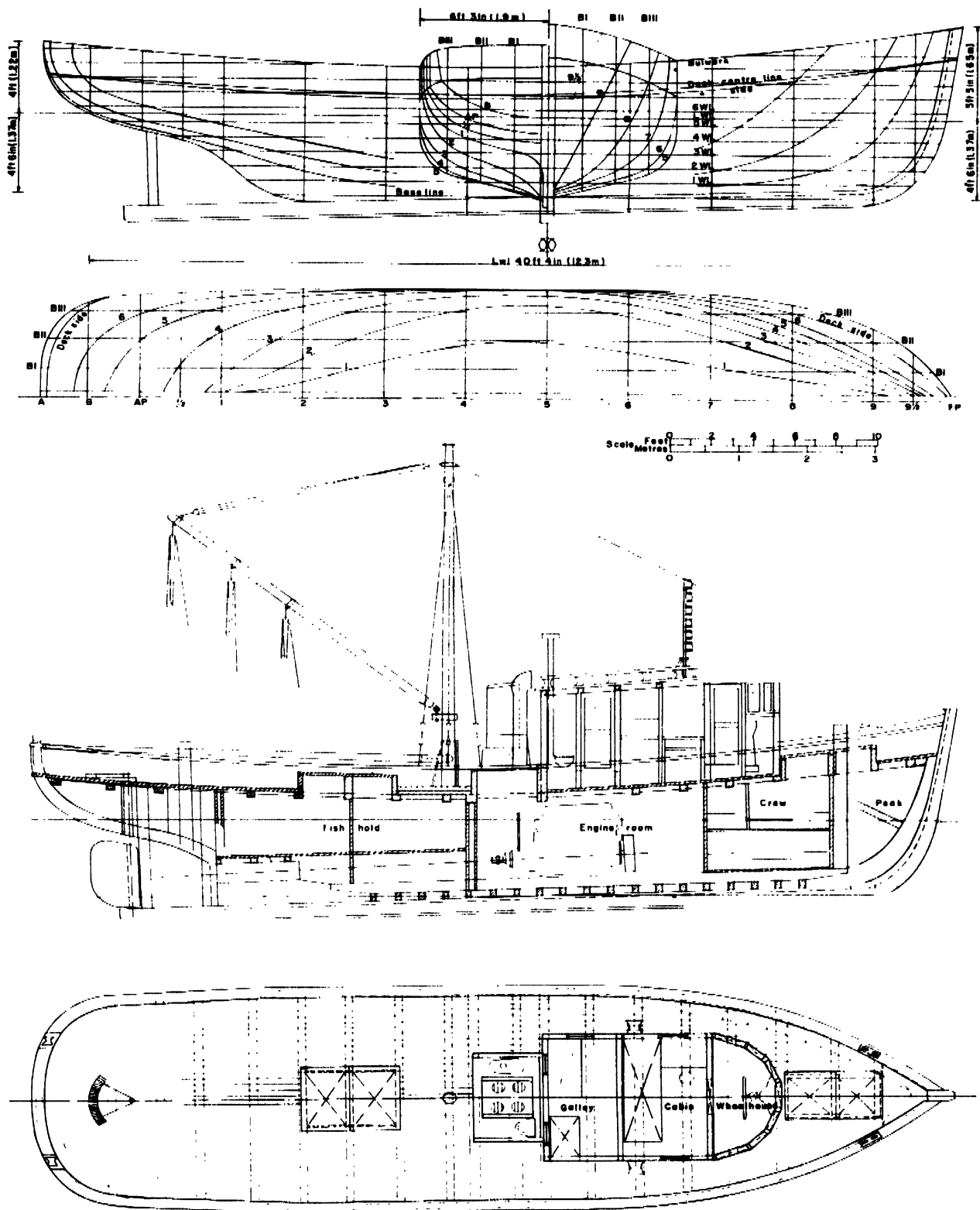
Fig 24. 40 ft (12 m) trawler—Taiwan
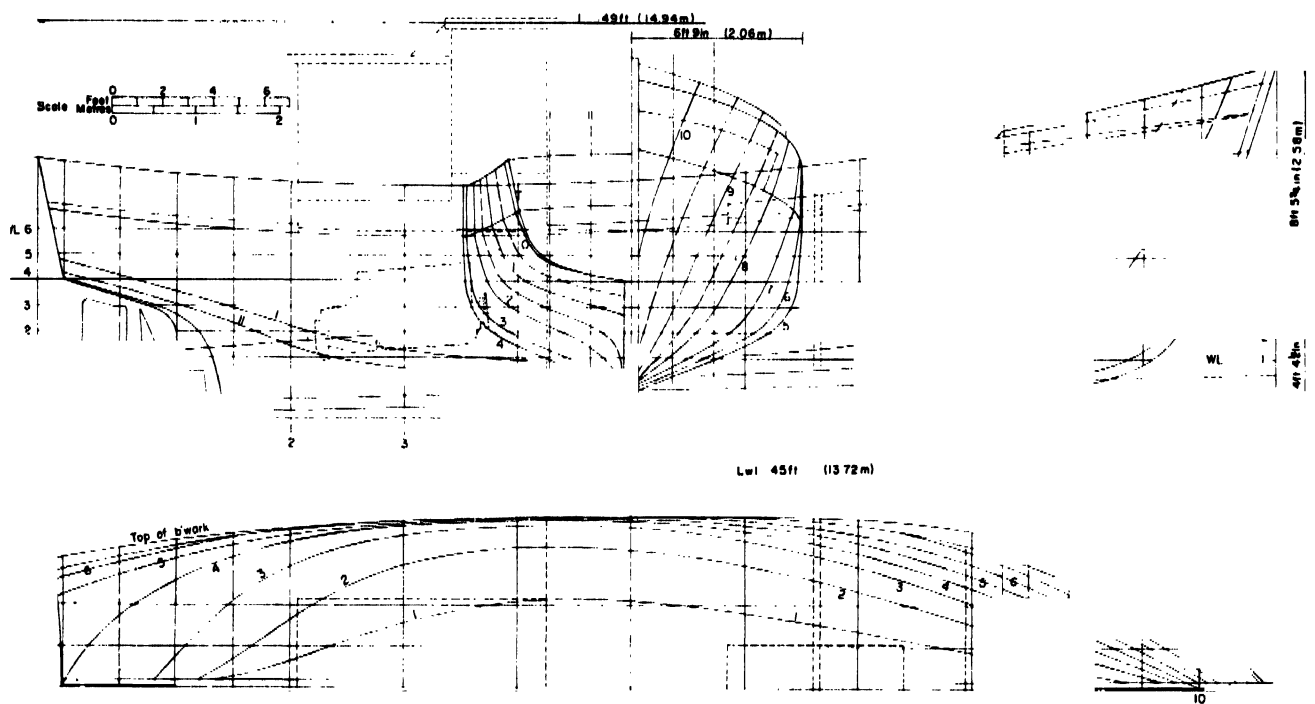
Fig 25. 49 ft (15 m) drifter-trawler

Profile

0	1	2	3	4	5	6	7	8	9	10
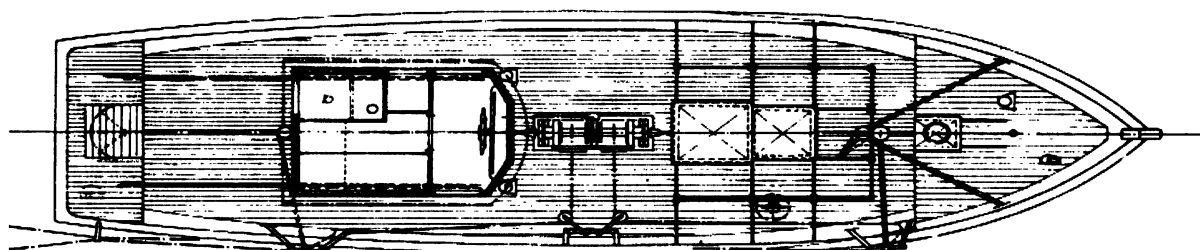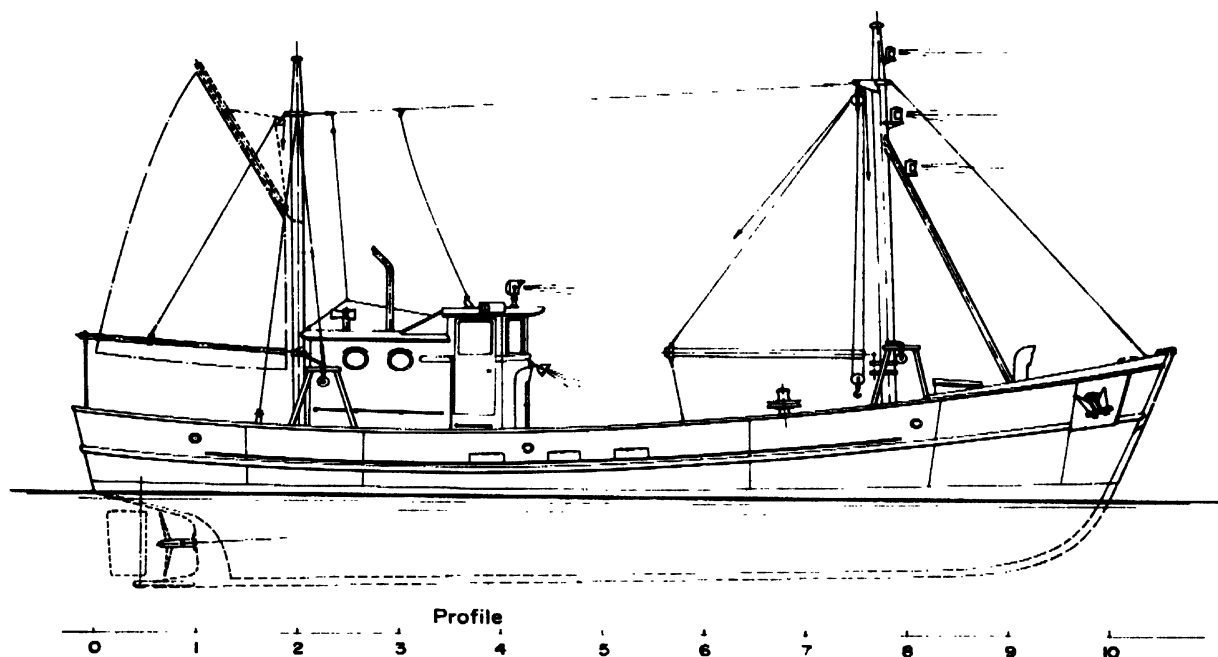
Originally proposed layout

Feet 0 2 4 6 8 10 12
Scale Metres 0 1 2 3 4
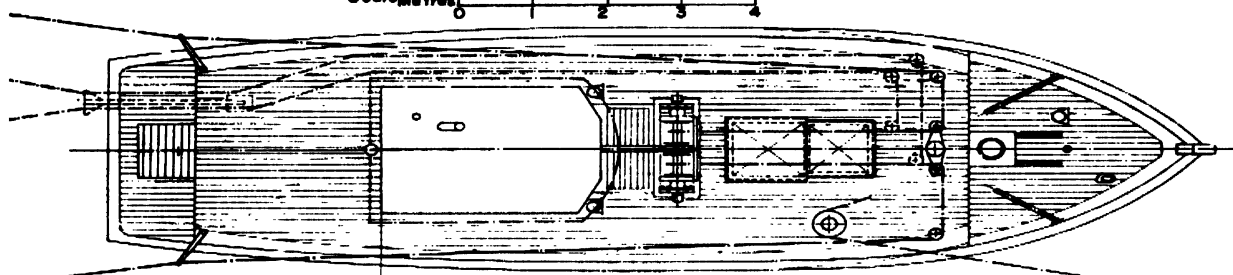
Deckhouse 1 beam space for'd.   Layout proposed by CIFT Gear Branch

Insulated hold abt. 350 ft³   Store 170 ft³
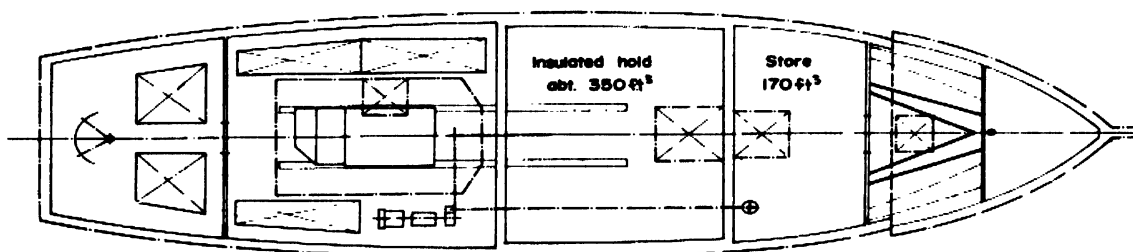
Under deck

Fig 26. 49 ft (15 m) drifter-trawler
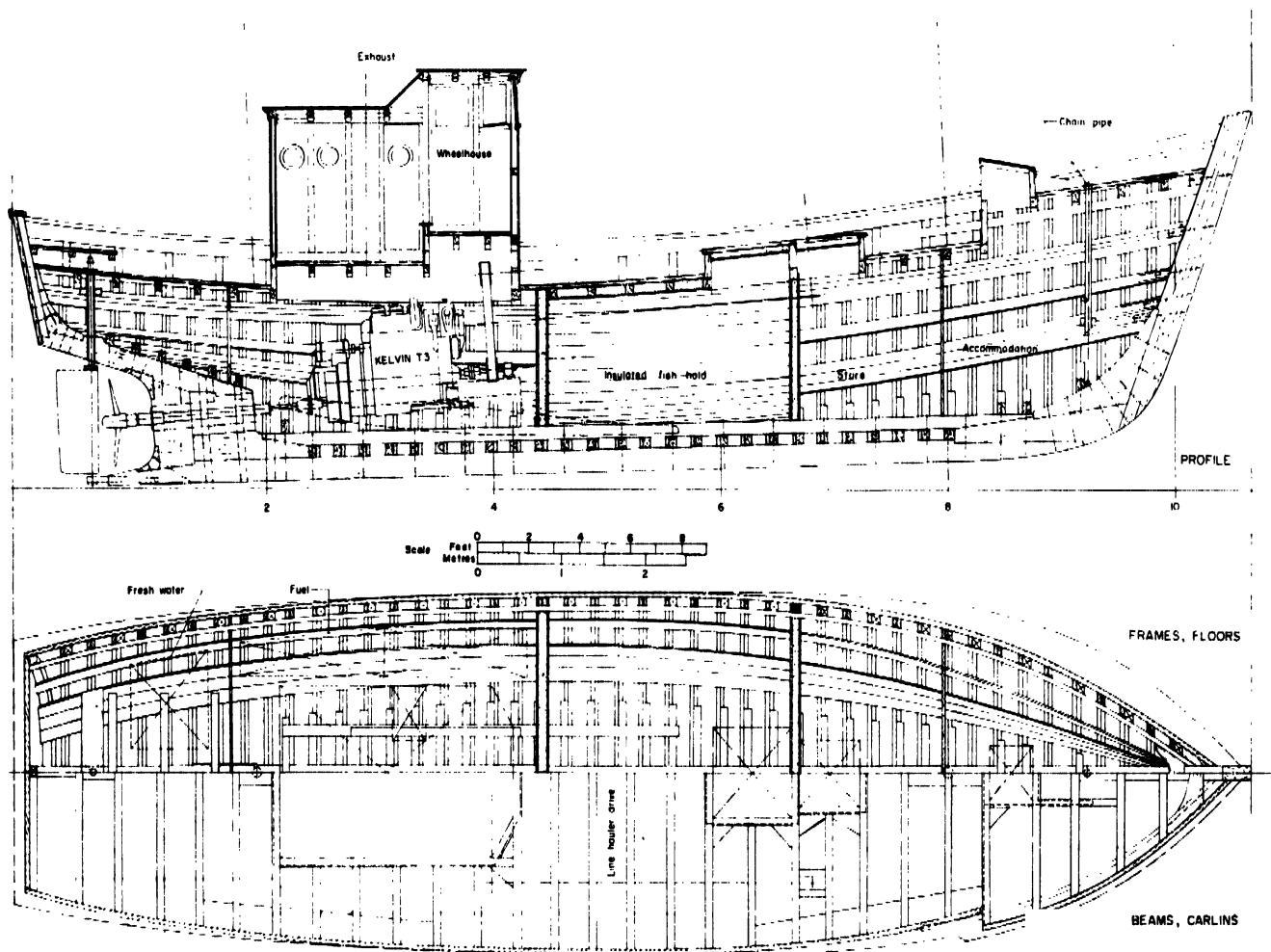
Fig 27. 49 ft (15 m) drifter-trawler

[464]
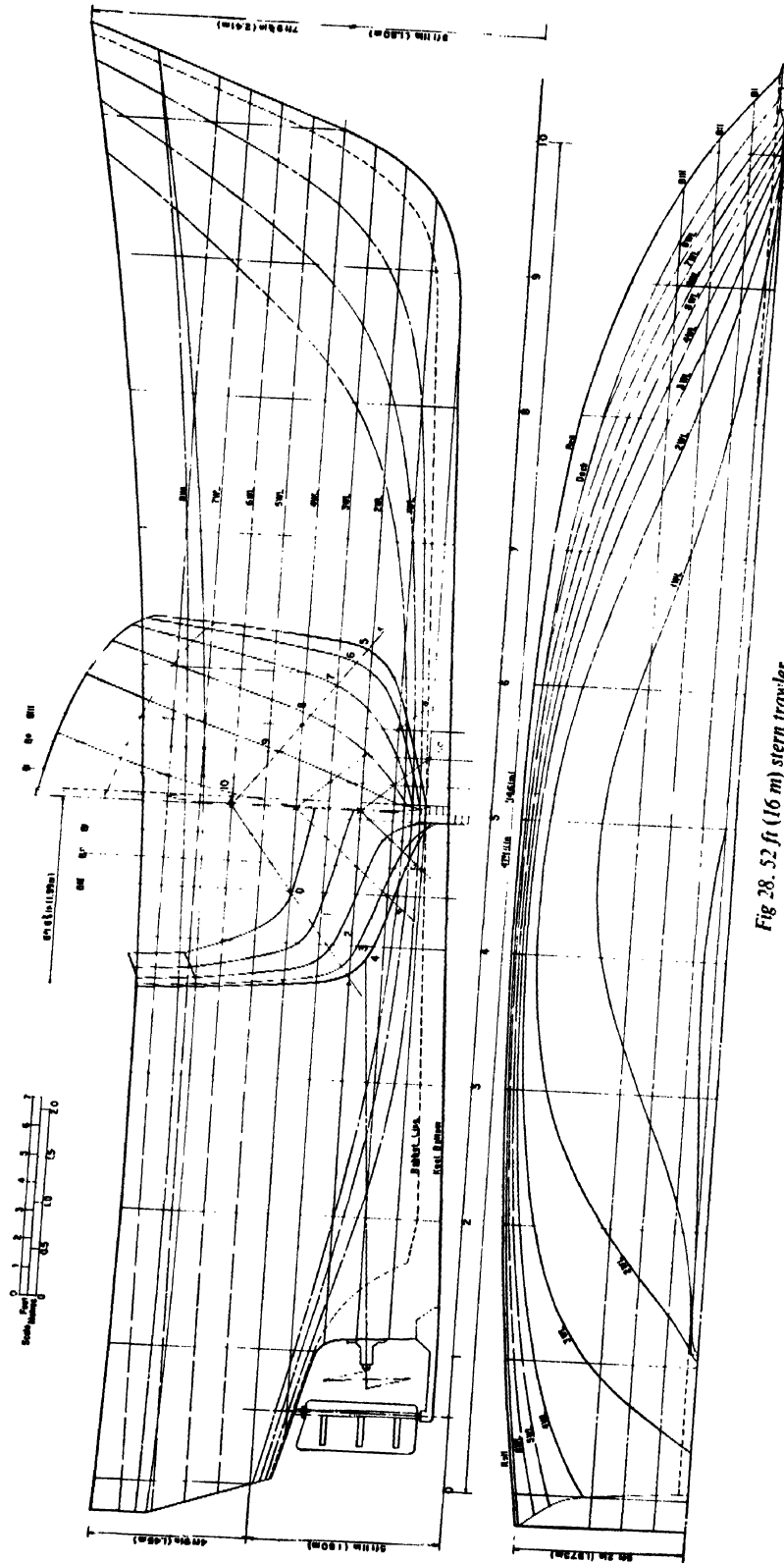
Fig 28. 52 ft (16 m) stern trawler

Fig 29 (top diagram labels)

Cooking Cabinet

Fish Hold Hatch

Trawl Winch

Upper & Lower Berth P & S

Wheel

Vent

Main Cabin

Exhaust

Lkr

House

Hatch

Ring For Cod End Tackle on Starboard Stay

Portable Guide Blocks

Engine Room Entrance

Hatch

Fig 29. 52 ft (16 m) stern trawler

Scale feet metres

7ft(8½in (2 35m)

8ft 3in (2 50m)

2ft 5½in (80 m)

Base

52ft 6in (16 00 m)

0   ½   1   1½   2   3   4   5   6   7   8   8½   9   9½   10

6ft 7in (2 00 m)
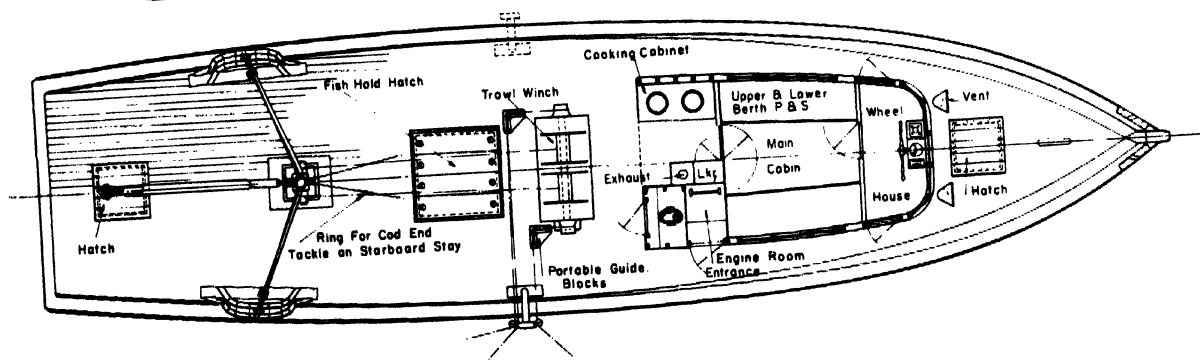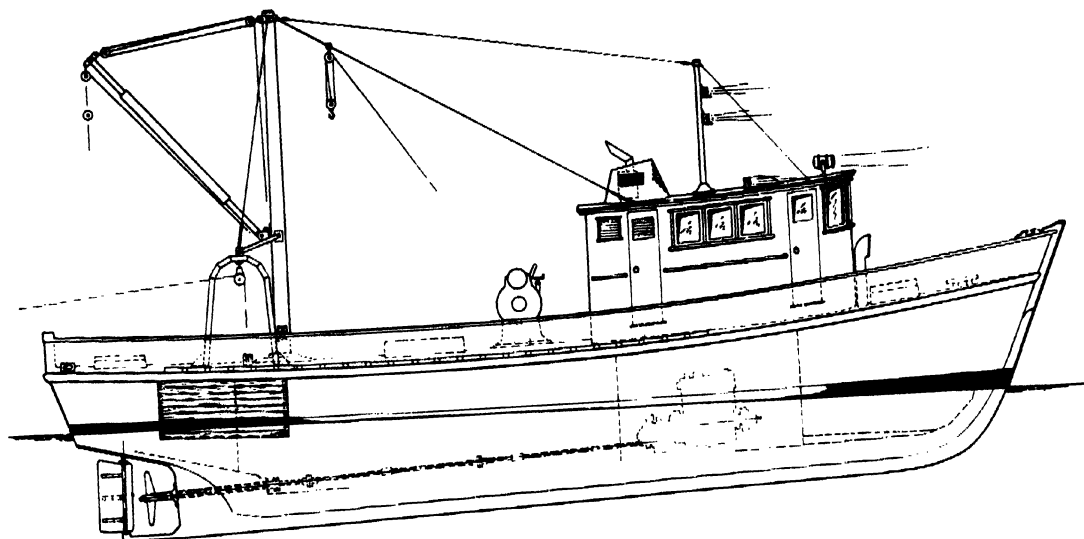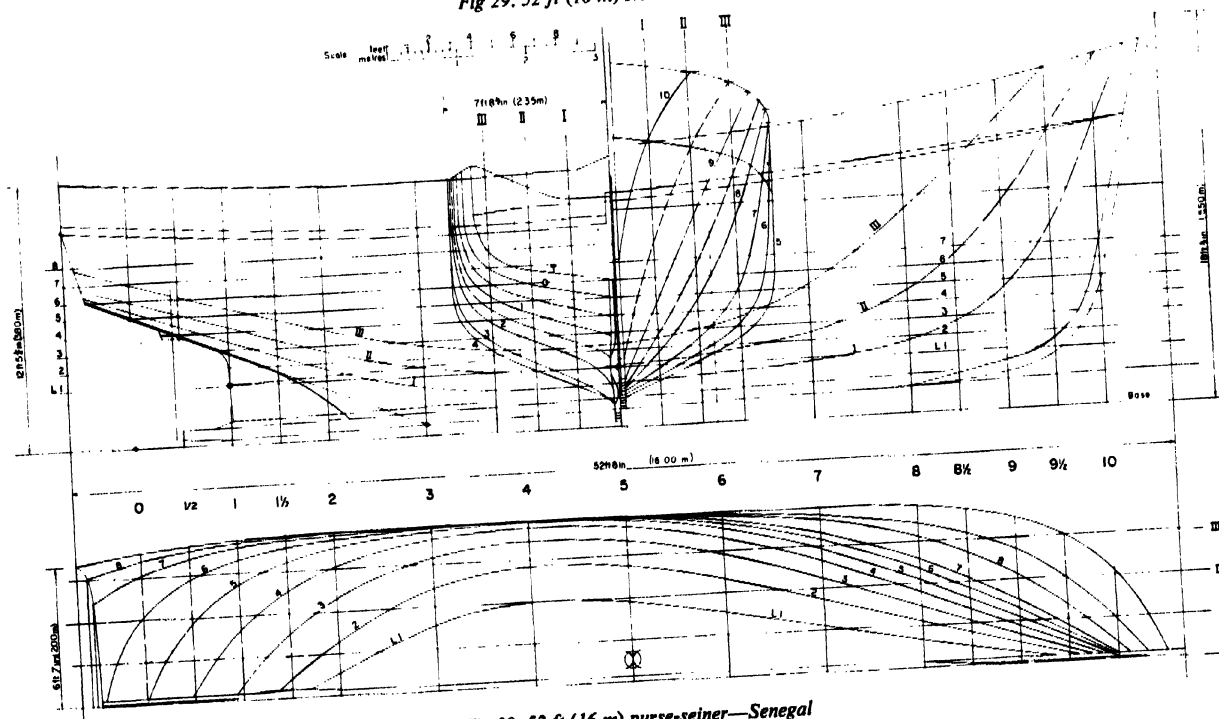
Fig 30. 52 ft (16 m) purse-seiner—Senegal

[466]

Fig 31. 52 ft (16 m) purse-seiner

Fig 32. 59 ft (18 m) trawler—Turkey
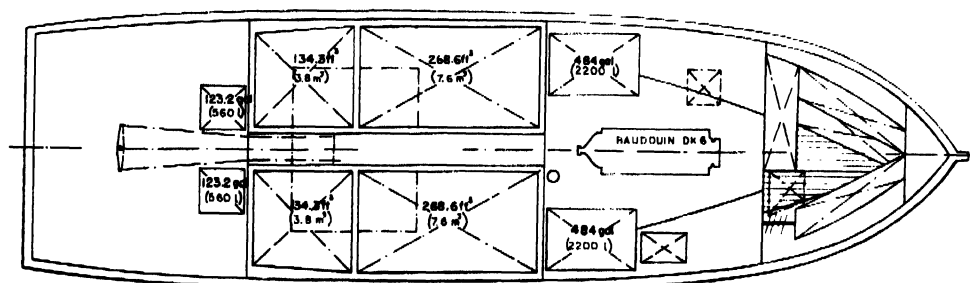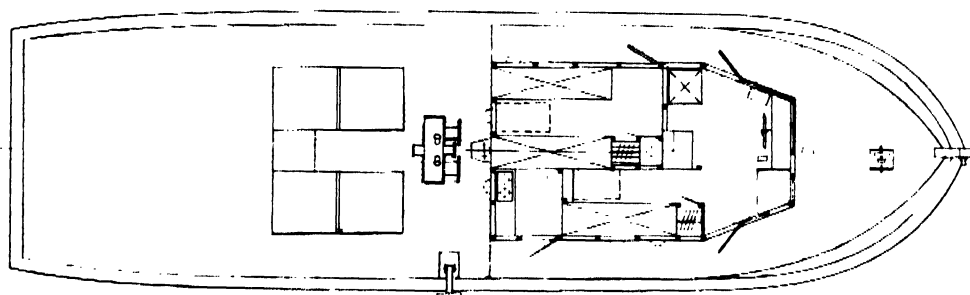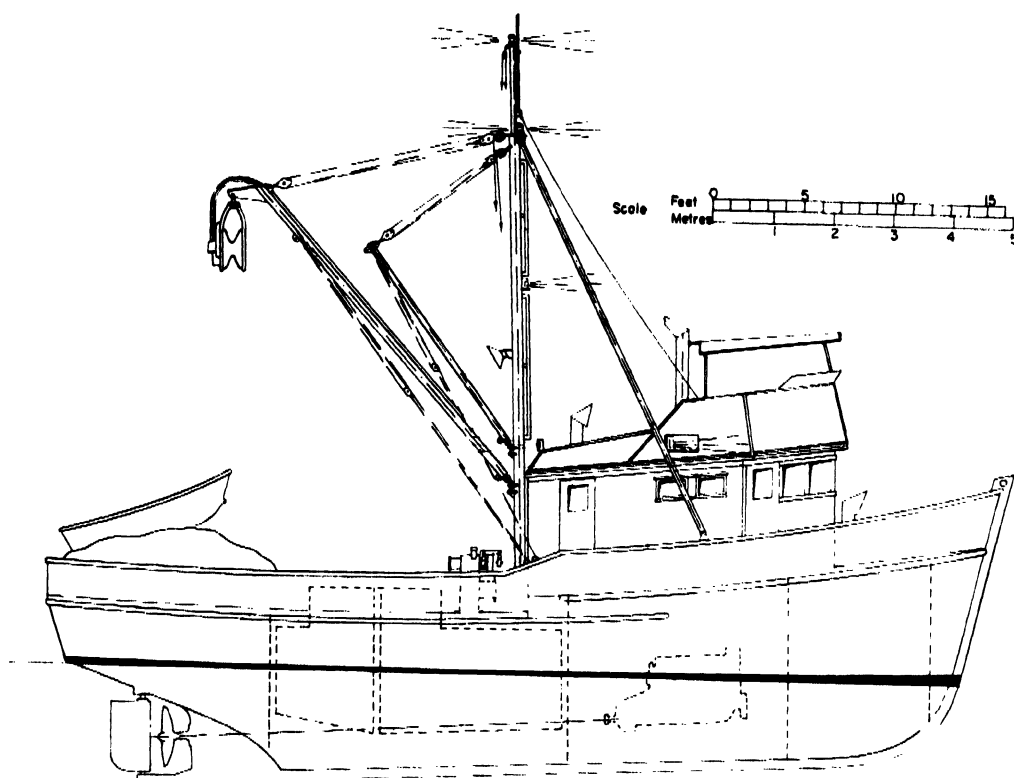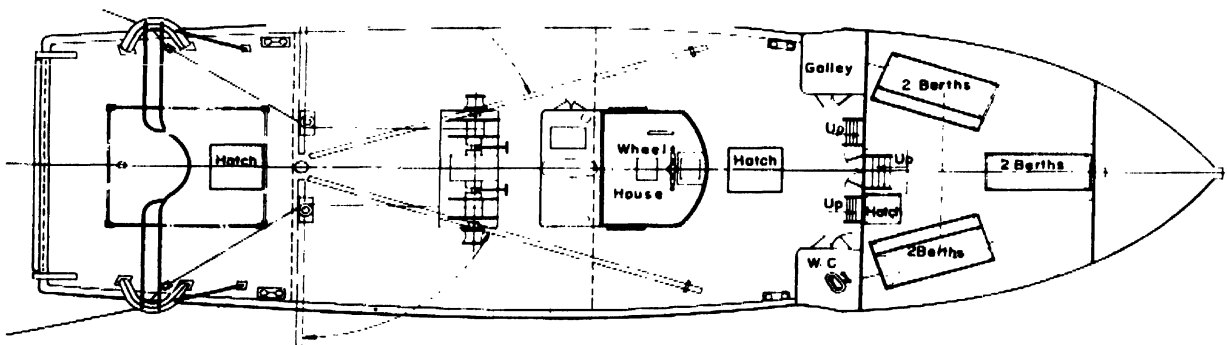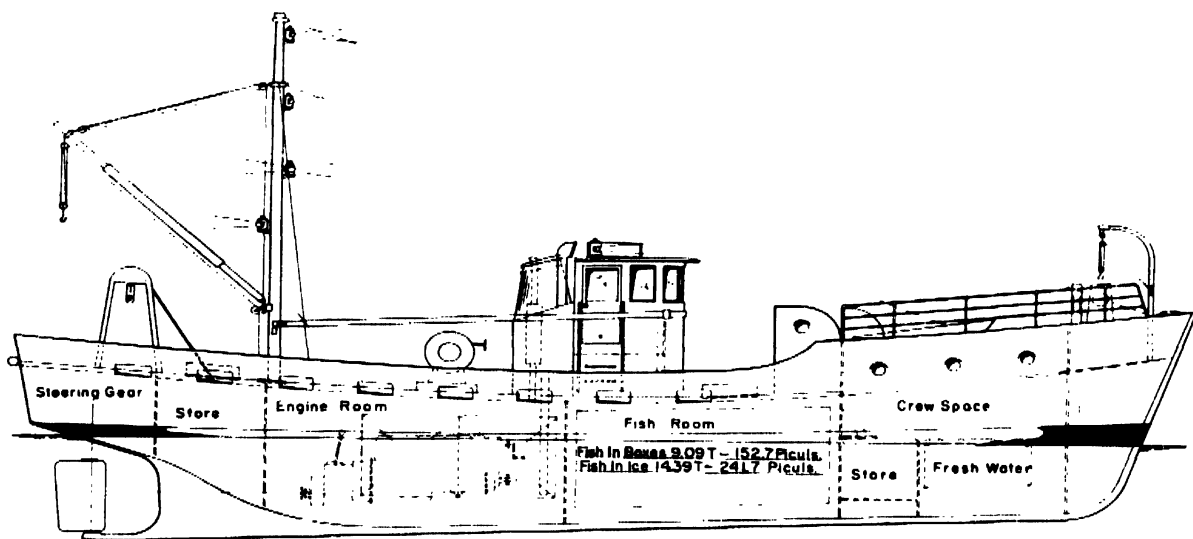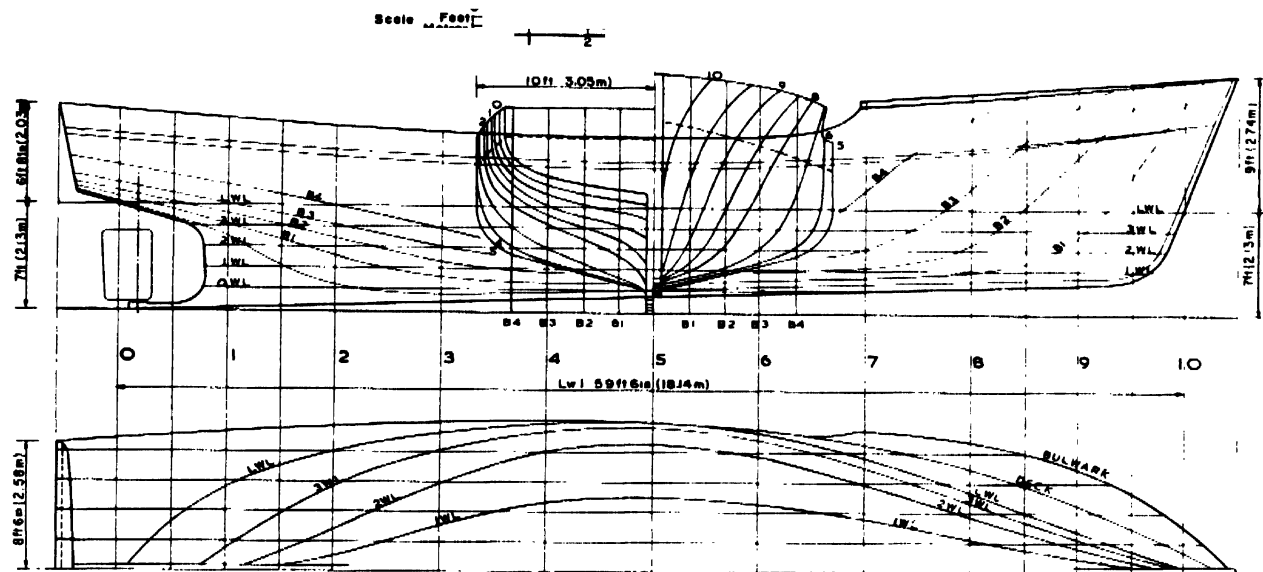
Fig 33. 66 ft (20 m) stern trawler—Hong Kong

Fig 34. EHP predictions

T_ϕ (sec)

Tender
Good
Very good
Stiff

Tender

Möckel lines

Suggested revised lines

Suggested range of good stability

B

10 m

32 ft
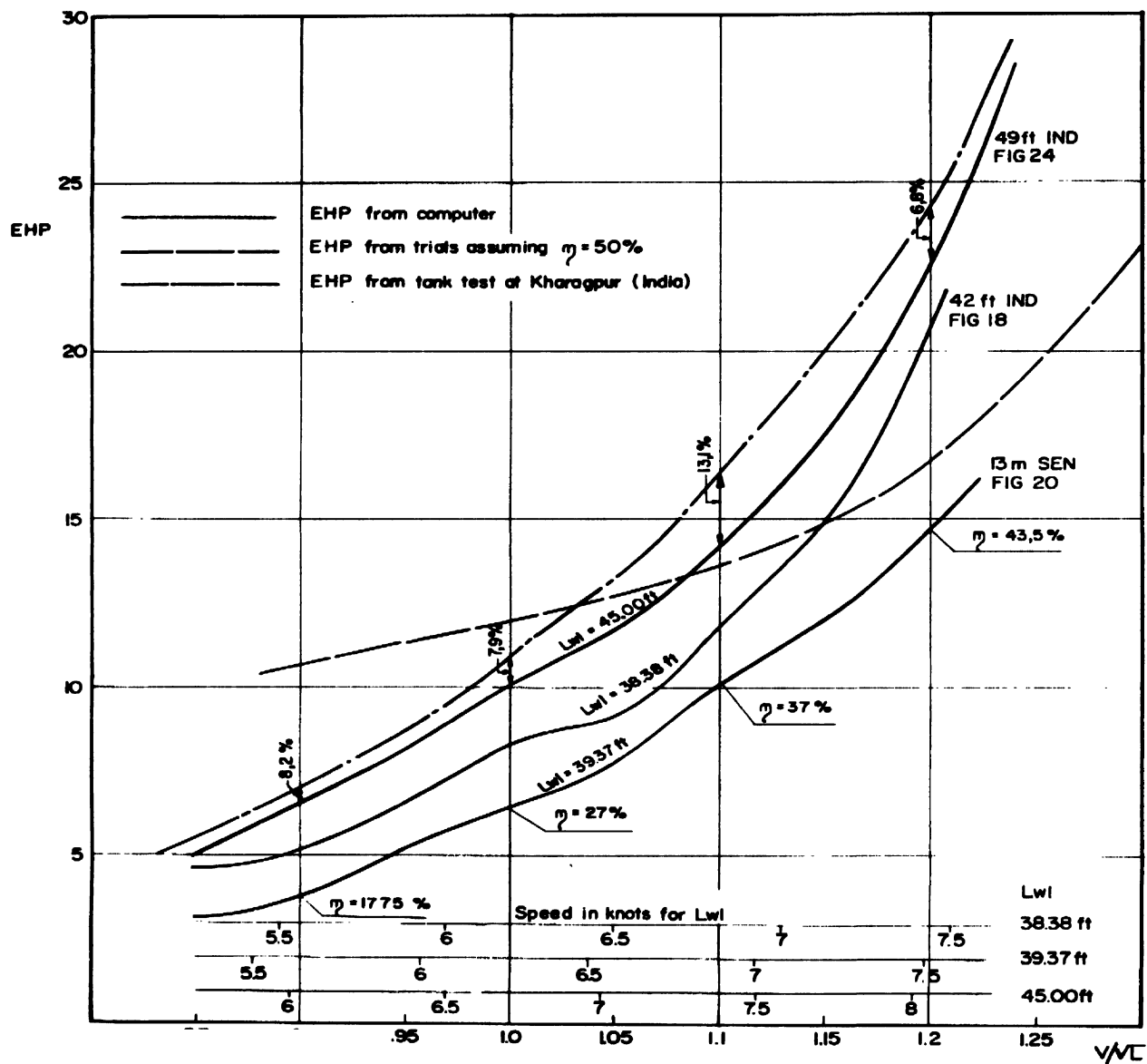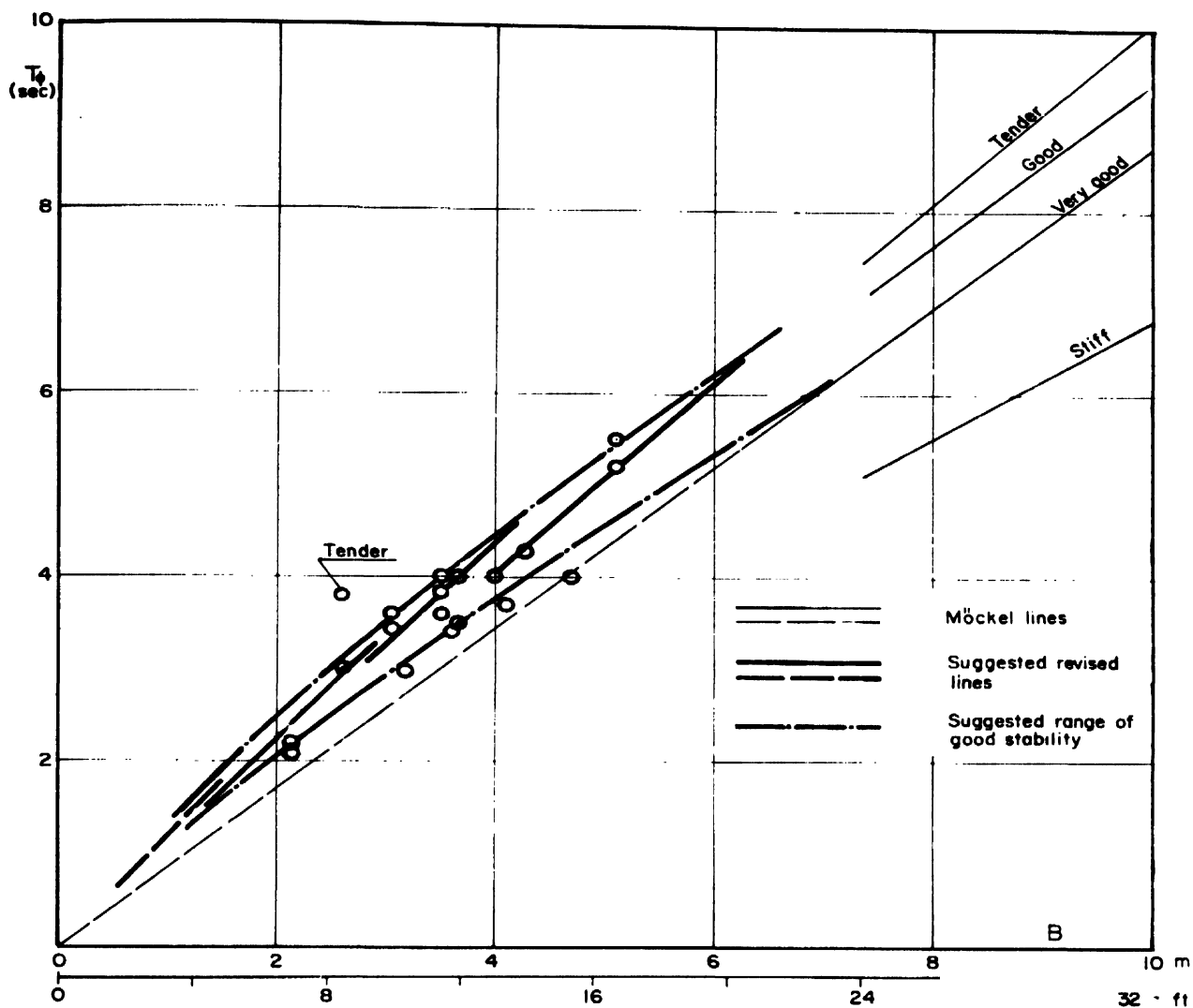
Fig 35. Rolling period as a stability criterion

T_ϕ/Bm

Bm

$f=0.7$ 0.8 0.9

$GM = (f \ B/T_\phi)^2$

$f=.78$ .82

Tender limit for B = 2 m
Tender limit for B = 4 m
Tender limit for B = 6 m

Tender

Stiff

Variation of minimum GM with B

GM

m

in
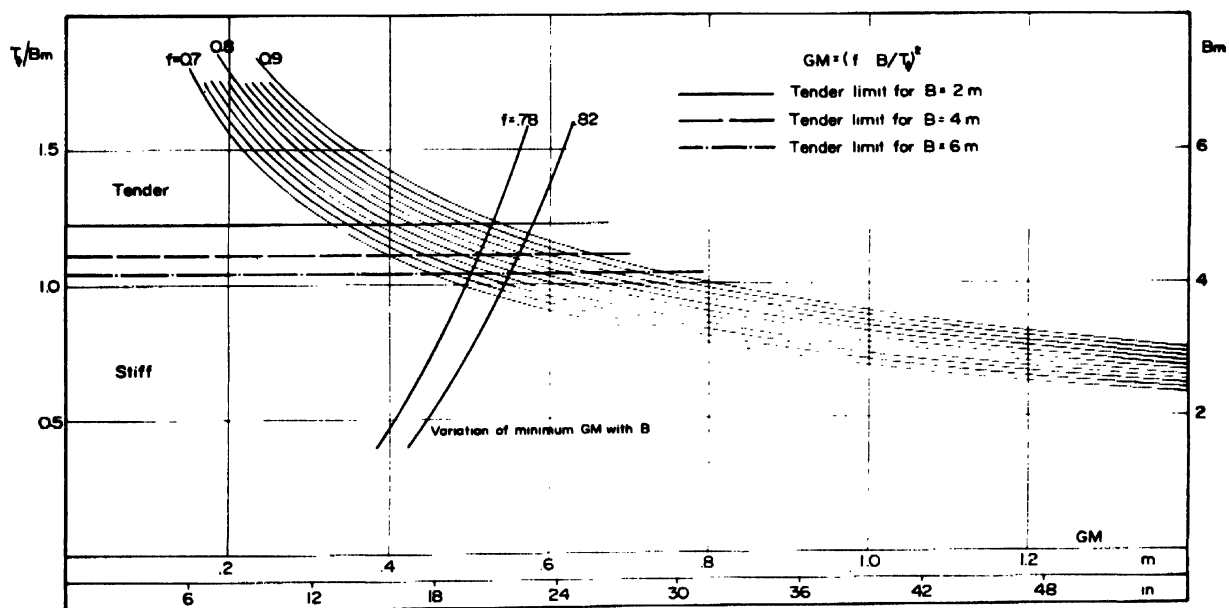
Fig 36. GM as a function of $T_\phi/B(m)$

[471]
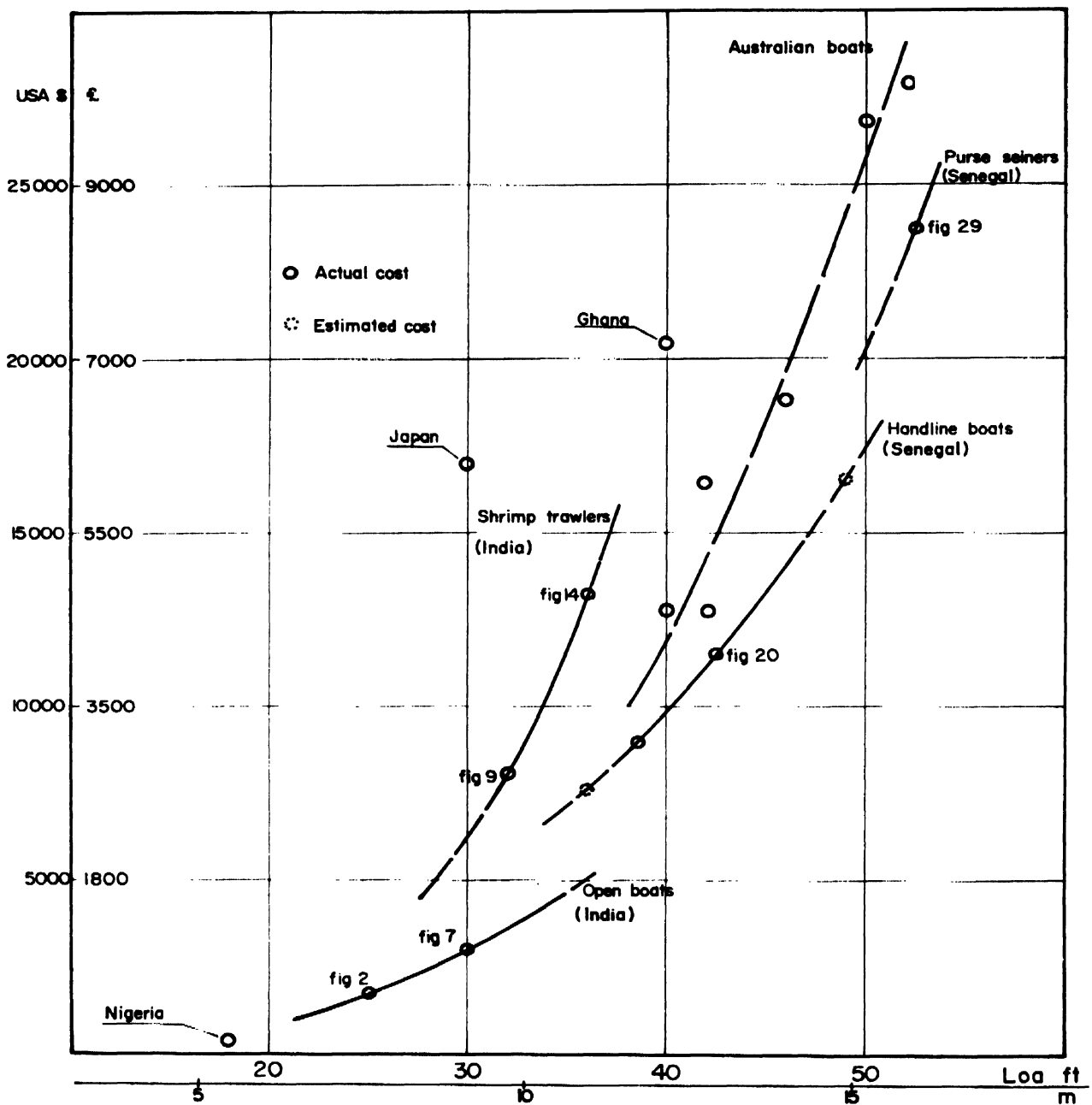
Fig 37. Cost trends for wooden boats
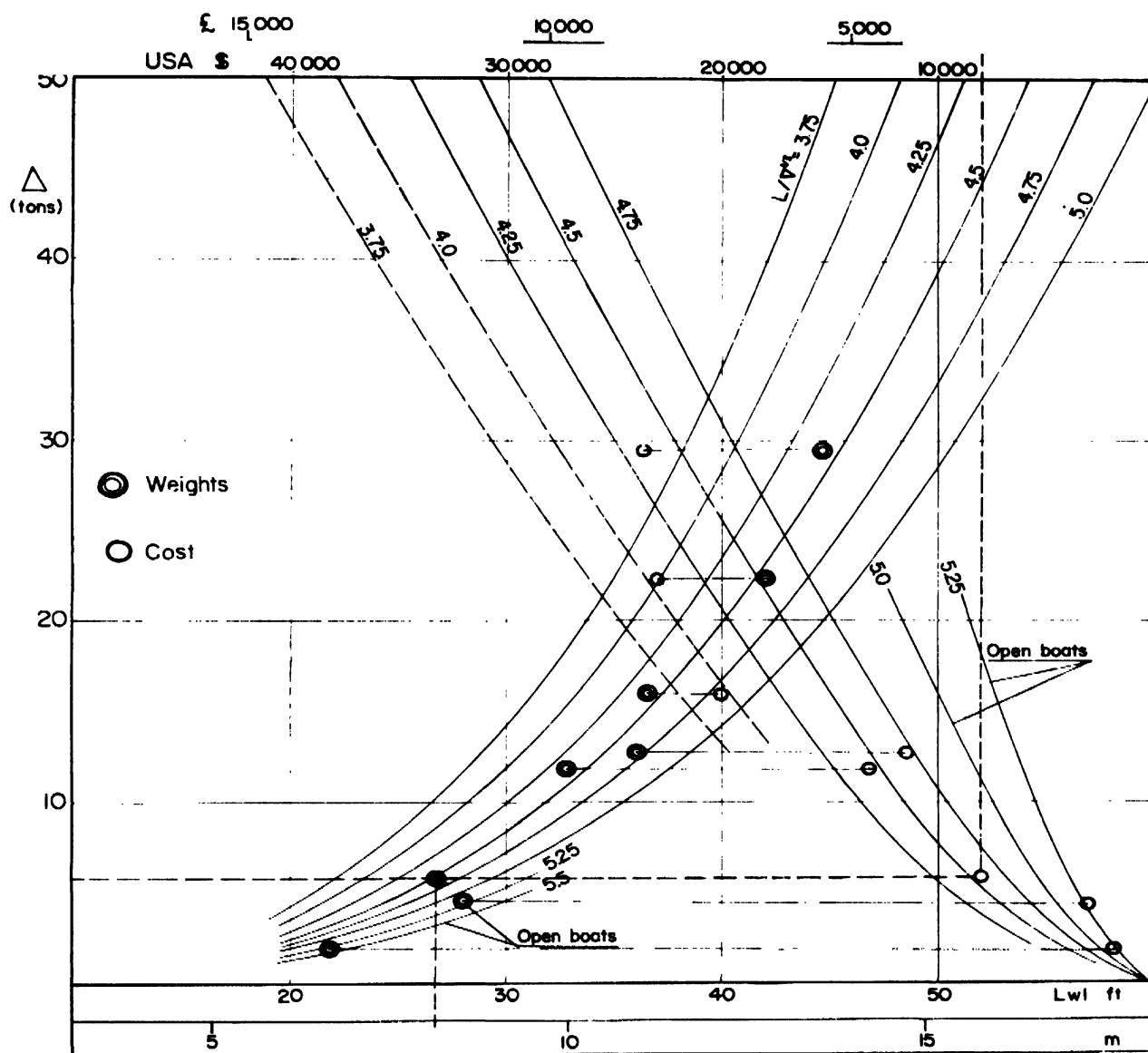
Fig 38. Weight and cost relative to L/▽ ⅓

in the computer work. This testing programme must comprise boats of widely differing characteristics of the parameters that exert a major influence on the performance of a hull

● Full scale ship trials for the models tested and computer analysis are essential to obtain a clear indication of the magnitude of correlation factors that might be required to allow computer predictions for very small boats to be used in the design stage. Exact power determination with the help of torsion meters is essential. Trials must be run at Δ, $L/\nabla^{\frac{1}{3}}$ and trim values corresponding closely to those used for the respective computer analysis—and model tests

STABILITY

Very little is known on the minimum permissible stability of small, wooden fishing boats. It is of importance to ensure that these boats have comfortable motions but retain sufficient stability to satisfy the requirements of safety in extreme weather and loading conditions. A minimum stability criterion for small fishing boats has not yet been formulated but the adoption of Rahola's criterion for static and dynamical stability has been suggested repeatedly. Small boat stability is often assessed by various rule of thumb methods, perhaps the most well known being that the period of roll should be about equal to the boat's beam in metres. This should satisfy the need for comfortable motions together with sufficient stability. In fig 35, actual rolling periods for a number of small wooden boats are plotted on the basis of beam; for comparison the lines given by Möckel (1960) are shown. All the plots, with one exception, represent boats fulfilling Rahola's criterion. The boats are in a range having length-beam ratios of 3.0 to 4.0 and length-displacement ratios of 4.0 to 4.6 and most are among those shown in fig 1 to 33.

Traung (page 139) shows that the minimum permissible GM to fulfil Rahola's criterion increases with length (maintaining L/B and $L/\nabla^{\frac{1}{3}}$ constant). This indicates that Möckel's lines for large trawlers could result in an unnecessarily high GM if applied to much smaller boats. The suggested range of good stability shown in fig 35 substantiates this view on the basis of practical experience. Freeboard is not considered in fig 35, but naturally plays an important role in minimum stability determination as shown by Jablonski (1960) and Traung (page 139).

A diagram that could be applied to check stability on small boats is shown in fig 36. It is based on the Weiss formula $GM = (f\frac{B}{T})^2$ (metric units) and together with fig 35 serves to indicate more clearly the limits of the experience rule $T_\phi \approx B$ in m for safe GM. By using the limiting lines suggested in fig 35 it is possible to define T_ϕ/B values for safe stability, with a corresponding range of GM values depending on f, for any particular beam. Such ratios are shown for $B \approx 6.5$ ft (2 m), $B \approx 13$ ft (4 m), and $B \approx 20$ ft (6 m). The respective "tender" limiting line indicates safe GM for rolling periods below 2.5, 4.4 and 6.3 sec respectively. GM values are plotted against beam for f=0.78 and 0.82.

It would appear safe, therefore, to suggest that small boats of normal proportions up to a beam of 20 ft (6 m) are satisfactory from a stability point of view if they have a rolling period of less than 1.1B in m. To substantiate this statement, it is necessary to see which minimum freeboard this would produce. Rolling periods below B in m should be avoided for the type of boats under discussion, as they would result in decidedly stiff motions. Again, this depends naturally on freeboard, which is not included in this analysis as most of the boats presented have ample freeboard even in the full load condition.

From the available reliable data of B, T_ϕ and actual GM of small wooden boats, it is not possible to deduce generally applicable values of f for different loading conditions. A careful investigation of the stability properties of a large number of boats is necessary to obtain a clear indication of f values to be applied for specific loading conditions and the appropriate ranges of parameters such as L/B and $L/\nabla^{\frac{1}{3}}$. The minimum permissible GM to satisfy an acceptable criterion of safe stability should be investigated for the same range of these parameters and also for a parameter expressing freeboard in terms of beam. This latter could be related to the actual loading conditions of fishing vessels. The results would allow conclusions regarding the permissible GM and T_ϕ for fishing boats to be drawn, and presented in a form similar to those of coastal cargo vessels given by Thode (1965).

Of all known methods of checking the stability of ships, the application of the Weiss formula appears to be the simplest and easiest, provided that reasonably accurate f values can be established to cover the range of loading conditions occurring for any given type of ship.

WEIGHT-COST DATA

There is an astonishing lack of reliable data of actual construction weights for wooden boats in most countries but particularly in those having a relatively new boatbuilding industry. It is almost impossible for the designer to find reference material that will allow him to judge with some degree of accuracy the light weight of a new proposed vessel. In general FAO naval architects suffer from this difficulty in obtaining suitable data from small boatyards because such yards are not used to keeping careful records. In many cases boats to their design were built in remote areas or after their departure. It is often as difficult to obtain reliable draft readings of the finished boat, together with a careful summary of weights on board, to allow a calculation of light weight to be made on the basis of available hydrostatic curves. The technical assistance mission to Senegal operated under much better conditions in this respect. The combination of boat design and boatbuilding training in a small boatyard under the active control of the naval architect and boatbuilder from FAO made it possible to collect reliable data of weights and costs of the boats built.

Table 4 gives the material and labour requirements for five representative boats, four of which were built in India and one in Senegal. The 42 ft (12.8 m) fishing boat from India and the 42.6 ft (13 m) handline boat from

TABLE 4
Basic construction material and labour requirements

ITEM		fig 2/3 25 ft IND	fig 9/11 32 ft IND	fig 14/16 36 ft IND	fig 18/19 42 ft IND	fig 20/21 13 m SEN
Boat building timber	ou ft	180	700	1050	1400	1100
(logs)	ou m	5	20	30	40	31
Copper rod and nails	lbs	110	400	500	660	galv.iron 440
washers, nuts	kg	50	182	227	300	oa 200
Spikes and nails	lbs		65	110	130	200
	kg		30	50	59	90
Screws	gross	18	75	100	150	incl. above
Copper sheet	sq ft	150	400	500	620	645
	sq m	14	37	47	58	60
Paint, glue	Imp.gal	17	25	35	45	55
	l	72	114	160	205	250
Insulation material	sq ft		250	300	350	480
(expanded plastic foam)	sq m		23	28	32.5	45
Labour man days (including installation of machinery and equipment)		500	1200	1700	2200	850

Senegal are very similar, not differing substantially in main dimensions. The lower requirement for boat-building timber in logs for the Senegal boat is explained by the better utilization of the logs due to careful planning and the fullest use of power tools, resulting in a considerable reduction of waste. The same applies to the labour requirements, the Senegal boat requiring only 38.5 per cent of the man days needed to build the 42 ft (12.8 m) boat in India.

The detailed weight breakdown for the 42.6 ft (13 m) handline boat is given in table 5 as an example of the degree of accuracy that can be obtained if careful records are kept.

Table 6 gives a cost analysis for six boats. It lists separately hull costs, the cost of insulation, electrical fittings, equipment, labour, and overheads and profit, but excludes the cost of main propulsion machinery. It is seen that hull costs as a percentage of total cost decrease substantially with increasing size and complexity of the boat. Cost of insulation clearly depends mainly on the price of insulation material, which is very high in India, while electrical installations remain quite constant. Equipment costs naturally increase considerably with boat size due to increased complexity of equipment. In the case of the Indian boats profit and overheads indi-

cate that the construction of bigger boats is less attractive for the small boatyards concerned. This may be largely due to the lack of work planning, and would also substantiate the view that bigger boats tend to require larger margins in cost estimation due to an increase in unforeseen complications. The labour cost provides interesting insight into the large variations existing between different countries. If the man day requirements in table 4 are compared, it is seen that the 850 man days needed to build the 42.6 ft (13 m) Senegal boat represent 27.7 per cent of the total cost of the boat, while the 1,700 man days required for the construction of the 36 ft shrimp trawler in India represent only 13.5 per cent. The cost per man day of labour in Senegal is four times higher than in India. In the cost comparison, it is seen clearly that even with high labour costs it is possible to keep the overall cost down to a reasonable level, provided fullest use is made of pre-planning, labour-saving methods and tools. Conversely, low unit labour cost does not guarantee low total costs.

The problem of realistically assessing costs of boats is especially grave in developing fisheries as the basic data for comparison is largely missing. On the other hand, it is of importance to provide safe guide lines to those concerned with economic planning. Only too often

are boat costs assessed unrealistically. Fig 37 gives the costs of a number of boats in relation to their overall length. It is impossible to extrapolate from this an average relation that could be valid on a world wide basis. Too many geographical and other factors would not permit this. Fig 37 indicates, however, that the boat prices plotted fall into a reasonably well defined area. The spread in costs for a given length is determined by the type of construction adopted, applicable labour costs and to a large extent by the type, and amount of equipment installed. It is interesting to note that this spread is about 100 per cent throughout the range for length and types shown. Costs of main propulsion engines are omitted throughout since they fluctuate widely due to tariff restrictions, freight charges and the like.

Fig 38 is an attempt to show boat costs in relation to weight with $L/\nabla^{\frac{1}{3}}$ in the light condition as a parameter. It is seen that considerably more reliable data is required

to indicate whether such a presentation could be usefully adopted. However, as far as the boats plotted in the vicinity of $L/\nabla^{\frac{1}{3}}=4.5$ and 5.25 to 5.5 are concerned, a good representation of their costs is obtained by the respective cost lines.

Diagrams of this type must be used with great caution and require a good understanding of cost trends in general and local trends in particular. It is suggested that such parameter diagrams could be employed in the planning stage of fleet development, if they were prepared on a regional basis. To simplify the presentation, a base of $L \times B \times D$ might be used and costs could be plotted per unit volume. The resulting parameter lines would then be straight lines. It is feared, however, that the error in extrapolations would be considerably larger than with the suggested parameter presentation shown in fig 38.

The lack of reliable data makes it imperative to consider the presentations under *Performance*, *Stability* and *Weight-Cost Data* as indicative only of work to be expanded in the future. Whether this work can be

TABLE 5

Weight estimate for 42.6 ft (13 m) handline fishing boat

GROUP	ITEM	WEIGHT	
		lbs	kg
A	HULL STRUCTURE		
A 1	Backbone	1550	704
	Worm shoe	66	30
	Transom knee	56	26
	Stem knees	44	20
A 2	Planking	4000	1820
	Transom and frame	286	130
	Butt blocks	110	50
A 3	Bilge stringers	725	330
	Clamps	285	130
	Clamp forward	76	35
A 4	Frames and floors	3240	1473
A 5	Bulkhead	81	37
	Double bulkhead	242	110
	Double bulkhead	210	96
	Bulkhead	81	37
A 6	Deck beams	1160	527
	Deck planking	1710	780
	Girders	415	188
	Brackets	198	90
	Blocking	42	19
	Tie rods	20	9
A 8	Engine stringer	242	110
	Engine bed	286	130
A13	Rubbing strake	185	84
A14	Bulwark cap and lining	620	280
	Sub total	15950	7245
A 15	Fastenings (5%)	796	361
	Total A	16746	7607
B	SUPERSTRUCTURE		
B 1	Aft cabin	529	240
	Wheelhouse	815	370
	Engine room entrance	143	65
B 3	Coaming and hatch	154	70
	Entrance forwd. cabin	115	52
	Aft platform	97	44
	Total B	1853	841

TABLE 5—continued

GROUP	ITEM	WEIGHT	
		lbs	kg
C	JOINER WORK		
	Aft cabin berths	172	78
	flooring	110	50
	lining, etc.	44	20
	Forwd. cabin berths	88	40
	flooring	66	30
	lining etc.	44	20
	Fish hold lining	507	230
	Insulation	44	20
	Hold partitions	331	150
	Ladder	15	7
	Engine room flooring	66	30
	Steel brackets	31	14
	Ladder	31	14
	Sub total	1552	703
	Fastenings (5%)	84	38
	Total C	1636	741
D	HULL FITTINGS AND EQUIPMENT		
D 1	Windows, portholes	33	15
D 3	Fuel tanks (incl. blocks)	880	400
	Water tanks	132	60
D 4	Rudder and stock	166	75
	Steering arrangement	66	30
	Chain, pipe, pulleys	110	50
D 6	Bitt forwd.	22	10
	Bitts aft	16	8
	Chain locker	22	10
	Ventilators	33	15
	Sub total	1483	673
	Fastenings (5%)	66	30
	Total D	1549	703
E	RIGGING		
E 1	Mast	176	80
E 2	Standing rigging	44	20
	Total E	220	100

TABLE 5—continued

GROUP	ITEM	WEIGHT	
		lbs	kg
F	MACHINERY, PIPING		
F 1	Main engine and gear	2400	1090
F 3	Shaft and couplings	132	60
	Stern tube	66	30
F 4	Propeller	90	41
F 6	Exhaust line	77	35
F 7	Controls and instruments	33	15
F 8	Cooling system	33	15
F 9	Fuel line	11	5
F10	Air bottle and fixing	110	50
	Total F	2960	1341
G	SHIP SYSTEM		
G 8	Galley box, gas bottle	154	70
H	ELECTRICAL		
H 1	Switchboard	22	10
H 2	Batteries	88	40
H 5	Wiring and lights	22	10
	Total H	132	60
I	OUTFIT		
I 1	Anchor	117	53
	Chain	430	195
	Rope	66	30
I 4	Tools and spares	88	40
I 6	Navigation equipment	44	20
I 9	Bedding etc.	176	80
	Total I	922	418
	SUMMARY		
A	HULL STRUCTURE	16746	7607
B	SUPERSTRUCTURE	1853	841
C	JOINER WORK	1636	741
D	HULL FITTING EQUIPMENT	1549	703
E	RIGGING	220	100
F	MACHINERY	2960	1341
G	SHIP SYSTEM	154	70
H	ELECTRICAL	132	60
I	OUTFIT	922	418
J	SOAKAGE, BILGE (5 % of A + B + C)	1013	459
K	COPPER	815	370
L	PAINT (3 % of A + B + C)	606	275
	TOTAL	28606	12985

Light weight from weight estimate   =   12.75 tons (12985 kg)
Light weight from trial records   =   12.23 tons (12450 kg)
Error in weight estimate   =   4%

undertaken or not depends to a large extent on relevant data being submitted for evaluation.

In view of its importance and established place in big ship design, the further development of the computer analysis technique is required to make this aid to design available also to the designer of small boats. Of utmost urgency in this connection is the widening of the range of the parameters through comprehensive model testing programmes.

Considerable uncertainty exists regarding the required stability of small fishing boats. The formulation of a simple criterion to assess minimum stability requirements in the design stage for the widest possible range of boats is of utmost importance, as is the establishment of a simple and accurate method of stability assessment for existing boats.

More attention should be paid to the collection and evaluation of data on weight and cost of small boats in order to be able to prepare graphical guides for the pre-assessment of boat costs in connection with the development of inshore fleets.

THE PLACE OF BOAT DESIGN IN FISHERIES DEVELOPMENT

Of the multitude of factors that point to the necessity of a planned approach in boat and fleet development, the following are of special interest:

- Boatbuilding has always been a traditional industry. In many parts of the world boatbuilding practices have stagnated and have not progressed with general technological development

- The scientific approach in naval architecture is comparatively new as is its growing influence on the design of fishing vessels. Earlier evolution of new types of vessels was by trial and error

- The traditional boatbuilder cannot predict the performance and behaviour of a new boat if its conception departs substantially from the accepted and familiar. He is, therefore, reluctant to try radically new ideas. Modern naval architecture provides the designer with the theories required to predict performance and behaviour of new boats

The application of these theories and the use of advanced computing techniques for hydrostatic, stability and performance calculations make fleet development possible with predictable results.

Four phases of development are generally apparent:

Mechanization of indigenous craft (canoes, log rafts, simple planked boats)

By fitting outboard or inboard propulsion motors.

Design adaptation of indigenous craft

By introducing small changes in shape and construction to adapt the craft to modern fishing techniques. Transition from man power or wind propulsion to power boat.

TABLE 6
Cost of boats in India and Senegal (excluding main propulsion machinery)

BOAT	fig 2/3 25 ft IND		fig 7 30 ft IND		fig 9/11 32 ft IND		fig 14/16 36 ft IND		fig 20/21 13 m SEN		fig 30/31 16 m SEN	
ITEM	$	% of Total	$	% of Total	$	% of Total	$	% of Total	$	% of Total	$	% of Total
Hull (timber, fastenings copper sheet, paint)	900	50	1790	58.7	3900	48.1	5780	43.7	4110	35.5	8370	28
Insulation					525	6.48	1050	7.9	205	1.77	510	1.7
Electrical fittings					315	3.9	525	3.97	310	2.68	1020	3.4
Equipment (incl. deck machinery)			420	13.75	1680	20.7	2950	22.23	2500	21.6	7850	26.3
Labour	630	35	525	17.2	1050	13.0	1790	13.5	3200	27.7	6520	21.85
Overhead and profits	270	15	315	10.35	630	7.82	1155	8.7	1260	10.75	5600	18.75
Total	1800	100	3050	100	8100	100	13250	100	11585	100	23870	100

Introduction of foreign boat types

Extremely tempting in cases where design adaptation of indigenous craft cannot be made or where economic reasons render an immediate fleet expansion essential.

Reasons against the application of this phase are:

● Financing generally requires foreign exchange and newly developing fisheries with little or no export potential find it difficult to recover the foreign exchange invested

● Operation of whole fleets of foreign boats can create maintenance problems. The development of maintenance facilities often lags considerably behind if fleet development is too forced

● Wooden fishing boats up to 50 ft (15 m) length can be built in nearly all countries with potentially important fisheries. The development of an indigenous boatbuilding industry should not be prevented by limiting fleet development to importing foreign boats. The chapter headed *Weight-Cost Data* shows that local boatbuilding prices need not be higher than abroad

Main factors in favour of this phase are:

● To provide ships for large scale off-shore operations in countries without a specialized shipbuilding industry

● To provide ships for special duties such as experimental and/or exploratory fishing, research, fishery protection, fishery assistance

Most developing countries lack the facilities to build such ships locally.

Development of national or regional boat types

This is highly recommended as it allows fishing fleets to develop in close association with general expansion of industries in any one country or region. Employment created in this way could be a considerable economic advantage, and the advantage of the possible creation of auxiliary industries should not be neglected.

This ultimate phase must be directly connected to general fisheries development and requires qualified technical personnel closely associated with or attached to the Fisheries Administration. Design development costs will normally have to be borne by governments; the fishing industry could in a later stage participate in sharing such costs, when the development work starts to provide sufficient capital resources.

It is essential that the government organization charged with boat development is not considered a competitor of private enterprise, but that it acts as a catalyst, adviser, and correlator.

No quick results can be expected during this phase. Much in development work remains experimental, but the application of specialized experience in fishing boat naval architecture and progressive use of the new computing techniques will reduce the amount of experimentation.

The development of national or regional boat types requires careful scrutiny of a wide field of influencing factors, among which:

● Geography and hydrography of the area of operation, including information on weather and sea conditions, prevailing winds, situation and adequacy of harbours and shelters

● The local fishing industry has to be studied in view of the comparatively large investment value represented by boats in the economic framework of the industry

● A resources appraisal should be undertaken to judge the economic feasibility of large scale boatbuilding programmes in the framework of fisheries development in general

● An assessment of the local boatbuilding potential is essential

Information required extends to the potential capacity of the yards, accepted construction methods, availability of skilled, semi-skilled and unskilled labour, basic construction materials (timber, metal and alloys, fastenings, insulation material, paints and glues, electrical equipment) as well as of generally imported equipment (engines, deck machinery, electronic equipment) to obtain an accurate picture of possible bottlenecks in supplies that could seriously disrupt production of the yards.

Design development procedure

A specialized fishing boat naval architect with supporting staff should be included in any group concerned with the planned development of fisheries.

A government desiring to develop its inshore fishing fleet in the framework of a national development plan will find three main possibilities of obtaining the necessary technical knowledge and assistance:

● Securing the services of a local naval architect specialized in fishing boat, or at least small boat design

● Engaging an expatriate naval architect either as an expatriate officer or as a consultant

● Requesting expert assistance through the United Nations Development Programme, or other international, bi-lateral, or private aid machinery

From experience the first approach is rarely possible in developing countries because of an acute shortage of technically qualified personnel. The second is not often resorted to by governments, while in past years many boat designs and fleet development projects were actively assisted by UN technical assistance personnel (table 1).

Apart from securing technically qualified personnel for design development (and possibly to direct boat construction programmes), any Fisheries Administration called upon to undertake such activities will have to create the technical services indispensable for their success. The establishment of a specific Fishing Boat Office would be a pre-requisite for success. Such an office should group together technicians from the three main fields of activity:

● Boat design

● Boatbuilding

● Marine engineering

The work programme of a Fishing Boat Office should list:

Survey of existing boats
Determination of requirements for new boats
Preparation and distribution of designs
Construction supervision
Recommendation concerning marine engines, propellers, deck machinery and electronic equipment
Provision of free advice to private enterprise regarding boats and equipment
Provision of information to the boatbuilding, and equipment manufacturing industry regarding development trends and future requirements
Staff training
Where necessary, training of outside personnel
Advice regarding legislation affecting boat development, such as scantlings regulations, construction standards, equipment rules, measurement rules, registration, and loan and subsidy regulations.

The extent to which this long list of activities can be implemented depends mainly on the availability of staff. In many cases it would be necessary to start very modestly and to expand the scope of activities as general fisheries development gains momentum. The important thing is to refrain from formulating rigid, long-term work programmes, but to organize the work according to the needs of the fishing industry which should be based on information supported by serious scientific investigations at least in such cases where a new resource suddenly creates large investment and production possibilities.

Arctic Fishing Vessels and their Development

by Kjeld K. Rasmussen

Les bateaux de pêche arctique et leur développement

Bref exposé sur l'évolution des bateaux de pêche groenlandais d'une jauge brute inférieure à 20 tonneaux, avec historique des divers types de bâtiments, faisant ressortir le développement rapide qui s'est manifesté depuis la Seconde Guerre mondiale. La communication renferme des notes sur la stabilité, les procédés de construction, les matériaux employés et la protection contre les glaces.

Il est permis de tirer des conclusions générales touchant un mode efficace de développement visant à réaliser des plans optimisés des points de vue de la technique et de l'économie, dans des conditions d'ordre administratif analogues à celles de la situation étudiée, où la programmation, le dessin et la construction des bâtiments ont lieu au Danemark, c'est-à-dire loin de la zone d'opérations.

L'existence d'une "génération" de bateaux normalisés présente un grand intérêt, et l'auteur suggère une méthode mettant à profit les caractéristiques des bâtiments de chaque génération pour améliorer la conception des futures unités. Pour faire de véritables progrès, il est indispensable de disposer tant de données dignes de foi sur les plans et les essais que de résultats de l'observation du rendement des bateaux en service. L'auteur propose de faire remplir un questionnaire par les usagers, et conclut en énumérant les avantages que présente l'appui des pouvoirs publics.

Los barcos pesqueros del Artico y su desarrollo

Se presenta una breve reseña del desarrollo de las embarcaciones pesqueras en Groenlandia para barcos menores de 20 toneladas brutas, acompañada de una breve reseña cronológica de los distintos tipos, atendiéndose principalmente al veloz desarrollo alcanzado en el período de la segunda guerra mundial. Contiene notas sobre estabilidad, construcción, materiales y protección contra el hielo.

Deben formularse algunas conclusions generales en cuanto al procedimiento para un desarrollo eficaz que tienda a idear técnica y económicamente diseños óptimos en condiciones administrativas similares a las que se dan en esta circunstancia, en donde la planificación, diseño y construcción se lleva a cabo en Dinamarca, es decir en un lugar alejado de la zona de operación.

Se exponen las ventajas de una generación de embarcaciones normalizadas y se sugiere un método por el cual cada una de las generaciones se utiliza para mejorar el diseño siguiente. Se explica que no se puede llevar a cabo ningún progreso efectivo sin datos de diseño y perfiles, por un lado, y de observación del funcionamiento de los barcos en servicio, por otro. Se propone que el personal que los explota rellene un cuestionario. Por último, se hacen constar las ventajas de la ayuda oficial.

BOAT development is depicted as being dependent on the combined effect of such factors as capital available for boatbuilding, development in fishing techniques and the fisheries products demanded. Greenland fisheries started with a very simple combination of these factors but has developed into a rather complex structure of boat types, fishing techniques and shore installations.

BOAT DEVELOPMENT IN GREENLAND

First phase, pre-1945

The development from the beginning had strong governmental guidance and support. Before World War II only the Danish government owned and operated mechanized, decked fishing boats below 20 GT. The local fishing was from kayaks and dories in fjords and sheltered areas. The government activity was in the form of exploratory fishing for cod, halibut, Greenland halibut and shrimp. In this way a foundation was laid, knowledge gained of fishing grounds and the structure of shore installations developed, ready for the great expansion of the post-war period.

Second phase, 1945 to 1952

Privately owned mechanized boats were introduced, being initially 18 ft to 22 ft (5.5 to 6.7 m) open boats, but gradually increased in size to 22 to 26 ft (6.7 to 8 m),

decked and partly decked. Salted cod played a predominant role, and the boats were primarily concerned in providing inshore line fishermen with more seaworthy boats, with some accommodation forward in the larger vessels.

Methods of fishing were handlining and set nets. The landings were delivered to numerous small salting plants along the coast.

The boats were usually designed and built by yards in Denmark. Some, however, were built in small boat yards in Greenland or by the fishermen themselves. The traditional procedure where the hunter built his own kayak had not completely disappeared.

Third phase, 1952 to 1962

The inshore cod fishery became more and more prosperous and the first filleting plants for frozen fish products were put into operation. A standard handline cod fishing vessel of 10 GT 30 ft (9.1 m) length was introduced. It was designed by Mr. Slaaby Larsen, a Copenhagen naval architect. The boat was decked, had ample accommodation forward, was fairly seaworthy, and became very popular. The hull was slightly modified over the years with a fuller deckline forward and aft, with a rounded forefoot which was essential for hull protection when hitting rocks, and later a raking stern was introduced for better deck space aft.

During this period very profitable shrimp fishing

grounds were discovered in Disko Bay in North Greenland, introducing an immediate demand for vessels for shrimp trawling. Previously shrimp trawling had been done exclusively by a few Government-owned 15 to 20 GT boats in Southern Greenland.

After 1958 an increasing number of boats of 17 to 24 GT was ordered by fishermen in Greenland encouraged by subsidies, favourable loans and good prices for shrimp landings. The boats were almost all of the normal Danish fishing boat type with slight modifications in the general and deck arrangements. All were side trawlers with mechanically driven trawl winches and line haulers, because these vessels were designed to fish cod and catfish when not shrimp trawling. Some were also fitted with harpoon guns for hunting small whales.

These boats were built with lines developed by each building yard, with only general arrangement and specification being provided by the purchaser, the Royal Greenland Trade Department (RGTD).

The good prices for shrimp made it possible for private fishermen to afford the larger boats. Many were of the opinion that these vessels were not used enough for cod fishing, this being a less profitable employment even when shrimping at times had to be restricted because the processing plants could not handle the landings of all the boats. The loans and subsidies were given without conditions as far as landings were concerned, so the fishermen could only be urged to fish for cod rather than shrimps. The vessels were not provided with a longline chute aft, but only with a line hauler amidships, so normal longlining was not possible, cod being taken by handlines and line gurdy or by set nets early in the season.

Some vessels occasionally hunted small whales so the pattern of fishing was mixed, and not altogether beneficial for a constant delivery to the shore installations for frozen fish products. With the extremely high cost of harbour and quay construction and the expensive freezing and filleting plants, it was a point of argument whether each of the mainly state-owned factories should have a number of fishing boats contracted to obtain steady deliveries. The idea was postponed until larger government-owned or controlled boats could be built, as these would be better suited and more independent of weather conditions during most of the year.

With the big demand for boats, built at many different yards in Denmark, it soon became necessary to have standard drawings for the larger boats to ensure uniformity and high standard of hull form and general arrangement, also detailed technical specifications to ease administration and inspection work, during construction.

Fourth phase, 1962 and onwards

In 1962, therefore, standard drawings and detailed specifications were compiled for a 16- and a 20-GT vessel, the 10 GT type already standardized, the 16 GT type designed by the RGTD technical staff and the 20 GT type by the author. Since 1962, these three boat types have been produced with virtually no modification except for variations in choice of main engine and small changes in accommodation and deck arrangement. The 20 GT design was to be fractionally below this gross tonnage because for vessels above this figure the Danish Ship Inspection requires that skippers should have passed an appropriate navigation examination and that the vessel passes periodical surveys of hull maintenance and repair, equipment and engines. From the Danish

Fig 1. Loading a 20-GT standard vessel

[481]
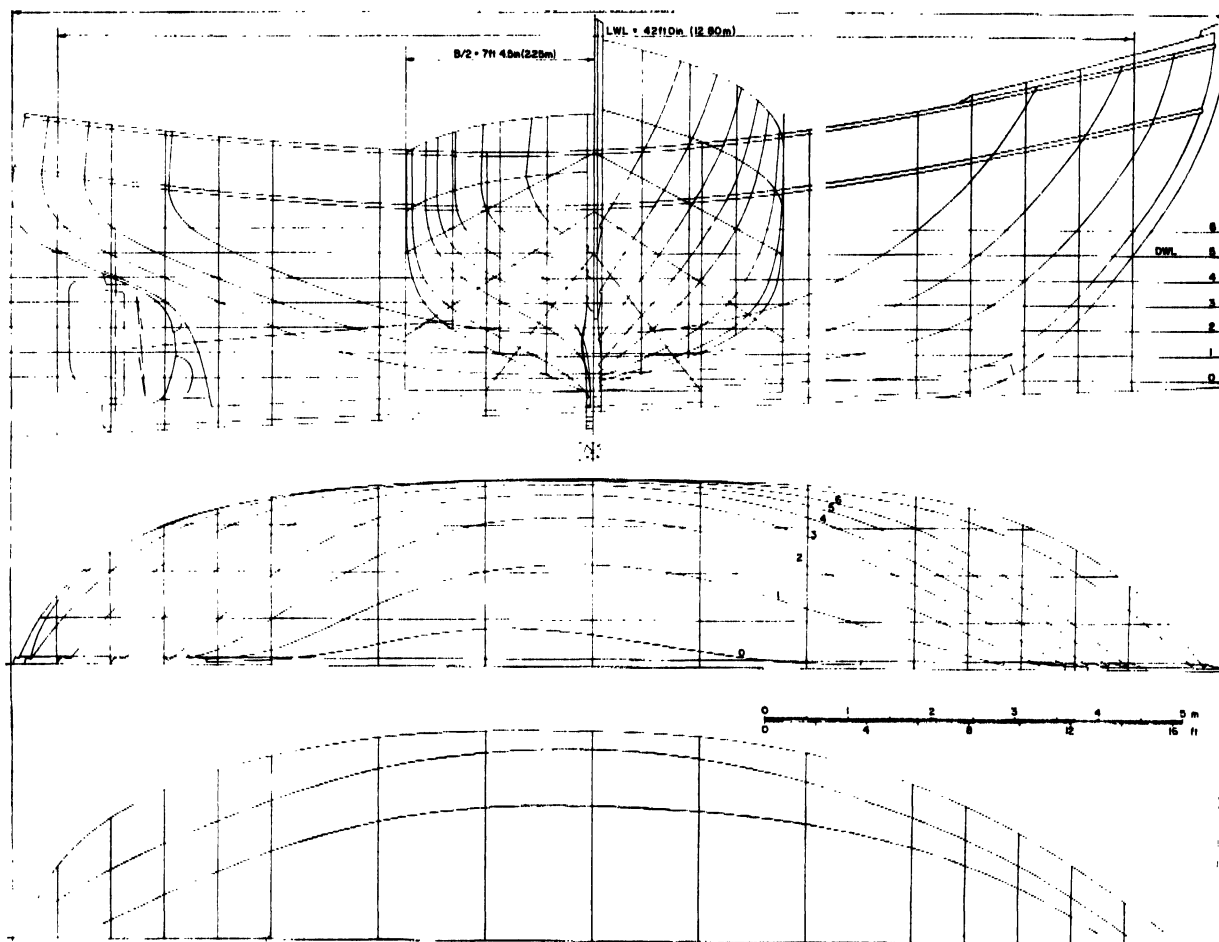
Fig 2. 20-GT standard vessel lines plan

Main data for 20-GT vessels

Boa	47 ft 5 in (14.45 m)	Displacement in salt water to Lwl	42.45 ton
Lwl	42 ft 0 in (12.80 m)	LCB	0.26 ft (0.080 m) aft
L max on frames	14 ft 9 in (4.50 m)	Cp	0.581
D mould	6 ft 11 in (2.12 m)	$\frac{1}{2}\alpha_e$ at	34.5°

Scantlings for the 20-GT fishing vessel		*inches*	*mm*
Keel	oak	$7\frac{1}{4} \times 11\frac{7}{8}$	185×300
Stem	,,	$7\frac{1}{4} \times 15\frac{3}{8}$	315×390
Frames, double sawn	,,	$3\frac{3}{4} \times 4\frac{3}{8}$ to $6\frac{1}{8}$	95×110 to 155
Frame spacing	,,	$18\frac{7}{8}$	480
Keelson	,,	$5\frac{7}{8} \times 6\frac{7}{8}$	150×175
Side keelsons in engine room	,,	$5\frac{1}{8} \times 7\frac{1}{4}$	130×185
Covering board	,,	2	50
Inner covering board	,,	$2 \times 7\frac{7}{8}$	50×200
Shelf	,,	$2\frac{1}{4} \times 9\frac{1}{4}$	55×235
Clamp strake	,,	$1\frac{3}{4} \times 8\frac{1}{4}$	45×210
Bilge stringers, 2 off	,,	$2 \times 7\frac{1}{4}$	50×185
Inner planking	larch	$1\frac{3}{8}$	35
Garboard strake	oak or beech	$2\frac{3}{8}$	60
Ordinary planking	,, ,, ,, below wl	2	50
Deck beams	oak	$4\frac{3}{4} \times 4\frac{1}{8}$ to 5	120×105 to 130
Deck planking	pine	2	50

official point of view this would have been advantageous as they had invested money in the vessels in the form of loans and subsidies; owners, however, wanted their boats to be just below the regulation limit because, due to

[482]
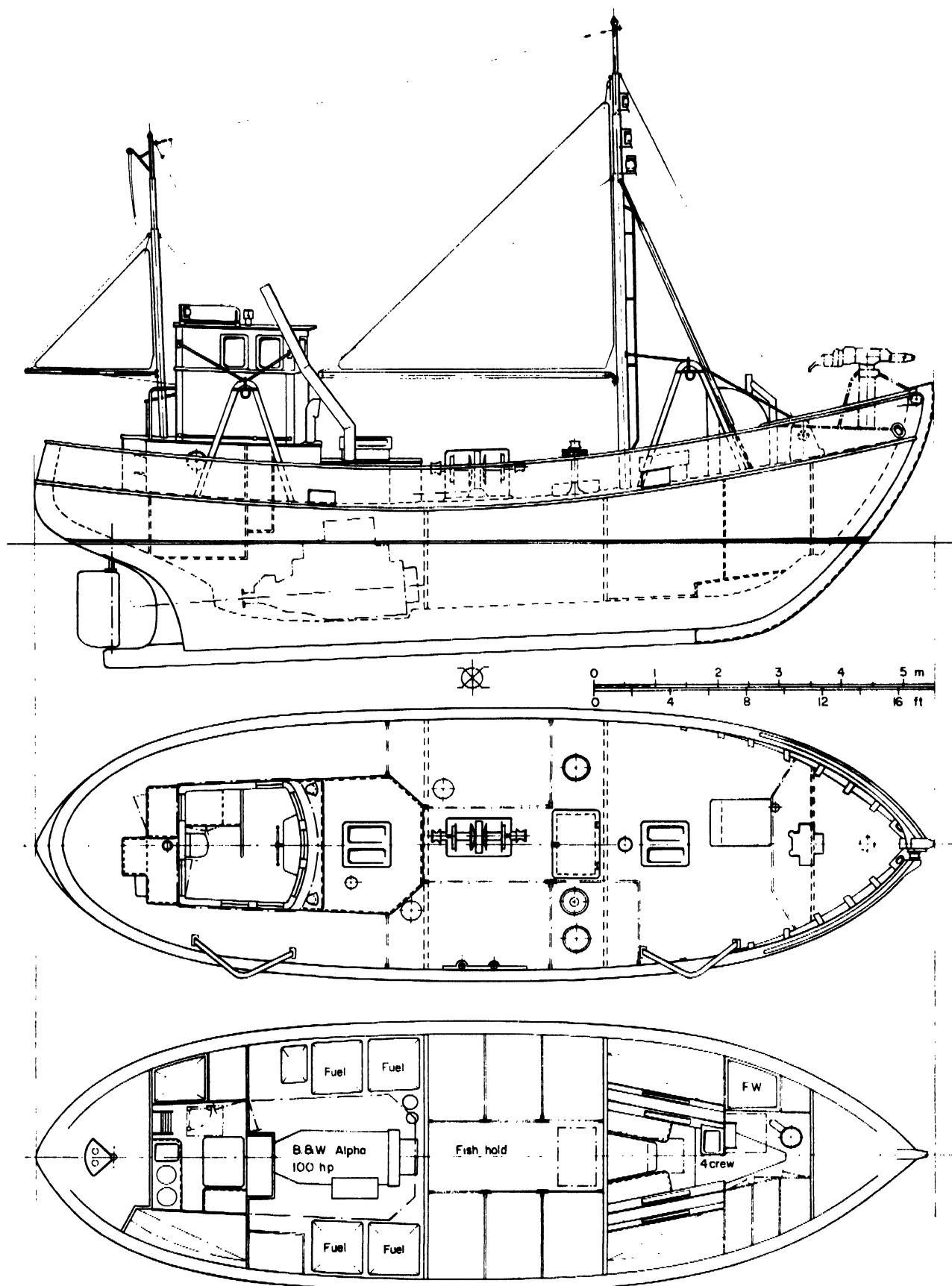
Fig 3. 20-GT standard vessel. General arrangement

Chain

3 men

Fish hold

Engine room

39 hp

Batteries

F.O.

F.O. 13 Imp.gls. 350 L.

L.O. 77 Imp gls 60 L.

60 L.

Line hauler

Hatch 3 x 2 ft 0.90 x 60 m

Steering position

Engine room

Fish hold

3 men
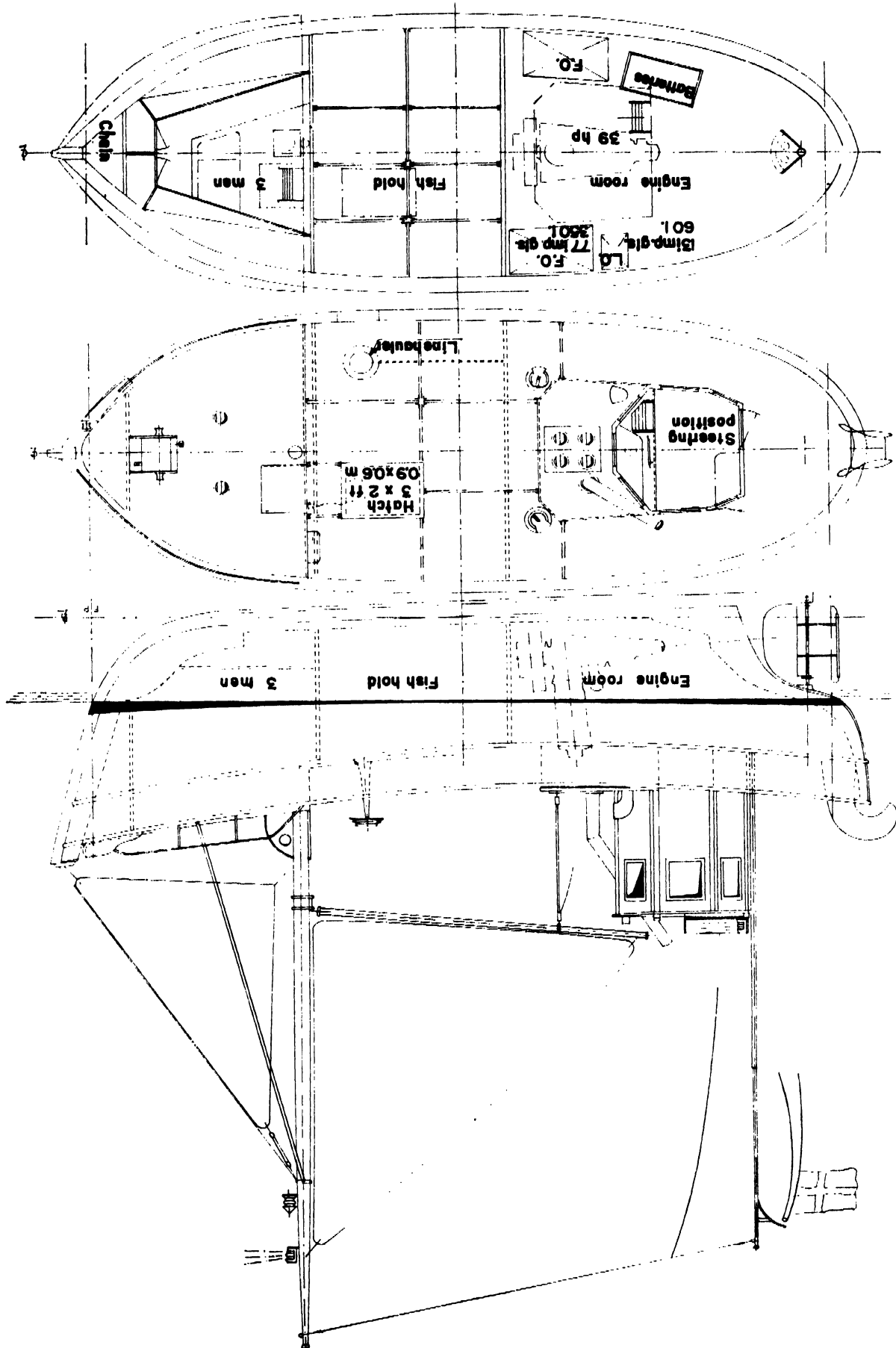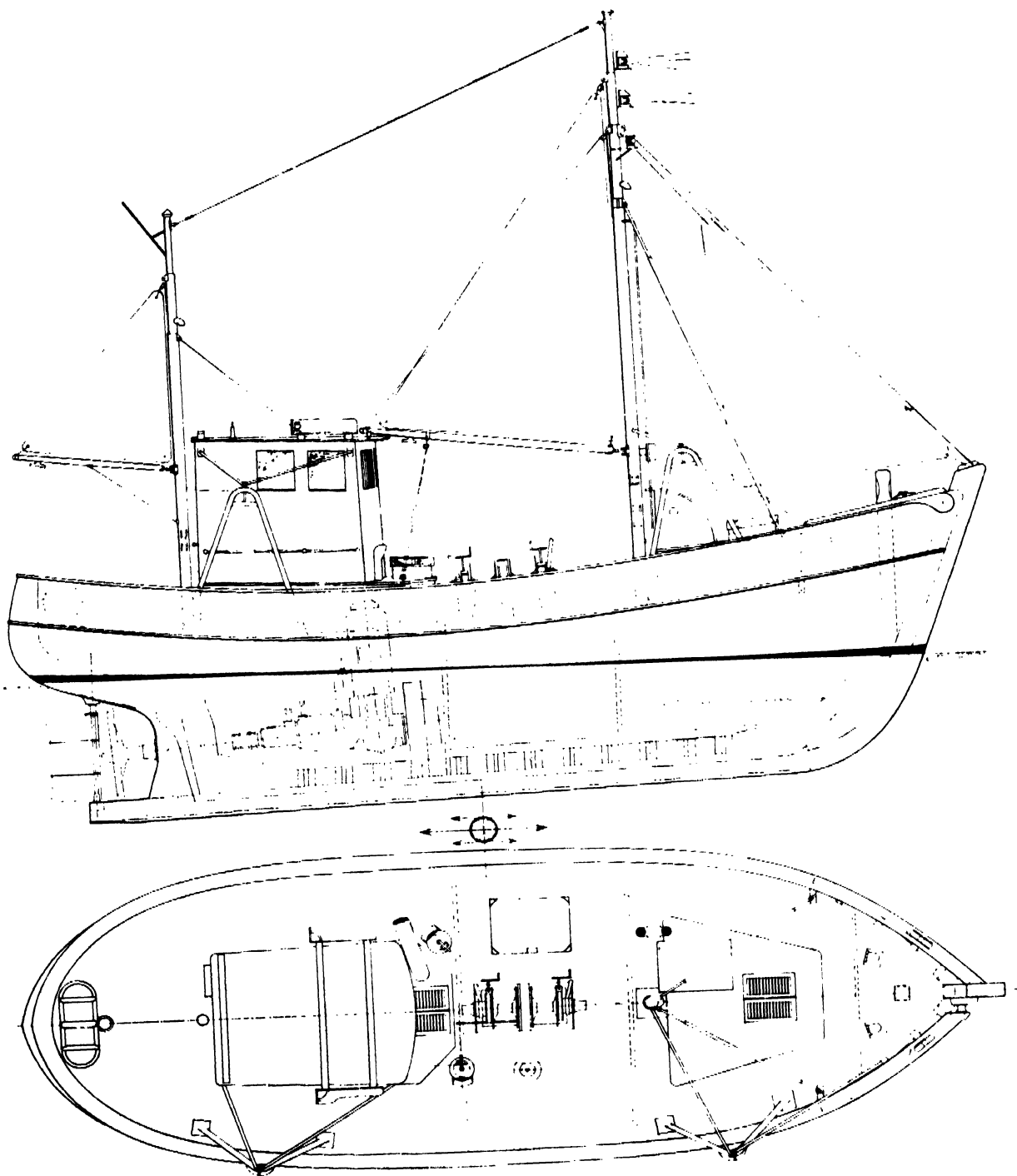
Fig 5. 16-GT fishing craft
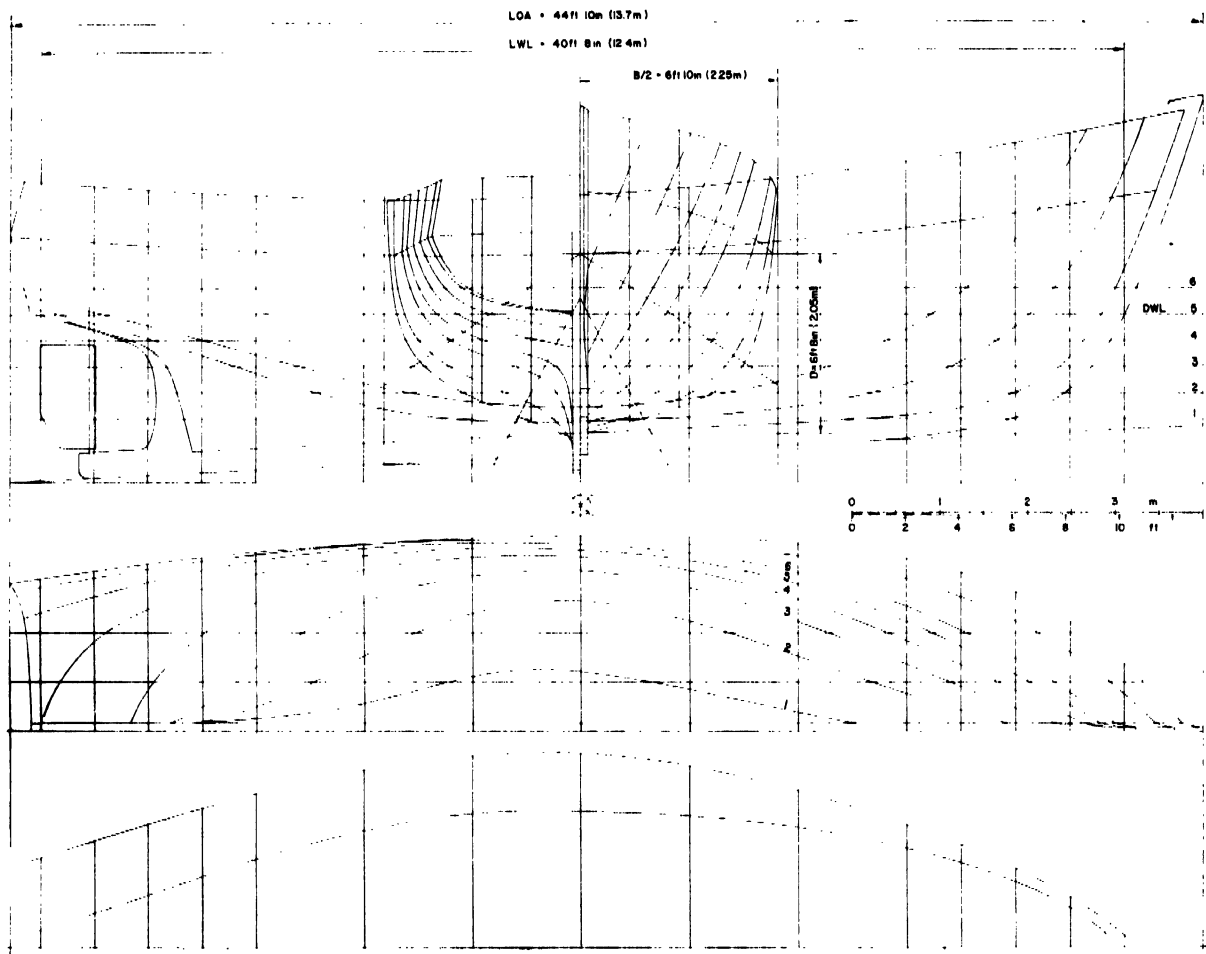
Fig 6. 45-ft (13.7-m) vessel. Preliminary lines plan

previous laxity in the enforcement of the regulations, some of the individually built boats, of even 23 to 24 GT, had been measured down. Fig 1 shows the loading of a 20-GT vessel weighing about 40 tons. This was one of the 32-ft fishing boats shipped to Greenland in May 1965, all in one big carrier. Of the 32 vessels, twelve were of the 10 GT type, ten of the 16 GT type and ten of the 20 GT type. The smaller boats were placed in the hold and the bigger on the deck. Fig 2 and 3 show the line plan and general arrangement of this type of vessel. Fig 4 and 5 show the general arrangement of the 10 GT and 16 GT types.

The following boats have been sent to Greenland during the last few years:

	10 GT	16 GT	20 GT
1961	5	5	4
1962	25	12	10
1963	10	11	5
1964	10	6	6
1965	15	10	10

Larger vessels

For years there has been discussion urging the construction of larger boats for cod fishing on the banks outside Greenland waters in the Davis Strait, as the major fishery

nations were already taking big catches there with their much larger vessels. With the partial disappearance of cod from the inshore waters it was thought imperative to build bigger vessels. A programme for such vessels sponsored by the Danish Government was launched in 1964. It is not described here as it is considered outside the scope of this paper which deals only with boats of up to 20 GT.

Further refinement of smaller types

A revision of the plans and the development of a second generation of the three standard type vessels was postponed because a decline in the cod fisheries since 1963 gave rise to speculation as to whether the smaller vessels were a good proposition. However, by the beginning of 1965 when proposals for larger vessels were submitted, new proposals for boats under 20 GT were also included. These proposals were sent to Greenland for comment by representatives of the fishermen, local plant managers, loan board, etc. Only after receipt of such comments will the detailed design work begin. This procedure has already established a better and closer contact between the planning administration in Copenhagen and the fishermen in Greenland. Previously the physical distance between the naval architect in
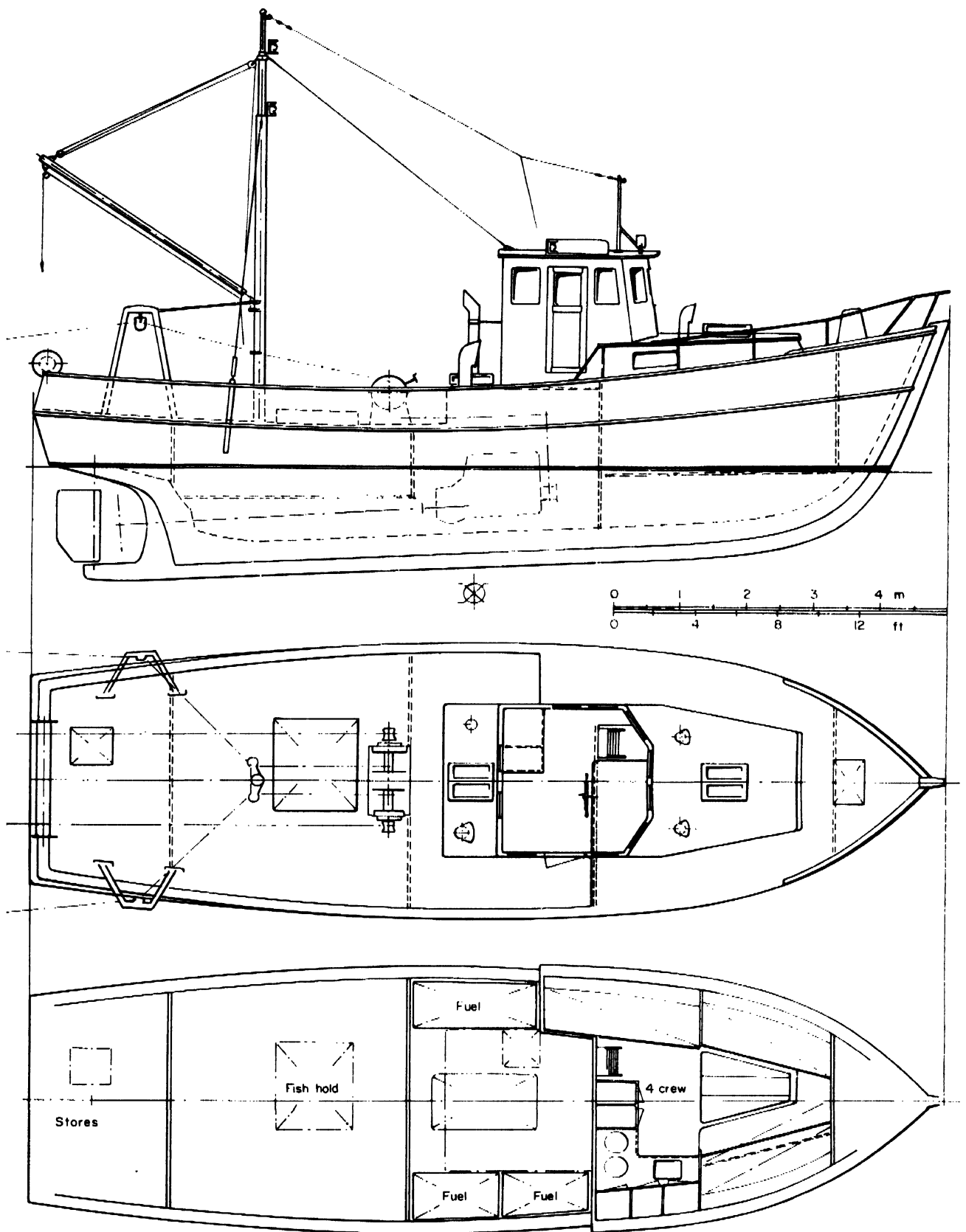
Fig 7. 45-ft (13.7-m) proposed vessel. General arrangement

Fuel

4 crew

Fish hold

Stores

Fuel

Fuel
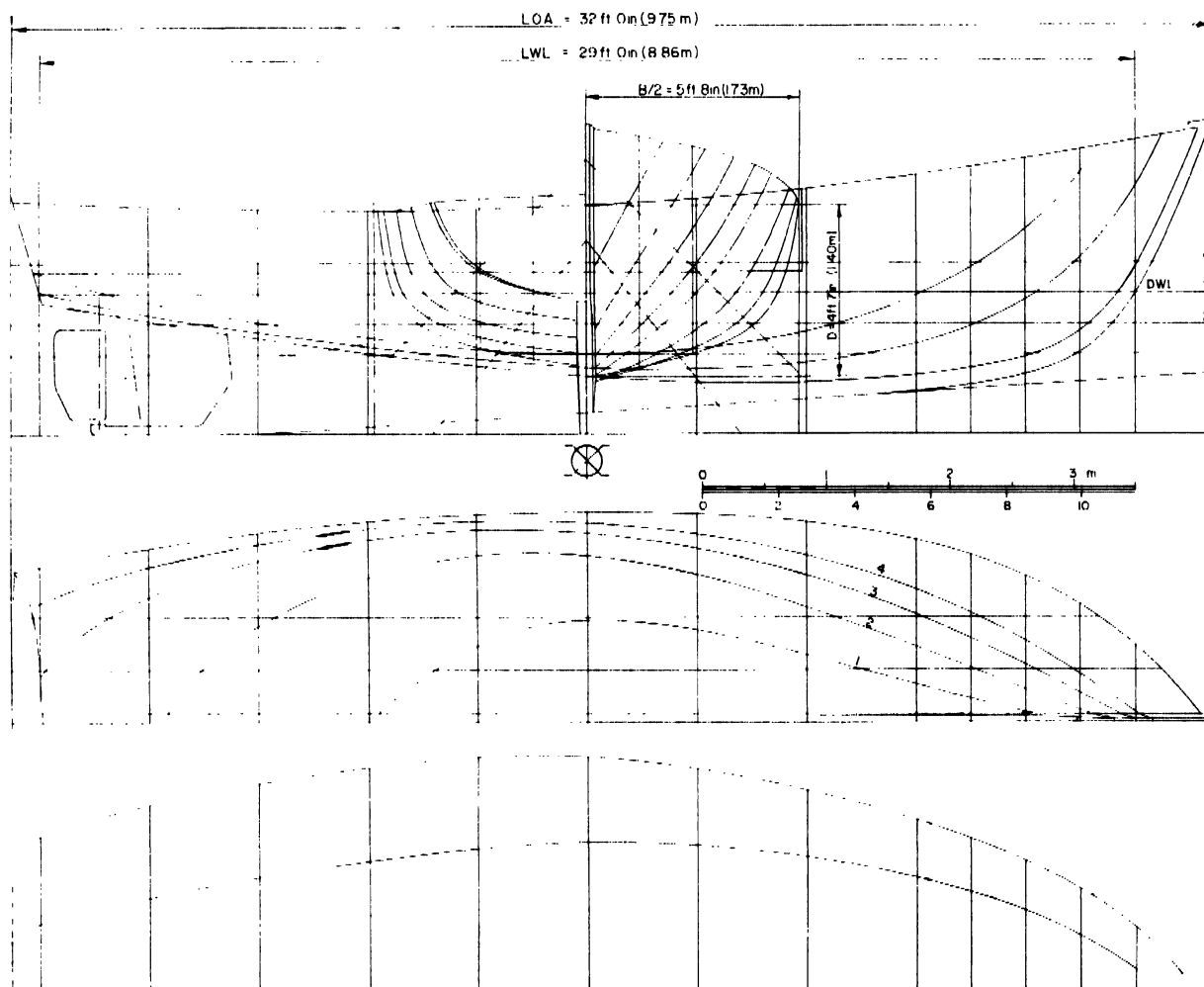
Fig. 8. 32-ft (9.75-m) vessel. Preliminary lines plan

Copenhagen and the prospective boat owner in Greenland has at times been too far.

Two types of vessels, a 45-ft (13.7-m) and a 32-ft (9.75-m) vessel, are described below for the development of smaller boat types for Greenland, being the author's entry in the current discussion.

The proposed 45-ft (13.7-m) vessel is thought to measure just under the 20-GT limit. The main emphasis is placed on spacious accommodation for the crew of four, and the introduction in Greenland of a working deck aft. Although fishing trips with the vessel will seldom exceed 24 hours, the crew must be comfortably accommodated since often they will be away from their home port for many weeks and have to live on board. Fig 6 and 7 show the lines and general arrangement of the proposed 45-ft vessel. The version shown is a shrimp trawler, but an additional arrangement can be made for longlining. Another possibility would be to operate the vessel for seal hunting in the season, carrying kayaks on the deck to and from the hunting grounds, and using the vessel as a carrier of the catch.

By having the accommodation and the engine room adjacent, the problem of heating can be solved by placing the traditional small oil burner in the engine room,

installing a coil for water circulation and having radiators placed in the accommodation and wheel house. Cooking will be done on bottled gas burners. In the existing standard types the oil burners have to be placed in the accommodation itself where they often obstruct good planning.

An engine of about 90 to 100 hp in the rpm range of 1,500 to 1,800 and with 3:1 reduction is envisaged. This is a departure from the traditional heavy duty engines, and this solution is chosen to reduce initial cost for the engine, for the sake of compactness and to reduce displacement. This engine is estimated to give a service speed of about 8 knots.

Main data for proposed 45-ft type

Loa		44 ft 10 in (13.7 m)
Lwl		40 ft 8 in (12.40 m)
B max on planking		13 ft 8 in (4.50 m)
D		6 ft 8 in (2.05 m)
Displacement in salt water to Lwl		30.45 ton
LCB	at „	0.53 ft (0.163 m) aft
Cp	„ „	0.575
$\frac{1}{2}\alpha_e$	„ „	29.5°
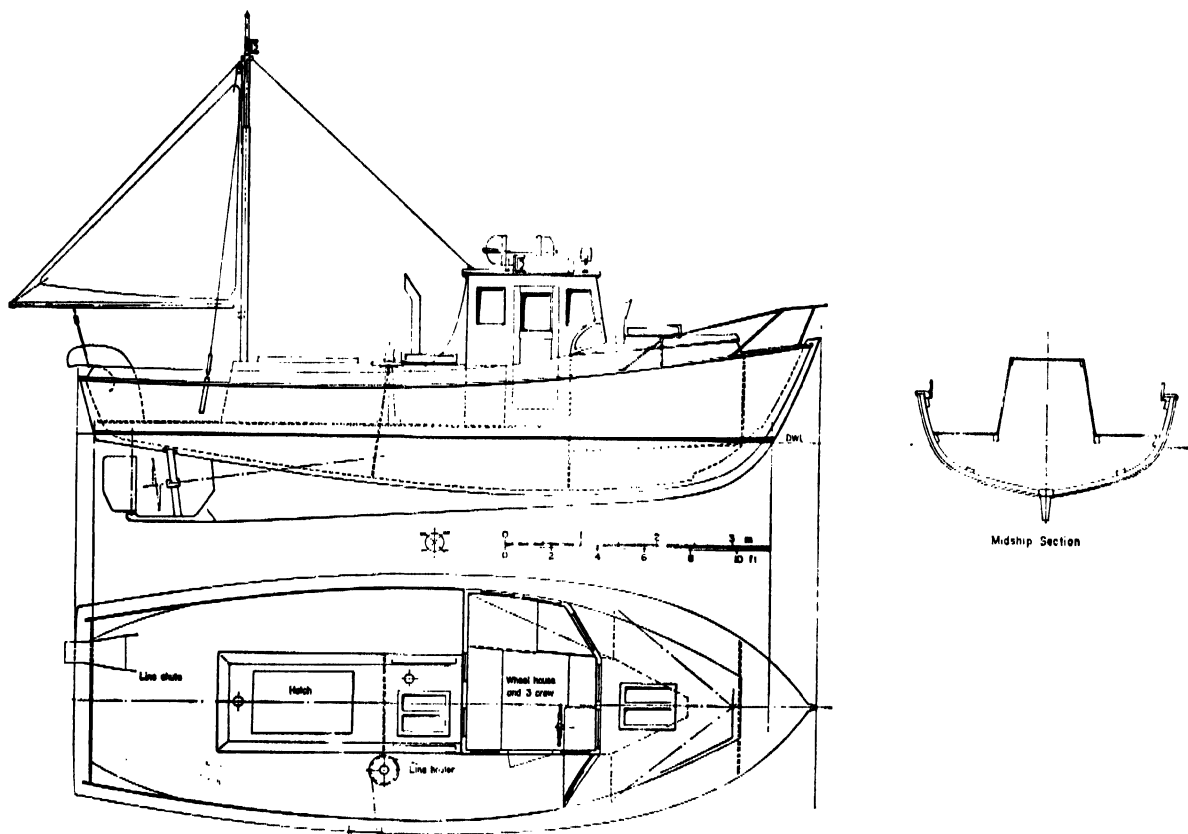
Fig 9. 32-ft (9.75-m) proposed vessel. General arrangement

A 32-ft (9.75-m) launch is also thought to be adaptable for various arrangements as to form and size of hold. Fig 8 and 9 show proposed lines and general arrangements. The main idea is to have a self-bailing working deck aft, where the crew have good protection. The version shown is a longliner with the hold in the form of a box on the working deck, with any additional catch stored in pounds. Accommodation for a crew of three is built into the wheel house. The main engine would be in the 40 hp, 1,500 to 1,800 rpm range with 2:1 reduction, which should give a service speed of about 7.5 knots.

Main data for proposed 32-ft type

Loa	32 ft 0 in (9.75 m)
Lwl (WL 3)	29 ft 0 in (8.86 m)
B max on planking	11 ft 4 in (3.46 m)
D	4 ft 7 in (1.40 m)
Displacement in salt water to Lwl	8.025 ton
LCB	at ,, 0.14 ft (0.0425 m) aft
Cp	,, ,, 0.590
$\frac{1}{2}\alpha_e$	,, ,, 28.0°

The two new types proposed would be constructed of wood, preferably with keel, stem frames and beams of laminated members, although heavy steam bent timbers may prove the best solution as frames for the 32-ft (9.75-m) type.

Special regard should be given to strengthening the parts of the hull most exposed to impact from ice and rocks, i.e. the foreship. By using laminated members and
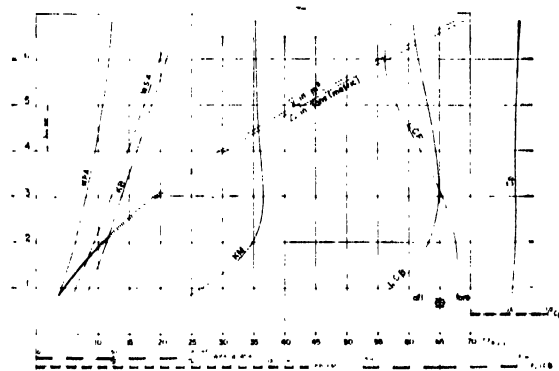
Fig 10. Hydrostatic curves for the 20-GT standard vessel

lighter engines a reduction in the light displacement of the vessels can be achieved. For both of the proposed types ballast should be carried in the form of iron and not in the form of costly boat-building timber, as previously practised.

STABILITY

Since 1962, even before it became compulsory for all Danish fishing vessels above 20 GT gross to have a proper stability analysis made, with cross curves of stability and an inclination test, all vessels sent to Greenland that were approaching 20 GT or above were analysed. The computer program developed at the Danish Ship-

[489]
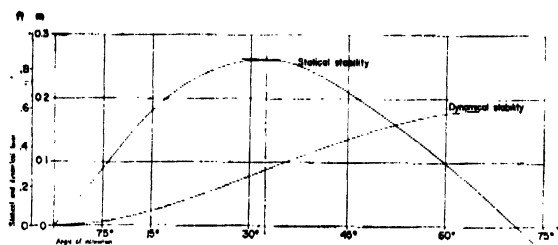
Fig 11. Statical and dynamical stability curves for the 20-GT standard vessel in light condition

building Research Institute was used to ensure uniformity in results. Fig 10 and 11 show the result of such an analysis.

CONSTRUCTION CHARACTERISTICS

The scantlings have been almost exclusively those given in the official rules for Danish fishing vessels, and so the vessels for Greenland have not been built heavier than the equivalent Danish vessels. It should, of course, be remembered that Danish scantlings are excessively heavy, and experience has shown that they are certainly not too light for use in Greenland. The typical relation between length in the waterline and light displacement is shown in fig 12.

In the opinion of the author they may even be reduced, and possibly a corresponding reduction made in the official Danish scantlings. Some smaller coastal vessels of wood sent to Greenland about thirty years ago and still in operation have, reportedly, much lighter scantlings than equivalent modern vessels sent to Greenland.

Construction materials have been almost exclusively white oak with the occasional use of beech for keels and keelson and for part of the bottom planking. For the small vessels pine and larch have been used for outside planking. Decks have been of pine. In the very dry climate, difficulties have been experienced in keeping the deck seams tight but in the last few years good results have been achieved by using rubber caulk in all deck seams.
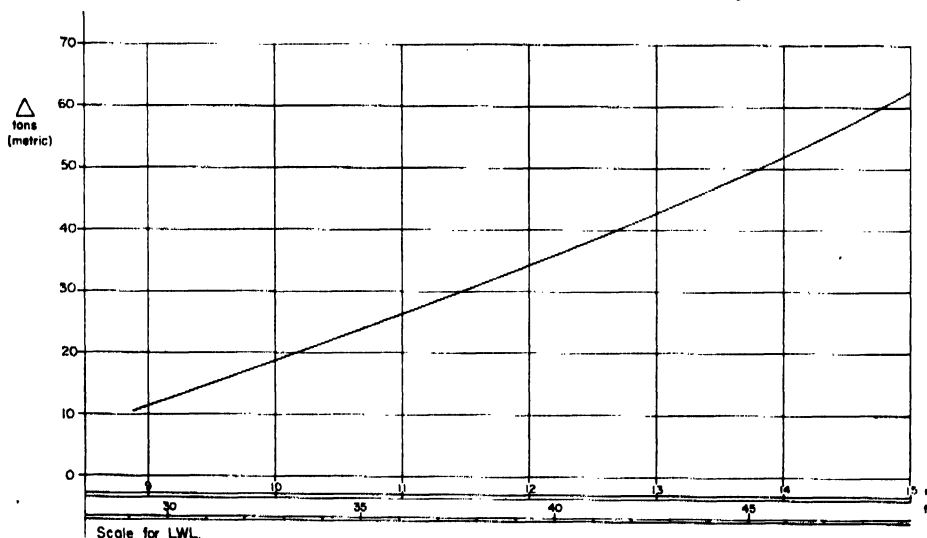
SPARE PARTS

The storage of spare parts in Greenland for standardized engines and equipment is well organized. Practically all workshops and repair yards are government owned, and they each have a store of spares so that the entire coastline is covered according to a central plan.

ICE PROTECTION

Hulls have to be well protected against chafing from ice. Initially, sheets of galvanized iron were used, nailed to the planking. Later, sheets of sea water-resistant aluminium proved a better solution because it was corrosion that eroded the galvanized sheets, and not deterioration due to ice chafing. A considerable area of the bottom is sheeted because pieces of floating ice are dragged along it. The sheets are nailed to planking starting from aft with about 2 in (50 mm) overlap and thickness of 0.04 to 0.08 in (1 to 2 mm).

Ice protection by wood has not been used except to give the clinker vessels, sent to Greenland, a smooth surface for securing the metal sheets. This partly accounts for the very few clinker-built vessels dispatched to Greenland. Various experimental attempts have been made for the protection of propellers, but for the small vessels described, the idea has been abandoned almost completely because the protection was of such a form that when the boats went astern bits of ice were virtually packed around the propellers. There was also a considerable loss of speed. As practically all fishing vessels in Greenland have controllable pitch propellers, damaged blades can be easily replaced.

The stem is protected by heavy galvanized iron bars above water, the stem and forefoot by a channel construction below. This, combined with a well rounded forefoot, gives added protection to the hull when hitting rocks, which happens several times a year. A reasonable rake of the stem gives better performance in ice conditions.

The factors above largely fix the whole shape of the fore end and this may be considered contrary to what

Fig 12. Curve of light displacement for standard vessels

some designers find is necessary for the shape of the foreship where over-icing is to be prevented. Icing on these vessels has not been experienced to a great degree, however, because operations are reduced during winter, length of trips are limited, and the shore always close at hand.

HEATING AND INSULATION IN ACCOMMODATION

Heating the accommodation is important. Normally, small oil burners of the type used in Danish fishing vessels are installed. Previously small coal heating/cooking stoves were used. With the introduction of gas for cooking and oil burners for heating, the existing coal stores have often obstructed good accommodation planning. Various methods, with hot-air circulation or radiators with hot-water circulation from central heating plant, have been tried, not so much in fishing boats but in numerous government-owned special purpose vessels. For cheapness and simplicity the small oil burner has not been surpassed and, therefore, is still used.

Living rooms are generally insulated between deck beams and along the inner planking of the hull. Material is mineral wool in thicknesses from $1\frac{1}{2}$ to 2 in (38 to 51 mm).

LOANS AND SUBSIDIES

Danish citizens permanently residing in Greenland may obtain a loan and/or subsidy for the purchase of fishing vessels under the following conditions: For vessels measuring 10 GT and below, loans are given up to 85 per cent of the total cost of the vessel delivered in Greenland, to be paid back over 10 years at 4 per cent p.a. No subsidy is given. For vessels above 10 GT a subsidy is given up to 20 per cent of the total cost of the vessel and loan for the difference between the subsidy and 90 per cent of the total cost of the vessel delivered in Greenland. Normally 20 per cent subsidy and 70 per cent loan is given. Loans to be paid back over 15 years at 4 per cent p.a.

CENTRALIZED PLANNING OF FISHING BOAT DEVELOPMENT

The foregoing, apart from being a general report on the development of fishing vessels in the vicinity of Greenland, has been to provide the background for general conclusions on the most efficient relations between the fishermen and the development planning body when separated by considerable distances; also on how the most successful vessels may be produced at any particular moment.

In this particular case, it must be borne in mind that the centralized planning authority controls the organization and administration of the development programme for an entire area for a considerable period.

The following is developed from the author's experience in the particular field, as a department naval architect and finally as a consultant, in this and associated fields.

The ideas proposed are not in practical use but the general proposal is to reduce the physical and technical distance between the fishermen and the controlling body by the intermediate links of masterfisherman, gear technologist, department naval architect and the consultant.

THE DEPARTMENT NAVAL ARCHITECT

Such a person may have had an education in naval architecture mostly founded on large ship design, and his knowledge of fishing boat architecture must stem from his own studies. It would be advantageous to all interested parties if he could be posted to the operating area when boat development is still at the initial stage of small boats, which will enable him to follow the technological development of the fisheries in that particular area and apply his basic knowledge in design theory and construction methods gradually as the requirements for bigger and more complex vessels increase.

On the other hand he could come from boatbuilding, having had some extra tuition in fishing boat architecture. This combination will often prove to be a very good solution and the only one possible in many cases. Naturally any keen person with some engineering education or a degree in science may also be given additional education and prove to be a useful department naval architect.

START OF BOAT DEVELOPMENT

It is rather obvious that the first proposals for boats, in a developing area, must come from the planning personnel and not from the fishermen, unless the local non-mechanized fishing boats are easily mechanized and improved so that they can be taken as a basis on which to work. In this case the fishermen may be useful to some extent. The idea of using local craft as a basis for boat development is difficult, because while it may be assumed that the modification of a local type is an initial step that a fisherman will accept, in most cases it is difficult to attempt to modify a local craft incorporating modern design features of hull form, adequate accommodation and cargo space and an effective fish deck arrangement.

On the contrary it has generally been proved that fishermen do not mind relinquishing their local traditional types and accepting a modern functional and well planned design, if such a boat will catch more fish and increase his net income.

DEVELOPMENT UNDER WAY

It is assumed that boat development is well under way and larger and more complex vessels are planned. So far the department naval architect has been able to cope with the design work alone, even with the gradually increasing volume of correspondence, relevant and irrelevant, specifications, etc. that are considered as part of his work.

A stage is reached when the situation requires more help in handling the more complex boat designs, especially if a standard design is to be developed where the extra care needed will require more work.

The fact is that the department must be expanded with a larger staff, that several boatyards are approached or a consultant employed for specific work. If the department is expanded, Parkinson's Law will most probably come into effect and soon the staff will do design and drawing work only occasionally, employing most of their time in administration and consultations with equipment manufacturers and boatbuilders.

If a boatyard, which has a design or will produce the required design for a specific purpose, is approached, the department is more or less dependent on that one boatyard since one builder will not normally allow other yards to construct his design. But given a boatyard with sufficient capacity and the right prices, this arrangement is definitely feasible.

Co-operation with a consulting naval architect, however, will in many cases be the best arrangement from the department's point of view. A consultant specializing in fishing and related vessels has the latest research in this field at hand, and is a good medium for contact with a research institution where he can advise on tests to be performed either by models or full scale. The consultant is, moreover, only paid for actual work done and he works to a specified time deadline that he must do his utmost to maintain if he intends to stay in business.

The department naval architect, for his part, should know the requirements of his department and have the most direct contact possible with the fishermen, gear technologists, fisheries biologists, loan board and national ship inspection. He also understands the same technical terminology as the consultant.

DECISIVE FACTORS IN DEVELOPMENT

It must be emphasized that factors, such as specific fishing techniques for the area, availability of different species of fish at certain seasons, distance to fishing grounds, policy of loan and subsidy for procurement of vessels and gear, naturally are all very decisive when selecting the size and type of boat. Furthermore, decisive factors valid when one type is planned may be completely different only a few years later. Within one set of factors there may have to be modifications in the light of performances of vessels already in service.

REPORTS ON MODIFICATIONS

Reports on essential modifications should come from the fishing grounds, the fishermen, those who maintain the boats at the location, or management of shore installations, etc. Typical reports may be on a deficiency in seaworthiness, speed, deck space, gear, hold space, crew's accommodation, etc. These are the design factors the naval architect should correct and incorporate when planning what may be termed as the second generation of boats. How does the department naval architect, in his often distant headquarters, manage to obtain such reports, in clear language, giving relevant concise information with the application of a boat designer's terminology?

It is imperative to have as full information as possible about the boat at the design and trial stage, such as hydrostatic curves, cross curves of stability, results of inclination tests, capacities of hold and fuel tanks, a hp against speed curve for the full-sized ship, propeller calculations, etc. Only with such essential background material can there be any real hope of analysing and interpreting the gathered information correctly. Such material has until now only been available for much larger vessels but, when many boats are to be built to one standardized design, it is considered important to carry out many more calculations for boats in the 20-GT range.

Reports should be collected as a combination of design and trial data, on-the-spot observations by the department naval architect or his staff and a systematical collection of reliable data for the vessels in actual operation.

When fishermen, who have only used primitive craft, are beginning to acquire larger mechanized and decked vessels, it takes some time before they can form an articulate criticism in technical terms, so that an improved second generation of standard boats can be planned and designed. In fact, this even seems difficult for many fishermen in highly developed fishing countries but it is believed that fishermen can be educated and encouraged to give the required information about the behaviour of their boats. The completion of questionnaires with the aid of local fisheries officers, shore plant managers, or the personnel from workshops and repair yards is one solution.

The main scope of the questionnaires should be to form a supplement as close as possible to the design and trial data already at hand. The questions for the smaller should be fewer and less comprehensive than for the larger types, and then again the degree to which information is collected should not be higher than justified by the amount of design data available or its eventual use.

The main object must be to work systematically and apply a step-by-step development in the technique of gathering and using the collected information.

STANDARDIZATION

Standardization means the construction of a number of boats from the same set of drawings. One may have a different size of engine and a different arrangement on deck and still call it a standard boat. The advantages of producing a number of boats from one design are many. Primarily, it is economically possible to carry out more detailed calculations ensuring a better design, to carry out model testing, stability investigations, etc., than when a design for only one or two boats is made. More detailed drawings can also be done and this ensures a better end product.

Construction costs for standardized vessels may be higher or lower, depending on whether a few yards are building many vessels in succession or smaller yards are building only one or two. These costs may be reduced, however, even if built in smaller yards. One way is prefabrication of sectional elements by gluing and assembling these elements at a central laminating plant. This method assures a uniform good quality of all the important construction members and, by pressure

treating the wood laminates prior to gluing, a very effective protection is achieved against fungi attack.

Standardization also facilitates inspection work during construction. In collecting data for planning the next generation of boats it is also probable that more reliable information will be obtained with many owners operating the same type of boats.

Standardization of hull construction has, of course, reached only an intermediate stage. Engine make and preferably engine size, gear and equipment should be standardized as much as possible, and a stock of spare parts and replacement parts should be maintained at key points in the operational area. An untold number of valuable fishing hours have been lost because spares were not available at reasonable distances from the landing places.

For the type of fishery development dealt with here it is only natural that the stocks of spares are financed by the government and stored in association with governmental workshops. If the maintenance yards and workshops are privately owned it could hardly be expected that they should maintain stocks of the rather extensive range of spares necessary if the arrangement is to be efficient.

Standardization does not mean that such a design can be built until it is forced to be changed by the overwhelming demands from fishermen, or their representatives, to produce something superior. The correct procedure must be, as soon as one design is launched, to start immediately preparing the possible changes so that the next generation design can improve on it; after a reasonable period of time, when the amount of systematically collected data has reached the appropriate level for reliable decisions to be taken, the revised design should be finalized. The proposals for such second generations of boats should include various alternatives. An excellent idea would be to construct perspective sketches drawn with the proposals viewed from various angles. This will demonstrate more clearly the appearance of the boat for those who are not used to considering normal projection design plans.

All the material prepared should be submitted to the operational area for comment and suggestions by fishermen or their representatives. All administrative organizations who are involved in the approval of the design, such as loan board, ship inspection, insurance companies, should also have the plans. Only after having taken all the proposed alterations into consideration should the actual detail design work start.

Where development of fishing is done with governmental support, approximately as outlined above, the technical achievements obtained in the process should not be retained as the secrets of the particular government departments but should be made available for the benefit of the private sector of fishing boat development. Such material should include reports on experiments with improved and more modern building materials, new techniques in construction and should add material to the current debate on improved stability, seakindliness and economical operation.

The Advantages and Uses of High-speed Fishing Craft

by John Brandlmayr

Avantages et utilisations des bateaux de pêche rapides

L'auteur examine les bâtiments de pêche à grande vitesse d'une longueur comprise entre 30 pieds (9,15 m) et 40 pieds (12,20 m), et fournit des données reposant sur une étude de la pêche aux filets maillants dans le Pacifique Nord-Ouest couvrant la période 1955–1965.

Les bâtiments de ce type, d'une vitesse maximale de 10 à 20 milles à l'heure (alors que les anciens bateaux ne dépassent pas 8 milles à l'heure) sont assez prisés, bien que le gros de la flottille du Pacifique Nord-Ouest appartienne à la catégorie des bateaux plus lents. On estime qu'un fond en "V" relativement étroit est celui qui convient le mieux. Parmi les matériaux de construction adoptés figure le contre-plaqué revêtu de polyester renforcé de fibres de verre, les alliages d'aluminium, ou le plastique renforcé moulé d'un seul tenant. Les bâtiments rapides construits en bois selon le schéma classique (membrures, lisses et bordé) ou en acier sont dans l'ensemble trop lourds pour les fins recherchées. La plupart des bateaux à grande vitesse sont équipés de moteurs à essence, les diesels n'ayant eu qu'un succès limité.

Le principal avantage des bâtiments rapides semble résider dans le fait qu'ils permettent de raccourcir d'un tiers la durée des sorties tout en consommant à peu près la même quantité de carburant.

Ventajas y aplicaciones de los pesqueros rápidos

Se estudian pesqueros rápidos con esloras de 30 a 40 pies (9 a 12 metros). La información presentada se basa en la experiencia adquirida con la pesca de enmalle en el Pacífico noroccidental entre los años 1955 y 1965.

Barcos de este tipo, con velocidades máximas de 10 a 20 nudos, gozan de cierto favor frente a otros más antiguos que no pasan de unos 8 nudos, aunque casi toda la flota del Pacífico noroccidental es de embarcaciones más lentas. Los materiales de construcción admitidos son la plancha de contrachapado con revestimiento de poliéster reforzado con fibra de vidrio, aleaciones de aluminio o fibra de vidrio moldeada, enteriza. Los barcos rápidos construidos por el procedimiento ordinario de planchas y cuadernas, o con acero, resultan generalmente demasiado pesados para estos fines. La mayoría de los barcos rápidos llevan motor de gasolina, y los diesel dan resultados limitados.

Las principales ventajas de los barcos rápidos parecen consistir en que hacen una singladura en las dos terceras partes del tiempo empleado por los tipos normales más antiguos, mientras que en la misma distancia recorrida consumen, aproximadamente, igual cantidad de combustible.

HIGH-SPEED fishing vessels of 30 ft (9.14 m) to 40 ft (12.19 m) in length have become well established in the gillnet fisheries of Oregon, Washington, British Columbia, and Alaska.

A number of different designers and builders have been involved with this class of vessel but the author will deal primarily with one basic hull form. This particular form appears to be well adapted to speeds from 10 to 20 knots and to be reasonably effective even below 12 knots.

It is estimated that about 1,000 gillnetters of this general type and speed are in service in 1965. A few more highly powered, faster vessels have been built but since no repetitive pattern of building them has been established their construction is considered exploratory.

ADVANTAGES

High vessel speeds are of greatest advantage in locations where man-hour costs are high and where fishing is open for short periods of time as in the North-American Pacific Coast gillnet fishery.

Speed must be related to the value placed on the fisherman's time and on the amortization of investment in vessel and gear. The fact that there is a general but very gradual increase in speed of fishing craft throughout the world indicates the obvious desirability of speed. On most fishing grounds there are now a few small vessels in operation designed to operate at speeds 50 to 100 per cent higher than their conventional counterparts. Currently the economics are against such craft in all but a few applications. With rising values of labour and improvement in boats it seems certain that before many years extra high-speed craft will become increasingly important. Possibly the hull type described in this paper may be used for a significant part of the world's fishing fleet under 50 ft in length and applications may even be found for larger similar hulls.

Planing hulls have long been in common use for yachts, military and some commercial craft. Limited knowledge and poor control of construction has plagued the development of planing hulls so that actual performance is often far short of that anticipated. This difficulty is most pronounced in the case of relatively heavy vessels with marginal power. Fishing vessel adaptations invariably fall into this category. The problem is aggravated by the fact that builders and operators do not realize the importance of weight nor of efficient propulsion and designers tend to calculate for ideal conditions.

HULL FORM AND POWER

To achieve a high speed in the light condition it is necessary to build a hull of suitable form and power and to keep the operational weight to a considerably lower value than permissible with conventional craft. The vessels must still be able to carry a load of fish

Fig 1. Typical lines of a 36-ft (11-m) gillnetter

nearly equal to conventional craft and to return home at a lower but still economical speed with this load of fish. The speed when fully loaded may be about the same as for a conventional vessel. A planing hull can only offer substantially higher speeds when carrying no load or a light load. In the case of Pacific Coast gill-netters it is important to reach the fishing grounds quickly and to move at high speed with a light load. A full load is rarely carried.

A final primary requirement is that the vessels must be seaworthy in light and loaded conditions although speed would be reduced to suit the weather conditions.

A typical hull form is illustrated by the 36-ft (10.97-m) gillnetter (fig 1). This general form and proportion has been used since 1959 and compares favourably in service with others on the basis of low resistance through the 10 to 20 knot speed range, sea-kindliness and sea-worthiness. The form was based on previous gillnetter hulls first built in 1955 and is similar to that used for low-powered planing pleasure boats.

Length overall	.	.	*Loa*	36 ft 0 in (10.97 m)
Length designed waterline	.		*Lwl*	32 ft 8 in (9.96 m)
Beam overall	.	.	*B*	11 ft 0 in (3.35 m)
Beam at waterline	.	.	*Bwl*	9 ft 4½ in (2.86 m)
Volume of displacement at				
waterline	.	.	∇	197 ft³ (5.58 m³)
Displacement at waterline	.	Δ	5.6 ton salt water
Longitudinal centre of				
buoyancy	.	.	*FB*	56.5% *Lwl*

This particular form is well regarded by most fisher-men who have had experience with it. They feel that fish-carrying capacity is adequate and have found con-struction costs about the same as for slower conventional craft.

The form is characterized by fine forward sections to minimize pounding and flat after sections for most

efficient planing with a comparatively heavy planing hull and limited power. This hull is narrower than most planing forms since it is designed for a wide speed range that might be considered at the bottom of the planing range and down into the upper part of the dis-placement range.

Alton (1959), Ashton (1949), Clement and Blount (1963), Lord (1963), Murray (1950), Saunders (1957) and Savitsky (1964) have presented important model test data which were studied by the author and his design associates and which have assisted in gaining an under-standing of planing hulls. The form shown did not originate directly from this data but evolved from a process of selection by user preference.

It is probable that slightly more rise of floor aft and slightly fuller sections forward would produce a better hull. The author's firm has been developing data for a standard series of hulls expressed in dimensionless units with corresponding performance values for a wide range of sizes and displacement conditions. It is hoped that quick performance predictions can thereby be made with a higher degree of reliability than is at present available.

PERFORMANCE DATA

Performance data under service conditions have been gathered for the published hull form and expressed in a speed, power and weight diagram. In all cases a single engine turned a propeller set in a wood or metal skeg, with the stern bearing supported by a strut and with a shoe extending from the skeg to the bottom of the rudder. Reported and observed performance varied by plus or minus 20 per cent. This great variation is chiefly attri-buted to the considerable effect of variations in all the factors that influence performance and is partly due to the inexact method of gathering operational information.

Fig. 2 Mean performance record of
a group of 36-ft gillnetters

The most reliable figure is the top speed at full power in the light condition. The remaining portions of the curves are very approximate but serve to illustrate the character of this form and propulsion system under various load (displacement) conditions. Fig 2 illustrates the mean of available performance records. The mean performance has been checked against data from other published sources and correlation has been found within 12 per cent.

Using the 5.36 tons (12,000 lb) curve which represents the light condition the speed power curve rises in typical fashion up to 11.6 knots at 140 hp. At this point the dynamic lift of the hull is very pronounced but the spray rail clears the water from the topsides, although the water closes back on to the topsides for the after 3 ft (0.91 m). The transom breaks clear along the bottom. The slope of the speed power curve is reduced in this area and above this speed is typical of planing hull forms. At 280 hp the curve rises to 18 knots.

With increasing weight on board, the transition from displacement to planing characteristics occurs at higher power outputs until at 7.15 to 8.05 tons (16,000 to 18,000 lb) the transition is barely discernible.

Running trim aft throughout the speed range is about 1¼° to 2° relative to static trim and is at its maximum just before the spray rails clear. None of the hulls were observed with more than 3¼° of trim at this speed and all tended to flatten out again at higher speeds.

The curves are based on the following figures:

Δ tons	(lb)	70 hp	140 hp
5.36	(12,000)	8.0 knots	11.6 knots
6.24	(14,000)	7.2 ,,	10.4 ,,
7.14	(16,000)	6.5 ,,	9.4 ,,
8.04	(18,000)	5.9 ,,	8.7 ,,
8.93	(20,000)	5.5 ,,	8.3 ,,

tons	(lb)	210 hp	280 hp
5.36	(12,000)	15.2 knots	18.0 knots
6.24	(14,000)	13.9 ,,	16.9 ,,
7.14	(16,000)	12.2 ,,	15.5 ,,
8.04	(18,000)	11.0 ,,	13.3 ,,
8.93	(20,000)	10.3 ,,	11.9 ,,

Of course with a propeller designed for best light load performance the available engine power gradually falls off when the hull is more heavily loaded and top speeds are lower.

During trials of these hulls it was the author's impression that a considerable increase in speed occurred for a small increase in power once the spray rails started to clear the water from the topsides, but not as pronounced as anticipated.

The spray rail shown in fig 1 and in fig 3 is not satisfactory. A good rail should act as a wave deflector and should extend from about 1.5 ft (0.46 m) aft of station 0 to 1.5 ft (0.46 m) aft of station 9 and its lower surface should be 2 in (50.80 mm) wide and horizontal and

should be in line with the chine. A sharp reverse in the spray rail will break spray into a fine wet mist. Omission of a spray rail will allow the bow wave to flow up the topsides and greatly increase resistance, thereby reducing speed.
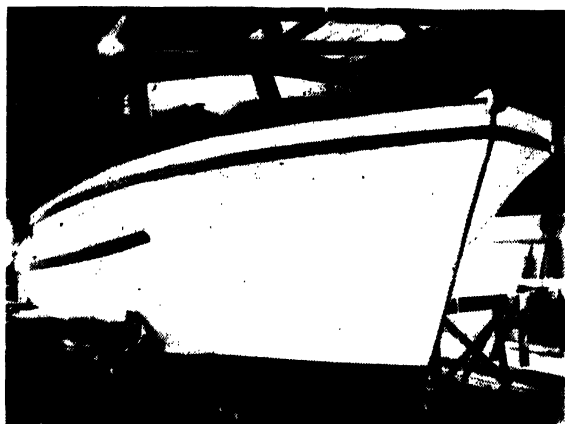
Fig 3. Plywood gillnetter

Leonard Alton, owner and skipper, reported in 1959, on approximately the following lines, the comments of a skipper on the boats under consideration:

● They were built primarily for speed and this will be of great interest to other fishermen. A run from Nanaimo to the Fraser lightship was timed on a calm day with all fishing equipment on board and fuel tanks half full and the average cruising speed was 15.1 knots. The vessel was powered by a converted car engine rated at 380 hp for car use. Converted for marine use with a 2.5 : 1 transmission, it produced about 300 hp. The engine was run at 3,100 rpm, but when increased to the full 4,400 rpm the boat would plane at 20 knots. Propeller was 23 in (585 mm) diam and 20 in (508 mm) pitch

● For high speed the displacement must be small and, with more than 70–80 salmon aboard, the boats perform as a normal displacement type gillnetter but had carried 3,700 lb (1,678.3 kg) at 10 knots

● It was a good sea-boat in the west-coast fishery conditions, having a shorter period of roll, and the lower beam probably accounts for the fact that, although 99 per cent of the San Juan gillnet fleet use stabilizers, they were unnecessary for this vessel

● At planing speeds in heavy seas there was some pounding but this only happened in short choppy waves. At higher powers this was eased and in a long swell the vessel ran smoothly

● The higher speed shortens the voyage time and it is possible to overcome strong tides instead of waiting

● The wide beam also provides ample room not only around the net and in the afterwell, which makes for easy handling and accessibility to the catch, but for good net and steering layout

CONSTRUCTION METHODS

Wooden

While some well-built conventional frame and plank wooden vessels operate at the speeds in question, it is the author's opinion that more sophisticated materials and methods of construction are required. Standards of high strength and light weight are so severe that shipyards accustomed to conventional craft can rarely meet them until they have built several boats. The initial
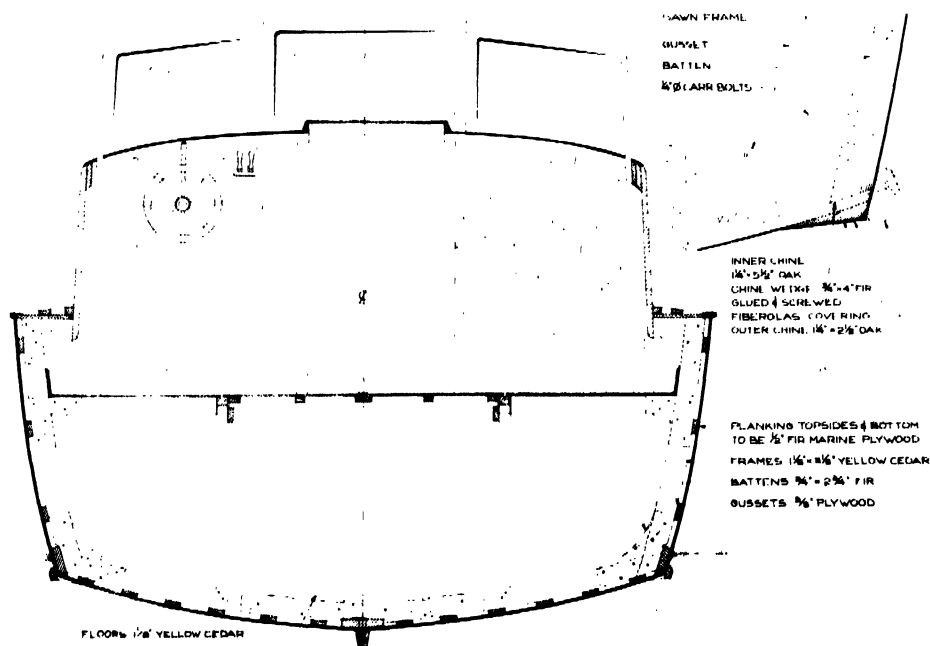
Fig 4. Typical section for plywood/fibreglass construction

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results are either too heavy, in which case performance suffers greatly, or the structure fails to withstand the stresses imposed.

Composite plywood and fibreglass

Carefully built craft designed with light wooden web frames and closely spaced longitudinal stringers planked with full-length marine plywood and sheathed with fibreglass provide a high strength to weight ratio as well as the ability to resist abrasion and other service deterioration. Using these materials boats can be economically built either individually or in small numbers. A typical structure of this type is shown in fig 4 and fig 5. It represents the lightest construction found to be
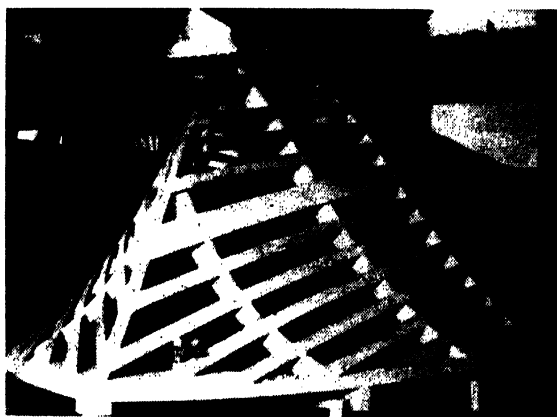
Fig 5. Plywood hull under construction

reasonably serviceable and most 32-ft (9.75-m) to 40-ft (12.19-m) hulls have a slightly heavier structure particularly with respect to the transverse and longitudinal framing.

With regard to durability of this comparatively recent method of construction, we have personal knowledge of a gillnetter in use for over ten years. Her owner recently reported that, although she had been used continuously, the boat was still in apparently very good condition and that the bilges were dry. This particular boat is illustrated by fig 6.

Moulded fibreglass

Moulded solid fibreglass shows great promise when the design and fabrication is competently handled. Quantity
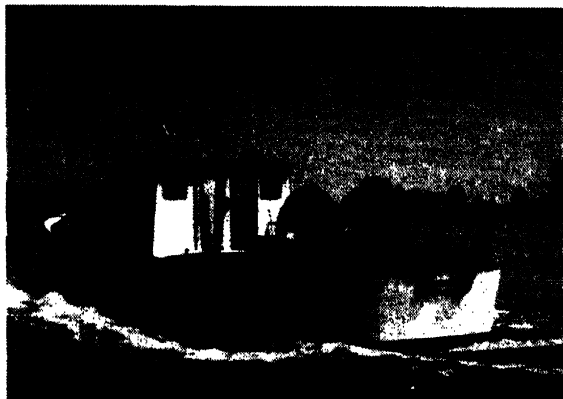
Fig 6. A 34-ft plywood gillnetter built in 1955 and still in use

production is essential for reasonable building costs and about 20 vessels should be the minimum quantity. Design and construction techniques have been well developed and published but there has been a tendency to underestimate the skills required.

Fig 7. An American aluminium alloy gillnetter

Aluminium

Aluminium alloys are the logical answer for a high strength to weight ratio. Again skilled handling of the design and construction is essential as is quantity production. Fig 7 and fig 8 show a welded aluminium gillnetter built by Marine Construction & Design Co., Seattle. Costs of construction and minor problems in maintenance have interrupted continuous building in the North-west Pacific. More experience with this material should lead to its increased use. It should certainly be considered by any group able to undertake a long-term programme of development and construction.

Fig 8. Two American aluminium alloy gillnetters

Steel

Steel is not suitable for construction of this class of small high-speed craft, except possibly in some of the best equipped shipyards working with high-strength alloys. The few vessels built in steel have been too heavy and, in general, shipyards have been unable to adjust to the strength to weight standards required nor to follow designers specifications. Costs of very light steel work have also been higher than for other materials.

POWER CHOICE

Light, high-speed gasoline engines are the normal power choice. A typical power plant is a single engine of about 425 in^3 (0.007 m^3) piston displacement producing 280 hp at 4,000 rpm and equipped with a 2.5 to 1 reduction

gear. This unit weighs approximately .446 tons (454 kg). Some fishermen are very careful in the tuning and maintenance of their engines and these men are best able to utilize the performance potential of fast boats.

A few installations of high-speed diesels have been satisfactory but due to excessive weight and lack of power, diesels, on the whole, have been unsuccessful. It is felt that with the further development of hull forms and light structures fast diesel powered craft will gradually find a place. If the builders can meet the designer's specifications, a new boat designed by the author's firm should provide a practical fast diesel gill-netter. However, its initial cost will be somewhat higher than other types. It is possible that the overall economics of operation will be better than for either the fast gasoline engine-powered boats or the slow diesel-powered boats.

ECONOMICS

The author does not feel qualified to discuss the operational economics of this type of fishing vessel or to compare it with others. In fact the income and cost figures are so vague and clouded by fishing limitations, regulations and other factors that an economic study using hypothetical examples is probably all that can be accomplished. The authenticity of figures used for such a study is questionable.

Some of the most aggressive and capable gillnet fishermen own the fast gillnetters and a statistical comparison could easily demonstrate greater earning capacity. Possibly credit for this goes to the men to a greater degree than to the boats.

Some comparisons can be made. Except for attempts to produce fast diesel-powered boats the first costs are about the same for good well-equipped gasoline engine-powered planing units and equivalent displacement gill-netters with the same gasoline engines or less powerful diesels. Carrying capacity is not important and the maximum is practically never used. Displacement types have greater carrying capacity but this is no advantage under current conditions.

The chief difference is that the modern displacement gillnetter cruises at 8 knots while the planing counterpart does 12 knots. There are claims of equal hourly fuel consumption rates. A more conservative and frequently demonstrated situation finds both types using about the same quantity of fuel over a given distance but the passage time is in the ratio of 3 to 2.

Fishing with the aid of an outboard on Lake Maracaibo, Venezuela

Discussion : Design of small boats

IMPROVEMENTS OF CANOES

Stoneman (Uganda): In Uganda where fishing takes place on 13,000 square miles of fresh water, lakes, rivers and swamps, of the 6,000 fishing craft in use, 40 per cent are still dugout canoes. A programme of replacement by more modern types of craft is being carried out, but due to the long life of some dugouts, the relatively high cost of replacements and the restricted building capacity for improved boats in Uganda, the dugouts will be in use for many years to come. Dugout canoes are still being made for some uses and are still preferred by some fishermen to more advanced craft.

In Uganda dugouts are normally single hollowed logs of hardwood, many species being utilized, though palm tree logs (highly unsuitable in many ways) may be used if nothing

paddles or poles. The longest dugout recorded from Uganda was 70 ft (21.3 m) long and had a beam of 4.5 ft (1.4 m). This exceptional canoe was used as a ferry. Such canoes are not seen nowadays and the trees for their construction are no longer available.

Method of making and cost

Many species of timber, depending on the availability are used. Suitable trees, at one time free to canoe builders, are now hard to find, a royalty of £5 ($14) per tree is payable in most instances to the Forest Department. Professional three-man teams of diggers with specialized hand-forged tools select and fell a tree and trim it roughly to the shape then and there, while the timber is still wet. It must then be transported to the lake side, as final trimming and hollowing out

Fig 1. Typical dugouts on River Nile

Fig 2. Final hollowing out of 30 ft dugout beside Lake Albert

else is available. On sheltered rivers, small lakes and swamps, small canoes up to 20 ft (6 m) long with 18 in (.45 m) beam and 1 ft (.3 m) depth are used, often very roughly finished, although this type is highly developed on the Albert Nile River, fig 1. Here the fishermen may live in their canoes for days at a time, the craft having a clay fire hearth amidships, papyrus mat resting on the gunwhales for shelter at night, and forked-stick outriggers to carry poles, paddles, hippopotamus and crocodile spears and so forth. These canoes too are exceptionally long-lived, many still in good condition having been passed down from father to son until the age (certainly over 50 years) has been forgotten. On the open lakes, Albert, Kioga and Victoria, much larger canoes are employed. These may be up to 40 ft (12 m) long with 3 ft (0.9 m) beam. Skilfully handled, they can be used in rough water carrying up to 1 ton of nets, gear, fish etc. At one time it was common for such canoes to make 150-mile coasting voyages, crossing 20-mile stretches of open lake under

relies on floating the unfinished canoe at intervals to determine the balance and stability. This three-man team will complete a 30 ft (9 m) canoe in five to six weeks; the prospective owner supplying them with food during this time (fig 2). When complete, the side of the canoe will be under 1 in (2.5 cm) thick and show considerable tumble-home as they follow the curve of the original log. The bottom and ends are 2 in (5 cm) thick, the end grain of the ends often splitting and falling out even before the canoe is finished. This requires repair work before it can be put into use. Most dugouts have blunt "swim-head" bows and stern, but on Lake Victoria roughly-shaped stems and canoe type sterns are carved out of the solid. Here too the canoe may be widened by wedging apart the gunwhales when the timber is still green.

A small 20 ft (6 m) canoe in a remote area may be as cheap as £20 ($56), a price which has not changed for 30 years. The large 40 ft (12 m) type at a busy and, by Uganda standards, efficient landing will still cost only £60 ($170). These prices would be grossly uneconomic to the builder if

he attempted to cost his labour etc. on commercial lines, but like many other primary costs in Uganda depend on the factor of "nil opportunity cost" where the producer's time and effort would not otherwise be utilized at all. While acceptable in the undeveloped Ugandan economy, this type of production makes it very difficult for other boatbuilders, working on commercial lines with salaried employees, to compete in price.

Despite its primitive appearance and connotation, the dugout as used in Uganda has certain definite advantages. First, cost is low and the life is long, 20 years at the minimum. Maintenance can be and often is nil and the craft is almost unbreakable. Even if swamped and capsized in surf the canoe can be left to wash ashore and recovered undamaged at leisure. The draught is small, rarely more than 6 in (0.15 m) and the long, smooth gunwhales and hull, free of projections of any kind, are ideal for the easy handling of gill and seine nets. It can easily be beached, being rolled up on shore like a log by two or three men. Against this, of course, the dugout is extremely slow and inherently unstable, it demands skilled handling even in calm water, and is most uncomfortable for the occupants. The hull shape ensures that bilge water, gear, fish and passengers all try to occupy the same space. Space inside the hull is so limited that only the minimum amount of attention to the gear or the catch can be carried out afloat. The instability is perhaps the greatest single disadvantage and leads to considerable loss of life annually on Ugandan lakes through swampings and capsizings.

produce annually more than 35,000 tons of fish. With the exception of Lake Tanganyika, it is largely a gillnet fishery in shallow water. Craft used are the traditional dugout canoes which in some fisheries, e.g. Lake Mweru, are quite seaworthy. These craft are very variable in dimensions and in their

Fig 4. Typical lake canoes in Zambia

standard of construction; but generally are about 17 ft (5.2 m) long, 2 ft (.61 m) wide and 17 in (.43 m) deep. A selection of dugout canoes are illustrated in fig 4. There is some unsponsored development beyond the dugout on Lake Tanganyika, where 18 ft (5.6 m) flat-bottomed fishing boats and 30 ft (9.15 m) flat-bottomed transport boats are made locally.

Fig 3. Large dugout converted to outboard power on Lake Albert

It is difficult to visualize much improvement to the basic dugout canoe. If a better type of craft is required, the fisherman turns to one of the modern, open, plank-built fishing craft widely used in Uganda. Minor changes to the dugout, such as floor boards, thwarts and so forth at once detract from its basic and major advantage of simplicity and lack of maintenance. Some few larger dugouts have been powered with low hp outboard motors with slight success, fig 3, but generally, once a fisherman has decided to get away from the simple dugout he turns to one of the more advanced boats straight away.

Zambia's lake canoes

Heath (Zambia): Zambia although situated in the middle of Africa has large lakes, rivers, flood plains and swamps that

These craft show Arab influence and a feature of them is the naturally-grown frames and knees cut from tree branches crudely fashioned and fastened with wire nails—they are unpainted yet reputedly last up to 15 years. On Lake Mweru, "Chombos" up to 50 ft (15.25 m) in length were built and operated by Greeks.

The demand for dugout canoes over the years, coincident with the increased development of the fisheries, has resulted in suitable trees becoming harder and harder to obtain; the Mweru fishermen at one time were hauling dugouts 40 miles (63 km) to the Lake.

In 1954 a boatbuilding school was set up on Lake Mweru under a Master Boatbuilder with the object of designing a suitable craft to replace the dugout, which could be made by locally-trained boatbuilders from local plank timber.

Fig 5. 23 ft (7 m) banana boat in Zambia

WEDGES

CLENCHED COPPER NAILS 2½ IN X IC

CLENCHED COPPER NAILS
TWO BETWEEN EACH TIMBER 1½ IN X 12g

COPPER NAILS
2½ IN X 8g CLENCHED KEEL TO HOG
AT 3 IN CENTRES

BOLTS 4 IN X ½ IN

SPACING BLOCKS
3 IN X 3 IN X ¾ IN

HOG 5 IN X 1½ IN

KING PLANK 3 IN X 1 IN

BOLTS 5 IN X ¼ IN MUSHROOM HEAD

PLANKING ½ IN HARDWOOD
¾ IN SOFTWOOD

RISERS 3 IN X 1 IN FASTENED 2½ IN 12g C/S SCREWS

RUBBING STRAKE 2½ X 1 IN SCREWED AT TIMBERS
3 IN X 12g C/S

THWARTS 12 IN X 1 IN

GUNWALE -TIMBER-PLANK THROUGH
FASTENED 3 IN X 8g CLENCHED COPPER NAILS

CAPPING ½ IN DEAD NAIL
FASTENED

NSOMS 1½ IN

TIMBERS 1½ IN X ¾ IN SPACED 10 IN CENTRES

FORE AND AFT KNEES 2 IN SIDED

Fig 6. Construction drawing of Zambia banana bout

0   1   2   3   4
SCALE FEET

ELEVATION

PLAN
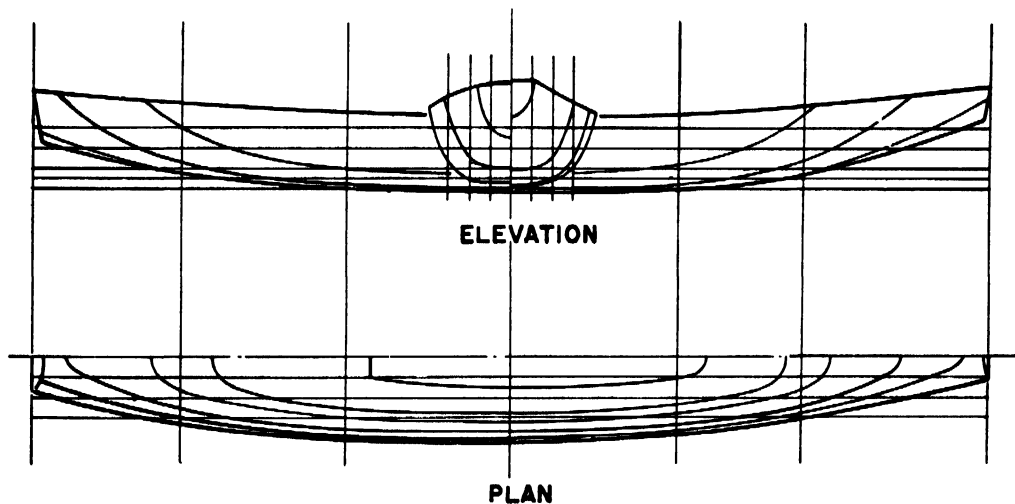
Fig 7. Lines drawing of Zambia banana boat

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In considering a suitable design as replacement for the dugout the following factors had to be taken into account:

● The craft must be paddled; rowing had been tried and was not accepted by fishermen and was of no use in narrow swamp channels
● Craft must be such that an outboard could be used if required
● Craft must be a good "sea boat" at the same time manageable in narrow shallow swamp channels
● Craft must be simple in design, made from local plank timber and constructed by locally-trained craftsmen
● Craft must be serviceable without excessive maintenance
● Craft must take fisherman and up to three or four crew and nets

To satisfy these requirements, the West-Ireland Curragh appeared to have the greatest possibilities. This craft, built traditionally as a wooden frame covered with heavy canvas, is very seaworthy. Experimental craft were built of similar shape, but planked both carvel and clinker, with different amounts of fore and aft rocker and slightly varying dead rise. Dimensions of 23 ft × 4 ft 5 in × 1 ft 10 in (7 × 1.35 × .56 m) moulded depth were chosen finally. Demonstration trips with outboard powered craft to all fishing camps along Lake Mweru were made, a favourable response being shown immediately by orders. So was born the plank canoe, or as it is commonly known in Zambia the "banana boat" so nick-named because of the banana-like shape, fig 5.

Fig 9. 23 ft (7 m) banana boat completed

Suitable locally-available timbers are—mulombwa (*Pterocarpus angolensis*) for planking and general construction—mupapa (*Afzelia quanzensis*) timbers (steamed ribs). These timbers are hardwoods and first-class boatbuilding timbers—the latter lending itself to steaming. With one boatbuilder and two helpers/learners, a craft can be planked in six days and be completed in three weeks. With regular maintenance and

Fig 8. 23 ft (7 m) banana boat lifted off mould/jig and ribs steamed in

The lines and construction plans of the round-bilged canoe are illustrated in fig 6 and 7. No machine tools are used in construction. All plank joints are scarfed and scarfs staggered, wedges are fitted under timbers in way of garboards, with space left to form limber holes. All edges of timber are chamfered or rounded to save snagging nets. The hull is built upside down on moulds permanently fixed to the floor or jig. When planked the hull is then lifted off, turned over and the ribs are then steamed and bent in place. Fig 8, 9 and 10 give a good impression of the construction and set-up.

Fig 10. Canoe constructed at Lake Kariba fisheries training centre

painting a prototype has lasted ten years and it can be expected to have a useful life for double this period.

Operating factors

Canoes used for fishing with 3 to 4 crew, carrying nets and up to 500 lb (230 kg) weight of fish, have a speed of 10 knots with a 9.5 hp outboard and almost 7 knots with a 5 hp out-
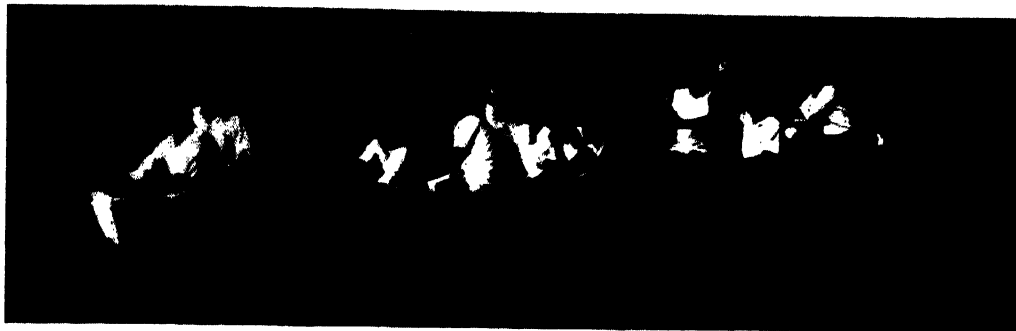
Fig 11. 23 ft (7 m) banana boat under load test with 12 men

board. Up to 1,500 lb (680 kg) can be carried if the craft is used for transporting goods, e.g. bundles of dried fish. Fig 11 is an illustration of a canoe with a load of 12 passengers. Even allowing 120 lb (55 kg) per man the load is 1,440 lb (650 kg) for a canoe weighing only 400 lb (180 kg).

Although the round-bilge plank canoe has been in operation on Lake Mweru for a number of years, a few with outboards, details of their costs and earnings as fishing craft have not been obtainable. However, the operations of crews under and after training at the Fisheries Training Centre at Sinazongwe on Lake Kariba, have been recorded in recent times. From the data obtained over periods of 5 to 32 months' fishing, average net profits have been of the order of £16 ($45) per month, with units comprising a round-hilged canoe, outboard of 3.9 to 5.5 hp, 25 nylon gillnets of 50 yards (45.7 m), a fisherman and two crew. Of the total earnings of the unit, 21.7 per cent was spent on petrol and oil, 22.7 per cent on wages (including a wage for the owner), other expenses 2.6 per cent, thus giving a profit of 53 per cent.

The catches of fish on Lake Kariba were not exceptional being of the order of 20 lb (9 kg) per 100 yards (91 m) of net. Higher catches could give better profits. The capital costs of a round-bilge canoe unit (boat, 5.5 hp engine and 25 nets) is about £300 ($840) in Zambia, of which £110 ($310) represents the cost of the canoe.

Fig 12. A flat bottom canoe for swamp and river

Several designs used

The round-bilge plank canoe (banana boat) is not the only craft considered as replacement or an advancement on the dugout in Zambia. A number of other designs have also been tried with greater or lesser success. A dory type craft was not acceptable because of the difficulties in paddling; a flat-bottomed plank canoe, fig 12 developed for poling in swamps, was found less seaworthy than the round-bilge plank canoe and with larger channels being developed, the latter craft is as effective. An 18 ft (5.5 m) gillnet skiff of plywood construction has found little favour with many fishermen because of the high cost of necessary maintenance, consequent on poor quality local plywood and high running costs. Recently a 24 ft (7.3 m) beach boat (FAO design BB 59) has been tried with some success, although the plywood construction was not entirely acceptable due to damage by chafing on rocks and sand. However, a modification of a glass fibre sheathing is expected to overcome this problem. The inboard-powered beach boat, as an advance on canoe-type craft, is considered to have possibilities in Zambia, particularly where a fair carrying capacity is required over considerable distances. Experimental craft of this type are also being constructed of fibreglass.

Canoes in the Pacific

Powell (Cook Islands): There are probably more canoes used as subsistence fishing craft in the Pacific than all other types of craft combined. In Melanesia the single hulled dugout canoe has and will probably always remain a popular type of vessel in all villages which face the sea, a lake or a river. In Micronesia and in Polynesia the canoe with an outrigger is generally preferred. Where water is generally calm and the prevailing wind is not strong, a single hull is more easily paddled, and children growing up in village canoes, develop the natural sense of balance which makes work possible in a canoe.

In the atolls and high islands of Polynesia where much fishing has to be done in the open sea, the outrigger canoe is common. It has been suggested that the outrigger float became necessary way back before recorded history where canoes had to be made from logs which were too small in diameter to make canoes with sufficient beam to be acceptably stable. This may be true, but it is interesting to note that when the first European sawn lumber was introduced into the Pacific, and it became possible to build canoes from planks, the use of the outrigger persisted and the traditional beam length ratio is maintained.

Polynesian fishermen who work in rough water prefer a canoe with a beam sufficiently narrow that a man sitting on the centre thwart fits comfortably into the canoe. It is then possible to feel more control over a canoe which can be

turned against the thrust of the paddle. A wide-beamed canoe is more difficult to control, as one tends to slip from side to side in rough water without being able to brace the outside of the thighs against the inside of the planking.

Value of the outrigger

There is a very good reason, of course, for the preference for the outrigger canoe where ocean fishing is practised. The advantages are not always appreciated fully by strangers to these islands. In the first place, the outrigger canoe is certainly not an easy craft to handle even in a lagoon. Its idiosyncrasies make it particularly perverse to anyone who does not appreciate that it is very sensitive to trim fore and aft. Polynesians, of course, have learned to use these seemingly unhandy tendencies to the best advantage. Outrigger canoes will always be preferable to open boats, when fishing has to be done over the ocean where the bottom is much too deep to make anchoring possible. These conditions exist in most areas where tuna and large pelagic fish are sought.

An advantage under these conditions is that the outrigger canoe with a reasonably heavy buoyant outrigger is more stable than a small boat. One sits facing forward and in consequence has a better view of the conditions which make fishing at times hazardous. Where very deep lines are used and it is necessary to keep a canoe vertically over the line in strong winds and tide, it is possible to tuck the paddle under the left arm and with a sculling motion keep the craft head to wind and sea. Most fishing is done in depths where a line length of between 50 and 250 fm (90 to 450 m) is used. The yellowfin tuna, wahoo, marlin, castor oil fish and large sharks are all heavy fish. They are all capable of breaking the planking of a canoe and all are powerful enough to cause a capsize if not handled with great skill. When a large fish is finally hauled alongside, it is essential that the fish is finally turning in the right direction before one starts to club it. This has to be done at times while the canoe has to be kept head to wind and sea. By day it is a hard means of fishing. In a strong wind and sea on a dark night with no help available should a capsize occur, it is indeed a type of fishing which one needs to be apprenticed at a tender age.

Not beautiful—but they do the work!

The canoes almost universally used through the Cook Islands are planked up with $\frac{5}{16}$ in (8 mm) Douglas fir planking and are built with grown frames cut from *Hibiscus tiliacus*. The bottom is shaped double-ended from two 6 in (15 cm) or one 12 in (30 cm) kauri board. The topsides flare out to give the necessary sheer without recutting the top edge. These canoes are frequently criticized as not being as beautiful, as the fine craftsmanship which one finds in other Pacific areas, but no-one who has worked with them offshore in a high sea of a strong trade wind can doubt that they do stand a surprising amount of rough water. The hull is something like a Grand Banks dory scaled down.

It is common enough on rough days to find a group of 40 to 50 canoes working over a fishing area where they remain invisible from one another as they rise and fall behind the ocean swell. The trade wind freshens up during the day and the numbers generally thin out and the better fishermen with long experience remain on the ground, when the tops of the seas are breaking over and the spray is driven down wind. Under these conditions, handling a large heavy fish is difficult. When a marlin is hooked, it is general for someone to go to the fisherman's assistance and hold his outrigger from either lifting or sinking too deep. A canoe that broaches, rolls over and often breaks off the float, which makes it difficult to paddle ashore. Under these conditions of strong wind and rough sea, fishermen will alter the trim of the canoe by pushing all the heavy gear forward. As the bow is depressed it holds less wind and the tendency to become "hard mouthed" and point up into the wind and sea is a decided advantage. Any heavy fish caught are pushed forward and the canoe is kept severely trimmed by the head.

When conditions become such that it is necessary to return to shore, the reverse process is used and the trim is by the stern. Under these conditions, the canoe will run down wind with a minimum of effort. By contrast, an open boat must be rowed with two oars which means that one must face aft. The high sides of a boat make rowing in a rough sea much harder work than paddling. While a rowing boat can be rowed faster than a canoe can be paddled in smooth water, the canoe scores every time when working to windward against wind and tide.

One- or two-man canoe?

At one time two-man canoes were in favour and two men could operate better than one man under some conditions. It is interesting to note however that although the single-hulled canoe with an outrigger float will stand a lot of rough water as long as the trim is watched carefully, the two-man canoes where the weight is carried more into the ends of the hull is not such a good sea boat. The secret of the smaller canoe appears to be that when the ends are light and the weight is carried over the centre of buoyancy, the rocking horse motion improves its seakeeping property. When landing through surf, one is faced by the improvement in running with the after end loaded, and in the danger of broaching when the weight is carried centrally, which are conditions which Pacific Islanders meet by long hard experience.

Where the temperature of the sea is high and flying spray is not depressingly cold, one can, of course, face rough water with much more confidence than the same conditions might offer where grey skies, freezing spray and certain death from a capsize would follow.

The single-man canoe much as it does the jobs for which it is built very well, does not lend itself to commercial fishing in many new ways. With the advent of outboards, larger canoes are being built over the Pacific and the basic type has been improved in many ways.

A large canoe has many advantages over a small boat when handline fishing, trolling, lift netting and several other special types of fishing are done commercially. In the first place, a large canoe can be driven much faster than a small boat with the same size of outboard. A small boat will not plane if it is loaded heavily. To make it plane requires a large outboard with a prohibitively high fuel consumption. If it is then slowed down for safety reasons in rough water, it throws spray aft which is difficult to avoid. When a strong wind dries this salt spray in an operator's eyes, it is unpleasant. A large canoe under these conditions will push along to windward with very little fuss at all. If the weight is concentrated in the centre of the hull, it will, if well designed in the first place, be quite a workable fishing craft.

How to fit outboards

Fitting outboards to canoes has always been something of a compromise. The single-hulled canoe without an outrigger has the big disadvantage that if it is built double-ended in the conventional manner, fitting an outboard bracket offers some problems of construction. Often the end is sawn off and a small transom is fitted. One then has a type of craft where it is difficult to get at the motor for any reason. The heavy motor carried right on the stern is certainly in the wrong place in rough water.

Attempts to fit motors through wells amidships are not always, if ever, successful. Outboard motors fitted on the

quarter of a double-ended canoe without an outrigger float have the big disadvantage that a canoe, like a boat, rolls in rough water and the motor is alternatively working either submerged too deep or with the propeller racing as the canoe rolls away from it.

Fitting an outboard to an outrigger canoe is very much simpler. The motor bracket can be designed to clamp about two-thirds of the waterline aft. In this position it can still be reached quite easily for running repairs; the weight of the motor is in the place where the canoe can carry it best. As the outrigger float stops the boat from any appreciable rolling, the propeller works to its best depth. The bracket can be made so that the motor will tilt up as needed. In canoes large enough the motor can be bracketed by the after outrigger cross arm which still leaves room to swing a paddle when necessary without striking this spar.

A loose steering paddle can be used as in a sailing canoe or a rudder hung on the stern with a deep blade can be steered with either a yolk line or a solid yolk or bell crank bracket attached and carried forward to the position of the outrigger. With this arrangement, one man can operate the outboard and steer the canoe quite comfortably.

The design of such a canoe can of course be varied without limit to suit the type of fishing that is contemplated. For instance, anyone wanting to use a canoe for trolling with several lines where some rough water is expected, can increase the height of the topsides. Some decking can be added, an increased well combing if necessary, and many other refinements that will make such a canoe quite a serviceable fishing craft that is neither expensive nor difficult to build. One further advantage is that where fishing craft have to be used without any harbour facilities, such a craft has quite shallow draft and is easy to beach. If the canoe is made very large, it is easy to haul ashore on wood or rubber rollers. Where ample labour exists as in most fishing villages, the canoe is very much easier to lift or drag ashore than is a boat of the same overall weight. This is of course because the available man power can be well spread out, where everyone gets a good hold to push or lift. Boats under such circumstances are much more difficult to skid ashore as there is little place to take a firm hold that is not too high to grip effectively.

Methods of handling

A hand winch, of course, simplifies things with all heavy craft. When a fisherman operates with a limited crew under conditions where it is advisable to drag the craft above high-water mark, then the outrigger canoe is at a great advantage. It is customary to lash together most Pacific canoes with coconut fibre or sennit lashing. In the atolls this art of lashing is well developed and some beautiful patterns are made. This takes time and the lashings stay in place until they are finally renewed. Metal is now replacing the sennit lashings. The big advantage of metal over sennit is that metal bands can be made into which all the cross arms or spars can be pushed on a taper. This facilitates assembling a canoe and has the advantage that such a canoe equipped with metal bands can be taken apart quickly. The outboard can be lifted off then the outrigger float can be removed quickly.

The two or three cross-arms can be slipped out of the sockets and any light decking which might be carried over these arms to hold nets or fishing gear can come off in one or more pieces.

The main body of the canoe can now be either carried or skidded ashore. When a hand winch is available, quite a large canoe can be dragged up a beach above high water. It is customary in most Pacific Islands to build a canoe house where all the fishing gear is stowed in the roof away from hot sunshine and torrential rain. This is a distinct advantage over an open power boat with an inboard engine. Such a craft left at permanent moorings can collect enough rainwater in a few hours of a tropical deluge for the water to creep up over the gearbox and engine sump. The thatched roof of a canoe house is generally much preferable to a "hard" roof, as the canoe, if a dugout, does not get the severe drying out that occurs under corrugated iron.

In fishing communities where the change-over from subsistence to a moneyed economy is still taking place, it is frequently the case that labour is still not considered in terms of a definite rate per day or hour. Under these conditions, where much of the catch is distributed among the fishermen's families, it is an advantage at times to carry more men that might seem at first to be economical than a western fisherman's concept of an economical number in a crew.

When handlining, the long canoe has the very superior advantage over a shorter boat of the same displacement, in than the handlines can be spaced further apart. This does much to prevent the entangling of lines which is common enough when many lines are used from a boat in very deep water.

Handling the sailing canoe

With most sailing canoes, the outrigger is always carried to windward and when tacking, the outrigger is still kept to windward by the simple device of making the canoe double-ended to the extent that the hull is steered alternatively from either end. Several types of rigs have evolved which simplify this type of sailing canoe. In Rarotonga many years ago a sailing club was formed using the local dugout canoes and the more conventional marconi rig was preferred to the lateen sails. With a marconi rig of jib and mainsail, the outrigger had to be used on one tack on the leeward side. It was soon found that when racing in strong winds the outrigger float was buried under a press of sail with disastrous results. Making larger solid outrigger floats with light buoyant timber had its limits and the hollow dugout float decked in was evolved. Making a hollow float from a dugout log requires some skill and careful workmanship if it is to stay watertight. Planking up a hollow outrigger float is generally much easier although hard chine floats are not as attractive-looking as a well-shaped hollow outrigger adzed from a log.

In Polynesia there have traditionally been many ways of attaching the float to the canoe. A variety of methods of attachment nearly all have lashings of sennit. The total assembly is always flexible. The flexibility of the outrigger canoe is carried to the extreme in the canoes of the Society Islands. These canoes are generally made so that the forward spar is stiff and strong and is generally made of a local hardwood. In the sailing canoes, it is extended out across the canoe to provide attachment for the rigging and also as a precarious perch on which the crew can balance the buoyancy of the solid outrigger float. The after end of the Society Island canoes is then made of a very light flexible spar which does very little more than space the after end of this float. This has one advantage and that stems from the greater flexibility that this arrangement gives the canoe, or in other words, it increases the stability of the canoe to the extent that as the outrigger is lifted into the air, the after end always trails in the water. The stability is greatly increased in this way, as it is quite difficult to capsize a canoe of this type with the outrigger lifting from the water. Capsizes occur just as easily in canoes when the float is submerged and if this float is not buoyant enough as occurs with solid timber, it is possible to capsize with the float driving under water.

Methods of attachment

The Society Island method of attachment is an improve-

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ment on the traditional Cook Islands method of using two fairly stiff solid spars. However when one attempts to sail with the solid spar to leeward, trouble develops as the fore end of this float is driven under water. Once the fore end of the float is submerged if the canoe is moving fast through the water whether by power or sail, the submerged fore end then drives in deeper and a capsize is almost inevitable.

Many years ago an answer to this problem was found by combining the advantages of the Society Island flexible attachment with a float made much more buoyant by being hollow. These floats are generally made to be buoyant enough to carry about 250 lb (115 kg) before they will submerge. The hollow float is of course much lighter than the solid float and when the stability is considered, it is general to set the float about 6 ft (1.8 m) out for an 18 ft (5.5 m) canoe. In a canoe of this type, it is possible for two men to sit on the rail without it lifting the float from the water.

Finally the float was improved by making it such that the centre of buoyancy was separated from the centre of gravity by about 2 ft (0.6 m). The forward point of attachment was then made between these two points. The forward cross spar then carries all the strain of the weight and the buoyancy when depressing the outrigger float. This means that it must be quite substantial. The after spar has been made stiffer than the Society Island canoes use and it is preferable to combine a strand of wire along the edge of this spar so that should it break for any reason, the front will not be separated from the canoe.

With a hollow float of this type firmly attached, but with a certain amount of flexibility still inherent in the whole assembly, the canoe can be driven through rough water with an outboard without the danger of capsizing from the float either lifting or submerging. Bronze strip and rods welded or silver soldered together simplify the method of attaching the spars to both canoe and float. A cheaper job could be made from galvanized mild steel.

Extra carrying capacity

Canoes of this type could be enlarged up to a much greater size than are used at present. In many areas of the world where large dugout canoes are in common use, their ability to carry nets and other gear can be very greatly improved by attaching a hollow outrigger float. A large outrigger canoe driven by an outboard attached about two-thirds of the way aft from which all the spars and the float can be both easily and quickly attached or dismantled. It could probably be improvised in many areas of the world where outboards cannot be used very successfully in rough water on the traditional single-hulled canoe.

Strangely enough, a hollow float does not make the drag that might be anticipated on one side of the canoe. Traditionally, Polynesian canoes have often been made with various methods of counteracting the supposed drag on one side by this float. When an outboard is attached to the hull on the same side as the float, any drag to one side is counterbalanced by the thrust of the propeller. It is no problem in practice.

At the present time a canoe of 24 ft (7.3 m) is planned, having a hollow outrigger float. Plywood and fibreglass will be used for both the hull and the float and the canoe will be kept to a fairly low freeboard so that it can be used on the fishing ground with a Hawaiian Opelu lift net. This net is used with ground bait which is released several fathoms below the canoe. It is necessary to keep the canoe over the net and bait and a long canoe which can be maintained stationary over the gear by two men paddling is much preferred to a boat which has to be either rowed or sculled.

Additional strengthening advisable

Anyone attempting to attach an outrigger to a dugout canoe ought to add some framing to the points of attachment, as the float can cause the hull to split down the grain if provisions in the form of timbering or standing knees are not added to strengthen the topsides. Motor brackets are not difficult to design to suit both the motor bracket and the topsides of the canoe. Bronze strip and rod is generally easier to use than wood, although wooden brackets are satisfactory if well designed and attached firmly. Where dugout canoes can still be made from good timber at a reasonable cost, they have some advantages over plywood canoes, if they have to work over rough coral bottoms where severe gouging and scratching of the bottom is an inevitable part of the fishing operation. Plywood can be made much lighter than dugout construction, no matter how well the dugout is made. Moulded veneer with fibreglass covering is perhaps the lightest and strongest construction of all, but it needs good workmanship and is expensive if carried out by a good yacht yard. The total cost of such a canoe, complete with outrigger float and spars would be at least comparable with a plywood dinghy. Adding an outboard to a conventional outrigger fishing canoe greatly increases the chances of swamping the canoe in rough water. At the same time, it also decreases the chances of bailing the water out of a swamped canoe.

An open dugout canoe can generally be freed from water quite easily by rocking the canoe fore and aft. Once the water inside has started to rush from end to end much of it can be made to pour out of the ends until a certain amount of buoyancy is regained. The rest of the water can then be thrown out of a dugout by using a paddle which is shaped something like the inside of the canoe at the ends. One then uses the paddle as a shovel and this is quicker and easier than bailing.

Well-made bailers

Sailing canoes are righted after a capsize by the occupants taking all the gear under the cross arms. Then by standing on the float and sinking it the added buoyancy lifts the hull of the canoe high enough to make some of the water pour out over the topsides. From then on, it depends on bailing. When a deck is added to the ends of a canoe, it does a little to keep spray from filling inside. It strengthens the canoe to some extent and it makes it possible to keep a few things dry below. It does help to stop the canoe from filling, but once filled, it makes it much more difficult to bail water out. In a sailing canoe or in one powered by outboard motor, it is quite easy to fit a venturi bailer with a plug which drains out every drip of water as long as it is possible to maintain any speed over 3 or 4 knots.

In many areas of the Pacific, bailers made from local timbers are used which generally fit the bottom of the canoe fairly closely and do not scratch or score up the planking after frequent use. These bailers are often well made and designed so that they can be used to throw a lot of water with a minimum of effort. Coconut shells sink, as do tins and most plastic buckets. The island wooden bailer is a useful piece of fishing gear.

Outboard problem when swamped

When outboards are attached to the traditional canoe they then offer the problem of what to do with a swamped canoe. The added cruising range which a motor gives also brings the added risk of being swamped offshore at night. While the wooden canoe has a natural buoyancy, it is seldom enough to float an outboard and still leave enough freeboard to make bailing possible. Generally an outboard will take a small

canoe which is filled straight to the bottom. One then has to cast off the motor quickly and drop it in deep water unless some provision is made beforehand. The better alternative is to build some buoyancy chambers into a new canoe or adding some foam plastic, inner tubes or some similar type of light buoyant material well fastened in.

Foam plastic poured in place is probably the easiest material to use where it is available at a reasonable price. Plywood and fibreglass are other easy ways of building buoyancy chambers into the canoe without greatly adding to the overall weight.

In the Hawaiian Islands, most of the small boats carry live wells which make it possible to keep small bait fish alive. Live bait is regarded as a necessity when fishing some species. The live well also improves the appearance of the fish which have to be kept for a long time, often all night, without any ice. Live bait wells are easy to build into a canoe, as the ends can be made as permanent bulkheads right across the canoe. It is important, however, that the well is either carried up to the top of the gunwale or some plugs are always kept attached permanently to the canoe, so that in the event of swamping it is possible to plug off the well section.

Evolution of centuries

The Polynesian canoes have probably taken thousands of years to evolve into their present simple form, that do one job in one locality well. In every island one can see limiting factors which make a slight change an improvement. Polynesians, like all fishermen in the world over, are just as

Fig 13. Section of outrigger canoe

conservative and just as reluctant to change from methods handed down through generations of fishing families. But the western world is already bringing materials that never existed before and the inevitable change from a subsistence to a moneyed economy is already spreading across the Pacific. As this happens, the traditional paddling and sailing canoe

offers quite an interesting place from which to start to add a power plant, mechanical gear haulers and all the factors which are necessary to change fishing from a means to an end into almost an end in itself.

Fig 13 shows the heights of the struts in proportion to the canoe. The cross arms should be level when the canoe is fully loaded. The outboard motor bracket can be made from either wood or metal. It is preferable that the fore side of the bracket contains a piece of wood or sheet metal as a spray deflector. Fitting this will depend on the actual motor in use. Wood or metal can be used for the outboard bracket. Wood is easier in some areas where metal working facilities are not readily available.

Steering the outrigger canoe

Fig 14 shows three alternative methods of steering an outrigger canoe:

A shows a double-ended canoe with a straight stern post. Rudder pintless and gudgeons are attached to post and rudder in the conventional way. This is simple, cheap and strong. The rudder is linked to a tiller mounted inboard or a "bell crank" or yolk lines can be used.

B shows a curved steering oar made out of either laminated timber or from a piece of grown hardwood. It is particularly useful where it is necessary to stand up to steer when manœuvring through rocks or lagoons full of coral. The oar passes through a metal rowlock which is drilled and pinned as shown.

C shows a rudder mounted on the port side of a rounded stern canoe. The side mounting saves problems with the curved stern post. The rudder is detachable and can be made to tilt when desired. The whole rudder assembly can be made of either wood or metal.

Fig 15 shows a typical small outrigger canoe fitted with an outboard. This arrangement is suitable for canoes up to about 25 ft (7.6 m). The decking can be made up in a variety of ways depending on the work for which the canoe is used. Light spars easily attached to the cross arms can be so made that they carry fishing nets, traps, pots or any variety of gear which does not depress the float too deeply. The spars made of either light timber or bamboo can be covered in turn with a woven mat of split cane, or a piece of heavy canvas, or heavy fish netting. This gear should be made so that it is easily detached so that the canoe does not have to be lifted ashore as one unit. Spears, dip nets, gaffs can all be stowed out of the way on this platform.

If the outrigger float is buoyant enough, it is a handy place for working if some provision is made to stop the outrigger float deck from being slippery when wet. The after arm should be so made that if it becomes broken in use

Fig 14. Alternatives for steering outrigger canoes

OUTRIGGER CANOE WHICH CAN
EASILY BE TAKEN APART FOR
STOWAGE OR PORTABILITY

HOLLOW FLOAT

LIGHT DECKING COVERED
WITH CANVAS OR NET
OR WOVEN CANE

BATTENS OR BAMBOO

FLEXIBLE CROSS ARM   HEAVY CROSS ARM

OUTBOARD MOTOR

LIVE
WELL

Fig 15. Arrangement of smaller outrigger canoe with outboard. Note position of outrigger

there is some attachment still remaining to the canoe. This is easily done with a strand of wire along one edge. If the after end comes adrift in rough water, it generally means the float takes charge and does some serious damage.

Protective measures

Fig 16 shows a very large canoe fitted with an outrigger and an outboard. As the float becomes bigger, it can be carried closer to the canoe as the stability increases. A light diagonal wire, as shown, takes the strain off the gunwales of the canoe and adds some strength to the whole canoe. This is especially desirable where the canoe is used at night in amongst coral or rocks where the point of the float can strike anything solid. It is advisable to round up the forefoot of both the canoe and the float. Live bait and fish wells are very desirable in most tropical areas. The tiller and linkage as shown can be used to some advantage where it keeps weight out of the ends of the canoe when beaching through surf. The side mounted rudder can be detachable and can tilt up. Decking on the ends of the canoe will be dictated entirely by the local conditions.

In general, it is very advisable to finish the ends of all spars and all exposed surfaces to a well-rounded edge to avoid damage to light nylon nets. When damage still occurs, a piece of canvas large enough to cover the working area, will save a lot of labour net mending.

Traditionally, most Pacific canoes are tied together with sennit made from coconut fibre. Some very beautiful lashing patterns are possible and the sennit has the advantage that it does not become loose through stretching with alternate drying and soaking. Nylon braided line is now being used where sennit is no longer made. Metal bands are not as flexible as the traditional sennit, but do make the canoe portable when it can be easily broken down into unit pieces within the capacity of the available crew and local conditions.

Anyone not familiar with canoes in their area may well find a choice between the type of canoe as illustrated and described and a double canoe. The double canoe, or catamaran, as it is becoming known in yachting centres, is regarded in this case as a craft where both hulls are the same size and a deck is carried across between the two hulls. To compare the two hulls is of course to point out the advantage and disadvantages. It is obvious that in some areas one or other will be preferred, depending on the type of fishing gear used. It is seldom that one type will do both jobs equally well.

Respective advantages listed

Single-hulled canoes with outrigger: the advantages might be as follows:

● Dugout canoes are traditional in an area and are a readily acceptable type of craft

LIGHT DECK COVERED WITH BASKET TYPE CANE NET OR CANVAS

WIRE BRACE

RUDDER

LIVE WELL   TILLER   MOTOR   STRUT   LIVE WELL
TO BRACKET
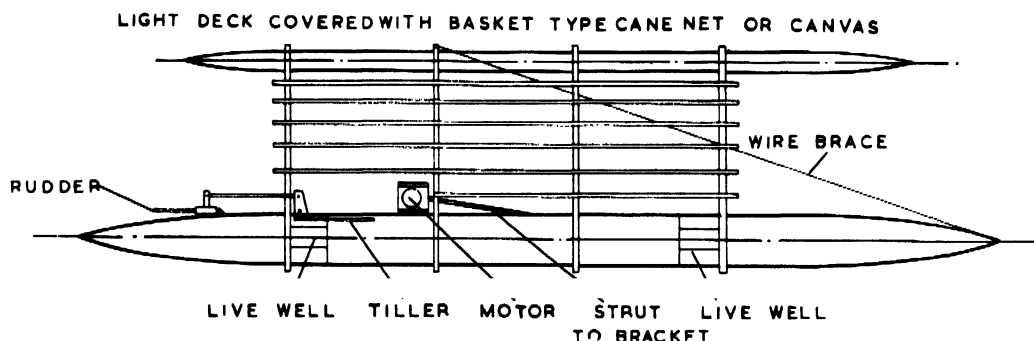
Fig 16. General arrangement of large outrigger canoe with outboard

[510]

- If large timber is still available, local craftsmen can make dugouts which already suit local conditions
- The dugout can be left thick below the waterline to withstand coral
- When broken down, the single dugout canoe, if heavy, can be skidded ashore to a boat shed
- A single motor will drive the canoe if mounted as shown
- The long canoe is much to be preferred when line fishing is done in deep water. The long canoe spreads the lines further apart, which is a big advantage where the lines are used in deep water
- Building a large canoe and a hollow outrigger is generally cheaper than a catamaran
- Nets can be handled from the platform as shown, for most types of net fishing
- Single-hulled outrigger canoes are generally far easier to use with either paddles or sails, should the motor break down

The advantages of a two-hulled canoe, the catamaran, are:

- Where nets such as ring, gill or barrage nets are used, the catamaran has a fine wide platform between the two hulls, which is advantageous for both hauling and setting nets
- Light plywood hulls covered with fibreglass are easy to build where this material is available at a reasonable price
- One motor is not as satisfactory in a catamaran, as in a single-hulled canoe
- Two outboards are an added safety factor
- If the hulls are left without decking, they might be suitable for line fishing, but they are not either as easy to keep up in a head wind and sea with paddles as is a larger single hull
- The spread of the lines when hook fishing is not as great
- Where possible to buy large American outboards cheaply and keep them locally serviced, the double plywood-built catamaran is a useful craft for many purposes
- In isolated and backward parts of the world the large modern outboard is still next to impossible to keep serviced. Fuel is far too expensive for it to be practical in most Pacific islands

The canoe builder's skill

Chipepo (Tanzania): The tree which the canoe-maker uses is a local wood which is called muninga or mupapa in East Africa and mukwa in Zambia. These two countries use the same wood for canoes. The canoe-maker can go into the forest with two or four men to help him to fell the tree. First, he can see that the tree is free from kinks and hollows in the side, by looking far off to see how the leaves look, then he can give orders to fell the tree.

The canoe-maker has three axes to fell the tree and chop off the branches. The second tool used is an adze—three big ones and two small ones—the bigger ones help him to scoop the hull and the smaller ones are used for finishing.

Fire and mud can be used after two or three months, when he finds that the hull is quite dry. He starts to smear the hull with mud inside and out and then he makes a fire inside and when the hull is hot he starts using the spans to expand the hull and make it into a good shape. The measurements which the canoe maker uses is to stretch his hands eight or ten times—giving him the length overall.

Not everyone in the community can make a canoe. This skill is limited to a few groups of specialists. This means

then that a canoe maker occupies an important part in society.

From the forest to the river the canoe maker is very worried. He is not sure of the stability of the hull and hides himself near the river until he hears the joyful cries of the women shouting and clapping their hands. After the launching, three or four men start paddling very rapidly and then you can see the hiding canoe maker jump for joy.

Eventually some of these canoes will be mechanized with outboards and the experience gained by other developing countries will be of much benefit to Tanzania.

Eskimo Practice

Frechet (Canada): The eskimos of Canada, who go fishing at great distances from the shore, are normally accustomed to carrying their kayak on their komatik (or dog sled) down to the shore. Then they have to leave both komatik and dog team and continue alone in the kayak to the place where they intend to fish. Being made of skins, the kayak is rather fragile and often tears on sharp edges of the ice. Clearly, something had to be done about this.

In another part of Canada, the inhabitants of the islands in the St. Lawrence river downstream from Quebec, have from time immemorial, crossed the river which carries down a lot of ice, in wooden canoes having greatly elongated extremities to enable them to ride up over the floes. These canoes were once built of massive oak and had steel runners that made it easy to drag them over the ice, but they were very heavy.

Nowadays canoes are made of reinforced fibreglass and also of aluminium. The aluminium canoe accordingly offers a useful substitute to both the komatik and kayak. The eskimo can keep his dogs near him and hitch them up to his canoe in order to haul it over the ice.

Over the great stretches of frozen lake, the half-track vehicle with skis fitted to the fore-carriage has become one of the most widely used vehicles in fishing operations. It comes in a number of sizes and can be used not only for standing line fishing and gillnetting, but also for trapping.

Small craft, powered by air-cooled motors, are now being produced in reinforced fibreglass. Among the new craft used for fishing over the ice may be mentioned the many aluminium boats propelled by air screws.

The greatest novelty of all, however, is an amphibious vehicle (dimensions range between 13 and 20 ft (4 and 6 m) with power units of between 60 and 80 hp) which has a series of very fat balloon tyres in a line along each side. Vehicles of the kind are capable of 60 miles/hr (100 km/hr) on ice and 8 knots on the water. Propulsion in water is obtained by connecting the engine to a hydraulic turbine providing a performance akin to that of a propeller. In the intake duct there is a knife-edged propeller-like device which crushes small pieces of ice or cuts up aquatic plants. Such a vehicle, therefore, can take any water conditions as well as offering cross-country transport—over steep mountain slopes, shingle, mud, marsh and snow and ice, or other adverse conditions. A Canadian project has been underway for several years: the development of a free-piston engine capable of using fish oil as fuel and particularly adaptable to fishing craft.

Modern materials displace old

Lee (UK): It is of considerable interest to note that glass reinforced plastic craft are replacing the traditional dugouts and other wooden craft. It would be useful to learn whether there is any difficulty in hauling them over the beach and whether the plastic is withstanding abrasion.

The use of styrofoam (expanded polystyrene?) is queried, observing that this material breaks down in the presence of gasoline and oil; expanded polyurethane or polyvinyl chloride would be much better.

Stability

Zimmer (Norway): Making a dugout canoe means a lot of hard work and a lot of wasted wood and the final result is rather inconvenient as a fishing boat. The way of making a dugout is based on times when man did not know how to make watertight connections between planks. The dugout is something of the past and will disappear.

As a naval architect, Zimmer made some remarks about dugout canoes. The tree trunk limits one to a circular amidships section. Positive stability means that the centre of gravity is below the metacentre, which is permanently in the centre of the midship section circle. When a man is standing up in the canoe the centre of gravity is higher than the metacentre, but because the weight of the man is acting where his feet are touching the canoe, he has control of the canoe. The strange thing is that, because of this, a man standing up in a canoe can give better steadiness to a canoe than a man sitting down and holding onto the rails of the canoe.

Zimmer had another experience with a plastic boat of typical V-bottom boat midships section. The bottom of this boat started flexing under speed. To correct this, the designer put in a double bottom at about waterline level with polystyrene foam in between. When it started raining or a lot of water collected in the boat, the centre of gravity was raised to a point above metacentre; then the GM became negative and the boat turned upside down.

Canoes will not disappear so soon

Traung (FAO): Zimmer is probably not correct when he says that dugout canoes are something of the past and will soon disappear. For the next 50 to 100 years they will certainly outnumber other fishing craft, because development is unfortunately not very fast.

Thomas, in his paper, as well as Stoneman, Heath, Powell and Chipepo give very good accounts of dugout canoe construction and, if this had been a meeting of ethnographers, FAO would probably have invited contributions from a great many other areas using dugouts as well. Perhaps someone could organize a dugout symposium one day.

canoes developed by such officers. Fig 17 is an example of such activites, which certainly doesn't leave much to admire.

An example of what also is happening is the man who wanted to make an 80 ft (24 m) dugout. He had found the real dugouts of his community to be good surf-going craft and he assumed that a larger version would keep the same good qualities. He obtained a drawing of an 80 ft craft made of aluminium, which was well fitted out with staterooms and no less than two WCs. When asked about the scheme, the FAO Fishing Vessel Section said it was "interesting", which sɐʍ ɐ polite way of saying they did not agree to the idea. He went to his Government with the letter, saying that FAO had approved his project and then FAO had to explain the use they made of the word "interesting".

While FAO Fishing Vessel Section does not believe in building "dugout" canoes, of any other material than logs, it has had good results with improving the stern as suggested by Thomas and fitting canoes with outboards. If no logs are available and boards, plastic or any substitutes must be used, more boat-like forms are more economical and efficient.

New type canoes give increased safety

Heath (Zambia): In developing countries, the numbers of dugout canoes run into hundreds of thousands—this is acknowledged by FAO. The dugouts every year are the cause of loss of life, yet in Zambia in the last ten years, there has not been one capsize or drowning recorded from these 23 ft (7 m) round-bilged canoes. In many countries, trees large enough for dugout building are becoming harder to find. The answer is surely canoes built of planks.

If FAO is opposed to canoe development, what is its answer to the problem of dugout replacement in subsistence fisheries, as dory or dinghy form boats are not accepted by the indigenous peoples?

In developing countries, the replacement of dugouts is a very real problem, that is why the drawings of a proven canoe were submitted for the benefit of others. The flat-bottomed canoe design for rivers and swamp areas will certainly not be suitable on the large lakes.
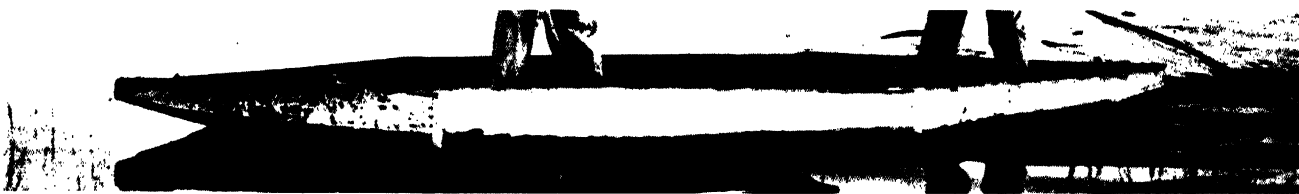
Fig 17. A dugout replacement made of mahogany planks at N'Guigmi, Lake Chad

Dugout canoes are made of both hard and soft woods. When made of hard woods, there is naturally, as Zimmer says, a lot of wasted wood, but when made of certain soft woods as is the case when using cotton wood trees in Jamaica, there are not many other competitive users for the wood. This is not always realized. When using hard woods, one can utilize the cubic content of a log much more economically by sawing it up into boards and making boats like the banana boat described by Heath. However, not being restricted to the diameter of the log, it would require very little more wood to make the craft with a more normal beam than the 4 ft 5 in (1.35 m) now used. A 7 ft (2.1 m) beam would give a boat almost twice as large, with hardly any larger consumption of wood or labour.

Expatriate fisheries officers in developing countries often consider themselves experts of boat design and construction and one can see shocking examples of planked "dugout"

Size needed for major progress

Von Brandt (Germany): Each fishing method requires a minimum length of boat and a minimum horse power. Very small boats are necessary for the so-called baby-trawls, as used in the Philippines and some fishermen of Madagascar use only two pieces of wood as a raft for handlining. But these methods have no influence on the production of large quantities of protein. This can be done by bigger gear, only like large bottom trawls and purse-seines, which are not adaptable from the indigenous craft as mentioned in Thomas' paper. Therefore from this point of view, mechanization of indigenous craft cannot be the final step and it is unfortunate when some authors argue that the mechanization of canoes and open boats is the best way for fishery development. This leads only to a cul-de-sac.

Also for handling the fish onboard, a minimum space is necessary. The small open sailing boats of the fishermen of

Sierra Leone can be found 20 miles offshore. They have two stoves to smoke and dry the fish and some boxes to store them in. To mechanize these boats would have only limited success. In Germany, the fish processing people have some doubt if even a vessel of 65 ft (20 m) is big enough to have all the equipment necessary to guarantee the quality of the catch required in the future. Also from this viewpoint, a minimum size of boat is necessary and the mechanization of small indigenous craft has no value.

Gurtner has mentioned in his excellent paper that four steps of development are necessary for the mechanization of indigenous craft to the development of national or regional boat types. Von Brandt agreed with this idea. As explained before, from the viewpoint of a gear technologist who has to look for bigger catches and from the viewpoint of a fish processor who has to look for better qualities, these very small craft, such as canoes and open boats, have no place in a developed fishery with all their need for high productivity and quality.

Even if small craft today have an important place in developing fisheries, this situation must be overcome and not stabilized.

NEED FOR TRAINING FISHERMEN

Sutherland (UK): Attention is repeatedly drawn to the problems facing developing countries and many possible solutions suggested. Some of these are of real value and should be borne in mind by FAO; others however showed little understanding of the difficulties which face the technician in the field.

Thomas in his paper lists the various pros and cons of indigenous fishing craft. A further point worthy of consideration is the danger that if the building of modern fishing craft outstrips the mechanization of local craft, there will be insufficient trained fishermen and engineers to run these modern vessels successfully.

The motorization of indigenous craft should be continued, firstly because of the low cost and secondly as a means of training fishermen to become familiar with mechanization.

Again the high cost of modern fishing vessels may create anomalies whereby the fisherman may find himself working as a crew member in company-owned vessels, instead of owning his own indigenous craft. An illustration of this is given in Gurtner's paper where he states that new 36 ft (11 m) shrimp trawlers were bought by processing firms. Sutherland presumed that they were crewed by local men, whose chances of saving sufficient money to obtain a modern craft would be very low. On the other hand, the dramatic effects of fitting outboards to indigenous boats in Ceylon was given in a previous paper by Kvaran. He stated that the average daily earnings of a fisherman in a catamaran was 1/6d (20 cents) a day and this was increased to 13/6d ($1.90) a day after an outboard was fitted. With this increase of earnings, the fisherman will eventually find the necessary capital to launch out and become the owner of a new modern boat.

Most inshore fleets in European countries are economically successful and this is almost certainly due to the vessels being skipper-owned or collectively owned by the crew.

BEACH LANDING

Carey (New Zealand): A fishing boat was fitted out some six or seven years ago with wheels to aid beach landing, fig 18. It has proved so successful that every boat in the area was soon equipped with the same gear. When first fitted, trailer wheels were used on a hinged A bracket made of 2 in (5 cm) pipe. The hinges were just below deck level and bolted through the gunwale. On the bar of the inverted A bracket, a lug was welded and when the wheels were down this was engaged by
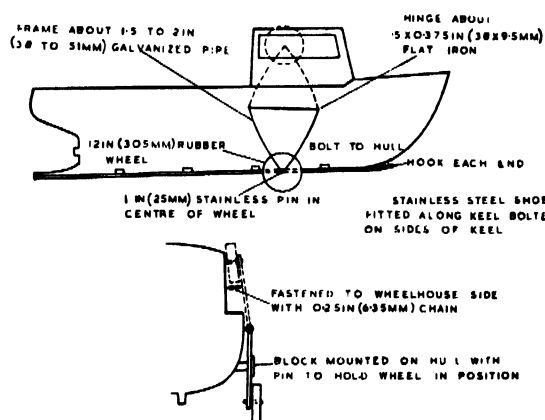
Fig 18. New Zealand beach boat with wheels

a form of tower bolt attached to a support block firmly bolted to the ship's side a few inches above the waterline. This held the wheels firmly in the down position. When the boat was afloat the tower bolt was released and the wheels folded up by pulling a lanyard with which they were lashed in the upward position. All this arrangement was forward of the working area of the boat about 2/3 of the overall length from forward.

These wheels did not carry the weight of the boat but merely supported her on even keel while she is hauled up or down the beach by means of a winch and wire rope, the rope being attached to a stainless steel shoe running the full length of the keel. The wire rope can be hooked on to the forefoot or to the end of the heel which is supported by a V-bracket to each side of the transom. The stainless steel shoe is important as it does not rust or cut into the beach. The wheels were arranged to clear the bottom of the keel by an inch so that the weight of the boat was not thrown on them. The idea works well although the beach at times got washed clear of sand and punctures were common on the exposed rocks. So solid rubber tyres were tried and these proved satisfactory for a while until further deterioration of the beach surface caused the wheels to collapse. Some of the boats are now fitted with all-steel wheels with a 4 in (10 cm) wide steel tyre. The steel wheels are standing up to the battering, but the rough condition of the beach is now telling on the hulls of the boats. It would seem that the original pneumatic tyre is the best if the beach surface is good.

Operating Practice

The method of using the apparatus is as follows: As the boat comes through the surf and grounds, both wheels are lowered and one of the crew gets out on to the beach and engages the lower bolt of the wheel bracket on the high side, the other crew member then rolls the boat over on to that wheel while the other lower bolt is engaged. The winch wire is hooked in and the boat pulled up the beach. The wheels are let down to support the boat. When ready for launching, the winch wire is hooked in astern and the boat hauled out until she is afloat. There are variations of this technique to suit the fishermen concerned.

It appears that the maximum height that the surf runs when landings can safely be made is 4 to 5 ft (1.2 to 1.5 m), although boats have landed under heavier surf conditions of up to 8 ft (2.4 m). This is not normal as they would not get off the beach if a heavy surf were running and only occurs when a wind and sea get up while they are fishing. The particular place they land is between two reefs and great care has be to taken not to breach as there is very little space to turn and

go out to sea again. The fishermen, however, claim that the particular model of boat would land safely in heavier surf conditions if more space were available, such as a long beach with a true surf coming in, and some of these boats have had to do just this when conditions have forced them to do so.

At the landing place in Nuggets Bay, the surf breaks 100 yards off shore in NE weather when the beach is then exposed to the sea and wind.

Features of the coble

Towns (UK): The traditional inshore fishing boat of the NE coast of England is the coble. Developed for launching from exposed beaches and originally sailed, fig 19, they are now built with inboard engines and are often built much larger. The design has altered little—the same peculiarities of design in relation to sailing ability, and the same construction are still adhered to.

Fig 19. Model of a 27 ft (8·2 m) coble showing the fine, deep forefoot, deeply raked rudder and narrow stern

Some smaller versions of modified design and much lighter construction have been built for pleasure fishing off open beaches. From their performance in surf, it would seem that larger boats of the same construction and following the same modified design principles would make satisfactory beach boats for commercial fishing. The displacement of these smaller boats was distributed more towards the ends, fig 20, reducing the forefoot, which caused broaching when running in sailing cobles, and broadening the stern so that more power could be used. The design problem of surf boats is
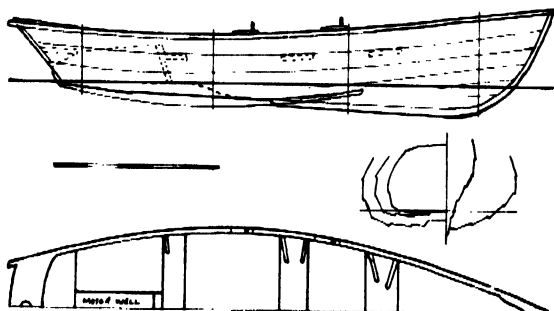
Fig 20. A 16 ft (4·9 m) coble showing sections general layout and position of motor well and tunnel

made much easier if the boat is made to launch and beach bow to sea, so that each end performs its own particular function, whether being beached or launched. If a boat is designed to be beached and launched bow foremost, then the logical conclusion would be almost identical ends, both of which would be a compromise.

An inboard well for outboard motor was incorporated and a tunnel, fig 21, so that, with the motor raised, the propeller

Fig 21. A 16 ft (4·9 m) coble with tunnel

could work without touching the beach, so enabling power to be used from the commencement of launching, fig 22 and 23. Weight was kept to the minimum, consistent with strength. This simplified hauling up beaches. An outboard was also preferred, because this could be removed to lessen the weight of the boat for the same purpose. It is also thought that a light boat is easier to handle in surf. Glued clinker plywood construction was used with a system of including stringers between the side planks at the landings, fig 24, where the angle between planks was more than 30 degrees. This gave a
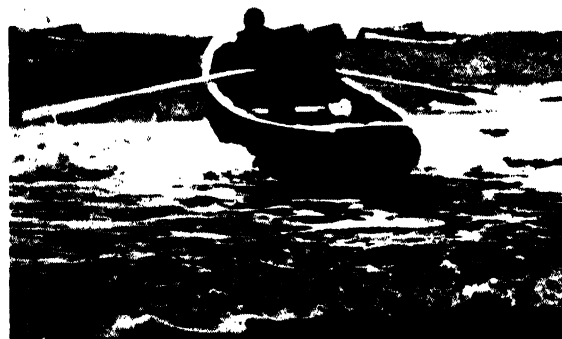
Fig 22. A 16 ft (4·9 m) coble, motor being started in shallow water with engine raised so that the propeller is entirely within the tunnel

wide bonding surface and incorporated all the stiffening required; no floors or timbers were needed. With this method an almost round-bilged boat can be built as easily as a hard chine design, but much stronger for the same weight as the width of the unsupported plywood panels is not great. The amount of stiffening and the width of landing that can be obtained is, within reason, unlimited.

Considerable tumble home was given to the sheer plank, as on large cobles, as this adds very greatly to the general stiffness of the boat. This plywood construction, with all other timber laminated, has stood up very well to sand beaching, but a more resilient form of construction might be necessary for rock-strewn beaches. The building system

Fig 23. A 16 ft (4·9 m) coble with motor in working position

requires little boatbuilding skill and is suitable for repetitive production. The basic principles of coble shape would seem to merit much more study. With modifications to suit power requirements, rather than sail, and a much lighter construction very useful surf boats could be developed.
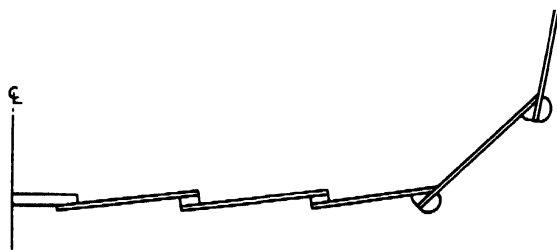
Fig 24. Glued clinker plywood construction with built-in stringers

Southern Californian surf boats

McKinley (USA): The 300 miles (480 km) stretch of flat hard sand beach of the Pacific shore from Santa Barbara to the Mexico-USA border has been used in the past ten years by a rather unique trailer-launched outboard-powered surf boat to fish for lobster and, where legal, to longline for shoal water food fish very successfully.

In the early days the few boats that fished through the surf were mostly open heavy skiffs powered with old automobile engines (with a rare gasoline marine engine), a few had small 15 to 25 hp outboards. These boats were wrestled with great labour on and off primitive trailers towed behind old passenger cars and were rowed through the surf until the engines were started and then lumbered off toward the fishing grounds to return later to the launching area, rowed back through the surf to be hauled by main strength back on the trailer again. The hulls which were heavy, wall sided, and flat bottomed, with a planking thickness more suited to ice

breakers than surf boats, suffered from deep draft because an inboard engine had to have a skeg to protect the propeller and the whole thing was most unsatisfactory.

The advent of good marine plywoods and the improvement in outboard engines both from a salt water compatability and power output standpoint led to a swift evolution in hull design so that a far lighter, yet stronger hull powered with a far more reliable and higher powered engine came into general use. There was still some problem with hull weight, however, as the boat still required many ribs or frames and strong keels to be able to withstand the shock of breaker impact and of grounding hard on the bottom when landing through the surf with a full load.

The introduction of a system of sheathing the entire exterior of the hull with fibreglass cloth at last allowed a really serious re-design of the whole boat with a drastic reduction in frame weight and planking thickness due to the increased shell stiffness the fibreglass imparted to the hull. A welcome number of dividends also arrived when using fibreglass such as a very greatly increased abrasion resistance, absolute water tightness of the hull seams and joints, a very large reduction in skin friction and best of all much reduced maintenance on the hull of the boat.

Along with this came light-weight transistorized fathometers and voice radios that were completely self-contained. Competition for markets brought prices down. The surf boat and all its systems went through a rapid development in a few years and the boats are now using powered pot or line haulers, radios and depth finders that were only found in far larger boats ten years ago. Equipment—"gurdy" or pot hauler—located usually starboard slightly aft of amidship—is a horizontal or vertical capstan driven by a 2½ to 8 hp single-cylinder air-cooled gasoline engine which sometimes drives bilge pump too—engine protected by box.

The immense growth in pleasure boating (mostly outboards) led to great improvement in boat trailer design so that shortly the slogan "one hand launching and loading" was no idle boast, fig 25.

Beaching and transport trailer—steel frame—two wheeled with wide section large diameter auto wheels and tyres—cradle fitted with one or more rollers and hand winch—tyre sometimes partly deflated during launching and beaching for better floatation on soft sand—reinflation for highway towing by high pressure air bottle—special hubs on wheels for water-tight bearing seals.

Tow truck usually ¼ to ¾ ton pick up type—four wheel drive rare as expensive. Wheels split rim with oversize so called "beach buggy" tyres front and rear—sometimes fitted with front mounted winch driven from engine of truck via transfer gear and dog clutch (rare). Trucks are usually very old used models as salt water damage ruins them in two or at the most three years. It is customary to swap winch, wheels and engine from truck to truck as corrosion destroys old one and it is junked and replaced.

Launch and beaching procedures are the same for lobster or trot line fishing:

● The chosen site is one reasonably close to the operating area that provides a smooth hard sand or gravel approach from a road and is reasonably free of reefs or rocks that may make launching and retrieving too hazardous

● After the boat and gear has been made ready the truck and trailer are backed into the surf until the surge will lift the boat slightly free of the trailer

● The fisherman starts the already warmed engine and as a surge nears engages the engine

● The beach man (or woman) watches for the signa from the boatman and as the surge arrives and the

boat moves aft of the cradle he engages the truck clutch and moves the truck and trailer clear of the departing boat

Depending on whether it is a stern or bow first launch, the boatman either backs into deeper water and then waiting the next surge spins the boat at full power around until he is bow on to the surf or else if launched bow first uses full power and the next surge to find deeper water and position himself to enter the breakers. As the breaker collapses the boat enters with moderate speed the foam of its advance and then at full power punches through the wave and into the slack water beyond. Entering the slack power is again feathered to adjust position and the surf passed using alternate bursts of the throttle or idle to thread the rest of the surf system until outside the surf line.

Returning again is greatly aided by the "walkie talkie" to receive advice from the truck driver as to the area of the least surf and the truck will position the trailer as an aiming point for the boatman on the beach opposite this area.

Once the beaching point is established the boatman watches the surf for enough time to pick the proper wave which is followed in on the back slope through the break point by use of the throttle to keep from overtaking the breaker and keeping ahead of the following wave.

As he approaches the trailer the beach man raises the tounge of the trailer and the boatman rides the surge right up the centre line of the trailer and holds the boat there with the throttle. The beach man then drops the tounge and rapidly hooks the trailer winch cable on the boat's towing ring located on the boat's stem slightly below the waterline. Once the winch line is pulled taut both boatman and truck driver man the winch and shake the hull all the way forward over the trailer rollers. The truck is then either hitched to the trailer and boat and trailer pulled clear of the water or else boat and trailer pulled clear using the power winch on the truck front bumper until high enough above the surge to allow the truck to hitch up as before.

The above sounds very chancy but with some practice is very rapidly done in rather a high surf. Practice is required and speed and co-ordination between both men essential.

Surf boats—hull

These boats are a local built design called the "Cardiff Skiff" and are made of marine plywood (best construction or of "exterior" grade commercial plywood). The cheaper wood is good for at the best only 3 to 4 years and its lasting quality depends on an outside sheating of fibreglass cloth for watertightness and abrasion protection. Interior of the cheaper boat is thickly painted with a cheap oil base house paint and fasteners are nailed.

The best construction boats are bronze screw or monel "anchorfast" nailed and all joints, frames and woodwork glued as it is assembled. These boats are also sheathed with fibreglass cloth and a better grade paint used inside. To date the oldest boat is nearly 10 years of age and is still in excellent shape. Fibreglass bottom is renewed as required (average once yearly) and this is the only major upkeep expense. The boats average 16 to 18 Loa (4.9 to 5.5 m) and 6½ to 8 ft beam (2 to 2.5 m). Beam width is controlled by California State laws restricting towed trailers to not more than 8 ft or 2.5 m width. Some of the latest boats measure up to 21 ft (6.4 m). Experience has shown that 18 ft (5.5 m) is about the maximum length that a two man crew can handle launching or beaching off a trailer on a sand beach.

The hulls are V-bottom design, very sharp forward and tapering to a fairly shallow V at the transom. In proportion to their length they have enormous freeboard and a very strong sheer particularly toward the bow. Transom is flat with a slight rake aft and the hull has extreme flare above the chine all the way aft to the transom. No deck or whaledeck is used.

A very small 2½ to 3 hp outboard is carried when long-lining and is used in "walking the line" after the longline set is made and for emergency use. This engine is lashed in the bilges and not kept on the stern when landing or going out through the surf.

The hulls are built upside down on a jig and laminated frames, stringers and keel are used. Sawn frames are not liked as they are "too heavy and split out in the surf". No projecting keel or shoe is used and a triple layer of fibreglass is used to fair in the chines and for protection of the keel strip. Chine batten is steam bent oak. Frames are widely spaced (18 to 24 in, 460 to 610 mm) and stringers and chine battens depended on planking is single sections of ⅜ in (9.5 mm) plywood for the bottom up to the chines and ¼ in (6.4 mm) or 3/16 in (4.8 mm) for the sides. Stringer and rib spacing is doubled the first 5 ft (1.5 mm) aft of the stem.

No flooring is used and bilges are open throughout the boat to facilitate bailing. If an inboard engine is installed (rare), it is in a watertight box with a hinged cover.

A finished hull is very strong and stiff for its weight and considering their power and the beating received during launching and in the surf it is well this is so, fig 26.

Surf boats—engine

With the exception of a few inboard/outboard drive or jet pump propulsion installations, the vast majority of these boats are powered by 50 to 100 hp outboards and by and large it has proved the most efficient. Primary problems are corrosion which is pretty well under control and the item of a heavy mass located in the extreme stern of the boat which is compensated for in the design of the boat.

The problem of swamping by waves coming aboard through the low transom required by outboard installations has been solved by the installation of, in effect, two transoms—the aft or true transom is low and strongly braced and is the one on which the engine is mounted, and the second is simply a watertight bulkhead far enough forward to allow the engine to tilt inboard if the lower end strikes bottom. The space in between as mentioned being decked and used for fuel tanks.

Modern American outboard ignition systems are now transistorized and geared and quite unaffected by moisture so this is no longer a problem.

Without exception the engines are electric started as the large size makes hand cranking impractical and if engine is stopped in the surf it is much too time consuming to restart by hand. Also the most favoured engine, an in line six cylinder type uses no reverse gear but is stopped and cranked backward to back down. Batteries are charged by an AC alternator built in to the engine's flywheel and battery ignition is used to fire the plugs as it is lighter and more reliable than the old fashioned magneto systems as well as being easier to seal against moisture.

Fuel consumption is still high by comparison to a four-cycle engine of the same output but only slightly higher and the overall dollar/hour cost is equal between engines for a season's use. Repairs are much simpler on the two-cycle engine and can be made without special tools or power machinery. Most owners do their own repairs at home.

Cooling systems are positive pressure pump circulated systems and work well in water with sand particles in suspension in it as the pump impellers are made of synthetic rubber and will not wear nearly as rapidly as the old metal pump gears.

Engine controls and steering station is slightly aft of amidships usually fastened to the box on the starboard side covering the gurdy drive engine. The boat is operated at all

times with the fisherman standing for better visibility and so his legs can absorb the fierce pounding of the hull in the surf or at high speed in the open water outside the surf line. This same pounding poses a problem with the old style float controlled carburation but modern engines use diaphragm injection carburettors, and this trouble no longer exists.

Experiments with motor wells through the hull have been made but the problems of excessive drag, sealing, motor tilting and working space lost in the boat require too many fancy solutions so they have been dropped without exception. No inboard engine installations have been made for several years, they are just too heavy and expensive to be competitive.

The excessive power (to European eyes) installed in these light hulls at first glance may seem wasteful but it is used primarily for steering and to accelerate the boat while in transit through the surf line. Sometimes only a few seconds are available between crests in which the boat has to be correctly positioned to meet the oncoming wave system, and then this high power is well worth the cost and the absence of skegs or keel and the high thrust of what amounts to an active rudder gives them a fantastically quick response to the helm.

The combination of this high speed, plus the mobility on the trailer allows a tremendous area of coast line to be available for fishing, so that if bad surf or some other condition prevents longlinging in one area a large choice is still at hand every day. The old slow displacement hull permanently afloat in some harbour allowed no such choice. Again this mobility allows the fisherman to do all of his hull, gear and engine work at his own home, where tools and working space are at hand—no small advantage. In fact a surprisingly large percentage of these fishing ventures are composed of husband and wife teams. He fishes and the wife drives the truck, and handles the beaching gear.

Suggested improvement of FAO beach boat type BB-59
If local tradition is against the use of outboards McKinley suggested that these boats be powered with rebuilt automotive engines, *not* diesel, for the following reason:

- low first cost
- easier to keep in service
- faster throttle response
- light weight per hp

The only really good competition offered the outboard engines for surf boat work is the following system:

A fairly small auto engine direct coupled to an axial flow high volume pump discharging through an above water swivelling nozzle in the stern. The water intake for the pump being through a large gridded opening in the boat's bottom alongside or straddling the keel—the so called "Jet Boat".

The engine cooling system is the same as that originally installed in the car the engine was removed from. That is to say the automobile radiator, cooling fan, water pump and plumbing are removed intact and reinstalled in the boat.

The engine is encased in an air tight box with an opening at the forward end for the radiator and a larger air exhaust trunk opening pointing upward at the aft end of the engine box. This exhaust trunk has a raised coaming about 12 in (30 cm) high and is fitted with deflector vanes to direct the air flow straight up. The cooling fan is fitted with a shroud between the radiator core and the fan and blades are usually increased in pitch to increase the air flow or the fan itself is replaced with one having a larger number of blades. Fresh water or anti-freeze mixture is used as the engine coolant

liquid and coolant temperature controlled by a conventional thermostat. Usual setting is 180°F (82°C).

The engine exhaust is directed through a conventional automobile muffler mounted vertically in the centre of the exhaust cooling air duct so that the muffler is cooled by the air flow around it and the engine exhaust gas is blown well clear of the interior of the boat by the same air flow.

US Coast Guard regulations require that the engine be fitted with a back fire trap and drip pan on the carburettor and that a bilge blower be used to vent air inside the engine box before starting.

The propelling pump or "jet pump" is a manufactured item that comes complete and ready to install as a unit including coupling flange, steering and reversing gear for the thrust nozzle and all fittings. The only modification found required for working in shoal water is that some users have had "stellite" leading edges brazed on the pump and stator vanes to reduce abrasion when suspended sand is forced through the pump in very shoal water when launching or landing through the surf.

The most popular engines are six cylinder, 140 and 170 in³ (2.3 and 2.8 l), engines. No clutch is used between pump and engine. Nor is an engine thrust bearing needed as thrust bearings are fitted to the jet pump itself and no load is transferred to the engine. The engine flywheel is removed and a spline machined in the flywheel centre hole to mate with a spline on a stub shaft fitted with a coupling flange. After reinstalling the flywheel the engine is mounted in the boat with the stub shaft inserted. Then the stub shaft and pump shaft coupling flanges aligned and bolted and the engine installation is complete. Engines are run with the boat out of the water to warm them prior to launching and for adjustments if required without any noticeable damage to the pump unit. The engine starter does not object to the small extra load of the pump rotor when engine is started with the boat in the water.

Unfortunately the total cost of the entire propulsion plant is higher than an outboard for the same service as the cost of the propelling pump is quite high and the engine bearers, jet pump mount and plumbing, the engine box and miscellaneous labour total up to quite a lot.

Steering effect in water down to less than 1 ft (0.3 m) in depth is very good and as the boat requires no skeg to protect the prop the deadwood can be cut away to increase turning speed and reduce draft both of which are very desirable in any beach boat.

Thrust output is a function of rpm and thrust build up from idle to maximum power quite satisfactory. Reverse thrust is poor being only 10 to 15 per cent of forward power so the boat operator has to adjust for this. Fine speed control, that is the ability to adjust speed by varying engine rpm is quite good but requires familiarization if a person has only conventionally propelled boat experience.

Fuel consumption is higher than a normal boat's but is balanced by the far better shallow water ability of these units for surf boat use.

A great virtue is that the installation can be serviced by any competent auto mechanic and unlike the very limited life of seawater-cooled engines this one is operating entirely in the environment originally planned.

In areas where air temperature is higher than normal a so called "heavy duty" radiator is required if prolonged high power operation is planned. These radiators are stock items from any American auto maker.

The engine/pump system has been very reliable and satisfactory and only the high cost of the patented pump unit keep them from displacing the outboards. Perhaps the Governments can reach an agreement with the patent owners for

Fig 25. *Surf-going fishing boats in Southern California are powered with strong outboards for optimum manoeuvrability in the surf. On shore they are easily launched and landed with the help of modern boat trailers*
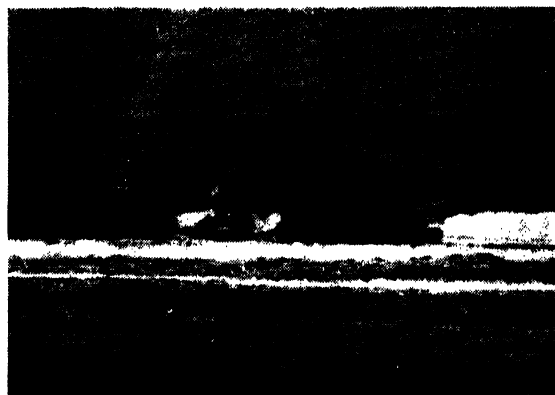
Fig 26. *The V-bottom pleasure boat type surf fishing boats in Southern California use light weight transistorized echosounders, voice radios and line haulers driven by a small inboard engine. Surf negotiation is facilitated by the active steering provided by the heavy outboards used*

local manufacture of the pumps and thus reduce the price for the benefit of their fishermen.

McKinley suggested a design study along these lines and some form of hire purchase plan with the fishermen.

Special method for tropical surf areas

McKinley also proposed an idea, which, at first glance, he said, may sound foolish, but really has merit in that it is a device which will enable a single fisherman to obtain sufficient fish each day to feed at least several other people, primarily in warm water areas, where steep coral reefs or rocky shores prevent the use of canoes or rafts from being launched from the shore for more conventional fishing.

The idea is to use a slightly modified surf board or paddle board of the kind now so popular as a sporting device, as a small scale fishing platform. This idea was suggested by a manufacturer of a popular surf board which is used on both coasts of the USA, in Hawaii and Australia. The standard tandem or two person board could be modified very easily into a unit that could carry one person and at least 200 lb (100 kg) of load through any surf condition up to swells of 8 ft (2.4 m) high, and that the board alone would not weigh more than 35 to 40 lb (16 to 18 kg) ready to launch. Any person of normal swimming ability could handle this board in the surf with only a few hours of instruction, and a day or so of solo practice.

The manufacturer's idea is to construct an open wood or plastic tray on top of the board, the width of the board, and about 4 in (10 cm) high by 4 to 5 ft (1.2 to 1.5 m) in length. This tray is to be covered by a securely fastened net and used to contain the fishing gear (say a longline set) on the outward bound trip, and the gear and the catch on the return trip.

A rig, somewhat to the order of this, is used illegally by poachers hunting abalone and lobsters. This was so successful that howls of dismay from sportmen's clubs and commercial fishing interests succeeded in having them barred from normal use.

The surfboard maker said that the best size is of the order of 12 ft Loa×28 in beam×5 in depth (3.7×0.7×0.1 m), and that made in his plant of a thick fibreglass shell stiffened with a hardwood spine and with the voids filled with polyurethane foam, they sell f.o.b. for £50 ($140) each in lots of a dozen—service life about 8 to 10 years. A cheaper board can be made of marine plywood but the angular shape is much harder to handle in the surf, and it is not nearly as durable as the moulded fibreglass unit, as well as being prone to leakage.

This "sharpshooting" board is not intended to be ridden back through the surf as is the more familiar sport board, but is paddled through by its rider in a prone position using his

hands to propel and guide the board (although a skilled surfer can ride them through moderate surf standing erect). The "sharpshooter" or "sniper" poaching board is often fitted with a glass bottomed well and rubber light screen, so that the operator can lie prone on the board and while he hand paddles the board along can look through the well and spot abalone, lobsters or fish of a size worth spearing—not sporting but very effective and the poacher doesn't expend his energy or in heat loss from his body into the colder water.

McKinley admitted that this might sound a most unlikely way to fish but it will work and the investment is very small which is very attractive, and it also allows serious fishing in an area not open to more conventional systems, along the coasts of, say, India, Africa and other tropical overpopulated areas of the world. Most of all, the areas that lack harbours or markets able to absorb large catches of fish, and areas where road transport does not exist to distribute large fishing tonnage, even if it were brought in by conventional fishing fleets.

Were some of the tropical governments to set up a factory using cheap local labour to make these boards in standard moulds, he believed that an acceptable one could be produced for around £10 ($25)—a unit with cargo tray and water glass built right into the board. This is very likely the most effective fishing system per dollar that can be made but would only be efficient in warm water fishing at the subsistence level, but is a system that *anyone*, male or female, above the age of ten, can master in a very short period of time and would be of great assistance to family groups in backward coastal areas all around the world within this temperature zone. Transportation of the board from home to beach presents no problems as, due to its light weight and modest size, it can be hand carried by a child.

Sharks here are often seen swimming in the midst of a group of surfers but do not seem to be interested in the boards as long as the rider keeps his arms and legs onboard, but in the event of an aggressive interest by them the user can retreat into the surf zone which the large sharks avoid.

Gulbrandsen (FAO): There are very few natural harbours along the coast of West Africa and for centuries the fishermen have been obliged to work from the surf-beaten beaches. Future developments will probably favour bigger boats working from well-equipped harbours. However, breakwaters are extremely expensive and the sand carried by the long shore current clogs the entrance in a few years unless frequent dredging is carried out. Both for economic and social reasons, fishing from the beaches will continue to play an important part for a long time to come.

[518]

The main weapon of the West African fisherman in his fight against surf and sea is the Senegal or the Ghana type dug-out canoe powered by paddles or by sail. These long, slender craft are a beautiful blend of each country's wood resources, skill and tradition. In recent years a great many have successfully been equipped with outboard motors. All attempts to

use inboard engines have failed. Several countries have also attacked the problem of replacing the dug-out canoe with a more modern boat, but no solution has yet been found. An analysis of the problem shows that the requirements for a beach boat are indeed difficult to fulfil:

● Low cost
● Strength combined with low weight
● Construction simple enough to be made by local boatbuilders, preferably of materials available locally
● Positive steering when negotiating surf

In 1966 the Government of Dahomey asked FAO to assist in developing suitable fishing boats. Based on Gulbrandsen's experience, gained from beach landing tests with a 21 ft (6.4 m) prototype fibreglass boat, built by FAO and previous FAO work (Gurtner, 1960), a new type of beach boat was designed to use a special rope landing technique (Estlander, 1955).

Fig 29 shows schematically the rope landing system consisting of a buoy anchored well outside the surf zone and a synthetic rope stretched between the buoy and the beach.

For the construction of the beach boat, new materials were considered, but aluminium was found to be too costly and a fibreglass construction would require an air-conditioned boatyard because of the extreme temperatures and humidity. The final choice was marine plywood which is produced in several African countries.

The prototype beach boat had the following characteristics:

Loa	23 ft	(7.1 m)
Beam max	6.9 ft	(2.1 m)
Hull weight	1300 lb	(580 kg)
Outboard motor	10-20 hp	
Cost of hull	£155	($550)
Cost of engine	£110	($400)
Total investment	£265	($950)

For a surf boat the outboard motor has several advantages.

Fig 28. FAO Dahomey surf boat coming in through the surf, utilizing a synthetic rope to assist steering and to dampen pitching. The boat uses an outboard engine to obtain as active steering as possible

It is light in weight, has optimum steering characteristics and can be tilted when approaching the beach. The motor was mounted in a well (fig 27) to get maximum protection against breakers from aft.

The prototype was tested in beach landing (fig 28) together with the rope landing system. Before launching the boat, the rope was put through roller fairleads forward and aft. When the boat was floated by an onrushing wave, the crew jumped on board and hauled the boat through the first line of breakers until there was sufficient depth of water to start the outboard motor. This is a critical phase in the normal way of launching. If the motor fails to start, the canoe is often thrown towards the beach by the next breaker, resulting in capsizing, swamping or a broken motor. By using the rope there was no difficulty in keeping the bow against the waves until the engine was started, since the boat could be hauled a good distance from shore before starting the motor, the risk of having the propeller touching the bottom was greatly reduced. Full speed was given at the right moment in order to cross the next line of

the development of motor transport so will the canoe be in operation for a very long time to come. Just as the bicycle is a cheap form of transport which the low-income individual can afford, so is the canoe a cheap platform from which to fish and one which the individual fisherman can afford. Moreover, the strong desire of the fishermen in developing countries for independence and self-employment is met by the canoe. Furthermore, the canoe fits into the techno-socio-economic situation of many developing countries. For one thing, there are many developing countries which will not be able to build fishing harbours for larger craft for a very long time to come, and even if such fishing harbours were built, it is likely that a new set of fishermen would have to be trained at a higher level and with a different concept to man the larger craft.

To force the fishermen in many developing countries to abandon their canoe is to drive them into unemployment. Fishing is usually the principal field in which they are skilled and even where other industries exist, the displaced fishermen
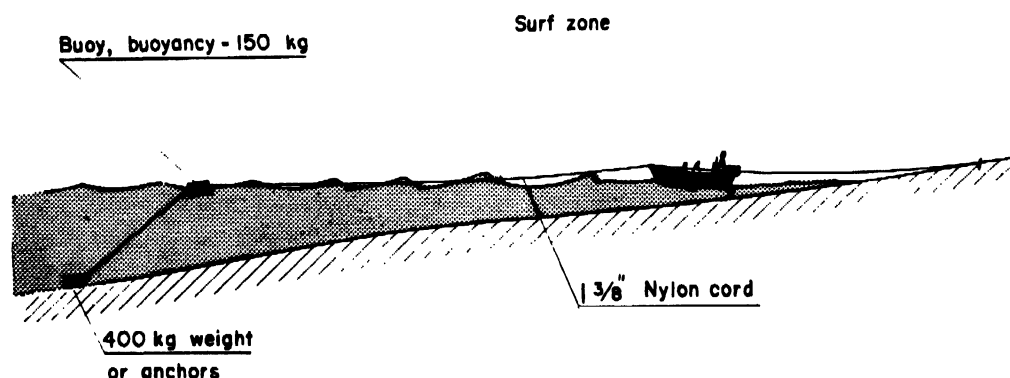
Fig 29. In Fishing Boats of the World (1955), *Estlander proposed the use of a rope when launching and landing a beach boat*

breakers as fast as possible. On arrival at the buoy, the rope was released from the fairleads and the boat could continue to the fishing ground. Coming back, the rope was picked up, put into the fairleads, and the skipper waited for the right wave to "hang on". He tried to position the boat a little behind the wave crest when it started to break. The boat was then carried by the wave like a surf board towards the shore. If the boat had been forward of the wave crest when it broke, it would have been in great danger of being swamped or broached, but the rope added much to security by counteracting the broaching.

The main targets in the design of this 23 ft (7.1 m) beach boat, namely low cost and minimum weight have been reached. These, coupled with the rope landing system, have resulted in the risks of beach landing being much reduced and in addition there is more space for gear and catch. The prototype has been used for several months by fishermen in a village of Dahomey, but it is still too early to make any definite conclusions. Only time will tell whether the glued plywood construction can withstand the stress of beach landing over a long period.

Author's reply

Thomas (FAO): Like Traung he disagreed with Zimmer that the dugout canoes are something of the past and will soon disappear. Just as the bicycle has not disappeared because of

would be unlikely to fit into these. They would not willingly exchange their independence for unskilled jobs in which they would become dependant.

Just as the mobility of the bicycle can be improved by adapting an engine so the mobility of the canoe can be improved by motorization.

The problem from the canoe fisherman's point of view is largely a sociological one which many technicians involved in large-scale fisheries do not appreciate. What possibly will happen is that in developing countries which can afford to build fishing harbours and provide facilities necessary for large craft a stratification will develop in the fisheries. The canoe fisherman will continue to operate his small craft and a new set of fishermen will be trained to man larger craft. In these initial stages the right thing to do is to undertake such improvements as can be made to the small-craft without seriously altering their behaviour or functional adaptability and certainly one of the ways of doing this is by motorization.

In remarking that the dugout canoe means a lot of hardwood wasted, Zimmer had failed to take into account the skill available in some countries. In many developing countries in which dugout canoes are made and especially those in which little interest has been taken in the fishing industry, the builders know how to build dugout canoes

but not plank boats. Moreover, it is not certain that the quantity of wood involved in making a dugout canoe could serve better economic purposes when it is considered that for the duration of the life of the canoe it is providing employment for the fishermen and crew and perhaps for vendors of the fish.

New material in old design
Because of their knowledge of the sociological problem involved in removing the conservative fishermen from his traditional craft, private, commercial and engineering interests in Jamaica manufacture from fibreglass a canoe which resembles, behaves and has the functional adaptability similar to the traditional dugout canoe. A fair number of these craft have been acquired by fishermen.

Von Brandt in referring to very small boats and pieces of wood used as raft stated that these methods have no influence on the production of protein. He says that this can be done by bigger gear only like large bottom trawls and purse-seines which are not adaptable from indigenous craft. But there is evidence to disprove the first part of his observations.

Heath pointed out that Zambia produces 35,000 tons of fish annually and that the craft used are dugout canoes. Gurtner also pointed out that in Senegal canoes account for 90 per cent of the annual fish catch amounting to 90,000 tons. In 1959 the catch in Ghana was 35,439 tons of which canoes produced 32,804 tons as against 2,635 tons produced by motorized vessels. In Jamaica in 1962/63 canoes were responsible for production of 15,000 tons. Motorization of the Jamaican dugout canoe (together with gear training) was responsible for the dramatic increase in fishermen's earnings. In some instances canoes with an annual turnover of £600 ($1,650) increased their income to £1,500 ($4,200) and more, whilst in others fishermen's income rose from £2 ($6) a week to £7 ($20) a week. The proof of the pudding is in the eating.

Von Brandt had also failed to take into account the characteristics of the sea floor in certain areas. For example, the sea floor over wide areas of the Caribbean are covered with coral and rocks which forbid the use of bottom trawls and in other areas the patchiness of shoals of pelagic fish would make purse-seining a very doubtful gear economically.

Again, von Brandt has evidently misread the paper. He believed it as advocating the mechanization of indigenous small craft as a final step and as the best way for fishery development whereas the paper advocated this as an initial step towards improving the productivity of the small-boat fishermen in developing countries.

NEWLY DESIGNED SMALL BOATS

Devara (India): Gurtner did a good job in bringing out a paper about various boat development projects undertaken by FAO experts in developing countries in Asia, Africa and Latin America.

The cost of boats in India is comparatively low. The boat development has progressed well in the last ten years in Andhra Pradesh, India. During 1953 to 1954, Mr. Ziener, an FAO naval architect, surveyed the existing craft and selected two types of local craft for mechanization. The first local craft, called *Nava*, was mechanized in 1955. In all, 44 navas were mechanized. As the manoeuvrability of these navas is not satisfactory, mechanization was stopped and well-designed boats were introduced. They were designed by Ziener, Gurtner and the Central Institute for Fisheries Technology (CIFT), Cochin and Devara and Sastry of the Kakinada Boatyard.

From 1960 to now, more than 200 boats (including navas) have been constructed and distributed. The performance and results of these boats are very encouraging. One fisherman

who was given a mechanized nava, is now the proud owner of a house worth £535 ($1,500) and three sailing boats with full sets of nets worth another £720 ($2,000), after paying back the subsidized cost of the boat. Another fisherman, who was given a 25 ft (7.6 m) boat, now owns a house worth £1,000 ($2,800), in addition to substantial savings in a bank account, after paying back fully the subsidized cost of his boat. Both of them are acquiring bigger boats now.

Originally, these fishermen conducted gillnet fishing, but now they want to do trawling for demersal fish and prawn and shrimps. There is a great demand for larger and larger boats. So the tentative target for the fourth 5-year plan is:

Two 50 ft (15 m) boats; 34 40 ft (12 m) boats; 78 32 ft (9.75 m) boats; 30 30 ft (9.1 m) boats.

It is also planned to establish a second boatyard and a small steel shipyard. With this present encouraging result and good response from fishermen, far better results should be achieved.

This developing fishery has attracted a few non-fishermen and they floated a firm with a capital of more than £360,000 ($1,000,000). The boat development scheme not only improved the economical condition of fishermen, but also provided employment for more than 350 workers, mechanics and administrative staff.

Trend in Japan
Takagi (Japan): Gurtner's paper is very much appreciated and he is to be congratulated on his great activities in fishing boat design.

The near-future trend of small fishing boat building in Japan is as follows:

- Small wooden boat building will slow down because of lack of timber and skilled labourers
- To recover the above situation, research and development of FRP fishing boats under a special research committee is under way
- Recently, many small steel fishing boats under 50 ft (15 m) are being built. The minimum length of steel fishing boats may be 32 ft (10 m) on the standard scantlings of steel fishing boat construction rules

Kojima (Japan): Generally speaking, Yokoyama's paper (Part II) highlights more intensively from a scientific point of view the small fishing vessels in Japan, which are great in number and have been used for a long period, rather than examining only the problems of their resistance, propulsive efficiency and seakindliness.

Good preparatory work
Rawlings (UK): Gurtner suggested to determine the exact power being developed by the engine with the help of a torsion meter in the band of horsepowers considered; but it is doubtful whether consistent results would be obtained.

Large torsion meters can produce an inconsistent pattern down the running range; smaller ones would probably be much less consistent. A more reliable and much simpler method is to calibrate the engine fuel pump against dynamometer loads, mainly to obtain reliable information against specific individual performance tests; adoption as a standard feature would not be encouraged however.

Thomas', Gurtner's, Rasmussen's and Brandlmayr's papers deal with widely differing types of small craft within comparatively narrow dimensional extremes, but it is most significant that they all have at least one thing in common, and that is the lack of truly factual and fundamental information even of a general nature, on which to work in the beginning and subsequently of performance in service under the widely varying operating conditions to be expected.

It is not the intent of this discussion to suggest recommended values for *GM* and freeboard; however, some suggestions can be found in two papers presented at this meeting; one by Traung, Doust and Hayes page 139, the other by Gueroult page 112. Where the proper parameters have been established, a curve such as fig 30 can be provided to the personnel of a fishing vessel to guide them in the matter of stability, any period of roll to the right of the curve, for a given freeboard estimated when among waves), indicating insufficient stability.

Authors' reply

Gurtner (FAO): There is no standard answer to Heath's problem. On-the-spot investigations by qualified technical personnel are necessary before an attempt is made to give recommendations regarding boat development.

Rawlings' suggestions are valuable and one must certainly look forward to the day when all engines delivered by his firm are fitted with calibrated injection pumps and are issued with full instructions on how to measure power delivered.

As Townsend stated, a wealth of information on the problem of fishing vessel stability was indeed presented in 1963 in Gdansk, Poland. Unfortunately, this material could not be published due to lack of funds, and in view of its availability to a very few people only, no reference was made in the paper to data contained in this material. International co-operation was, however, continuing in this field, and the problem of finding and proposing for adoption a suitable criterion or a series of criteria for fishing vessel stability was being dealt with by a special IMCO/FAO committee as outlined by Nadeinski, page 182, and it was hoped that the findings of this committee would be published for general use in the near future.

He was sorry to have to disagree with Sinclair and Tyrrell regarding the effect of low angle of entrance. FAO experience to date had shown clearly that low angle of entrance need not be detrimental to good seakeeping qualities. On Tyrrell's remarks concerning the construction of the boats shown he felt that local traditions and preferences would be extremely difficult to overcome and the ultimate in modern construction practices could only be considered when more experienced carpenters were available. In the absence of these he considered it safer to rely on scantlings that were perhaps a trifle on the heavy side.

ARCTIC FISHING VESSELS

Zimmer (Norway): Rasmussen says that the hull must be protected from ice by galvanized sheet iron. A tarred felt between the plating and the wood makes for added protection. What thickness of plating does Rasmussen propose? The heating of ships in Arctic climatic conditions is mentioned. By freshwater cooling the engine and thermostatic control, the cooling water could provide reasonable heating if lead to radiators when the ship is underway. When the engine is idle, an electric dynamo could be used to provide extra heat electrically.

Gurtner's very substantial and fine piece of work is extremely useful and interesting. The stability problem is well treated and he gives important information of period of roll. The main difficulty in the stability problem is overloading. In a wooden boat when loading fish on deck up to the coamings freeboard then gets almost nil and the bulky wooden bulwarks help to maintain stability. However, this is not the case in steel vessels.

van den Bosch (Netherlands): Emphasized the importance of not judging stability alone by the initial stability. Zimmer had mentioned that fishermen tend to load the vessel up to

the coaming so that freeboard becomes extinct. For a small trawler, the range of stability in the condition quoted by Zimmer must indeed have been so large that the vessel was virtually uncapsizable, and the buoyancy of the wooden bulwarks cannot have done much.

Special Danish designs

Christensen (Denmark): Thanked Rasmussen for an excellent paper on Arctic fishing boats and their development. The Danish Royal Trade Department intends to build larger fishing vessels for Greenland and in 1965 they have finished the construction of two 82 ft (25 m) wooden boats—one 95 ft (29 m) steel boat is still under construction. One problem encountered is how to introduce a higher standard of living in the Northern part of Greenland. In this area, there are special problems insofar as processing which has been the same for centuries. Most of the seas are covered with ice and only for a few months in the summer is it possible to use a boat. They had therefore been trying to find a small boat which could do this fishing just a few months each year.

The boats have to be light, strong and inexpensive. In 1965 24 ft (7.3 m) boats have been built. This boat type has the accommodation forward. It is still too early to comment on the results, but is is already indicated that this type of boat is excellent. On the other hand, the construction is not good enough and therefore a new type of construction, maybe laminate or plastic might be better. Of the particular design problems for fishing vessels in Greenland, one of the most important is to construct a boat having the biggest flexibility for different fishing methods. It is very difficult to have a multi-purpose boat which is excellent for all fishing techniques. It is necessary to select the most important fishing methods used, i.e. longlining, handlining, gillnetting, pelagic netting, bottom trawl and seine netting.

Referring to the Norwegian type vessels, the engine is semi-diesel of simple construction and the boats fish in threes, one equipped with an echo sounder so as to locate the fish for all the boats. It is very difficult in Greenland to develop the fishing industry based on small vessels and therefore it is essential to have bigger boats of over 60 ft (18 m) for use in the open sea. This is the present stage of development of the fishing boats in Greenland, but the small vessels will still be able to fish along the North and South coasts of Greenland.

Methods in Newfoundland and Greenland

Harvey (Canada): Newfoundland has severe winter conditions and the boats encounter heavy ice. To protect the outer hull planking, a sheathing of greenheart is layed over the outer planking with tar paper between the wood. The fastening of galvanized iron must be kept clear of caulking seams and must be short enough not to go through the planking. Steel reinforcing plates are placed at the bow and around the stembar. Also around the skeg and under the stern. These plates are fastened with special screw nails and care should be taken that they do not interfere with seams and pierce through planking.

Danielsen (Switzerland): The connection with the development of fishing vessels of Greenland can be taken as a very good example of the importance of the interrelationship between fishing, processing and marketing. Characteristic for these small boats in all the North Atlantic area is the seasonal variations in the catch. For the boats described by Rasmussen under 20 GT, the catching curve will be as fig 31 for the Greenland waters.

With an investment on shore of about £133 ($370)/tons raw materials processed during the year, one will very soon realize the economical consequences of not using the factory
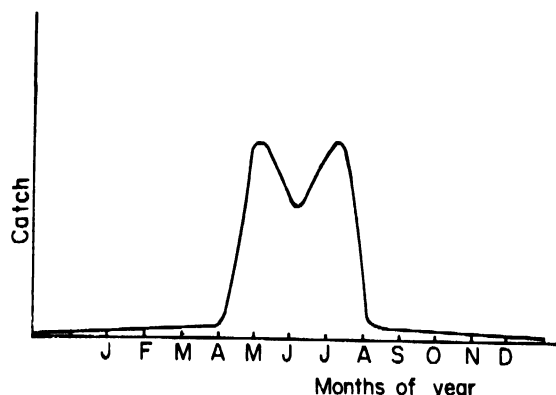
Fig 31.' Relation of catch and month in Greenland

for more than four to five months during the summer time. This would be like a shipyard running under these conditions with a degree of utilization of 25 per cent. Further problems arise in the marketing of a product with a limited keeping quality and which is processed during a very short period of the year.

This is a very important point in all decision-making concerning the development of the fishing industry, especially in developing countries. A very good example should be Greenland. The explanation of the lack of success in some countries is to be found in the lack of understanding of the suboptimization of all functions from raw material procurement through processing to marketing. Boat operators and naval architects must show a better understanding of this problem in the future.

Training of fishermen in Hong Kong

Orchard (Hong Kong): The main objectives of the Fisheries Development and Extension Division in Hong Kong have been (1) the initial mechanization of indigenous craft coupled with the training of fishermen, (2) the gradual improvement of boats generally, including the training of boat builders, (3) and the introduction of better fishing methods, particularly the introduction of single-boat otter trawling to replace the two-boat trawling traditionally carried out.

One of the most important original steps—taken on the advice of Traung—was the local recruitment in 1956 of a qualified and experienced craft technician. This officer proved very worthy but left the post on promotion. In his place came Choi Kwok-leung, who is now senior Craft Technician. There is in Hong Kong an establishment of altogether six craft technicians: that is two boat designers backed up with a draughtsman; one mechanical and one electrical engineer; plus a master shipwright, and these officers are all fully committed on useful work. In addition to this staff, the Division has a master fisherman who has together with Choi been so largely responsible for the acceptance and success of the work.

Following news concerning the success of a 40 ft (12 m) modern shrimp trawler, a "clear stern" modified junk-type shrimp beam trawler of 64 ft (19.5 m) was built by a graduate from one of the training courses run by the master shipwright of the Division. This particular boat costs HK$58,000 (£3,637, US$10,000). Trials 9½ knots. Bollard pull 5,200 lb (2,360 kg), GM lightship condition 5.43 ft (1.66 m). The boat is now fishing successfully, local fishermen are accustomed to a stiff ship, and now a 66 footer (20 m) has been designed.

There is the Government loan system of just under HK $200,000 (£12,500, US$35,000). Fishermen given loans should follow the instruction of the Government technical officers, the boat should be built to the government design

and under its guidance and supervision. This marks the beginning of buildng to detailed plans, and to specifications of a higher order than ever in the past. In previous years, the Government has had to "retail" development and so gradually earn the confidence of the fishermen, but now hopes to be able to put across the development work on a "wholesale" basis.

Retvig (Denmark): Just a brief remark to Rasmussen as regards the government's point of view to approving designs and dimensions, which, of course, is their duty. Denmark will not keep technical achievements (so far as they are obtained) a secret. On the contrary, the Danish authorities are always ready to discuss problems arising from practising the rules. The reason is, of course, that the administration has the highest interest in the rules being applied in the right way (not only for the benefit of the administration, but what is much more important, to the satisfaction of the shipbuilder and the fisherman) and in order to collect experience from practice, so that it is able to amend the rules prevailing today so that they work as sensibly as possible.

Author's reply

Rasmussen (Denmark): Agreed with Christensen and Danielsen that expensive filleting plants cannot be fed by small boats operating only during a short season. If all the functions from marketing to processing had been well explained to the naval architect, results would have been better. There is no fishing in winter in Greenland, but small boats play a role in seal- and bird-hunting. The 20 GT boat-type proposed in Rasmussen's paper could carry kayaks on deck to travel to and from the hunting grounds.

In reply to Zimmer, tarred felt is provided under the sheeting for ice protection. Sheet thicknesses are given in the paper.

Use of freshwater cooling with the heated water to circulate to radiators for heating the boat is a good system, but in harbour, when the engine is not running, there will be no heating and that is why one must have a small oil heater for radiators in port. Use of the oil heater could also heat the engine before starting in cold weather.

To Harvey, Rasmussen said that greenheart was not available and that is why there was no mention of it in the paper.

To Retvig, no reference had been made to the Danish Ship Inspection Service when it was stated that governments held back information. This office has given all possible assistance.

HIGH-SPEED FISHING CRAFT

MacLear (USA): On the US East Coast, about four years ago, a high-speed boat was used for lobstering. She was designed and built to be able to go further off-shore than existing vessels. The boat was about 40 ft (12 m) overall and was expected to cruise at 21 to 28 knots. She had an open transom to facilitate hauling lobster pots. However, no other such boats have apparently been ordered.

A fast 36 ft (11 m) boat was designed, which is almost identical to Brandlmayr's design. One hundred and fifty of these boats have been built, with a wide range of engine horsepower and their performance is similar to Brandlmayr's graph. One boat was fitted with two diesels of 1,015 hp together for off-shore sport racing and this permits extending the performance curve.

In fig 32 the average boats operate in the range (A), the fast boats were in range (B) of the curve. The boat, which was used exclusively for racing, had a speed of 52 knots and cost £18,000 ($50,000), fitted with two engines and spares worth £11,000 ($30,000). These engines were estimated to
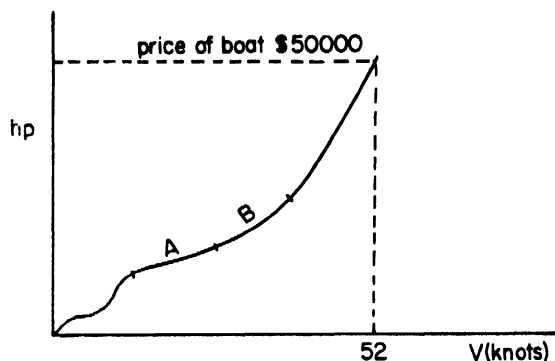
Fig 32. Speed-power curve

give a service life of 22 hours per engine, and indicate how expensive it is to go fast on the water.

High-speed inshore day boats are amply seaworthy, and it is only economics that limit the speed of fishing boats.

In connection with canoes, MacLear once owned a gaumier or canoe used in Martinique and St Lucia, BWI. It costs £6 ($17) and could be amortized in one good day. This 100 per cent return on investment in one day, while it seems a miraculous business opportunity, is not so good when one considers the rest of the fishing season in St Lucia. When fishing for red snapper two or three men row and sail their gaumier at a total of 20 to 30 miles in one day to fish with hand lines in 600 ft (180 m). On a bad day, their catch may only number 20 red snappers, and the return per man is very poor.

Interesting speed problems

Borgenstam (Sweden): In the design of the fast gillnetter described by Brandlmayr, there are some interesting hydrodynamic problems involved which might need some clarifying. The speed-range of 10 to 20 knots is a very critical one. It represents a transition region between displacement and planing conditions, where neither of the hull forms is ideal. Unfortunately there is a tendency also for modern pleasure craft to come right into this speed bracket, which should be avoided if at all possible.

Brandlmayr remarked there have been great variations in reported and observed performance. The explanation for this is the form of the power curve of a planing craft. It intersects the curve of available power at a very small angle. Even small variation in resistance or engine power will thus cause the intersection point to move considerably, so that the top speed is much more influenced than is the case with a displacement craft. This fact makes it desirable to use an engine with a very full torque curve, which is the case with the big US car engines. Diesels are usually not only too heavy but they also often have a too flat torque curve to go well with a planing or semiplaning hull.

In a planing craft it is important to prevent unnecessary increase of the weight, apart from that caused by the useful fish load. The designer must keep a careful control over the weight not only during the design but also during the construction and operation.

Lee (UK): The hull form, longitudinal position of centre of gravity, and the position and type of spray chine, are probably ideal for a lightly loaded boat operating over the speed range stated in smooth water conditions, but fuller sections forward and a steeper rise of floor aft would improve seaworthiness, as Brandlmayr suggested.

It should be recognized that high-speed craft involve more maintenance. The engine must be kept at peak performance

and the bottom kept clean. A light wooden hull construction fails with repeated pounding and requires frequent attention. A light metal construction involves many problems arising from dissimilar metals, moreover special welding equipment is required for building such craft.

The high durability of the plywood boat sheathed with glass reinforced plastic, shown in fig 4 of Brandlmayr's paper is of great interest and some information about the resin and reinforcement and method of application would be appreciated.

High cost of extra profits?

Gillmer (USA): Undoubtedly the advantages of using high-speed fishing craft are most attractive and enticing and it takes little imagination to visualize the ensuing increased profits caused by more rapid transportation of the catch to the market, the more numerous trips possible to and from the fishing grounds, the possible elimination of refrigeration, etc. It would seem, however, that these bright and beckoning advantages must have been thought of often in the past and had there been no engineering obstacles, would have become at this time more of a generality.

Brandlmayr, in his discussion under economics, included in his statement some surprising claims in a comparison of displacement boats versus planing boats, in terms of operating fuel consumption. The inference here would appear to be that planing hulls are 50 per cent more economical than displacement hulls. There seems to be no statistical data or descriptions of test comparisons, hull forms and weights involved, etc., in the paper to substantiate such claims and it is felt that if such exists, they would have been included in the paper.

Generalization on such unsupported claims can lead to false conclusions. It would have been far more desirable had Brandlmayr approached this most interesting area of comparison more objectively. Resistance or power curves in terms of specific resistance or specific power ($R/\triangle$ or $P/\triangle$) plotted against speed might have been more revealing for these hull types. It would have perhaps thrown more light on the ability (or lack of it) of light planing hulls to carry a pay load efficiently.

McNeely (USA): In many countries the cost of fuel would prohibit the use of high-speed fishing craft. As Brandlmayr pointed out, high-speed craft may be used in only a limited part of the world's fisheries, such as where (1) the value of the fish is exceptionally high, (2) the day fishery exists, and (3) the weight of the catch is relatively small. High speed craft would probably not be suited to trolling which is usually carried on at greatly reduced engine power and speed.

Sinclair (UK): One other point on Brandlmayr's paper. When considering high speed for fishing vessels, it should be remembered that these are generally not good seaboats and in areas where bad weather is frequent they may be harbour-locked much more frequently than their orthodox competitors.

Takehana (Japan): In Japan, some fishermen are planning to change from traditional pole and line fishing to tow-line fishing. So they require a lighter and higher speed boat. Japanese traditional small wooden fishing boats are so heavy that their speed is limited to under 8 to 10 knots. They are planning to change hull to steel, but it is difficult to make a steel boat under 10 GT lighter than wood, due to corrosion and the welding technique of thin plates. Fibreglass reinforced plastics may be better suited to these high-speed boats than steel, and having regard to the boatyard facilities, conversion from traditional wood to moulded fibreglass would be easier

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than to steel. So Takehana was going to recommend them to make fibreglass boats. The higher initial cost of this material may be covered by higher speed and higher fishing ability.

Author's reply

Brandlmayr (Canada): Agreed with Borgenstam's excellent explanation of performance characteristics and wished he had done as well. Many fast boats are disappointing and over-rated in this marginal range. Speed predictions usually backed with many pages of calculations often lack the under-standing of the principles.

In reply to Sinclair on seaworthiness, these boats are generally fishing in protected waters, but they make a sur-prising speed at sea especially in long swells. Seaworthiness with these boats is very much a matter of boat-handling. They are most difficult to handle in short seas and better in long swells. A good seaman with experience can run between the swells and run down the slopes. There is less roll and the ability to accelerate away from following seas is useful to an experienced man.

On Lee's question about covering plywood with FRP, conditions must be dry and polyester resin is used with surfacing mat applied first and then covered with woven roving.

Gillmer's questions were to some extent answered in the paper but they are questions worth repeating. The engineering obstacles to high-speed fishing craft are the need for light, powerful engines and sophisticated structures. In recent years a few builders have overcome these obstacles to a limited extent, but most have failed through insufficient power,

overweight, lack of strength or poor hull form. These obstacles continue to be formidable. Concerning fuel consumption: reports were gathered from fishermen using boats on their usual passages. The displacement hull forms were believed to be much heavier and, of course, were designed for carrying capacity. On significant runs to fishing grounds they tended to be driven at nearly full throttle using engines of about the same power as the light planing types. Curves of specific resistance or specific power plotted against speed would be of interest but while operational data on distance, time and fuel consumed were available, weight figures were not. It is somewhat like comparing the fuel consumption of a dump truck with that of a passenger automobile when both are travelling empty. Planing hulls are not efficient pay load carriers unless the pay load has an hourly cost as is the case of highly-paid personnel.

DEVELOPABLE SURFACES

Michelsen (USA): It is amazing that it should take so long to develop such a simple, straightforward method of generating developable hull surfaces. Is it that one by nature tends to make things more difficult than they really are? To anyone who has tried to use the cone-cylinder method of hull form design, this must certainly never be the case, more especially so after reading Kilgore's paper. He is to be congratulated on having the ability to challenge established design pro-cedures and for presenting a simple underlying principle of developable surfaces in a lucid and concise manner. No more can now be said on this subject as related to hull design.
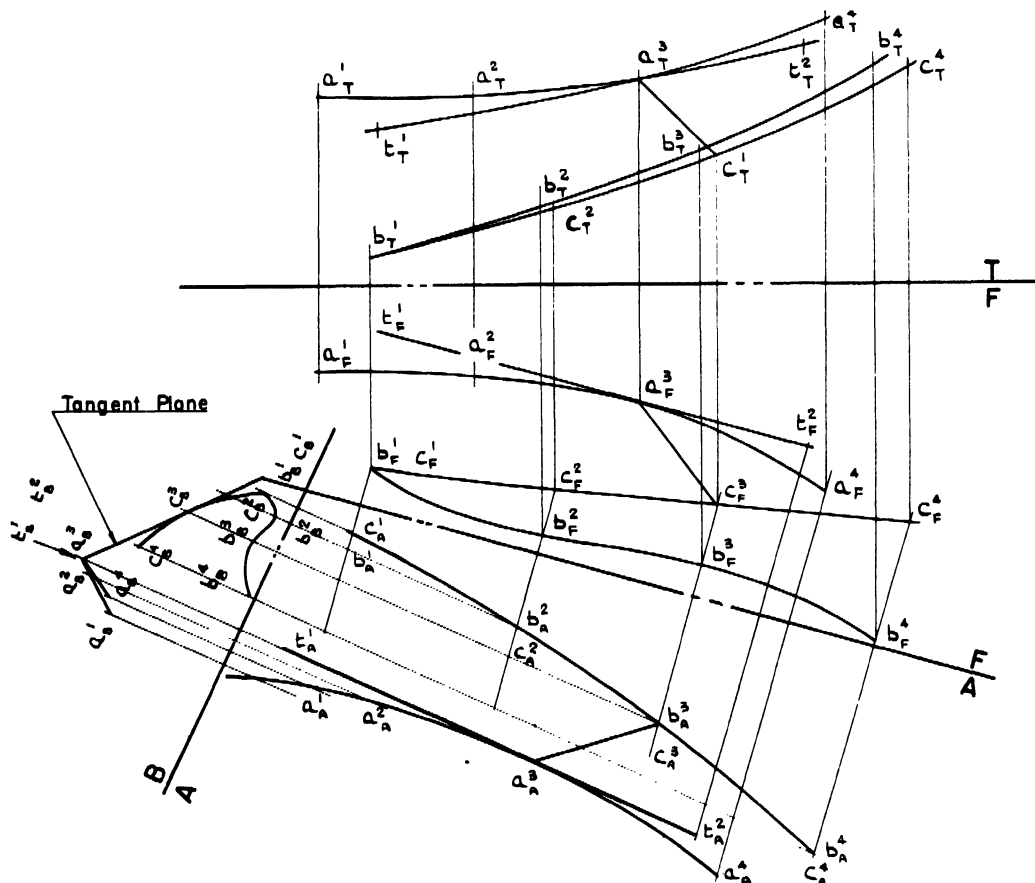
Fig 33. Rotation of co-ordinate system to explain Kilgore's method

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Kilgore stated that proof of existence is very involved, but perhaps a rotation of co-ordinate system will provide what is needed. Graphically this is shown in fig 33 of this discussion. Assume two segments of space curves A and B, given by their top and front views; the question is then asked, does there exist a plane which is tangent to curves A and B at points located between end points of segments? To furnish the answer, a tangent is drawn to curve A at an arbitrary point A[3]. By using two successive auxiliary views, a point view of this tangent is obtained. Obviously all planes containing the tangent will appear as an edge in this second auxiliary view. Therefore, if a tangent plane exists, that is tangent to curve A at point A[3], it will be possible to construct a line from the point view of the tangent (in the second auxiliary view) which will also be tangent to some point on the curve B. In fig 33 it is clear that curve B does not satisfy this requirement. Curve C, on the other hand, does meet the criterion stated above and the line A[3]C[3] is a tangent element.

Uniqueness follows directly from elementary theorem of geometry regarding the uniqueness of tangents to a plane curve from a point not on the curve. To use an old, well-used phrase: "The proof of the pudding is in the eating." He hoped therefore, that boatbuilders will freely help themselves to what has been served. He was thoroughly convinced that anybody who uses Kilgore's method of developable hull surface design will find the savings in labour cost to be of great significance, both in the drawing room and in the shop. The impact of this paper on future boatbuilding practices should not be underestimated.

Allen (USA): As a builder of large numbers of steel and aluminium small boats, he expanded on practical considerations for the construction of fair hull forms.

The general problem with light gauge steel hull construction is to obtain fairness. After establishing the shear and chine lines by a developed surface technique, it is necessary to allow considerable deviation in the mid-panels for expansion during seam and butt welding or rather the contraction of the periphery of the plates.

For vessels of 33 ft (10 m) length, a jig with no frames is used. Leveau's fig 4 to 6 show a boat on the jig, fig 5 a hull with no frames removed from the jig, fig 6 internal structure installed at a later stage.

In vessels of 33 to 85 ft (10 to 25 m) with plating of $\frac{1}{4}$ in (5.35 mm) thickness, the following guides are used:

- Minimum number of transverse frames to establish hull shape
- Flexible longitudinal frame structure to which the plating is attached
- Welding sequence which permits pressure to be applied to the mid-panels from the inside of the hull to expand the hull form rather than to restrain the plating to the transverse frame shape

Real service rendered

Benford (USA): Kilgore has done the industry a real service in presenting this exposition of the design of developable surfaces. Beforehand, Benford had always assumed that developable surfaces required endless trial-and-error with families of cylinders and cones. There is now a better set of tools for this task. The result is that the naval architect can design a cheaper hull in less time than before.

Kilgore's comments on the application of straight-line frames is worth noting. However, canted frames throughout a vessel will create intersection problems at bulkheads, hatch-side girders, etc. But, of course, reluctance comes from the tradition that the frame location was the shipbuilder's primary index for fore and aft location. Kilgore is certainly funda-

mentally right in recommending straight canted frames and that the disadvantages will be little more than distractions to an imaginative designer-builder.

How important are the savings inherent in developable hull forms? If the structural hull contributes one-third to the total cost of the fisherman's boat and gear, and if the hull cost can be reduced by 25 per cent, then there will be about an 8 per cent saving in invested cost. A boat built in the older way might cost £180,000 ($500,000). An 8 per cent reduction would be £14,000 ($40,000). To many fishermen this might be the difference between success and failure in financing a new boat. Furthermore, few people realize the great influence of first cost on profitability of an operation. Considering the risks, both physical and financial, an investor in a commercial fishing boat should be satisfied with nothing less than a 12 per cent rate of return. If a 20-year life is assumed, a 12 per cent interest rate and a 48 per cent corporate profits tax, the annual cost of capital recovery comes to 21 per cent of the investment. Thus the £14,000 ($40,000) in reduction of building costs is equivalent to a saving in operating costs of £3,000 ($8,400) per year. This would assuredly be welcome to any fisherman and illustrates the wisdom of careful professional design.

For Kilgore's next paper on this subject is suggested an explanation of how to design developable surfaces within the restraints imposed by the minimum bending radii of different thicknesses of plywood.

Hull shape problem

Colvin (USA): While there is much merit in Kilgore's desire for lighter structures and lower costs, one must still accept the fact that planked hulls will continue to be built for many years to come, and that in certain areas the advantages of a planked hull often outweigh the disadvantages of not being able to predict the strength of testable sheet material. On paper, it is often more simple to convert from the heavier structure to a lighter and usually better structure, than it is in practice; for, as the weight of the material decreases, the skill of the builder increases, and with it come a host of new methods, all of which must be learned before he can successfully construct the lighter hulls.

There is no question at all of the ability of a designer to design the hard chine or V-bottom hull that has equal or only slightly higher resistance than an equally well-prepared design of a round-bottom hull. If the material for the shell of the hull is to be of marine plywood, then there is no question that a developable surface must be prepared, and that the designer must not in any case sacrifice any more than is absolutely necessary to come within the preconceived ideal shape that he is trying to obtain, for, on a heavily warped surface, the joining of small pieces of wood and their butt blocks or liners would increase the labour manifold over a developable surface. However, when the material of the shell becomes steel, then there is no conceivable excuse to adhere directly or indirectly to a developable surface.

It had been Colvin's practice in the last decade to use the V-bottom hull in the midbody and afterbody; but, in the forebody he never hesitated to depart from the V-bottom hull to gain a finer entrance or, at least, an entrance that is compatible with the speed of the vessel and its seakeeping characteristics. By actual comparison, the additional time involved in framing up a conical surface in steel equals out the additional time spent in cutting a plate to a smaller width to adhere to a non-developed surface. Many times that the stressing of developable surfaces by designers with the view of time-saving in the plating of hulls tends to blind them to the fact that framing becomes more difficult and it can, in many instances, be more advantageous to make a

radical departure rather than try to obtain simplicity in shell application.

From a draughtsman's viewpoint, the fundamentals of developing a surface can be rather easily understood; however, there are a number of methods where the developable surface is external to the hull where the ambiguous point is found by trial and error. Rabl (1959) outlined a method of multi-conic development where the development of the surfaces was within the hull boundary limits and external points were not necessary to find or to think about. Also, the method that he used gave direct means of determining expanded shapes. The method outlined by Kilgore approaches this in its simplicity and gives a reliable development. The final development indicates a great deal of flam added to the underbody forward which, in some instances, could give a bow that was too full to utilize without either an increase in horsepower or an increase in displacement. The altering of the displacement prismatic coefficient and longitudinal centre of buoyancy can be acceptable in smaller craft, but must be corrected in larger vessels.

Colvin is in full agreement with Kilgore that there is enough plasticity in most materials to accommodate slight deformation, which makes it advantageous from a building point of view, to dispense with developing frames when they approach a curvature of less than one-fortieth the span. Again on paper, there is absolutely no reason why the frames must be square to perpendicular to some other main portion of the hull.

Other technical points

It is true that welding has ended the necessity for right angles and square framing, but only from a strength point of view. From a builder's point of view, unless a very complicated jig were set up, it would be unduly expensive and difficult to set up a hull that has lost all of its reference points. In very full hulls, it is still necessary to use cant frames as it is in the round stern, cruiser stern and fantail types of hull. The attachment of bulkheads, the building-in of fuel tanks, fish pens, etc., still indicate the desirability for framing that is square to the centreline. The combined longitudinal-transverse framing system on all forms of hulls is preferred to a straight transverse system, especially in the forebodies. With sufficient combined transverse and longitudinal framing, a very light shell can be applied, giving a vast reduction in overall weight of the vessel without a reduction in longitudinal, transverse or panel strength.

The fallacy of believing that fully-developed hulls reduce the need for high skill in metalworking is common; however, when given just a welder and a shipwright who are not masters of their art, some shocking results will occur to the best plans prepared. The skill of the designer many times is lost through poor builders, and many poor designs are improved by good builders. Developable surfaces may lessen the need for heavy tools and furnaces in large vessel construction, but in sizes to 75 ft (23 m) whether V-bottom or round-bottom, furnaces are not a requirement and that the shell framing on most vessels up to and including 50 ft (15 m) can be cold-worked by hammering. As an example, on a 45 ft (14 m) deck length, 22 ton displacement, round-bottom hull, three men can loft, make patterns and the frames, and have the frames set up with transverse frames on 17 in (430 mm) centres in 10 working days.

McNeely (USA): Kilgore's paper makes a lot of sense in its description of the use of differential geometry to develop contours of a hull consistent with good architectural practices, but predictable in shape for precision assembly of pre-cut and shaped sections. However, are not most steel vessels constructed in this manner?

Verweij (Netherlands): This is a very useful method, since it can be applied to whatever construction material is used for the actual boats. Especially if fibreglass is chosen and only a very small number of boats have to be built, it will result in a great saving of cost for the mould if the hull consists of developable surfaces. The mould cost for building two fibreglass landing craft of 36 ft (11 m) length was 7.5 per cent of the value of the finished boats.
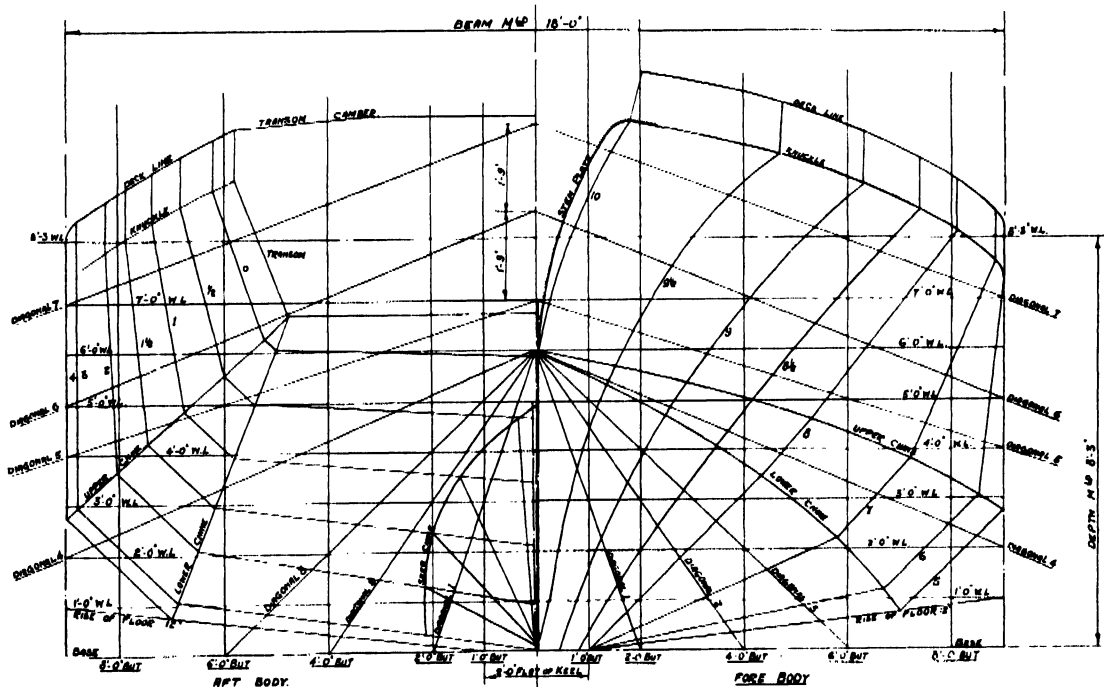
Fig 34. Body plan of a British steel chine boat

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Double chine vessels

Lee (UK): Design based on developable surfaces sometimes involves difficulty in balancing the $\overline{FB}$ and $\overline{FG}$ and it is desirable to have ample margin in the distribution of the main weights and to allow for ballasting. While the statement in Kilgore's paper that the backbone and ribs are best forgotten, may apply to small smooth-water craft, they are essential for all other types. The single chine forms illustrated are likely to suffer heavy pounding in a seaway and the flare of the forward sections do not appear to be sufficient for fishing in open seas.

It may be of interest to note that British 75 ft (23 m) motor fishing vessels of wooden construction are being re-placed by double chine vessels of steel construction; the body plan and shell profile are shown in fig 34 and 35. All the plates and frames are fitted without fairing, thus reducing the amount of skilled labour required. The frames forward are rounded slightly to take the curve of the plate where it is twisted in the plate rolls; rounding of the frame is shown in Kilgore's fig 5. With this form pounding on the flat sections aft has necessitated the fitting of longitudinal stiffeners

components, care being taken to keep these as close as possible to those established in the beginning (by use of cones and cylinders)
- Adjustment of the form so obtained in order to adhere as closely as possible to the original features. Hulls have longitudinal framing in welded steel

To save time and labour, plating joints are arranged in such a way as to:
(1) Make the best use of whole rolled sheets
(2) Keep down waste
(3) Reduce the number and length of joints

Paulling (USA): Kilgore's paper presented an interesting example of the application of rather sophisticated mathematical reasoning to the solution of a real and apparently simple engineering problem. With the results presented so succinctly here, the designer of craft of developable form is freed of his most serious handicap, i.e. the difficulty of producing a hull with predetermined properties, and is granted nearly the same control over the geometry of the hull he produces as the designer of a moulded form. Further,

Fig 35. Shell profile of a British steel chine boat

(intercostal) full welded, and full welding (in place of inter-mittent welding) to floors.

Toullec (France): People in France are watching with great interest the construction currently proceeding there on a series of small aluminium boats where the lines and the method of drawing are similar to those advocated by Kilgore. It is not suggested that the French have developed the method before Kilgore, but just that they entirely share his view.

French owner pleased

Foussat (France): In 1962 an overseas owner, who had no preconceived ideas against developable hulls, ordered from Foussat's firm a large 66 ft (20 m) 300-hp steel launch, constructed on Kilgore's principles. He was so pleased with its sea behaviour that he ordered a bigger one. The procedure in designing the hull is as follows:

- Drawing of approximate form with straight-line sections to have the desired centre of buoyancy, volume and underwater hull form coefficients
- Translation of this form into developable surface

considering the trial and error nature of previous methods of developable hull design, this method presented should lead to significant saving in the naval architect's time.

Paulling did not fully agree with Kilgore's statement concerning the relative resistance of round-bottom versus chine hull forms. In particular, at the higher speeds which are often characteristic of small craft, the chine hull often shows a definite superiority in resistance. In a head seaway, perhaps the average moulded hull form may have an advantage, but the greater damping in roll of the chine hull is likewise an advantage in beam seas. In any case, by the use of multiple chines, a developable hull form can be produced which will approximate, as closely as necessary, the hydro-dynamic characteristics of a given moulded hull. For this purpose, double chines will probably be adequate in any real case.

Author's reply

Kilgore (USA): In regard to the proof of uniqueness, attention should be called to the principle that the cross product of unit vectors not orthogonal results in a scalar

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coefficient less than unity. Kilgore omitted to show such a coefficient in the proof, but this does not affect the general truth of the theorem.

Kilgore replied with reluctance to some contributors who have defended methods of generating approximately developable surfaces. He said that he should not care what fallacious notions anyone might choose to entertain, but on the other hand he felt an obligation to the large number of people, not expected to know any better, who waste their labour and money in following procedures they have read in published papers. For the benefit of these people, the distinction between a ruled surface and a developable surface is here repeated: All developable surfaces are ruled surfaces, but very few ruled surfaces are developable. Some ruled surface may be constructed between two space curves by *any* arbitrary procedure, but if the procedure does not satisfy the fundamental requirements of Definition 2.3 of the paper and Theorem 2 it is not a developable surface. It may be almost developable, but each time you design a hull by fallacious methods you run the risk of failure.

He also replied to some misconceptions. The example hull is not presented as a recommended design, but only as an illustration of graphical procedure. In regard to transverse stations along the keel, he had not proposed that web frames or bulkheads be eliminated, only saying that no structural reason exists for perpendicularity of plate stiffeners to primary landings. In proposing that one shipwright assisted by welders and labourers could build a large hull by simplified methods, it is not supposed that either the shipwright or the welders would be incompetent.

Benford's analysis is illuminating. He shows what far-reaching effects an initial saving can have. While the ratio of 25 per cent is only an example, his analysis shows that any saving is a good investment.

Michelson's remarks are humbly received. He has offered further insight into the geometry of developable surfaces, thereby enhancing the value of the paper.

With regard to Allen's remarks, the technique of fitting and fastening frames after the plating is hung is very good, and works especially well with longitudinal framing. Many hulls have been framed in this way without previous detailed development of the surfaces, but the inexperienced builder should be warned that he can find himself with some freakish results if he does not know in advance what he is doing.

Toullec's gallant endorsement is gratefully acknowledged. Foussat supplies additional testimony that the designer can keep control of hull form in using developable surfaces, and that economy in construction usually results.

Paulling's reaffirmation of the hydrodynamic efficiency possible with hard chines, comes from a man who has made a great many observations of flow phenomena. Kilgore believed Paulling would also endorse his plea for additional research on flow lines around hard-chined, displacement hulls. Johnson (1964) has also shown that hard-chined hulls may be superior to optimum moulded forms even for displacement hulls. It is necessary to go into this problem more thoroughly, and particularly to study the effect of varying displacement when hard-chined hulls are compared with equivalent moulded forms.

GENERAL

Troup (UK): Had been a naval architect with a company, which, apart from building small vessels, provided a design service for anyone who wanted to build a vessel and had no facilities for design or a drawing office in which to develop these designs. Designs were developed for New Zealand, India, the Middle East, South Africa and even for such remote places as the upper reaches of the Zambesi. A complete set of working drawings were completed for each design. They were carefully drawn, detailed in every way, and in accordance with what was modern shipbuilding practice. There were usually very few questions about these drawings, but these were surprising, until it was realized that they had been dealing with people who had no tradition of shipbuilding behind them.

Questions such as "Why don't you show flexible mountings under the engine?" could be asked, or "could we build this vessel upside down?"—"And if we do build it upside down, how do we get it upright without straining it?"—"Why is the propeller so big?" and they might well have asked "How do we line a shaft?"

Only a few contributors have offered any real practical help to these new shipbuilders in various parts of the world. FAO has done a first-class job in training naval architects and producing designs for fishing vessels, but some action should be taken to produce papers which would be devoted to the very difficult business of actually building a ship—how to lay it off, how to erect it, how to erect the rudder, how to weld awkward corners, or better still, how to avoid awkward corners, how to get bilge pipes through double bottoms, how to bore out a stern tube. These new shipbuilders need the experience of traditional shipbuilding countries and they need it in a good, solid, down-to-earth practical manner.

There is no advantage in advanced fish boat designs, if there is not at the same time an increase in shipbuilding skills. There is a very great thirst for knowledge in some countries today, and what they need to a very great extent is simple basic shipbuilding.

New Zealand skills well developed

McKenzie (New Zealand): Wanted to take the opportunity to correct an impression created by Troup's remarks. Troup placed New Zealand in the category of developing countries and in the category of countries who had received assistance in the way of receiving plans of fishing vessels, but unfortunately had no experience of boatbuilding. Whilst those in New Zealand would welcome any information to assist in a better design of fishing boats and will also assist the fishing fleet in adopting more modern methods to lower the cost of production, New Zealand should not be regarded as a country having no knowledge of boatbuilding. The coast line is approximately two thousand miles long and the nearest neighbour, Australia, is separated by twelve hundred miles of, at times, very turbulent waters, the Tasman Sea.

Of necessity, New Zealanders have been boatbuilders for over 100 years and the native race, the Maoris, prior to the arrival of the white man, built canoes of up to 100 ft (30.5 m) in length. These were hewn out from trunks of trees. New Zealand had built fishing vessels, passenger vessels and pleasure craft in wood and up to 70 ft (21 m) in length for many, many years. During the last world war they had an intensive ship-building programme for a small country and some 50 to 60 minesweepers and small tugs were built for war service. The minesweepers were constructed from drawings supplied by UK and based on a trawler design. These vessels were constructed in steel, wood and in some cases were composite vessels. In the past ten years, many new fishing vessels have been constructed, all welded steel vessels up to 65 ft (20 m) in overall length and wooden vessels up to 70 ft (21 m) in length. Some of these vessels have been constructed from imported plans and others were designed by New Zealand naval architects.

In an endeavour to create uniformity and offer some assistance to designers and boatbuilders, the Survey Section of

the Marine Department of New Zealand, had recently produced a small booklet which set out the requirements and the acceptable scantlings for wooden vessels of up to 70 ft (21 m) in registered length. At present, a 68 ft (20.8 m) fisheries patrol vessel is being built in New Zealand and a speed of 21 knots is specified and guaranteed by the builder.

Jet boats designed and made in New Zealand made history by conquering the Colorado River in the US. These Hamilton jet boats are now manufactured under licence in many parts of the world. These few facts show that New Zealand has some knowledge of boatbuilding.

Progress in Canada

Sainsbury (Canada): The need for increased education of all concerned with fisheries is apparent to all and has been stressed on many occasions; the benefits of an increased general standard in addition to specialized training can in fact be seen in the fishing activities of countries where a real attack has been made on education.

Two years ago the Government of Newfoundland, together with the Government of Canada, established a course of fisheries in St Johns, with three main tasks:

(1) To increase the general standard of education among young fishermen who did not complete schooling

(2) To train these young men in the basic subjects of their vocation

(3) To operate courses in all branches of the fishing and marine industry to provide the technically trained personnel needed by the industry

The courses under this heading are of a very high standard, of three or more years' duration. Students from outside Canada are able to attend the college by special arrangement with the Government of Canada through one of the following programmes: the Colombo Plan—the Commonwealth Caribbean Assistance Programme—the Special Commonwealth Africa Aid Programme—Educational Assistance for Independent French-speaking African States—Economic Assistance to Commonwealth Countries and Territories. Training programmes available under these plans are administered by the Director-General of External Aid, 75 Albert Street, Ottawa, Ontario, Canada. Information regarding the course of fisheries may be obtained from this address or by writing to the College direct.

It is worthwhile noting that the plans provide free trans-portation to and from Canada, a clothing allowance, books, equipment and supplies allowance, enrolment fees, and a monthly allowance sufficient to maintain the student during the studies. These arrangements could be very useful to developing countries, and at the course of fisheries cover, in addition to short vacation courses, three or more year courses in nautical science (navigation), marine engineering, fish plant engineering, food technology (fisheries), electronics, naval architecture and shipbuilding.

The basic course in naval architecture and shipbuilding extends over 3½ years and is based towards the size and type of vessels which includes all the ships discussed here. A diploma in technology is awarded and past graduate training in a number of fields (including fishing vessel technology) is available. Special interest to developing countries is a 15-month course to provide students with qualifications in engineering or a similar field with training in naval architecture and shipbuilding.

Much more information on the college and all the courses will be found in the catalogue of information which may be obtained from: the College of Fisheries, Navigation, Marine Engineering and Electronics, St Johns, Newfoundland, Canada.

Orchard (Hong Kong): The need is to train boatbuilders within the developing countries concerned. Textbooks with fundamental basic details are helpful and FAO does, most successfully, stimulate training in boatbuilding within the various developing countries themselves. However, to bridge the gap between developed and developing countries, we ourselves have to do the grafting.

FAO's hardwon experience

Gurtner (FAO): In addition to what has been said about the need for training and dissemination of information, not much will be achieved by distributing written material to boat-builders in developing countries. Many of these able boat-builders only speak and write such minority languages as Malayalam or Ouolof, while others perhaps speak some English or French, but cannot read it. Furthermore, their capacity to absorb written information is generally not great, due to lack of experience and formal schooling. This was realized in FAO long ago, and it is felt that it is very important for experts to be on the spot to give advice and to impart training to boatbuilders; they are not interested in papers, but in practical, visual help.

PART VI

DEVELOPMENTS

Recent US Combination Fishing Vessels

by Luther H. Blount and Edward A. Schaefers

Bateaux de pêche polyvalents récemment mis en service aux E.U. d'Amérique

Les bateaux de pêche polyvalents existent depuis de nombreuses années sur la côte ouest des Etats-Unis d'Amérique, mais depuis peu se manifeste un intérêt pour ce type de bâtiments dans d'autres secteurs du pays. Des navires mixtes à passerelle à l'avant, conçus principalement comme chalutiers à pêche par l'arrière, ont été construits en Nouvelle-Angleterre.

Le chalutier à rampe arrière *Narragansett* vire son filet entièrement par l'arrière. On ne s'est heurté à aucune difficulté en matière de "croches" ni d'embarquement de paquets de mer. Pour la pêche du poisson de fond, la rentabilité est bien supérieure à celle des grands chalutiers de Nouvelle-Angleterre travaillant sur le côté.

Le *Canyon Prince*, bâtiment plus petit, pratique le chalutage du poisson de fond et du poisson destiné aux industries des sous-produits. Certaines unités de la Nouvelle-Angleterre, quoique n'ayant pas été conçues comme bateaux mixtes, effectuent des opérations de pêche très variées. On peut citer par exemple le *Silver Mink*, chalutier crevettier du type Floride. Le succès remporté par ce bateau avec le filet coulissant est dû pour une large part à la tactique employée. Le *Silver Mink* n'est toutefois pas adapté à la pêche du thon à la senne en haute mer, et doit attendre que celui-ci pénètre dans les eaux côtières.

Dans le golfe du Mexique, l'attention s'est portée sur des bâtiments hybrides qui pratiquent la prospection des gisements pétrolifères sous-marins en sus de la pêche de la crevette et des "snappers" (Lutjanidés). Le Service des pêches commerciales des Etats-Unis a mis au point un prototype expérimental de bateau de pêche commerciale pratiquant plusieurs métiers, destiné à l'exploitation du vaste réseau de lacs naturels et de lacs de barrage des régions centrales des Etats-Unis. Sur la base de la pratique acquise en pêche, la principale recommandation formulée est de remplacer le moteur diesel classique par un hors-bord diesel installé à l'intérieur.

L'*Astronaut*, bateau polyvalent de taille moyenne pour la pêche du "king crab", construit sur la côte Pacifique, fournit un excellent exemple de la substitution de l'énergie hydraulique et électrique au travail manuel. Les auteurs terminent par une comparaison, fondée sur des expériences de roulis au bassin, entre une quille massive et des quilles de roulis montées sur un ferry-boat, indiquant qu'il y aurait tout intérêt à organiser des essais analogues pour les bateaux de pêche.

Recientes barcos mixtos en los E.E.U.U.

En los Estados Unidos, los barcos pesqueros mixtos han sido cosa corriente en la costa del Pacífico durante muchos años, pero en los últimos tiempos también en otras zonas del país ha ido surgiendo interés por ellos. En Nueva Inglaterra han sido construidos barcos mixtos con el puente a proa, fundamentalmente diseñados como arrastreros por popa. El arrastrero con rampa a popa *Narragansett* cobra el arte completamente por popa. No se ha tropozado con problemas para liberar enganches o por inundaciones del puente. La rentabilidad de un arrastrero para pesca de fondo es mucho más elevada que la de un gran arrastrero de Nueva Inglaterra que actúe por el costado.

El *Canyon Prince*, embarcación de tipo más pequeño, se ha dedicado a la pesca de arrastre de fondo y a la de peces industriales. Algunos barcos de Nueva Inglaterra se han dedicado a una diversidad de operaciones pesqueras, aunque no están proyectados específicamente como barcos mixtos. Uno de ellos es el arrastrero *Silver Mink* para camarones, del modelo de los utilizados en Florida. Las técnicas de pesca desempeñan un papel importante en el éxito de sus faenas de pesca con red de cerco. Este barco es inadecuado para la pesca del atún con red de cerco en aguas de altura y depende de la migración de los peces a aguas más cercanas a la costa.

En el Golfo de México, la atención se ha concentrado en los barcos mixtos que llevan a cabo trabajos de estudio petrolero en aguas de altura, así como la pesca de camarones y de pargos. La Oficina de Pesca Comercial de los Estados Unidos ha ideado un barco de pesca mixto comercial-experimental para trabajar en el gran sistema de embalses y lagos existentes en la parte central de los Estados Unidos. Basándose en la experiencia de trabajo, la principal recomendación consiste en sustituir los motores normales diesel internos con unidades de propulsión diesel internos-externos.

Un barco mixto de tamaño medio construido en la costa del Pacífico estadounidense es el *Astronaut* para la pesca de centollas, el cual es un magnífico ejemplo de la ventaja de la sustitución de la potencia manual por la energía hidráulica y eléctrica. Por último, una comparación de la quilla maciza y de la quilla de balance en un transbordador indica que tal ensayo podría ser ventajoso en las embarcaciones pesqueras.

I N the USA, the term "combination-type fishing vessel" is usually associated with the Pacific coast. This type of vessel, ordinarily under 100 GT, is designed to purse seine for salmon, trawl for groundfish and shrimp, longline for halibut, use pots for crabs, and troll for tuna and salmon. Various factors, such as seasonal availability of the major fish species, adequate conservation measures, short seasons, social-economic considerations, and the realization that diversification provides increased opportunities for efficient year-round operation, were initially responsible for its development. On the US Pacific coast, according to Hanson (1955), single-purpose craft are extremely wasteful, although some types, such as large tuna vessels, perhaps can be justified. The tendency for US fishing vessels of under 100 GT to be multi-purpose vessels has spread from the Pacific north-west to the north-east coast (New England). Some companies have designed and constructed even offshore oil survey and service vessels easily adaptable to the Gulf of Mexico shrimp and snapper fishing. Finally, in an attempt to determine the most practical type of vessel to fish the unexploited vast network of central US inland rivers and reservoirs, a prototype experimental combination vessel for commercial fishing operations has been designed and constructed. This report reviews recent trends in the design, construction, and operational experiences of US combination-type vessels. Particular emphasis is placed on specific vessels designed for operation in specific geographical areas.

ATLANTIC (NEW ENGLAND) COAST COMBINATION VESSELS

After large European stern-ramp trawlers appeared off the north-east Atlantic coast, the New England trawling industry showed interest in the US west coast style of combination purse-seiner-trawler that uses stern-trawling techniques. Additional stimulation for the introduction of combination vessels was the need to develop a purse-seine tuna fishery. New methods were obviously required, but the advanced technical experience of the US had not been in this direction. Stern trawlers of European design were 120 ft (36.6 m) or more, and many US operators felt these would be unprofitable in the medium-distance fishery.

Medium-distance vessel, *Narragansett*

It appeared that a combination stern trawler of 65 to 100 ft (19.8 to 30.5 m) designed primarily as a stern-ramp trawler, but readily adaptable to purse seining and scalloping, would be most suitable. Background information was assembled to design a vessel with the features of the west coast net-drum trawler and the smaller European stern trawler. Pacific coast trawlers have used a stern-trawling system, except that the entire trawl was swung to the side of the vessel and hoisted aboard amidships in a series of lifts. The net-reel drum system introduced in the late 1950's (Wathne, 1959) brought most of the net over the stern; however, the cod-end still had to be swung to the side of the vessel for bringing aboard. The boat had to be stopped dead at the time the gilson was connected to the cod-end. The vessel was then turned sharply port or starboard to swing the cod-end over either side rail and backed astern until the cod-end was at the side for emptying. This required stopping, turning, and backing and would not always be practical in the north Atlantic because of weather and

sea. If the cod-end could be hauled directly over the stern, the boat could continue under power in one direction for the most comfort and efficiency in handling.

An east coast shipyard decided, therefore, to design and construct a medium (50 to 150 GT) stern-ramp trawler with its net drum just aft of the bridge; this location would allow the entire net to be hauled aboard over the stern. The optimum size of stern trawler for the offshore banks, such as Georges Bank and Browns Bank, was calculated to be about 113 GT and 83 ft (25.3 m) Loa (table 1). Several designs were developed along the lines of the traditional "eastern rig" with the bridge aft, but offset to accommodate the net. Considering all factors however led to the decision that the "western rig" with the bridge forward was a more feasible combination vessel design. One factor seldom mentioned in the construction of "western rigs" is that they cost more to build than the "eastern rig" for the following reasons:

● The engine either has to be located forward of the fish hold or placed aft with a more complicated arrangement
● Controls have to be led further
● Crew's quarters are more expensive
● Separate heating and services have to be supplied for two areas

Specialized equipment

An additional consideration in designing and constructing the stern-ramp trawler, *Narragansett*, was the availability of several recent mechanical systems in the US that made some automation possible. The most important among these was the air tube clutch and brake operation that allows finely and remotely controlled clutching and braking. Furthermore, no important mechanical elements in the system are subject to salt-water deterioration. Another development that made the

TABLE 1

Principal characteristics of the *Narragansett*

Dimensions			
Loa	83 ft (25.3 m)	T, keel, light	9 ft 2 in (2.79 m)
Length registered	76 ft (23.2 m)	T, keel, loaded	11 ft 6 in (3.52 m)
B	22 ft 6 in (6.86 m)	GT	113 (111)
B over guards	23 ft 6 in (7.16 m)	NT	95 (93.5)
D	12 ft 3 in (3.73 m)	△ light	142 tons (140 ton)
		△ loaded	228 tons (224 ton)

Capacities		*Propulsion*	
Fish hold	4,300 ft³ (120.4 m³)	Main engine	380 hp w/air clutch
Fuel oil	3,500 gal (13,247 l)	Drive	gear belt
Fresh water	600 gal (2,271 l)	Propeller	Controllable pitch 60 in (1.54 m) diam

Deck Gear
Trawl winches—2 single drum, 1,000 fm (1,830 m), ⅝ in (15.9 mm) diam wire per drum
Net drum—1 single
Winch and drum—120 hp drive
Rigged for stern trawling

Electronics
Fish finder—Radio receiver
Depth sounder—Loran
Radar—Auto pilot
Radiotelephone

Accommodation—9

Electrical
AC system 5 kW off main engine
DC system 150 A and 60 A alternators off main engine, 50 A alternator off winch engine 2 × 32 V battery banks

Structural
Plating—bottom and bilge strakes ⅜ in (9.5 mm) sides, deck and whaleback ₅⁄₁₆ in (7.9 mm), ¼ in (6.3 mm) elsewhere
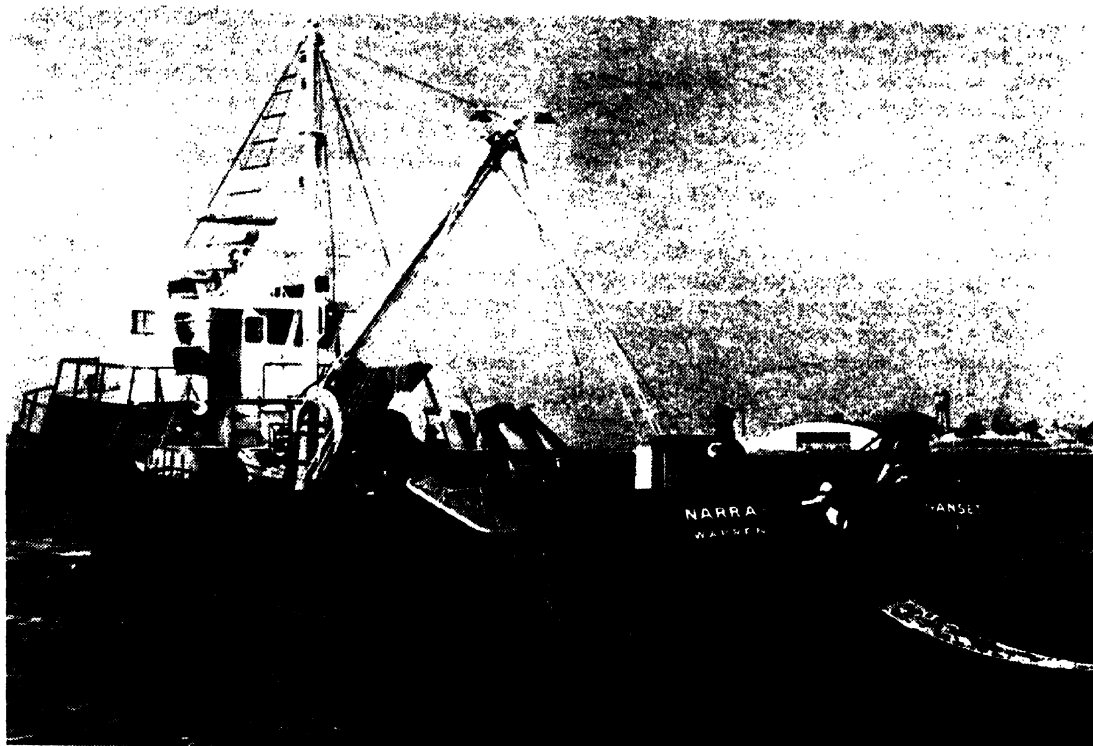
Fig 1. Medium distance combination stern-ramp trawler. Setting the trawl
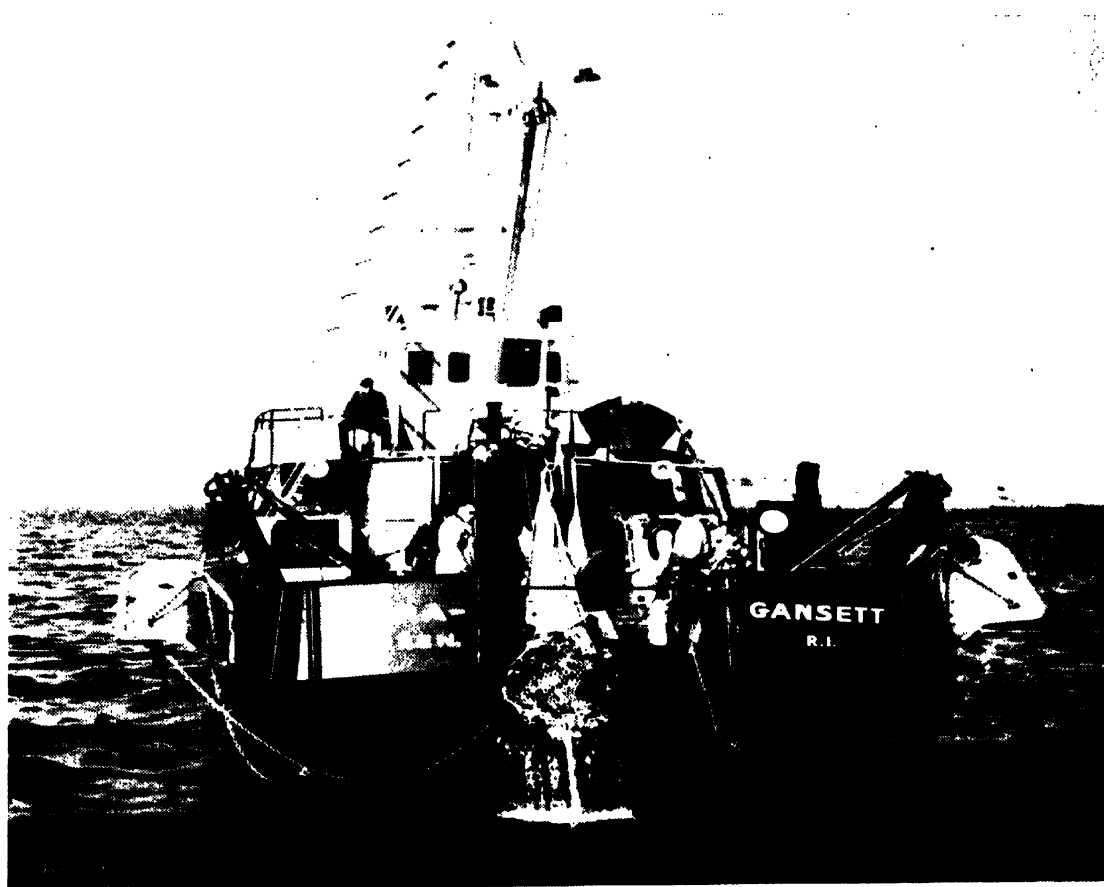
Fig 2. Hauling the cod-end

"piggy-back" stern drive feasible is the toothed gear belt made of stainless steel cables surrounded by rubber and nylon fibre composition with teeth of moulded nylon. This has been available only in very recent years. Other devices include an infinite variety of air control mechanisms and specialized valves.

Stern trawling system

According to Manning (1964), by European stern trawler standards, the net hauling system is both simple and effective (fig 1 and 2). The otter trawl is dragged by warps led through sheaves on conventional gallows and on the frames. These gallows are fitted against the bulwarks and port and starboard, a short distance forward of the rudder post. The trawl warps lead to trawl winches port and starboard, which are controlled from the bridge. The engine-in-stern, belt-driven trawler, is one of the first US vessels to have a trawl handling system adaptable to remote and automated control. This is accomplished by means of a remotely controlled net-winding drum, located forward The main engines are "piggy-backed" over the shaft to keep them as far aft as possible, thus increasing the fish hold space. The vessel is one of the first attempts to combine the navigation bridge and net hauling controls at a single station, with 360° observation overlooking the deck. All power-assisted equipment is controllable from this point.

The trawl board connections utilize a system developed on the US west coast. The net can be disconnected from the trawl boards and re-connected to leads attached to the net drum.

The *Narragansett* carries 1,000 fm (1,830 m) of 0.625 in (15.9 mm) trawl cable on each trawl winch.

Automated hauling features

Initially, the *Narragansett* was fitted with an automated system that allowed the winches to be stopped after the desired length of trawl cable had been shot. This system however, was too radical for the New England crew, who preferred to hand-control the payout. An automated haulback system also was installed in the vessel to allow course to be set upward or downwind and the net hauled in by pushing a button. Both winch drums, which are locked together for the operation, function simultaneously and haul the trawl wires more or less evenly. An air-operated limit control stops the winch drums when the doors reach the gallows frames, and the brake is applied automatically. This system, too, bowed to tradition and reverted to hand control, retaining only the feature of interlocking the clutches and brakes. This example bears out the fears expressed by Pain *et al.*, (1964) that fishermen who are being faced more and more with a mass of highly scientific "black boxes" would be frightened of them rather than consider them as "big brothers".

Controlling propeller thrust

Delicate control of propeller thrust may be accomplished by varying the pitch of the vessel's controllable pitch propeller. This is particularly important: firstly, to obtain enough force to shoot properly and carry the net off and out over the stern; and secondly, to provide just enough steerage way when hauling and splitting. On the *Narragansett*, a stop has been put on the pitch control to prevent the pitch from going to below the setting that provides minimum forward speed while trawling.

Specialized techniques

No serious trouble has developed with regard to hang-ups on the bottom. The vessel always has been capable of backing over the obstacle and retrieving the net. At any time during fishing or hauling, a single lever remotely controls the winches singly or collectively. In addition, the air-controlled winch drums can literally "inch" the cable in or out. The problem of steering or control when the net is hung on the bottom has been solved by placing the gallows frames far enough forward so that the vessel can pivot under the warps. For emergency turns, one warp or the other is slackened off at the bridge control-console so that the trawler manoeuvres quickly if the net is fouled on the bottom. Deck flooding has not been any problem. The vessel's ramp is short and steep and the incline begins several feet above the waterline. The ramp is closed off to the sea by a tailgate that is opened while setting and hauling.

Economic analysis

As a commercial fishing vessel, the *Narragansett* also represents important economic change from the normal offshore New England side trawler. The crew is normally seven compared with 17 on the typical large offshore side trawler. This is a significant increase in the ratio of capital to labour. Studies of industries that have been characterized by increasing productivity and efficiency have one common factor—an increasing capital to labour ratio.

Even though the *Narragansett* may not bring back as large a catch as the larger side-trawler, the profitability in terms of earnings per fisherman and yield per dollar invested in vessel and gear is much higher. In vessel design we must accept the principle that these are the final criteria

TABLE 2

Economic analysis of trawling operations, *Narragansett* and side trawlers

| | | | Side trawler | |
		Narragansett	high earning	low earning
Number of trips		15	27	24
Average trip	days	7.7	10.4	10.7
Average crew size		7	15.8	15
Total landings	lb	979,400	2,882,500	2,044,700
	(kg)	(440,000)	(1,308,655)	(928,294)
Landings/trip	lb	65,300	106,759	85,196
	(kg)	(29,600)	(48,469)	(38,679)
Landings/man trip	lb	9,329	6,756	5,673
	(kg)	(4,230)	(3,067)	(2,575)
Landings/day absent	lb	8,481	10,265	7,962
	(kg)	(3,840)	(4,660)	(3,615)
Value of landings	£	36,300	92,488	63,428
	($)	(101,700)	(258,966)	(177,598)
Value/day absent	£	315	329	242
	($)	(881)	(922)	(678)
Min. wage and food cost/day absent	£	38	87	84
	($)	(107)	(244)	(235)

of design success. Of particular importance to the vessel owner is the decrease in costs for payment to the crew for trips where the value of the crew share does not cover the guaranteed minimum wage. The relative advantages of these economic factors are demonstrated in table 2. Data on side trawlers are for vessels 150 GT and over and are based on average annual operation per vessel (for the years 1960 to 1963). Figures for the *Narragansett* are based on data for 15 groundfish trips during 1964.

Diversified operations to date

During the first five months of successful operation, the ship was engaged in groundfish and deepwater lobster trawling and made several longlining trips for swordfish. Then a charter was obtained to help dismantle offshore platforms on Nantucket Shoals and Georges Bank. The vessel supplied the wrecking crews with food, acetylene and oxygen equipment, and freight etc. and brought back the dismantled equipment. This charter enabled the ship to make much more money than it would have under normal fishing. The charter lasted for three and a half months.

The vessel was ideally suited for a number of reasons:

firstly, the dismantling operation was far out at sea and a strong, medium-range vessel was needed to withstand the rigours of the North Atlantic; and secondly, all hoisting gear was already aboard and only one and a half days were required to remove the fishing equipment, features that a normal supply boat would not have.

Later, the *Narragansett* was sold to her present owners, who were contacted by a Gulf of Mexico oil exploration firm that wanted a boat. The boat was easily reconverted and engaged in oil exploration for about nine months, with once again a very handsome profit and, incidentally, with several of the original fishing crew aboard. The boat is now again commercially fishing.

Short-distance combination stern-ramp trawler, *Canyon Prince*

Following the success of the *Narragansett* as a groundfish trawler, the desire of various industrial fish trawling interests for a smaller combination stern-ramp trawler was met with the 65 ft (19.8 m) Loa *Canyon Prince* (table 3, fig 3 and 4).

The vessel was designed for operating from small harbours, primarily for industrial fish. Since the distances

Fig 3. Short distance combination stern trawler

[539]

TABLE 3

Principal characteristics of the *Canyon Prince*

Dimensions

Loa	64 ft 11 in (19.8 m)	T, keel, light	8 ft 3 in (2.52 m)
Length registered	61 ft (18.6 m)	T, keel, loaded	10 ft 6 in (3.2 m)
B	20 ft 6 in (6.25 m)	△light	67 tons (65.9 ton)
B over guards	21 ft 2 in (6.56 m)	△loaded	130 tons (127.9 ton)
D	9 ft 6 in (2.89 m)		

Capacities

Propulsion

Fish hold	3,500 ft³ (98 m³)	Main engine	335 hp
Fuel oil	3,800 gal (14,383 l)	Drive	marine shafting-std
Fresh water	300 gal (1,135 l)	Propeller	4 blade, 60 in (1.54 m)

Deck Gear

Trawl winch —double drum, 450 fm (823.2 m)
  ⅝ in (15.9 mm) per drum
Net drum—1 each
Winch and drum—main engine power drive
  take-off
Rigged for stern trawling

Electronics

Fishfinder-Radiotelephone
Depth sounder-Radio receiver
Radar—Loran

Structural

Plating—bottom and sides ⁵⁄₁₆ in (7.9 mm),
  decks ¼ in (6.3 mm)

Electrical

AC system 7.5 kW auxiliary
DC system 60 A alternator off main
  engine, 2 × 32 V battery banks

Accommodation—8
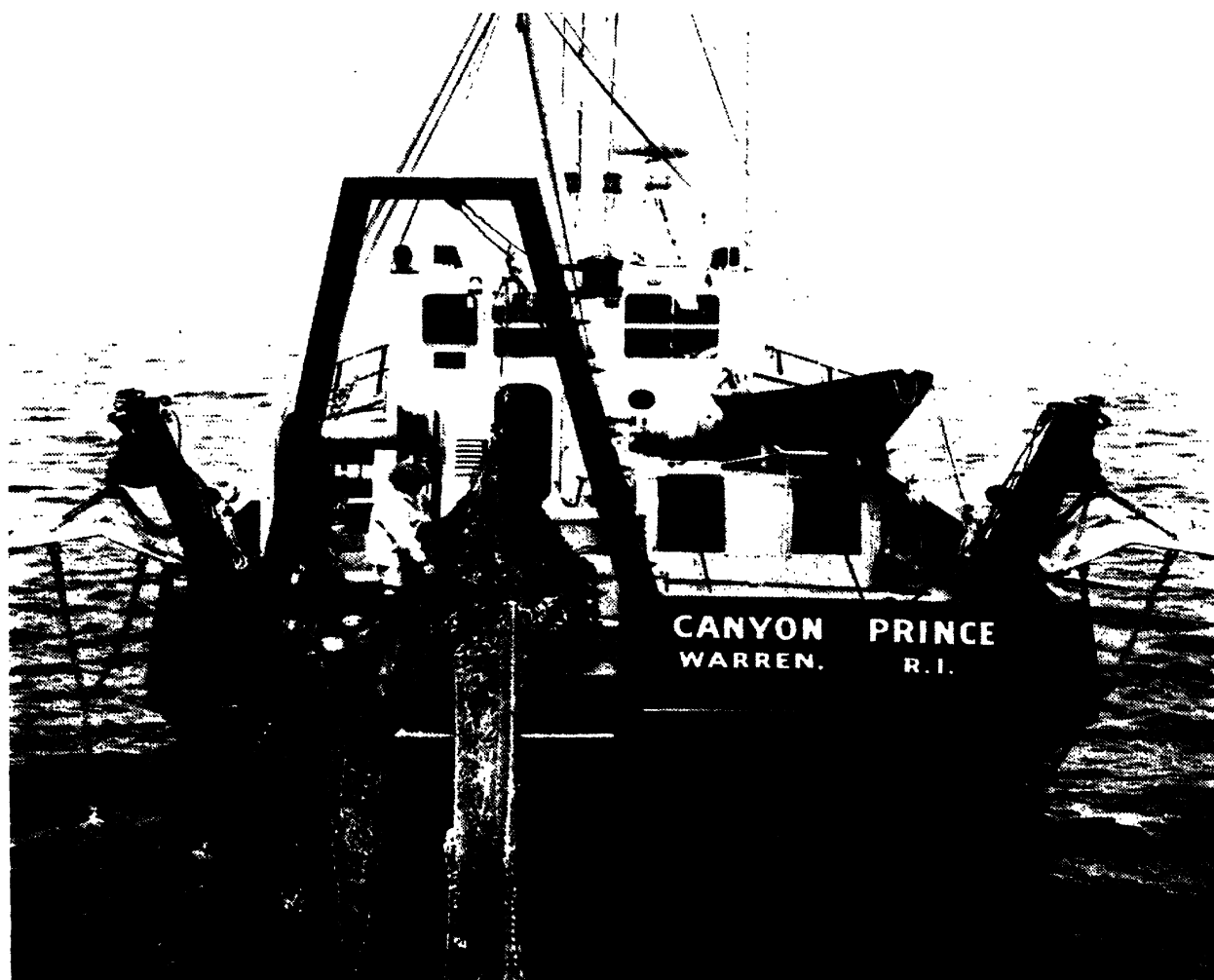
Fig 4. Emptying the catch

to the grounds were short, usually less than 75 miles (120 km) for red hake and 25 miles (40 km) for tuna, this vessel has been quite profitable. It was found that in designing smaller boats, it was necessary to offset the net drum and balance the opposite side by the trawl winch to achieve enough deck working space. On the *Canyon Prince*, the ramp was located the same side as the net drum and worked quite well, particularly for ground-fishing. For industrial fish operations, however, moving the net drum to the stern made it much easier to split the big catches. The net drum was situated just far enough forward of the transom to allow the net to be repaired from each side. The control with a fixed propeller, while not as delicate as with the variable pitch propeller, was acceptable. Some trouble has occurred. On several occasions when the propeller has been inadvertently left in neutral and the vessel has had little or no headway, the doors and net have come into contact with the propeller.

Modified shrimp trawler as combination vessel, *Silver Mink*

Although the expanding industrial bottomfish industry supplying pet food factories in the Gulf of Mexico has utilized existing standard shrimp vessels, the basic method is still the same—trawling. Of particular interest is the use of a conventional Florida type wooden shrimp trawler for various types of fishing in New England waters.

Fish trawling and tuna seining

The *Silver Mink* (fig 5), originally designed as a shrimp vessel, has been used for a variety of fishing operations other than shrimping. Initial New England operations concentrated on trawling for industrial fish (fig 6) as well as readily marketable food fish. A unique use of this vessel occurred in 1958 when it was rigged for tuna

Fig 5. Shrimp vessel rigged for tuna purse seining

purse-seining (Squire, 1959). The vessel landed 161 tons (163 ton) of bluefin (table 4) during a short season of about ten weeks. Previous sporadic efforts by regular west coast seiners in earlier years produced a maximum catch per season of only 122 tons (123.8 ton). Table 4 shows the tuna seining results for the *Silver Mink*, 1958 to 1961
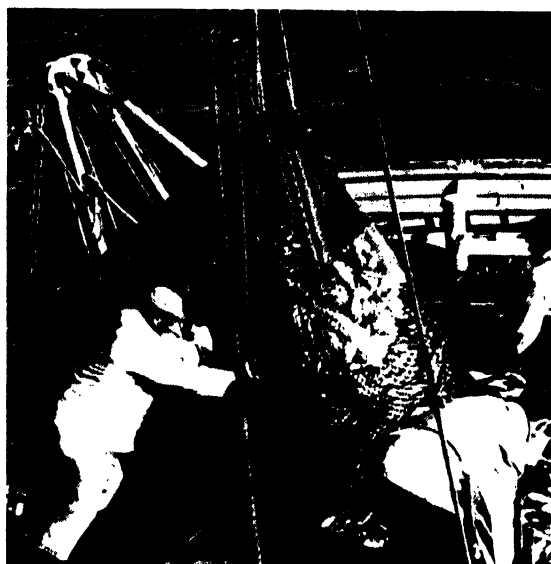
Fig 6. Emptying industrial fish trawl catch
(note removable gallows)

TABLE 4

Comparison of tuna seining results,
Silver Mink, 1958 to 1961*

	1958	1959	1960	1961
Tons (ton)	161 (163)	678 (688)	302 (306)	921 (934)
Length of season—weeks	10	7.5	4	13
Number of trips	29	30	20	86
Number of fish	—	11,577	4,620	—
Average weight of fish—lb (kg)	—	130.8 (59.4)	146 (66.5)	—··

* Includes catch of an additional 65-ft (19.8-m) purse seiner in 1961.

Modifications

Modifications of the vessel for tuna seining were simple and consisted of removing the trawl gallows and installing an extended boom for initially strapping the net aboard. The existing double-drum trawl winch was used for purse-seining operations. The tuna purse seine was of linen and cotton netting 310 fathoms (567 m) long and 25 fathoms (45.8 m) deep. Most trips were on a daily basis out of Provincetown, Mass., in the immediate area of Cape Cod, namely Cape Cod Bay and Massachusetts Bay. Later, the natural fibre seine was replaced with nylon, a power block was installed (fig 7) and aeroplane spotting was employed. Initial success led to an expansion of the east coast tuna fishery from inshore waters near Cape Cod to a high-seas fishery extending south to Cape
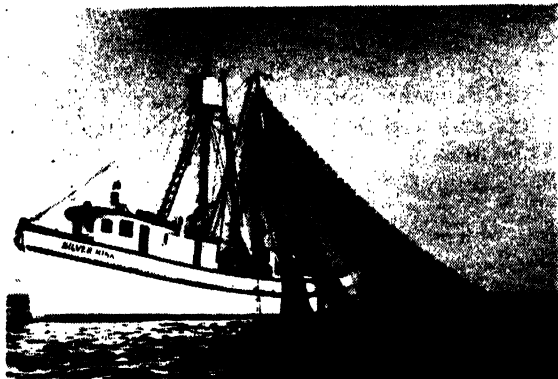
Fig 7. Hauling a tuna purse seine net

Hatteras, NC. In 1963, according to Wilson (1965), the total catch by 16 US vessels and two Canadian vessels was over 18 million lb (8.2 million kg). The success of the initial fishing for tuna stimulated the owner to use the vessel for purse seining herring, alewives and mackerel until the tuna runs start, usually in late July.

Fishing tactics

Fishing tactics play an important role in the operation. For example, it was ascertained that, while scouting for tuna, the vessel often would encounter only schools of herring or mackerel that could not be taken with the large-mesh tuna seine. To assure that the correct net is on board, an aeroplane is now used for fish-scouting while the vessel remains at the dock. The aeroplane scouts waters adjacent to Provincetown during the morning. If tuna are spotted, the pilot radios the vessel and the tuna seine is loaded; if mackerel or herring are spotted, the other seine is loaded. The pilot circles the schools until the vessel arrives and sets the seine.

During the autumn of 1964, the vessel purse seined 268 tons of mackerel in about five weeks. From January to June 1965, 616 tons of herring, 446 tons of alewife and a few mackerel were caught. This is a case where a combination of factors, namely, a versatile vessel, availability of a variety of fish in commercial quantities in strategic geographical locations, adequate markets and, probably most important of all, the ingenuity and resourcefulness of the owner-captain, result in maximum utilization of the vessel.

Limitations of vessel for tuna seining

While the vessel made favourable tuna catches during subsequent years, catches have fluctuated considerably, because it has to operate in inshore waters. The large size of the seine and accessory equipment precludes operations in weather and sea conditions encountered in offshore waters. Success is therefore dependent on the bluefin tunas being available in inshore waters. The east coast tuna fishing grounds have been extended to offshore waters by vessels of the regular California tuna seining fleet, including some of the largest individual vessels of that fleet. Catches in offshore waters have included considerable quantities of skipjack tuna, which are not available to the inshore fleet.

This is not the only case of a shrimp vessel being used as a seiner. Robas (1961) reported that a standard 50-ft (15.2-m) steel Mexican flag shrimp vessel was successfully seining jack crevalle in the Gulf of Mexico. A seine 180 fathoms long (329 m) and 22 fm deep (40.2 m) was set from an elevated table on the stern.

GULF OF MEXICO COMBINATION VESSELS

Until recently, there has been little, if any, attention given to the construction of multi-purpose combination fishing vessels for the Gulf of Mexico. The main reasons are that rather standardized single-purpose vessels have prevailed in the two major fisheries—trawlers in the shrimp and purse seiners in the menhaden fisheries. The recent booming of the offshore oil industry in the Gulf of Mexico has required great numbers of vessels. Oil survey vessels are used for seismic explorations, transporting cargo, ferrying workers to and from offshore drilling platforms, and general utility work.

Modified oil survey-shrimp vessels

A style of vessel was developed which is readily adaptable from oil survey to use in shrimp and industrial fish trawling, as well as snapper fishing. The simplicity of design tends to reduce the cost and they can be built even by the smallest shipyards in the Gulf of Mexico area.

Although the space devoted to the various features of the vessel varies with its intended primary service in the oil industry (cargo, passengers or explorations), the basic hull design is the same. The length varies from about 70 ft (21.2 m) to 100 ft (30.5 m). A vessel designed primarily for passenger-carrying service to offshore oil drilling platforms with the features of a shrimp vessel is shown in fig 8 and 9. This vessel has a fuel capacity of about 25,000 gal (84,600 l), water capacity of 2,700 gal (10,219 l) and is twin-screw with two 330-hp diesel engines. It is usually equipped with air conditioning. While it may be too large to interest most shrimp fishermen, scaled-down versions can easily be built. For example, several 70 ft (21.2 m) vessels have been constructed this year. These are scaled-down versions of the 95 ft (29 m) vessel and have either single or twin-screws. The single-screw type is 300 hp and the twin-screw type has two 230-hp diesel engines. The fish-carrying capacity is about 175,000 lb (79,450 kg). These vessels are currently chartered to oil interests, but are built to replace the fleet of conventional wooden shrimp vessels.

As early as 1954, vessels were built in the Gulf of Mexico expressly for oil explorations with the object of future use as shrimp vessels. Such a vessel, originally used in oil exploration and now rigged for shrimp trawling, is shown in fig 10. The lines are those of a large Gulf of Mexico shrimp vessel, but the house is modified along the lines of current oil survey vessels. This 83 ft (25.3 m) vessel is constructed of wood, of 120 GT and 82 net tons. After lengthy service in oil explorations, the vessel engaged in commercial shrimp fishing. It is currently used in biological research on shrimp.

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ELEVATION LOOKING FWD.

Fig 8. Preliminary arrangement combination commercial fishing and oil survey vessel

Fig 9. Preliminary arrangement combination fishing and oil survey vessel

[543]

Fig 10. Oil survey vessel modified for shrimp trawling

RESERVOIR COMBINATION FISHING VESSELS

The central area of the USA has vast networks of reservoirs and lakes formed by dams designed for flood control, irrigation, navigation and hydro-electric purposes. Some of these, such as the Oahe Reservoir in the Dakotas, are large bodies of water. This particular reservoir is 250 miles long (402 km), varies in width from several hundred yards to several miles, and will eventually have a water area of 376,000 acres (158,000 hectares). Another example is Kentucky Lake in Tennessee, which covers 158,000 acres (64,100 hectares) and has a potential commercial yield of 32 million lb (14.5 million kg) of fish annually.

Since the major portion of the fish in reservoirs cannot be absorbed immediately for human food markets, the development of highly productive fisheries must rely on industrial-type outlets. This means high-volume fishing at low-landed value. The relatively small open-boats now used in US inland fisheries are definitely not suited for such fishing.

To determine the most effective craft for economically harvesting the untapped fishery resources of these areas, the US Government recently began operating an experimental fishing vessel equipped to fish with trawls, gill nets, trap nets and other types of seines and capable of making simulated commercial fishing tests as well as conducting research activities. It could be modified easily for commercial fishing.

Type and design

In developing design criteria for the experimental vessel, *Hiodon*, various factors necessary to "fit" the vessel to the intended fisheries were considered. The original work was scheduled for the Oahe Reservoir which appeared to offer good potential for early development of a commercial fishery. A well-equipped, multi-purpose vessel capable of operating independently at distances of 100 or more miles (160 km) from home port for periods of over one week was essential for experimental operations as well as commercial operations. Such a vessel should be primarily flat-bottomed with a barge-type bow and tunnelled stern to allow rudders and propellers to be

completely above the bottom of the hull. Consideration of methods was also necessary to permit ease of transportation of the vessel overland to other reservoirs. This design, coupled with twin-screw propulsion, would permit fishing in shallow water. The vessel should be of welded steel construction capable of withstanding weather and storms in the Mississippi drainage area. The possibility of grounding during shallow-water operations necessitated the use of 0.25 in (6.3 mm) hull plating throughout.

The *Hiodon* is equipped with modern deck machinery and electronic equipment. The deck equipment consisting of two single drum trawl winches, power block, net drum and articulating crane, is driven hydraulically by a dual pump coupled to one propulsion engine. This pump provides oil at 1,800 lb/in^2 (130 kg/cm^2) to a single remote station which controls all functions of the deck machinery. This arrangement allows the vessel to be safely operated by a two-man crew. Electronic equipment includes a 35-watt radiotelephone and a "white-line" type echo-sounder. The echo-sounder is equipped with a controllable transducer for both horizontal ranging and vertical depth sounding or fish detection. The vessel, constructed in 1965, has the following characteristics:

Construction	all steel welded
Length	46 ft (14 m)
Beam	14 ft 6 in (4.4 m)
Hull depth	4 ft (1.2 m)
Draft	2 ft 6 in (.76 m)
Main engines (2)	85 hp each, diesel
Net drum	1,500 lb (681 kg), 45 ft (13.7 m)/min
Deck crane	2,500 lb (1,135 kg) capacity
Trawl winches	Single drum, port and starboard, capacity each drum: 2,000 ft (610 m) of $\frac{5}{16}$ in (7.9 mm) wire, 2,000 lb (908 kg) at 160 ft (48.8 m) per min.
Cruising speed	8.5 knots
Cruising range	1,500 miles (2,413 km)
Displacement, light	20 tons
Displacement, loaded	35 tons
Accommodation	4 personnel
Propellers	26 in (66 cm) diam, 20 in (50.8 cm) pitch
Generator	6 kW

Drawings of the profiles and deck arrangement are presented in fig 11, and fig 12 shows the vessel underway.

A transporting unit was built to facilitate moving the vessel from one reservoir to another. This unit consists of two assemblies, a heavy-duty wheel and axle assembly fitted with "I" beams shaped to fit an inverted "T" attachment under the stern of the vessel and a towing frame pinned to the bow (fig 13 to 15). The towing frame is equipped to fit the towing facility of any standard transport truck. This unique arrangement permits travel over gravel or hard surface roads at speeds to 50 mph (80 km/h).

[544]

Text labels visible in the figure:

HIODON

Asdic

Winch

Hydraulic
control

Net reel

Deck crane

Trawl
gallows

Hyd
oil

F.W.

F.W.

Lub
oil

2 X 85 HP Diesel engines

Fuel tanks P & S

Fish tanks
P & S
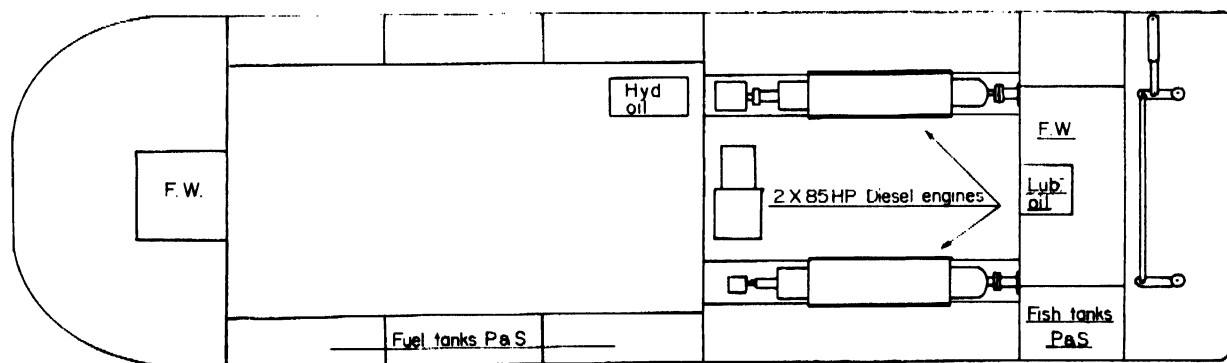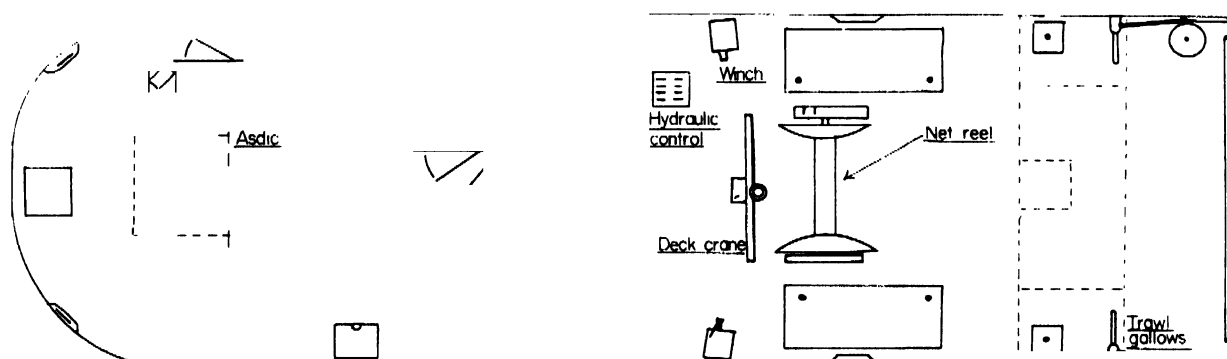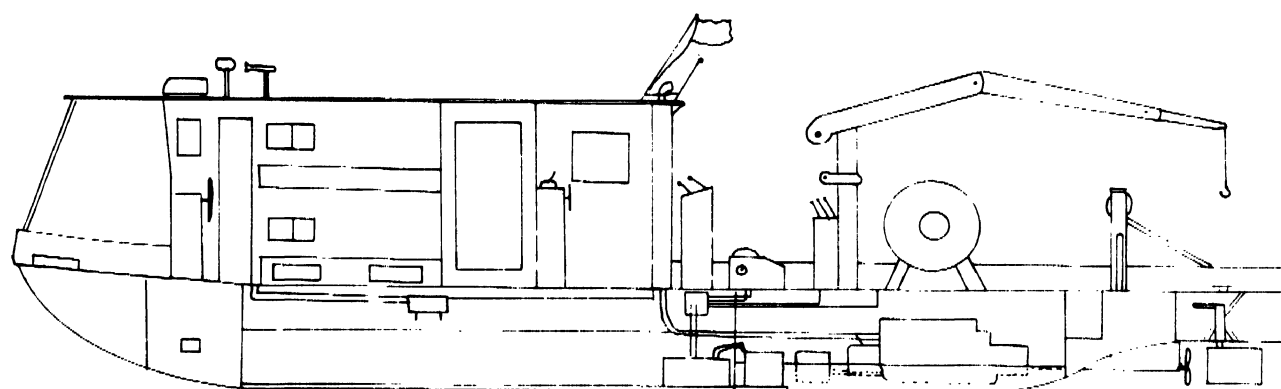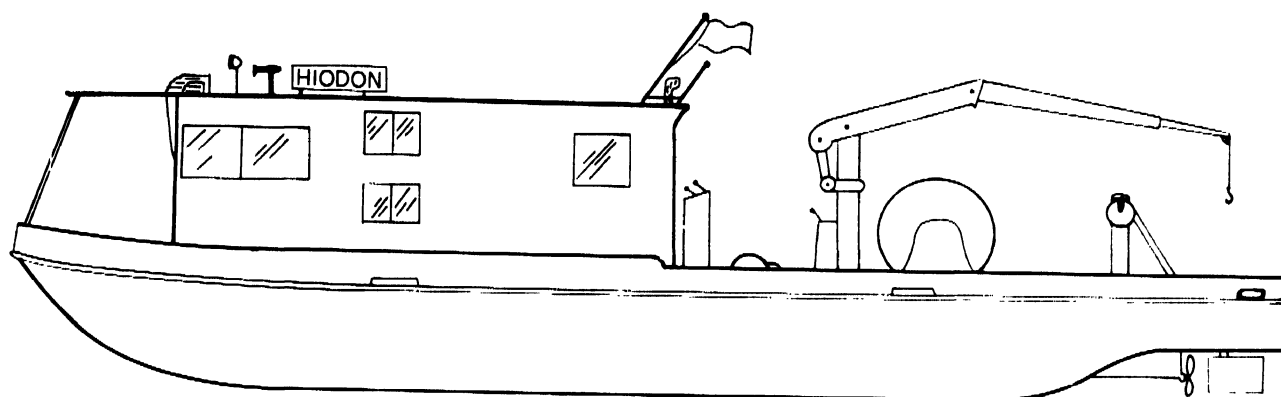
Fig 11. Reservoir vessel, general arrangement

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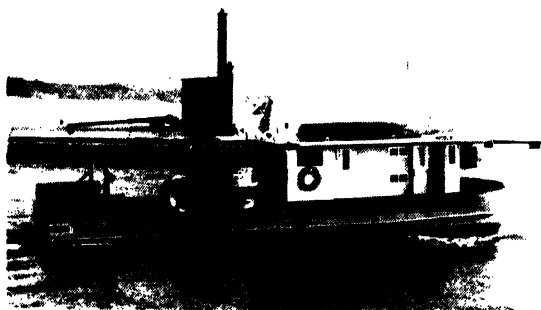
Fig 12. Reservoir vessel
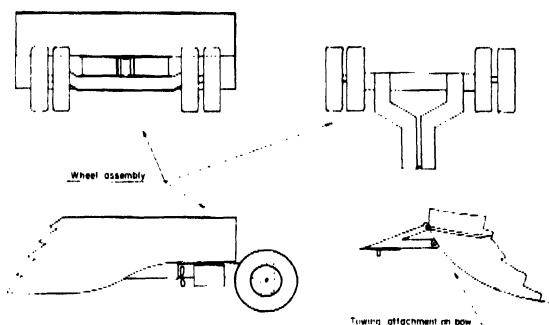
Fig 13. Towing arrangement for land transport
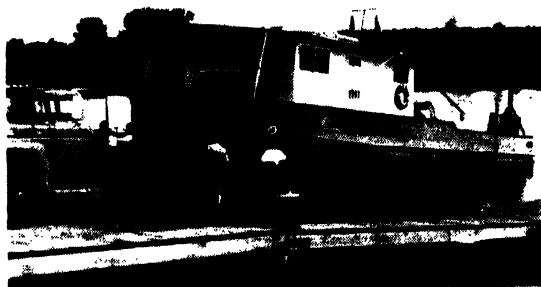
Fig 14. Hooking the vessel to a truck

Fig 15. Transporting the vessel

Recommended changes for future designs

Based on initial operations, substantial improvements would be obtained over the existing design by incorporating the following modifications, especially in a commercial version (fig 16).

Hull design

A longer bow curve of inverted-spoon type would reduce water resistance and help overcome the tendency to nose down in upper speed range.

Main propulsion

Replacement of standard engines, through-hull shafts, skegs and rudders with inboard-outboard diesel propulsion units would reduce engine room space requirements, increase hold capacity in an area of the hull where increase in payload would not affect trim, eliminate the need for a tunnel stern which is lifted by propeller wash considerably, and simplify maintenance and repair since outboard section of propulsion unit can be lifted to deck level to facilitate propeller work and rudders are not needed with inboard/outboard propulsion units.

Auxiliary power

A separate engine of about 60 hp diesel should provide auxiliary power to drive 10 kW generator at one end and 35 hp hydraulic pump the other.

Deckhouse

The deckhouse on a commercial version should be much smaller because it can be operated by two fishermen, who will have no need for covered laboratory space.

Deck gear

The deck machinery complex (including two trawl winches, net reel and articulated crane) with controls could be located from bulwark to bulwark between the 22 ft (6.7 m) (from the bow) and the 28 ft (8.54 m) marks. This is about midway along the length of the hold space and would facilitate dividing the hold into fore and aft sections fitted with hatches within easy reach of the articulated crane.

PACIFIC COAST COMBINATION VESSELS

Schmidt (1960) reported that the U.S. Pacific coast combination vessels had been developed primarily as purse seiners modified for use as trawlers and longliners. Most small combination vessels of the Alaska Limit seiner size, maximum registered length 50 ft (15.3 m) and about 58 ft (17.7 m) Loa, are still designed primarily as purse seiners, but the major secondary use is for king crab fishing with pots (Allen, 1964). Most of the very few medium-size combination vessels recently built in the Pacific north-west have been designed firstly for trawling and secondly for king crab fishing.

The vessel *Astronaut* (fig 17) is a good example of this type (Anonymous, 1962). The main feature of this vessel is the substitution of hydraulic and electric power for manpower. The principal characteristics are:
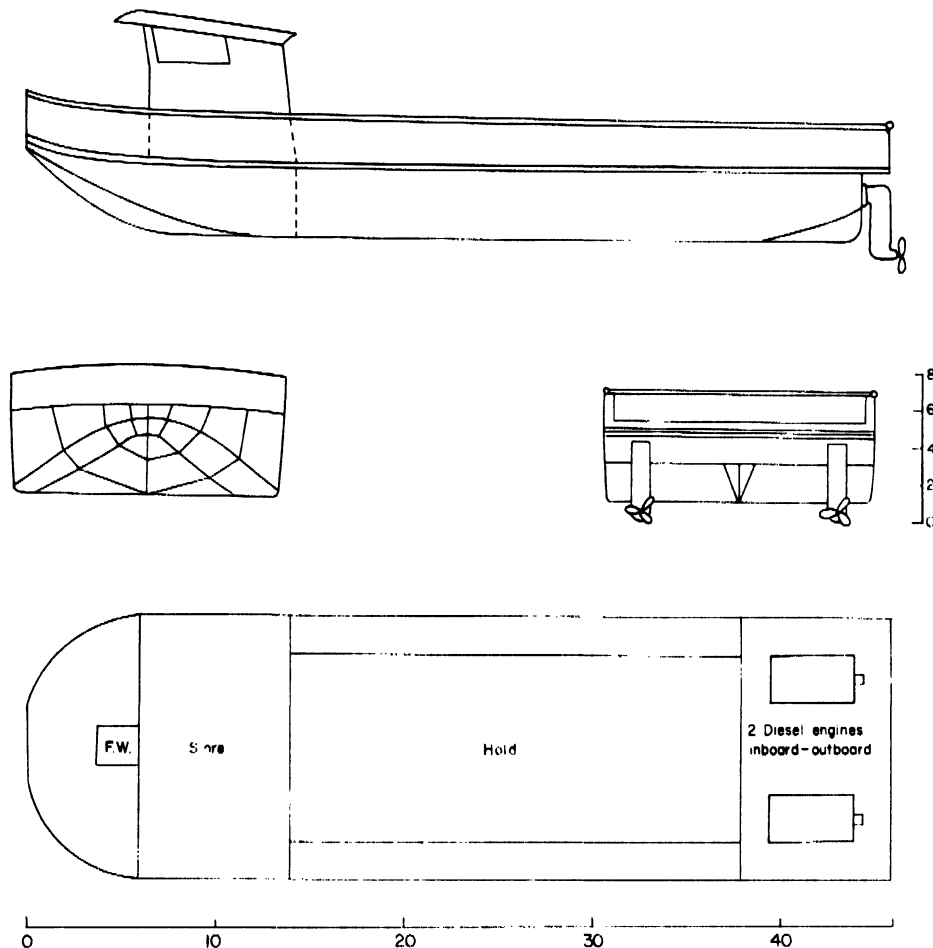
Fig 16. Proposed modified reservoir vessel

Loa	66 ft	(20.1 m)
Lpp	59 ft 4 in	(18.1 m)
B	18 ft 2 in	(5.6 m)
T	10 ft 7 in	(3.2 m)
GT	77	
NT	31	
Fuel oil	7,000 gal	(26,495 l)
Water	3,000 gal	(11,355 l)
Engine power	227 hp	
Generator	20 kW	
Accommodation	6	

The vessel is of all-steel construction with 0.31 in (7.9 mm) plate on the Vee-bottom and 0.25 in (6.3 mm) on the sides and decks. After initially fishing groundfish, the vessel is now fishing king crab pots in Alaska.

SPECIFIC DESIGN STUDIES DESIRABLE

The need for specific fishing boat design studies has been brought out at the First and Second FAO World Fishing Boat Congresses. During the design and construction of the *Narragansett* and *Canyon Prince* the roll damping effect of bar keel compared with bilge keel was considered.

Scientific analysis through model rolling tests are far too expensive for the individual small fishing vessel con-
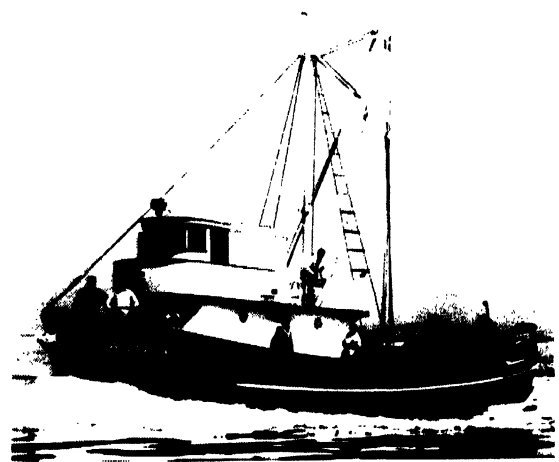
Fig 17. Combination trawler king crab fishing vessel

struction yard to finance. The need for such tests, however, is clearly evident in comparing the seakindliness of the *Narragansett* and *Canyon Prince*. The need for these tests is further brought out in model rolling tests to determine the effect of a bar keel on the 150 ft (45.7 m) Loa vehicle-passenger ferry *Uncatena*.

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Because the *Narragansett*, which did not have a bar keel, rolled heavily before bilge keels were installed, a bar keel was installed on the *Canyon Prince*. Model tests of bar keels on vessels of the size of the *Narragansett* are particularly recommended since vessels of this size are too large to utilize effectively onboard

Fig 18. Representative curves of rolling amplitudes from model rolling tests, m.v. Uncatena

stabilizers as roll damping devices. To strengthen our recommendation that such tests be undertaken for fishing vessels, the report of the model rolling tests to determine the effect of the bar keel is included as an Appendix. This report clearly indicates that bilge keels are really unnecessary when a bar keel of the proportions used on the *Uncatena* is installed (fig 18 and 19).
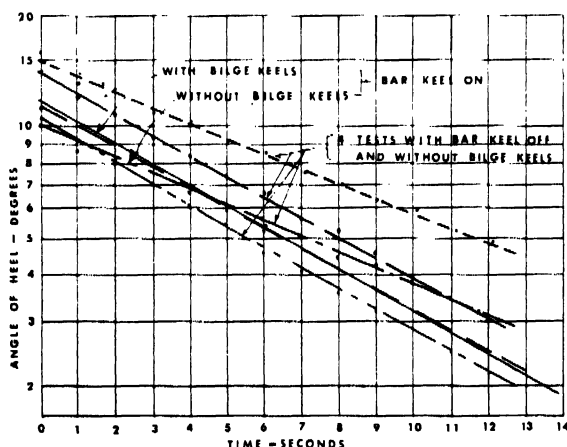
Fig 19. Curves showing rate of decrease of rolling amplitude from model rolling tests, m.v. Uncatena

CONCLUSION

There is a growing trend in the USA for combination-type fishing vessels to be built in areas other than the Pacific coast. This trend has been brought about by the realization that, by building combination-type vessels, fishermen are able to harvest several types of fish, each of which may require a different type of gear. This provides for year-round use of the vessels and removes the risk that one-purpose boats always face dependence on a single type of fish, the abundance and availability of which may fluctuate greatly. There has also been profitable employment for combination vessels designed for oil exploration work and fishing. Model tests to determine the roll damping effect of bilge keels and a bar

keel would have been of considerable benefit in the design of the *Narragansett* and *Canyon Prince*.

APPENDIX

During the design of the *Uncatena*, it was decided to fit a deep bar keel along the centreline at the bottom of the vessel with the expectation that this member would: (a) overcome any tendency that the vessel might have towards directional instability; (b) increase resistance to drift downwind; and (c) substantially reduce the amount of rolling in a seaway so that bilge keels would not be needed. Since the preliminary design profile had considerable rise of keel (from the end of the skeg to the bow), a deep full-length bar keel could be worked in without increasing maximum service draft, by reducing the rise of keel and modifying slightly the shape of the hull form over the forward half of the vessel. Since the intended route passes through shoal water, actual service draft is critical.

This bar keel is 1.25 in (3.2 cm) thick and projects 13.5 in (34.3 cm) below hull between the curve of the forefoot and amidships. Aft, as the hull form rises, the bar keel blends into the centre line skeg, having the effect of increasing the skeg depth, particularly near amidships. The depth of the bar keel above includes the thickness of a flat bar 6 in (15.2 cm) wide, welded, T-fashion, to the bottom of the bar keel to provide a suitable resting surface on keel blocks when the vessel is dry-docked.

Comparing the final underwater profile of that with the keel and that without, a strip about 13 in (33 cm) deep and approximately 124 ft (37.8 m) long, equivalent to 134 ft^2 (12.5 m^2) has been added to the lateral area of the vessel. This is based on the assumption that the bar keel would replace a flat plate keel in area.

Bilge keels were considered for this vessel and roll tests were made using a $\frac{1}{24}$ scale model of the vessel's hull, ballasted and with a metacentric height suitable for one of the expected service conditions. These tests were conducted in the model testing tank at Massachusetts Institute of Technology, by forcibly heeling the model to a specific angle, then suddenly releasing it and recording roll amplitudes for several seconds. The rate of decrease of roll amplitude was plotted from the amplitude-time graphs obtained and a comparison made for corresponding conditions.

Subsequently, the bar keel was removed from the model, together with its extension along the bottom of the skeg (representing a strip 13 in wide, 124 ft long) and the model was again rolled, ballasted as before, in order to get information as to the roll damping effects of the bar keel.

Records of decreasing amplitude of roll were made, as before. These tests were made only with the model at rest (not being towed) in order to avoid effects of water pressure, resulting from flow, against the hull. Comparison of the rate of decrement of roll from these tests with those previously obtained for zero model speed

indicates that the bar keel does have a measurable effect as a roll-damping device.

With the bar keel on the model, but without bilge keels, the amplitude of rolling decreased from 20° (full roll, port to starboard) to 10° in 5.6 sec, an average rate (for this range of amplitude) of 1.79° per sec. With the bar keel removed, the average of four roll tests gave the time to reduce the roll from 20° to 10° as 6.3 sec, an average rate of 1.59° per sec over this range. It was also found that removal of the bar keel was accompanied by a slight increase in the period of roll of the model, from 1.85 sec to 2.0 sec.

Figure 18 shows two roll amplitude curves obtained with the "envelopes" of maximum amplitudes added. The curves shown are for zero model speed, one is for the model with bar keel and without bilge keels; the other is for one of the four tests with the bar keel removed.

Figure 19 shows the comparison, at zero model speed, of the rate of decrease of roll amplitude. Here the steeper the curve, the more effective is the roll-damping. The flat bar on the bottom of the keel was not fitted to the model, due to the small size. A bar such as this, presenting a horizontal surface, even though small in vertical area but with four relatively sharp edges to impede the flow of water from side to side under the keel as the vessel rolls, would augment the roll-damping effect of the bar keel.

The late Dwight S. Simpson advocated the use of box or bar keels of substantial depth, as greatly assisting in roll damping, for resisting drift, and for improving directional stability.

Recent Developments in Japanese Tuna Longliners

by Jun Kazama

Evolution récente des thoniers palangriers japonais

Les thoniers palangriers japonais, qui opèrent maintenant dans tous les océans, ont fait de grands progrès depuis 1952. L'évolution survenue tant dans les terrains de pêche que dans la situation de la main-d'oeuvre impose maintenant un nouvel effort de développement. La conception des futurs navires s'en ressentira (automatisation de l'appareil propulsif, des installations de congélation, du pilotage, etc.).

Reicentes innovaciones en los palangreros japoneses

Desde 1952 los japoneses han hecho grandes progresos con los palangreros del atún, los cuales operan hoy en todo el mundo. Los cambios experimentados por los caladeros y por la mano de obra reclaman hoy otra etapa de innovaciones. Todo ello influirá en facto res del proyecto de embarcaciones como la propulsión, la refrigeración y los aparatos automáticos de gobierno.

SINCE 1952 tuna-freezing equipment has been installed on Japanese tuna longliners, extending their fishing range to world-wide coverage and increasing both the size and number of vessels. The daily catch, however, has gradually decreased in recent years to an average of only 2 to 2.5 tons per day, less than half that of five to six years ago. This has increased the fishing time per trip and hence increased the expenses and reduced the profit. This has influenced the design and recently-constructed vessels show a general reduction in size, while paying more attention to the quality of frozen products and methods of reducing manual labour.

CHANGE OF SHIP DESIGN

The recent trend in tuna longliners in Japan is that the number of small vessels under 40 GT has increased and the midwater vessels over 300 GT, which were built in large quantities until 1962, have given place to medium-sized vessels of 290 to 190 GT (table 1).

The small vessels under 40 GT have been built since 1960 as they were outside the Government restriction. They were built initially to catch tuna in Japanese home waters, but then they made longer trips as their numbers increased, and reached the Midway and the South Pacific Islands, although many accidents occurred due to overloading. Under such circumstances, the Government included these vessels in the restriction in 1964 and started to control the total number and the main particulars of these vessels. Table 2 shows their principal particulars.

The number of large midwater tuna longliners over 300 GT has decreased, because the reduction in catching rate increased the fishing time, hence increasing expenses and reducing profit. A 340-GT tuna longliner built in 1960 has the following particulars:

L registered . .	139.40 ft (42.5 m)
B moulded . .	25.58 ft (7.8 m)
D moulded . .	12.46 ft (3.8 m)
GT . . .	339.5
Fish holds . .	14,030 ft³ (397.5 m³)
Fuel oil tank .	6.530 ft³ (184.9 m³)
Fresh-water tank .	760 ft³ (21.6 m³)
Complement .	32
Main engine .	800 hp diesel
Service speed .	10.5 knots
Fish-carrying capacity	270 ton
Deep freezer .	12 ton/day

This vessel was scheduled for a 5,000 sea-mile voyage, assuming a fuel-oil consumption as follows:

During voyage: 790 gal (3.0 m³) per day	days	gal	m³
outward	20	15,800	60
homeward	20	15,800	60
During fishing: 475 gal (1·8 m³) per day	days	gal	m³
fishing	120	57,000	216
fish hunting	10	4,750	18
total (voyage+fishing)	170	93,350	354

TABLE 1. **Tuna fishing vessels launched in the last ten years**

Year	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	Total
39 GT	—	—	1	3	25	108	139	40	39	36	391
40 to 99 GT . . .	8	1	4	7	12	24	25	60	31	26	198
100 to 149 GT . . .	5	8	5	6	6	3	5	1	67	23	129
150 to 199 GT . . .	1	—	—	—	1	2	1	6	55	28	94
200 to 299 GT . . .	4	2	3	13	17	19	66	71	66	53	314
300 to 499 GT . . .	26	16	14	10	19	42	40	38	26	13	244
500 GT and over . . .	2	10	9	—	6	7	2	5	2	1	44
Total	46	37	36	39	86	205	278	221	286	180	1,414

TABLE 2. Particulars of 39-GT tuna longliners launched in 1960

						Wooden construction	Steel construction
Length registered	.	.	.	.	ft (m)	65.10 (19.85)	65.10 (19.85)
Breadth moulded	.			.	ft (m)	14.34 (4.37)	14.76 (4.50)
Depth moulded	.			.	ft (m)	6.86 (2.09)	6.20 (1.89)
Gross tonnage	.			.	.	39.71	39.92
Main engine	.			.	hp	D-160	D 180
Trial speed	.			.	knots	8.34	8.58
Electric generator	.			.	No. kW	2-3	1-10, 1 3
Refrigerator type	.	.	BTU/hr (Kgcal/hr)			NH₃ 29,000 (7,300)	R₁₂ 13,200 (3,320)
Number of crew	.			.	.	17	18
Fish hold	.			.	ft³ (m³)	1,484 (42.0)	1,589 (45.0)
Fuel-oil tank	.			.	ft³ (m³)	484 (13.7)	495 (14.0)
Fresh-water tank	.			.	ft³ (m³)	117 (3.3)	106 (3.0)
Light load Δ	.			.	ton	75.16	69.96
T				.	ft (m)	5.02 (1.53)	3.74 (1.14)
C_b				.		0.64	0.67
GM				.	ft (m)	1.18 (0.36)	2.13 (0.65)
Full load Δ				.	ton	119.55	110.06
T				.	ft (m)	6.86 (2.09)	5.38 (1.64)
C_b				.		0.71	0.73
GM				.	ft (m)	1.21 (0.37)	1.64 (0.50)
Freeboard				.	ft (m)	1.30 (0.41)	0.99 (0.31)

The physical perseverance of crew and fishermen, of course, enters the question, but the lack of fuel oil capacity is also a problem. The vessel originally carried additional fuel-oil (about 7,920 gal (30 m³)) in inflatable bags in the fish-hold on departure, which provided sufficient fuel-oil capacity when a daily average catch of six tons could be expected.

Now a vessel must call once or even twice at a port during the fishing period to refuel, thus adding 10 to 20 days to the trip. It is not so unusual for a vessel of 340 GT to make a voyage lasting over 200 days. Recently, the Federation of Japan Tuna-Fishing Cooperative Unions has sent a fuel-oil and fresh-water supply boat for these tuna vessels around the fishing area in the Pacific, but has not been able to satisfy all their requirements.

This is reflected in the size of newly-built vessels in a tendency to reduce the size of vessels under 300 GT to 290 GT to 190 GT. Midwater tuna longliners, which had been increasing in size since 1952, have now reverted to medium size. A special design feature of recent vessels is in the remarkable increase in breadth (B/D= 2.1 to 2.2) because of the raising of the centre of gravity caused by relocating the refrigerator, originally in the engine room, to the deck behind the freezing chamber. The principal particulars of these medium-sized tuna longliners are shown in table 3.

These medium-sized vessels also have not sufficient fuel-oil capacity for the intended range, and carry additional fuel oil in a specially-constructed fish hold for this purpose, usually the forward, which holds fuel oil, in bulk, on departure and fish on return.

TABLE 3. Particulars of medium tuna longliners

						190 GT 1964	250 GT 1964	290 GT 1963
Year launched								
LBP	.	.	.	.	ft (m)	109.55 (33.40)	125.00 (38.10)	134.50 (41.00)
B moulded	.	.	.	.	ft (m)	22.63 (6.90)	24.60 (7.50)	25.27 (7.70)
D moulded	.	.	.	.	ft (m)	10.34 (3.15)	10.99 (3.35)	11.48 (3.50)
Gross tonnage	.	.	.	.	.	192.95	253.96	294.84
Main engine	.	.	.	.	hp	D-650	D 800	D 750
Trial speed (at MCR)	.	.	.	.	knots	12.03	12.02	12.21
Service speed (approximately)	.	.			knots	10.0	10.7	10.5
Elec. generator	.	.	.	No. KVA		2-60	2-80	2-80
Aux. engines	.	.	.	No. hp		2-80	2 100	2 105
Refrigerator	.	.	.	BTU/hr (Kgcal/hr)		2 × 362,300 (91,300)	1 × 494,100 (12,450) 1 × 362,300 (91,300)	1 × 416,300 (104,900) 1 × 34,600 (87,300)
Freezing capacity	.	.	.	.	ton/day	4.0	6.4	7.5
Freezing chamber	.	.	.	.	ft³ (m³)	1,250 (35.4)	1,906 (54.0)	2,143 (60.7)
Freezing lobby	.	.	.	.	ft³ (m³)	696 (19.7)	862 (24.4)	579 (16.4)
Fish hold	.	.	.	.	ft³ (m³)	6,960 (197.2)	10,490 (297.0)	12,400 (351.1)
Fuel-oil tank	.	.	.	.	ft³ (m³)	4,595 (130.2)	5,185 (146.8)	5,980 (169.3)
Fresh-water tank	.	.	.	.	ft³ (m³)	658 (18.6)	652 (18.5)	955 (27.1)
Light load Δ	.	.	.	.	ton	267.71	322.22	329.96
T	.	.	.	.	ft (m)	6.05 (1.844)	6.05 (1.843)	5.63 (1.716)
C_b	.	.	.	.	.	0.622	0.606	0.587
GM	.	.	.	.	ft (m)	1.64 (0.50)	2.23 (0.68)	2.20 (0.67)
Full load Δ	.	.	.	.	ton	465.62	602.03	695.31
T	.	.	.	.	ft (m)	9.52 (2.902)	10.02 (3.055)	10.59 (3.229)
C_b	.	.	.	.	.	0.689	0.681	0.676
GM	.	.	.	.	ft (m)	1.41 (0.43)	1.73 (0.53)	2.26 (0.69)
Freeboard	.	.	.	.	ft (m)	1.44 (0.44)	1.60 (0.49)	1.52 (0.46)
Number of crew	.	.				26	28	29

TABLE 4. Particulars of large tuna longliners with catcher boat

		880 GT 1963	1,500 GT 1962	2,800 GT 1963
Year launched				
LBP	ft (m)	186.40 (56.80)	238.90 (72.80)	288.80 (88.00)
B moulded	ft (m)	36.10 (11.00)	42.00 (12.80)	48.60 (14.80)
D moulded	ft (m)	16.40 (5.00)	18.70 (5.70)	19.68 (6.00)
Gross tonnage		886.98	1,490.50	2,801.32
Main engine	hp	D–1,600	D–2,200	D–2,400
Trial speed (at MCR)	knots	13.79	14.79	14.10
Service speed	knots	*12.0	*12.5	*12.5
Elec. generator	No. KVA	2×200, 1× 90	2×300, 1×80	3×300
Aux. engines	No. hp	2×240, 1×110	2×360, 1×100	3×360
Refrigerator	BTU/hr (Kgcal/hr)	3×805,000 (202,800)	3×1,167,300 (294,100)	4×1,167,300 (294,100)
Freezing capacity	ton/day	22.5	40.0	60.0
Freezing chamber	ft³ (m³)	5,850 (165.7)	11,200 (317.1)	20,980 (591.0)
Freezing lobby	ft³ (m³)	1,885 (53.4)	3,135 (88.8)	13,210 (374.4)
Fish hold	ft³ (m³)	42,400 (1,201.6)	79,600 (2,254.2)	119,900 (3,394.3)
Fuel-oil tank	ft³ (m³)	15,700 (444.7)	24,120 (683.3)	48,950 (1,386.2)
Fresh-water tank	ft³ (m³)	2,225 (63.0)	4,340 (125.6)	6,130 (170.7)
Light load Δ	ton	852.0	1,270.4	2,048.9
T	ft (m)	7.25 (2.209)	7.40 (2.256)	8.22 (2.507)
C_b		0.610	0.585	0.619
GM	ft (m)	3.45 (1.05)	6.00 (1.83)	4.63 (1.41)
Full load Δ	ton	1,923.0	3,278.2	5,274.4
T	ft (m)	14.05 (4.285)	16.24 (4.948)	15.20 (4.635)
C_b		0.700	0.693	0.685
GM	ft (m)	3.45 (1.05)	4.14 (1.26)	4.63 (1.41)
Freeboard	ft (m)	2.80 (0.85)	2.93 (0.89)	1.67 (0.51)
Number of crew		63	112	148
Number of catcher boats		2	4	6

* Approximately.

About ten years ago, a tuna longliner mothership was designed, that carried catcher boats on board and unloaded them in the fishing area. This mothership was 1,800 GT and had six catcher boats of 13 GT each. Since then, about 46 such vessels have been built with two to six catcher boats each. The motherships were 800 to 3,000 GT and the catcher boats, of wooden or steel construction, were mostly 19.9 GT, which is the upper limit of restriction by the Fisheries Law. The number of catcher boats is generally as follows:

Mothership	Catcher boats
700 to 800 GT	2 × 19 GT
1,300 to 1,500 GT	4 × 19 GT
over 2,000 GT	6 × 19 GT

The particulars of these and the catcher boats are shown in tables 4 and 5 respectively. In the light condition, a catcher boat of wooden construction weighs about 25 to 30 tons, and one of plywood and steel construction about 19 tons. Therefore the mothership must be equipped with a heavy derrick arrangement, usually consisting of two derrick posts, four derrick booms and four cargo winches of three to five tons at 100 to 130 ft/min (30 to 40 m/min). Therefore, the stability may be insufficient, especially in the case of small-sized vessels.

Fig 1. Recent 500-GT tuna longliner

TABLE 5. Particulars of catcher boats on board tuna fishing vessels

Construction		20 GT Wooden	20 GT Plywood	20 GT HT Steel	19 GT *FRP
LBP	ft (m)	52.50 (16.00)	52.50 (16.00)	49.20 (15.00)	49.20 (15.00)
B moulded	ft (m)	11.78 (3.60)	11.94 (3.65)	11.45 (3.50)	11.78 (3.60)
D moulded	ft (m)	5.42 (1.65)	4.99 (1.52)	4.76 (1.45)	4.99 (1.52)
Fish hold	ft³ (m³)	424 (12.0)	593 (16.8)	424 (12.0)	325 (9.2)
Fuel oil	ft³ (m³)	52 (1.5)	53 (1.5)	49 (1.4)	57 (1.6)
Fresh-water	ft³ (m³)	18 (0.5)	11 (0.3)	14 (0.4)	11 (0.3)
Main engine	hp	D–90	D–90	D–90	D–120
Weight	ton	25.0	19.8	19.9	13.4

Fibreglass reinforced plastic.
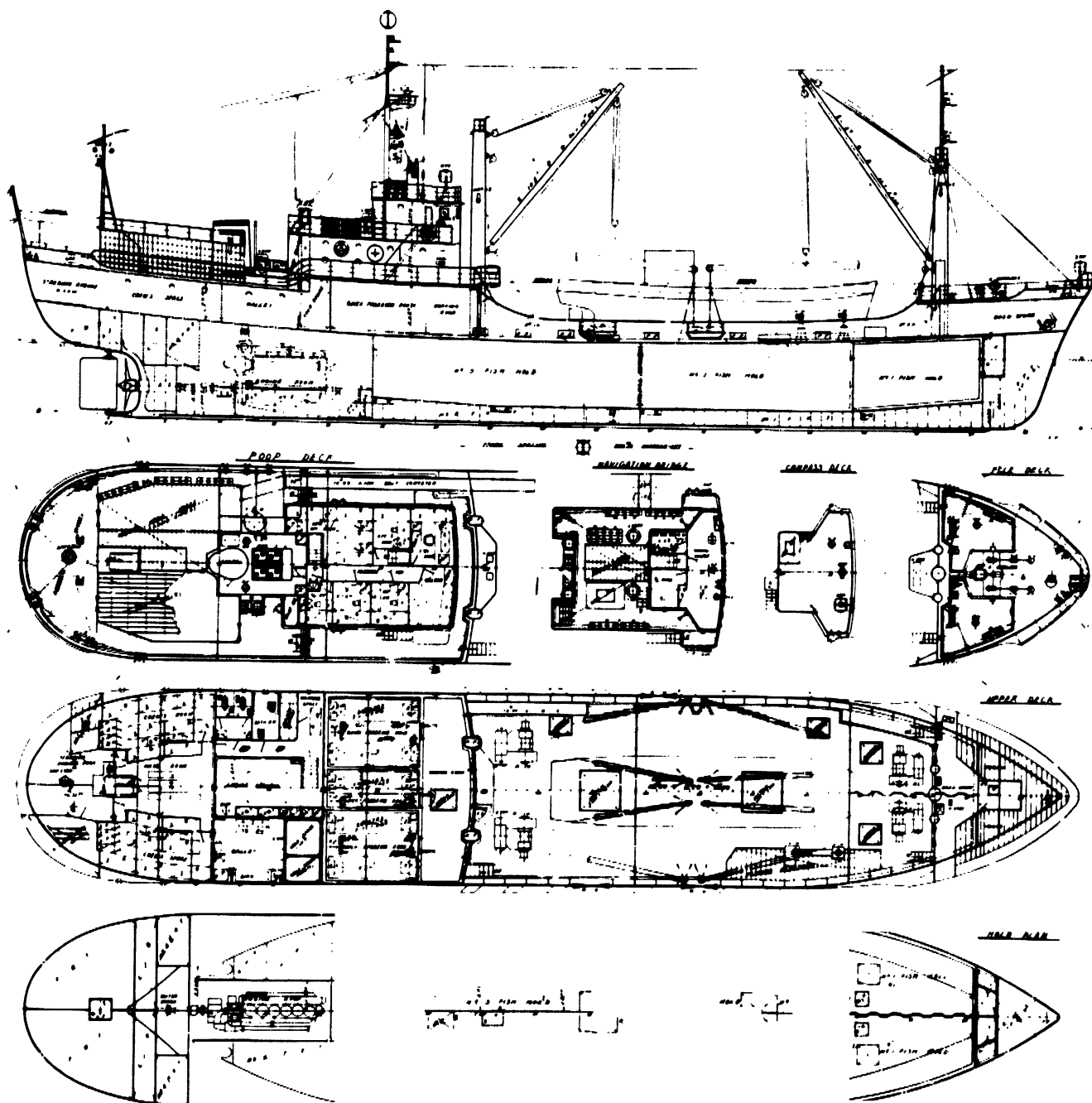
Fig 2. Recent 500-GT tuna longliner

Recently a vessel, under 500 GT, carrying a catcher boat of 19 GT on board, was designed to cope with the recent decrease in catch. The stability on the voyage with a catcher boat on board is no problem, but it is somewhat dangerous when the vessel hauls or lifts the catcher boat at sea, sometimes causing a large heel with the deck-edge immersed. So far, however, no accidents have occurred (fig 1 and 2).

It is essential to reduce the weight of catcher boats in the case of these motherships. In 1965 a catcher boat with a fibre-reinforced plastic hull was built for this purpose. It weighs about 13 tons, only two-thirds that

of steel or plywood construction. The derrick arrangement weight has also been reduced, giving a considerable decrease in the heeling. The success of this catcher boat gives good future prospects for this design and it may come into wide use.

FISH HOLD AND REFRIGERATION

Small tuna longliners under 100 GT have not yet generally been installed with deep-freezing equipment. but with ice cooling and auxiliary refrigeration. This is because of the lack of available space to install a deep-

freezer with sufficient capacity for preserving the daily catch, and also the length of voyage and size of vessel hardly warrant it.

Tuna vessels over 100 GT are generally installed with a deep-freezer with a capacity of 4 to 10 tons per day. Some 110-GT vessels have the freezing chamber below deck, but in vessels of over 190 GT it is mostly installed on deck. This is generally a semi-airblast freezing system, although occasionally Ottesen's salt-brine system is used. The semi-airblast system is considered the most suitable because the frozen tuna are sold in a round or semi-dressed state. The salt-brine system is not favoured, although it is labour saving. Salt-brine frozen tuna has a lower market price in Japan.

The refrigerant for the deep-freeze and the hold refrigeration is usually ammonia gas, the direct-expansion system. Others, such as the indirect or Freon gas direct system, are scarcely used because the ammonia direct-expansion system has a higher freezing efficiency and lower running costs.

Fish-hold refrigeration is generally done with hairpin coil evaporators on the bottom, walls and ceiling of the holds. The airblast freezer in the freezing chamber consists of evaporator coil racks and power air blowers. The installation standard for the semi-airblast system of Japanese fishing boats is given in the Fishing Boat Inspection Regulation by the Government as follows:

Deep freezing

pacity BTU/hr	Refrigerator capacity (kgcal/hr)	Evaporator cooling surface ft²	m²
3	144,800	36,500	860	80
5	238,100	60,000	1,450	135
10	460,300	116,000	2,900	270

Frozen fish-hold refrigeration

Hold capacity per compartment ft³	m³	Refrigerator capacity BTU/hr	(kgcal/hr)	Evaporator cooling surface ft²	m²
1,770	50	61,500	15,500	707	65.7
3,530	100	86,500	21,800	1,010	93.8
5,300	150	105,600	26,600	1,211	112.5
7,060	200	115,500	29,100	1,328	123.4

The above standard has been unaltered since 1959 (Doke and Chigusa, 1960). However, the temperature standard has changed; from −22°F to −40°F (−30°C to −40°C) in the freezer chamber and from 0°F to −13°F (−18°C to −25°C) in the storage hold, to improve the quality of frozen tuna products.

In these few years, defrozen tuna meat had as good a market in Japan as fresh raw meat, indicating the high quality of frozen tuna. To meet these requirements, the majority of recent tuna longliners have increased the length of evaporator coils in the fish-hold and freezing chamber by 20 to 30 per cent and have thickened the insulation materials by 1.0 to 2.0 in (25 to 50 mm). The refrigerators also have increased in capacity by about 50 per cent and some vessels have used an additional two-stage system and/or refrigerant liquid pumps.

A contemporary NH_3 refrigerating system installed in a 250-GT tuna longliner is shown in fig 3.

PROPULSIVE MACHINERY

The majority of propulsive machinery installed in Japanese tuna longliners is of slow rotation, four-stroke, vertical trunk piston-type diesel, with turbo-supercharger. The outputs of these engines are comparatively high for the vessels' size:

GT	hp	rpm
39	160 to 250	400 to 450
110	400 to 450	385 to 430
190	550 to 650	340 to 390
250	700 to 800	340 to 380
350	800 to 1,000	310 to 330
500	1,300	290 to 310

Engines with an output less than 450 hp generally have reversing gears, and those over are self-reversible with the friction clutch between flywheel and thrust shaft. The mean effective pressure in cylinder of these engines is generally 106.6 to 156.5 lb/in² (7.5 to 11 kg/cm²). The engine is cooled by seawater circulation and only rarely by fresh water. Table 7 shows an example of the propulsive engines installed recently.

The tuna longliner must steam, while fishing is in progress, at a speed of four to five knots, because the most suitable hauling speed of fishing line is believed to be 40 to 50 baskets of lines, or 39,400 to 49,300 ft (12,000 to 15,000 m) per hour. The vessels, however, may have a speed of six to seven knots even at the lowest revolutions,

TABLE 6. **A contemporary NH_3 refrigerating system installed in a 250-GT longliner**

Refrigerator (2 stage compressor)		
3 cylinders, 2-stage compressor, 45 kW motor	2 × 7.09 × 5.51 in (180 × 140 mm) 1 × 5.91 × 5.51 in (150 × 140 mm)	1 set
Refrigerator		
2 cylinders, 30 kW motor . .	2 × 7.09 × 5.51 in (180 × 140 mm)	1 set
Condenser, shell and tube . .	329 ft² (30.6 m²)	× 1 set
	230 ft² (21.4 m²)	× 1 set
Cooling water pumps, 2.2 kW motor	1,059 ft³ (30 m³)/hr × 39.4 ft (12 m)	× 2 sets
Liquid receivers, vertical . .	21.5 ft³ (0·610 m³)	× 2 sets
Oil separators, ,, . .	12.5 × 35.4 in (318 × 900 mm)	× 2 sets
Accumulator, ,, . .	14 × 41.4 in (355 × 1,050 mm)	× 1 set
Gas purger, ,, . .	8.5 × 23.6 in (216 × 600 mm)	× 1 set
Intercooler, ,, . .	12.55 × 66.6 in (319 × 1,690 mm)	× 1 set
Electric axial flow fans for quick-freezing room, 1.5 kW motor		× 8 sets
Thermometer, electric-resistance system	−58° to 86°F (−50° to 30°C)	× 1 set (20 points of elements)
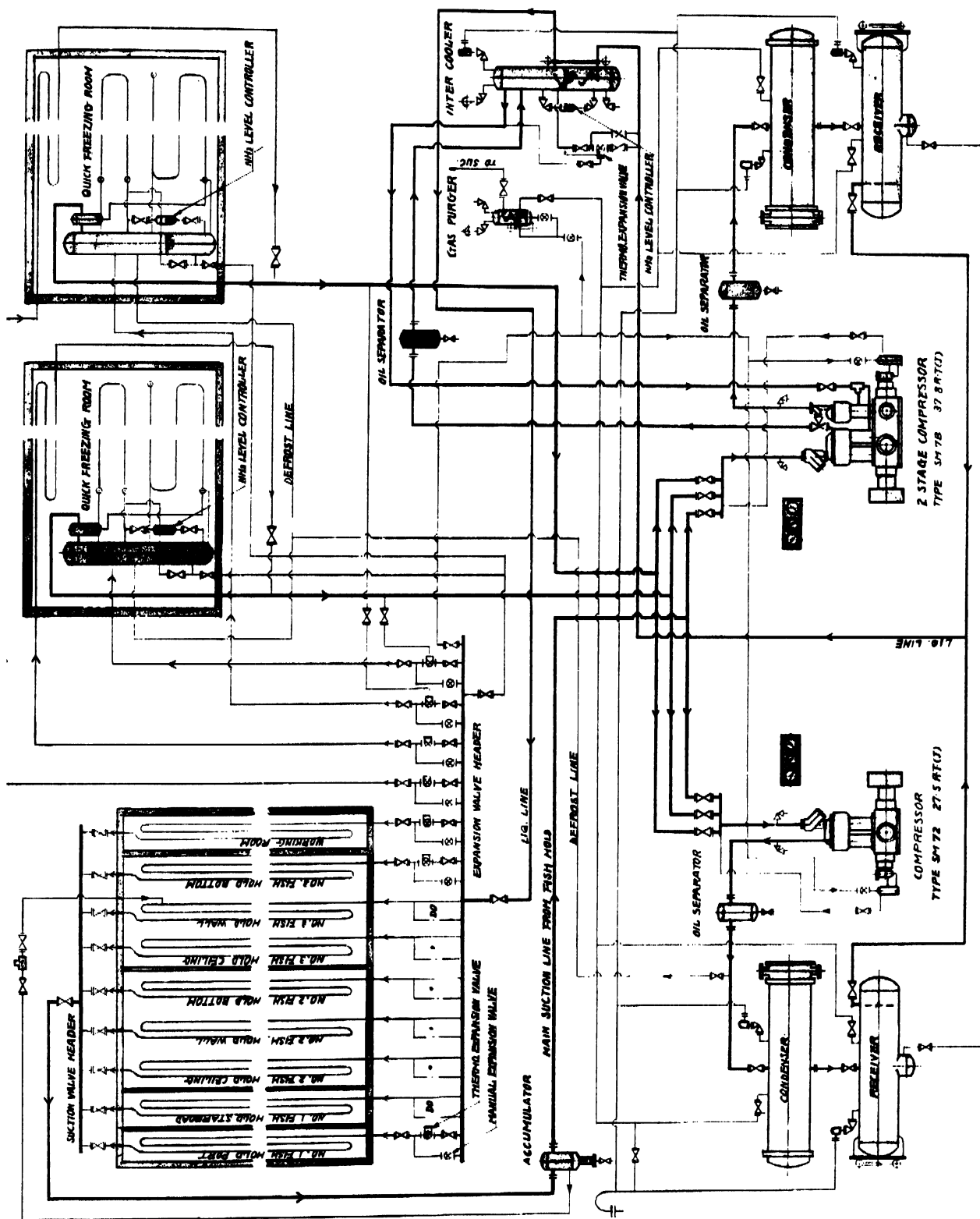
Fig 3. 250-GT tuna longliner refrigeration arrangement

[555]

TABLE 7. Specifications of propulsive machinery for tuna longliners

Model	hp	rpm	No. of cyl.	Diam. of cylinder		Stroke		Weight of engine		Weight of engine per hp	
				in	mm	in	mm	lb	ton	lb	kg
27/40	600	390	6	10.6	270	15.8	400	22,700	11.2	39.8	18.1
32/45	650	350	6	12.6	320	17.7	450	39,500	17.9	60.8	27.5
30/42	700	370	6	11.8	300	16.5	420	34,850	15.8	49.8	22.6
28/44	750	380	6	11.0	280	17.3	440	32,400	14.7	43.2	19.6
32/45	750	350	6	12.6	320	17.7	450	40,800	18.5	54.4	24.7
33/46	850	330	6	13.0	330	18.1	460	39,900	18.2	47.0	22.4
35/50	1,000	330	6	13.8	350	19.7	500	48,500	22.0	48.5	22.0
37/52	1,000	320	6	14.6	370	20.5	520	58,400	26.5	58.4	26.5
40/57	1,300	290	6	18.8	400	22.4	570	69,000	31.3	53.1	24.1

and therefore they maintain the speed of four to five knots by means of an on-and-off clutch, which may sometimes be used over 30 times per hour. This uneconomical and troublesome procedure has been normal practice for a considerable time.

Recently the controllable pitch propeller (cp) has been widely introduced. The cp was initially used about ten years ago on several tuna longliners, but it was not widely accepted because some vessels met with serious trouble due to the entanglement of the fishing lines around the shaft between the propeller boss and the aft end of the stern tube. In recent years it has become really popular due to the simplification of the pitch control mechanism and reduction in costs. About one-fifth of recent vessels use them and are satisfied with the easy control of the ship's speed during fishing. A clutch is still installed between flywheel and thrust shaft for the purpose of disentangling the fishing lines around the propeller shaft.

The remote control of the main engine is also widely used, together with cp. Many systems have been developed, utilizing mechanical, compressed air, electric and electro-hydraulic, for remote control of engine revolutions, starting, stopping and reversing. The most popular systems are electric or electro-hydraulic with the remote control panel and measuring instruments situated in the wheelhouse adjacent to the autosteering stand. Lately, medium-speed diesel engines of 600 to 800 rpm with reduction gear, as well as high-speed generator engines, have been used and have saved space. These geared diesel engines, however, are not yet widely used because of their poor durability. Midwater tuna longliners are obliged to go on long trips and the main engines must run continuously for quite long periods, very often over 4,000 hours. The most durable, heavy-duty, slow-speed diesels, therefore, are still preferred by the majority of midwater tuna longliner owners, and only a few vessels with small engines, less than 650 hp, have used geared diesel engines. Table 8 shows an example.

METHODS TO REDUCE MANUAL LABOUR

Modern tuna longliners normally have the following crew and fishermen on board:

GT	Crew and fishermen
39	. 18
190	. 26
250	. 28
290	. 30
350	. 32
450	. 34

The number of crew has not changed over the past five to six years. On the other hand, the daily average catch has decreased. These vessels are therefore forced to extend the duration of the trip and thus increase the expenses. To offset this, the owners try to reduce the crew and fishermen by reducing their manual labour. This is currently a serious problem for all the fishing industry and particularly the Japanese tuna fisheries. A committee has recently been organized to investigate this problem. It consists of the Fisheries Research Institute, the Federation of Tuna-Fishermen Cooperatives, fishing firms, fishing boat builders and machinery manufacturers. The tentative recommendations for study by the Committee are:

● (a) Mechanization of fishing operation
● (b) Automation for freezing tuna
● (c) Automatic control of engine and steering

(a) It is quite difficult to mechanize the whole fishing operation, namely the throwing of lines, buoys, hooks and bait from the ship's stern in three to four hours, hauling them back with the catch on the fore deck in 12 to 14 hours and conveying the lines and buoys from the fore deck to the aft deck. The mechanical equipment now used is the power-driven line hauler and a conveyor belt for longlines and buoys after hauling. The Committee has investigated the possibility of using an

TABLE 8. Specification of medium-speed propelling machinery for tuna longliners

Model	hp	rpm	No of cyl	Diam. of cylinder		Stroke		Weight of engine		Weight of engine per hp	
				in	mm	in	mm	lb	ton	lb	kg
16/20	260	1,200	6	6.3	160	7.9	200	7,500	3.4	28.8	13.1
20/26	420	800	6	7.4	200	10.2	260	14,550	6.6	34.7	15.7
20/26	420	900	6	7.9	200	10.2	260	15,000	6.8	35.7	16.2
25/32	650	720	6	9.8	250	12.6	320	22,700	10.2	34.9	15.7

automatic throwing machine for the lines and bait, a power winding reel for the lines after hauling or a complete conveyor system for the lines and buoys from line hauler to the after-casting platform. Automating the whole operation presents certain difficulties because the rate of flow of the fishing gear is not constant, as it is entangled by the movement of tuna. Therefore the design of the fishing lines themselves may also have to be studied in respect of material, hardness and swivel arrangements, etc. The Committee has not yet reached a definite conclusion on this.

(b) The question is which freezing system is preferable: salt-brine or airblast? The salt-brine system requires little labour compared with the airblast system, but may not be accepted because the salt-brine frozen tuna has a poor market value in Japan. On the other hand, the airblast system produces better quality frozen tuna, but requires much more labour and space. Thus the Committee faces two problems; firstly how to improve the quality of salt-brine produce for good market prospects, and secondly how to automate the airblast freezing system to reduce labour and to obtain compactness.

(c) The majority of tuna longliners have already been installed with automatic steering control and the main engine remote-control systems, but even if completely automatic machinery control is applied, there is little chance of reducing labour, because most of the crew are absorbed in assisting in the actual fishing operation and not in handling the ship.

CONCLUSION

Modernization of Japanese tuna longliners is now being closely studied, aiming at the most economical operation with the least labour and expense. This may give rise to an entirely new type of midwater tuna longliner, with advanced mechanization of fishing gear and fish processing plant.

Development of Japanese Stern Trawlers

by Tatsuo Shimizu

Evolution des chalutiers japonais à pêche par l'arrière

L'auteur expose l'évolution générale ayant abouti au chalutier japonais moderne à pêche par l'arrière, en soulignant le grand rôle joué par la nécessité d'aller pêcher de plus en plus loin pour satisfaire la demande accrue. Il décrit la technique moderne de construction, examinant les moteurs, l'aménagement du pont, certains paramètres de formes, le profil du tableau arrière, tant au-dessus de la ligne de flottaison qu'au-dessous de la voûte, et les divers types de gouvernail. Après avoir étudié plus à fond les appareils propulsifs, l'auteur traite de la commande des treuils de pêche, de la longueur du pont de travail, des emménagements, et du fonctionnement du treuil de pêche. Sont ensuite abordés les chalutiers d'une jauge brute de 300 tonneaux et leurs caractéristiques les plus marquantes: moteurs de grande puissance, treuils de pêche, hélices à pas variable. L'auteur passe ensuite brièvement en revue les grands navires usines jaugeant de 3 000 à 3 500 tonneaux, et termine en traitant de l'évolution future.

Arrastreros japoneses que pescan por la popa

Se examinan los antecedentes del proyecto de modernos arrastreros japoneses que pescan por la popa, con el gran efecto resultante de verse forzados a pescar muy lejos para hacer frente al consumo. Se pasa a describir la práctica moderna de la pesca, con un examen general de los motores, el trazado de la cubierta, algunos parámetros de la forma del casco, el perfil vertical de la popa de espejo, sobre el agua y bajo la bovedilla, y la disposición del timón. Se estudian más detenidamente las máquinas propulsoras, y siguen capítulos dedicados a las maquinillas de arrastre, la longitud de la cubierta de faena, los alojamientos y el funcionamiento de las maquinillas de arrastre. Se examinan arrastreros de 300 toneladas brutas y sus características peculiares más importantes, como los motores de propulsión y maquinillas de arrastre muy potentes y las hélices de paso variable. Luego se analizan sucintamente buques factorías de mayor tonelaje (3.000-3.500 toneladas brutas). Por último se discuten futuras innovaciones.

WHEN the Japanese trawler fisheries were searching for new overseas fishing grounds to expand operations beyond the region of the East China Sea and Japanese waters, where fishing until then had been prosperous, a study of European stern-trawling techniques was first undertaken. In 1955 the training ship, *Umitaka Maru*, of Tokyo University of Fisheries was then built, following closely the design of a European stern trawler. In 1957, the *Taiyo Maru No. 51*, a larger trawler, was built by a Japanese firm, but as the data on stern-trawler construction was still insufficient it was planned that the vessel would serve both as a deep-sea trawler and as a carrier for the Antarctic whaling industry. This design proved so successful, however, and such good results were obtained by the two vessels in the North Pacific and New Zealand waters that about 30 stern trawlers of 1,500 to 2,500 GT were launched by

Fig 1. Sankichi Maru No. 51, 299 GT

Japanese fishing companies during the years 1960 to 1963. These trawlers not only operate in waters off the North-West African coast and transport their catch to Japan, but are also required to process frozen fish for export, meeting the various consumption requirements peculiar to the importing countries.

Large trawlers were developed with the capacity of operating for long periods in distant waters. They were fully equipped with filleting machinery and meal plant to produce various finished products with the minimum of wastage. In 1964 designs were so improved in the 2,500 to 3,500 GT range that adequate space to accommodate essential maintenance personnel and equipment was available. From an economic aspect the larger the trawler the larger must be the catch which can only be acquired from deep water fishing grounds, entailing heavier duty trawl winches.

Stern trawlers of 300 GT were also built by lesser Japanese fishing companies for operation mainly in the North Pacific utilizing a powerful trawl winch and main engine. Their small size naturally restricted their operational range and they operated more efficiently working co-operatively with a factory vessel rather than as individuals. Due to seakeeping considerations, and hence working conditions aboard, it was necessary to increase their size to 500 GT. The general appearance of typical stern trawlers is shown in fig 1 to 4, and main particulars given in table 1.

TYPE AND SIZE OF VESSEL

The initial consideration in designing a stern ramp trawler is the position of the main engine aft or amidships. Japanese trawlers operate far from their home ports and

Table 1: Typical Japanese stern trawlers, 300 to 3,500 GT

Name of ship	GT	L ft	L m	B ft	B m	D ft	D m	Diesel hp	Year built	Crew complement	Hold capacity ft³	Hold capacity m³	Sharp freezing capacity	Trawl winch capacity
Sankichi Maru No. 51 (fig 1)	299	123.0	37.6	26.6	8.0	11.8	3.6	4 x 86 kw motor	1964	32	9,650	273	6.7T/D	6t x 197ft (60m)
Chuyo Maru No. 7 (fig 2)	299	124.5	38.0	26.6	8.1	12.8	3.9	1,000	1965	25	10,950	310	6.7 "	7t x 262ft (80m)
Ebisu Maru	314	128.5	39.2	26.2	8.0	11.8	3.6	1,000	1964	29	10,700	303	16.0 "	7t x 262ft (80m)
Fukuyo Maru No. 1	314	132.0	40.2	26.2	8.0	12.8	3.9	1,200	1965	24	11,800	334	6.2 "	7.5t x 262ft (80m)
Akebono Maru No. 50	1,425	255.0	72.8	39.4	12.0	18.7	5.7	2,000	1960	87	54,800	1,550	40.0 "	10t x 213ft (65m)
Taiyo Maru No. 61	1,497	226.0	69.0	37.4	11.4	18.7	5.7	1,800	1957	70	56,000	1,588	37.5 "	72t x 148ft (45m)
Taiyo Maru No.65	1,828	230.5	70.3	39.4	12.0	27.2	8.3	2,000	1960	67	69,600	1,971	24.0 "	13t x 141ft (43m)
Taiyo Maru No. 75	2,160	243.5	74.2	42.0	12.8	28.5	8.7	2,470	1963	74	62,600	1,772	30.0 "	13t x 197ft (60m)
Kiso Maru	2,522	260.0	79.2	44.3	13.5	29.2	8.9	2,750	1963	75	84,100	2,380	35.0 "	20t x 115ft (35m)
Unzen Maru (fig 4)	2,525	260.0	79.2	44.3	13.5	28.5	8.7	2,400	1961	70	86,000	2,435	33.2 "	24t x 148ft (45m)
Taiyo Maru No. 81	2,807	269.0	82.0	46.0	14.0	30.2	9.2	2,880	1964	99	70,600	2,000	48.6 "	18.6t x 197ft (60m)
Daishin Maru No. 12	2,967	289.0	88.1	48.8	14.9	23.6	7.2	3,380	1963	85	122,000	3,457	52.0 "	15t x 197ft (60m)
Zuiyo Maru (fig 5)	2,970	269.0	82.0	46.0	14.0	30.2	9.2	2,880	1964	112	68,700	1,945	62.0 "	19.7t x 216ft (66m)
Takachiho Maru (fig 6)	3,495	292.5	89.2	52.5	16.0	24.0	7.3	3,710	1964	104	1?3,000	3,483	55.0 "	23t x 230ft (70m)

therefore the ratio of fishing to voyage time needs to be considered when fixing the refrigeration, refrigeration hold, fuel oil, fresh-water tank and provision store capacities. A sufficient after draft for all loading conditions must also be considered. To satisfy these conditions the following arrangement is indicated: fat amidship for fish hold, fore peak and double bottom for fuel oil tank and the remainder engine room. This is a description of the engine aft type. A problem is the location of the engine casing and funnel. A large engine casing will reduce the fish treatment space on the shelter deck and a centre-line funnel will complicate the trawl-winch layout. With the exception of the prototype vessel, the *Taiyo Maru No. 51*, this was solved by adopting a layout similar to a whole factory ship, that is the engine casing reduced to a minimum in way of the shelter deck or the casing and funnel divided longitudinally and sited at the sides of the deck. Apart from the prototype, therefore, all large Japanese trawlers have been built with engine and shelter deck aft.

In general, Japanese large stern trawlers have larger L/B values in the range 5.7 to 6.0, whilst other countries tend to the range 5.5 to 5.7, but the latest factory trawler of about 3,000 GT has a smaller L/B ratio to accommodate factory equipment. The block coefficient of Japanese trawlers also tends to be higher when composed on deadweight. This means that some loss in comparative ship's speed is inevitable.

For ease of sliding up the otter boards, the transom was inclined slightly forward, but with the increase of deep-sea trawling, this slope has become vertical or even inclined aft, thus permitting the trawl net warp to come up almost vertically on to the top roller and so avoid faying on bulwark roller. The engine aft allows a constant after draft to be maintained although it has been noticed that this type of vessel suffers from panting under the counter when the midship hold is empty. The

increase in tow-rope force required has a tendency to increase the engine power, hence decreased propeller revolutions and increased propeller diameter. This necessitates a raising of the counter and decreases the stern immersion which increases the susceptibility of panting in heavy seas. To avoid this, either the after

Fig 2. Chuyo Maru No. 6, 299 GT

draft must be increased or a spade-type rudder, as in the British stern trawler *Ross Valiant*, must be introduced. To help the net-hauling operation the after end of the stern ramp is to some extent submerged, giving a corresponding increase in total ship resistance, but this is found to be negligible.

TYPE OF ENGINES FOR PROPULSION

Most Japanese stern trawlers have single direct engines but some European trawlers on the other hand use diesel-electric propulsive systems. There is hesitation in Japan in using this system because of the following reasons when compared with single direct engines:

- Higher installation costs and fuel costs
- Larger engine room required
- Insufficient working knowledge and practical experience

The Japanese Fisheries Agency is proposing a prototype guidance vessel with diesel-electric system. The "Father and Son" and other systems are also under consideration. Most Japanese trawlers built since 1953 are equipped with remote control from the wheel house to the engine room and some are equipped with automatic systems for fuel oil purification and refrigeration.

TRAWL WINCH

The type of trawl winch required, whether it be electric or electro-hydraulic drive, and in the latter case, high or low pressure, is decided by the cost and the winch characteristics. It is difficult, therefore, to reach any definite conclusions as to a best type. Initially electric drive was used and since then almost all vessels have been equipped with AC motors for trawl winches. The AC motor as it stands is unsuitable for this purpose and low pressure electro-hydraulic drive was adopted. With the expansion of deep sea trawling, higher winch winding speeds were necessary. To adapt the low pressure system is not simple because of the large pump room required, so recently AC Kraemer type electric or high pressure electro-hydraulic systems are used. The trawl winch capacity is calculated from the maximum intended trawling depth and size of net. Winches of current stern trawlers have capacities of 12 to 23 tons × 295 to 197 ft (90 to 60 m) wire speeds per minute.
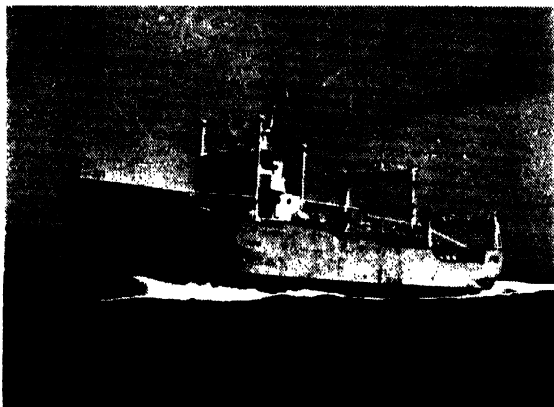
Fig 3. Fukyo Maru No. 1, 314 GT

NOTES ON GENERAL EQUIPMENT

Working deck

The advantage of having engines aft is in providing ample working deck length if the disposition of the engine casing can be correctly adjusted. The distance between the upper edge of the stern slipway to the trawl winch is some 100 ft (32.8 m) for 1,500 GT and 130 ft (42.7 m) for 3,000 GT vessels. To obtain this the bridge must be well forward and, consequently giving a centre of wind pressure well forward, this has the disadvantage of pro-

ducing a tendency to drift to leeward. To overcome this the working deck length for even a large vessel is restricted to about 100 ft (32.8 m).

Accommodation space

Processing and refrigeration equipment occupy much space in Japanese distant-water trawlers. This equipment demands a larger crew to operate it than is common in other countries, so adequate accommodation space is necessary. A factory trawler has a crew complement of 110 to 130, therefore any reduction in this number by adopting automatic control systems is desirable. Hence automation and accommodation should be studied as interdependents.

Fig 4. Unzen Maru, 2,525 GT

Trawl winch operations

Most trawl winches are side operated but in several large trawlers control rooms have been situated just aft of the bridge with the clutch and brake operated by pneumatic remote control. Depending on the ship's operational area, care must be taken not to lose the net by snagging on natural underwater projections. For this purpose an alarm system, triggered by excessive strain on the warps and recorded in the bridge and control room, has been installed. This is remotely recorded by an oil-pressure or wire resistance strain gauge at the top roller of the gallows or on the rope way of the warp. This is now under practical proving tests in a large stern trawler.

300-GT TRAWLER

In 1960 the Japanese Government allowed trawlers to operate in the North Pacific and trawlers of such small displacement were neglected. In 1962, however, the *Chuyo Maru No. 5* was built and has had a favourable reception. After consideration, the main engine was fixed amidship and the long fo'c'sle accommodated the after part of the engine room, this caused a reduction in working space but not accommodation. From 1963 to 1965 ten more stern trawlers of 300 GT have been built, equipped with more powerful engines and trawl winch when compared with the ship's size and also controllable pitch propellers. These were designed as independent middle-water trawlers, with heavy catches on short

voyage times, and fishing period. The main engine was 800 to 1,200 hp. For the engine aft type, a compact engine was essential and so the geared diesel was the obvious choice. The controllable pitch propeller and power trawl winch enable a steady winch rotation which is oil-pressure-driven from the main engine.
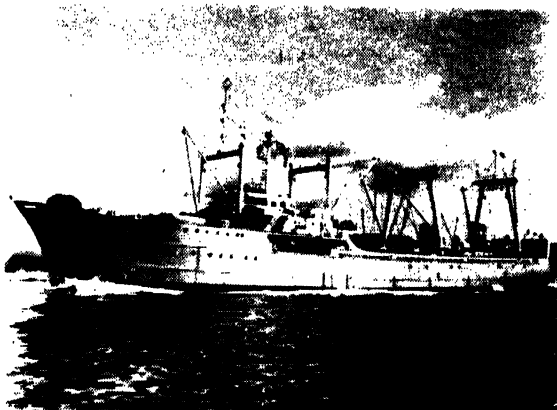
Fig 5. Zuiyo Maru, 2,970 GT

Basically, three types have been developed:

- Shelter deck
- Engine midship with long fo'c'sle
- Engine aft with long fo'c'sle

The *Sankichi Maru No. 51*, built in 1964, has a diesel-electric propulsive unit with two three-phase motors, reduction gearing and a controllable pitch propeller.

JAPANESE FACTORY TRAWLERS

With trawlers being forced to fish in more distant waters, it was necessary to increase the size of vessel, to increase the fish hold capacity and to still maintain an economic proposition. Nowadays, in order to maintain the full edible standard of the catch, the relay base system, which has come to be possible with co-operation from other nations, has been established, and whilst fish for domestic consumption is washed and then frozen whole, fish for export is processed almost to fish block. Non-processible fish and fish offal are profitably reduced to

meal. For this purpose, full processing factory trawlers of 3,000 to 3,500 GT, equipped with Baader and meal plant, began to be built by 1963.

EXAMINATION OF FUTURE DEVELOPMENTS

Large factory trawlers are expensive and can make no commercial profit unless they are fully utilized because of the installations and large crew required. It appears that vessels specially designed and equipped for a specific fishing ground must be considered. This would enable a minimum of equipment to be installed. A careful analysis should be made, therefore, of the specific area in respect of depth of water, prevailing weather and sea conditions, types of fish and associated processing and the marketing possibilities.

Fig 6. Takachiho Maru, 3,495 GT

Wages and living standard in Japan have risen, and better accommodation must be provided because of the long periods at sea. Simplification of handling vessels, fishing and factory operation must be studied seriously. This is without mentioning the obvious need for improved fish gear. It is, therefore, necessary to look well ahead and to attempt to forecast future requirements, by studying both private and national economics. The plan for building a large guidance vessel for the investigation of fishing grounds arouses great interest.

Small Stern Trawlers

by W. M. Reid

Petits chalutiers Canadiens à pêche par l'arrière

Après avoir fait l'historique des petits chalutiers modernes à pêche par l'arrière de la côte nord-est du Pacifique et décrit le milieu dans lequel ils opèrent, l'auteur étudie les deux principaux types de chalutiers arrière sans rampe, l'un convenant aux engins pour fonds mous, l'autre aux engins pour fonds durs. Il décrit ensuite 4 types de petits bateaux à rampe arrière, caractérisés par la méthode d'embarquement du chalut: (a) corps du chalut laissé dans l'eau; (b) embarquement des ailes sur les deux bords; (c) embarquement des deux ailes sur un bord; (d) embarquement du chalut entier sur la rampe au moyen d'un tambour; et conclut en passant en revue l'évolution future du dessin des chalutiers.

Pequeños arrastreros de popa canadienses

La historia y las condiciones de operación ambientales de los modernos arrastreros pequeños para la pesca por la popa, en la costa del Pacífico Noreste plantea una discusión sobre los dos tipos principales de los referidos arrastreros sin rampa, uno apto para artes de pesca en fondos lisos, y el otro para artes de pesca en fondos accidentados. Sigue una descripción de cuatro tipos de pequeños barcos con rampa en la popa, caracterizados por sus métodos de manipulación de las redes: (a) dejándolas en el agua, (b) recogiendo las pernadas por una y otra banda, (c) recogiendo las pernadas por una banda, (d) combinando la rampa y el tambor. Por último, se estudian las futuras tendencias del diseño.

W HILE the term "stern trawling" is of fairly recent origin and is generally taken to mean those vessels which tow and recover the trawl over the stern, as opposed to those which tow and recover the trawl from the side, there exists on the Pacific coast of Canada and USA a very large fleet of small stern trawlers or draggers, 45 to 90 ft (13.7 to 27.4 m) length overall, which have combined the best features of these two systems of fishing for more than 30 years.

It has been normal practice to tow the trawl with warps leading to davits (gallows) located one at each stern quarter of the vessel, exactly as the modern stern trawlers, with the exception that the codend is lifted over the side for emptying.

This system of handling the trawl may have been an inheritance from Mediterranean fishermen who migrated to the Pacific coast after 1918. Many improvements in the mechanical handling of gear has increased the efficiency to a level of productivity equal to vessels many times their size.

For over 20 years the author has been designing fishing craft up to 100 ft (30.5 m) (about 180 GT) operating on the west coasts of Canada and USA. Knowledge of this vast area is essential to understand the factors influencing the development of the "Pacific coast" type of vessel.

The sketch map, fig 1, shows the north and west coasts of Washington, British Columbia and Alaska, extending through the Bering Sea to the eastern coast of the USSR. This clearly shows the extensive and rugged coastline along which these vessels operate. To illustrate, the airline distance between the major British Columbia fishing ports of Vancouver to the south and Prince Rupert to the north is some 500 miles (825 km); however, the actual coastline between these two points has a total length of nearly 13,000 miles (24,000 km).

The climate is generally mild, being influenced by the Japanese Current. Harbours are usually ice free to well

Fig 1. The fishing boats with wheel house and engine forward used on the Pacific Coast of Canada and USA are operating along an extensive and rugged coast line

above 55° north although heavy snowfalls and fog are common.

Tides range from −2 to+16 ft (0.61 to 4.87 m) at Vancouver to −2 to +26 ft (0.61 to 7.92 m) in southeast Alaska. Tidal velocities tend to be strong, averaging 3 to 6 knots in the Hecate Strait trawling grounds.

A most unusual phenomena along the entire coast is an ocean groundswell, running in from a generally westerly
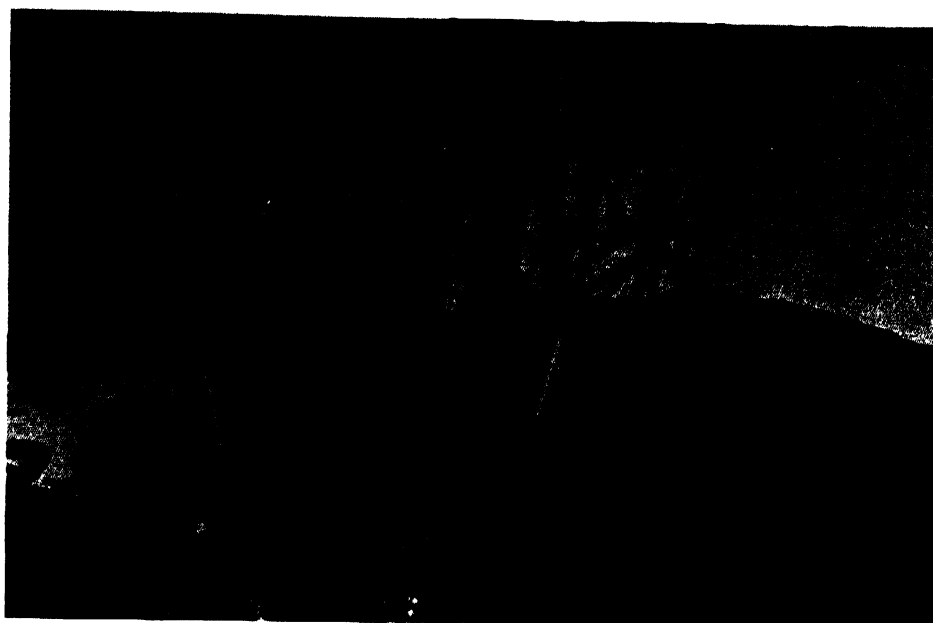
Fig 2. The typical Pacific groundswell very often shows a lack of wind generated waves

direction. This is a long, lazy swell, varying slightly with location and season but usually from 4 to 6 ft (1.2 to 1.8 m) in height and wave length up to 350 ft (110 m) in open sea. However, as these swells move in on the continental shelf they tend to shorten and steepen noticeably (fig 2). The groundswell is independent of any weather system and when wind-generated waves are superimposed a very confused and unpleasant sea results.

Average wind conditions along the entire coast are fresh to strong, with generally fair winds from the north-west, and storm winds from the south-east. However, the Gulf of Alaska and Bering Sea regions produce a local disturbance called the Alaska "Williwas" from a northern quadrant which, although not cyclonic in origin, produces recorded winds in excess of 125 nautical miles/hr (230 km/hr).

Table 1 shows the frequency of daily maximum wind speeds recorded by a Canadian weather station located at Cape St. James, Queen Charlotte Islands. These velocities are based on a four-year average and are the least severe conditions recorded by three such stations, the others being at Sandspit and Spring Island.

The Cape St. James weather office is nearly central to Hecate Straits, the most prolific trawling grounds on the

west coast. The yearly average wind speeds on 8.4 days out of 10 equals or exceeds Force 5 and on 4.7 days out of 10 equals or exceeds Force 7, or moderate force.

Because virtually all Canadian west coast trawlers above 75 GT are combination boats fishing several types of gear over the year, it is of interest to note the dis-position of the major fishing grounds in fig 1, and the very great distances involved. Gulf of Alaska and Bering Sea fishing trips are 20 to 35 days and may involve 2,300 miles each way.

This paper describes the arrangements and techniques used by small rampless Pacific Coast vessels and those used by the somewhat larger Atlantic Coast stern ramp trawlers.

Vessels engaged in this fishery have the typical wide stern and wheelhouse and engine well forward, providing the relatively clear after deck for fishing. Vessels of this type were described by Hanson (1955).

VESSELS OF 25 TO 49 GT WITHOUT RAMP OR DRUM

Back to 1912 the trawl was towed over the stern as an accepted practice, although not in the form known today. Vessels used were usually small salmon seiners fishing out

TABLE 1

Frequency of daily maximum wind speeds in nautical miles at Cape St. James

Wind Speed	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Fre-quency	Per cent
0-18	4	1	5	4	6	5	7	8		3	5	4	57	16
19-24	2	1	4	6	7	6	4	9		4	4	2	56	16
25-31	4	5	5	6	10	8	9	10		5	5	5	80	21
32-38	6	8	4	8	5	7	7	3		7	4	7	71	19
39-over	15	13	13	6	3	4	4	1		12	12	13	101	28

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of season and were 45 to 50 ft (13.7 to 15.2 m) long by 11 to 12 ft (3.4 to 3.7 m) beam; single decked with the wheelhouse and engine well forward; powered by 60 to 100 hp heavy duty petrol engines. The mast and salmon purse winch were about amidship (as today) and the winch was no more than a powered whipping drum. The trawls were small, seldom more than a 50-ft (15.2-m) opening and the wooden doors were light enough to be lifted aboard by hand. Manila rope was used for all running lines, the rope bridles being spliced into a single manila warp. The crew was the skipper and one man or at the most, two.

The trawl was towed from a wooden bollard located on the centreline just forward of the net platform (approximately 0.75 L). Shooting the net was just throwing the trawl into the water, followed by the boards as the wings came tight, then one man would slack off the bridles on the bollard and run the warp off to the desired length.

When hauling, the boat was stopped and the warp pulled in until the boards could be lifted on to the deck. The vessel would then steam ahead until the trawl broke surface, the bridles were recovered, and the boat would then back down until the codend was alongside. At this point wings and belly would be fleeted aboard, using a single fall from the boom end to the purse winch. The codend would be similarly lifted aboard for emptying, using a double tackle.

In 1919, Jack Shannon conceived the idea of using a heavy beam, hinged at the inboard end and projecting 3 to 4 ft over the rail, to carry a trawl lead block. Using, for the first time, a single wire trawl warp and bridles and a small, single drum winch in place of the usual powered whipping drum, the trawl was towed from the single block on the beam, which was amidships, opposite the winch.

Hauling the gear was simplified, as the single warp and bridles could be rolled on to the winch drum, pulling the boards up to the lead block on the beam. The same procedure was then followed for getting the codend on board. Between tows, the boards were left hanging at the lead block, when travelling the beam was pivoted, bringing the boards on to the deck.

This system, known locally as "beam trawling" is still used by many smaller boats unsuitable for fitting a trawl drum and may be the forerunner of the Gulf of Mexico "double-rig" shrimp trawlers which use two "beams" or outrigger booms, one to each side.

One of the first known boats to be rigged to tow a trawl from stern davits using two trawl warps was a small Canadian salmon seiner named the *Ispaco 1*. In 1934 a very crude arrangement of quarter davits and hanging blocks, combined with a centreline bollard, was installed on the vessel. As the salmon purse winch has no drum for wire, the trawl warps were of manila rope and were belayed around the centre bollard. When shooting gear the trawl was dropped over the stern and allowed to stream aft until the wings became tight, the bridles were slackened on the bollard to drop the boards into the water, then the warps were slackened off to the desired length for fishing.

Not until 1937 was a Pacific coast trawler fitted with a double drum winch capable of handling two wire trawl warps through stern davits and the deck arrangement thus worked out is the basis for virtually all such vessels operating today. The winch was set athwartship, with
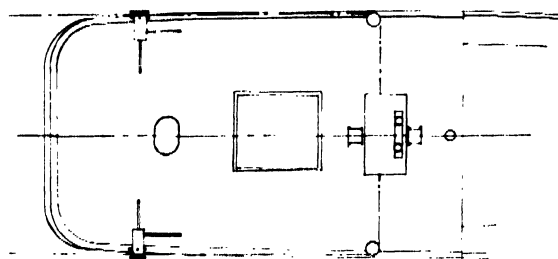
Fig 3. Traditional deck arrangement for Pacific Coast trawlers with a thwartship-placed winch permitting the trawl warps to be led straight to the bulwarks

the trawl warps leading to a flat sheave mounted on the bulwark rail cap then aft on each side to the quarter davits and hanging blocks (fig 3).

The advantages are obvious, as there are no running lines across the working deck area and consequently no need for bollard or other lead sheaves mounted on the deck. This is also a natural lead to the davit when purse seining.

One disadvantage is the need for spooling arrangement on the winch as the distance from winch to bulwark lead is not usually enough to provide for natural spooling of the wire. A second disadvantage is that when the wings are hauled up to the davits and the codend taken around the side for emptying, much loose web remains in the water around the stern with the possibility of fouling the propeller and rudder. Even if the excess web is fleeted aboard, the wings are still lying across the stern and it was to solve this problem that the trawl drum was developed.

TRAWLERS FITTED WITH DRUM

Since being developed by a Seattle fisherman in 1952 the trawl drum has virtually become standard equipment on all west coast trawlers and is finding an increasing acceptance among Atlantic coast fishermen.

While there are no standard dimensions for trawl
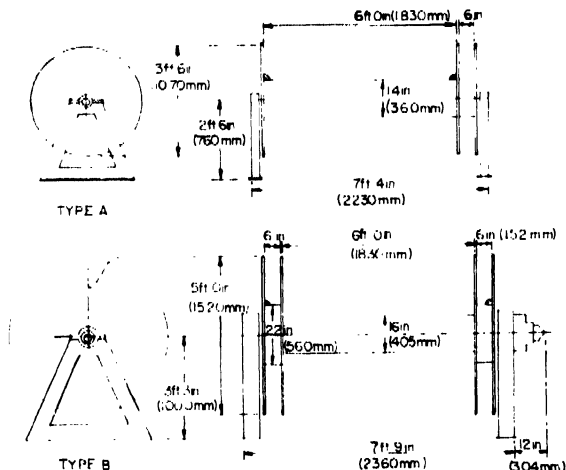
Fig 4. Typical dimensions of trawl drums constructed recently

drums, as most have been built to suit individual needs, the majority are constructed generally to the dimensions shown in fig 4.

Type A is suitable for trawls up to 80 ft (24.5 m) headline and 100 ft (30.5 m) groundline if fitted with smooth bottom gear; type B for any trawl now in use on the west coast if fitted with rough bottom gear of 14 in (35.5 cm) and 18 in (45.7 cm) bobbins and rollers.

Type A makes use of the so-called "yo-yo" drive, and is just a rope around the winding drum with a lead to the shipping drum on the winch. When hauling the trawl, the free end of the rope is taken around the whipping drum and, unwinding on the drum, winds the independent cables, sweeplines and wings on to the storage drums.

Shooting the gear is just the opposite, the hauling rope being allowed to slip on the whipping drum with a consequent braking effect and, as the pull of the trawl unwinds the drum, the hauling rope is rewound on the winding drum (fig 5).

Type B is a fairly recent Canadian development intended to further simplify the handling of the sweeplines, which are rolled on to sweepline drums, making manual handling of the wire to ensure even wraps on the barrel (fig 6). A slot cut through the inner flanges of the sweepline drums allows the wire to be passed through on to the main drum when the wings start to come aboard. This much larger drum is powered with a piston reversing hydraulic motor, usually of 45 hp at 1,200 lb/in² (85 kg/cm²), fitted with 3:1 gear ratio for drum speeds of 0 to 15 rpm.

The hauling sequence is basically as follows:

● The trawl boards are hove up to the gallows and left hanging on the warps and the boards clamped to prevent slamming
● The independent cables are unhooked from the boards and clipped to eyes on the drum
● The drum winds in the independent cables until the pull of the trawl is taken by the drum, then the pennants are disconnected from the sweeplines and hung on the gallows
● The sweeplines, wings, and belly of the trawl are wound on to the drum, leaving the length required to get the codend aboard for emptying

Advantages:

● It makes a "big" trawler out of a boat too small to accommodate a stern ramp
● Reduces the number of crew required to handle trawl to the winch operator (engineer) and two men to hook the doors and connect the independent cables
● No manual hauling of web
● Although the codend must be lifted aboard it is simple to split the codend on large tows and empty the catch into the desired deck pond
● Faster handling of the trawl when hauling as warp pull and drum pull are in line with the ship
● Because the bulk of the trawl is stowed on the drum, the working deck is kept clear, even on relatively small vessels
● There are no running lines or wires crossing the deck, resulting in greater safety
● The crew are not required to handle moving wires
● The working area, at the after end of the vessel, is much less affected by pitching and the forward
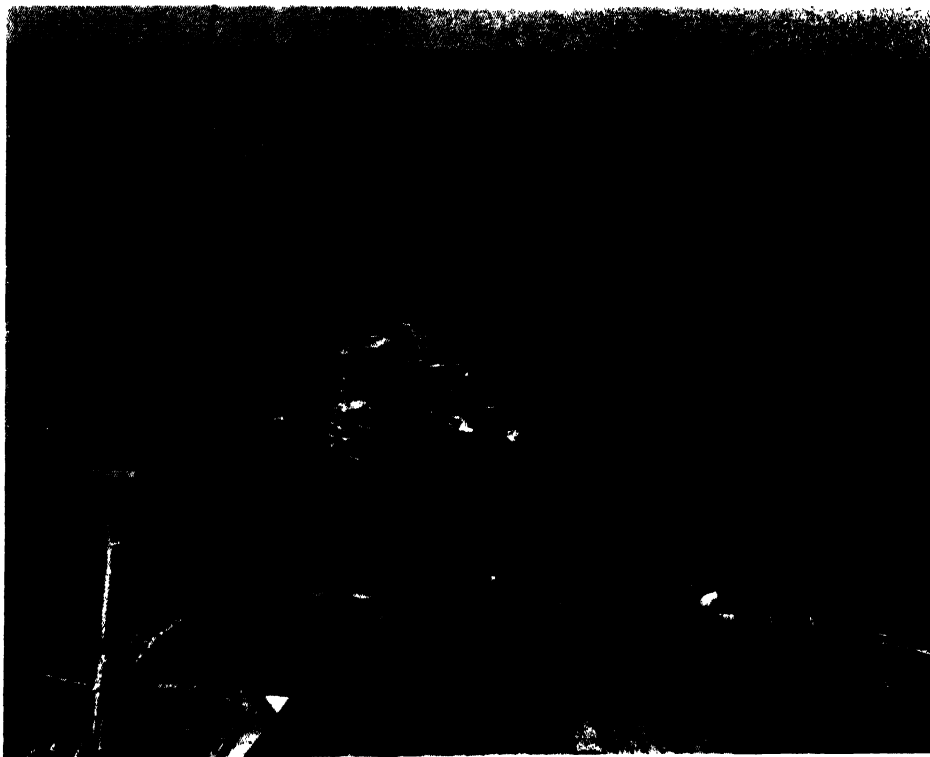
Fig 5. Trawl drum driven by a rope from the trawl winch

Fig 6. *Improved hydraulically driven trawl drum having separate sections for the sweep lines*

deckhouse offers a greater degree of safety and comfort to the crew

● The extreme simplicity of the drums, ensuring low initial cost and trouble-free operation

● The greatest advantage of the drum is the increased earnings resulting from the fewer number of crew. Typical west coast drum trawlers of 70 to 75 ft (21.3 to 22.9 m) and 100 GT, with a crew of four men, consistently land an average of 110,000 lb (49,900 kg) of iced fish for five days fishing. This will be taken on 4.2 tows of 2.1 hr each per day for a mean catch per tow of 5,239 lb (2,376 kg). This may be extended to show a production of 624 lb (285 kg) per man/hour expended

Favourable comparison

This compares most favourably with much larger 110 to 116 ft (33.5 to 35.4 m) stern trawlers on the Atlantic coast which are consistently landing 260,000 lb (117,950 kg) of iced fish for eight days fishing time, working with a crew of 12. This catch will be taken on an average of six tows per day of about 1.8 hr duration for a mean catch per tow of 5,425 lb (2,460 kg). However, the production per man/hour is only 252 lb (114 kg). In both cases only the larger fish were dressed, the balance iced in the round.

It must be admitted that a direct comparison cannot be drawn between large trawlers operating on the Grand Banks and small trawlers fishing in the north Pacific, but it indicates the relatively high efficiency of a small drum trawler. The figures for catch and effort are the average for all vessels of this general size operating in each area and were supplied by the Fisheries Research Board of Canada.

An interesting experiment is being conducted by the Industrial Development Service of the Department of Fisheries (Canada) using a standard hydraulically-powered trawl drum on a conventional side trawler, with the intention of eliminating all manual hauling of

the web. To date the fishing tests have not been carried out.

TRAWL WINCHES

Although briefly covered by Alverson (1959) the winches used on the smaller north Pacific trawlers are of special interest.

All vessels used for combination fishing such as
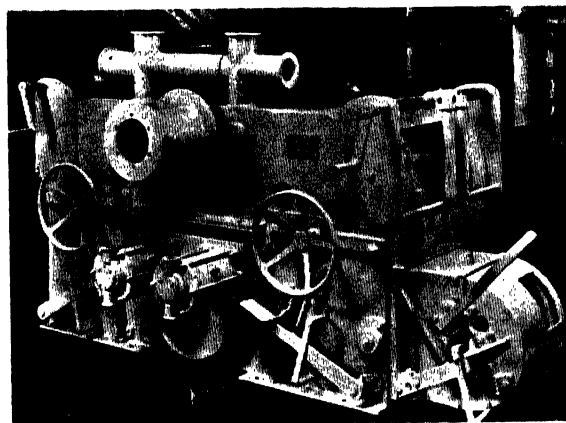
Fig 7. *Typical Pacific Coast combination winch suitable for trawling as well as for purse seining*

trawling, herring and salmon seining, halibut long-lining and tuna seining make use of the "combination" winch (fig 7).

Vessels solely for trawling are quite often rigged with individual or "split" winches positioned just inside the bulwarks and leading directly aft to the trawl davits. Although this eliminates the need for spooling gear, it requires an awkward arrangement of leads when purse seining and is not much favoured for this reason.

The combination winch is always set with an athwartship lead from the main drums and when trawling each warp is taken around a heavy sheave (at least 16 × wire

dia) located at or on the bulwark cap and in line with the winch, then directly aft to the quarter davits. Although this requires a right-angle lead, the friction loss is less than the usual system of deck or bollard mounted sheaves which alter the direction of the wire at least three times. The greatest advantage is the complete absence of running lines crossing the working deck where men may be sorting and dressing fish or mending gear. While less important in large trawlers, this is essential in vessels under 100 ft (30.5 m) where working space is always at a premium.

When seining, the purse lines are both led from the same side of the winch to the seine davit, the main drums often being vertically offset to simplify this. The spooling gear, either hand or mechanically operated, can be moved to either end of the winch depending on use. A cargo or "brailing" drum is fitted either at the port side or on top of the winch. A removable longline hauler is fitted at the port after side of the winch. Independent spool drums and pipe cavil are fitted as shown. Major characteristics of some typical combination winches are shown in table 2.

SMALL STERN TRAWLERS WITH RAMP

With the present type of trawl gear there are only four basic handling methods for small stern ramp trawlers, although there are many variations of procedure. These are:

- Leaving the trawl in the water and bringing only the codend up the ramp
- Taking the wings up each side and hauling the codend over the square
- Taking both wings up one side and the codend and intermediate up the ramp
- Taking the entire trawl up the ramp by means of a trawl drum

It would seem pertinent to discuss some of the advantages and disadvantages of these systems.

Leaving the trawl in the water

This method is exemplified by such stern trawlers as the Canadian *Polar Fish*, the British *Universal Star* and others. The basis of this system is the use of either a pivoting arch or overhead gantry to lift only the codend up the ramp. A variation is the Pacific coast practice of lifting the codend aboard over the side on vessels not fitted with a drum. In both methods the wings, belly and intermediate are left floating in the water.

Advantages:

- Involves the least amount of handling of net when fishing, as only three men on deck are required to handle the gear
- Requires least amount of deck space beyond that needed for dumping, cleaning and sorting fish. May be as little as 20 ft (6.1 m) from winches to stern
- Suitable for very small trawlers of 40 to 50 ft (12.2 to 15.2 m), particularly for combination boats already fitted with a boom

Disadvantages:

- The net is left floating across the stern with the ever-present possibility of fouling or rolling up
- Unless both wings are hauled up to one side the codend must be lifted over the floating net
- Impossible to examine or repair net during normal fishing sequence
- When fishing is finished, or the net is required on board for repairs, trawl can be recovered only by successive fleeting or pulling aboard by hand
- Experience has shown that when fishing in rough weather there is very often trawl damage due to vessel heaving or sliding over the floating net
- If an arch is used, the restricted drift between the recovery blocks and the deck limits the amount of fish that can be brought aboard in one lift
- It is awkward to split the codend when working over the stern with the trawl floating in the water,

TABLE 2

Major characteristics of some typical combination winches

	Small Boats 25 to 60 GT	Medium Boats 50 to 90 GT	Large Boats 80 to 150 GT
Base dimensions	36 × 57 in (90 × 145 cm)	36 × 70 in (90 × 180 cm)	48 × 90 in (120 × 230 cm)
Drum capacity each	300 fm ½ in (550 m 12.7 mm)	600 fm ⅝ in (1,100 m 143 mm)	750 fm ¾ in (1,370 m 19 mm)
Line pull ½ drum each	3,150 lb (1,430 kg)	7,500 lb (3,400 kg)	7,800 lb (3,540 kg)
Line speed ½ drum trawling	180 ft/min (55 m/min)	180–200 ft/min (55–60 m/min)	220 ft/min (67 m/min)
Input horsepower	30 hp	50–60 hp	90 hp
Hydraulic oil reg'd.	40 gal/min at 1,200 lb/in² (84.5 kg/cm²)	60–80 gal/min at 1,200 lb/in² (84.5 kg/cm²)	80 gal/min at 1,600 lb/in² (112.5 kg/cm²)
Line speed ½ drum seining	100 ft/min (30.5 m/min)	120–140 ft/min (36.5–42.7 m/min)	140 ft/min (42.7 m/min)
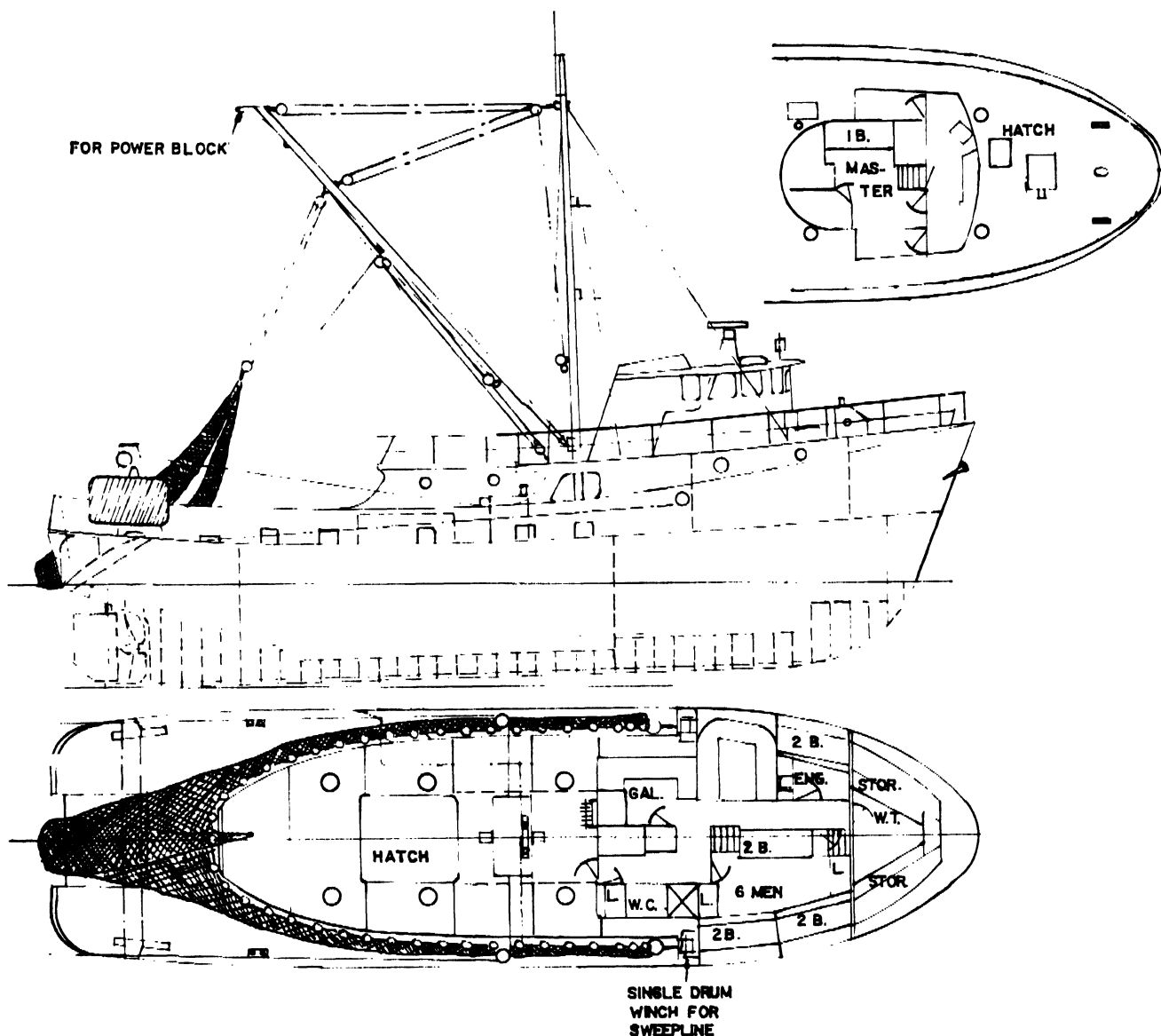
Fig 8. Proposed deck arrangement for a 79 ft (23.8 m) combination fishing vessel

although if the codend is brought around the side this becomes a much simpler problem

● If a single trawl winch is used and is set to lead fore and aft, a complex system of lead blocks must be used unless the warps are led directly from the spooling pins to the gallows blocks. In either case there are running lines crossing the working area. A better system would be to use thwartship leads from the winch to the bulwark sheaves, then aft to the quarter blocks, thus keeping the working area clear

Taking the wings up either side

This method is exemplified by the Canadian stern trawlers *Grand Monarch* and *Donald Rheal*, the proposal by Birkhoff (Stern Trawling, 1963) and by the author's design of a 79-ft (24 m) vessel for combination fishing (fig 8).

The basis of this method is to have a bobbin tray port and starboard of the working deck, each of a length to accommodate half the head rope. A small hydraulic single drum winch is fitted at the forward end of each tray to handle the sweeplines. The codend is hauled up the ramp and lifted over the square by a lazy-decky connected to the chocker strap. This is clipped to a messenger line from the brailing winch through a lead on the boom. A variation is used by the British vessel *Ross Daring* which lifts the codend aboard over the side.

Another variation is to eliminate the small sweepline winches and haul the wings forward with the main trawl warps, which are disconnected from the boards for this purpose. This can be done only if the winch is a combination type with thwartship leads or split winches are used.

If, as shown in fig 8, the vessel is fitted with a hydraulic ramp gate which is kept closed at all times except when shooting and hauling gear, the hauling sequence is as follows:

● Hauling warp the gate is closed

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- Trawl boards are hooked and left on the main warps
- The independent cables are unhooked from the boards and clipped to the messengers from the sweepline winches. Recessed links and G-hooks are used
- The ramp-gate is opened and the sweeplines placed in the ramp opening
- The bridle pennant is disconnected and hung out of the way as sweeplines and wings are hove up the ramp
- When the headline is tight against the restraining track the lazy-decky is clipped to either a mast or boom tackle and the intermediate and extension piece is doubled up the ramp
- The codend is lifted with a boom tackle for emptying
- The ramp door can be closed if desired as soon as the codend clears the ramp although this depends on the length of the intermediate and extension pieces

Advantages:

- The entire trawl is brought aboard in two pulls
- The net is well spread out for quick repairs, and replacing the groundline is a simple matter
- The bobbins, being contained by the track, cannot roll around in bad weather
- Vessels of only 80 ft (24.4 m) Loa can handle trawls up to 110 ft (33.5 m) ground-rope, such as a modified Granton or Yankee 41, fitted with rough bottom gear. There is no objection to leaving part of the groundline on the ramp
- The trawl is clear of the main fish ponds during emptying of the codend
- The gear can be shot immediately after emptying, without interfering with the cleaning and sorting of catch
- Maximum safety for deck crew as all running lines are clear of the working area, with the exception of the nylon haulback
- Maximum safety for ship and crew as the ramp gate almost eliminates the possibility of flooding the main deck by a sea breaking over the ramp. This is important on small trawlers with their relatively low freeboard
- Experience on Canadian trawlers indicates no undue wear on codend is caused by dragging over the floats, bobbins, etc
- The main winch can be under cover
- For winter fishing portable sides can be fitted above the bulwarks and extending from the break forward aft to the gallows. This will provide maximum crew protection from wind and spray

Disadvantages:

- Splitting of large tows is awkward when working over the stern
- Small stern trawlers of 80 to 100 ft (24.4 to 30.5 m) of length do not have sufficient moulded depth to permit tween-deck storage of wet fish. It is therefore necessary to dump fish into deck

ponds for cleaning and sorting. This results in the codend having to be lifted over the square
- Somewhat greater mechanization is required if separate sweepline winches are used. The alternative requires much more handling of running lines and results in slower handling of gear
- If vessel is to be used for combination fishing, changeover is more complex because of the dual bobbin trays

Taking both wings up one side

The basis of this method is the French "Amyot" system and modified by the author in the design of a new trawler to be built on the Pacific coast (fig 9).

This makes use of a bobbin tray fitted to one side of the deck of a size to handle both wings and of a length to handle the doubled footrope. A small hydraulically powered double-drum winch is fitted to haul the wings up the tray. The codend and intermediate only are brought up the ramp, the trawl being doubled around a faired post at the side of the ramp.

The hauling sequence is virtually the same as system B except that the starboard independent cable must be passed across to the port side before being clipped to the messenger line from the sweepline winch.

A second bobbin tray fitted to the starboard side with a complete trawl made up in the tray will permit instantaneous change of gear, eliminating lost time due to repairs or change of bobbin line.

For a trawl of 120 ft (36.6 m) groundrope the shortest practical length of vessel would appear to be about 95 ft (29 m) length overall, although the determining factor is the amount of water that is trapped on deck and consequent effect on vessel stability. A partial solution is to use narrow waterways on each side of the deckhouse, thus reducing the permeability of the deck.

Advantages:

- There is always a trawl ready for shooting with no handling required
- The codend does not have to be lifted over the square
- The fish ponds are clear for emptying, sorting and cleaning
- Shooting can be carried out with fish on deck
- One trawl can be spread out for repairs without interfering with the shooting or hauling of the other
- The fishing operation can be handled by only three men including the winch operator. If the fish is being landed iced in the round, one additional man for icing would be required and, if dressed, two additional men would be required. The crew, for eight-day trips, will not exceed six men including the captain, whatever the method of handling
- Deck configuration is ideally suited to protected operation of crew and machinery
- Maximum safety for crew due to absence of running lines and containment of bobbins in trays
- Maximum safety of ship due to use of ramp gate and narrow waterways for bobbin trays, thus reducing amount of water that is trapped on deck
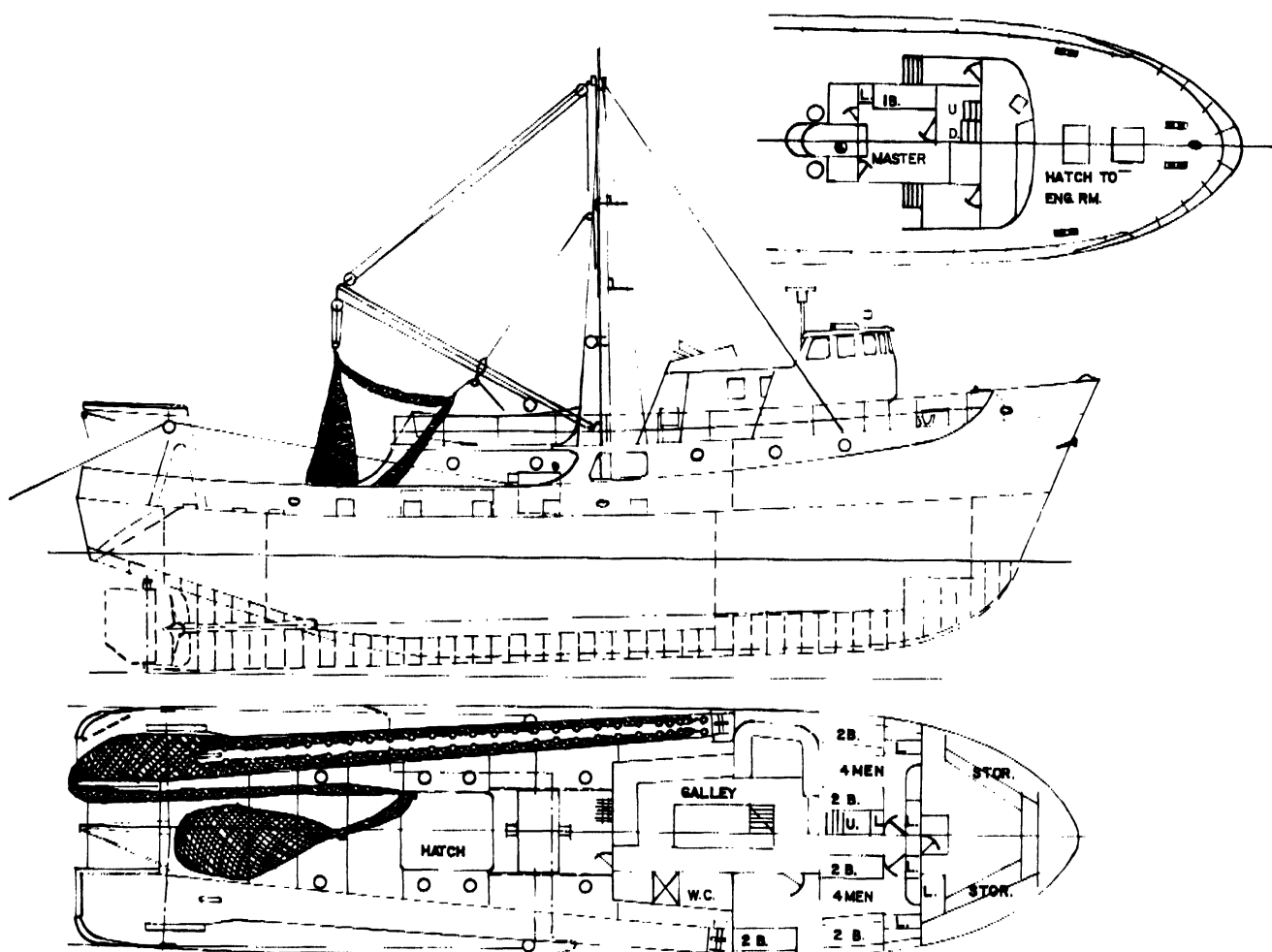
Fig 9. Modified "Amyot" system for handling the trawl net on deck which requires a vessel length of about 95 ft (29 m)

Disadvantages:

- Higher initial capitalization due to greater mechanization. However, productivity should reach average levels of 900 to 1,000 lb (410 to 500 kg) per man/hour, resulting in increased earnings
- More involved changeover if vessel to be used for purse seining

Combination of ramp and trawl drum

This method is exemplified by the proposed designs of Alverson and Schmidt (1959) and by the US trawlers *Narragansett* and *Canyon Prince*.

The basis is the use of a west coast trawl drum mounted coaxially with the trawl winch, the lead being aft. The trawl is hauled up the stern ramp and along the deck by the drum until the codend is aboard and can be lifted with boom tackles for emptying.

The hauling sequence is basically similar to that described for a stern mounted drum trawler, with the exception that hauling would be continued until the codend was on the ramp or could be reached with the boom tackle.

There are several advantages to this system with particular application to fairly small vessels of 60 ft

(18.3 m) or more, if such vessels recover the codend over the stern.

Advantages:

- The entire trawl is brought on deck in one pull
- A minimum of labour is required to handle trawl
- The drum pull is in line with the ship so manocuvrability is not impaired
- No special winches are required for the sweeplines
- System can be operated in as little as 30 ft (9.2 m) deck length
- Trawl can be easily rolled off the drum for repairs, if deck space available
- Codend is well positioned for lifting with boom tackle

The principal advantage of a drum is the ability to haul and store the trawl at the stern and clear of the working area. If the drum is positioned at the forward end of the deck this advantage is lost and experience indicates that most, if not all, of the following comments are valid.

Disadvantages:

- Hauling speed must be lower than is usual with a drum to prevent undue wear on the net by dragging over the deck

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- Virtually the entire trawl must be on the drum before the codend is available for lifting
- When shooting gear, the trawl must be either successively fleeted aft, using a haulback tackle, or the drum and chute must be mounted sufficiently high above the deck that the trawl will pull off after the codend has been dropped back in the water
- Some form of chute from the top of the ramp (or stern) to the drum must be used to restrain the net from sliding over the deck and is essential if rough bottom gear is being used
- In smaller vessels, up to 75 ft (22.9 m), the chute or net tray covers a large proportion of the available working deck
- The codend must be emptied into ponds clear of the trawl chute and warps. Such ponds may be very limited in size if both the warps and chute cross the working deck. The only exception would be if all catches were "clean" and could be emptied directly into the storage hold by way of the main hatch, although the fish would still have to be hand-stowed into the wing pens
- If the trawl needs repairs, it can only be spread over fish on deck, or must wait until the deck is clear
- If the stern ramp is deliberately shallow and runs well into the working deck (in lieu of a net chute) the following comments apply:
   (a) Increased possibility of flooding the deck if vessel backs down over fouled gear
   (b) Deck is badly arranged for holding fish for cleaning and sorting
   (c) Difficult to locate loading hatches for easy access to wing pens, and main hatch may have to be used to transfer fish below
   (d) Changeover to other fishing gear, notably seining, is unduly complicated because of covering the ramp

A variation of this system which eliminates most of the above disadvantages is to offset the trawl drum to the port side of the stern and the ramp to starboard (fig 10). The hauling sequence is identical to that described for any drum installation except the codend is lifted up the ramp with the boom tackle, leaving the intermediate doubled around a faired post between the drum and the ramp. The principal advantage is that no trawl net crosses the working area and fish may be emptied to suit loading requirements.

A second advantage of landing the codend up a ramp, rather than over the side, is the opportunity to close in

Fig 10. Arrangement of trawl drum and ramp

both sides of the working deck with portable bulwarks, providing effective protection for the crew from wind and spray.

FUTURE TRENDS

In those countries where year-round operation with one type of gear is impractical, due either to seasonal appearance of fish stocks or to incidence of bad winter weather, the need for a combination boat becomes inevitable. If such a vessel is considered, two factors play a dominant part in the earning capacity of the vessel. These are:

- The ease with which a gear changeover may be carried out
- The capital investment required for the various types of gear

Since trawling, purse seining and longlining are the three most commonly practiced methods of fishing it is essential, in planning a combination boat, to make provision for maximum efficiency in each of these fisheries.

In the case of really small trawlers of from 36 to 50 ft (11 to 15.2 m), there can be little argument with the use of a trawl drum, whether the codend is brought over the stern or the side. The cost of the drum is extremely low, especially so if a rope-drive is used. Further, the saving in manpower is important in both the amount of living accommodation required on board and in the increased earnings per man.

Since trawlers of this type simply do not have sufficient power to tow even moderately sized trawls fitted with rough bottom gear, the limitations of the drum in storing anything larger than 18 in (45.7 cm) bobbins is not a pertinent factor.

In larger vessels of from 50 to 75 ft (15.2 to 22.9 m), the use of a trawl drum, such as the Type B, again has too many advantages to be ignored. Chief among these is the ease with which the drum can be removed during changeover, the hydraulic drive commonly being used to power either the power block or the longline hauler. A stern ramp is not essential since lifting the codend over the side with boom tackles (the boom remaining fixed at the centreline) has been standard Pacific coast practice for many years despite the frequency of heavy weather during operations.

Since both purse seining and longlining require considerable space across the stern, the absence of a ramp simplifies the changeover. However, a ramp offers one indirect advantage in that if the codend is not being lifted over the side the bulwarks can be closed in for protection from wind and spray.

It is in this general size of vessel that the author would make the suggestion of using two trawl drums mounted side by side at the stern, the second drum being used to stow a spare trawl. Then fishing is uninterrupted because of damage repairs or if a change from smooth to rough bottom gear is required.

From 75 ft (22.9 m) or over, a ramp becomes quite practical if the vessel is consistently fishing rough bottom, since the handling of heavy bobbins can be better done by either of the systems shown in fig 9 or 10 than by the use of a drum.
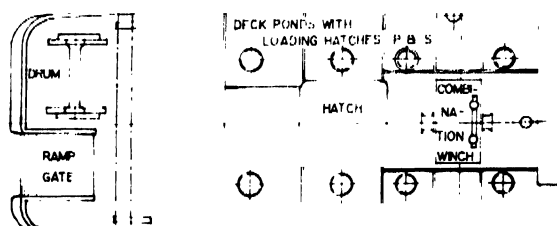
New Trends in Stern Fishing

by Jan F. Minnee

Tendances nouvelles dans la pêche por l'arriere

Le succès de la pêche par l'arrière pratiquée avec de grands bateaux s'est affirmé ces dernières années, et les armateurs de bateaux de petit tonnage commencent à s'intéresser à cette technique. L'auteur présente des recommandations d'ordre général quant à l'agencement et au dessin de petits navires à pêche par l'arrière. Des détails sont fournis sur trois récentes réalisations (1962, 1963 et 1965): un navire tirant le chalut à perche par l'arrière; un bateau polyvalent (présentant comme innovation une installation pour manoeuvre de la senne par l'arrière); un pétonclier à pêche par l'arrière utilisant trois dragues.

Nuevas tendencias en la pesca por la popa

La pesca por la popa ha tenido éxito en las grandes embarcaciones de pesca en estos últimos años, pero también van estando interesados en ella los propietarios de embarcaciones menores. Se formulan recomendaciones generales para la distribución y diseño de pequeñas embarcaciones para la pesca por la popa. Se presentan tres diseños recientes (1962, 1963 y 1965) correspondientes a un arrastrero de vara por la popa, una embarcación de aplicaciones múltiples (con una propuesta para la pesca con redes de cerco por la popa) y un arrastrero para la pesca de vieiras por la popa mediante tres rastras.

IN the few years since its introduction, stern trawling has proved so advantageous, from the point of view of fishing tactics and vessel design, that even owners of small boats—the most conservative of fishermen—wonder whether stern trawling may be worthwhile for them. The small-boat fisherman works under many handicaps. He generally has a small crew whose education is limited. Government regulations about tickets and licences limit the size of his boat. To take full advantage of his restricted power, he must use a variety of fishing methods which change with the season. Above all, the small-boat fisherman has little money. He cannot afford to gamble on relatively new and untried techniques.

DESIGN REQUIREMENTS

Designing a small stern trawler is more difficult than designing a large one. The problems are greater and often more controversial. The requirements are contradictory. For example, a small-boat skipper wants the biggest boat with the lowest tonnage and, of course, the lowest price. He wants the ease of remote-control of operations, but he wants mechanical simplicity. He wants a multi-purpose vessel on which he can change operations at sea. A recent trend is the demand for sheltered processing space apart from the fish-deck.

SMALL-BOAT DESIGNS

Some general particulars for designing small stern fishing craft are given below:

Hull shape and particulars

Breadth should be maximum in order to ensure sufficient GM and large deck area, especially at the stern.

Depth: in connection with breadth, sufficient freeboard for dry deck while heeling, ensuring adequate dynamical levers.

Draft aft maximum for restricted water depth, to give good propeller immersion for satisfactory towing thrust and protection.

Adequate flare and sheer forward and preferably a forecastle for dry decks and good seakeeping performances.

High midship section coefficient (C_m) for moderate prismatic coefficient. The old vee-bottom midship section, which may have had good sailing properties, should be avoided for modern power-driven boats. A smaller prismatic coefficient produces better speed and towing characteristics because of waterline fore and aft and larger hull dimensions for the same tonnage, enabling ballast to be put lower in the vessel. From experience the seakeeping properties are improved and there is less slamming and better propeller performance in waves.

Short deep bilge keels to increase the short rolling period caused by the fairly high GM. These keels should extend only over the fullest part of the midship body to avoid unnecessary increases in resistance.

Hull subdivision and arrangement

The deck area aft, needed for gear handling, depends on whether a ramp is used. Stern trawlers with a ramp need sufficient afterdeck length to accommodate the length of the trawl wings plus extra length for placing straps at the top of the ramp. In this system, each haul brings all the gear aboard with a generally horizontal direction of towing.

Stern trawlers without a ramp require only sufficient deck space to accommodate the trawl doors. The gear is hauled more or less vertically and the codend is brought aboard between the trawl doors. To minimize space requirements and maintain a normal transom stern, the rampless system offers better possibilities for small vessels both for single and multi-purpose layouts. A rampless stern trawler, however, still requires a minimum fishdeck length of 10 ft (3 m). The centre-line casing becomes an obstacle in boats under about 70 ft (21 m) with engines aft.

As a rule, processing should be done on top of the fish hold, the fish-hold hatch being the last position in processing. If space allows, the route of fish for pro-

cessing should start on the after fishdeck and finish at the first available fish-hold hatch. These hatches should, of course, give easy access to the entire fish hold for easy loading and unloading. The limited deck space does not permit the use of a portion of the fishdeck for processing only, since the whole deck area must be available if net repairs are needed.

Wing engine-room casings against the ship's sides are not only unattractive but also unacceptable in certain fishdeck arrangements (e.g. in beam trawling).

From experience of vessels up to about 90 ft (27 m) Loa, the most economical way of hull space utilization is to locate engine space forward, with wheelhouse and winch nearly on top of it for short communication, more direct control and mechanical drive. This introduces the problem of a long propeller shaft, passing through the fish hold aft. In way of the shaft, the fish-hold floor must be raised, but the loss is compensated since the S-shaped framing aft gives more capacity than the vee-framing forward. In these stiff hulls there should be no technical problems with this shaft, providing there is easy access to the stern gland and modern self-adjusting bearings are used.

When underdeck crew accommodation is needed, often the case in small craft, the best position is between engine room and fish hold, practically amidships, where the ship's motion is relatively small.

With fuel tanks aft, the less accessible hull spaces are used and trimming effects are small. As fuel is burned, its weight is replaced by fish. In this case, the vessel becomes heavy-ended, introducing a large longitudinal moment of inertia that increases the pitching period. Good flare and high sheer or forecastle are needed to prevent wet decks.

Vessels over 90 ft (27 m) Loa using the rampless system may be laid out in the conventional way, engine room aft and fish hold forward, especially when a long forecastle is required for accommodation and processing or for bad weather conditions. Here there is sufficient deck area to have a fishdeck aft and a processing deck amidships, separated by the engine room casing. The catch will then be transferred by a conveyor belt which serves as a moving worktable, giving better working conditions; its mechanical assistance, though adding to the boat's initial cost, increases earning power because it attracts better crewmen.

Winch and wheelhouse

Except for power, the most important factor for a boat's fishing efficiency is the positioning of winch and wheelhouse. Although the general arrangement or hull subdivision frequently determines these positions, they deserve more consideration. Generally the winch controls should be in the wheelhouse. On both large and small boats, this gives more direct control of the winch in relation to vessel manoeuvres and vice versa. Beyond that, on smaller craft, the skipper has direct contact with the gear handling and he can take rapid corrective measures in emergencies. With the winch adjacent to the wheelhouse, expensive remote control systems are avoided.

Both winch and wheelhouse should be as far aft as possible. This results in better steering and provides the best view during fishing operations. Several factors complicate this positioning: minimum deck length aft, position of the fish-hold hatch, engine room location, spooling distance and other factors. Once again a compromise position must be selected.

Much care must be given to arranging the various wheelhouse instruments. Their size and number are increasing continually, yet the designer must ensure an all-round view from the controls during critical stages in fishing operations. The captain's cabin should be adjacent to and forward of the wheelhouse if possible, but must not obstruct the view from the wheelhouse. The space under the wheelhouse floor may be used for the winch motor, electronic equipment, convertors, fans or the small harbour electricity set.

The general arrangement and stability considerations control whether winch and wheelhouse are situated on the main deck or above. As a rule, warps and other wires should be led well above the working deck so as not to cause obstruction. The number of guide rollers should be kept to a minimum as each additional one adds to line wear, but sufficiently wide guide roller spacing makes for easy spooling on the drums. These should be as narrow as possible to enable the fitting of extra drums for auxiliary purposes.

So as to be adaptable, the winch should be designed to perform the main part of the varied handling requirements and must provide the mechanical power for gear handling. Therefore the winch should be able to cope with many ropes and wires, either simultaneously or selectively in order to reduce manual handling to a minimum. Winches with six independent drums are common today in the Netherlands. After the introduction of a multi-purpose winch, it takes some time for a crew to become accustomed to not working on the warping ends. Warping ends still are occasionally useful, even with modern equipment, but the winch is usually badly situated for them. Again a compromise on winch location must be reached, although it must not interfere with deck work. With the good selection of compact gears now available, it is better to have some well located additional hydraulic gear. The winch itself should have all the modern requirements such as reverse systems in the main drive and auxiliary drums with small flywheel effect (small moment of inertia), thus facilitating easy stopping and reversing.

FISHING EQUIPMENT

Since small boats use many fishing methods, a general detailed explanation of fishing gear is difficult. However, all fishing relies on a skeleton of basic equipment to which a variety of specialized equipment may be added for specific methods. From experience of multi-purpose designs, the following are worthy of note:

Basic equipment

A multi-drum winch: minimum: two main drums plus two auxiliary drums plus two warping ends.

A fishing mast, single or bipod, preferably unstayed. This mast should carry either a transverse outrigger at a

1- 4 warp trawl
2- gilson
3- split strap
4- codend
5- wing
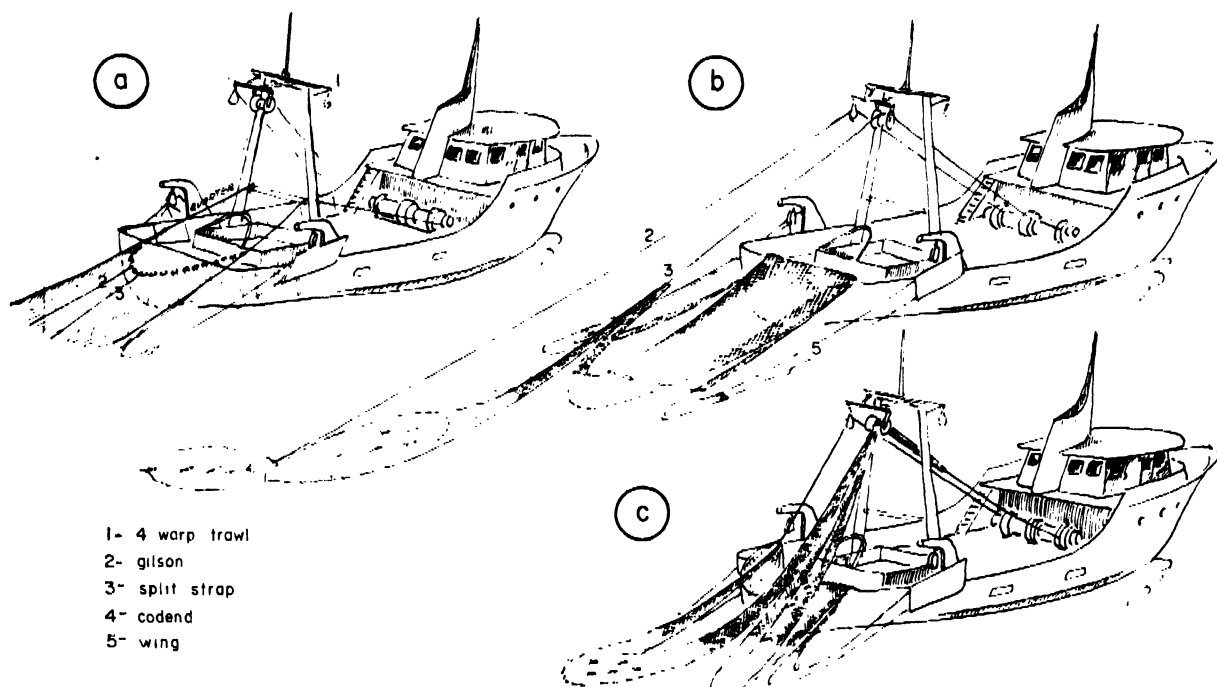
Fig 1. Ground and midwater stern trawling (split net system)

certain height to provide suspension for blocks or rollers in line with the different winch drums and with the inclined transom stern, or two derricks providing the same suspension points. These should be able to be rigged either fixed together with diaphragms or cross-bars, or independently for beam fishing or purse seining.

A pair of gallows, either as part of the mast structure without any other attachment (leaving bulwarks and deck completely free) or as removable structures bolted only on top of the port and starboard bulwarks, which must be reinforced locally.

A system of removable stanchions and boards on deck to provide fishponds, or other means of storing the catch on deck during processing.

The necessary guideblocks, leading the wires and ropes from the winch to the different blocks. None should be mounted on deck, and preferably on the mast structure only. This leads to a variety of possible layouts by the addition of special equipment.

Special equipment

For stern trawling, both on the bottom and midwater (fig 1) (single or two-boat fishing with two or more warps): add big net roller on the transverse (outrigger), a guide frame for the gilson and loose netting, and a bag arrestor. The vessel may be laid out with open or closed processing space or with just an open-sided sun awning. In fig 1a a split of yoyo-system is shown. The quarter ropes are hauled up either over the low rollers or over the handling mast blocks (dotted).

In fig 1b, by the splitting strap (3), the fore part of the net is dried and the codend filled. By means of the gilson (2), the codend is hauled aboard. In fig 1c the codend is hoisted, swung aboard and emptied. The codend is then returned to the sea and a further pull of the splitting strap (3) refills the codend and the procedure is

repeated. This system enables an unlimited amount of catch to be hauled in without the risk of bursting the codend. It can be used for midwater and bottom trawl gear of any size and shape with normal deck layout and is easily converted to other fishing methods.

For beam trawling with two-door shrimp trawls, groundfish rakes or scallop rakes: use the outfit with two derricks, or add two derricks. Layout may be similar to fig. 1, but for beam trawling open sides are preferable.

For purse seining (Pacific system): add powerblock and outfit with two derricks, boom swing winch, purse davit and some other special equipment (net grating, etc.). For stern purse seining (for which a proposal is given later) the outfit for stern trawling is sufficient, with only the powerblock and topping brail boom added.

For longlining a special type of capstan should be added and some less important equipment for running out the lines. The general arrangement should show at least one side open.

For gillnetting a power-drive net roller on the stern bulwark is needed. In addition there should be some labour-saving equipment, such as a webshuttle machine. The layout may be similar to that used for stern trawling, even with an all-enclosed processing space. Since herring driftnetting is declining now, there is very little interest in developing new tactics for this method in the Netherlands.

MULTI-PURPOSE DESIGN PRINCIPLES

The above may give the impression that a sound multi-purpose design is easy to produce. There are, however, a few very important points:

● Whenever a compromise has to be found between controversial requirements, this should never be an excuse to spoil the whole layout

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1	warp	7	gilson
2	boom	8	top stay
3	topping wire	9	frame stay
4	back stay	10	frame for stern trawling
5	front stay	11	stopper
6	gilson block or	12	trawl gallows
	netroller	13	hinged fishpond
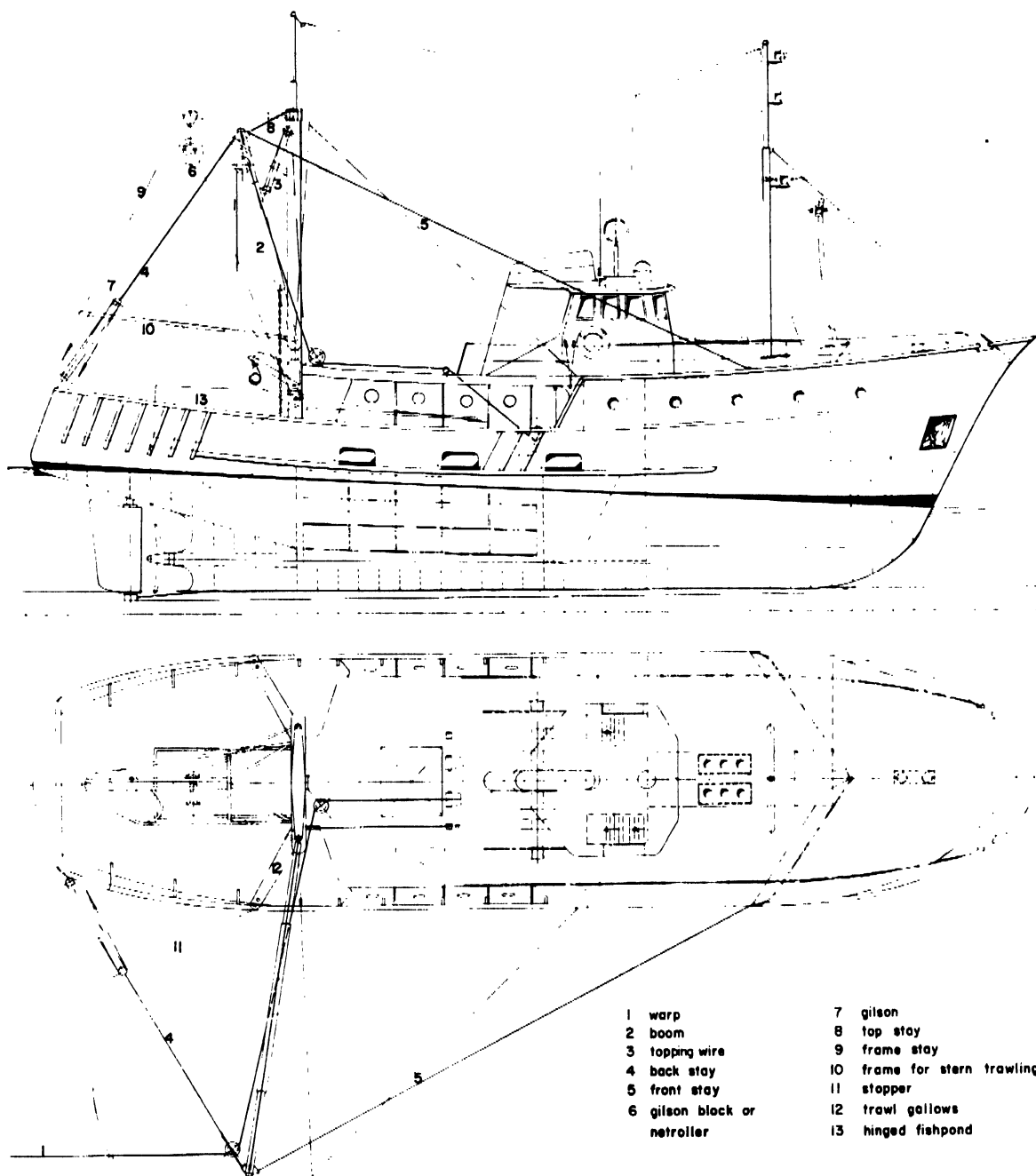
Fig 2. Dutch stern/beam trawler

● The minimum basic equipment may be too elaborate. Items that do not exist are never in the way

● After thorough practical study of the fishing methods that are to be catered for, do not hesitate to propose a modification or something basically different, because most methods have been developed, through time, on different boat types and from different viewpoints. This will not be easy, but may sometimes lead to real development and progress.

RECENT DEVELOPMENTS

A few specific examples of new developments are shown. These are from the designs of the author, recently completed for owners in the Netherlands, Mexico and Canada. Most details in the general arrangement need no explanation after the previous pages, so that only particular points will be given some further consideration: fishing equipment and special tactics.

Dutch stern/beam trawler

First vessel completed in the Netherlands in March 1965.

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Particulars

Loa	.	.	.	73 ft (22m)
Lpp	.	.	.	60 ft (18 m)
B .	.	.	.	18 ft 8 in (5.6 m)
D .	.	.	.	8 ft 8 in (2.6 m)
Power	.	.	.	380 hp (reversible and reduction gear)
Winch	.	.	.	2 × 400 fathom ½ in (12.7 mm) wire
				2 × 100 fathom ½ in (12.7 mm) wire

Mechanical drive off main engine

Tonnage	.	.	49.5 GT
Hold capacity	.	.	1,750 ft³ (50 m³)
Fuel capacity	.	.	560 ft³ (16 m³)
Fresh-water capacity			50 ft³ (1.4 m³)
Accommodation	.		6 (2 × 3 persons)
Gear	.	.	.	(a) ground trawl with tickler chains
				(b) midwater two-boat trawl
				(c) two beamrakes 30 ft (9 m) wide

Fishing equipment

Basic

- Four-drum winch on maindeck, controls at winch and in wheelhouse
- Bipod (unstayed) fishing mast with two derricks 23 ft (6.9 m) long and with suspension frame carrying: two gilson blocks for beam trawling or one gilson block plus one net roller when trawling
- Cantilever-gallows built on mastlegs, port and starboard

- A turn-over fishpond, hoisted by the gilson messenger, that gradually discharges catch on to sorting tables in the processing space, where men can work upright (a non-expensive device utilizing the force of gravity and a substitute for the conveyor belt aboard larger vessels)

Special

This is the first small boat in the Netherlands arranged with a sheltered work space. To accommodate the beam-trawl-rakes during sailing, sides must be open and bulwark rails entirely free but, when fishing, the gap between the shelterdeck and bulwark rails can be closed by hinged flaps, providing an enclosed space for processing and net repair.

Warps and ropes, topping wires, etc., are led over the shelterdeck to guideblocks and footsheaves, adjusted by different attachments to suit the various situations. A guide frame is fitted for stern trawling and also serves to steady the bags of the beam rakes when hoisted (fig 2).

Tactics

The main difference in stern beam trawling and conventional beam trawling, carrying the derricks on the foremast (Verhoest and Maton, 1964) is that the towing points (derrick-tops) are considerably aft of midships (fig 3b). Consequently:

- Slightly reduced manoeuvrability must be compensated for by increased rudder area
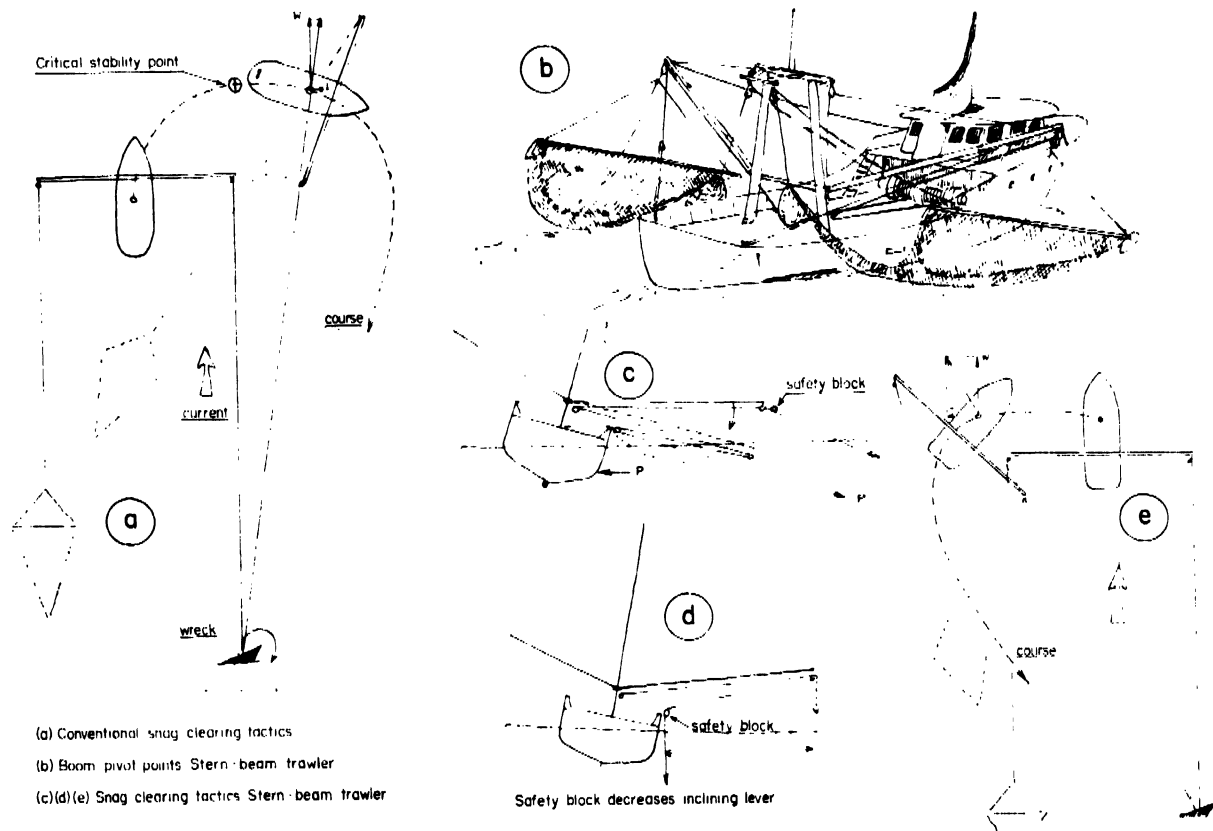
(a) Conventional snag clearing tactics

(b) Boom pivot points Stern-beam trawler

(c)(d)(e) Snag clearing tactics Stern-beam trawler

Safety block decreases inclining lever

Fig 3. Beam trawling

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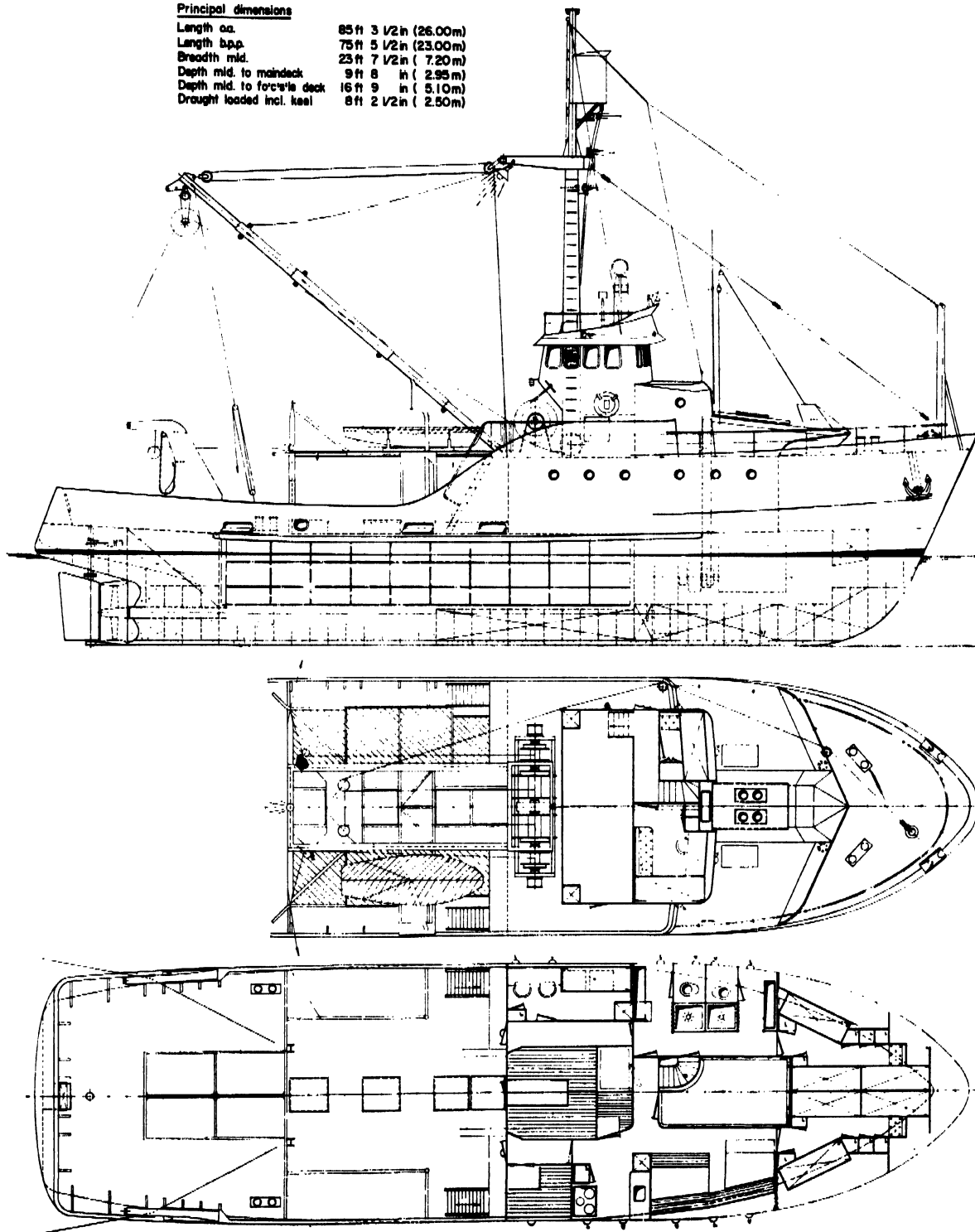
Fig 4. Multi-purpose fishing vessel

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● Safety is increased (see fig 3a, Conventional). When fishing with the current and one rake gets caught, the stern beam trawler will not tend to turn in the tide as the conventional beam trawler does, thus avoiding dangerous situations in which the current might capsize the vessel. To free the caught rake (figs 3b, 3e, 3d, 3e) the stern beam trawler should move astern, meanwhile either swing the boom into the line of pull or shift the warp-block attachment from the derricktop to the bulwark (in this vessel, to the gallow), to increase the hoisting power on a short lever and then the rake can be pulled free of the obstruction. This " going astern " manoeuvre has other advantages over the conventional method of turning up into the tide. The warp will not wind around the obstruction and the warp of the other rake will neither shave under the keel and foul the propeller nor handicap completion of the turn by swinging over the after-deck. There is little chance of the above happening when using the winch only, even though the vessel will not go astern in a straight course (hydrofoil action)

Mexican multi-purpose fishing vessel

First vessel completed in the Netherlands in December 1963.

Particulars

Loa	.	85 ft $3\frac{1}{2}$ in (26 m)
Lpp	.	76 ft 4 in (23.20 m)
B	.	23 ft $7\frac{1}{4}$ in (7.20 m)
D	.	9 ft 8 in (2.95 m)
Power	.	2 × 240 hp at 1,500 rpm reversible reduction
Winch	.	2 × 600 fathom $\frac{3}{4}$ in (19 mm) wire
		2 × 600 fathom $\frac{3}{8}$ in (9.5 mm) wire

Mechanical drive off main engine

Tonnage	. .	125 GT
Hold capacity.	.	3,500 ft^3 (100 m^3)
Fuel capacity .	.	1,320 ft^3 (37.8 m^3)
Fresh-water capacity		700 ft^3 (20 m^3)
Accommodation	.	9 to 16 persons
Gear	. . .	(a) bottom and midwater trawl, single or two-boat stern trawling
		(b) beam trawling with two-door shrimp nets or ground rakes
		(c) purse seining

Fishing equipment
Basic

● Four-drum winch on upper deck: controls in the wheelhouse
● Bipod fishing mast (enveloping the engine exhausts) carrying two derricks, coupled together when trawling, providing suspension for gilson block and net roller, or used independently when beam trawling or purse seining
● Two removable gallows mounted on top of bulwarks aft, port and starboard
● Removable fishponds on deck, adjustable to suit the fishing system

Special

● Framework to support guide blocks in different positions and gilson blocks when beam trawling: also providing a canvas sun awning over the working space and fish hold
● Power block, purse davit and other equipment for seining
● Longline capstan

The first of five vessels of this type was for fishery research in the Gulf of Mexico, exploration of new fishing grounds, testing the most adequate fishing methods and
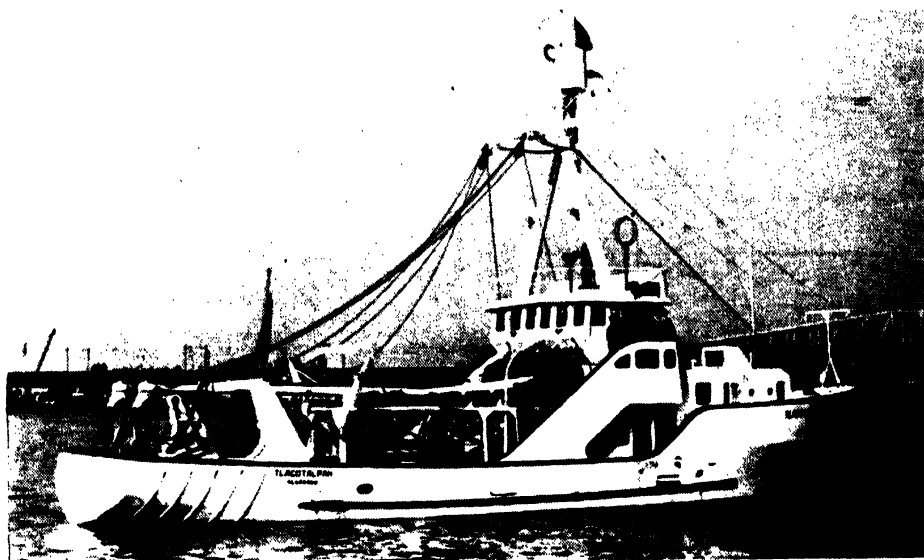
Fig 5. Multi-purpose fishing vessel

instructing new crews. For this reason, she has been arranged with air conditioning and accommodation for up to a crew of 16. All these vessels have refrigerated fish holds supporting the ice-cooling system. The high-speed twin-engine arrangement and wide casing enables engine exchange and shore overhaul (fig 4 and 5).

Tactics

When pursing the seine over the side from either amidships (Pacific system, fig 6) or further forward (Icelandic
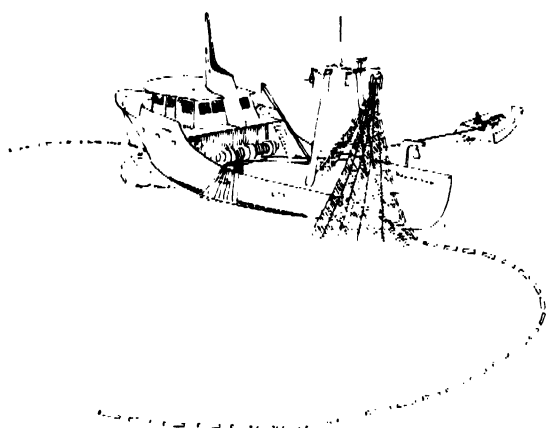
Fig 6. Pacific method of purse seining

system, Jakobsson, 1964), the pursing force tends to pull the vessel into the seine. A powerskiff, bowthruster, active-rudder or other means are needed to keep the vessel free of the net.

In an attempt to achieve higher efficiency, stern purse seining has been proposed. In fig 7a, the seine net is shot over the starboard corner of the transom, while a circular course is steered. When the circle is completed, the buoy is picked up. The vessel then turns stern into the wind and the purseline is attached to the drum through the port gallow, and the towline is belayed on the portside. The starboard purseline is taken on to the starboard drum through the starboard gallow. The corkline is hauled through the powerblock and pursing starts on both drums simultaneously. In fig 7c pursing is completed, and in fig 7d the rings are released from the purseline and put on the bulwarkrod, the purseline being rewound on the starboard drum. The port spreader boom can form a brailpit for brailnet or fish pump. The following advantages of stern purse seining may be noted:

- The vessel can manoeuvre with rudder and propeller counterbalancing the pursing force of the winch without any auxiliary aid of skiff
- The fish are frightened into the net by the propeller
- Deck equipment of stern trawler can be used, a powerblock being the only addition
- A four-drum winch can handle all operations— pursing, towing and brailing
- The guide frame may be used as brail boom
- No hydraulic boom swingers are necessary, merely topping
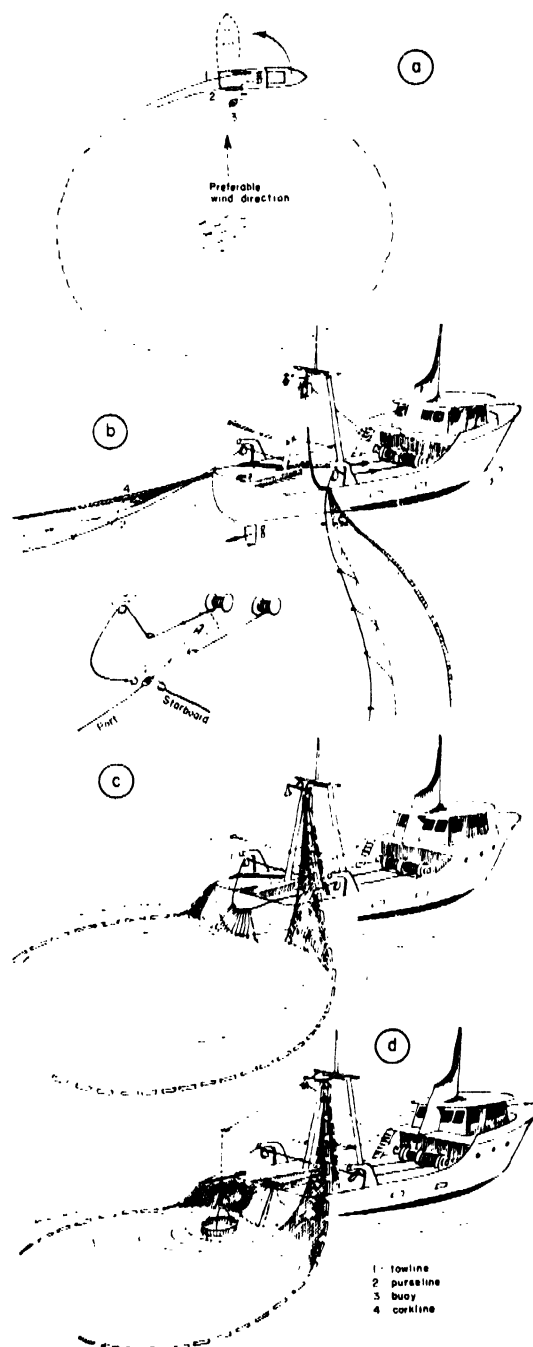
Fig 7. Purse seining over the stern

- The rampless stern trawler has ample deck space to store two complete Icelandic seines—one deep and another shallow, but both with double bunt ends
- When brailing with stern to the wind, the whole system (ship and net) is in an equilibrium position

Triple-rake scallop dragger-stern trawler

First such vessel completed in Canada in December 1962.

Particulars

Loa .	116 ft 6 in (35.5 m)
Lpp .	99 ft (30 m)
B . .	26 ft 3 in (8 m)
D . .	14 ft (4.25 m)
Power .	660 hp at 750 rpm reversible reduction 3 : 1
Winch .	2 × 600 fathom ⅞ in (22.22 mm) wire
	2 × 600 fathom ½ in (12.7 mm) wire
	Mechanical drive off main engine
Tonnage . .	350 GT
Hold capacity .	7,000 ft³ (200 m³)
Fuel capacity . .	2,060 ft³ (62 m³)
Fresh-water capacity	875 ft³ (25 m³)
Accommodation .	20 persons
Gear . . .	(a) Granton bottom trawl
	(b) midwater trawl
	(c) three scallop rakes 10 ft (3 m) wide

Fishing equipment

Basic

- Four-drum winch on shelterdeck: controls in the wheelhouse
- Single pole, unstayed, fishing mast with transverse outrigger to provide the suspension for gilson block and net roller for stern trawling
- Fixed gallow structures, part of the ship's sides
- Usual fishponds on deck

Special

- Guide frame and bag arrestor designed for directing and holding heavy bags when trawling in rough weather
- A longitudinal outrigger at the mast aft
- Two short, but sturdy, derricks for towing scallop rakes
- Two hydraulically-driven topping winches for the above-mentioned derricks, controlled in the wheelhouse
- A hydraulically-operated stern flap for emptying the scallop rakes, controlled at the stern

The vessel is designed for operation in the rough weather and ice of the Canadian Atlantic grounds. The design should provide maximum seaworthiness, comfort and protection. Except for the fishdeck aft, which has three high sides, all work spaces are entirely closed (fig 8, General arrangement).

Fig 8. Trawler-scalloper

Labels in figure:
- chafing bars
- clubstick
- fixed booms
- (a)
- (b)
- (c)
- (d)
- (e)
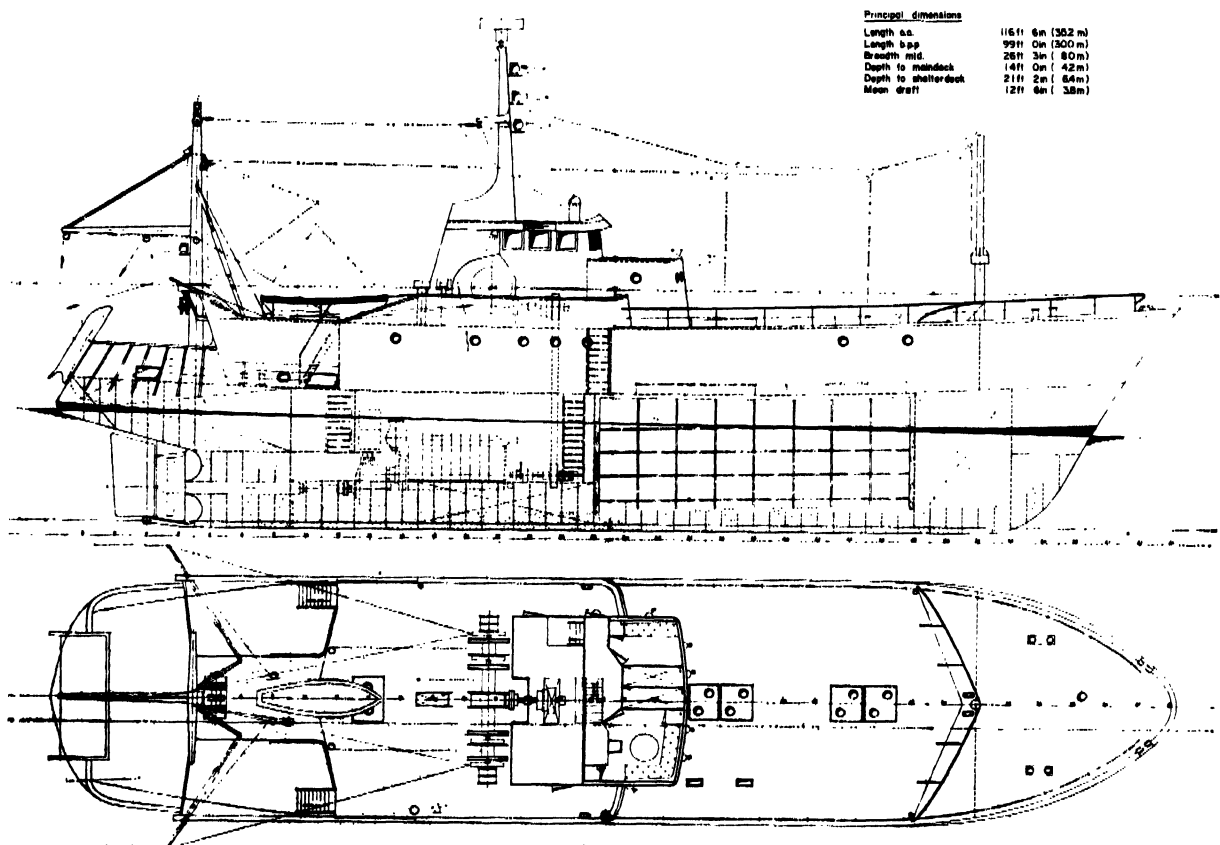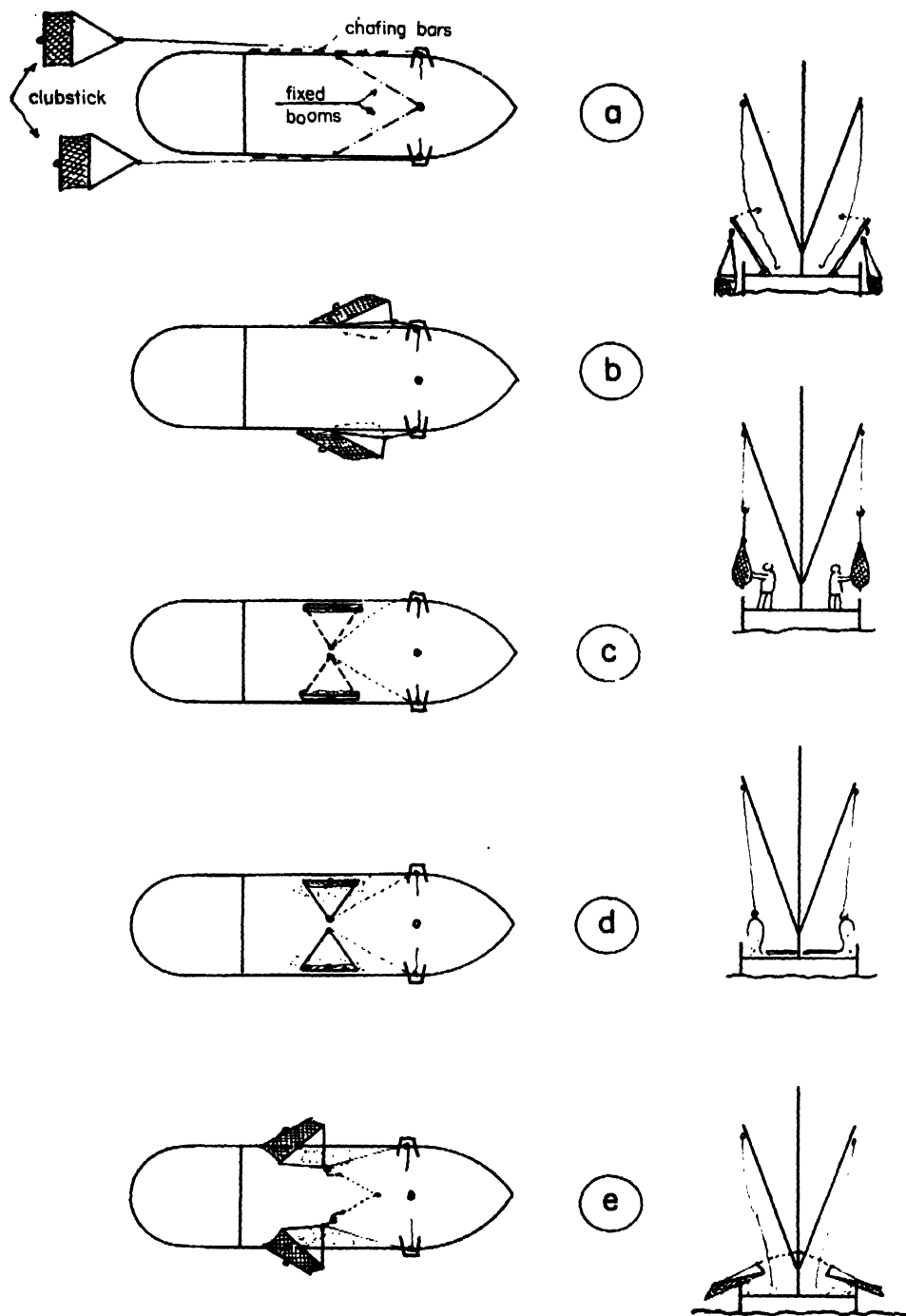
Fig 9. Conventional Canadian scallop dredging

Tactics

The triple-rake stern scallop dragger enables more production than the conventional two-rake system (much like beam trawling, figs 9 a to e): Two rakes 10 ft (3 m) long with wire bags are towed on the adjustable forward gallows. The rakes are then hauled up under the gallows and the boomrunners attached. They are hoisted over the bulwarks, lowered on to the deck, and then the club-stick is hoisted until the bag empties, then the rakes are laid on the bulwark rail. The sliphooks are attached and the rakes are re-shot. The three-rake system operates as follows: two are towed on short derricks, just reaching outside the vessel to port and starboard. The third rake runs through the centreline outrigger aft. Towing time (about 20 minutes) is just enough to maintain a rotary operation. Two rakes are at the bottom all the time, while the third is being hauled, emptied and shot again. This increases production by about 50 per cent. To accomplish this, each rake, when it is due for hauling just before it breaks the surface, is brought in at the vessel's centreline and pulled up the stern flap. There it is caught by its clubstick (at the bottom of the wire bag) in leads and chocks on the flap sides. The flap is overturned hydraulically, allowing the contents to slide down the deck. Finally the flap returns to its original position, ready for shooting the rake again (fig 10a, b, c).

A further advantage of this flap is that the rake, weighing about 4,000 lb (2,000 kg), is being held tight during this whole procedure: in the conventional operation, the heavy rake sways from the top of the conventional hoisting derrick, over the crew. A specially-developed self-loading conveyor carries the shells from the aft deck into the processing area, and serves as a moving tabletop where the work is done under standardized conditions.
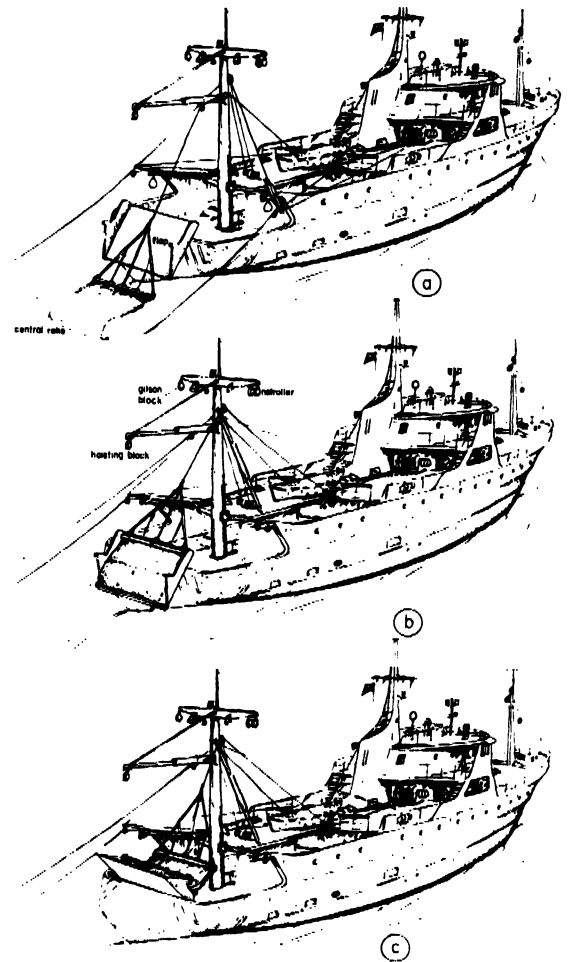
Fig 10. Triple rake stern scalloping

Discussion : Developments in the design of vessels and gear

DEVELOPMENTS FOR BETTER OPERATION

Labour easing

Hovart (Belgium): Rationalization, when applied to handling of gear and catch, means a rationally equipped fishing vessel with the right man at the right place. As in other industries, work-time studies on fishing vessels are necessary. It is important to know what must be improved, what can be improved and what cannot, how the improvements can be carried out, what gain of time and labour can be obtained and what are the costs involved, etc. To solve these problems it is necessary to have quantitative or numerical values of labour in general, and of the labour of crew members in particular.

Time study measurements have been carried out in Belgium on coastal vessels equipped for beam trawling. On different vessels, all handling, even the mechanical, e.g. the work done by the winches, was analysed in detail. The handling was split into two categories—handling of gear and handling of the catch—each category was further subdivided so that every movement in the handling of the fishermen could be noted. For each of these movements the MTM timetables were used to find the working or action time. Many observations are required and the collaboration of the fishermen is essential. But to control the investigations initially some of the handling was measured by means of a stop-watch, then also model tests were carried out. These tests are very important to test improvements before being brought into practice.

Many improvements are possible, even with small alterations, e.g. regarding the procedure of handling, the order of working of the crew for shooting and hauling the gear, the handling of the catch, the location of equipment, etc. It should be stressed that rationalization does not always require more complicated equipment, as other factors, such as costs, quality of labour also have to be taken into account.

It is certain that the shipbuilding industry can obtain useful data from time studies. To mention a few: the type of equipment, the advantages of the equipment to be installed, the working deck, the construction of the fish hold, etc. Time studies are important for the owner and the fishermen. Not only a clear idea about the division of work on board can be obtained, but also arrangements can be made to facilitate the work, to permit more rest, etc., and this is an important factor in solving the crew problem.

It should be mentioned that the first publication on time studies on coastal vessels is nearly ready, and it is hoped that it will be useful for the fishing industry, since on an optimum fishing vessel, optimum labour conditions are necessary for the final goal to be reached.

Drum system approved

Roberts (UK): Roberts said he was not a designer, nor an engineer, but a fisherman now engaged in fleet management. In his youth he spent many weary years as a deckhand stooping to get deckloads of Arctic cod and occasionally floating overboard and successfully back again, and from those days he had tried to improve the working conditions of fishermen.

Labour saving in handling trawls is the ultimate aim of those who have a vessel manning problem, whether it be economic or just the lack of available crew men.

Roberts had seen nothing better than the drum system of the Canadian stern draggers, described by Reid. Some years ago he had the privilege of fishing from one of those vessels but hesitated to adopt the system in *Ross Daring* because they needed to use fairly heavy bobbins on rough ground in the North Sea. It now seems that drums well built as described in Reid's paper can cope with bobbins up to a diameter of 18 in (0.45 m), and this discovery may well be one of the most important in recent years as a labour-saving device in handling trawls.

Reid's suggestion of fitting two drums side by side is particularly good. Two trawls are then instantly ready for use, and in the case of North Sea fishing, possibly 5 to 10 per cent more fishing time would result. Who can ignore a 5 per cent increase in production? Also, the skipper can use his two drums alternately for comparative fishing trials for new nets and net materials. There is no reason why, on a large vessel, another deck is used to carry two more drums with a codend ramp in between each pair of drums.

Many fishermen today cannot mend their nets and much of this work is done ashore by older men. The vessel could back into harbour, moor astern and unroll the nets conveniently and take on the repaired nets from the previous voyage.

One day there will be an efficient gutting machine for small vessels, but until then every effort should be made by designers to get fish to the fishermen at waist height. Reid's paper does not discuss this point—perhaps his fishermen do not gut, but still use pitchforks to stow fish.

Ohlsson (Sweden): Could net drums, as described by Reid, be used on Swedish-type side trawlers for fishing in the rough weather conditions in the North Sea?

Traung (FAO): Reid's suggestion for drum trawling belongs to the most interesting possibilities to improve many fishing boats in many parts of the world. Reid mentioned that care should be taken not to use too heavy trawls. With the introduction of lighter netting, the weight of these trawls could be reduced. It would be very interesting to hear Reid's reaction to using drums even on side trawlers.

Benefits of net drum

McNeely (USA): One of the principal advantages of the net drum is its utility in poor weather conditions, when strapping in a net is both hazardous and time-consuming. Minor disadvantages include the necessity of removal of the net for repairs to webbing. Whenever very long nets are used, rapid retrieval is a distinct advantage.

Reid's paper shows separate slots for the groundlines. Most Pacific North-west trawlers do not have this feature, but from the standpoint of safety, it would seem desirable to have them. Some hazard is present when fishermen guide the bridles on to

the drum (level winding). The separate slots reduce that hazard.

Shelter

Frechet (Canada): In Canada where fishermen are exposed to extreme weather conditions, ingenious shelters were recently developed. The Great Lakes steel gillnetter or combination

Fig 1. A Great Lake steel gillnetter outside view

dragger may look a little like a submarine, fig 1 and 2, but offers excellent comfort, since the deck area is totally enclosed. Portable side covers are removed on hot summer days for open-air circulation, but just one cover is removed on cold winter days. The gear is set through this opening; a sliding canvas may close it before fishermen are ready to trawl. The side opening, which extends into the roof, permits hauling a
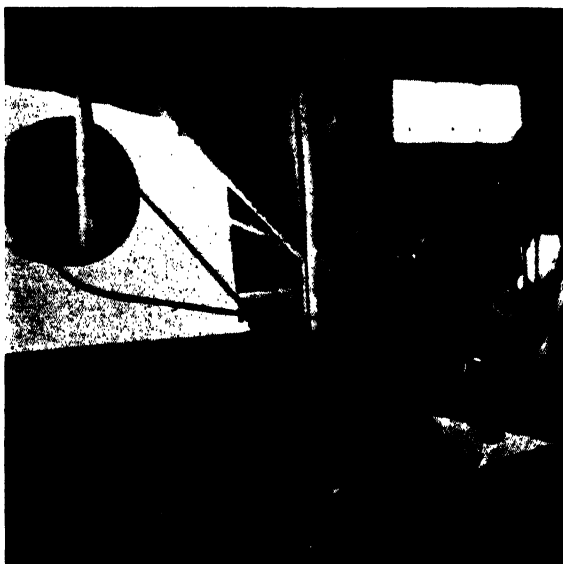
Fig 2. A Great Lake steel gillnetter inside the shelter

full codend. These principles are now applied to stern trawlers and even side trawlers plan to cover the whole deck in the same way. Recent stern ramp trawlers are not only of the "tween" deck type, but trawling operations are carried out under shelter on the lower deck.

Canadian longliners are usually partly sheltered under a canopy. On the Pacific coast, the 68 ft (21 m) combination

boats which longline halibut in the Bering Sea, some 2,500 miles away, usually carry a portable covering superstructure aft. It is sometimes made of plywood, otherwise of canvas over a steel pipe framework, of aluminium or even of translucent reinforced fibreglass. Atlantic types of longliners have a canopy with portable side covers. This construction extends behind the forward wheelhouse and usually covers a wide well.

Recent scallop draggers are provided with excellent shelters located on each side of the after superstructure. Recent side trawlers have the winch totally enclosed either in front of the poop deck superstructure under a starboard side canopy, or under the whaleback.

There are a number of other shelter arrangements not located on the main working deck. For instance, the hurricane decks are fitted with wooden or translucent plastic wind deflectors and crows-nests are totally encircled by removable plexiglass windows. On many vessels, the comfort of fishermen working in cold weather is ensured by radiant heating. The latest installations involve the use of quartz infra-red lamps or reflector heat lamps.

One must object forcefully to naval architects or others referring to fishing vessels as "working platforms", as if they can be open to all bad weather conditions. Fishermen now need and deserve "a home away from home". In the Hardy memorial lecture (page 25), Rinman rightly stated: "A happy ship is an efficient money-making machine." A prerequisite to happiness consists of adequate shelters to provide comfort for fishermen.

Roberts (UK): With too much shelter the skipper may well lose some control over his ship and crew. By covering all the working spaces, top hamper is added and a skipper used to handling a ship in rough seas will have the extra hazard of windage to contend with. Also, if he cannot easily see his crew, he will be faced with even more difficulties.

Traung (FAO): Disagreed with Roberts' remarks because there will not be anyone wanting to crew fishing vessels if no better shelters are provided in the future. With care in design and close-circuit TV it is possible to keep each corner under control.

Reid (Canada): Shelter need not obstruct the master's view of the working deck, as such shelters are most necessary to stop wind and spray and can therefore be open at the top— particularly needed for hauling codend over the stern. A check of the sight line from the bridge wing will show that the winch man can be easily seen, and this is the important point.

Internal heating facilities

Rawlings (UK): Regarding the matter of heating shipboard accommodation in temperate and sub-temperate climates, in the larger classes of steel fishing vessel, consideration might generally be given to installing air-cooled engines to drive the generators and auxiliary plant, the hot cooling air from the engine can then be harnessed for heating—provided this hot air is controlled in ducting. This practical method has already been used with advantage in warming crew cabins and wheelhouse, but more particularly in circulating hot air across the tank top, in way of machinery space in the larger steel vessels, thus combatting condensation in a particularly vulnerable part of the ship, usually subjected to corrosion attack.

Safety of the crew

Lyon-Dean (UK): Reid places quite high the importance of safety. Very little has previously been mentioned about safety precautions for the fishermen as distinct from safety of the

vessel. In the Moray Firth, scarcely a week passes without some fisherman going overboard by being caught in the bight of a rope or being swept over the side by a rope jumping from its fairlead. It is found that, although certain safety devices are insisted on and others recommended, in practice they are usually disregarded. Slippery decks, slippery iron-runged ladders are a potential source of injury, and the major injuries of oil skins catching in the winch drums are well known. As a doctor in a fishing port, Lyon-Dean saw and treated these casualties and he knew that many of them could have been avoided.

He asked designers, engineers, work study engineers and fishermen to co-operate and use their combined intellectual ability and common sense to make the working areas at sea as foolproof as possible so that safety conditions on board fishing vessels will be comparable with those in a factory on shore.

To reduce accidents

Minnee (Netherlands): Lyon-Dean had stated that many accidents still happen. Several ways in which these can be minimized are:

● Keep the warps and other wires as far above the working deck as possible, out of the way of the men
● Winches should be remote-controlled so that the whole control of the vessel is centralized—good all-round visibility is necessary, especially from the wheelhouse to the fish deck aft. The wheelhouse for this reason should not be too far forward. There should be no view-obstructing shelter as far as the gear operation is concerned, so that the skipper can control the work of his crew. However, for processing, the mate can take over operations and therefore excellent shelter can be provided in this area
● It is important to bear in mind the improved location of accommodation. For crews sleeping aft or midships, movement is far less
● Non-slip (and anti-corrosive) deck covering can be found in asphalt compounds

Seakeeping

Kilgore (USA): Blount and Schaefers report the paradoxical result that adding a deep bar keel decreased the rolling period. Increasing the damping coefficient and increasing the added inertia both cause lengthening of the natural period, and yet in this case the opposite effect occurred. The notion that the rate of extinction of excited motions is important in seakindliness persists so firmly among people who rely on their intuition for understanding of physical phenomena that a brief review seems warranted.

The equation of periodic motion with damping, whether the damping be linear or of some higher order, tells all the story there is to tell, with very high accuracy. The solution of the equation yields the natural period of motion,

$$T\phi = \frac{2\pi}{\left[\dfrac{GM}{I_{xx}} - \dfrac{N^2}{I_{xx}^2}\right]^{\frac{1}{2}}}$$

where the meaning of the symbols can be found in the glossary. The mass moment of inertia here, I_{xx}, includes the added inertia of entrained water, and $2N$ is the damping coefficient. This period determines the seakindliness in roll, the habitability and hence the usefulness of the ship. The damping rate, determined by the magnitude of the coefficient $2N$, does cause the period to be a little longer than it would have been in the absence of any damping whatever, but N^2/I_{xx}^2 is so small in comparison with GM/I_{xx} that for practical purposes it may be ignored.

On the other hand, note that increasing the moment of inertia has a most significant effect on rolling period, provided that $\overline{GM}$ is not increased concurrently. Bilge keels and bar keels achieve their effect commonly by increasing the virtual moment of inertia, entraining large masses of water at a distance from the axis of roll. Indeed they also increase the damping rate, but this part of the function has a negligible result.

Now, if metacentric radius is increased by adding heavy appendages, the rolling period may be decreased in spite of the augmented moment of inertia. This evidently is what has been accomplished. Although the deep massive bar keel has resulted in an increased hydrodynamic mass moment of inertia, and has also increased the gyradius of the ship itself, it has at the same time lowered the centre of gravity of the ship and thus increased $\overline{GM}$. The total effect is a reduced rolling period. The faster extinction rate will not be noticeable when at sea the motion is constantly re-excited. Seamen always would choose the ship with slow roll and slow extinction rate before a ship with fast roll, no matter how rapid the extinction rate, if such an alternative were presented.

Solution sought

Lee (UK): Would Blount and Schaefers explain why, if it is necessary for the propellers of the inboard installation in *Hiodon* to be completely above the bottom of the hull, the propellers of the inboard/outboard installation shown in fig 16 in their paper are below the bottom? Are there any special arrangements for avoiding grounding of these propellers and when the vessel is grounded how is it got off?

The remarks about the effect of bilge keels and deep bar keels are of interest. May it be stated whether such protections on the vessel's bottom affect the performance of the fish finder and depth sounder.

Selman (UK): Blount's and Schaefers' fig 19 referring to rolling tests with model of *Uncatena* is very confusing. What is the difference between the four curves given for the naked model? What were the dimensions of the bilge keels and what were the results with these bilge keels alone? To what does the full line in fig 19 refer?

Authors' replies

Blount (USA): In reply to Kilgore on seakeeping: The net difference in GM resulting from the weight addition of the bar keel is apparently in the order of 2 per cent for the full size vessel. This is evidently insufficient to cause the indicated change in period. It is unlikely that weight and KG changes in the model were held precisely to scale as far as the bar keel was concerned, since the effect being investigated was decrement of amplitude rather than difference in period. It is also thought likely that model weight changes were below rather than above scale value. There is some doubt, therefore, that the effect cited in the discussion accounts for the change of period, which in any case has the status of a corollary observation without relevance to the primary object of the test.

Selman wanted to know the difference between the four curves given in fig 19 for the naked model. The only difference among the four "naked model" curves shown on fig 19 is the initial angle at which the model was released. All were plotted for zero speed of advance. The slopes should all be the same, but are not. An average of the four slopes is probably as good as any one of them.

In reply to Selman's queries regarding the bilge keels: the dimensions were 39 ft 6 in (12 m) long by 18 in (0.45 m) wide (full ship size). No tests were made with the bilge keels

alone. He also asks about the full line in fig 19; this is for the model with both bilge keels and bar keel attached, at zero speed of advance. The arrow marked "With Bilge Keels" on this diagram should actually lead to this line. The arrow marked "Without Bilge Keels" should go to the dashed line instead of the dot-dash line.

Schaefers (USA): In designing the *Hiodon* it was felt that, since the vessel was scheduled for experimental operation in a recently filled reservoir, grounding would be a problem because information concerning bottom conditions and water depths was unavailable. Accordingly, the vessel was designed with a tunnelled stern to allow the rudders and propellers to be completely above the bottom of the hull. Initial operations indicated that the replacement of the standard engine arrangement with inboard/outboard propulsion units and elimination of the tunnel stern would be desirable for the reasons stated. Even though grounding will certainly occur, and the propellers of the inboard/outboard units will be below the bottom, these units allow the entire submerged portion of the unit to be raised through a 90 degrees angle. Thus, when the drive portion touches bottom, the unit automatically raises. If the vessel actually becomes grounded, the unit can be set at an angle so that the propeller is above the bottom. The propeller action is then reversed and the vessel backed off.

With regard to the effect of bilge keels and deep bar keels on the performance of the echo sounder and echo ranger, no adverse performance of either type of unit has been reported from such vessels now in service.

TUNA CATCHING

Ando (Japan): The main problem in tuna fishing in Japan is the low profitability, due to prolonged days for one voyage that has caused the following tendencies. First, the size of boats is to be smaller than 300 GT. Until 1960, most people wanted to have boats over 300 GT, but later it was found that, to have a full catch in such a large boat, they had to make voyages of more than 200 days. Naturally, that raised serious problems, how to get fuel supply. Therefore, smaller boats, less than 300 GT, are now preferred so as to shorten the days of a voyage. Second, the temperature of the fish hold has been lowered from 0 to $-13°F$ $(-18$ to $-25°C)$ and the freezing room from -22 to $-40°F$ $(-30$ to $-40°C)$ to be able to improve the quality of frozen fish during long trips.

Thirdly, there is a requirement to study more about labour-saving to secure the necessary labour and to increase profitability. However, the fishing technique is so delicate that much improvement cannot be expected in the near future. On the Government's suggestion, a special committee has been established, in co-operation with a research organization, a fishermen's organization and suppliers of various equipment, to find suitable solutions to all these problems. Apart from these problems for large longline tuna fishing boats, there are those with the small-sized tuna fishing boats of less than 40 GT. As the Government did not require approval for the building of such boats, they have increased very much in number since 1961. They started to look for fish far away in the South Pacific. They were naturally overloaded, and many accidents occurred. Therefore, finally the Government was forced to place their construction under control, limiting the number of boats and placing minimum requirements on the boats.

In order to solve the problems with decreasing catch and increasing days of voyage with large fishing boats, it is considered to be one solution to carry small catcher-boats on board, and this catcher-boat system has been recently employed by boats of less than 500 GT. The stability of the

mother boats when loading and unloading the catchers has to be carefully considered. So far no trouble has occurred.

Tuna purse–seining

Guicheney (France): Since about 1956 fishing for tuna in the tropics has developed considerably, France being one of the countries interested.

The earliest craft confined their searching to the immediate vicinity of Dakar. Nowadays tuna boats travel as far as Pointe Noire, and their range is extending a little each year with the increase in the size of the fleet. The method most widely employed is that of the rod and line using live bait.

Information accumulating chiefly since 1960 on fishing with large seines in the Pacific and on the at times spectacular results obtained with this method has led to its being tried out in West Africa. Several attempts made by American tuna clippers in the Gulf of Guinea in 1961 and 1963 met with complete failure. At the present time a fleet of Japanese tuna boats is understood to be trying out netting techniques in these parts, though without much success either. In nine cases out of ten the encircled fish dive under the net and escape at an astounding speed. Nor does deepening the nets provide an answer to this aspect of tuna behaviour, which does not seem to be so inexorably the rule with species in the east Pacific. It would be interesting to try to explain this difference between fish of the same species, but that is not the purpose of this contribution.

Experience also shows that good results can only be hoped for by combining methods, involving the location and attraction of schools of tuna by the use of live bait followed by their capture by seining. These remarks, of course, refer to fishing grounds with which Guicheney was personally acquainted, and to operations conducted in the daytime.

Fig 3. French tuna seiner Danguey

A steel-hulled tuna boat, *Danguey* (fig 3), was refitted to handle a large-size tuna seine; it has the following principal dimensions:

Loa	121 ft (37 m)
B	25.6 ft (7.80 m)
D	13.5 ft (4.10 m).

It has one propulsion engine, 650 hp, and two electric generator sets, 200 hp, 120 kW. The catch is stowed in eight holds with a total capacity of 5,300 ft³ (150 m³). Freezing (in brine) at -0.4 to $-4°F$ $(-18$ to $-20°C)$ is provided by a plant comprising three units extracting 75,000 kcal/h, i.e. a total of 225,000 kcal/h.

Deck gear listed

Deck gear consists of the following main items:

- One hydraulic winch, 120 hp, with a lifting power of 12 tons at empty drum. The winch is of the traditional
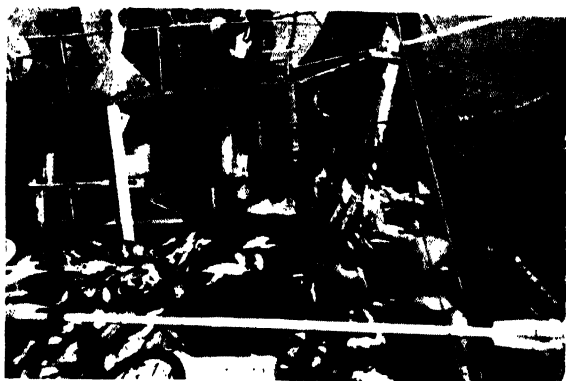
Fig 4. French tuna purse-seiners use trawl-winch type winches and extra small winches

trawl-handling type, with two drums and two gipsies, and is mounted astern, fig 4

● Two trawl-type gallows mounted on the port side, fig 5. The forward end of the purseline is hauled on the forward gallow, the rear end on the rear gallow; the purse rings are thus supported between the two gallows. This arrangement, which differs from that traditional with the Portuguese gallows widely used by American tuna seiners, has given complete satisfaction

● One-drum, one-gipsy electric winch, 35 hp, for hand-manoeuvring the breastline of the rear wing. This winch is platform-mounted astern, above the main winch, fig 4

● One hydraulic power block, 35 hp, mounted at the top of a fixed tripod mast

Fig 5. French tuna purse-seiners use double gallows
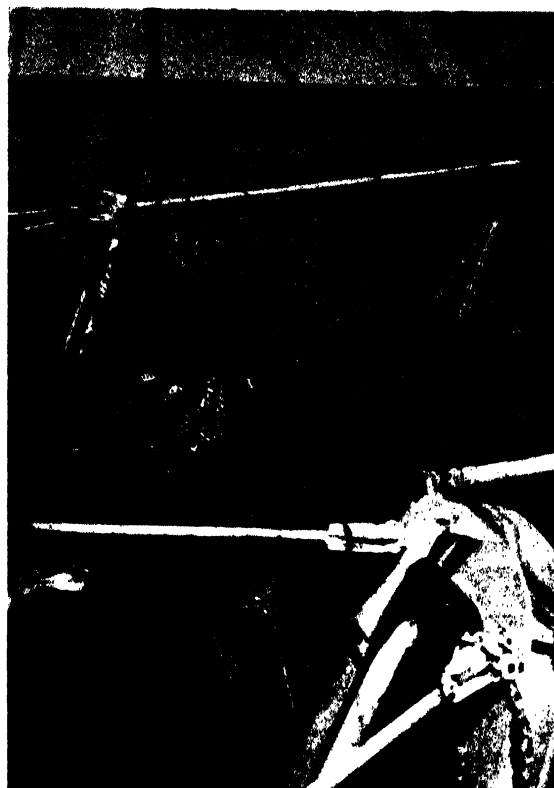
Fig 6. Derricks mounted on gallows help support corkline

● One derrick, 2.5 tons capacity, chiefly for hauling the excess webbing once the purse has been formed. This derrick is mounted at the foot of the port tripod and can be swung sideways. It is driven from a small hand winch and off one of the gipsies of the hydraulic winch

● Two derricks, 1.5 tons each, mounted on the respective gallows, fig 6. These derricks can be swung to a horizontal position, at right angles to the axis of the boat. Their purpose is to support the floatline by stout slings during pursing

● A deck area of approximately 480 ft² (45 m²) at the stern for stacking the net. The bulwark surrounding this space has been raised 3.3 ft (1 m) and made to slant inwards for the dual purpose of making it easier to slide the fish on board and of ensuring adequate frictional hold on the net which, on the inboard side is stacked on wooden duckboarding with an 8 in (20 cm) clearance above the deck

Net characteristics

The net had the following characteristics when it first left the braiding sheds:

● Length (in fishing condition): 546 fm (1,000 m) in four detachable sections of 136.5 fm (250 m) each
● The two middle sections were exactly similar, so that the total length could be brought down to 410 fm (750 m) if desired
● Depth: 69 fm (126.5 m or 1,265 meshes stretched)
● The webbing had meshes with 2 in (50 mm) bar

During the 1962/63 fishing season, it was decided to remove one of the middle pieces of webbing and so reduce the total length to 410 fm (750 m).

Trials with the original 546 fm (1,000 m) length, showed that the power required for pursing exceeded the capacity of the winch whenever the sea was not absolutely calm.

Prior to the 1964 season, further modifications were deemed necessary in order:

- To strengthen the last bunt. The original bunt was fitted under the new one, replacing the earlier webbing in such a way as to extend the selvedges to the entire forward extremity of the net, where the fish concentrate
- To fit one zipper close to the bunt
- To replace the 0.55 in (14 mm) chain by another of ⅜ in (10 mm) diameter in order to reduce the sinker effect

Methods of manoeuvre

To manoeuvre the net, a flat-bottomed, wooden, unsinkable (double-bottom) skiff of approximately 20 ft (6 m) length, powered by a 35 hp outboard motor was used, fig 7, the specific purpose of which was to hold fast the tow wing of the net (running end of the purseline and forward wing) in order to aid the seiner to set and haul the forward breastline and the purseline.
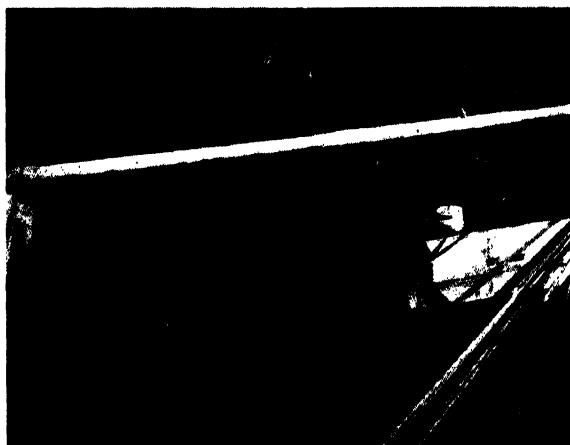
Fig 7. French purse-seine skiff

During the first two seasons a small tuna boat (non-refrigerated) casting live bait was used. Present efforts are being directed to rendering the seiner independent of the auxiliary boat by having specially designed skiffs capable of being hoisted on board.

Once on the fishing grounds, the two craft (seiner and bait skiff) take up positions half a mile to a mile from each other. The net is carefully laid out on the seiner, corks to starboard, webbing in the middle, sinkers to port, and rings hanging over the rail (all other currently used arrangements with smaller seines have caused tearing or other damage). The purseline is wound on the port winch. The running end passes through the gallows and the rings and is seized on the flat-bottomed skiff, which is towed by the seiner while the end of the purseline and breastline are roved until all is ready for shooting.

The moment a school of fish is sighted, the bait skiff heads in that direction and tries to hold it by throwing live bait overboard. If the seiner itself is the first to reach the school it, too, throws out bait in order to gather the fish around it while awaiting the arrival of the skiff, which takes over the task of holding the school. The manoeuvre described varies considerably in time depending on the reactions of the bait and how it presents itself. In a case of a compact school rising easily to the bait, the actual baiting lasts only a few minutes. Otherwise, fairly scattered fish or fish lying at some depth, must be brought together or nearer the surface and, in an extreme case, the operation may last several hours. The role and the competence of the man in command of the skiff are decisive to the success of the entire fishing operation.

All the time that the skiff is manoeuvring, the seiner stays a fair distance astern and to leeward. The skipper of the bait skiff keeps in touch by radio with the skipper of the seiner, and tells him when, in his judgment, the school is sufficiently compact. Then the skipper of the seiner cruises in his direction, keeping to leeward, and arrives at a position crosswise to the wind and astern of the skiff. He then releases the net and circles the bait skiff which continues to throw overboard large quantities of live bait until encirclement is complete. A hundred metres or so from actually completing the circle, the seiner shuts off its engines. Braked by the net, it continues in its course by impetus until coming to a virtual standstill on a level with the skiff. The end of the purseline is then cast aboard the seiner, passed over the roller on the forward gallows and wound on to the port drum. Then both drums are wound simultaneously. When the breastline arrives on board, the winch is stopped for a few seconds in order to unloop the purseline. The forward wing is firmly fixed on the bow side of the forward gallows. The pursing operation is completed by shipping the rings between the two gallows.

Precision needed in operation

The encircling operation needs to be conducted with some precision if the rear wing is not to leave the seiner. If that happens, the rear breastline is dipped and the rear wing must be hauled again before pursing is attempted. Pursing and traction on the wing requires too much power for these operations to be executed correctly at one end and the same time. In any case, experience proves that no time is lost by completing them in two distinct stages.

Once the rings are on board, the skiff relinquishes its end of the net (at a predetermined point on the float line) and goes to leeward of the seiner. A bridle is passed between the two, whereafter the skiff helps the seiner to get clear of the net, if that is necessary, and in any case to avoid fouling it.

While this is going on, the rear wing on the net is passed over a powered block and hauling commences. The rings are slipped, one by one, off the purseline as the net comes in. The net is stacked on the afterdeck ready for the next set.

Once the last ring is aboard, the float line is looped on to two gallows and the catch drawn up in the bunt. The first fish are lifted aboard.

Experience shows that there are always a number of fish gilled or otherwise caught up in the folds of the net, and these have to be removed by hand. Gilling may take on serious proportions and cause trouble in the case, for example, of skipjack. If the catch is large, most of the fish gravitate to the bottom of the bunt and no longer struggle, in which case it is necessary to haul on the bunt webbing to dry the fish as much as possible. A brailer with a handle some 40 ft (12 m) long is hooked to the derrick and plunged into the catch, which can thus be hauled on board by lifts of 900 to 1,100 lb (400 to 500 kg) a time.

The time required for the various operations described is as follows: 5 to 7 min for encircling; 11 min for pursing; approximately 45 min for hauling the net and 30 min readying the gear for the next set. The time for actual hauling of the catch on board naturally varies according to the catch.

Some adjustments needed

In December 1962, following a number of satisfactory sets (22 tons albacore caught in the first few days) difficulties arose due to the excessive length of the net—at the time 546 fm (1,000 m). This was shortened to 410 fm (750 m) in order to reduce the great pull exerted on the net by the swell or the wind, however slight, and to facilitate, first the braking and, secondly, the manoeuvring of the rear wing by means of the main winch.

For this reason, and because the boat was out of service while the conversions were being made, the number of days at sea between 25th December and 28th April totalled no more than 77. During these 77 days tuna were detected on only 40 days, allowing only 37 actually for fishing, since on 3 days the schools detected did not rise to the bait and attempts at shooting the net without carefully setting it were unavailing.

Accordingly, the total fishing days represented only 48 per cent of the time spent at sea, which, for a 325-ton total catch, gives an average of 8.8 tons daily (consisting of about a quarter skipjack and three-quarters albacore).

Average haul per set, which was approximately 5 tons in January and February rose to 10 tons in April.

A 35-hp electric winch was installed for the purpose of helping the manoeuvring of the breastline of the rear wing; an additional derrick was also installed in order to take up excess webbing during pursing. Other modifications concerned the strengthening of the net and a reduction of the weight of the sinkers.

During the 1963/64 campaign, with no interruptions this time, the average monthly catch came to approximately 102 tons, with the following proportions:

albacore 70 per cent
skipjack 30 per cent

Catches would certainly have been 10 to 15 per cent higher than this, considering that schools of skipjack were frequently disregarded in order to continue looking for albacore.

Method suited for wide adoption

The number of days when fish were detected amounted to about half of the total spent at sea and, practically speaking, for each day when fish were detected, a catch was also made, so that the fishing method here described can apparently be very widely adopted. Only on very few occasions weather or fish behaviour of such a nature was encountered that a catch could not be made once the fish were detected. On each day when fish were detected, the catch averaged 8.4 tons, i.e. about 4 tons for every day at sea. For the campaign as a whole the average catch per set was slightly over 5 tons.

The observations made during the *Danguey*'s first two campaigns off the African coast bring out a number of points which are decisive for the success of tuna seining.

The tuna seiner, *Danguey*, caught more than double (a ratio of 100 to 46) the catch of the ten freezer tuna boats with the best performances using the rod-and-line and live-bait technique.

Nevertheless, it should be noted that daily catches were largely the same in 1962/63 and in 1963/64 despite the technical improvements introduced, and that to achieve even that result more sets had to be made. This may be attributable to two causes: first the method of baiting, and the second, which seems sufficiently definite to warrant mention here, the depletion of the fish population (this doubtless subjective impression should perhaps be taken with due caution). Yet the threat that seems to hang over the tuna fleet—namely, a decline in catch in the future, should be seriously examined.

Type of bait

The bait skiff is extremely important, and it is reasonable to suppose that, with a perfected method, markedly different from that used in rod-and-line fishing, yields with seining could be boosted by some 30 per cent. This statement is based on the following considerations:

- Small-size bait is preferable to the medium-size used for rod-and-lining. Baiting should produce a "mass effect"
- It is necessary to throw the bait very energetically into the water during the encircling operation that takes only a few minutes. The relatively slow procedure with the rod is out of the question at such a critical moment
- The crew of the bait skiff must on no account dip their rods in the water—but this is difficult to avoid when hands are used to rod-and-lining

All the same, a very rapid change is apparently coming over crews, in favour of seining and the wider introduction of bait skiffs should afford some solution to the problem.

Bait is still cheap, only about 2 tons being needed to land 100 tons of tuna. The essential thing, however, is that the bait must be thrown into the water very energetically during the encircling operation.

Except when the fish are very scattered, and generally when they are found in company with schools of porpoises, seining is possible whenever lining is; on the other hand, seining is possible even when conditions preclude lining.

The seine used by the *Danguey* differs from others by reason of its relatively small mesh size (50 mm) and not merely as regards weight and dimensions. Generally, therefore, it is the drag caused by the webbing in the water that demands extra power for circling.

Important points

The following points should be emphasized.

Apparently the dimensions of the present net are very close to the optimum. The use of smaller nets does not seem appropriate because of the uncertainty of the tuna grounds off the African coast. It is indeed possible to catch tuna with relatively small 270 to 330 fm (500 to 600 m) nets, but this involves a decidedly higher number of sets when fish may not be taken at all. Besides a lower yield, it is by no means unreasonable to hold that with a general use of excessively small-sized nets the fish will "get wise" to the situation sooner and, accordingly, be more evasive. The trouble in certain cases in taking schools where rod-and-line methods had already been attempted only support this assumption.

The adoption of larger nets would undeniably offer a better average haul per set, though the greater time needed for manoeuvring would offset the benefits so accruing, at least with methods currently employed.

The rapidity of manoeuvring is a decisive element in the efficiency of the method.

The arrangement of sinkers is very important and has little in common with the standards prevailing in this field. For a tuna net, the 8 lb sinker weight per fathom length (2 kg/m) of net is too little and, accordingly, steel purselines are much better than those made of nylon.

Lessening of the labour required for pursing must be sought in a judicious design of the net and not in reduction of its dimensions. Much can be done to improve new nets.

Tuna seine manoeuvring calls for the following gear:

A 2-drum, trawl-type winch (or American type seine winch) with traction on each drum of at least 5.5 tons on half drum, i.e. for a winding-on speed of about 4 ft/sec (1.2 m/sec) an

effective power on the two drums of about 140 hp, with the facility whereby the entire power can be transferred to a single drum when winding on is complete (in other words, a tractive force on the purse line at that moment of between 8 and 9 tons). The capacity of the drum should be:

On one of the two drums 550 fm (1,000 m) 0.9 in (23 mm) dia. warp
On the other drum 275 fm (500 m) 0.9 in (23 mm) dia. warp (minimum)

Detailed requirements

The winch for rear breastline should be of the drum type and have a brake, and a capacity of approximately 165 fm (300 m) of ⅝ in (16 mm) dia. cable. The winding-on speed must be quite low (1.6 ft/sec or 0.50 m/sec, at the most) and the traction should be in the region of 2 to 2.5 tons. The purpose of the winch is to provide a braking effect on the boat and on the body of the net at those times when the rear wing is attached to the boat only by means of the breastline, and to lift the wing on board (where it is immediately roved through the powered block). It goes without saying that it is possible to relay this winch to the main one if one adds a third drum to the latter.

There should be a powered block of sufficient capacity (the 35-hp rating is recommended) mounted at the end of a swing derrick capable of taking 6 to 7 tons (static) load. The derrick in question should have a 90 to 100° slew from the axis of the boat (the slew excursion is limited by the position of the rear purseline roller), and should preferably be able to peak with a 3- to 4-ton load.

There should be a derrick of at least 2.5 tons capacity above the forward warp roller. This derrick serves to lift the forward wing until the first ring is reached in such a way as to hold the net up close against the boat in order to prevent the fish escaping through any open spaces that would otherwise be created.

It is not possible to give an exact description of the arrangement of the rollers, something to be worked out for each individual case. Nevertheless, the principle adopted on the *Danguey* is far better than the Portuguese gallows system generally used on seiners. The system in question consists of two gallows sufficiently far apart for the rings to be lifted at working height above deck level between the two gallows rollers and fall automatically on the deck without a derrick being necessary.

The afterdeck, on which the net is stacked, measures about 485 ft² (45 m²) in area, which leaves enough work space. It does not seem possible to reduce that area very much without paying some penalty, since the net when stacked reaches a height of 6.5 ft (2 m) on the float line side in any case. The bulwarks, especially the one aft, should offer a fair slope (about 20 per cent slant on the inner side) and be free of any rough edges. It is highly desirable that the bulwarks on the chain and ring side should be lined with wood to diminish noise when setting. The net must be stacked on duckboarding with a 4 in (10 cm) clearance above the deck to facilitate draining.

Factors in manoeuvring

Manoeuvring the seine creates a fairly large upsetting moment. A mean heel of at least 10° was recorded during many sets. Now, since the boat has a displacement of about 500 tons and a metacentric height of approximately 2.1 ft (0.65 m) the corresponding upsetting moment is of the order of 17 to 18 tons ft (52 to 55 tons m). Clearly, when subjected to this moment, the vessel must have an adequate reserve of stability.

The earliest results obtained with the fishing method described here may be taken as quite satisfactory. In 1966, six or seven French tuna boats were setting out equipped for tuna fishing with seines and live bait. However, these were converted tuna longliners, of recent construction and modified either while in building or after delivery. For the tuna seines operating in the eastern Atlantic, provision must be made for:

- Fishing gear with the characteristics described above. In particular, the dimensions of the net and power rating of the winch should be generously calculated
- The employment of at least one bait skiff most of the time during the fishing season. In order to ensure sufficient autonomy in the seiner, the best solution, in the light of current experience, consists in employing power skiffs with a hold of about 70 ft³ (2 m³) in size for live bait and diesel motors of sufficient power to allow of a speed of at least 6 to 8 knots. The skiffs should have a crew of two or three men of considerable skill (since they make all the difference to the success of a set)
- Carrying on board the seiner a sufficient quantity (approximately 2 per cent by weight of the fish hold capacity) of bait for the entire trip. Experience shows that, fish mortality being what it is, the actual amount of bait should not exceed 3 to 4 per cent by weight of the water in the live wells. Assuming an average storage density of frozen tuna at 0.65 (of the available space), the volume of the live wells will need to be about half that of the total fish holds
- A freezing plant able to handle daily peak hauls of up to (exceptionally) 30 to 40 tons. Accordingly, freezing-brine techniques are called for, and these in turn require a heat exchanger and a reserve of chilled brine

To the extent that one may legitimately extrapolate the results obtained so far, it would be prudent not to assume an average catch of over 8 or 9 tons for each day fish are detected. Now, experience seems to suggest that with currently available craft and gear, fish are detected on no more than half of the days of a fishing trip. There seems to be little doubt that much might be gained by improving detection methods, by say, air scouting, high-power sonars and a better understanding of fish behaviour.

Varied lessons to be learned

Doust (UK): Kazama's paper is a most fascinating report on the tuna longliner in Japan, and one from which many lessons applicable to other fishing vessels can be learnt. The first comment refers to the influence of catching rate on the ship's size. The opening remarks amplify the importance of making more realistic forward estimates of catching rates.

For example, it may be inferred that since recently-constructed vessels show a general reduction in size that the earlier designs were developed on too optimistic a basis. Exactly the same situations have occurred in the case of wet fish vessels longer than about 160 ft (48 m) based in Western Europe, and the application of some type of air-blast freezing system in an attempt to increase the edible life of the catch would seem worthwhile. By such means the time available from commencement of fishing operations to landing can be increased, thereby improving the quantity of saleable fish and increasing the number of hauls per day at sea.

Other methods described

Beaudoux (France): It is customary to group under the name of longliners, craft intended for a very wide range of types of

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fishing, from tuna fishing in pelagic waters, of which the Japanese provide the most notable example, to the working of rocky bottoms where trawling is out of the question, this latter method being used in particular by Scandinavian fishermen.

Apart from the basic principle of longlining, the actual applications are diverse in the extreme. Many studies have been made on the two main branches of longlining, and this contribution is limited to a brief summary.

(a) Faroes method—longlining for bottom species, fig 8

Grounds—Fresh fish: Faroes and Iceland banks. Salted or frozen fish: Newfoundland and Greenland banks
Length of trips—10 to 12 days in the case of fresh fish; 60 days approximately in the case of salted or frozen fish

Fig 8. A Faroes longliner for bottom species, Nornagestur

Gear—The longline consists of a main line in sisal to which are attached the branch lines carrying the hooks. The main line is stowed in baskets in lengths of between 150 and 165 fm (275 and 300 m). Each craft carries 100 to 150 baskets—a total length of line, therefore, of 15 to 27 nautical miles (27.5 to 50 km). Buoys at 1.1 or 1.6 nautical miles (2 or 3 km) intervals for retrieval of the sinkers holding the line down. A light buoy is used to mark the beginning of the line
Operations—The lines are set astern from the main deck, with the craft cruising at 7 to 8 knots. Hauling is done onto the main deck aft and to starboard, using a winch with horizontal warping heads. The above operations and those involved in preparing the fish need a 24-man crew

(b) Surface longlining for tuna, fig 9

Grounds—Generally speaking, all waters, whether seas or oceans, near the tropics. Particularly abundant in tuna are the Pacific around Fiji and Samoa, and the Atlantic off Dakar
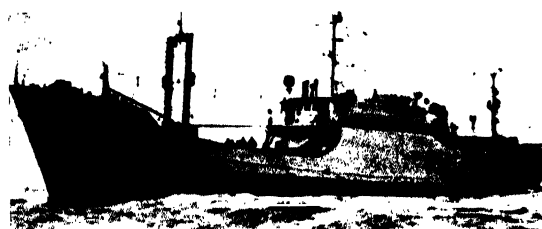
Fig 9. A freezer tuna longliner for surface species, Daguite

Length of trips—25 to 30 days approximately in the case of fresh fish; 60 to 75 days approximately in the case of frozen fish
Gear—In this case the gear consists of a main line in synthetic material to which are attached the branch lines carrying the hooks. It is stowed in baskets in 220 fm (400 m) lengths, any one boat carrying a total length of between 43 and 76 nautical miles (80 and 150 km), divided among 270 to 470 baskets. The float line is supported by glass floats with bamboo perches in between. Light buoys facilitate retrieval of the lines and in some cases a radio buoy is also used
Operations—The line is set astern of the upper deck, the craft cruising at 7 or 8 knots. The operation takes, on an average, 4 hours with a 12-man crew. The line is hauled forward, at a point level with the main deck, and to starboard. Two winches with vertical warping heads are used in this second operation which takes 9 to 10 hours with a crew of 24

The craft accordingly reflect, on the one hand, the fishing methods used and, on the other, the climatic conditions to which they are suited. That is why Scandinavians in particular prepare their lines and set them, under cover, from the main deck, while the Japanese perform the same operations unsheltered astern on the upper deck. Although these craft differ in the layout of their below-deck areas, their general

TABLE 1
Main particulars of three types of longliners built in France

Characteristics	Faroes longliner		Tuna longliner		Tuna longliner	
	ft	m	ft	m	ft	m
Length overall	119.0	36.31	167.0	50.95	98.5	30.00
Length between perpendiculars	102.3	31.20	147.4	44.85	82.0	25.00
Breadth	23.6	7.20	29.4	8.95	21.3	6.50
Depth (to main deck)	12.3	3.75	14.4	4.40	10.2	3.10
LBD ft³ (m³)	29,750	843	62,300	1,766	17,800	504
Draught amidships on departure for fishing grounds	11.4	3.48	10.3	3.14	8.4	2.57
Displacement on departure for fishing grounds	450 ton		719 ton		259 ton	
Block coefficient	0.577		0.557		0.615	
Prismatic coefficient	0.696		0.673		0.668	
GM	3.51	1.07	2.49	0.76	1.64	0.50
Fish hold capacity ft³ (m³)	7,720	220	16,800	480	4,210	120
Fish hold capacity	143 ton		310 ton		78 ton	
Volume of fish hold /LBD	26.1 per cent		27.2 per cent		23.8 per cent	
L/B	4.3		5		3.85	
L/D	8.3		10		10	
B/D	1.9		2.04		2.1	
Method of conservation	icing and salting		freezing		icing	

characteristics have various points in common. Three types of longliner have been built in France, one for Scandinavian methods and the other two for tuna longlining. The main characteristics are given in table 1.

Table 1 suggests that some of the results might be compared and the corresponding curves plotted (fig 10). The most important characteristics have therefore been shown, viz: block coefficient C_b; ratio of fish hold volume/LBD; ratio L/B; ratio L/D. From the aforementioned curves, taking into account the results achieved with boats already built, the following conclusions emerge.
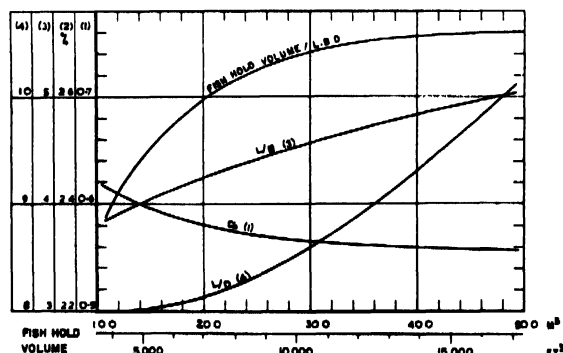
Fig 10. Curves of a few parameters of tuna longliners

Allowing for the operational conditions specified by the owners or prospective owners, and the financial returns demanded of the craft, it is possible, on the basis of the anticipated tonnage offering the highest returns, to determine with a fair degree of precision the principal characteristics of the craft: block coefficient and the L/B ratio. The ratio between volume of fish hold and LBD will then be given automatically. It goes without saying that the values from which these curves were plotted were obtained under optimum conditions of transverse stability, trim and seakindliness. In particular, the initial stability (GM) of all these craft on leaving port for the fishing grounds lie within the range 1.6 to 3.3 ft (0.5 to 1 m).

Designing the interior
The choice of design and its interior layout would be governed by the methods of fishing and of preserving the catch. One general remark is necessary, however, in conclusion, namely that the gross weight carried is in general distinctly (15 to 20 per cent) greater than with other fishing craft, in particular trawlers. This is due principally to the fact that with craft not designed for trawling—the required speeds and towing power not being very high—installed power ratings are appreciably lower than for trawlers which, furthermore, have a much greater amount of deck gear, winches and various other apparatus, so that the space taken up by the engine on longliners is correspondingly smaller than on trawlers, thus rendering possible much larger fish holds.

Forms are, of course, fuller than for trawlers, as the block coefficient values makes clear. A further consequence is that longliners are very economical from the standpoint of fuel consumption and therefore, with equal power rating, of much greater cruising range.

Finally, mention should be made of the pronounced trend nowadays towards longliners with freezing equipment installed, whatever their size. Until recently, only longliners with a capacity of over 100 tons were thus equipped; nowadays there are a number of craft below that size with one or more

freezing tunnels, but usually some more intensive refrigeration method is used.

Below in table 2 are given the principal characteristics of the refrigeration apparatus for longliners of 300 and 70 GT respectively:

TABLE 2

Principal characteristics of refrigeration apparatus for 300 GT and 70 GT longliners

	300 GT longliner	70 GT longliner
Volume of fish holds ft³ (m³)	16,900 (480)	3,875 (110)
Volume of freezing tunnels ft³ (m³) . . .	5,280 (150)	—
Refrigeration apparatus range . . .	490,000 kcal/hr	15,000 kcal/hr
Liquid refrigerant . .	Freon 22	Freon 12

JAPANESE STERN TRAWLERS

Doust (UK): Shimizu's paper is an excellent summary of the development of the larger deep sea trawlers and the factory-type vessels in Japan. It reflects many of the problems which have been and still are facing owners in other countries, more remote from the prolific fishing grounds.

The block coefficient of Japanese trawlers quoted is rather higher than other countries and there is the attendant loss in speed. For vessels which freeze the whole or most of the catch on board, excessive speed is detrimental to economic performance and it would seem quite in order to accept such a lower free-running speed, permitting economical savings in fuel consumption, greater radius of action and a better ratio of fish to fuel capacity.

At present, the economic justification of these large vessels, especially in regions where the highly-qualified technical staff required on board the vessels are being competed for by shore-based industries, requires very careful consideration and emphasize the need for more reliable automatic machinery, deck- and fish-handling equipment. Shimizu proposes the adoption of vessels specifically designed for a specific fishing ground to minimize the equipment required. This principle is now gaining favour in the design of fishing vessels of size above about 130 ft (40 m) in length, since the vessel and gear can be tailor-made for specific adverse weather conditions, bottom conditions, depth of water and range of operations. Many cases could be quoted where the design of vessels has been spoiled by attempting to cope in the design with too many fishing possibilities.

To overcome the tendency for the larger deep sea trawlers to drift to leeward and lose course stability at low trawling speeds, lateral thrust units fitted at the bow and stern have been successfully employed. Experiments with such units in the ship division of NPL have shown that special care must be taken in sighting the lateral tunnel required. Fairing of the mouths of the tunnel is required, particularly when the lines of the vessel have rapid curvature in this region.

Studies made by WFA
Eddie (UK): On the question of whether to have warping ends on winches, one might note the very comprehensive study of the operation of the winch of a large stern trawler carried out by the Industrial Development Unit of the White Fish Authority (UK). To avoid losing fishing time, high light-hook speeds are needed for some parts of the operation of handling the trawl; at other times, heavy pulls are needed; therefore, if the job has to be done by having a lot of little auxiliary winches scattered about the deck, and these are of the common constant-torque hydraulic type, they have to be

of quite big horsepower. The idea is economic only if sophisticated hydraulic systems with near constant-power characteristics are adopted, otherwise the use of warping ends on the winch is advised.

The UK has experience of large stern-fishing freezer trawlers with engines aft, engines forward and split diesel-electric. The present trend is towards a single engine forward driving a controllable pitch propeller, second most popular is diesel-electric.

If a controllable pitch propeller is used in this class of ship, there is considerable fuel saving if it is possible to vary propeller rpm. Further on the subject of propulsion economics, careful selection of machinery on a basis of measurements made in service conditions can make a great difference to costs: one popular class of machinery (diesel-electric was selected on the basis of theoretical estimates and comprised $3 \times 1,000$ hp engines; measurement at sea showed that for fishing a maximum of 1,200 hp was required and this class of vessel, therefore, could not quite fish on one engine—two were usually run. As a result of these measurements, the specification of subsequent vessels has been changed to $2 \times 1,400$ hp engines, with consequent savings.

Processing layout

On layout of freezer trawlers, it is very desirable to keep the fish awaiting freezing in chilled sea water, because this gives consistent high quality, as the Poles have shown by experience. It is obviously necessary that the buffer storage be arranged on a first-in, first-out basis, and the whole thing needs very careful thought on the part of the naval architect.

The processing plants in British freezer trawlers can handle about 30 ton/day. These ships are from 210 to 240 ft (64 to 73 m) overall; they make trips of 30 to 60 days. The total number of crew is 26 to 27, which is a long way from the 100 to 110 mentioned in the papers. This is possible because the fish is frozen in the whole, gutted form in vertical plate freezers. The vertical plate freezers in use in British freezer trawlers are suitable for fish about 4 ft (1.2 m) long and 4 in (10 cm) thick. The type of freezer would be useful for fish up to 5 ft (1.5 m) by 6 in (15 cm) thick.

Returning to the subject of optimizing the design, it may be worth mentioning *Saint Finbarr*. This freezer trawler is 210 ft (64 m) overall with 1,400 hp and carries the same amount of fish as vessels 240 ft (73 m) overall with 2,000 hp. According to such information as is available, her capital cost was 15 to 20 per cent less, her fuel costs are about 20 per cent less. Owing to her lower speed, she loses about 4 or 5 per cent of fishing time in a year. She has shown herself to be as effective for catching fish as the more powerful type, so it would seem that she must be a more economic solution. In any case, this example, like the other, shows that it is important to have design on reliable measurement of what is actually required and on subsequent selection of the solution with least costs for a given amount of fish produced.

Cardoso (Portugal): Shimizu should be complimented on the very interesting paper presented. Could he give an indication of the block coefficients and maximum section coefficients at maximum load and the general arrangement plans of the vessels mentioned? This would considerably add to the value of the paper and make it easier to understand the special problems mentioned and the solutions found.

Load on the warps

Hatfield (UK): Shimizu mentions a load indicator for the trawl warps. An exchange of information here might be useful. The White Fish Authority developed a trawl warp load indicator for stern trawlers about 18 months ago.

Although used first for research, it proved so popular with fishing skippers that it was fitted to three of the newest UK stern trawlers in its development form. It has now been taken over for commercial production by a firm of internationally-known marine electronic engineers, and ordered for some six or seven new vessels.

It is used not only for detecting snags but for setting engine power while towing in a tideway and setting the winch brakes. It works as follows: the stern pulley cannot be used for reading the load since the included angle of the warp over this pulley changes substantially. The warps have therefore been passed over jockey pulleys on the mizzenmast. These pulleys hang on strain-gauged tension loadcells and since the included angle always remains the same, the load on the pulley is always proportional to the load on the warp.

A pair of indicators marked in tons is placed on the wheelhouse and the system is calibrated *in situ*. Each meter also has an alarm contactor which the skipper can set at a value slightly above the towing load by the turn of a knob.

Designs built on experience

Kristinsson (Canada): It is evident from all the papers presented that considerable data exist on the design and operation of fishing vessels and that data gathered both from experimental and actual performances now available could form a good base for the development of future designs. The best vessels are obtained by collective efforts from the naval architect, the owner, the fishermen and the gear technologists.

A considerable amount of hydrodynamic data has been established in the past by model experiments of models tested in series and, as stated in the Traung, Doust, Hayes paper, data gathered by FAO will be issued as soon as time and funds permit. As such data is much needed by some of the boat designers, funds should be made available in the shortest possible time. In order to come up with the best boat to fulfil specific fishing requirements, the following are the major factors: hull form; fishing gear; machinery; fish handling.

Not enough attention has been paid to the handling of fish on board after it has been caught. This does not apply to factory vessels but to fishing trawlers gutting the catch and storing it in ice.

Convenient gutting lines and carriers should be designed to enable the fishermen to work in a more convenient position at waist level, instead of bending down and throwing the fish several feet away into a washing box or in a fishhold. The method of sorting and handling fish has not been improved on for many years and most primitive methods are used in most instances; then it takes much too long time to unload the catch.

Container systems, pumping or carrying systems should be given close study. Engine room automation should be closely considered and all machinery should be started and operated from the wheelhouse, having the engine room manless, with the exception of one master mechanic, who could work the normal $7\frac{1}{2}$ hours a day, for the purpose of maintenance and not watch keeping.

The economic size of fishing vessels is an important factor which is very much overlooked by many designers and operators. An economic relation between hold cubic and size of vessel should be closely studied. Some vessels of 148 ft (45 m) length, having hold cubic of only 9,500 ft³ (270 m³) and in other cases 125 ft (38 m) length vessel having the same hold cubic. This does not seem reasonable and is uneconomical, especially from the construction cost point of view. Especially if one considers the fact that a vessel of 125 ft overall length with well-designed hull form can fish in

rougher weather than a vessel of 148 ft length, having poor hull form.

ⲅ The design of fishing vessels is an interesting and challenging problem and as so many different factors are involved, a good teamwork will always produce the best results.

SMALL CANADIAN STERN TRAWLERS

Gueroult (France): Reid has covered the entire field of small trawlers and Gueroult congratulated him on his excellent paper. It was interesting to see how the same problems as one's own are solved in the antipodes.

Stern trawling methods came to Northern Europe from the Mediterranean via the Pacific coast of North America, before reaching Britain via the Norwegian whale factory ships. The drum is a most important addition, though the limits of its use remain to be seen. All the bobbins and floats are wound on the drum together with the net. Accordingly, it offers an acceptable solution for both large craft and small, where so much deck space is rendered useless because the net has to be laid out there. The proper place for the drum seems to be on the centreline and not too close to the stern, so that there is room for the crew to work between the drum and the aftrail. The layout in Reid's fig 10 has probably not a great future ahead of it. All asymmetric solutions disappear in time.

Fishermen in the US and Canada are fortunate in having special winches for the various operations. The simplicity of the drum and of its operation suggests that much would be gained by installing a second one for a spare net in order to avoid losing time on net repairs. With the appropriate hauling gear, all handling of the net in the water or completely on board, with the wings on one or both sides, hauling in the codend over the stern or over the side are possible and equally good. It is for the skipper to decide which method is most practical for the state of the sea and the catch.

Once a simple solution is found for small boats, it will be adopted for all tonnages. The conclusion to all this, then, is that no amount of care in the matter of designing deck gear for small boats is too much.

Gueroult agreed with Roberts re shelter. The skipper should be able to see his crew at their tasks and cannot do so if he is on the bridge. The latter should be designed in such a way as to leave the crew under cover and yet in view of the skipper.

Comparison with British conditions

Corlett (UK): Both the papers by Reid and Minnee are very interesting and admirable. The Pacific Coast fishing vessels certainly work in arduous conditions and it would be interesting to have supplementary information on prevalent wave heights and lengths in perhaps Reid's table 1. A special feature of sea conditions around Britain is the considerable wave height often associated with relatively short wave lengths. For example, 10 ft (3 m) significant wave heights are observed in Beaufort 8 in the south of the North Sea, very often with the bulk of the waves in the region of 100 to 150 ft (30 to 45 m). Often in confined waters due to shoals, vessels cannot choose their course and so running and broaching behaviour can be critical, especially on 50 to 75 ft (15 to 23 m) boats.

The detailed description of trawl drums given in Reid's paper is of interest and value and there is no doubt but that this method will find increasing acceptance, especially on smaller boats. If the drum is placed close to the stern, occupying the bulk of the width of the stern on a small boat, she will then be capable of trawling from the stern, but must recover her catch from the side and is, of course, not a true stern trawler. Some of the advantage of stern trawling is then

lost but, on the other hand, the simple mechanization of the gear handling will probably compensate for this. At the same time, possibly one of the most significant uses for the trawl drum may be on side trawlers, especially perhaps in the 100 ft (30 m) region, where there is an urgent need to reduce the man-power used in the light of increasing competition from semi-mechanized stern trawlers. A heavy bulwark roller with side rollers to contain the net would appear to be about the only modification needed to such ships in order to accommodate a trawl drum although there might be some alteration needed to the arrangement of fishroom hatches.

The side by side trawl drum/ramp arrangement does mean that a small ship can trawl and recover over the stern, but the efficiency of this arrangement is somewhat dubious in areas where heavy catches are obtained. Fig 1 to 4 of Blount's and Schaefers' paper show the relative congestion of this arrangement and the codends shown are very small. If a large catch is obtained, it is easy to see that there might be considerable difficulty in handling the codend up the very small, narrow ramp.

Care needed in comparing figures

The use of catching figures per head of crew in the way Reid has done, while quite legitimate, can be misleading if taken out of context due to the influence of varying grounds and practices as to the processing and handling of fish. For example, a particular gantry trawler of 90 ft (27 m) overall length in North Europe caught 27,000 to 45,000 lb (12 to 20 ton) per day and carries 15 men, but of these only three are actually required for gear handling. All fish however is gutted and dressed and practice in this latter respect has a very considerable bearing on the crew carried. A more indicative measure would be the catch per haul measured against the number of men actually required to handle the fishing gear itself and on this reckoning the ship quoted above would, of course, compare very favourably indeed.

Reid's description of the basic methods of gear handling are not all of ramp types or necessarily applicable to ramp types. For example, the method of handling by lifting the codend only was pioneered on the *Universal Star* and has been incorporated in a considerable number of trawlers since, not one of which has a true ramp. Reid refers to disadvantages of this method of fishing and, with respect, Corlett disagreed with him on certain points. For example:

● The net left in the water does not in practice foul up as suggested, and this trouble is quite unknown
● The net does not float, but the codend does, and there is no difficulty at all in bringing the codend forward over the net and it will be found that there is no tendency for the two to get entangled
● Fig 11 shows a deck arrangement of a small stern trawler with this arrangement. It can be seen that the whole arrangement is extremely convenient and the gantry can be used for successively fleeting the net so that a particular point can be reached systematically and with the net in the flat. The mouth of the net and both wings can be hauled straight on board in a manner very similar to that of Reid's type B, and at any time the fishing sequence for the latter type can be adopted if net examination is needed. However, the work, time and wear on the gear involved in having to adopt this not too desirable fishing sequence is avoided, except when it is necessary for examination and repair. Corlett was not impressed with the idea of dragging the fish bag over the bobbins on every haul and he did not believe that this would attract many fishermen
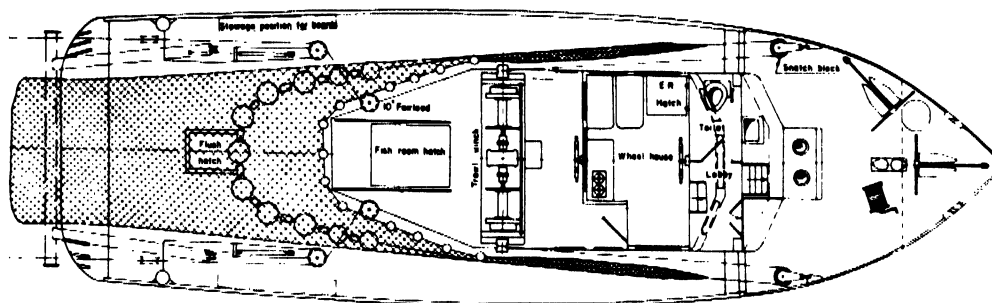
Fig 11. Deck arrangement of a small gantry stern trawler

● Corlett's experience did not agree with Reid's experience, that when fishing in rough weather there is often trawl damage due to vessel heaving or sliding over the floating net. Corlett did not know of such behaviour

● The restriction to the lift in a well-designed trawler of this type with a properly raised ramp gate is the gantry lift and not the height of the gantry, although of course this must be adequate. Double bagging is not difficult as the codend is not really floating at this stage; it is being partly lifted and is in fact easier to get at than with a side trawler

● Good practice here is to use synchronized split winches with auto-spooling and with these the quoted difficulty does not arise. Alternatively, the arrangement shown in fig 5 of Minnee's paper is sometimes adopted. Finally, where the bag is dragged up a stern ramp as opposed to lifted, the implication is a ramp extending to below the waterline. On small ships such as those working in extreme conditions this is not ideal and additionally tends to waste a fair amount of the deck space

Trends in Dutch fishing

Turning to Minnee's paper, Corlett was very interested in some of the detailed features of the boats he had put forward and considered that his arrangement of trawl winch and deck house in fig 4 is particularly attractive. It is slightly unfortunate in a vessel of this sophistication and capability that a warp should be led forward to handle the anchor, and an anchor winch with its own wire would seem to be well justified. The arrangements of warps is good but is leaving whipping drums open a desirable practice nowadays as the use of these wires on slipping drums is probably the most prolific source of accidents?

Turning to the hull, the use of a fixed nozzle in association with a large balanced rudder is interesting. It would seem questionable whether this gives really good manoeuvrability, that is to say, of the character associated with steering nozzles or other optimum arrangements, particularly whether the vessel is controllable astern.

One other important point is the question of propeller noise and nozzles. Minnee stated that in the stern purse seining proposal, the propeller noise will frighten the fish into the net. This is possible. Looking at Minnee's fig 7(a) it can be seen that the fish will tend to swim towards the centre of the purse providing the ship can go around them fast enough but it is questionable whether this is so and probably the need will be to make as little noise as possible. In this respect a nozzle whether fixed or steering is of great help as the bulk of the noise from a propeller comes from the top vortices and these are very largely suppressed by a shroud, especially with the type of propeller which is clearly implied in Minnee's

drawing, namely square tips with very little tip clearance. A nozzle purse seiner would probably cause very much less disturbance to fish than a ship without a nozzle.

Minnee's fig 7 and his proposals for purse seining over the stern are interesting. The main difficulty seems to be that of brailing. Minnee's arrangement for brailing is not attractive. Topping a loaded boom is a slow and expensive business and will cause considerable wear on the gear. It is always better if possible to slew at a fixed luffing radius.

Comment on details

Dickson (FAO): Commented on Minnee's fig 2 on stern trawler/beam, trawler. The gallows are too far forward for stern trawling:

(1) when towing and turning the warps would rub across the rail at the stern

(2) If gear snags on the bottom at some stage, it is brought directly below the boat when breaking it free. The wires may be all spun together and waiting on the shooting marks to come in view before slowing the winch, the twisted wires can foul the bottom of the boat. Quite a bit of speed is needed then to clear the gear aft of the propeller when the gallows are so far forward

Why cantilever gallows? These are convenient on small boats, where the board is light and can be lifted in by hand. However, ease of access to the board bears the consequence that on a bigger boat with heavy doors and in a rough sea, the operator has less protection. He is safer with the ordinary inverted U-type.

In Minnee's fig 3 it is proposed to run the ship astern or winch it astern until it is over the snag. If there is a following sea, with this shape of stern, this would be a very wet procedure. It is better practice to slacken the winch brakes, pay out wire and steam the boat round to face the snag, then steam towards it reeling in the slack.

Christensen (Sweden): Minnee's paper was most interesting. To optimize a fishing vessel and make a better ship, one always needs to consider the special kind of fishing water one is fishing in. This often is the reason for new types of vessels, but not always.

As a consulting engineer in Sweden, Christensen has the experience that the stern trawler is not desired in those waters. This argument is based on the fact that he had tried to introduce the stern trawler—without any luck—as this type of vessel has not shown any better economy than the conventional side trawler.

At present, a new model of this type has been tested, as the demand for more speed and horsepower requires a more careful design of the lines, combined with extensive model tests to state all the propulsive dates. Concerning engine

arrangement, deck and navigation equipment, there is a really great demand for automation.

Well arranged winch controls

Smettem (UK): The vessels illustrated in Minnee's paper show a good deal of imaginative thinking and one is particularly impressed by such details, as the simple arrangement of winch controls in the wheelhouse in his fig 4 and the clear working space afforded by raising the winch to the foc'sle deck position. One does wonder, however, if the warping ends are really necessary with a 4-drum winch, especially as a man cannot stand behind, due to the close proximity of the wheelhouse. Could Minnee state the winch pull on mean drum for the vessel shown in Minnee's fig 4.

The trawl handling methods shown in fig 1 are fairly conventional for the small stern trawler and this method was pioneered on the *Universal Star*, but in the case of that vessel with the use of a hydraulically-operated stern gantry. Many smaller stern trawlers are now fitted with this device and a higher degree of automation can be achieved by its use.

The proposals for purse seining over the stern are very interesting and this seems to be the logical method of handling a purse seine. The difficulty with this method is to provide an efficient method of brailing in the restricted space at the stern and on the surface Minnee's proposals would not appear to solve this problem.

If the brailing boom is topped only, as proposed, some sort of guying arrangement will still be necessary to prevent the boom swinging with the roll of the vessel. In addition the fish can only be dropped on the after deck, which already contains the stacked up purse net. In the event of the fish being brailed on to a carrier vessel, hanging winches will be necessary to swing the boom across for this operation.

Could Minnee elaborate on his proposals, as the problem seems to be to provide a quick and efficient brailing system which can transfer the fish to the working deck forward of the stacked net or feed a carrier vessel alongside without the use of a complicated guying arrangement.

The double rig trawl method

Juhl (USA): As noted by Knake, Murdock and Cating (1958), first attempts to develop the double-rig trawling methods in the Gulf of Mexico were made in 1955 by shrimp fishermen in Texas. These intial efforts caused widespread industry interest and many individuals contributed further development during the past 10 years. The popularity and acceptance of double-rig

Fig 12. Paravane-type stabilizer used by some of the Gulf shrimp vessels. Shown is a stainless steel model— most are of galvanized steel construction
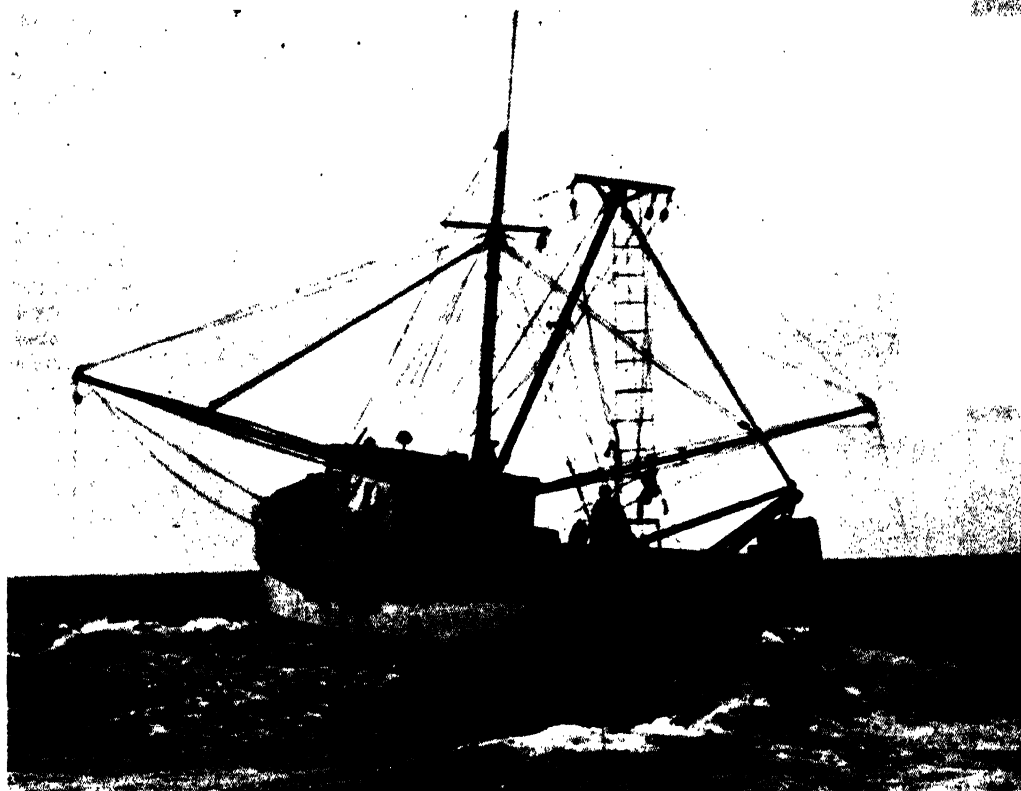
Fig 13. Stabilizers suspended from the outriggers' extremities of a shrimp vessel fishing a single trawl in deep water

fishing led to the conversion of many conventional shrimp trawlers and has influenced vessel deck and gear arrangement to a degree where practically all new constructions are of the double-rig type.

Although the double-rig method of shrimp trawling has reached a fairly advanced stage of development, it is still evolving. A recent innovation has been the introduction of stabilizer planes which are suspended from the midpoint of the outriggers during fishing operations and while at anchor in the fishing grounds. The stabilizers help considerably to dampen the roll of the vessel. One major shrimp boatyard includes stabilizers as standard equipment in all new constructions (fig 12).

Normally the stabilizers are suspended from blocks mounted about two-thirds out on the outrigger booms. Fig 13 shows the stabilizers suspended from the extremities of the booms. This practice is employed in the deepwater (200 fm or 370 m range) royal red shrimp fishery which currently utilizes a single trawl.

Another development of recent origin is the use of tag lines on the trawl doors. The tag line, long enough to reach the deck, is permanently tied to the upper part of the doors. Recovery of the line is accomplished with a pole. Formerly, a crew member had to catwalk out to the end of the outriggers and tie a line to the door's chain for subsequent hauling aboard. This practice was dangerous at all times, especially during heavy seas.

Main trawl winches have increased in size and ruggedness to allow for greater versatility for faster setting and haulback of gear and greater cable capacity for fishing in deeper waters. Also, they provide for use of larger diameter cable which reduces breakage, lasts longer and improves safety.

Table 3 shows information of the shrimp vessels over 5 GT operating in the Gulf of Mexico during 1963 and 1964, compiled from published and unpublished US statistical data. Similar statistics on vessel characteristics are not readily available prior to 1963.

Number of Double Rig Vessels 2059
Number of Single Rig Vessels 723
Total 2782

Single-Rig ▪
Double-Rig ▨
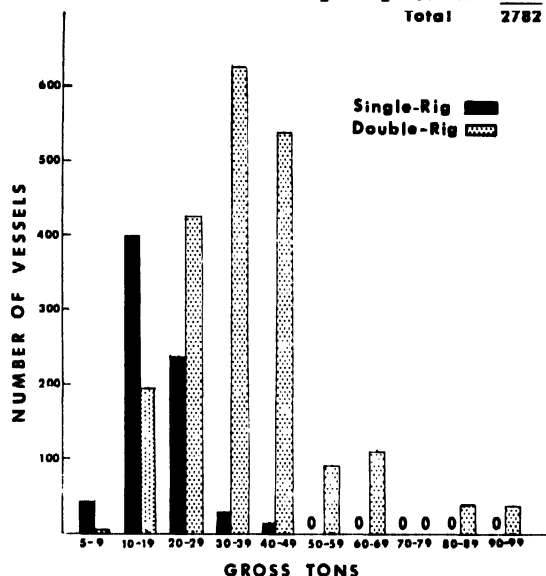
Fig 14. Number of shrimp fishing vessels over 5 GT operating in the Gulf of Mexico during 1964, single and double rigs

but to a lesser degree, the single-rig trawl data also shows reduction in manpower. Increase of single-rig vessels in 1964 over 1963, as shown in table 3, may indicate conversion of smaller double riggers to single rigs, or entry of vessels engaged in other activities into the shrimp fishery.

Many of the new constructions, vessels in the 65 to 75 ft (20 to 23 m) category, are operating in international waters off the north-east coast of South America. The migration to these grounds is indicated in fig 14, which reflects this reduced

TABLE 3

Average measurements and characteristics of shrimp trawlers operating in the Gulf of Mexico during 1963 and 1964

	GT	1963 Loa ft (m)	No. in	Size* of net	Total No. of vessels
Double rig	37.2	53.6 (16.5)	2.85	43.5 (13.4)	2051
Single rig	17.4	45.3 (14.0)	2.12	57.0 (17.6)	646

	GT	1964 Loa ft (m)	No. in crew	Size of net	hp†	Total No. of vessels
Double rig	39.3	55.2 (17.0)	2.71	44.5 (13.7)	197	2059
Single rig	18.4	45.4 (14.0)	2.06	55.5 (17.1)	145	723

*Net size measurement is length of leadline.
†hp data not available for 1963.

Reduced manpower

For the Gulf of Mexico fleet, data shown in table 3 are fairly similar for the two years. However, the average number of crew members per vessel for 1964 on the double-rigged vessels has decreased by 0.14. This implies that five per cent of this fleet of over 2,000 vessels employs one man less. Similarly,

Fig 15. Length overall and number of shrimp vessels operating in the Gulf of Mexico during 1964, total vessels are 2,782

number of vessels in the higher GT category. It also shows the majority of the double-rigged vessels fall in the 30 to 49 GT class. This tonnage class coincides with the 50 to 59 ft (15 to 18 m) length groups shown in fig 15. However, the GT-length relationships are not well defined in the upper and lower extremities of the graphs in fig 14 and 15.

Fig 16 shows the relative size of the nets (footrope measurement) used by double and single-rig vessels. Footrope measurement of the two nets used by the double riggers have been combined. The lower graph indicates a decrease in size of nets on double-rig vessels for 1964 in the 84 to 90 ft (25 to 27.5 m) range and a slight increase in the nets with groundropes 99 ft (30 m) and over. The upper graph shows an increased usage of 60 ft (18 m) and smaller nets on single-rig vessels during 1964 as compared with the previous year.
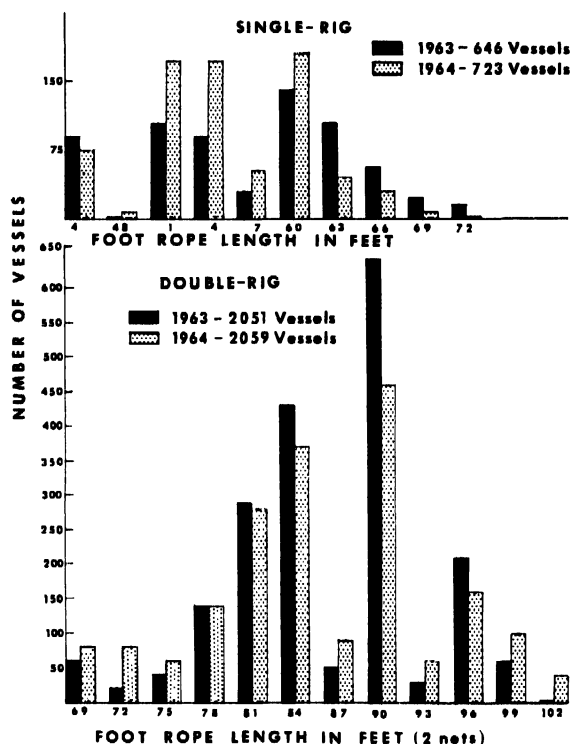
Fig 16. Number of shrimp fishing vessels and their trawl net size, operating in the Gulf of Mexico during 1963 and 1964, single and double rigs are shown separately

Data on shrimp vessel main engine hp are available only for 1964 and not classified by rig type. Fig 17 clearly shows the predominance of hp preference. A comparison of this graph with those of fig 14 and 15 indicate poor correlation between hp, vessel length and GT. The reason for this discrepancy may stem from the popularity and preference of certain model engines, available only in specific hp. This practice may account for many vessels, over and under typical characteristics (shown below) to be overpowered and others underpowered (Juhl, 1961).

Data collected indicate certain vessel measurements and characteristics which allow describing a typical Gulf of Mexico double-rig shrimp vessel as follows:

GT . . 42 to 45
Loa . . 55 to 60 ft (17 to 18.5 m)
Main engine . 200 hp
Trawl net size . 90 ft (27.5 m) footrope (two nets combined)

The present trend, however, is towards larger vessels, in the 65 to 75 ft (20 to 23 m) class, of 60 to 80 GT and 275 to 300 hp main engines. Steel hull construction is rapidly gaining acceptance, although wood is still preferred by the majority of the boatyards.
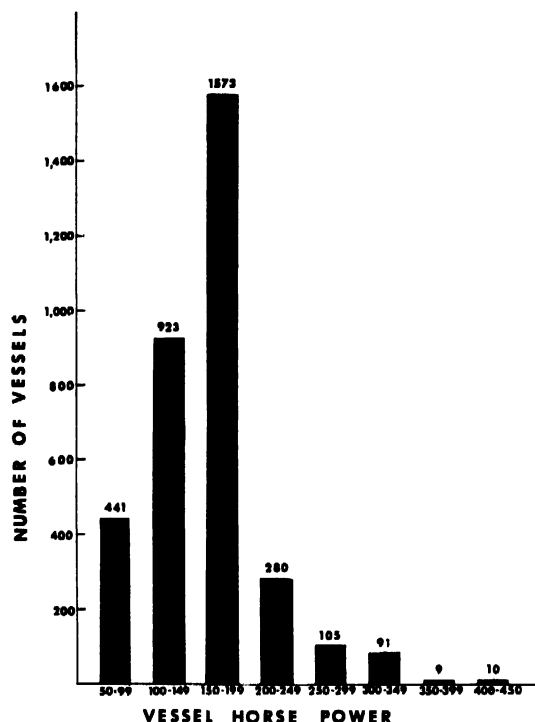
Fig 17. Predominance of hp preference of shrimp vessels operating in the Gulf of Mexico during 1964

Composition of Belgian fleet

Hovart and Verhoest (Belgium): Table 4 shows that the near and middlewater fleet represents the most important group of the Belgian fleet; at the end of 1964, this fleet totalled 230 vessels. There has been a movement towards bigger vessels with more powerful engines, and more powerful engines have been installed in old ships. The number of coastal boats has decreased. In the period 1955 to 1964, the number of coastal boats has been reduced with 108 units.

TABLE 4
The Belgian fleet, end 1964

		Ranges
Costal fleet		
number . .	144	
hp . . .	8,784	15—119
GT . . .	2,474	5—57
Midwater fleet		
number . .	230	
hp . . .	45,119	120—349
GT . . .	15,664	33—185
Deep-sea fleet		
number . .	44	
hp . . .	28,105	350—2,330
GT . . .	11,142	118—1,399

The new middlewater vessels are traditional side trawlers. The introduction of the double-rig shrimp beam trawling for the coastal fisheries must be mentioned. The main advantages are:

● The horizontal opening of the two beam trawls is greater as compared with one otter trawl for the same resistance

[598]

- The length of warp has much less influence on the performances of the beam trawl than on the otter trawl
- The opening does not change during course alterations.
- The influence of tides is much less on a beam trawl than on an otter trawl, as the opening is fixed whereas with otter trawls the resistance and shear of the otter boards is highly affected when fishing in tidal areas
- Shrimp trawling is usually carried out in muddy and soft bottoms. This does not affect the opening of the beam trawl, as the opening is constant and the footrope catanary adjusted to an appropriate and constant ("raking") light in the bosom. Such bottoms do affect the shearing effect of the boards so that the opening of the trawl varies, with the result that the footrope tends to dig in soft bottoms when the boards close
- Double-rig operations allow easier adjustment of the gear to the fishing conditions, as it is possible to conduct comparative fishing at all times because two nets are constantly in operation at the same time
- The direction of wind and tide has no influence on the shooting of the gear. As only the codend is hauled aboard, the whole operation can be mechanized, leading to faster operation with less crew

Increase of comfort

On the new side trawlers the comfort of fishermen was much improved, but the simplification of the handling of the gear and catch was still an open problem.

Two small stern trawlers have recently been built in Belgium, namely the *O.100* and the *Z.594*. The *O.100* is classified in the coastal fleet and the *Z.594* in the midwater fleet.

Beam trawling is applied for shrimps and flatfish. The two derricks (1) in fig 18 are set at an angle of approximately 0 to 30 degrees (and pointing a little more aft than abeam). The vessel steams ahead on a straight course, while wearing out both nets by means of the warps (3), coming from the mean drums (2a) of the winch over the blocks (4), attached on the deck gallows (5) to the top of the derricks. While operating or afterwards, the derricks are lowered by the drums (2b) at an almost horizontal position. After hauling, both nets are heaved to the boomtips. The derricks are put to an angle of about 30 to 40 degrees and only the bag is then hauled on deck, the codend emptied and the gear prepared for the next haul.

Pair-trawling is applied in wintertime for sprat and herring fishing. The operational method is the same as on side trawlers, except that the net is paid out over the stern.

With bottom-trawling, the warps (3) are running from the mean drums (2a) of the winch, over blocks (4) hanging on the gallow (5) to the otter boards. The net is dropped into the water over a stern reel (6) by the *O.100* or the stern ramp (6) by the *Z.594*. Sufficient warp is paid out in relation to the depth. By hauling, the otter boards are hung in the gallows, the dandylines are unshackled from the boards and fixed at a line coming from the drums (2b). Using these drums, the net is hauled over the reel or stern until it is on board, excepting the codend. The codend is brought on board over the reel or stern by means of a runner coming from the derrick (7).

With the possibility of the application of these three fishing methods, it is expected that an increase of fishing operation and a decrease of the uncertainty of supply will be possible. On the other hand, better working conditions are provided and a simplification of the manual work is realized by a rationally-designed working deck and the possibility of handling the winch directly from the bridge.
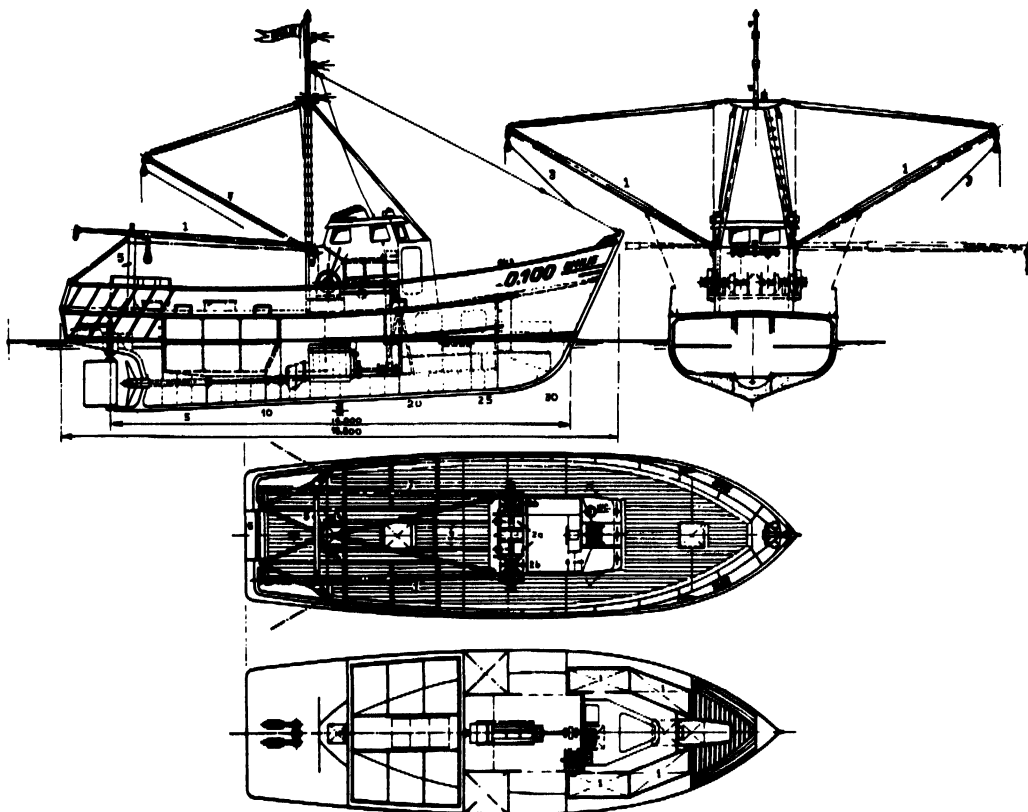
Fig 18. Recently built Belgian combination fishing boat, O.100
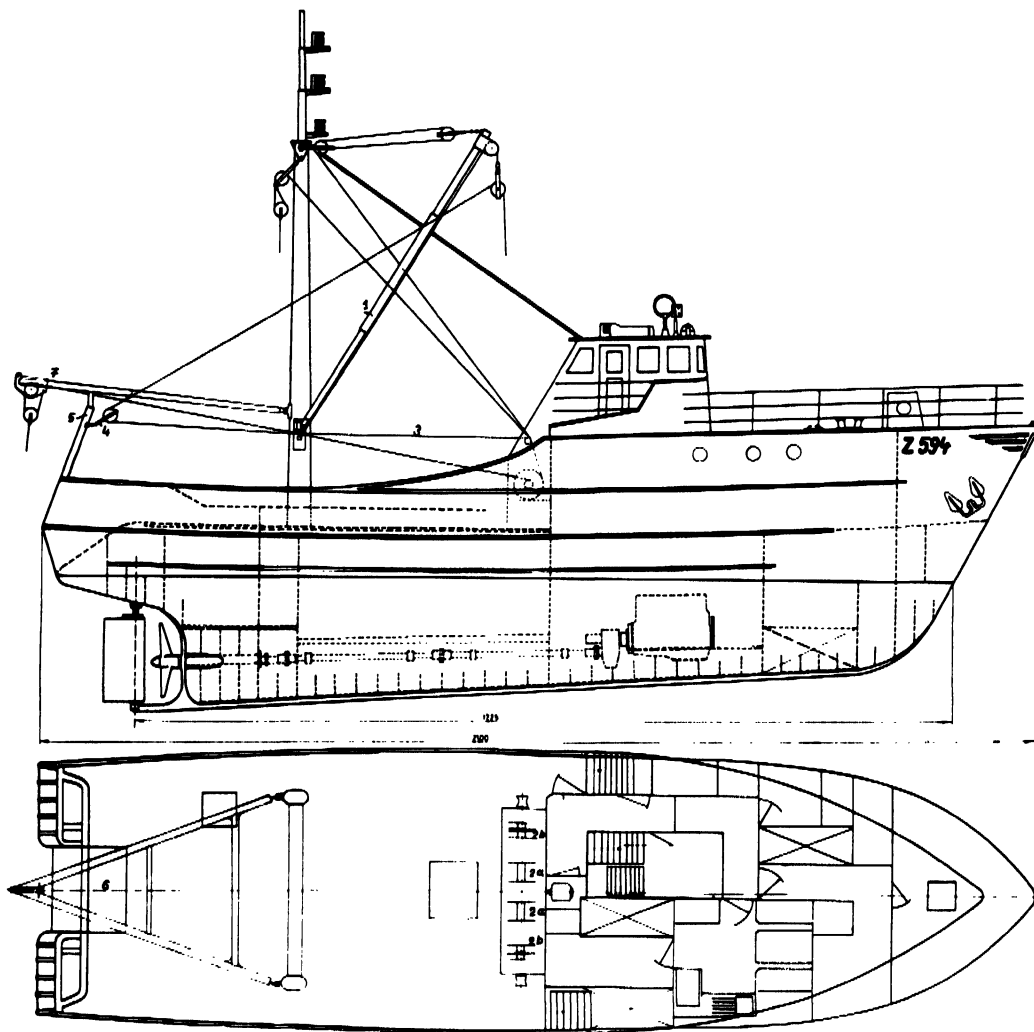
Fig 19. Recently built Belgian combination fishing boat, Z.594

The first-built combination vessel, *O.100*, fig 18, has the following characteristics:

Loa	.	55 ft (16.8 m)
Lpp	.	46 ft (14.0 m)
moulded breadth		16.5 ft (5.0 m)
depth	.	7.9 ft (2.4 m)
draught aft	.	7.0 ft (2.1 m)

The fish hold has a capacity of 775 ft³ (22 m³). The fuel-oil capacity is 1,300 Imp gal (6,000 l) and freshwater capacity 130 Imp gal (600 l). The propulsion engine is a four-stroke diesel, which develops 150 hp at 1,250 rpm. This engine allows the boat to get a speed of 9 knots. The winch is a four drum winch with friction clutches and is controlled from the wheelhouse. The vessel is further equipped with a hydraulic steering gear, echo-sounder, radio and direction finder. The crew consists of three men, a skipper and two mates.

The *Z.594*, fig 19, has the following characteristics:

Loa	.	69 ft (21.0 m)
Lpp	.	56.5 ft (17.25 m)
moulded breadth		19.7 ft (6.0 m)
depth	.	9.85 ft (3.0 m)
draught aft	.	10.5 ft (3.21 m)

The fish-hold capacity is 2,100 ft³ (60 m³). The fuel capacity

amounts to 1,750 Imp gal (8,000 l) and freshwater tanks hold 875 Imp gal (4,000 l).

The vessel is powered by a diesel providing 220 hp at 1,500 rpm and can do 9 knots. A hydraulic steering gear is fitted and a six-drum winch is controlled from the wheelhouse. The wheelhouse equipment includes radio, direction finder, echo-sounder and a radar set. The crew consists of four men, namely a skipper, an engineer, a mate and a deckhand.

Safeguards for beam trawling

Of the two trawlers, special safety arrangements have been taken for beam trawling. One disadvantage of beam trawling is that the stability of the vessel can be greatly impaired when one of the trawls becomes hung-up by a bottom obstruction. The forces acting on the boomtop become so great that the vessel may capsize. The forces arising from a hang-up of one net may be taken to culminate at a point at the top of the beam which is high above and far outside the centre of gravity and tends to heel the vessel over. Therefore, a special security release system had been introduced by Hovart and Verhoest. This system:

● Allows the forces acting at the top of the boom to be brought to a point lower down, even when there are winch or other defects which prevent veering out of the warps

[600]

NOTE   A : POSITION OF BUOY THROWN INTO AND PICKED UP
    C, F : POSITION OF CURVED WARP MAKING SHIP TURN TO PORT SIDE
    D : POSITION OF NET THROWN INTO

C

WARP

B

D

TRAWL NET

A

G BUOY

E

WARP

F

SHOW THE POSITION "B"

PLAN

WARP

BUOY

SIDE VIEW

SEA SURFACE

PLAN

WARP

TRAWL NET

BUOY

SHOW THE POSITION "E"

SIDE VIEW

BUOY

TRAWL NET

WARP

SEA SURFACE

TRAWL NET

PLAN

BUOY

SHOW THE POSITION "G"

WARP

SIDE VIEW

SEA SURFACE

BUOY

TRAWL NET

WARP
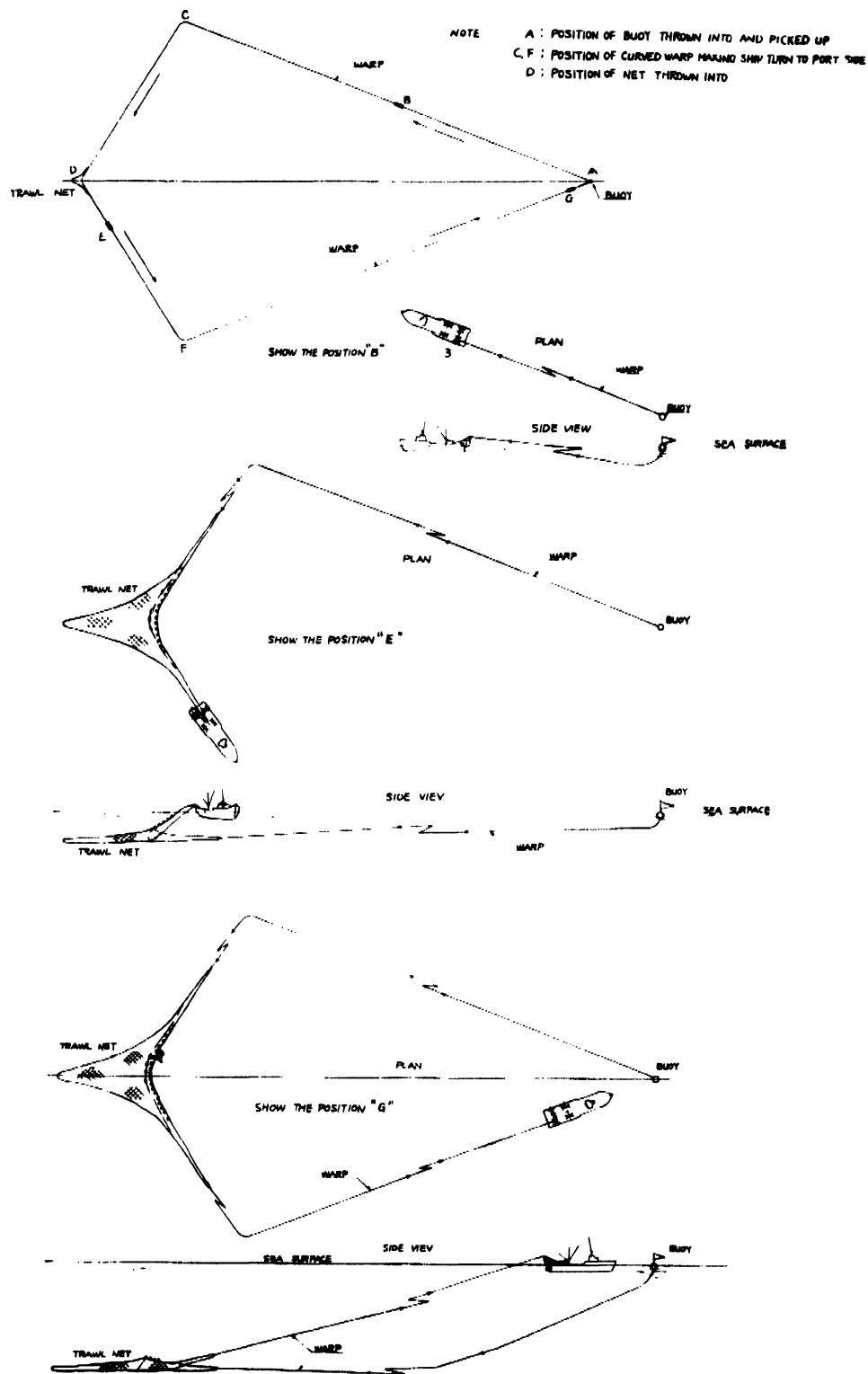
Fig 20. Positioning of gear during fishing operation of Japanese Danish seiner

[601]

- Transfers the forces to a point which allows the vessel to manoeuvre the gear clear of the obstacle
- Allows the net to be hauled quickly and in a safe way

On the *O.100*, the warps coming from the winch are led through a block attached to the stern gallows and run over a derrick block to the gear. The derrick block is attached to the boomtop by means of a sliphook.

When the gear meets an obstruction, the sliphook is released, which in turn releases the boomblock, so that the towing forces now act on the block attached to the stern, which ensures full stability of the vessel. The free net is then hauled over its own boom, after which the vessel is manoeuvred in the usual manner to free the hung-up gear from this obstruction. The gear is hauled hard on to the block in the stern where it is stoppered. The boomblock is then hauled back to its position at the boomtip and the gear is further hauled in the usual manner.

At the beginning, on the *Z.594*, the warps were led from the winch to a block attached to the double mast and they were run directly to the boomderrick. This solution proved to have many disadvantages when hauling the hung-up gear. Therefore the same security system as on the *O.100* was installed.

The *O.100* and *Z.594* are the first two small stern trawlers in
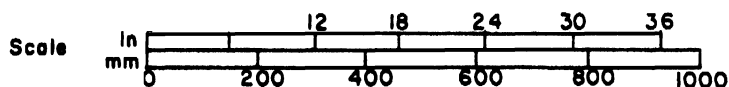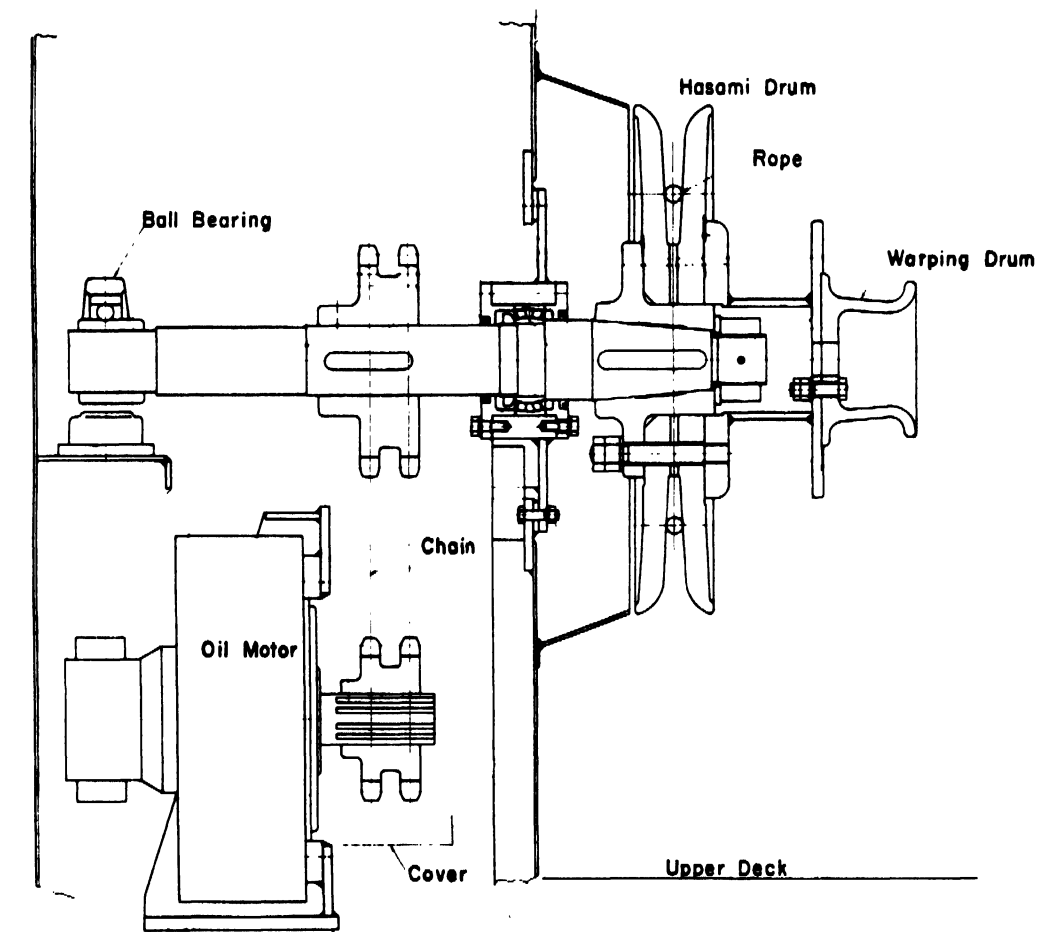
Particulars

	Load	Winding	Speed	Rope Type
	Ton	Ft/Min	M/Min	
Hasami Drum	2.5	295	90	Compound
	1.5	394	120	1.09~1.25 In (28~32mm)Diam. 8700 Ft (2650m) Length
Reel	3,5			Wire 0.62 In (16mm) Diam. 230 Ft (70m) Length
Warping Drum				Wire 0.62 In (16mm) Diam.

Winch Drum

Fig 21. Layout of winch for Japanese Danish seiner

[602]

Belgium, and they are operating very well as compared with the best vessels, so the construction of small stern trawlers is being continued.

Japanese one-boat trawling

Okamoto (Japan): The operation of Japanese-type small trawlers is similar to that of Danish seiners because the use of trawl-doors is prohibited, near the Japanese coast. There are approximately 1,100 boats of this type, from 15 to 100 GT, and the catch reaches 655,000 tons, equivalent to about 10 per cent of the total catch of Japan. Recently more than 50 steel boats of 50 to 100 GT have been built every year. The catch by otter trawlers was 14,000 tons only in 1963.

Takagi (1955) described a Danish seiner to the First Fishing Boat Congress. Since then many similar boats have been built. Fig 20 shows the setting sequence of warp and seine. At point A, the warp will be thrown into the sea, attaching a buoy at one end of the warp and change the course of the boat at point C. At point D, the codend is thrown into the sea, after passing point F return to the point A. After picking up the buoy, towing starts. Sometimes the net is set clockwise. After the seine has reached the sea bottom, towing is made for a while with slow speed and the net is hauled up by a taper-type sheave between two discs of winch drums, as in fig 21. As a comparison the movement of the trawl net and warp in the sea is shown in fig 22.

Fig 23 shows the pulling up of the seine net and warp on the stern of the boat. With ordinary side operation, the seine net is pulled to the side of the boat, and the fish are scooped from the gunwale. One cycle of operation takes about 1½ hours. Otter trawling sweeps the sea bottom, but the Japanese Danish seining is different, as clearly seen in fig 20 when fish is surrounded by the rope on the sea bottom. It is not yet completely studied whether or not fish are gathered by the rope only. The following are important points:

● Ropes are not to flap up from the sea bottom so that as much fish as possible can be gathered
● To drive fish into the net with good timing and control of winding up speed of rope and thrust of propeller adequately are essential. Such control depends on fish species and the water depth

Up to 10 years ago, the winch and propeller were directly driven by the same main engine and control was difficult, as the rope speed and thrust of propeller could not be adjusted independently. Such control could be done only by very experienced fishermen and they kept the technique secret.

Advantages gained

The advantages of this fishing, in spite of the control difficulty, are that fishing can be done on uneven or slanting sea bottom and it is possible to operate in deep sea. Otter trawler fishermen call the sea more than 165 fm (300 m) depth deep sea, and 165 fm (300 m) operation is common for this type of trawler. In fact operation is practical and very effective in 275 fm (500 m) depth and it seems possible to explore further deeper sea bottom. Another point is that the otter trawlers are so effective that many fishing grounds are over-fished, but Danish seiners will not damage the fishing grounds.

In the past 10 years, fishing procedure has been improved. Firstly, by using hydraulic system winch, speed adjustment became flexible. Secondly, by the adoption of controllable pitch propellers, adjustment of thrust of propeller became possible, combining these two arrangements to solve the most difficult points of the operation. Now, an important problem is how to improve fishing efficiency and save manual labour. There are a few other matters; in the past, manila rope was used for the warp but it lasted only two to three months. Synthetic fibre has been tested, but did not stand the severe operational conditions. Then compound rope was applied
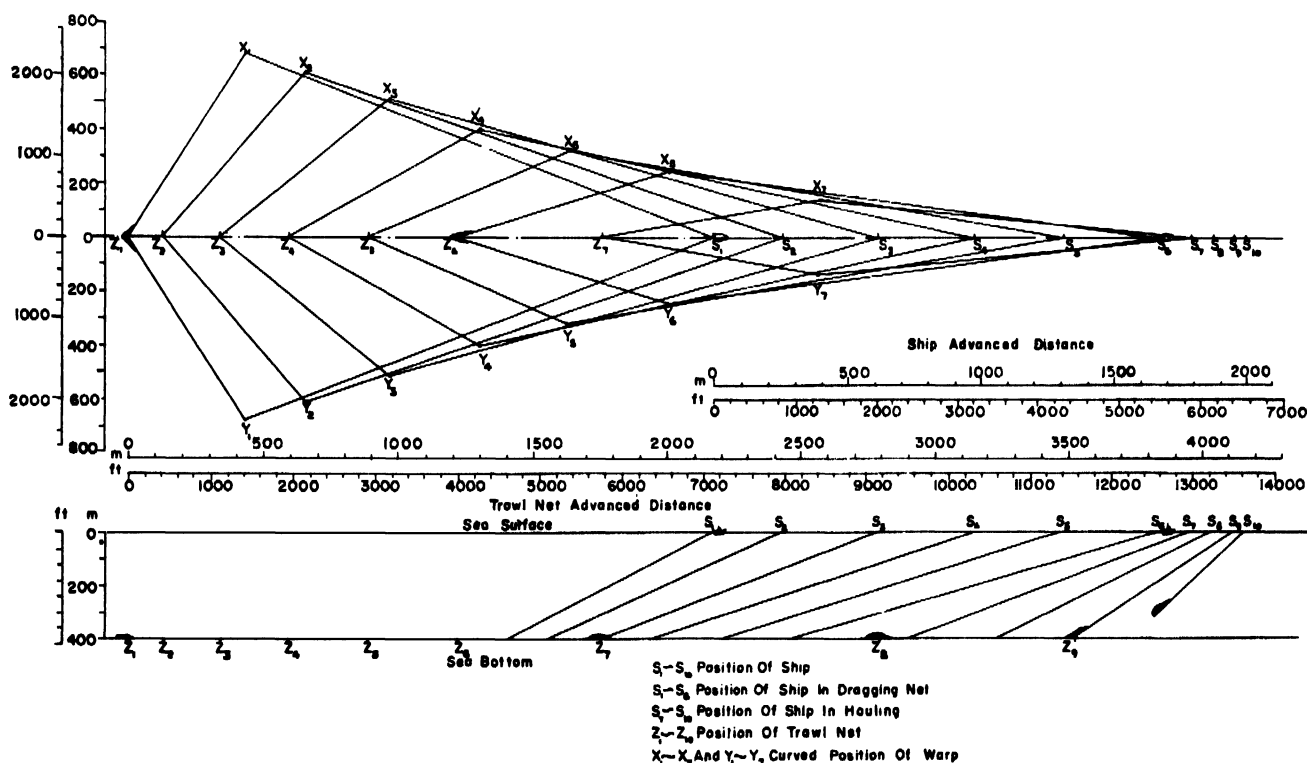
Fig 22. Movement of trawl net and warps is different from that of the Danish seine shown in fig 20

[603]

START TO PULL UP NET

UNTIE COD LINE & OPEN COD END

PULL UP NET

SETTLE OF NET IN ORDER TO NEXT CYCLE
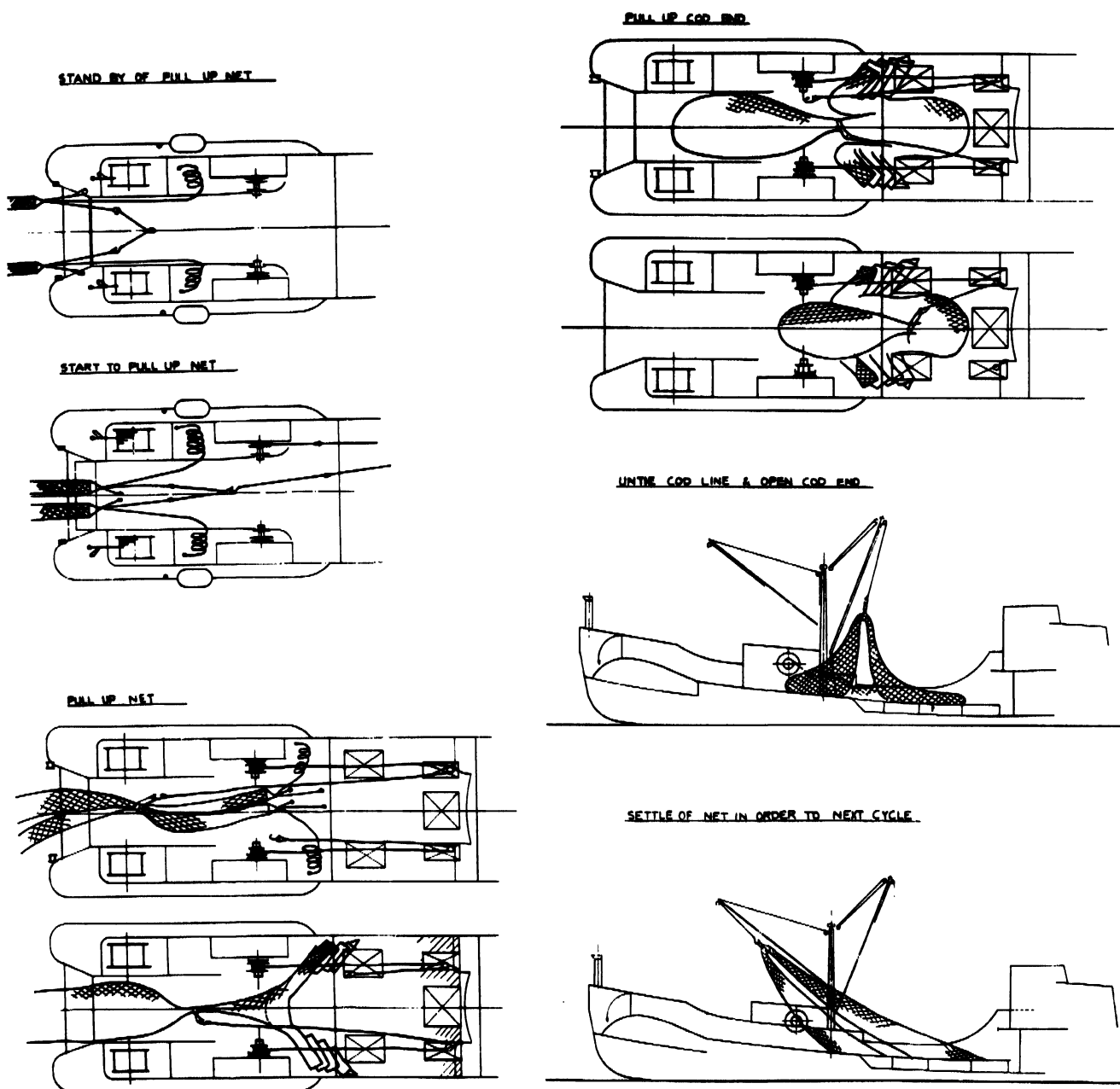
Fig 23. Hauling sequence of Japanese Danish seine

synthetic fibre outside with wire inside as a padding. In 1960, this arrangement was first tried and the improvement was completed in 1962. Compound rope costs twice as much, but lasts one year or more and is therefore economical. Another problem with using compound rope is that it is almost impossible to coil by manpower, and has to be wound by a reel, which has contributed greatly in saving time. Compound rope sinks quickly because of its larger specific gravity. This large specific gravity has another benefit in that it facilitates throwing the rope exactly to the point aimed at, which is especially good for deep-sea operation. Another merit is that 20 per cent more area can be surrounded by compound rope than manila rope. The use of wire rope was once considered, but its specific gravity was too large and it dug into the sea bottom.

Better hauling capacity

The improving of the hauling operation was undertaken and working over the stern has been found most advantageous. The difficulty of the Japanese-type Danish seining is that the wing nets are so long that some device to pull them up is needed. The first boat which tried stern operation was *Sankichi Maru No. 51* built in 1964. This boat 122 ft (37.2 m) Lpp, 300 GT, electric propulsion, was built for operation on the Bering Sea. Devices were originated on this boat to operate independently either the right or left hand side drum of the winch. This made seining possible, irrespective of the direction of wind and tide, because the adjustment of tension of warp at either right or left side drum was possible, and controllable pitch propeller was also used. The adoption of a bow thruster will add further improvement in the future.
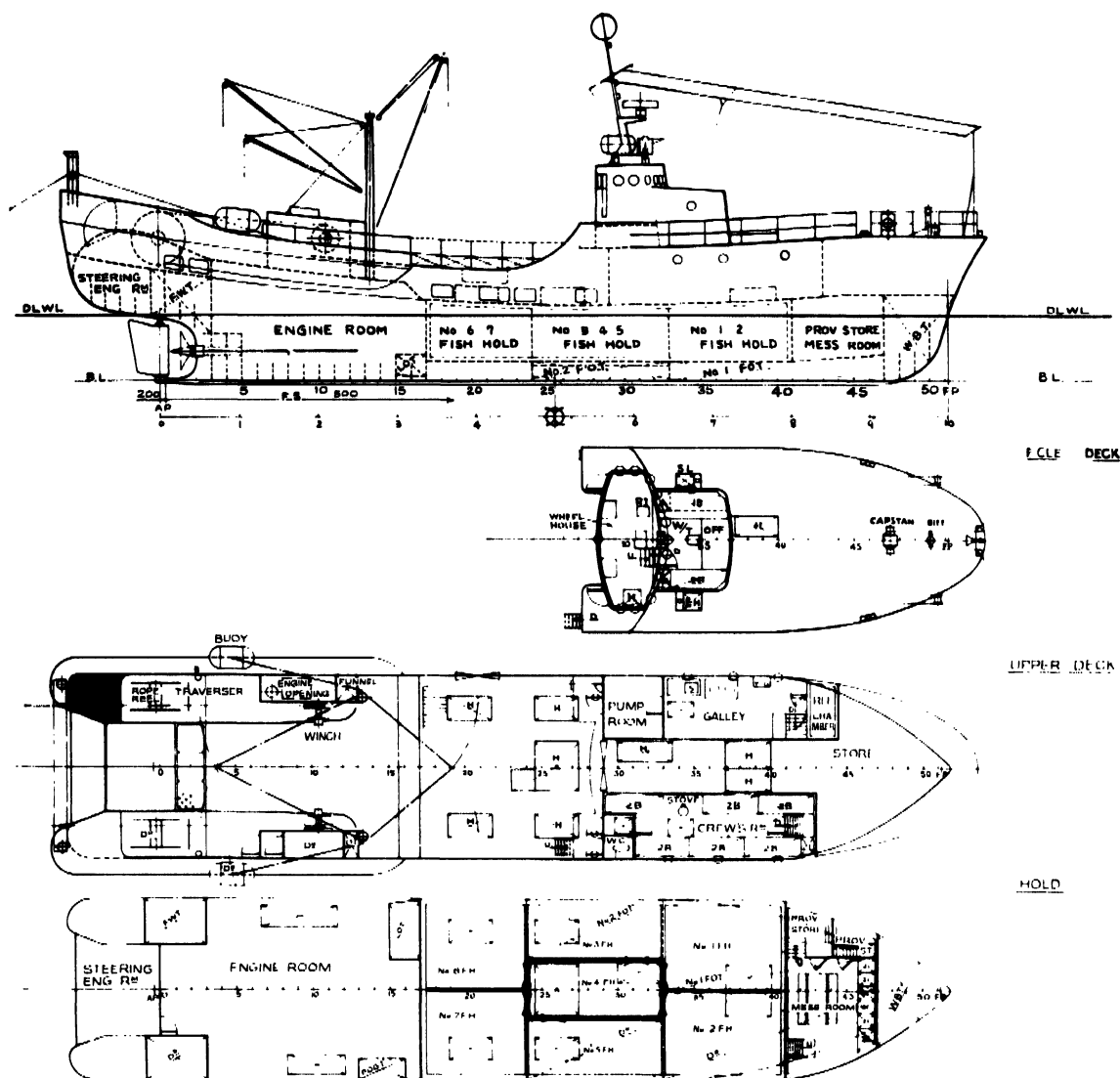
Fig 24. General arrangement of a Japanese Danish seiner

Because of the good results of *Sankichi Maru No. 51*, two other same-type boats were completed and three additional boats are under construction.

A somewhat smaller boat of the same type is shown in fig 24, *Sankichi Maru No. 51* has a long foc'sle type and has a ramp at the stern. There are many opinions about the advantages and disadvantages of installation of a stern ramp for such a small boat. In the case of otter trawlers, unigan type or system to pull up codend by derrick from the side of stern are used. However, in the case of this type of boat, the most effective way is the ramp system, which can take up to 15 tons of catch at once, which often occurs in the high season. Such an arrangement necessitates the increase of freeboard at the stern, raised deck over the engine room 2 ft (0.6 m) higher than the upper deck and top of the ramp 3.3 ft (1 m) higher than the upper deck. A removable door is installed near the top of the ramp. This door is remote-controlled from a safe place on the deck by a hydraulic unit. All these devices are designed for protection of the deck from

seawater and when waves still break over, the water will be discharged through a gutter; the water from the middle of the deck will be discharged from the scupper with sufficient area at the centre part of the bulwark.

Engine room layout

The propulsion engines are twin engines with one shaft so that they are used for main and auxiliary purposes. Another advantage of such engines is that the size is small. According to the general layout, it is possible to have steering room, fishery winches, reels, etc. at one place on the engine room, thus giving remarkably good convenience for the operation and maintenance. As the engine room is ideally installed at the stern, it is possible to make 3,450 ft^3 (98 m^3) of fish hold at the centre of the boat. In the waters near Japan, fish resources are rich, but market prices of fish are so low that large hold capacity is absolutely needed. Concentrating machinery in one place on board results in the saving of labour, which is most important under the present circum-

stances in Japan.The bridge is so made that both forward and aft of the bridge can be seen. The principal dimensions are as follows:

Loa	. . .	100 ft (30.65 m)
Lpp	. . .	85 ft (25.90 m)
B	. . .	20 ft (6.10 m)
D	. . .	8.2 ft (2.50 m)
d	. . .	7.3 ft (2.20 m)
Main engine	.	510 hp
Speed (trial max.)		11.5 knots
GT	. . .	96
Fish hold	. .	3,450 ft^3 (98 m^3)
Fuel oil	. .	950 ft^3 (28 m^3)
Complement	.	15
Built	. . .	September 1965

Operating methods

Details of the fishing operation are shown in fig 20 and 23. Fishing winches are installed at both sides of the stern. This means that with this arrangement, the long wing nets can be hauled up without being disturbed by the limited space on the normal deck arrangement. Fish are caught with the codend and hauled on to the upper deck at the bow side of the winches. Therefore, before finishing fish handling on board, one is able to prepare throwing or pulling up the net. Winches are installed on the entrance casing for the engine room, thus saving weight and space. Winches are driven by hydraulic oil pumps with a pressure of 2,000 lb/in^2 (140 kg/cm^2) driven by the main engine with a capacity of 2.5 tons/295 ft (90 m)/min, or 1.5 tons/400 ft (120 m)/min. Reels installed on both sides of the stern automatically wind up ropes coming from winches. The whole operation of the hydraulic winch is controlled electrically from the bridge. However, for the sake of safety, emergency stop can be made by the side of the winches. Load and speed of the winches are indicated in the bridge. It is expected that with this system the daily catch will increase by 30 per cent.

The main engine consists of two sets of 260 hp, 1,200 rpm diesels, a reduction gearbox and a controllable pitch propeller. The output at the propeller shaft is 510 hp at 360 rpm. In the front engines there are two generators each of 45 kW with reduction gear. Two sets of hydraulic oil pumps are similarly driven from the other side of the main engines. These machineries are all remote controlled from the bridge, namely: starting of engines, regulation of engine revolution, on and off of the driving clutch of propeller shaft, regulation of propeller pitch angles, various warning apparatus and watching arrangement. The steering gear is of the rotary cylinder type and is mechanically hydraulically operated and the whole steering angle is 90 degrees. The operation handle of the rudder is assembled with control panel of the engine. Rudder and controllable pitch propeller are operated from front and rear of the centre of the bridge, both starboard and port side. Capacity of the fuel stands for about two weeks' voyage.

Care of the catch

Until now most fishing boats of this size cooled fish with crushed ice. Only a few boats are equipped with refrigerators. Fish near the cooling coils get frozen, but fish inside are left unfrozen in the case of bulk storing. It has therefore been found that pre-cooling with brine of about 28°F (−2°C) is the most effective and economical method. To facilitate the cooling operation on deck, the brine cooler and two pumps are installed at the port side of bow foc'sle. The refrigerator is driven by a motor of 15 kW and is controlled from the bridge.

Loading and unloading the boat is undertaken by belt
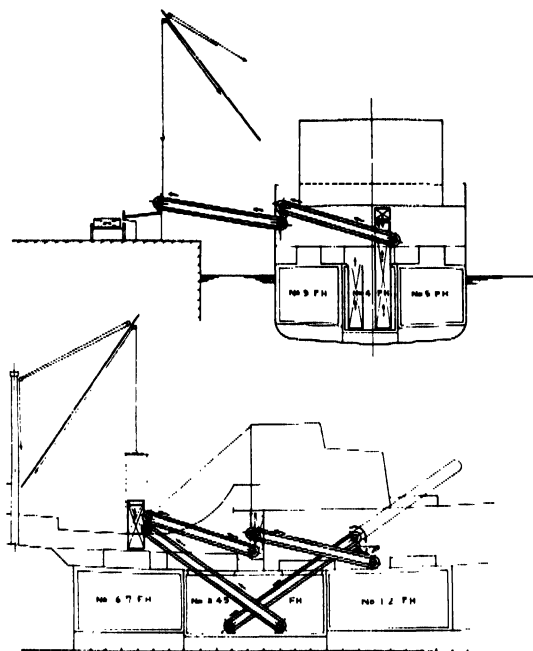
Fig 25. Belt conveyor arrangement of a Japanese Danish seiner

conveyors. No. 4 fish hold shown in the general arrangement plan is the conveyor room for fish unloading, and the conveyor arrangement at the port is shown in fig 25. Fish in a fish hold are flowing out from the hatch near the floor to the conveyor room and land automatically. This system is also available to store fish in fish holds during the fishing operation.

Finding the exact location of a boat is very important, not only for adequate voyage, but also for getting good economy efficiency while fishing. Therefore radar, direction finder, loran and a gyro compass are installed.

Steps in development

Birkhoff (Germany): When developing a new type of fishing vessel, there is normally the tendency to find first of all simple basic solutions and to advance step-by-step to more sophisticated solutions for vessels with increased main dimensions. Reid's paper shows, for example, purse-seiners, adapted to a certain extent to the requirements of stern trawling. After one decade of experience in the field of deep-sea trawling with large units of very sophisticated layouts, an effort is now being made to reverse this tendency.

In consideration of all advantages of the new successful larger type of vessel, the next effort is to grant the same advantages also to smaller types, which are used for midwater and inshore fishing. The aims, which should mainly be reached in this respect are:

(1) Gain in time for active fishing by decreasing the gear-handling time
(2) Extended mechanization of gear-handling
(3) Ability to catch at worst weather conditions
(4) Increased protection for the crew

With regard to the limited financial resources of the owners of these smaller vessels—sometimes in fact the skipper—the additional cost for a stern trawler, compared with the existing side trawlers, should be kept as low as possible. It should in fact be considerably lower than the usual 15 per cent which occurs with bigger stern trawlers.

Restricting to some extent the requirements of the above-stated items 3 and 4, it is possible to eliminate the whole

WHEELHOUSE

DIESEL OIL   NET+ROPE STORES   ENGINE ROOM   WET FISH HOLD   DIESEL OIL   FORE PEAK EMPTY   DIRTY WATER   FRESHWATER

STORES   ENG CASING   KAPTAIN

COOL PROV   GALLEY   MESSROOM   ENGINER + SPARE   OFF'S LAVATORY   DRY-ROOM   2 MEN   CONV BELT   3 MEN   OFF'S LAVATORY   OIL SKINS   DECK LAVA-TORY   DRY PROV   MATE + SPARE   3 MEN

DIESEL OIL   NET + ROPE STORES   ENGINE ROOM   WET FISH HOLD   DIESEL OIL   CHAIN LOCKER   FORE PEAK

Fig 26. 100 ft (30.65 m) stern trawler with ramp

shelterdeck, for instance, in case of no danger of icing up. During the last year, several single-deck stern trawlers have been built with only a partial tweendeck.

In consideration that the crew is accustomed to work on the open deck and, as a matter of fact, generally prefer this if the weather is not too bad, a step further was taken by introducing a new single-deck stern trawler type with an extended foc'sle, running into a light centreline bridgedeck, as connection to the sternramp (see fig 26). This centreline connection deck gives a certain overhead protection to the gutting area, which is at the same time protected to forward by the foc'sle. The latter one also contributes to the vessel's seaworthiness.

However, the demands of the above-mentioned items 1 and 2

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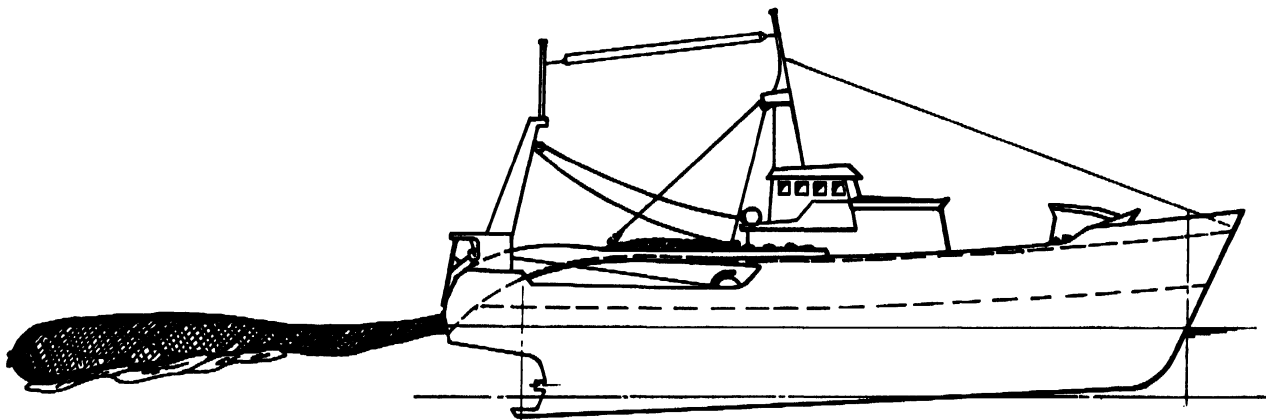
Fig 27. Final location of net hauling on 100 ft (30.65 m) stern ramp trawler
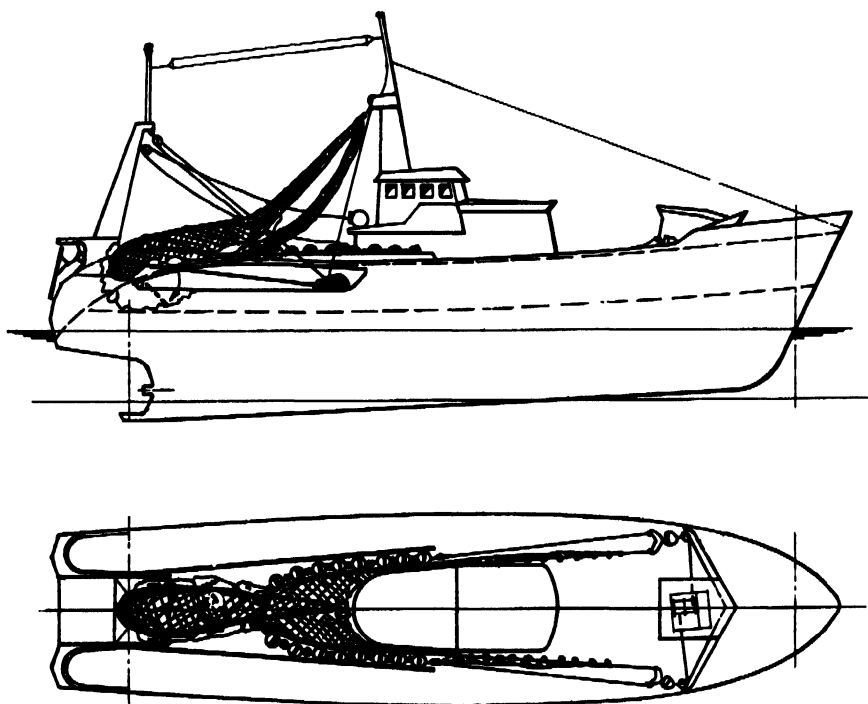
Fig 28. One pull brings the codend to the right position on the deck of 100 ft (30.65 m) stern ramp trawler

are met by using four-fifths of the ship's length for a single long pull of the gear on to the deck (see fig 27). Now, only one pull is still necessary to bring the codend on deck and deposit it in the right position for emptying it (see fig 28). Due to this way of operation, it is now possible to empty the codend into the ponds on maindeck within about 10 sec, depending on the weight of the codend.

Such a type of ship, with the dimensions of a middlewater trawler of 100 to 120 ft (30 to 36 m), opens up the possibility of using the heaviest gear, such as the 140 ft (43 m) bottom trawl with 18 or more heavy bobbins, like they are used on big German stern trawlers.

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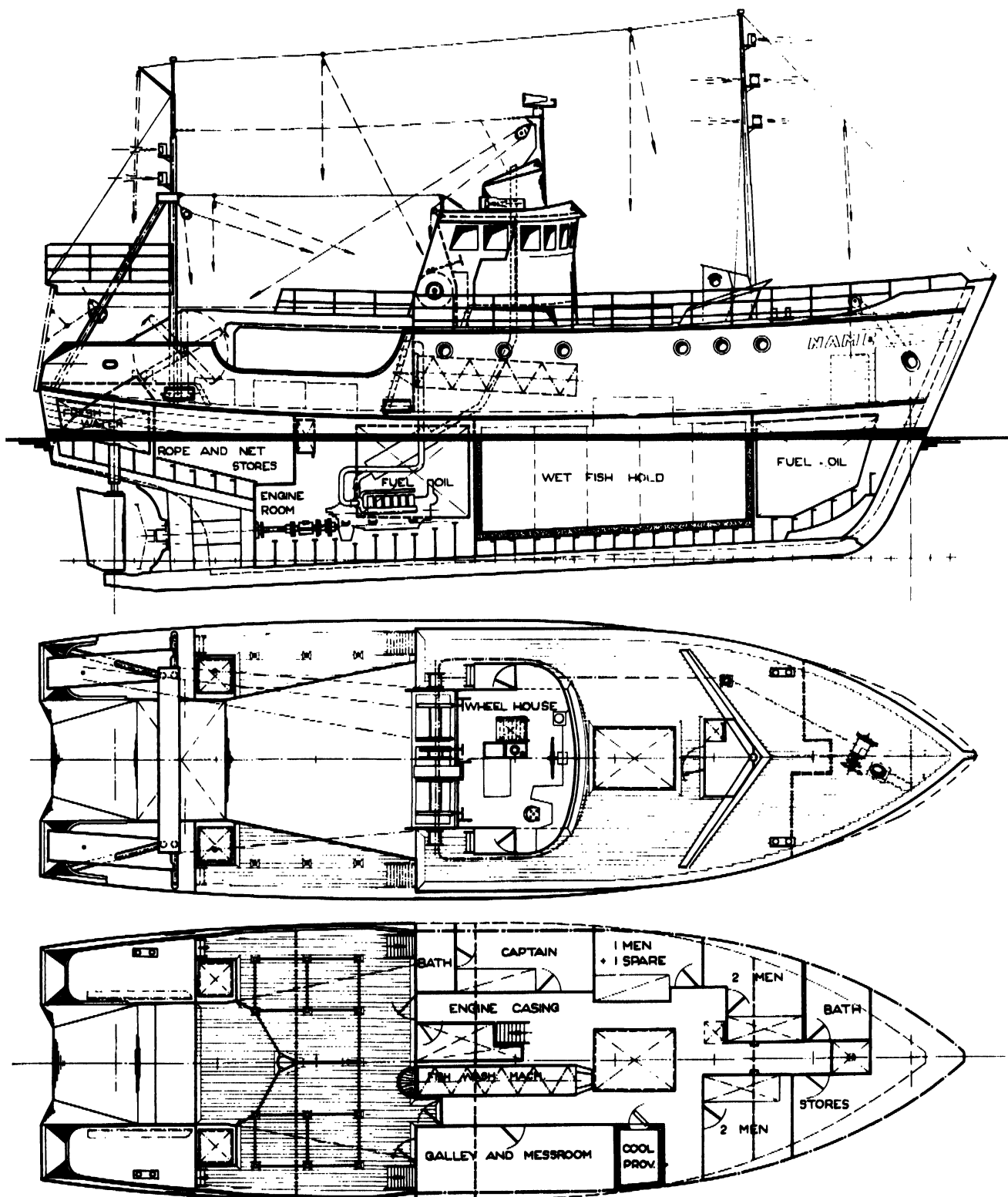
Fig 29. 80 ft (24.4 m) stern trawler with ramp

Loa	*79 ft (24.12 m)*
Lw	*72 ft 2 in (22 m)*
Lbp	*65 ft 7½ in (20 m)*
breadth	*23 ft (7 m)*
draught max with keel	*12 ft 5⅝ in (3.8 m)*
depth to main deck	*11 ft 5¾ in (3.5 m)*

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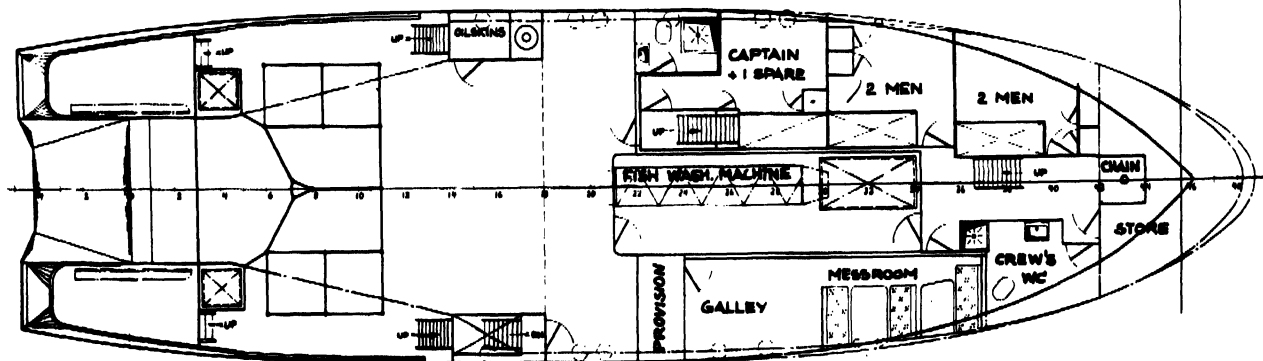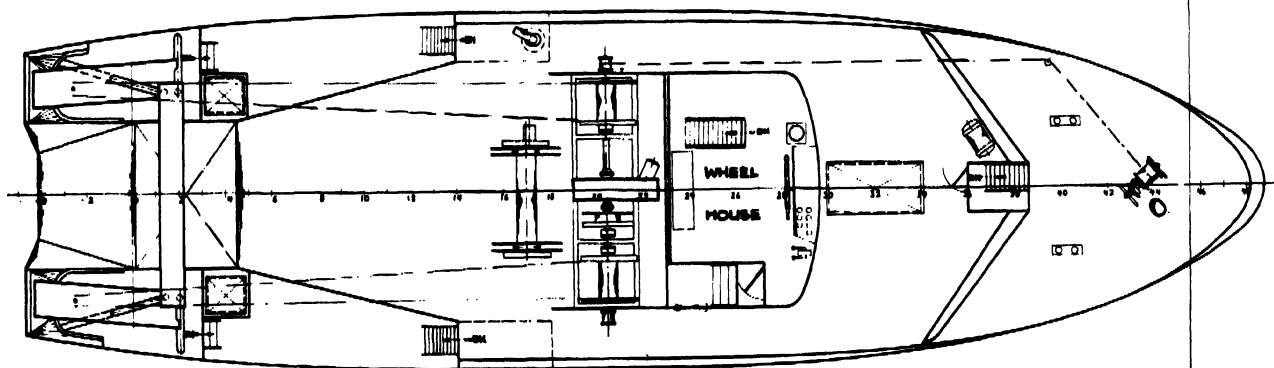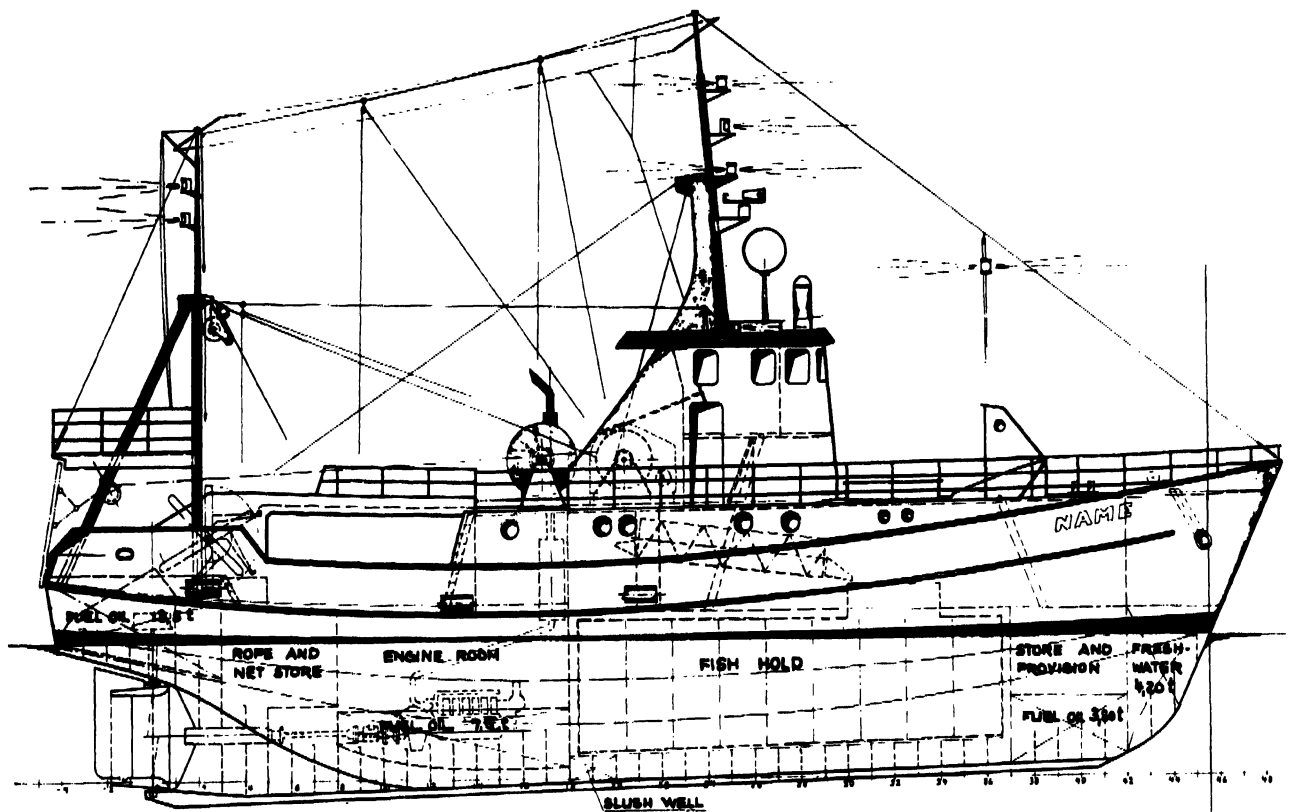
Fig 30. 90 ft (27 m) boat of steel construction

Same type for inshore and midwater vessels?

For the inshore and nearwater fisheries Birkhoff was trying to develop the same type of vessel, but using lighter trawl gear. Here, it seems to be advantageous to use the net-veer-drum system in addition to the existing trawl winch, or—a new task for the winch maker—a special trawl winch, eventually a split-type, which can coil up the trawl warps, sweeplines and net wings together. Furthermore, an opening at the forward end of the codend is proposed, which allows an emptying of the codend to forward, so that the length of the ramp can be regarded as part of the utilizable deck area. Thus, the codend is only hoisted onto the ramp and not the deck. A pivoted flap, forming the upper end of the ramp, tilts the codend to forward, spilling the fish into the culling and gutting checkers. When doing this, the aft part of the codend must be held by a rope which runs over the bipod post block. The forward-emptying of the codend by means of this tilting operation allows a very low block position which limits at the same time the height of the aft bipod post and consequently results in a light and cheap construction.

With an 80 ft (24 m) boat of composite construction and a 90 ft (27 m) boat of steel construction, fig 29 and 30 for example, these proposals can be realized. Here, a quadripod post is used, which has at the same time the function of a double-gallows aft. The pivoted ramp which is raised up into a vertical position during free running, forms a recess, which is provided with freeing ports on port and starboard sides, for the purpose of water drainage.

Comparing the small single-deck stern trawlers with ramps leading to the upper deck only, with the type proposed here,
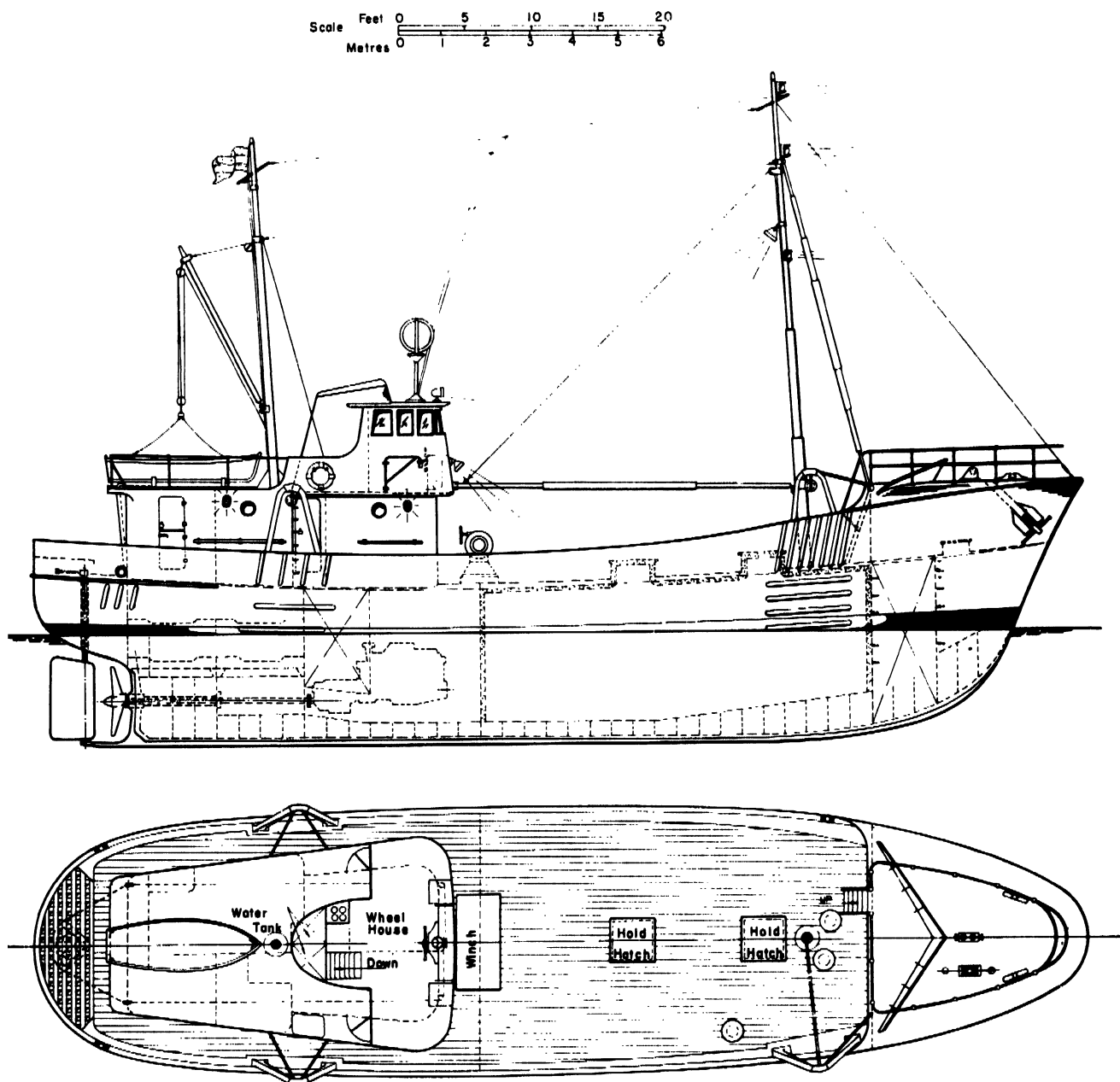
Fig 31. General arrangement of 79 ft (24.12 m) midwater trawler

the advantages regarding seaworthiness, gain in time, etc. when hoisting the trawl gear over a ramp up to the foc'sle deck level, are quite evident.

In consideration of future developments, it should not be forgotten that such a type of vessel offers many possibilities with regard to further mechanization and eventually automation.

Conditions in Argentina

Santarelli (Argentina): Argentina has a high consumption of red meat and it has become important to maintain, and even increase, the country's meat exports, which are one of the main sources of foreign exchange.

Fish is to be found in great quantity and variety off the long coastline of Argentina. In 1959 there were about 300 inshore fishing craft and about 20 trawlers, most of them of antiquated design. It became necessary to modernize the fishing fleet. A number of craft were built, most of them of steel. Although the country had experience in building wooden boats, it had practically none in the field of steel construction. Nevertheless, even this was fortunate in that rule-of-thumb practices (with craft built to no plans and with no preliminary studies) could be avoided and there could now be a technical approach to the problem, with the principles of naval architecture and boatbuilding practice as a basis.

In this connection, special mention should be made of the papers read at FAO congresses which have been of the utmost usefulness.

One point should first be noted, however, namely that catches have risen by something like 100 per cent over the last six years, and that an annual rise of 20 per cent is expected in the future.

At the present time, 40 distant water and middlewater craft are under construction. Since Santarelli had been personally responsible for the design of some of these, he referred briefly to their principal characteristics.

Fig 31 shows a middlewater type used chiefly for merluza trawling. Several of these were built between 1960 and 1964.

Principal characteristics:

Loa	79 ft (24.12 m)
Lpp	71 ft (21.70 m)
Moulded breadth . .	20 ft (6.06 m)
Depth of hold . . .	11.5 ft (3.50 m)
Mean draft	9.85 ft (3.00 m)
Displacement . . .	165 tons
Volume of refrigerated hold .	3,360 ft³ (95 m³)
Volume of fuel tanks . .	600 ft³ (17 m³)
Fresh water tanks . .	9 tons
Cruising speed . . .	9.5 knots

The hull is of steel; working deck of wood. The construction is of the transverse type, with welded joints. It has the Bureau Veritas certificate.

Type of lines

The lines are of U-type section and have a prismatic coefficient in the region of 0.60. The craft has a raking stem and a cruiser stern. Metacentric height minimum 1.4 ft (0.43 m). It has an excellent working platform and is easy to manoeuvre. Average speed during trials and in operation 10 to 10.2 knots; power 300 to 350 hp, depending on the engine installed. It is fast revving (1,200 to 1,300 rpm), four-stroke, single-acting and compressed air starting. Reverse/reduction gear with 4 : 1 ratio; the propeller is of the fixed-blade type. Water cooling, with heat exchanger.

The engine has a power take-off, with clutch transmission for driving the pump or the winch, depending on whether the hauling gear is hydraulic or mechanical. There is a 15-hp generator set. There are also pumps for bailing, fish cleaning,

fresh and sea water for use on board, and a standby compressor. Also in the engine room is located the freezing equipment (coolant: Freon 22) of 12,000 kcal/hr rating and an 8-hp electric motor.

The fishing winch has a low pressure 400 lb/in² (28 kg/cm²) hydraulic drive, otherwise it is mechanical. Capacity: 400 fm (730 m) of ¾ in (19 mm) dia. cable on each drum.

There is a boom capable of taking up to three tons, which is used for hauling the net. There is also a smaller (1-ton) boom for lifting the codend; when this is hauled in very full it has to be supported half and half by two booms.

Anchors are worked from hand winches or a train of rollers from the fishing winch. Steering is manual, the rudder being operated via chains and pulleys. Radio direction finder (fixed loop), echosounder and radio telephone. The wheelhouse also contains the controls for the propulsion engine.

Good crew quarters

The crew consists of 10 men. Effort has been made to ensure that the men have comfortable quarters, even within craft of these reduced dimensions. The craft have met with favour among fishermen. They work the year round, with 45 to 50 trips a year, depending on the distance of the fishing grounds.

The fishing craft shown in fig 32 is the largest built in Argentina to date, it was completed in 1964.

Principal characteristics:

Loa	115 ft (35.17 m)
Lpp	101 ft (30.90 m)
Moulded breadth . .	24 ft (7.35 m)
Depth of hold . . .	13 ft (4.00 m)
Mean draft . . .	11 ft (3.40 m)
Displacement	380 tons
Volume of refrigerated hold	6,700 ft³ (190 m³)
Volume of fuel tanks .	2,800 ft³ (80 m³)
Freshwater tanks . . .	18 tons
Cruising speed	11.5 knots

This craft is used chiefly for fishing merluza, but it has also achieved excellent catches of bacalao on trips totalling about 25 days.

The hull has transverse sections and is welded throughout. It has Bureau Veritas certificate.

The lines are of the double chine type with an ample deadwood at the stern to ensure adequate stability when under way. It has a raking stem and a cruiser stern. Metacentric height (minimum) 1.58 ft (0.48 m).

Tests have been made with a model of this boat. The velocity obtained (subsequently corroborated by experience with the actual craft) were 11.5 knots at 540 hp.

Main and auxiliary power

The propulsion engine, 4-stroke, single acting, has a 540 hp rating at 500 rpm. Starting is by compressed air. The engine is water-cooled, and has a heat exchanger.

The transmission has a 2:1 reverse/reduction gear. The propeller has four blades (fixed). At the forward end of the engine there is a power take-off, clutch-operated, for driving the hydraulic pump, which absorbs 80 hp.

Two auxiliary diesels, of 50 hp at 1,000 rpm each, have been installed to drive two dynamos (30 kw, 220 volts DC). One of these motors drives the bailing pump and a compressor, while the other drives a 240-volt battery charger for emergency lighting. There is a bilge pump for the engine room, others for fish cleaning, fresh and sea water, etc. A refrigerating unit of 15,000 kcal/hr rating (coolant: ammonia) driven by a 10 hp motor, maintains a temperature of 32° F (0° C) in the fish hold.

There is a low-pressure hydraulic fishing winch, with two
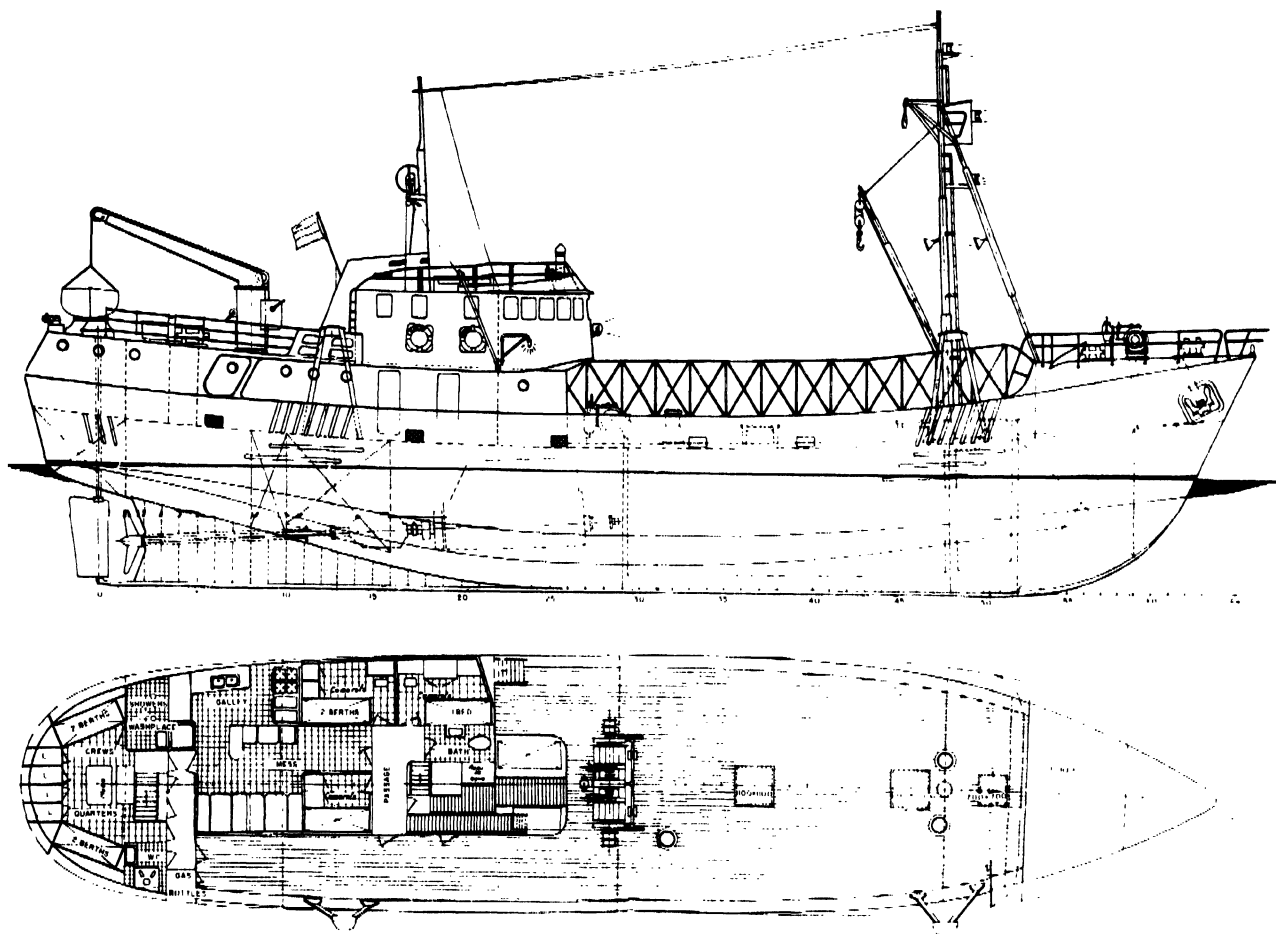
Fig 32. Layout of 115 ft (35.17 m) Argentinian trawler

drums, each with a capacity of 900 fm (1,650 m) of ¾ in (19 mm) dia. cable and fitted with an automatic guide. Within the hauling train itself there is a hydraulic winch for the anchors.

There is a mast with a crosstree to which is attached a pulley lifting up to 5 tons at a time and which supports a 3-ton boom. Over the wheelhouse a 1-ton auxiliary boom has been installed for handling the codend.

The rudder is manually and hydraulically operated. Navigational equipment includes radar and a radio direction finder (fixed loop). There is an echosounder and fish detector and a main and auxiliary radio telephone. In the wheelhouse there are also the controls for the main engine, and manœuvres can be directed from the bridge or from the engine room.

The crew consists of 16 men, who have good quarters, the galley and mess being particularly spacious and comfortable. The skipper's quarters consists of a sitting room, cabin and private bath. All baths on board have hot and cold water.

The craft has worked without interruption ever since delivery to the owners and has brought in excellent returns. The crew are very satisfied with its sea behaviour and with the modern conveniences with which it is equipped.

In late 1964, realizing the increased demand for fish and also the fact that the merluza was shifting habitat, being found ever farther away from the ports, the fishermen were anxious to have a craft affording greater range, although without being too expensive.

Type of vessel evolved

The appropriate technical and cost/benefit studies were undertaken, and from these there emerged a type of boat described below. Five boats on this design are currently under construction.

Loa	.	.	.	.	90 ft (27.45 m)
Lpp	.	.	.	.	78 ft (23.80 m)
Moulded breadth	.	.	.	21.3 ft (6.50 m)
Depth hold	.	.	.	12.5 ft (3.80 m)
Mean draft	.	.	.	10.6 ft (3.25 m)
Displacement	.	.	.	.	265 tons
Volume of refrigerated hold		4,770 ft³ (135 m³)
Volume of fuel tanks	.	1,360 ft³ (38.5 m³)
Fresh water tanks	.	.	.	9 tons
Design speed	.	.	.	.	11 knots

The hull follows the general lines of the craft just described, except that under the hold there is a double bottom containing four fuel tanks. It has a bulbous bow and a transom stern. Model tests were conducted in the tank of the Facultad de Ingenieria (Engineering School) of Buenos Aires, and results confirmed the estimated speed obtainable with a 400 hp engine rating. The minimum metacentric height has been calculated as 1.7 ft (0.52 m).

The propulsion engine will be of Argentine manufacture

and will have reduction gearing in the transmission, which also has a controllable-pitch propeller. There will be a main electrical generator and one auxiliary generator coupled to the propulsion engine (110 volts AC, 50 cycles).

The fishing winch (hydraulic or mechanical) will be able to take 700 fm (1,300 m) of ⅜ in (9 mm) dia. cable.

The crew will consist of 14 men, who will be accommodated in four cabins. The skipper's cabin has a private bathroom.

The rudder will be hydraulically-controlled and servo-assisted or controlled. Radar, radio direction finder, echo-sounder, radio telephone, etc., will be installed on the bridge.

In *Fishing Boats of the World:2*, page 684, Santarelli has described boats used in inshore fishing in Argentina.

Due to the rising demand for raw material for fish meal and for fish for human consumption, research was begun on a boat able to fish anchoveta (anchovy), caballa (mackerel) and other pelagic species, with ring nets, and merluza with trawls.

Stern trawler designed

From these studies a stern trawler gradually took shape and although it was not easy at first to overcome resistance from the fishermen to this innovation, they were won over in the end, so that there are now under construction three craft of the following type and four others of a very similar design. Principal characteristics:

Loa	.	.	.	.	64 ft (19.45 m)
Lpp	.	.	.	.	55 ft (16.86 m)
Moulded breadth	.	.	.	18.3 ft (5.60 m)
Depth of hold .	.	.	.	9.35 ft (2.85 m)
Mean draft	.	.	.	8.25 ft (2.52 m)
Displacement .	.	.	.	120 tons
Volume of refrigerated hold	2,500 ft³ (70 m³)
Volume of fuel tanks	.	335 ft³ (9.5 m³)
Fresh water tanks	.	.	.	2.5 tons
Design speed	.	.	.	.	10 knots

The hull is of steel and the deck of wood. The engine room is forward. Under the hold there is a double bottom containing four fuel tanks.

The lines are of the double chine type with a transom stern, which also has a ramp. The minimum metacentric height has been calculated at 1.57 ft (0.48 m). Model tests were conducted in the tank at the Facultad de Ingenieria of Buenos Aires, and results confirm that the design speed is obtainable with a 200 hp engine rating, reduction gear and controllable-pitch propeller. The auxiliary equipment described for the other craft will be installed and also refrigeration plant.

The fishing winch will be hydraulic and have a capacity of 350 fm (640 m) of ¾ in (19 mm) diameter cable. The rudder will be hydraulically operated.

The craft will have electronic navigation and fish-finding equipment. The crew will consist of eight men, who will have the necessary shipboard comforts, despite the fact that the craft is intended for short trips only.

A combination craft

Recently Santarelli had been asked to design a fishing craft for both trawling and 'atun' (tuna) catching. In Argentina 'atun' is fished for the most part by Japanese methods. It is first caught, then headed and, where desired, cut up on deck and then frozen. Construction has already begun to this design. Principal characteristics:

Loa	108 ft (32.92 m)
Lpp	96.5 ft (29.40 m)

Moulded breadth	.	.	24 ft (7.35 m)
Depth of hold .	.	.	12 ft (3.70 m)
Mean draft	.	.	10.6 ft (3.25 m)
Displacement .	.	.	.	350 tons
Volume of fuel tanks	3,000 ft³ (85 m³)
Freshwater tanks	.	.	.	16 tons
Estimated speed	.	.	.	11.5 knots
Designed power rating	.	.	550 hp

The hull is derived from that of the craft shown in fig 32. It will have a quick-freezing room with a capacity of 5 tons every 24 hours, down to −40° F (−40° C), and a refrigerated storage room at −4° F (−20° C).

It will have the Izui-type line hauler, an hydraulic winch for the trawl itself, an hydraulic powered block on the foremast, and windlass and capstans likewise hydraulically operated. The steering gear is hydraulically operated and servo-controlled. The craft will have radar, radio direction finder, radio telephone, echosounder, log and apparatus for measuring the temperature of the sea water, etc.

The craft described in this contribution are being built with help from the Argentina Government, which supplies credit up to 70 per cent of the construction costs, at low interest and with a fairly long repayment period. The Government also gives a subsidy covering approximately 20 per cent of the construction costs.

Improved scallop craft

Pross (USA): Recent design changes in the type and size of fishing vessels in the US New England scallop fleet have materialized as a result of severe competition from other countries.

The first scallopers were 30 ft (9.14 m) "cat" sailboats which used 3 to 4 ft (.91 to 1.22 m) drags. In the 1920's and 1930's, power draggers employing 5 ft (1.5 m) drags in the 65 ft (19.8 m) range came into being. From then on there was a continuing progression in the size and modernization of the scallopers. In the late 1930's and early 1940's, shucking boxes were added. By 1958, there were 70 to 80 boats in the New England scallop fleet, mainly centred about New Bedford, Mass. It was about this time that the Canadian scallop fleet expanded from about one or two boats to 90 with an average length of about 90 ft (27 m). In the last five years, the New England fleet has dropped to 30 boats. One of the reasons for this decline was that smaller vessels (about 73 ft or 22.3 m) could not stay out as long, therefore smaller catches resulted; also they were unable to operate in rough winter weather on the Georges Banks and therefore became non-competitive. This competition has resulted in the design and construction of steel stern scalloper/trawlers averaging 95 to 100 ft (29 to 30.5 m).

One such scalloper is currently being constructed under the US Fishing Fleet Improvement Act of 1964. The vessel is a single screw, steel, diesel-powered stern scalloper with raked stem, transom stern and multi-chine hull designed for stern scalloping and bottom and midwater stern trawling in the West North Atlantic fishing grounds. The inboard profile is shown in fig 33. The fish hold is located about amidships, the engine room forward of the fish hold and the crew's quarters forward of the engine room. The superstructure space forward contains the galley and messroom, crew's head, shower, staterooms and upper engine room. Living quarters for the crew include a ten-man foc'sle and one two-man room. A single stateroom for the captain and a double stateroom for the engineers are located in the superstructure. The pilot house and chart room are above the superstructure forward. The foc'sle, engine room, fish hold
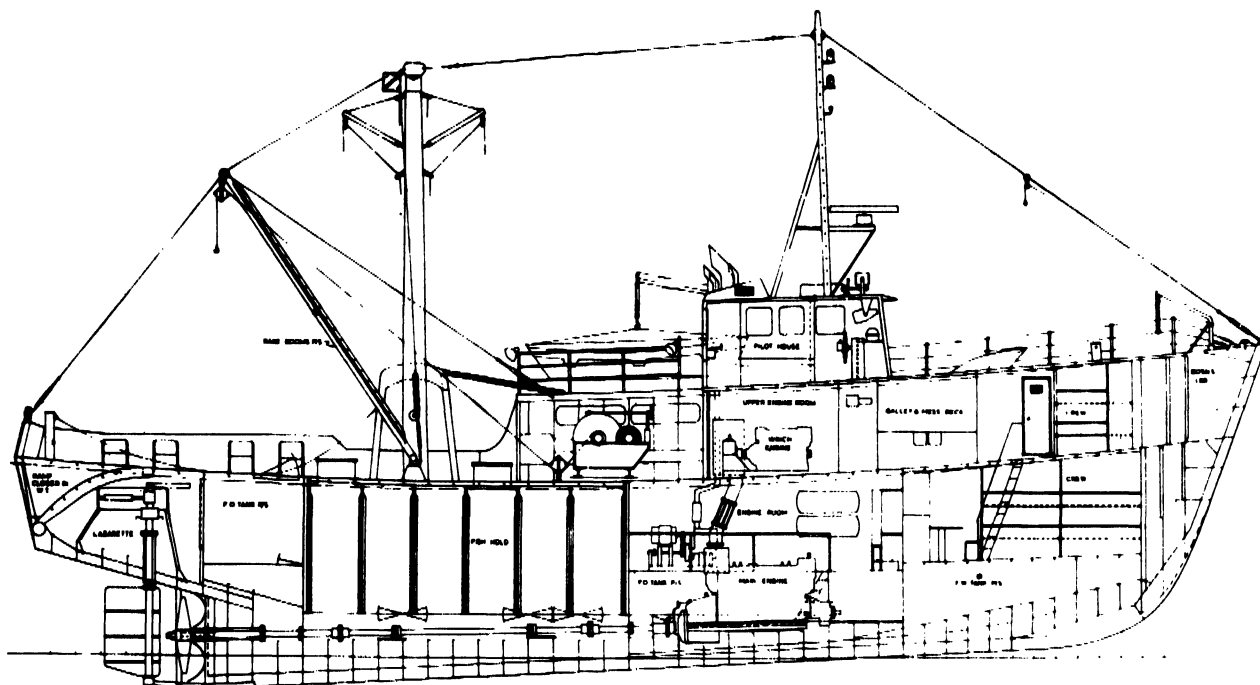
Fig 33. 100.5 ft (32 m) Loa steel stern scalloper

and lazarette are below the continuous main deck. The principal characteristics are:

Loa	100.5 ft (30.63 m)
Lwl	93.25 ft (28.42 m)
Lpp	84.0 ft (25.6 m)
Breadth . . .	24.37 ft (7.43 m)
Depth to main deck .	13.5 ft (4.11 m)
Draft, designed midships .	10.0 ft (3.05 m)
Scantling draft . .	12.0 ft (3.66 m)
Displacement, ready for sea	320 tons (325 ton)
Total power, continuous .	765 hp
Speed, trial . . .	11.5 knots
Radius of action . .	3,000 nautical miles
Complement—officers .	3
—crew .	12
Fuel oil	11,600 gal (9.800 Imp gal, 43.9 m³)
Fresh water . . .	3,000 gal (2,500 Imp gal, 11.35 m³)
Lub. oil . . .	250 gal (210 Imp gal, .95 m³)
Fish hold . . .	4,200 ft³ (120 m³)
Refrigerated stores .	100 ft³ (2.83 m³)
Weight of catch, at 40 lb/ft³	168,000 lb (76 ton)

Works from both sides

The vessel is rigged for scalloping over both sides of the stern. The scallop rake booms are mounted on the main deck. The rake booms are used in lowering outboard and hauling inboard the 16 ft (4.88 m) scallop rakes. The gallows consist of hinged steel weldments mounted on the main deck which may be swung outboard over the rail for towing.

The trawl warp (1 in or 2.54 cm) diameter plow steel wire is lead from the winch to sheaves on deck, to the trawl block on the gallows to the rake. The trawl winch is a four-drum diesel-driven model, each 27 in (.686 m) drum with a capacity of 450 fm (825 m). The drums are independently clutched to

a low-speed shaft by means of air-actuated clutches On each end of the winch, cargo winch drums are provided'from which the single part rake hoist is run. A 150 hp diesel drives the trawl winch through a fluid coupling, clutch reduction gear, chain drive and shafting arrangement. Four unloading booms with single part tackle lead to two single drum hydraulic fish hoists mounted on the mast legs. They are arranged to take out fish from the forward and after hatch.

After the rakes are towed for a pre-determined period, they are lifted up onto the deck and turned upside down. The catch is sorted on the deck. The scallops are taken from the pile on deck, placed in baskets and carried forward to the shucking houses. The stones are debris are shovelled overboard through the rock doors built into the bulwarks. The scallops are dumped into the shucking boxes where they are opened, the meat removed and then placed in the wash box. The empty shells are dropped in the space outboard of the shucking box, where they fall overboard through the shell doors. The meats are washed in clean sea water, packed in clean linen bags and stored in the fish hold in ice.

Many benefits listed

The arrangement and design of the new scallopers, with the mast, booms, gallows, etc., located aft and the trawl winch, shucking houses, etc., located forward, provide numerous advantages:

● Exposed working deck is more sheltered by extended superstructure forward, providing more protection for the deck crew handling the rakes and catch

● The pitching motion of the vessel is much less violent on the aft deck of a vessel, which provides a more steady working platform

● The above two advantages allow for fishing in more violent weather than is possible in the old conventional scalloper

● The increase in length of the deck working area will allow larger dredges to be towed, therefore providing a more efficient operation

[615]

- The shucking houses are not open to the weather forward as in the conventional scalloper. This provides the men doing the shucking much greater protection from the wind and sea. This area is also less subject to flooding from seas breaking aboard
- The steel boats can take a greater beating than the previous wooden boats
- The increase in length, depth and breadth have given an increase in freeboard, greater stability and provides for better handling in rough weather
- All machinery, living spaces and operational spaces are located forward. This allows the crew to move about from mess, galley, machinery spaces, wheel house and sleeping quarters without having to cross the open main deck, a wet and potentially dangerous area in bad weather. The galley and mess are no longer in the foc'sle
- An oilskin locker, open to the deck and to the quarters, allows the crew to enter from the deck in wet, dirty oilskins and boots, remove them for drying and enter in clean, dry clothes, without tracking sand and water through the quarters
- The wheel house arrangement allows the captain on the bridge to operate the ship from the auxiliary control station in the aft end of the pilot house, permitting full visibility of the fishing operation. The centreline located wheel house and all-round windows provide 360 degree visibility from any location in the pilot house. Day cabin is provided for the captain in the pilot house
- Ample space is provided for the later installation of new and improved gear, such as conveyors, automatic shucking machines, etc

A new fleet of US steel stern scallopers is slowly emerging on the scene. Competition has forced the way with the result that a new design and arrangement for this type of vessel has been developed. Operational experience will show if the new scalloper can hold its own in this competitive field.

Author's reply

Minnee (Netherlands): Dickson put up a very practical question about the trawl warps rubbing the aft rail.

Adequately decreasing the width of the rail aft and sufficient height of the blocks will prevent this. Cantilever gallows are necessary on this particular boat, leaving the bulwarks free for stowage of the beamrakes, but there is no problem of course in fitting a removable guard to prevent the door from swaying when hoisted over the rail. Besides this, normal V-frame gallows have the warps rubbing the aft leg of the V, when turning the boat. Going stern up in a heavy following sea should be avoided with a sterntrawler stern this should be restricted: "when weather permits".

Corlett wondered about the manœuvrability of fixed nozzles with normal rudders associated—it can be proved that there is no decrease at all. This system is used for different reasons: extra thrust by little and constant tap clearance, less vibration and maintenance of rudderbearings, constant thrust during pitching (no racing), excellent propeller protection and less propeller noise (mine sweepers are equipped with nozzles to protect themselves from acoustic mines).

Smettem asked whether warping ends are necessary with a 4-drum winch as now generally used. They are still very handy and until the winchmakers provide friction-clutched auxiliary drums of very light construction, most rope-handling can be done faster by means of warping-ends. Those imperfect 4-drum winches on multi-purpose vessels are still fitted for handling topping lifts of booms or top warps on 4-seam-trawls and for purse-seining.

For safety reasons, the man handling the warping ends will stand aside, so that there is no real need for space behind the end. On the Mexican vessels, the total pull on the mean drum's diameter amounts to about 4 tons. The sterntrawl method shown is conventional compared with sidetrawling today, where there is a minimum of mechanical installations, but all advantages of sterntrawling are achieved in tactics and deck-layouts.

No sterngate, nor hydraulically operated gantry can improve this, which is the reason why they are not used. However, there were a few problems to be solved, mainly in the guiding and holding of the swaying bag on a rolling and pitching vessel, referred in the paper as to guider frames and bag arrestor.

Reply to ramp advocacy

Birkoff is a strong promoter of ramps, but in Minnee's opinion most of his arguments for general application of ramps can be refuted by considering:

- The average catch per haul generally is small, say 4 tons (daily catch 25 tons) which can be shipped in two bags of standard construction netting. The real catches vary considerably on most grounds, which means, that more than 50 per cent are smaller and a few per cent are really high, causing extraordinary heavy strain on the gear and lifting equipment. The splitting method permits the use of light standard gear and moderate-sized equipment for handling each size of catch without risks of spoiling
- The space gained by omitting a ramp enables one to locate the wheel house further aft and give a simpler sternstructure with maximum safety and shelter for the crew without all kinds of mechanically driven flaps and doors. These neutralize in the cost of vessel and equipment, the so-called gain in operation time. When these are measured in split-minutes they sound good, when sitting in the office, but every fisherman knows, the heartbreaking efforts necessary to keep the gear going and the time involved in repairs. In theory the time benefits gained by a ramptrawler compared with the splitting system in good average fishing amounts to 15 minutes per day, which has no influence on timetables in which mending consumes, sometimes several hours, besides the risks of losing codends and fish and the shooting, which takes even more time with a ramp. There must be a very good reason for the particular choice of a ramp, in general, Minnee doubted it

Shimizu responds to queries

Shimizu (Japan): He was grateful to many people for their attention and study of his paper. Doust requested him to cite examples pertaining to unsuccessful combination trawler designs, but Shimizu would frankly mention that, apart from unsuccessful examples, they are continuing strenuous efforts in the following respects.

(a) A large deepsea trawler (factory trawler)

So long as it may be expected that large amounts of initial investment are required, it involves some risk to design trawlers specially fixed to a certain fishing ground. Therefore, for instance, in addition to operating in the North Pacific waters—the main fishing ground—the possibility of operating in African waters is also required. In this connection, there is no conclusive choice of kinds and lines of Baader system and proportional ratio between refrigerating holds and meal hatches, with the

result that some lines of Baader are useless; or there appear hatches full of meal, and on the other hand, the refrigerating holds are quite empty and vice versa

(b) Small sized trawler

It will be methodical to decide power of trawl winch and main engine after laying down the scale of trawl net beforehand. But in fishing anyhow, the net is apt to be larger. Consequently, it causes such a simple trouble as being unable to wind up, with the result that too great a quantity of fish is caught in a large net

(c) Lpp of trawler and waves

Tenyo Maru No. 3—a reconstructed stern trawler operated the fishery in the North Atlantic waters. This trawler was of 4,000 GT, 304 ft (99.8 m) Lpp. Satisfactory operations were unexpected in this water, due to the danger of the hull's intensity by panting in harmony with the waves. On the other hand, a stern trawler of 300 GT which followed *Tenyo Maru No. 3* at that time, had no fear of it. The *Tenyo Maru No. 3* is at present operating in North Pacific waters.

The above seems to suggest that there is necessity to design beforehand such a scale and type of vessel as will be in harmony with those wave lengths which may arise in the waters to be encountered

In reply to Cardoso, Shimizu said: block coefficients and midship coefficients are given in table 5.

TABLE 5

Block coefficients and midship coefficients of various vessels

Names of vessels	C_b	C_m
Taiyo Maru No. 61 . . .	0.649	0.947
(The same as *Taiyo Maru No. 51*)		
Taiyo Maru No. 65 . . .	0.678	0.945
Taiyo Maru No. 75 . . .	0.654	0.954
Taiyo Maru No. 81 . . .	0.651	0.963
Fukuyo Maru No. 1 . . .	0.680	0.942
Chuyo Maru No. 7 . . .	0.679	0.947
Zuiyo Maru	0.663	0.960

To Hatfield's comments Shimizu added that *Taiyo Maru No. 82*, built in 1964, is equipped with oil pressure tension meter just before top roller of gallows, that is, link mechanism system with top roller. In consequence, with no effect from warp angle, warp tension can be read in the control room fitted with an alarm.

Taiyo Maru No. 83, built in 1965, is fixed with deck roller between top roller and trawl winch, and strain gauge with an alarm is also equipped with utilizing it. In addition, automatic "off" mechanism of main engine clutch according to trawl winch torque is also adopted.

Handling the purse-seine net

Bardarson (Iceland): It is stated in Minnee's paper that when using the Icelandic system of purse-seining, it is needed to keep the vessel free of the net by a power skiff, bowthruster, active-rudder or other means. This is not exactly done in all cases. Only one Icelandic fishing vessel has until now been fitted with a bowthruster and active-rudder, and although most of the Icelandic purse-seiners do have a power skiff for emergency cases, it is only very seldom used.

It seems that it would be more difficult to use the method for purse-seining over the stern in bad weather and sea conditions, than the Icelandic method. The movement of the vessel is greater at the stern than amidships and when the

vessel is pitching, the seine net after closing could be at a rather small distance from the propeller (see situation (c) and (d) in fig 7 of Minnee's paper). Therefore the statement that rudder and propeller will counterbalance the pursing force of the winch might not be so advantageous compared with the Icelandic purse-seining on the starboard side. The statement that the fish are frightened into the net by the propeller sounds as a kind of wishful thinking. It is Bardarson's experience that it is wise to make the least possible noise with the propeller before the purse-seine has been closed at bottom. Minnee seems to consider stage (b) of fig 7 to be when the noise from the propeller would be useful to frighten the herring into the net. Here the net has not yet been closed at the bottom and excessive noise could very easily result in that most of the herring would escape under the net.

Regarding the statement that no hydraulic boom swingers are necessary, merely topping, this might be right, but the derrick would need some side guidance at its lowest point, during topping and at its highest point. These guiding wires or ropes would have to be varied in length during this operation. Therefore some equipment would be needed for that purpose which is not explained in the paper. It is stated that the rampless stern trawler has ample deck space to store two complete Icelandic seines —one deep and another shallow. Then there will not be much deck area left for herring on deck, and as this is only a 125 GT vessel, it is doubtful if it would be advisable to carry constantly two nets on deck, each weighing 7 to 8 tons.

It is stated that when brailing with stern to the wind, the whole system (ship and net) is in an equilibrium position. This might be so in calm weather and no sea, but if the vessel is pitching in heavy seas, there could occasionally be some disorder in the situation, and then the short distance from the propeller under the ramp and the net hanging into the sea abaft, it might cause trouble. The vessel concerned was completed in December 1963. It would be of interest to know if this vessel has been purse-seining with this method, and if so, what the experience has been.

Basic strain in drying up

Allen (USA): The basic problem in purse-seining is strain on the net during the last phases of drying up large catches before and during brailing. They have vessels of 54, 66, 73, 82 and 83 ft (16.5, 20, 22.3, 25 and 25.3 m) in length. The quicker motion of large vessels has resulted in substantially greater net damage and lost catches. Since the vertical accelerations of the stern are much greater than when lying beam to the sea, this proposed system may result in a serious problem.

A power skiff or bowthruster is necessary. However, the South African pilchard, Peruvian anchovy, US menhaden and Icelandic herring fisheries are all working without skiffs. Some of the fleet in Chile uses skiffs for towing, the major requirement for the skiff is to support the cork line during brailing. In certain fisheries, this would be essential for stern seining. Possibly several substantial booms not shown in the drawings could be used. Operating identical vessels in trawling and seining in South Africa, they had evolved a system of fishing similar to that used in Canada.

Reid (Canada): Complimented Minnee on an excellent paper. His proposed system of purse-seining seems to offer a simple and very inexpensive method of changing over. However, a seine skiff is probably necessary to make a fast set – particularly for tuna or herring—and Allan is right about the need for extra cork line buoyancy, and in addition to skiffs, it is quite common to use other fishing vessels to support the cork line.

A Canadian development is a somewhat larger storage

drum for purse-seining—the drum set being some 8 ft (2.4 m) diameter × 8 ft (2.4 m) long barrel—which will hold a 380 × 40 fm (700 × 73 m) seine and is used on quite small vessels of 45 to 55 ft (13.7 to 16.8 m) fishing with only five men, so efficient that the USA has outlawed the method.

Dual use of stern trawlers?

Birkhoff (Germany): An efficient stern trawler with ramp can also be used for purse-seining and the ramp will facilitate shooting and hauling the seine. Minnee's proposal of purse-seining can with advantage be used also on a stern trawler with ramp, the heavy purse rings could be wound up to the ramp's wavetrap or over the lateral stern bulwark. The bipod post could be provided with a powered block, which would deposit the voluminous seine on to the geardeck, where it would be ready for the next shooting operation.

There are some other interesting advantages in using a ramp trawler for purse-seining. For instance, such a vessel can use its own propulsion as compensating force against the pull of the powered block, and also for aligning the purse-seine when the fish in the wings try to press forward around the ship. When it is not advisable to pump out the purse, i.e. in case of bigger fish or different fish sizes, the time-consuming brailing operation can be avoided by using a kind of codend, recessed into the buntends of the purse-seine, which can be hoisted up the ramp like a chain one after the other (see fig 34). There should not be any problem in chasing the fish into these codend-shaped recesses. The fish, trying to escape from the purse, will certainly completely fill the recesses.

Pumping out the purse will take about one hour for 100 tons of fish. Now, in the proposed case, several of the mentioned bag recesses are arranged around the purse taking up, equally filled, say 10 tons of fish each. When trawl fishing, it takes about 20 seconds to hoist such a codend on to deck and to empty it into the checkers. Thus, supposing the seine gear of the discussed vessel is well adapted to the new way of operation, it should be possible to hoist such a buntend bag within 20 seconds as well. That means that the hoisting of 100 tons of fish of a purse-seine, which is filled in the proposed special way, would take less than four minutes. Of course, the

installations have to be well adapted to this quick boarding of the fish. A conveyor belt should help the continuously-working washing drum to transport the fish to the fishhold hatches.

Considering the seasonal employment of purse-seining and stern trawling, the somewhat higher expenses for a combination vessel should be compensated by the advantage of having a very seaworthy ship with highly mechanized standard of gear handling, which results in a considerable gain in active catching time, and consequently in a better catch result and profit for the ship.

The development of such a vessel, being not only a matter of the naval architect, presents at the same time a problem to be solved by the gear specialists and trawl manufacturers. Thus, suppose there is a good co-operation among these people concerned, it is likely that such a vessel will be developed in the not-too-far-distant-future.

Minnee replies on seining problem

Minnee (Netherlands): Bardarson mentioned that power skiffs on Icelandic boats are not necessary to assist the operation, which is true and therefore it is already a big advantage over the Pacific method. But the Icelandic boats have very little similarity with stern vessels, which was the aim. Referring to the remark on net stowage and space for brailing, Minnee's idea was to drop the fish just behind the sternrail on a chute or tunnel leading forward. The net can be stacked right over this tunnel so that no storage space is lost. To brail-out the sacked-up net takes only 10 to 15 ft (3 to 4.5 m) of length of net in the water, which can be enlarged by using a spreader boom. Corlett and Smettem also asked for more details about the brailing operation with a topping boom.

Minnee admitted that the sketches in the paper are rather simplified and do not show the guider frame usually fitted in, which the gilson and other wires are led in a strictly longitudinal direction, no matter the rolling of the vessel. This avoids guys of variable length, boomswingers, etc., while the topping is by auxiliary winch-drums.

Transferring the catch to a carrier-vessel however should be done in the usual way.
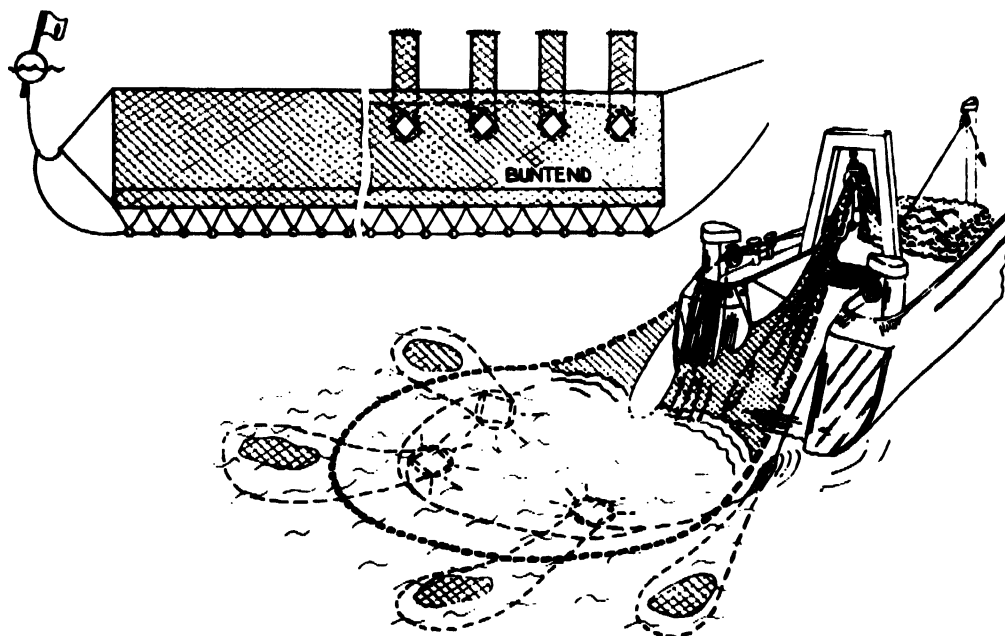
Fig 34. Purse bagging by a recessed bunt-end

The aforementioned guiderframe may also support the corkline, another reason for omitting the skiff.

Allan mentioned this and the problem of the accelerations at the stern. Here the same precautions have to be taken as side seiners turn their stern into the swell; sternseiners therefore should probably turn off the swell. This proposal is really not more complicated.

The escape of fish during the pursing period has been the subject of different precautions. Tuna boats throw "cherry bombs" to frighten the fish back into the purse. Icelandic fishermen have tried to hang a "barrier" from the starboard side of the vessel, why could not propeller wake do something worthwhile in this respect?

COMBINATION FISHING VESSELS

Gléhen (France): Fig 35 shows a type of boat which has spelled high returns for the seafolk of Brittany. This is a wooden combination boat, working shellfish (crayfish, lobster, and crab), but which can also engage in tuna long-lining and trawling. The boat has a very high initial stability because its centre of gravity is very low by reason of the water contained in the fish well; GM – 4.5 ft (1.39 m). The water in question does not have a free surface effect as is evident from the plan.
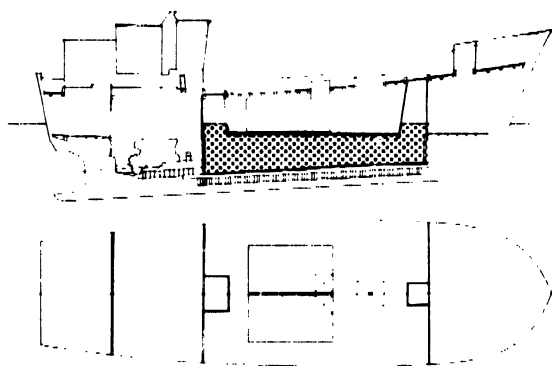
Fig 35. Arrangement to decrease surface effect

The craft also has great stability of form because it has flat longitudinal sections, a high freeboard and a very high prismatic coefficient (0.68) and a large beam (rolling period 4.5 sec). In the well, the shellfish can be kept alive for several months without the water having to be renewed mechanically.

Intensive shellfish gathering off the French coast has depleted the area; but this has only meant that the fishermen have built bigger boats and have repeated the process outside the territorial waters off Cornwall, Ireland, Morocco and Portugal and in the Mediterranean. As if that were not enough, they have built bigger boats still—up to 115 ft (35 m) in length, though still in wood—and they have gone as far afield as the Arguin banks off Mauritania and even to the coasts of Brazil and Honduras, where crayfish are very abundant and scarcely exploited, but they have been chased away. The waters off Angola, Brazil, Honduras, Madagascar, Mauritania, Senegal and elsewhere represent a veritable gold-mine. Small boats will be adequate because shellfish are taken very near the coast.

Wells are of delicate construction. As many as 400 stoppers may be needed for fish wells to ensure complete watertightness. Certain precautions have to be taken with the shellfish in the well. They must be prevented from killing and devouring each other.

Marketing poses no problems. All the wealthier countries are ready buyers, since shellfish are a great delicacy. Air freight is minimal when set beside the selling price. Paris takes deliveries of live lobsters from Canada and live crayfish from South Africa. One importer has installed at Orly Airport a fish tank capable of keeping up to 11,000 lb (5,000 kg) of live shellfish for several months at a time. The example could be followed in all parts far from the sea.

Active building in USA

Whittemore (USA): Blount and Schaefers make reference to the construction of combination vessels in the US Pacific Coast. In recent months, there has been stepped up activity in the construction of fishing vessels in this area. A number of vessels are being built in the 70 to 100 ft (21 to 30 m) overall length size, primarily for the king crab fishing with pots and carrying the crab live in circulating sea water in the fish holds. Some of the vessels are for single purpose king crab fishing, some are for combination king crab and trawling, and others are being considered for combination king crab fishing and chilled seawater salmon packing. In the latter case the vessel would operate in the king crab fishing in the winter time when it is most profitable and in the carrying of salmon in chilled seawater from catcher boat to cannery during the salmon runs in the summertime.

The use of bar keels to effect roll dampening, as suggested, has been considered necessary on small vessels, especially where draft is no limitation, not only to effect roll damping, but to provide directional stability of high displacement to length vessels as well. However, the keel should not be simply a single vertical plate. Rather, it should have a flat bar set horizontally, running the full length of the vessel's keel. This provides added strength, additional roll dampening, and prevents damage to wooden keel blocks when the vessel is dry docked. Sometimes the centreline keel is fabricated as a box keel rather than as a single plate keel where it is desired to take advantage of the steel surfaces to provide keel cooling for the main engine or auxiliary engines and avoid the corrosion and maintenance problems of heat exchangers.

In the case of shallow draft vessels where there is no room for a keel below the plating on centreline, it is suggested that side skegs approximately a quarter beam of the vessel from the centreline be used in order to provide roll damping and directional stability for the vessel. The centreline keel is of more value than bilge keels. This is especially true on fishing vessels which handle gear over the side. In such cases, the bilge keels can cause damage to the fishing gear and the bilge keels themselves are subject to damage.

Year round fishing activity

Hovart (Belgium): The general aim of the construction of combination vessels is to obtain maximum utilization of the vessel throughout the year. Generally speaking, the fishing season of the Belgian coastal and near midwater fleet is as follows:

● From March to October is the season of beam trawling for shrimps
● From October to March is the season of the sprat fishing and the spent herring fishing
● Throughout the year some ships use, however, bottom trawling

The fishing operations are very irregular, and as a reconstruction of the coastal and near midwater fleet was planned, the question was raised if it could be of economic interest to apply on the same vessel different fishing methods. With the combination vessels it will be possible to do so—to increase the fishing intensity and diminish the uncertainty of supply.

Interesting category of craft

Gueroult (France): Multipurpose or combination boats, i.e. those engaging in more than one type of fishing, make up an

interesting category of craft and one correspondingly difficult to discuss. It is only natural, with the failures of the past, that the general view should be somewhat pessimistic, and people's caution is justified. The failures have been due largely to attempts to make the side trawler capable of performing two jobs at once—which is simply accumulating incompatibilities. The fact remains, however, that Scandinavian vessels have nearly always used both trawling and Danish seining methods. Nothing could be simpler than those boats with their dual-purpose deck gear.

With an afterdeck free of obstructions and with a reasonable programme from the owner regarding the use of the craft, there is no difficulty in combining bottom and surface fishing. Longlining can always be added, though not, of course, Japanese tuna longlining methods, which call for considerable deck gear and a large crew.

A combination boat is conceived before all else for fishing different species at different times of the year, and for countries where fish resources are not over abundant. In either case it is a question of economic necessity. Boats that can be used for both stern trawling and tuna seining are also giving satisfactory results. If the emphasis is to be placed on one type of fishing rather than the other where deck gear is concerned, bottom fishing would have a slight priority over surface fishing. At all events, the combination boat will always be, technically, something of a mongrel.

Technical and economic problems
Hildebrandt (Netherlands): The naval architect and the economist have different ways of thinking. The naval architect is especially interested in studies of one or more separate parts of the vessel and its auxiliaries and has to build what the fisherman wishes. The economist is rearly only interested in the whole of the boat and especially maximizing the profit of it. The vessel is not his aim, but the profit. Now, in the Netherlands, studies of costs and earnings have taught that it is in general impossible to reach maximum profits with combination boats. Therefore, specialize! The combination boat is many times a vessel of yesterday based on irrational feelings: it is run with the hare and hunt with the hounds. The specialized boat is an optimal ship based on rational calculations: the vessel of tomorrow.

De Wit (Netherlands): The problem of combination boats cannot be solved in the simple way Hildebrandt points out. Though he does not state clearly which fishing methods were combined, he probably has in mind Netherlands fishing vessels combining herring drift-netting and herring trawling. The requirements for these fishing methods differ so much regarding the number of crew and engine output that Hildebrandt's statement might be true for a compromise between these two specific fishing methods.

Nevertheless, there are many successful combination boats in the Netherlands. The small trawlers of about 80 ft (24 m) length were originally built for bottom trawling for bottom fish. Now they are generally beam trawling with double-rig for bottom fish and can very easily switch over to pair-fishing for pelagic fish. The engine output, the crew and the fish-hold capacity suit these different fishing methods very well.

Therefore a combination fishing vessel can be an economic proposition if the requirements for the fishing methods to be exercised cover each other for a big part. On the other hand a contradiction between these requirements is no sound base for a good overall economy in most cases.

Main problem is the catch
Minnee (Netherlands): It is generally true that combination boats are not very good in many respects. Naval architects

should never cease their efforts to improve these boats because combination vessels in many cases are the only way to make fishing economical. The Norwegians, for example, have great peaks in their fishing seasons and to make the best of it, they have to use different kinds of fishing gear at different times of the year. Reid's paper encourages continuing with combination vessel design.

The aim should be to obtain optimal solutions both ways, not to result in a sterntrawler with an unsatisfactory layout for purse-seining or a purse-seiner with a poor arrangement for sterntrawling. The main problem often does not lie in the fishing, but in the preservation of the catch, different species in different seasons.

To carry on with combination vessel design, it is meaningful enough to try this system in order to obtain optimal solutions both ways, not to result in a stern trawler with an unsatisfactory layout for purse-seining and a purse-seiner with a poor arrangement for stern trawling.

The main problem does not lie in the fishing, but in the preservation of the catch. Transferring the catch to a carrier vessel alongside cannot be done at the stern, of course, and most likely should be done in the usual way.

Specialized proposals
Toullec (France): Small craft engaging in stern trawling and seining should have a clear working space aft. The most commonly used layout, accordingly, has the propulsion engine and crew's quarters forward. In Toullec's proposals, fig 36 has the engine installed aft, yet leaves a sufficient area of clear deck available. The accommodation space is well out of the way and, also, there is a sheltered place for handling the fish. The proposed design exploits these possibilities to the full by keeping a large space aft of the engine room unobstructed. This results in a greater improvement in the crew's comfort and more working space, greater safety and efficiency—characteristics which go together.

In this way the main winch can be driven by the propulsion engine. The winch itself is placed slightly to port, giving more unbroken working deck. A variant of this principle consists in having a winch with two separate drums, controlled from the bridge, and standing in more central relationship to the shelter deck. The wheelhouse is placed centrally, thus affording a view of all fishing operations, as advocated by Roberts.

Accordingly, the general layout, when all is said and done, is of very low cost. The boat described, being intended for the smaller fisherman, is kept within the latter's financial means by the specification of simple gear, not by reducing hull dimensions. For the same reason there is no call for large fish holds, the latter to be considered appropriate for smaller craft subsequently enlarged to benefit from advantages other than that of a larger fish-hold capacity.

Coming now to seakindliness, this design is based on similar trawlers working the difficult waters of North Western Europe in winter. The experience there gained makes it possible to build in a minimum reserve of stability to counter the heeling couple due to wind and fishing gear (care must be taken not to exceed this couple, which has a different value for each size of boat, if the desired seagoing qualities are to be assured. Here = 16 tonm, (under the French regulations of 8th February 1962). A good multipurpose boat is only possible above a certain size.

Safety considerations call increasingly for high freeboard aft and yet, at the same time, a well-immersed afterbody and a smooth form in order to mitigate the effects of buffeting when the craft pitches. Rudder and propeller should not be too far aft in order to avoid fouling the trawl; practice shows that placing them a small distance forward suffices. Balanced afterbody, depth and sheer are all bound up with one another

Main deck

Lower deck
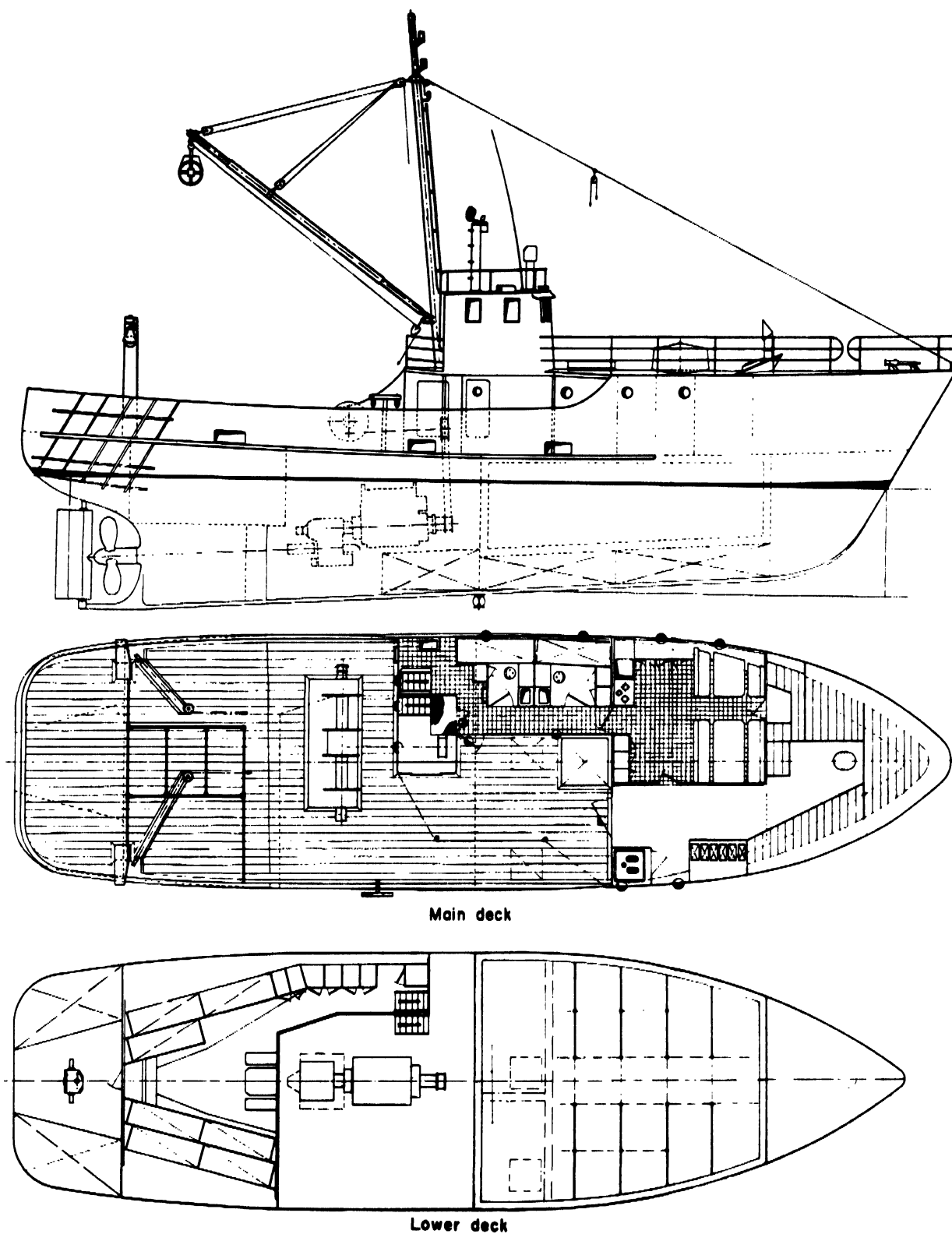
Fig 36. French combination trawler seiner with the following dimensions:

Loa	78.7 ft (24 m)
Lbp	68.8 ft (21 m)
B	21.3 ft (6.5 m)
d_{muz}	10.2 ft (3.35 m)
Volume fish-hold	2,470 cu ft (70 m)
Volume fuel-tanks	920 cu ft (26 m)

and govern satisfactory design. Contrary to what was the case with certain early stern trawler prototypes it is with a good depth of hull that the best compromise can be obtained.

Deck layout and the possibility of installing two fish holds means that the craft can engage in more than one type of fishing, though, clearly, it can never be perfectly adapted to all types. Working plans for each mass production series should allow for the various types of operation anticipated, e.g.:

trawling, seining, short trips (no special fish holds)
tuna, lining and seining (fish holds—live wells)
longlining, trawling for bait, shrimping, etc.

Where the craft is used only as a trawler, the shelter deck could be prolonged aft and the part between decks closed off with a metal door, thus providing a fish processing room.

Small craft must work in all seasons

Barthoux (France): Small-scale fishing is before all else seasonal, and the boats and gear employed are of all shapes, sizes, tonnage and power rating. If it is, first of all, to survive, and in the second place, to develop, the small-scale fishing sector must keep abreast of the economic situation and technical progress and take advantage of all the improvements introduced in the last few years. Most of all, fishing must no longer be seasonal and should be converted to standard bottom trawling, though without abandoning during the high season, fishing for migratory species (tuna, sardine, sprat, etc.). Accordingly, for small-scale fishing, what is needed is a combination boat, i.e. a trawler/seiner which can engage, without undue difficulty, in other types of fishing (fishing with live bait, dragnetting and longlining).

It is with these considerations in mind that the Ministry of the Merchant Marine, wishing to enhance the productivity of small-scale fishing, has sought, as part of a plan for a rehabilitation of the country's fishing economy, a design for a combination boat suitable for mass production in the country's shipyards. The characteristics of these boats have been arrived at after taking into account the wide differences in the financial means of fishermen, in port installations, and in the customs prevailing at different parts of the coast.

A preliminary study showed that France's small-scale fishing sector needed boats of much the same type, but having different dimensions and engine ratings, with hull lengths ranging between 52 to 100 ft (16 to 30 m). In 1962, accordingly, the Ministry announced a contest, inviting the country's shipyards specializing in small fishing craft to submit studies for such a boat, and also designs for trawler/seiners of one or other of the following classes:

length overall 52 to 92 ft (16 to 28 m) (wooden or
steel hull)
length overall 72 to 79 ft (22 to 24 m) (wooden or
steel hull)
length overall 85 to 92 ft (26 to 28 m) (steel hull)

All these were to be prototypes of stern trawlers so that no modifications would be required for their use whether as trawlers or seiners. The shipyards were informed that the designs would be awarded prizes in accordance with their technical worth, and also that they would be made available to fishermen desirous of having one or other of these types built. The contest benefited the small-scale fishing sector doubly in that boats could now be standardized—with the advantages of mass production and the correspondingly lower unit price—and, secondly, the experts would not have to pay for the studies thus made available.

Collected designs helped progress

Designs and related documents submitted by the various shipyards taking part in the contest have been condensed in a handbook brought out by the Central Sea Fisheries Committee, representing fishing boat owners. The publication has had wide circulation and has proved a valuable source of information in the development of small-scale fishing in France. Ever since, the trend has been towards the construction of trawler/seiners having steel or wooden hulls and stern fishing arrangements. Nevertheless, many matters remain to be finalized before it is possible to decide on the best system of stern fishing on small trawlers.

Fishing boat owners, convinced of the need for a combination boat and of the efficiency of stern fishing methods, for enhanced safety and workability in that the crew are sheltered from the elements, are joining forces with the shipbuilders in research on the best type of gear to introduce. Stern hauling on small trawlers will probably always mean shipping the net in successive lifts using tackle fixed to the rear mast, leaving the remaining lengths of the trawl in the water, since there is no room to instal a hauling ramp. Nevertheless, better hauling gear will certainly be devised. Equipping small trawlers for seine fishing is likewise progressing. The use of the powered block is gaining ever wider popularity, though seine and trawl winches are being combined in order to save space and weight. The most widely used system is the two-drum trawl winch, together with a capstan with one vertical and two horizontal warping heads, the entire mechanism being belt-driven, via a clutch, by the propulsion engine. With this system, the handling of the purseline and hardening up of the seine still remain manual (over the warping heads).

With purse-seiners, experience has shown that when fishing for tuna, it is sometimes necessary to complete setting and hauling operations within something like ten minutes. French manufacturers have therefore developed a three-drum winch (two for the purselines and one for the warp), powered, via a clutch, from a central hydraulic drive and thus of very flexible control. On these criteria, a combination winch is being developed that will have three drums, two of them being used for both trawling and seining, the third exclusively for completing seining manoeuvres.

The Ministry of the Merchant Marine is currently having constructed a 105 ft (32 m) research vessel, equipped as both trawler (stern type, without hauling ramp) and as seiner. In addition, there is a one-drum winch, likewise hydraulically operated, for hauling the tow wing of the seine. A hydraulically powered block is also specified.

The experience gained with this vessel may offer guidance in deciding the type of gear to be used on combination boats, a question which remains crucial for small boats, since their dimensions render them less adaptable to new techniques.

SPECIALIZED BOATS

Winter (USA): Bottom fishing for grouper and red snapper forms an important segment of the commercial fishing industry in Florida, USA. The fishing is done by independent operators who sell their catch to shore-based processing plants, and no state agency compiles figures on the value of the catch. To do so would be almost impossible, as vessel operators are extremely close-mouthed and may also not engage in the fishery on a continuous basis. A conservative estimate, however, would place the number of vessels engaged in this fishery at from 300 to 400.

The principal type of vessel used is schooner rigged with a length of approximately 65 ft (20 m). These vessels are usually equipped with an auxiliary engine and are used for the long voyages to the snapper fishing grounds off Campeche,
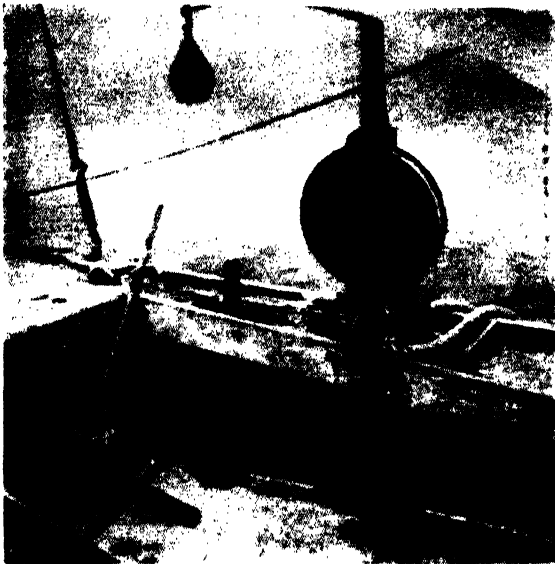
Fig 37. A reel in common use

Mexico. Many other types of vessels are engaged in the fishery, however, and it would be truthful to say that almost anything that will float can be found in the fleet. These vessels are usually converted from other uses and cannot be considered exceptionally seaworthy. On the contrary, they are often very old and require constant repairs if to remain in service. As a consequence, they are used only for voyages to fishing grounds 50 to 75 miles off the coast, and the slightest heavy weather means an immediate return to port.

The fishing method used consists solely of hook and line,

due to the rocky fishing grounds, which precludes the use of any type trawl or net. The lines used are solid or braided stainless steel with hooks rigged any of three different ways. Fig 37 is a photograph of a reel commonly used on the boats engaged in the fishery. These are usually constructed on the spot, using whatever materials are locally available. They vary slightly in design but are basically the same—a reel capable of holding up to 300 ft (90 m) or more of wire line, a spring (generally made from an old automobile spring), and a small block over which the line is payed out and reeled in. Up to ten of these reels may be installed on a single vessel. Some experimentation has been carried out with electric reels, but these have generally proved to be unsatisfactory, due to the corrosion problem. Some operators prefer to use reels and rods ordinarily used for sport fishing when they are engaged in "picking" fish—that is, when fish are scarce, and only one fish at a time is being caught.

Locating the fish

The vessels are usually equipped with echosounders which are used primarily to locate the rocky bottoms where fish are to be found, but occasionally sounding leads with hollow bottoms are used. The hollow is filled with soap and the soap is examined after each sounding for traces of coral rock which indicates the possibility of fish. When a location is found by either method the vessel is anchored and fishing begins. If the location proves unproductive the vessel is moved until satisfactory results are obtained.

Since the bottom areas where fish may be found are usually quite small, great skill is required on the part of the vessel's master in estimating the length of his anchor rode and wind and tide direction in order to bring the vessel directly over the rocks.

Because of the age and variety of vessels engaged in the

Plan
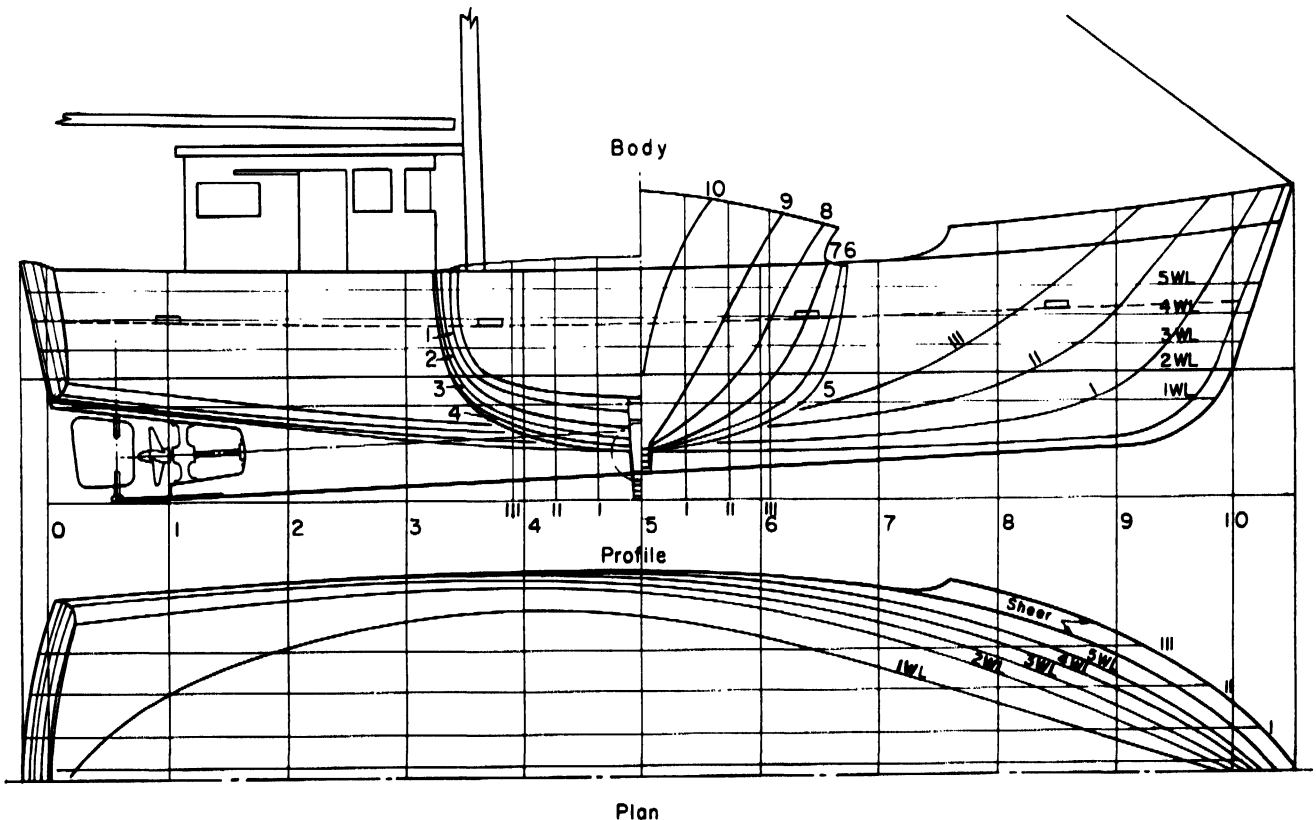
Fig 38. Lines of grouper and red snapper fishing boat

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fishery, there is no standard type of construction, both steam-bent and sawn frames being found at random. Recently-constructed vessels, however, have tended towards double-sawn frames, spaced on 12 in (30 cm) centres and generally have averaged 46 ft (14 m) in overall length. Construction is from native woods, generally long-leaf yellow pine for keels and stems, with cypress for planking which is usually 1¼ in (32 mm) in thickness. Planking methods are generally carvel, but no caulking is used, the seams being allowed to swell shut. Lately, good boatbuilding lumber has become increasingly scarce in the State and fir is being substituted for cypress in the planking. Fig 38 illustrates the lines of a recently-constructed vessel for this fishery and more or less illustrates the type of vessel that is built primarily for this trade.

Power and equipment

Motive power for the vessels is almost exclusively diesel, with the engines ranging from 65 to 90 hp as a rule, although larger engines are found in a few modern vessels. Speeds average 10 to 12 knots. Cruising range, with the exception of vessels designed to operate on the Campeche Banks, is limited, since the fishing grounds are located 50 to 100 miles off the coast, with the actual fishing done while the vessel is anchored. Costs of construction vary greatly, but it would seem safe to say that a new 46 ft (14 m) vessel of wooden construction would cost from £5,400 to £7,100 ($15,000 to $20,000), ready for sea.

Fish-hold construction ranges from simple wooden boxes to well-insulated holds lined with 3 to 6 in (7 to 15 cm) of styrofoam. In the foam-lined holds, the foam is placed directly against the ceiling, fastened in place and covered with wire mesh, over which a layer of cement ½ to ¾ in (13 to 19 mm) in thickness is placed.

Refrigeration consists almost entirely of chipped ice. The fish, in the less well-constructed holds, can be held up to a maximum of 20 days, but very few voyages last this long as the average catch is from 5,000 to 7,000 lb (2,300 to 3,200 kg), which requires about a week to 10 days to catch. Methods of storing the fish vary. Some of the shore-based processing plants require that the fish be gutted immediately after being caught. Others do not. Generally the fish are stored in layers, with 2 to 3 in (5 to 7 cm) of ice between layers.

Crew strength and operation

Crew accommodations on the vessels range from extremely primitive to fairly complete. In no instance, however, could they be termed luxurious. The crew usually numbers four to six, with perhaps a dozen being found on the larger vessels. While extremely competent at their trade, the fishermen, with the exception of the master, seldom meet very high standards otherwise. Masters average £5,360 ($15,000) yearly income.

The vessels are usually operated on shares—one share for the vessel, one for the master and one share divided amongst the crew, although this may vary slightly.

Grouper landed at the dock in the early part of 1965 was bringing approximately 1/3 ($0.18) per lb, with snapper bringing approximately 2/5 ($0.34). These prices, however, have been under extreme downward pressure recently from imported fish, which can be sold at retail levels, filleted, at from 2/5 to 2/10 (0.34 to $0.40) per lb. As a consequence, great difficulty is being encountered in raising capital to invest in more modern vessels for the fishery or in modern shore-based processing plants. Despite these difficulties, however, it is thought that bottom fishing for grouper and snapper will be an important fishery for some time in Florida, as the fish are readily available, as are average vessels that can

Fig 39. Snapper fleet in Pensacola Harbour

be converted to the trade. A snapper fleet docked in the harbour at Pensacola is shown in fig 39.

Problems for developing countries

Paz-Andrade (Spain): The present technical situation in the developed countries affects development in countries which are increasing their fisheries. Fishing in general now finds itself in a vicious circle. The skipper wants to increase the size of his vessel without becoming involved in complicated economics concerning the rentability of his ship, this increase in size is a reaction against two factors:

- Overfishing of resources, thus requiring larger ships to get the maximum possible catch from dwindling resources
- The need to make longer and longer trips

This circle must be broken. In Spain there was a fleet of small ships, coastal, side and pair trawlers. The pair trawlers dominated and gave good results. However, the time came when the need for refrigeration and new fishing grounds further away from home ports, e.g. South Africa, indicated the need to find a midway solution. For example, one enterprise bought a factory ship of 5,000 tons. They built ten small stern trawlers, which were equipped also for purse-seining and these were combined with existing small vessels to give a fleet in which small catchers worked in combination with a factory ship. This provided a good fleet combining smaller vessels with large freezing factory ships and economically it was a good solution.

Spain is now the second most important nation in Europe producing maritime fishing equipment. In Spain the fleet consists of 30,000 vessels, but although there is a large factory processing vessel, some 20,000 vessels are still propelled by sail or oar. Thus it can be seen that they are in the midway stage of fisheries development. Especially from the social and economic position, one must still consider the small fishing boat, but one is particularly interested in utilizing them in larger enterprises, say with a factory ship as the mother ship and a fleet of small catcher boats.

Australia's crayfish industry

Cormack (Australia): Well boats predominate the Australian crayfishing industry. The boats are usually full-ended with the fish well situated amidships. Accommodation is arranged forward with the engine and wheelhouse aft. The wheelhouse

is constructed over the engine-room trunk and is readily removed. A few recent boats have been built with the engine and wheelhouse forward (fig 40). These are proving far better boats working among pots, giving better vision to the helmsman. The boat illustrated was top crayboat out of Port Adelaide in her first season 1963–64. In this latter type, sails have been dispensed with entirely. These boats are all built locally, constructed of Australian timbers, with the exception of deck beams and decking, for which some builders use oregon pine. For these latter members, Australian oak has been used for beams and Tasmanian celerytop pine for decking with success.
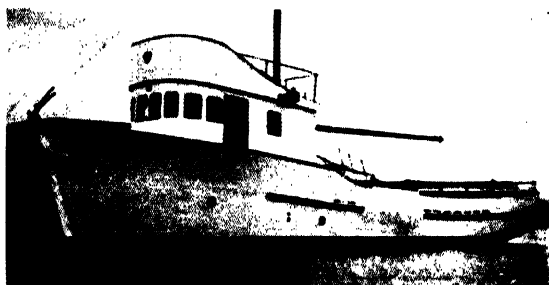
Fig 40. Linda Bruce, *51 ft Loa × 15 ft B × 6 ft 6 in D. Top Port Adelaide cray boat in her first season 1963/64*

The crayfish boats range in size from 18 to 60 ft (5.5 to 18 m) overall in length. The smaller boats are invariably half-decked, working only a few pots, close inshore and single-handed. Average size would be in the 40 to 50 ft (12 to 15 m) range. For the crayfishing industry, the most economical boat would be in this range. The most suitable are beamy, full-ended boats with the beam carried into a short, wide counter. The advantage of the big deck area for working
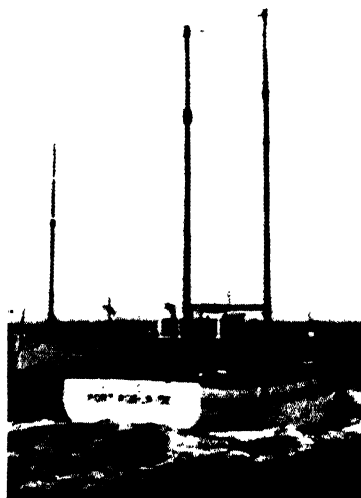
Fig 41. Star of South *from the starboard quarter*

and also the carrying of pots is obvious. Average number of pots worked per boat is 70 to 80. A typical example is shown in fig 41, whilst fig 42 makes a comparison of the beam of these boats with normal standards.

Boats in South Australia are divided into two classes, those working Kangaroo Island shores and those working the

South East Coast. Those working Kangaroo Island are based on Port Adelaide, 80 miles distant. Of consequence, the large deck area provided by a large square stern is necessary, as all cray pots are recovered and returned to port each voyage. Each voyage would be of 10 to 14 days' duration.

In the South Eastern ports such a large deck area carried right aft is not nearly so important and many boats there have cruiser sterns. These are virtually day boats only and
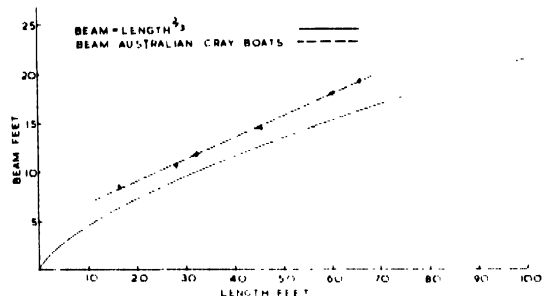
Fig 42. Beam-length curve of Australian cray boats

the pots are left on the grounds for the entire season, necessary running repairs being the only exception. The working area amidships, the lowest point of the sheer, which is kept to a minimum, being a little aft amidships. A sheer height at this point of 2.5 ft (0.75 m) being considered a maximum. For pot-hauling purposes, the pot line is led over rollers fitted to the bulwark rail capping to a vertical winch. This winch

Fig 43. Pot winch set for hauling

is driven from the main engine. A typical winch is illustrated in fig 43. The ability of the boat to hold her position during the pot hauling is a decided advantage, and experience has shown that the boat with a steep rise of floor does this reasonably well.

Choice of the owner

Choice of engine make and power in these vessels has been mainly on the whim of the owner. In many instances, boats are overpowered or as in others the engine is never run at maximum revolutions. Thus the cost in both original outlay and running is far from economical. The same could be said for propeller selection. In most propellers for these boats are purchased "off the hook". With a correctly-designed propeller, together with adequate fairing of the sternpost into the propeller, added to a better selection of horsepower for a given hull, would greatly reduce running costs. Fairing of the sternpost was advocated by Traung when visiting Australia in 1964 and 1966.

The fish well is one of the most vulnerable parts of these vessels, and unless properly constructed, is a continuing source of annoyance. Bed logs of the well should be securely
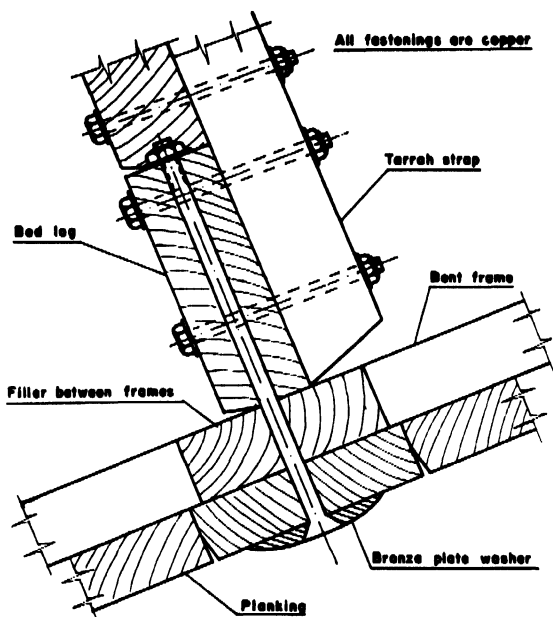
Fig 44. Fastening well into hull

through-fastened, and the bolts set up on adequate plate washers against the hull planking (fig 44). These plate washers are bronze castings and shaped to offer the least resistance. The holes in the washers to accommodate the bolt head should be tapered for the entire thickness of the washer. This will ensure that the head of the bolt will perform its function at all times even if some corrosion to the head has taken place.

Construction of "wells"

The thwartship bed logs are fitted directly to the hull planking, i.e. between the bent frames. The fore and aft bed logs are fitted over the frames; the space between the frames being filled with hardwood blocks. The succeeding logs forming the well are bolted to Jarrah straps secured to bed log and beams and carlines. These straps are fitted on the outside of the well. The logs are seamed on the inside to take the caulking.

The well bottom over floors and frames is usually covered with concrete at least 3 in (76 mm) in thickness. A longitudinal bulkhead (open sheathed) is fitted to prevent excessive turbulence in the well during heavy weather, which could kill the catch. This also, of course, reduces the effects of the free surface within the well.

In all these well boats, closely-spaced transverse floors are fitted in lieu of full-length keelsons. These are of Jarrah or Karri fitted between the frames to the planking. Fastenings are copper through throat and tail. These floors are left straight across the top with the exception of those within the fish well. These latter are usually trimmed hollow at the throat to avoid excessive depth of concrete in the well as mentioned above.

Water is introduced into the well through vents cut in the hull planking. This water is carried at all times, whether carrying fish or not. Further saving in running costs could be made if a tank were substituted for the well. Water which could be circulated mechanically, as in a bait tank of a tuna boat, need then only be carried when the fish have been caught. Some half dozen of recent additions to the crayfishing fleet have been so fitted. However, in the majority of these, the move was unsuccessful, through some lack of experience of the crews concerned. Fortunately in one boat, the scheme was

a success, due mainly to the perseverance of the owner, and according to him the tank is far superior to the well. A boat so fitted has the further advantage of being readily converted to tuna fishing.

SIZE RESTRICTIONS

Hoekstra (Netherlands): In the Netherlands there are certain limitations on the size of the inshore trawlers regarding the crew. The inshore fishing vessels in former days were mainly in the category of 20 GT. Trawlers and drifters in the size of 120 GT. Vessels of 50 GT and more were obliged to have a licensed skipper and engineer. As long as these inshore fishing vessels were about 20 GT there were no problems, but due to the increase of electronic equipment and better crew accommodation, the deckhouses became bigger and bigger. To retain good stability, especially when beam trawling, the principal dimensions had to increase and after a time the 50 GT limit was reached. On the other hand there was, and there still is, a shortage of licensed men, and in spite of this the size of vessels continued to increase and could not be stopped for economical reasons at the 50 GT limit.

Builders tried to build fishing vessels of a maximum length and not exceeding the tonnage limit, using all the tricks of tonnage measurement, to give the vessel such a form that the demand for bigger ships does not result in exceeding the 50 GT limit. This might result in new ships having less stability than the older ones. The application of measurement rules now can result in a licensed crew or not for ships of the same length. Thus the gross tonnage is not a good indication of the size of a fishing vessel, and should not be used in laws, in which it is necessary to indicate the size of a vessel. Length overall, for instance, is a better indication.

Dutch small trawler-owners are hesitating to accept designs of a fishing vessel of less than 100 GT fishing over the stern. It may be true that the fishing operations are easier when fishing over the stern. However, there is an objection from the point of view of accommodation. When steaming into a heavy sea, the pitching of the vessel makes forward accommodation
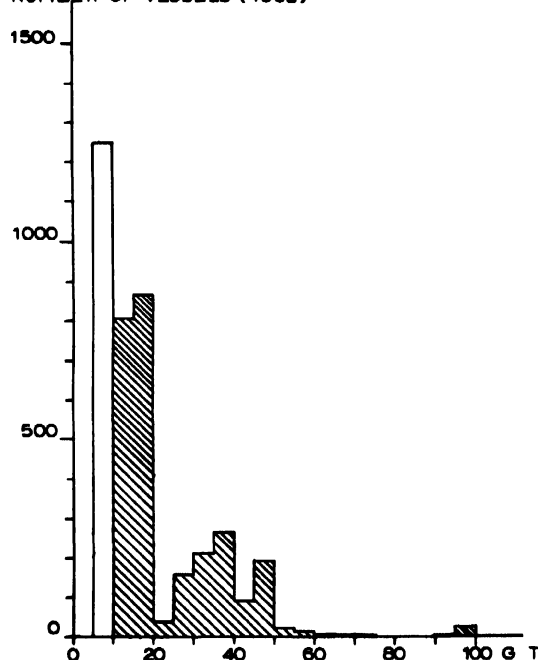
Fig 45. Number of Danish fishing vessels in function of GT
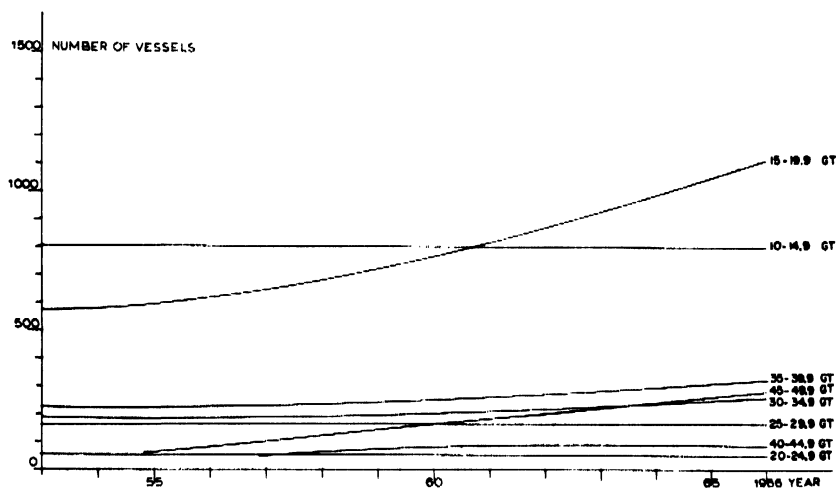
Fig 46. Number of Danish fishing vessels in function of time

very uneasy. Here is the dilemma of better fishing operation conditions or better accommodation.

De Wit (Netherlands): It can be agreed with Hoekstra that gross tonnage as a measure of the size of fishing vessels has had an unsound influence on design. There is a growing tendency to replace gross tonnage by length. For certain regulations, e.g. number of crew, in the future, length will be used in the Netherlands for classifying fishing vessels.

Practice in Denmark

Pedersen (Denmark): Gross register tonnage may be a highly-misleading guide for classification of size of a vessel. Length, or still better, displacement, gives a much more exact figure on the size of a vessel. Demands for trained crew, safety

equipment, port duties, etc., when exceeding certain GT limits, play a vital role in respect of limitation of size. The trend naturally will be a concentration of vessels with GT just below such limits, or to use every effort to get the vessels "measured down" below the limit.

In Denmark there are GT limits on 20, 40, 50, 100, 200 etc. GT. Some naval architects specialize in the design of these so-called paragraph vessels. In the range 5 to 100 GT in which most fishing vessels fall, the 20, 40 and 50 GT limits clearly are distinguished in fig 45. Only boats above 10 GT are taken into account. For vessels above 20 GT, a skipper must have a certificate, while below this limit anyone is allowed to sail a boat. Therefore most of the smaller boats are classified at 19.99 GT. For vessels above 50 GT, two crew members must have certificates. Therefore vessels
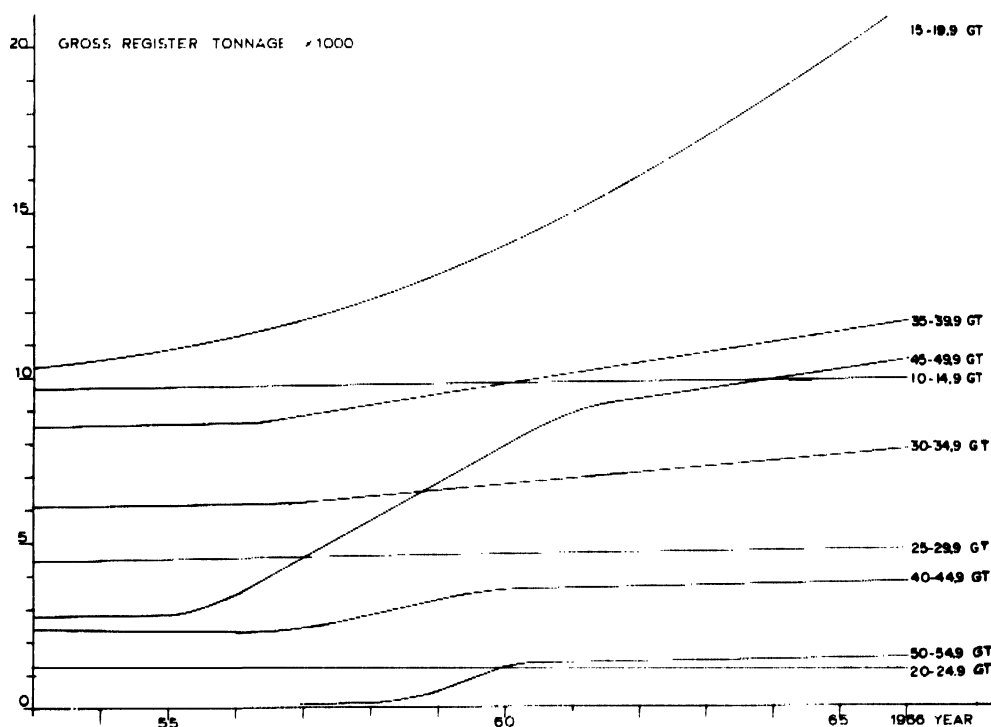
Fig 47. GT of Danish fishing vessels in function of time

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group about the 49.9 GT value. Above 40 GT harbour duties in many Danish harbours rise rapidly; consequently many vessels are registered at 39.9 GT. In Esbjerg, the largest fishing harbour in Denmark, approximately 35 per cent of all boats are registered in the 35 to 39.9 GT range. Fig 46 shows how the number of vessels inside various GT groups vary as a function of time.

In fig 47 the gross register tonnage inside various GT groups is shown how it varies as a function of time. If the smallest group of 10 to 14.6 GT, which shows the constant trend, is excluded, the most popular and expanding group is the 15 to 19.9 GT group, which is followed by the 35 to 39.9 GT, and the 45 to 49.9 GT group.

As is well known, register tonnage is measured as the inside volume of the vessel. Most owners want to get as large a vessel as possible, and there has been a tendency to increase moulding dimension of transverse members to obtain a large displacement for a fixed GT. On so-called "large" 20-ton boats, the frame moulding is kept constant from keel to deck, and even increased considerably above the rule scantlings. The authorities have only cared about the inner volume of the vessel, and it is a fact, roughly speaking, that many vessels are registered at 19.99 GT regardless of outside dimensions.

This tendency, however, became so exaggerated that the Ship Inspection authorities in 1962 stated that only an increase of 50 per cent above the rule scantlings (moulded dimension) was accepted for the purpose of giving a reduction in the measuring and calculating for the gross register tonnage.

USA's Improvement Act

Pross (USA): A brief description of the US Fishing Fleet Improvement Act of 1964 under which scalloppers and other vessels are to be constructed might be of interest.

● The US Fishing Fleet Improvement Act of 1964 was designed to make the US fishing fleet more competitive with vessels of other countries

● Up to 50 per cent subsidy is paid on construction of fishing vessels. This subsidy is based on an estimate of the foreign cost of the vessel in a selected shipbuilding centre, i.e. the owner pays the foreign cost and the US Government pays the difference between the foreign cost and the lowest domestic bid. Reason: old law not allowing catch to be brought into the US from anything but a US-built vessel

● The giving of the subsidy by the US Government has a slight catch, i.e. Congress realized that the re-building of the same old type of boats would not improve the relative status of the US fishing fleet. Therefore, the vessels have to be of advanced design, have the most modern gear available aboard them, be able to fish in extended areas. To do this (fish in extended areas) the vessel must have increased fuel capacity, larger main engines, increased hold capacity over previous vessels etc., i.e. they must be a much better boat than is currently operating in the same fishery or they must be seeking to exploit new fisheries

● The programme is essentially just beginning, but already quite a variety of vessels has been submitted. In addition to the 100 ft (30.5 m) steel stern scalloper already described, the following types are in various stages of processing:

    100 ft (30.5 m) steel stern trawlers
    97 ft (29.6 m) combination boats, as described in Reid's paper
    88 ft (26.8 m) steel longliner-trawlers used for swordfish

    86 ft (26.2 m) steel shrimp boats
    150 ft (45.7 m) aluminium menhaden boat
    220 ft (67 m) steel menhaden boat
    150 ft (45.7 m) tuna vessels
    265 ft (80.7 m) stern factory trawler with filleting machines, fishmeal plant, plate and blast freezer and all the other equipment associated with this type of vessel

As Congress and people become more aware of the importance of the fishing industry to the USA, this programme should expand and the number of vessels built under it increase greatly.

Trends in Portugal

Cardoso (Portugal): Competition in fisheries, overfishing or near-overfishing in some areas and the extension of exclusive fishing zones have spurred the owners and technicians to demand the building of larger, faster and more sophisticated ships which can move faster from distant fishing grounds, stay there longer, process the fish and offals and entertain and attract a crew.

The growth in size of fishing ships in the last 10 or 15 years has been a curve like—a cubic, at least. It is, however, becoming more and more evident that the curve of profitability as a function of size is a Gaussian curve of some kind —see Gueroult's fig 8. It is no wonder, therefore, that already some valiant efforts are being made to make fishing vessels more compact, with reduced crews and consequently considerably smaller.

The fishing vessel should be not only a safe machine for catching fish, but also a safe machine for making money. This function of the fishing vessel has not been too often mentioned. It is important that the biologist, the economist and the technologist help the naval architect, in influencing and determining that point.

The combined purpose is to increase the wealth and welfare of nations and to build economically wrong, although technically beautiful, fishing fleets, would be catastrophic for that wealth and welfare.

FUTURE DEVELOPMENTS

Chairman's introduction

Nickum (USA): We now come to that nebulous and limitless area which we call "the future". While this session is open to any ideas and any concepts that you may have, some form is needed to keep the discussion along logical lines and I therefore suggest that we channel our discussions into the following categories.

First, let's look at methods of fishing. For thousands of years we have been catching fish by three basic methods. One way is with a hook; another is with a harpoon, and the third is with a net. Isn't it time for something new? Can the fisheries' technologists find a shape or a colour, a noise, a taste, a light, or a vibration intensity that fish either don't like, or like, which would allow them to be repelled or attracted into a fishing harbour? If the experts on the behaviour of fish and the fishing gear technologists can find some new way to catch a fish the naval architects have all the knowledge necessary to design the new types of boats which may be required.

Let's talk about future types of equipment. What kind of equipment and machines do the fisheries people need? Do they need radar that will scan and locate fish at the surface of the water in amongst the waves? Can they locate schools of fish accurately enough so that we could build a machine for them which could be towed through the schools and would deliver fish oil out one side and fish meal out the other?

What kind of propulsion equipment will be used 20 years from now; and are the manufacturers expending their research and development funds in the right way? We have heard about outboard motors and the problems of life and dependability of units primarily built for pleasure craft when operated in remote locations without servicing and spare parts facilities. We have heard manufacturers say they can't spend large amounts of money making the units more rugged and dependable just to supply a demand that is only a very small percentage of the total overall market. Is there a way in which we can correct this?

Let's consider methods of design. Are we neglecting developable surface forms such as Kilgore's, now that we have methods to produce them? Are we going far enough in computer studies, either in developing optimum ship forms or in developing a tool for better utilization of fishing time in getting fishing vessels to more productive grounds?

We have heard here about the individuality and character which we admire in fishermen—their desire to own their own boat—their desire to be their own master. This is, of course, valuable and certainly promotes initiative. But let's face the fact also that in this modern world unfortunately it is the big organizations that are making the major developments. Shouldn't we face the inevitability of a change from small individual enterprises to major group efforts?

Aim is increased productivity

Finally, let's consider the business of catching fish in its entirety rather than its separate parts. Remember that the basic purpose of this meeting is to get increased productivity in fishing. We want to catch more fish with fewer man hours of labour and fewer costs for physical facilities. At the present time we take our fishing equipment, place it on board a ship, and don't use it at all while it is going out to the grounds. We fish with it for a while and then turn around and take it all the way back into port and let it sit while we unload and get ready to start the cycle all over again. During this period while the fishing gear is not being used the fishermen are either doing nothing or are navigating and sailing the ship to and from the grounds. Think of an idea like this. Suppose we take a stern trawler, for example, and let the deck at the stern consist of a number of small compartments, each fitted with watertight hatches. The vessel catches a load of fish. Instead of turning the ship around and heading back for port let's put the fish in these removable compartments; run up to a nearby location where some spare compartments are floating, drop the loaded compartments into the water, pick up the spare compartments and start fishing again. A mother ship can come out and pick up the loaded compartments, transfer their cargo to her hold, fill the compartments with stores, oil or water, and leave them ready for the next fishing vessel of the group.

Perhaps we can have a hydrofoil boat running to and from this central gathering spot which can bring out new crews and take the old ones back. Perhaps we should use aeroplanes. Isn't this a means by which we could get rid of unproductive hours, and get the fisherman home to his family, so that he has a working week comparable to a man working on shore? Isn't this a way the fishing vessel operators can compete for labour with the manufacturer?

Trends must be considered together

Margetts (UK): Future methods of catching and future types of ships should not be considered separately. Cardoso is concerned about the changes occurring in fish stocks. The so-called developed countries have overfished many of their own local grounds and are still searching further afield. Big ships or big fishery units will put more pressure on the in-shore fisheries, where it will be even more important for units to be adaptable so as to switch between different catching methods and catching different species of fish. In many developing areas, the local sea fishermen will be competing with big units from developed countries.

The biologists expect that the searches of the world oceans will reveal some unexploited stocks, particularly of pelagic fish. The major fishing fleets will probably continue to develop power methods in which a premium will be on towing and hauling powers.

Gear technologists and biologists are working towards better designs of gear, especially of trawls, and towards understanding the behaviour of fish, the better to turn their natural reactions to account in achieving their capture. Most modern development is in big ship methods. Although some of the general genuine principles of design of gear will apply to small-boat methods, it will not always be wise to scale-down big gear to small size, e.g. big single-boat midwater trawls are now used to catch cod in midwater, but small single-boat midwater trawling is not likely to be successful for catching cod.

Nowadays more attention is being paid to fish farming of marine species. It is unlikely that this will be done, in the manner envisaged by Cousteau and Hardy by totally under-water operations requiring submarines and dual-purpose underwater boats or tractors, but is likely to be by intensive farming in enclosed sea waters where there will be a need for specially designed small boats and river craft.

The most modern aid to fish-catching is electricity. The use of electricity in sea fishing is being successfully adopted at the research level and practical commercial methods may follow, probably by using electro stunning in conjunction with trawls. If so, there will be new scope for ship designers to build ships including all the extra generating plant.

Danger of pollution

von Brandt (Germany): The future of sea fisheries may possibly be the same as it has developed, especially in Europe, for the freshwater fisheries. In fresh water the pollution of rivers and lakes is increasing rapidly, transforming the freshwater fishery from the fisheries in lakes and rivers to the pond fishery and hatcheries.

It may be that this will also occur in sea fisheries. Perhaps it will be impossible to prevent the contamination of the sea, e.g. with atomic waste. Also in this case sea fisheries may be driven away from the open sea to protected enclosed areas with known stocks kept under regular management like cattle and so on.

In the near future midwater trawling is expected to become more and more important for small and large vessels as mentioned by Margetts. It is also to be expected that in future the depths for bottom trawls will increase to 3,000 ft (1,000 m) and more. That would cause new problems for better deck arrangements, such as winches and warps. It may also occur that a higher efficiency of bottom and midwater trawls may be achieved by means of electricity.

Effect of noise on fish

Takagi (Japan): In 1936 it was known that when whales were followed by catcher boats, they tried to run away. This is the reason why people used the steam whalers. However, if boats run parallel with whales inshore, they do not run away from the boats. In 1936 an experiment was made to measure the speed of whales in open sea near Japan. Ten boats were run parallel one to the other, with a submarine chaser capable of over 20 knots at each end with the eight whalers in between. As soon as a whale was found, the outer submarine chasers started to run after the whale and as a

result it was observed that even a whale over 80 ft (25 m) could not move any more after 30 minutes. The surface speed of the whale was 14 knots. Therefore it was concluded that whales would not be able to escape from boats faster than 14 knots and noise from the boats should not be any problem. Thus Japanese whalers started to employ diesel engines.

Bardarson (Iceland): Studies on the hearing of fish have shown that fish have a hearing range apparently within the same range as the human ear, possibly somewhat more, but varies according to the species. It has been indicated that herring and fish of the same family are more sensitive to noise and have a greater range of hearing than most other kinds of fish. These observations are based on experiments carried out in aquariums or in the open sea, by keeping the fish within a limited area with nets. By sending out sound in different ranges and noting the reaction of the different types of fish, the sensitivity of the fish concerned could be registered and compared. The above results are in conformity with the practical experience of Icelandic fishermen. It is the general opinion of Icelandic fishermen that noise from fishing vessels does not generally disturb cod fishing, but can considerably disturb herring which is to be caught with purse-seine especially in good weather during the day.

Icelanders seek quiet approach
If a single fishing vessel is approaching a school of herring, and when catching, it is a general opinion of Icelandic fishermen, that it is of great value to keep noise from the fishing vessel to a minimum to prevent the school from disappearing into a safe depth beyond the depth of the net. When several vessels are spread around, thus making the noise level rather similar and constant within a certain area, it seems that the herring are not so disturbed by the noise as when the noise comes from one source only. Constant noise therefore seems not to cause as much disturbance as a sudden change of noise. It is not a new idea that noise from fishing vessels disturb fish to make fishing impossible. When steam ships came after sailing ships, it was thought that the noise from the steam engine would soon drive the fish from the fishing grounds. This proved not to be the fact. Later, the noisy diesel engines followed after steam engines in fishing vessels, and then came many types of noisy auxiliary engines and equipment, but still fish are caught on the fishing banks. This should, however, not be taken as an indication that fishermen's views as regards the herring fishing should not be taken seriously.

Some fishing vessels catch less herring than others, although the vessel's type and size might be similar and the ability of the captain and crew comparable. By listening with an underwater microphone and recording on a tape recorder the sounds from different fishing vessels at the same distance at the same place and same weather and sea conditions, it may be found that ship noise and character of the noise varies for different vessels. If testing in the same manner one vessel, it may be found that the type of noise and noise level can vary widely, with altered revolutions of the main engine, with altered pitch on a controllable pitch propeller, by starting, stopping or changing the revolutions of auxiliary engines and equipment such as pumps, winches, etc.

Tracking fish with tape recorders
By first listening to and registering on a tape recorder the characteristic noise from a certain fishing vessel, then taking the vessel on land and changing one item at a time and then registering the noise in the same way again, at exactly the same distance, same depth of water, same surroundings etc., there is a possibility of comparing the different single items affecting noise. This is a practical approach to a problem

with full-scale tests on the ship itself. It is a very costly and time-consuming method, but is still believed to be the only practical way to study the noise from a certain ship.

Excessive noise may be due to many things. Among them are damaged propeller blades, propeller cavitation, insufficiently balanced or inexact pitch of the different blades of the same propeller, limited space around the propeller or disturbed flow of water to the propeller, which can be due to thick and square sterns as in wooden vessels—auxiliary engines on top of a flat tank can also produce vibrations and noise. All these, and many other items have to be considered when studying noise from fishing vessels.

It is believed that noise from herring fishing vessels should generally be kept to a minimum, but it appears that underwater noise from fishing vessels and its influence on fish has not yet been studied sufficiently. Experiments in this field are needed both on a scientific and technical basis, to increase knowledge of the problem as a whole. Such experiments are, however, costly and complicated, since so many different unknown factors are involved. At any rate noise should be given more consideration in the future development of fishing vessels than has been done generally until now.

How fish react to noise
Høgsgaard (Denmark): In Denmark soles are caught in shallow water, but fishermen say that soles cannot be caught in the daytime because they are so deep in the sand that they are not taken out with the net. A Scottish film about Danish seines showed how fish escaped from the seines; when the fish had been collected by the sweep lines and were nearing the net, the most powerful of the fish went right up and over the top. Then on the headline of the seine between the two wings, Høgsgaard placed a line on which he placed two artificial fishes of white plywood, with cork. When the soles started to go up in the water, they were frightened by the white fish and escaped down into the seine. This has been proved many times.

Traung, page 385, mentioned that fish can be scared by the noise of ships and Bardarson said the same, and Høgsgaard having travelled around the world so much said he had similar ideas. About ten years ago he had talked with a man in Nova Scotia, owner of two boats, from which the crew harpooned swordfish. This man said that they kept the old-type engine, the engine without a reduction gear between the engine and propeller shaft. With this engine the ship can move closer to the swordfish. And then some years later, Høgsgaard went to the Faroes and there were three small whalecatchers from Norway which operated very well until one day one of the ships just couldn't get near the whales. The owners cabled to Norway for the reason and the Norwegian who had sold the ship cabled back advising putting the ship on the slipway to inspect the propeller, as it might have been loose. This was the case.

Propellers sometimes not to blame
Recently a young naval architect asked whether Høgsgaard could make him a noiseless propeller, to which he replied that he could not but would make a propeller making less noise than the normally-designed propellers. Cavitation causes air bubbles and that means more noise again. A more modern propeller will go smoothly through the water. The young naval architect had complained that the herring shoals would not go near the six purse-seiners they had in Iceland, and Høgsgaard mentioned the story of Nova Scotia. It might be that these ships have noisy reduction gears and one should not put the blame on propellers. It is very difficult to make reduction gears with little noise. However, the thickness of oil used in the reduction gear is also relevant. So if fish are

scared away, it does not always depend on the propeller. It is important to make noiseless gear that can be used in fishing boats for the progress of the industry, and the type of teeth is very important. The propeller people say it is the fault of the gear; the gear people say it is the fault of the propeller. It would be valuable to know what frequencies fish do not like.

Handline fishermen always stop the auxiliary engine because the noise frightens fish—however, with a diesel car engine as auxiliary engine, one will have, not a noiseless, but a very quiet engine when fishing, which will also afford the crew a little more comfort. Anyone who has been aboard ships knows that when the big engine is running one is in Heaven, but when the auxiliary engines are running, one is in Purgatory!

SUBMARINES

Pedersen (Denmark): Who are the best fishermen? Fish themselves. It is a fact that bigger fish eat smaller fish. The big mammal of several hundred tons lives upon shrimps.

These mammals only open their mouths and swim through schools of shrimps in the Antarctic Ocean. It might be possible to adopt this simple principle of catching animals in the water, by making an artificial mammal, steered by man. This means that such a submarine fishing boat, fig 48, should have a "mouth" and "stomach", and the operator, when detecting a school of fish on his sonar apparatus, dives down to the proper depth, opens the "mouth", steers through the school, which is collected in the "stomach" tanks, where the fish may be kept alive until reaching port, just as in normal fish well vessels.

The "stomach" tanks are fitted with nets of proper mesh sizes in order to allow undersize fish to escape. Fish can be sorted automatically if different mesh sizes are fitted in the different tanks, just as stones, grained stones and sand are sorted through a sieve. Water will flow freely into and through the "stomach" tanks from small openings in the "mouth". Supplies of food and oxygen are thus provided for keeping fish alive inside the tanks.

Power may be supplied from diesel electric alternators, in connection with a battery feeding a slow-running electric
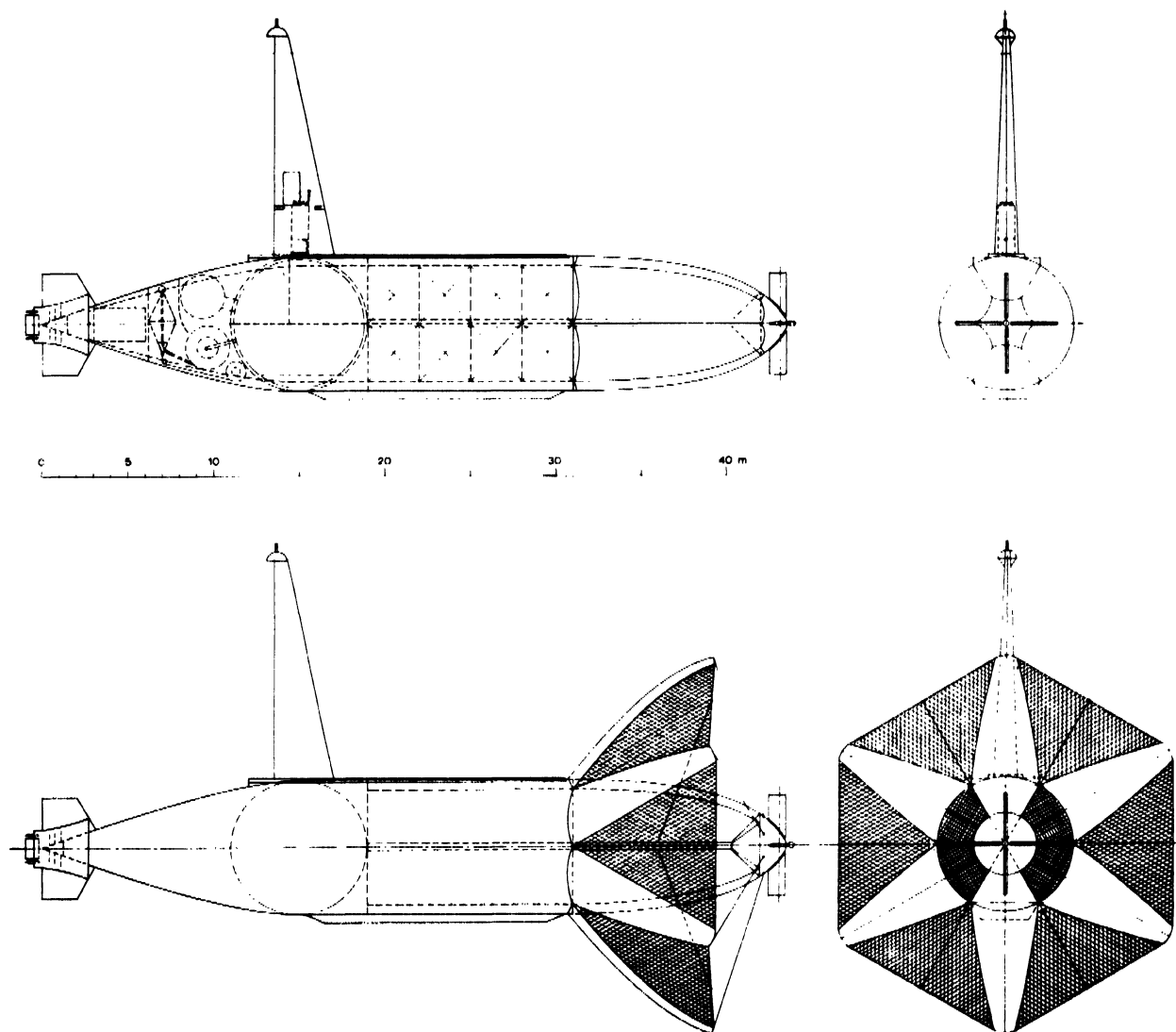
Fig 48. Submarine fishing vessels utilizing the mammal principle of fishing

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motor, which again drives the large diameter propeller. Vertical and horizontal rudders fitted behind the propeller and in the nose, provide good manoeuvrability. The cylindrical main part of the body is divided in six parts with longitudinal bulkheads around a centre pipe. The upper part contains the buoyancy tanks; the lower part the fuel oil supply, which rests directly on the seawater, as in normal submarine practice.

The battery is situated below the fuel oil tanks in a special pressure pipe. The electric motor is covered in a shield into which compressed air is led in order to avoid water entering the motor. Separate engine room and operator living room will be of advantage. The engine room need not be contained in a pressure hull, as compressed air can be led into the room when diving in order to keep equilibrium in pressures. As diesel alternators are stopped when diving, this arrangement seems satisfactory.

Cruising depth is limited by height of the snorkel mast naturally. This may be made so high as to allow a safe margin for greatest draught of surface vessels in order to avoid collision.

Possible advantages of submarine fishing

- The operator never touches the fish. He does not have to haul a net with fish in bad weather, kill and gut the fish, prepare and stack them in the hold under difficult conditions. The only thing the operator has to do is to find the fish, collect them, and bring the living fish to a processing plant, either on land or on a factory vessel at sea. The vessel can thus operate either as an independent unit or as a member of a fishing fleet
- There will be no trouble with winches, warps, nets and ground gear, as such items do not exist. Maintenance costs on nets will be low, as only a trawl mouth net is needed
- The vessel can fish independent of weather conditions, as it is always calm below the water surface
- Through the periscope, antennae, decca etc., situated on top of the snorkel mast, the operator will have the same, or a better view, as a skipper on a surface vessel, when the boat travels as a surface vessel

The following questions require answers:

- Can the fish be kept in good condition in the "stomach" during a fishing trip of, say, ten days, if the concentration of fish is high?
- Can the school be concentrated and attracted towards and into the mouth by using, for instance, light, electricity, or other attracting devices such as stimulating solubles let out into the water from the end of the mouth?
- Can the school be "frozen" for a moment by using a form of shock-waves (ultrasonic sound, etc.) transmitted from the nose in order to harvest the school?
- Is there any risk that sound from the electric engine may frighten and split the school (constant low-frequency noise level assumed)?

Investigations made by FAO

Traung (FAO): When the first atomic powered submarine went under the Arctic icecap, officers in FAO were impressed by the possibilities of fishing untapped resources under the ice, using a submarine without any contact with the surface. One FAO naval architect with previous experience of submarines looked into the possibilities of adapting a second-hand submarine for this purpose. He started off by investigating whether it could tow a trawl and then found that the hauling of the trawl would be quite complicated—how to

separate the fish from the net, shoot the net again, etc. Then somebody suggested considering the submarine as being at the end of a codend of a free-running trawl. It was suggested to use a simplified trawl, towed by four small torpedos that were radio controlled from the submarine, which was hung in the codend. The gear had then a very large screening area and the fish would be collected in the bow of the submarine for further transfer to some pressure chambers, where they could be properly boxed, iced and kept. Still again, there was a problem how to handle a net like that, and another idea was to have some telescope poles which one could press out by air through the bow of the submarine. The poles were to have many small holes so that air bubbles could be sent out and the unit form a kind of new fishing gear working with air as "webbing". The air webbing would force the fish into the pressure chamber, which then from time to time could be locked, the water pumped out and the fish put into a fish room.

Fish attracted by light

Margetts (UK): The answer to whether light or electricity can be used to attract fish is yes. Of the two, electricity offers most likelihood for the whale-type catching submarine. A steady noise from the engine would not likely frighten fish, but sudden noise generated within the submarine or by opening of the jaws is likely to scare the fish away. Bardarson's observations about Iceland herring fishing support the suggestion that steady sound is not so important, and also that visual stimuli are very important in frightening fish. As the supposed noise effect is most marked in Iceland in calm weather and daytime, the inference is that the real thing affecting the herring is sight not sound. To continue Pedersen's analogy, it is very likely that his submarine will be like the shark from which, when they can see it, other fish flee. The opening of the mouth of the submarine is likely to be frightening to fish in clear water.

Høgsgaard and Takagi both referred to the effect of ship's noise on whales, the former speaker compared the reactions of fish and whales. The hearing of a whale, which is a mammal, is very different from that of fish and the behaviour of the two in reaction to noise is not comparable. The fish scarers on the headline of Høgsgaard's trawl, it is believed, act by scaring fish downwards by sight in daylight, as do the kites on bottom herring trawls, while the effect of tickler chains suggests that a lot of soles are not disturbed by the noise of the oncoming trawl.

Some research work has been done in UK identifying and measuring the noise generated by a trawler and different sets of trawls and aquarium experiments are being conducted investigating the reactions of fish to sound and other stimuli. More scientific evidence on these subjects is required and an analysis of the noises from ships could be profitable.

The opening of the jaws of the submarine wide enough to be effective in catching fish—perhaps 150 to 300 ft (50 to 100 m)—while still moving forward presents a big problem to the naval architect as the drag will increase enormously. There is also the problem of stability and control of the draft if it should catch a lot of fish, such as cod, with air bladders; change in depth of the craft will alter the buoyancy of such fish and ascent could be very hazardous.

Fish reaction to skin divers

Bonnassies (France): Just after World War II in France, a suggestion on the lines of Pedersen was made to the French fishery authorities, that is for submarine-type fishing. The first difference was that the propulsion was by electric motor which was fed by a mother ship. Secondly, compressed air was installed to force the water out after the capture of the

fish. In the main fish-containing compartment, there were electromagnetic means of deciding when the container was filled. The container was then ejected and rose to the surface as it was designed to be buoyant and was retrieved by the mother ship. It is perhaps of interest that fish probably are not frightened by the sight of menacing objects as has been supposed. Skin-divers had little trouble in easily making reasonable catches when this sport was first introduced, but perhaps because of some memory device of the fish, the fish now appear to avoid them and catching is more difficult.

Light might well attract fish and an asdic type of apparatus as envisaged should be easily obtainable. Notably the Germans and the Russians have experimented in the use of electricity as a method of stunning fish and thus easily collecting them. This collection could be easily undertaken by the underwater submarine.

The suggestion to the French fishing authorities remained as only a suggestion and was not exploited. A prophet is never heard in his own land.

Birds are good fishermen

Dickson (FAO): Pedersen referred to the fish themselves and to sea mammals as the best fishers of the animal world, but he forgot to mention the birds. It is by their keen eyesight, their means of communication both visual and vocal, also by their great speed of movement that seabirds possess such remarkable searching power. Searching power is the very essence of fish finding and it is in this very field that a technical revolution is underway, a revolution which has started to transform fishing operations. As fishing vessels become bigger and faster, as fishing operations extend farther and farther from the home port, organized fish finding becomes more essential. The means are to hand, modern communication systems can ensure that data is fed to a central point, data processing methods can then deal with it there and communications can redistribute the processed data. What is mostly lacking is organization and enough technically and scientifically trained people in the fishing industry.

The daily catch rate per hundred hooks operated by the tuna longliners is transmitted to Japan along with the position of the vessel. This data is processed by a centralized technical staff and within two days the summarized catching rates are re-broadcast to the fleet. The re-broadcast is received by facsimile machine which prints out the catch rates by area squares on a world chart. The system is similarly used for the broadcast of weather charts. Thus skippers can have an up-to-date picture of generalized weather and fishing conditions in all surrounding areas. Some trawler fleets are also on the threshold of such developments and it may be that as well as catch data, echosounder search data will also be processed and the two thus become better correlated.

Value of collection and communication of information

Communication instruments of this sort, plus the use of more instrumented fishing gear, such as netzsonde guided midwater trawling, the telemetering back to the ship of information on fishing gear performance, sonar guided purse-seining and the like, look more promising than submerging a man on the fishing gear. His field of visibility is so very limited and the safety precautions surrounding him so considerable that the ratio of information gained to money spent is likely to be much lower than with the submersion of fish finding and observational instruments. It is not meant to imply by this that mankind has no future under the oceans, but simply that the idea of a man sitting in the place of the brain of an artificial whale is not the most promising approach.

There is also a structural objection to the artificial whale idea with its fishing gear at the head-end pushing it along as it were so that the catch enters by way of the "whale's" mouth. This arrangement implies large members in compression and it is to be noted that all the biggest and most successful fishing gears can only be so big because they are completely flexible, and therefore without any members in compression.

AIRLIFT PUMPS

Reid (Canada): Airlift pumps are used in Canada for discharging fish out of the net. In a dewatering device of a 12 in (300 mm) pipe, compressed air is introduced which tends to boil the water at standing point, and with this system a 25 lb (11 kg) cod has been driven up to 14 ft (4.25 m) above the level of the water.

Utilizing the possibilities of this airlift pump, one can imagine a fishing system utilizing two tug boats operating one mile apart and each towing a large oversize trawl door. The tugs would also tow together a fish collecting vessel some two miles behind. The trawl doors together would tow a trawl of gigantic proportions and in the codend of the trawl one would have a pipe connection to the fish collecting vessel, to which the fish would be delivered by help of the airlift pump.

In midwater trawling, it is difficult to keep the correct trawling depth, but with the two tugs in this way towing the trawl and the collecting vessel, it would be a simple matter to slacken or tighten the trawl to achieve the desired vertical height of the gear. Please consider this as one off the-cuff idea.

Promises recalled and answered

Lenier (France): At previous FAO fishery congresses the Japanese have promised many good developments for the future. For instance at the FAO Research Vessel Forum in Tokyo in 1961 there was a suggestion that work was being done on bulbous bows for trawlers. It was suggested that a ship would require only one-twentieth of a conventional vessel's power, but no result of this suggestion has been published.

At the Rome Fishing Boat Congress in 1959 some pictures were shown of a proposed nuclear power fishing vessel, for which is was said that funds for construction were already available. No more of this suggestion has been heard either. Could the Japanese delegation enlighten us on these subjects?

Takagi (Japan): Answered Lenier's queries:

● Inui of the University of Tokyo presented his paper on the so-called Inui bulb to the FAO Research Vessel Forum in Tokyo in 1961 (Inui, 1961). Since then, this bulb has been applied to many vessels, not only Japanese vessels, but also vessels of various countries. Even in Göteborg a few vessels under construction have Inui bulbs. This bulb was applied to a few fisheries research vessels, but until now has been used mainly for merchant vessels. The fuel saving is some 20 per cent, a reduction of the power to one-twentieth was never claimed.

● The atomic fishing vessel proposed at the second fishing boat congress in 1959 was in a session about fishing vessels in 1975. Fortunately, there are ten years more until 1975 and Japan will certainly complete an atomic research vessel before then, because an order for such a boat will be given in 1967.

PROPULSION

Borgenstam (Sweden): Gas turbines have often been talked about and are now to a certain extent used by the Navy.

What about using gas turbines in fishing boats? Unfortunately, inherently in the gas turbine is a high fuel consumption and a complicated construction. It is also sensitive to salt water in the inlet area. The development of gas turbines is towards units with high output, especially suited for the Navy. Fishing vessels will probably be the least possible application of gas turbines.

Concerning outboards, it must be remembered that it is the pleasure boats who are the main users and they will therefore decide the design. However, for small fishing boats one could keep the top part, the engine head, which is now well developed with good enclosure and good starting property, and modify the lower part. In the usual motor, the top part of the engine is 75 per cent of the total cost, while the lower unit represents 25 per cent. A new more slow-running lower unit will probably cost three times the price of the present lower unit. However, outboards have so many advantages that the effort might be worthwhile.

A lot has been said about the necessity of teaching. There seems to be a great need for new teaching methods, for example, plastic models to better illustrate what is taught.

COMPUTERS

Doust (UK): Several computer programmes are available to designers of future vessels, which relieve one of many routine calculations formerly done by hand machines, although, even now, full advantage of these facilities is not always taken by some trawler yards. Such programmes are, at present, concerned with the evaluation of hydrostatics, capacities, stability characteristics, including design stability and hull strength. For those not familiar with output data derived from such programmes, the section of the Traung, Doust and Hayes paper dealing with stability characteristics is a typical example showing how the computer can be used to assess the adequacy of beam and freeboard and to ensure an adequate range of stability.

Now that resistance and carrying characteristics of the smaller fishing vessels has been expressed in terms of their hull shape and dimensions, it is possible to use a computer to evaluate the relative merit of new proposals, thus avoiding unnecessarily high-powered and inefficient designs which in terms of fuel wastage on an international scale represents enormous financial losses. It is a fact that an inefficient hull design from the powering viewpoint is often the result of badly chosen form parameters, leading also to bad motions and seakeeping qualities, which further drastically reduce economic efficiency.

With the theoretical developments now taking place in the analysis of ship motions, wetness and loss of speed in various sea states, it should be possible in the not-too-distant future to define the desirable hull qualities, for fishing vessels in a seaway more closely than is at present possible. It is therefore an urgent requirement to study the quantitative effect of factors thought to be, or already known to be, of major influence on seagoing qualities, such as freeboard and flare allied with the vertical and longitudinal distribution of area above the waterplane, stem and stern contour shapes, in addition to the distribution of weight in these vessels.

Probably the least understood aspect of vessels below 100 GT is the combined importance of dimensions, speed, fish carrying capacity, fuel capacity, range of operation and engine power on the economic efficiency. In this field, the computer offers considerable scope in providing an additional design tool, whereby the functions of a fishing vessel can be simulated. By expressing the technical and economic performance in an equational form which can then be interpreted by the computer, the best economical areas can be derived

using linear programming or similar optimization techniques.

Since fishing vessels often tend to be built in fairly large numbers to reduce shipbuilding costs, the mathematical representation of the hull surface enabling computer-controlled flame-cutting machines to be employed, is now a reality and several fishing vessel designs are already being mathematically faired.

The next logical step is one on which several workers are engaged. This is to start from the optimized hull form parameters and to develop a method whereby the computer actually calculates the best form for the required condition together with its shape. Three dimensional computer display units are already available, which could be adapted for the design of fishing vessels thereby enabling the effective changes in one dimension to be seen in the other two dimensions.

Computers can co-ordinate through-put

Eddie (UK): The use of computers in design is not confined to relieving the naval architects of their tedious arithmetic—although of course that is a very worthwhile objective. An example of another kind of application may be of interest: the use of the methods of operations research to solve the problem of choosing the optimum throughput for the processing plant in a deepsea trawler.

It is well known that the rate of catch can fluctuate very violently; single hauls can represent catching rates up to at least 10 times the average for the trip. It is desirable although not necessary for certain types of product, that the fish be processed immediately after catching, but in the case just quoted the processing plant would then be hopelessly uneconomic. A plant which could deal only with the average rate of catch, however, implies a very large buffer store at times of good catching, and this is unacceptable because of the handling problem and also because considerations of product quality impose strict time limits on buffer storage before freezing; the situation is further complicated by biological phenomena like rigor mortis. It is not practicable to ask fishermen to stop fishing when fishing is good. The best choice for the size of the processing plant therefore lies somewhere between the average and the peak catching rates, but the range of choice is very wide and the choice is difficult. Processing plant is very expensive in first cost and in space and the choice obviously has a very great influence on the economics of the vessel.

Practical use by WFA in Hull

The Industrial Development Unit of the White Fish Authority working in conjunction with the University of Hull has developed a computer programme which provides a solution of the simulation type. For numerical solutions, this requires records of fishing on a haul-by-haul basis, shifting grounds and dodging weather, for the fishery under consideration, sufficiently comprehensive to be statistically representative of the pattern of operations on those grounds. This information is stored in the computer. Various designs of vessel are then postulated with different sizes of processing plant and if desired, different sizes of hold, and the computer simulates fishing operations with these vessels for, say, two to three years, each succeeding haul being chosen at random from the store. It can then be seen how often each design would have had to stop fishing, what proportion of the catch has to be handled in and out of the buffer store and so on. The programme also includes consideration of costs and earnings insofar as these are affected by the choice of processing plant and size of hold.

For the type of work described in Hatfield's paper, access to a computer is not essential, but can be very desirable. Many hundreds of metres of multiple-channel analogue

traces are produced on such trials and the results are digitized by means of trace analysis equipment; the use of a computer for the subsequent calculations is sometimes desirable.

Work of data-loggers

Recently, data-loggers have been used by the Industrial Development Unit of the White Fish Authority to record automatically the performance in service conditions of deep-sea fishing vessels and their machinery, throughout commercial voyages, as a logical extension of the type of work described by Hatfield. These automatic loggers record ship speed, propeller revolutions, shaft torque, wind speed, fuel flow, etc.; the information is stored by punching a paper tape. The tape is recovered at the end of the voyage and the information upon it is digitized by a computer and subsequently calculations may be carried out also. Since automatic data-loggers should be of interest to vessel managements as well as to research development workers—they can be used for monitoring engine temperatures and so on and as alarm systems— it may be as well to remark that these need not be very large and expensive devices, such as are used by some tanker-operating firms: the logger referred to above is a 20-channel instrument which with the associated punch unit and black boxes will occupy between a quarter and half a cubic metre; the basic logger costs about £1,500 ($4,200). This makes it feasible for quite small fishing vessels. One problem is that ship motion introduces fluctuations in such parameters as shaft revolutions and torque, but these can be automatically integrated over a period of many seconds and averaged; this is practicable if the correct choice is made by the designer of the type of electrical circuit to be used.

Problem of keeping abreast

Cardoso (Portugal): The impact of computers allied to modern methods of experimentation and testing make many times obsolete today what was modern yesterday. All agree that the naval architect of this day and age works hard just to keep abreast of every day's developments. The best sources of information are the large national laboratories, experimental tanks and research centres. It is, however, difficult to obtain the latest published reports of such centres. It would be good if those centres, either by publishing a journal or by keeping the international technical press abundantly informed of the progress of their work, could make the general practitioner well-informed of the latest information on the best methods and data involving modern design of ships.

Gone are the days when a good technical education and a flair for design would be sufficient for the production of successful designs, providing the best all-round solution. So many variables must now be taken into account that only the most up-to-date methods lead to a good solution. Thus this request is of capital importance for the practising naval architect, both in developed and developing countries.

Research and testing centres have never enough funds to carry on the programme they wish to complete. More widespread knowledge of their results could lead to a means of income not to be neglected.

NEW BOAT TYPES

Odero (Kenya): In Kenya there are about 5,000 fishing vessels and about 500 pleasure fishing vessels. Whereas practically all sport fishing vessels are mechanized in one way or another, only about 50 of the fishing craft use engines. The low figure of mechanization is probably due to the fact that the fishermen have in the past been content with the situation and have never had any incentive to improve their fishing vessels.

Most of the fishermen are now convinced about the need to

raise the standard of fisheries, which would require properly built fishing vessels using engines. However, the fishermen are too poor to pay for such improvements; furthermore the vessels they have—canoes and sail boats—are not suitable for engines. Attempts to fit outboards to some of the canoes have proved on the whole rather clumsy. However, it might be possible to find a practical way to instal outboards on some of the present canoes.

Meanwhile, the more well-to-do fishermen are being persuaded to buy the 28 ft (8.5 m) Mwanza fishing canoe from Uganda and these are well designed for outboard installation. The Government is keen to develop the fishing industry and there are plans for building a boat yard. But first of all there is a need for boatbuilders and if possible expert designers.

Impact on new gear needs

Birkhoff (Germany): In consideration of new catching possibilities by using, for example, electric current or light, one should first of all utilize all possibilities of the actually used trawl gear. With the introduction of the pelagic gear, trawl operations have become far more flexible. Thus, this gear offers the best possibilities of further development.

Sooner or later, there must be a further reduction of crews. A high percentage of the crews are now leaving for other industries which offer better wages. Consequently the wages of a single man must be increased to render the work as attractive as possible. This can only be reached by a further mechanization or extended automation of the whole catching operation.
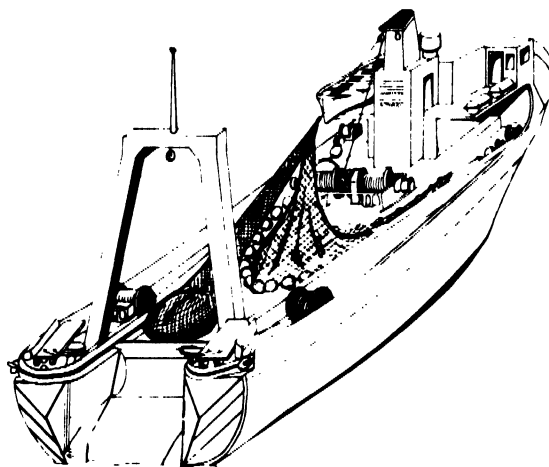
Fig 49. Automation of gear handling

As an example, on a proposed 130 ft (39.6 m) stern trawler, nearly all gear handling is to be carried out mechanically or by means of automatic control (see fig 49). Only one man is needed at the control desk in the wheelhouse and one man on the geardeck, who controls the automatic work. The only direct work this man has to do, is to hook the combined hoisting and shooting tackle into a becket at the codend. With such a high reduction of manual work on deck, and a corresponding automation of fish processing and storing, a crew of six men would be sufficient for a midwater stern trawler.

On such a vessel, trawls like the "western trawl" as well as the "bottom trawl", which is used on big European stern trawlers fishing off the East coast, can be automatically handled.
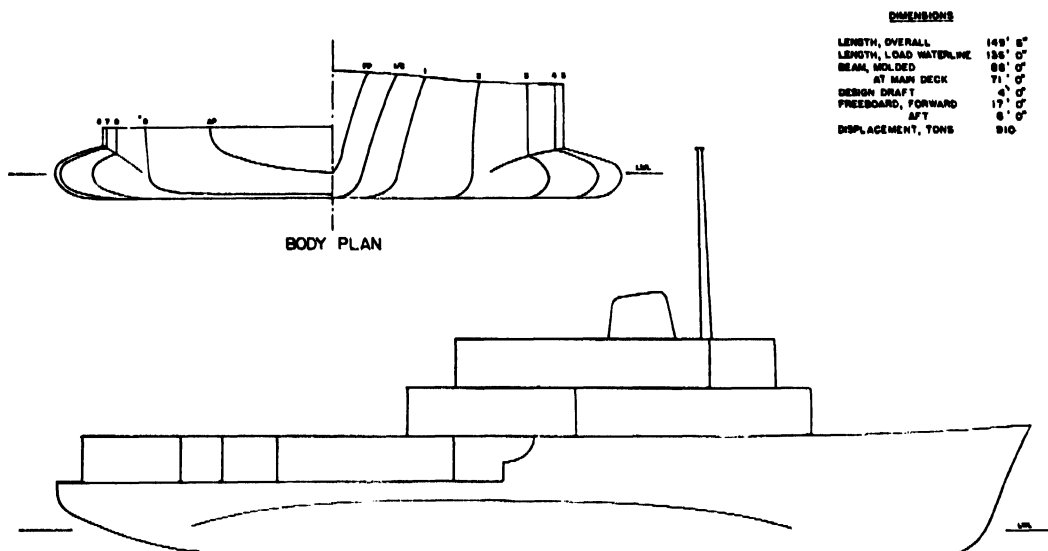
BODY PLAN

Fig 50. Profile and body plan of Popoffka
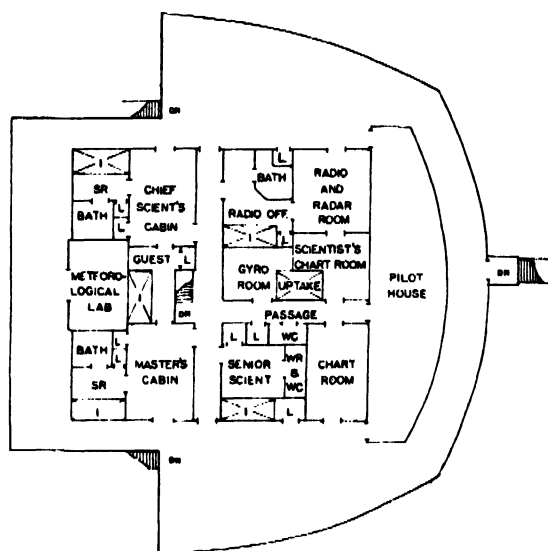
Fig 51. Bridge deck of Popoffka
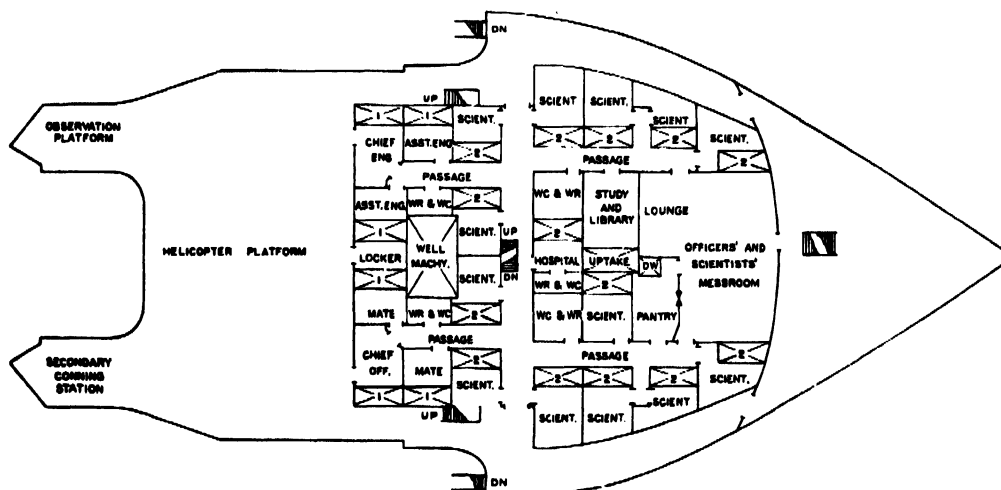
Fig 52. Upper deck of Popoffka

[636]
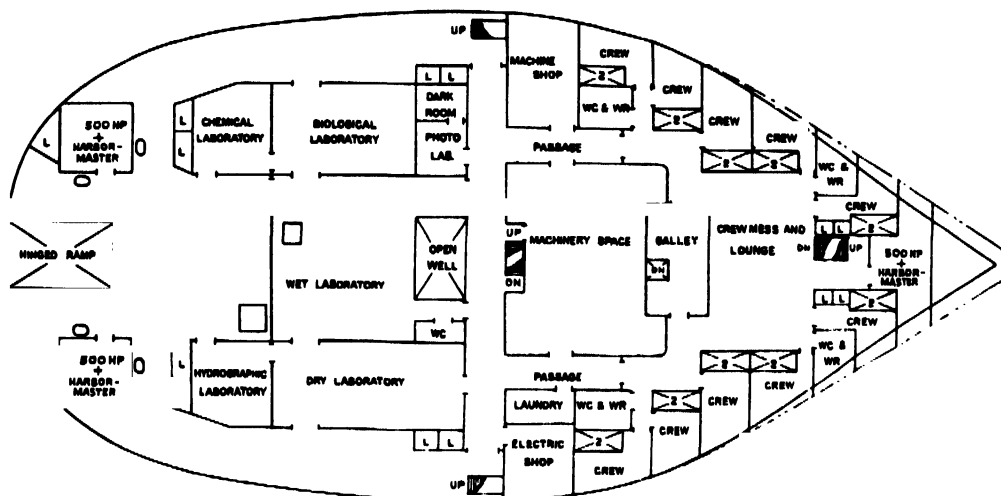
Fig 53. Main deck of Popoffka
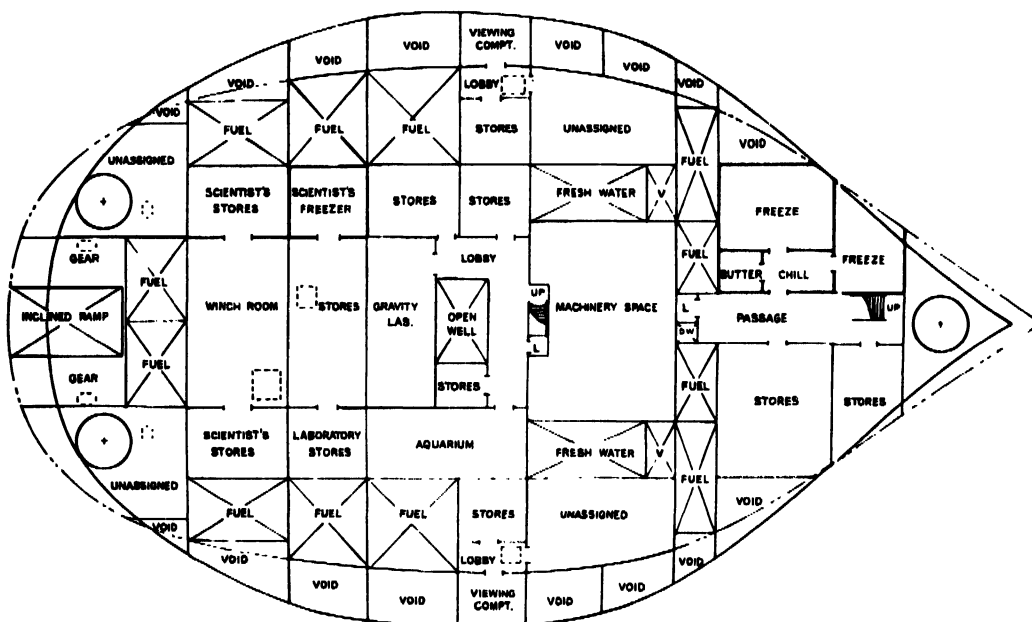
Fig 54. Lower deck of Popoffka

Requirements of new research vessels

Sutherland (USA): There are recurrent complaints about all existing research ships. Generally speaking, they include limited operation radius, inadequate laboratory facilities, accommodations for scientists and crew are too few in number and lacking in comfort, there is insufficient open deck area, a lack of manœuvrability at creep speeds, and inability to continue operations in high seas states. Research personnel continually seek better and better tools. Seldom does a group completely agree on specifications, for each man builds upon his own experience and has distinct opinions as to the overall importance of different ship characteristics, and how much he is willing to sacrifice in other areas in order to meet "real" requirements.

Research on the popoffka (page 195) suggested that it might be adopted for the solution of several special ship problems, especially where the fuel cost and speed to a given station are of relatively small importance to the success of the voyage. As a demonstration of popoffka qualities, sketches

of a research vessel designed to meet everyone's requirements are presented - impossible as such an achievement may be.

The target of this preliminary design was a ship of less than 150 ft (45 m) in length, to displace not over 1,000 tons, to have a sea speed of not less than 10 knots, to offer far more in facilities and comfort than any existing ship of comparable size, and to have the ultimate in manœuvrability and position-keeping ability. Further study would be required to assure that hoped-for qualities can actually be attained.

The hull configuration is scaled-down from *Livadia*. Minor variations in hull outline and dimensions could perhaps be made without penalty, and possibly improvements in the design could be made, considering that modern testing facilities and methods, as well as better materials, are available 80-odd years after *Livadia* was built.

Fig 50 to 54 inclusive show possible arrangements which meet the criteria established in the previous section. The design appears well balanced, but many additional investigations need still be made. Notable features of the design,

uncommon in conventional research vessels of similar displacement or length, include:

simple construction
double-bottom throughout most of length
excellent watertight subdivision
8 ft (2.4 m) deck heights throughout
numerous void spaces adding to reserve buoyancy
unassigned spaces reserved for growth
large sheltered working deck areas
retractable, steerable propulsion units
push-button ship control from bridge or secondary conning station
manœuvring and positioning capability
large open well amidships
ramp of suitable dimensions
helicopter platform (or van space)
viewing compartments
aquarium
eight large laboratories, plus appropriate shops
unmatched stability and heavy-lifting capability
boat stowage outboard of main deck areas
comfortable and adequate accommodations
long endurance on station
alleged seakindliness making anti-rolling devices unnecessary

Possible propulsion methods

For both propulsion and positioning, it is proposed to use three 500 hp, electric drive, retractable, steerable right angle drive units. One of the three identical units would be located on the ship's centreline near the bow, the other two well off the centreline at the stern. Provision is made for complete retraction of the units into the hull, as for instance when a clear-bottom area is needed in order to avoid fouling gear. Units could be serviced while in the retracted position. All the right angle drive units should have infinite speed control, available by using either DC motors, or AC motors with eddy-current couplings. All units would be remotely controlled from the bridge, or the secondary conning station aft, and on occasion by an automatic pilot. The right angle drive unit would swing perhaps 70 in (1,780 mm) propellers, with or without Kort nozzles, at about 325 rpm maximum. The performance to be expected from 500 hp right angle drive units is detailed by Wanzer on page 407. With infinitely variable thrust which can be directed at any angle, it is possible to overcome any conceivable combination of forces imposed upon the ship by wind, sea, current and operations. So powered, the ship can maintain any desired position, with any prescribed heading.

In table 6, it is noted that 1,500 shaft hp has been provided for a trial speed of 11 knots and service speed of 10 knots. It is unlikely that amount of power will be required for those speeds. Actually scaling-down from *Livadia*, and her full-scale trial results, using Froude's well-known Laws of Comparison, Admiralty coefficients, etc., it appears that this research vessel version of a small popoffka would require about 610 shaft hp in order to make 10 knots under trial conditions. Probably the ship would make the stated speeds using only two of the three right angle drive units, but the third would be very helpful in meeting positioning requirements, and sometimes during operations it may be advantageous to retract one unit and "steam" on the other two, without great sacrifice in speed.

Some may note the failure to assign space to chain lockers and ground tackle. Adequate space is available for such assignment, if desired. But ideally, the ship would automatically hover over her assigned anchorage using her propulsion and positioning units. Signal input to the automatic control is obtainable from a small taut wire to the bottom. Trend of the wire, and its tension, would control direction and amount of thrust of the propulsion units. Using a similar system, but with different input and with lesser total positioning power available, much larger *Cuss I* maintained position "for days on end", as reported, within a circle of 50 ft (15 m) radius in 12,000 ft (3,700 m) of water while engaged in the preliminary phase of the *Mohole* project.

Besides tabulating the principal characteristics, complement, living and laboratory areas for the popoffka research vessels, tables 6 and 7 offer a convenient comparison of the popoffka with a catamaran design and two conventional ships.

It is believed that the small popoffka design shows to advantage in several respects, but it is acknowledged that not everything one expects to achieve during the early preliminary design stage of a ship remains attainable at the time a contract design is completed.

Contract design of the smaller catamaran used in the comparison is understood to have been completed, though the ship has not been built. The other two larger ships used in the comparison have been put into service. Data presented for the catamaran design, and for the two conventional ships have been obtained from Traung and Fujinami (1961).

TABLE 6
General characteristics of research vessels

Popoffka ft	Popoffka m		Atlantis II ft	Atlantis II m	Miami Catamaran ft	Miami Catamaran m	Agor Class ft	Agor Class m
149.5	45.5	Length overall	209.74	64	41	43	208.3	63.4
136	41.5	Length, load waterline	195	59.3	30	39.6	196	60
88	26.9	Breadth, moulded	44	13.4	57.6	17.6	37	11.25
71	21.6	Breadth, at main deck	—	—	—	—	—	—
4	1.2	Design draught	16	4.9	8	2.44	14	4.27
—	—	Drag	3	0.9	—	—	1	0.3
17	5.2	Freeboard, forward	21	6.4	17.75	5.4	—	—
6	1.8	Freeboard, aft	8	2.44	8.75	2.67	7.25	2.21
910		Displacement, tons	2,110		640		1,373	
1,500		Shaft horsepower	1,400		950		1,100	
3		No. of propellers	2		2		1	
11		Speed, trial knots	13		13.5		13	
10		Speed, service knots	12		13.1		12	
361		Displacement/length ratio	284		281		183	
0.86		Speed/length ratio	0.86		1.15		0.86	
1.55		Length/beam ratio	4.42		2.26		5.3	
22.0		Beam/draft ratio	2.75		7.2		2.64	

TABLE 7
Space facilities on research vessels

	Popoffka ft²	Popoffka m²		Atlantis II ft²	Atlantis II m²	Miami Catamaran ft²	Miami Catamaran m²	Agor Class ft²	
Living areas									
Chief scientist	170	16		198	18	170	16	234	22
Other scientists	1,016	95		1,094	102	585	55	672	62
Master	170	16		198	18	180	17	234	22
Officers	478	44		726	68	233	22	336	31
Crew	900	84		914	85	430	40	252	23
Scientists' and officers' mess	430	40		480	45	415	39	306	28
Crew's mess and lounge	400	37		232	22	200	19	—	—
Galley	228	21		216	20	180	17	200	19
Washrooms and toilets	488	45		525	49	510	47	-	—
Library	92	9		204	19			240	22
Scientific areas									
Laboratories, below main deck	605	56		458	43	120	11		
Laboratories, on main deck	1,515	141		1,010	94	1,160	108	1,200	112
Laboratories, above main deck	188	18		1,010	94				
Open area above main deck	6,900	645		1,208	112	1,800	167		
Open area on main deck aft	2,920	272		1,780	163	2,400	223		
Complement									
Scientists		28			25		17		15
Officers		8			9		5		8
Crew		20			19		12		14
Guest		1			...		—		—
Total		57			53		34		37

By any other mode of comparison, it also can be shown that the popoffka offers advantages, if its disadvantages are acceptable. The same claim can as validly be made for the catamaran and the conventional hulls.

Popoffkas are a specialized type of ship which might be useful for special purposes. Unique capabilities are necessary today in several areas, and one might be willing to sacrifice other qualities in order to obtain outstanding stability, large deck areas, the manœuvrability associated with short length and unconventional propulsion machinery, and seakindliness.

If reliance can safely be placed in the published professional literature, quoting some of the most eminent authorities of the day, popoffka hull seems to offer attractive advantages. The reliability of the literature can be easily confirmed or refuted by model tests in a modern laboratory.

New and improved fish products

Danielsen (Switzerland): The demand for protein is tremendous and increasing year by year. The development in the USA and Europe is a good example of the increased need for sophisticated fish products of high quality. This development has a paramount influence—and will have in the future—on the design of fishing boats.

Modern preservation technique is today being extended to developing countries—Africa, South America, etc.—the result of this quite obviously will be a sound economical background for the modernization of the fishing and a change from smaller boats to larger sea-going vessels.

The fact that, on the near-by fishing grounds, there has been a tendency to overfishing, so that the fishing nations have been forced to look for other grounds in distant waters, together with the development of the processing technique, will influence the size of the ships, technique used, etc. This will be of major importance for developing countries. Another factor not less important is the formation of market communities and the larger companies need and desire to diversify and expand. These companies will be thinking only in economical terms and therefore this will probably influence the future more than anything else.

For this rapid development, it is very important that fishing boat operators and naval architects are dynamic and quick to adapt to all changes in the environment without being bound to traditions and politics, but are thinking in economical terms only. The potentials in the sea are at least one well-prepared meal from fish to every single individual in the world once a week. Let this be the objective in the future!

Increasing complexity of needs

Paz-Andrade (Spain): World fisheries are going through a period of transition towards: a different level of greater complexity on the extractive side, and greater volume in production; factors triggering off the process are the growing need for protein foods and the impact of technological innovation applied to production; the process involves the rehabilitation of developing or economically depressed areas, humanitarian and social responsibility of the prosperous or technologically developed countries.

The process has as its main objectives:

(1) priority for distant-water fisheries, involving freezing of catch at sea
(2) full utilization of catch, obviating rejection of species which could be used for by-products other than fishmeal, thereby correcting the trend towards mass-scale and indiscriminate concentration on the latter;
(3) introduction of advanced equipment involving heavy capital outlay, including mother ships, factory ships, trawlers, freezers, refrigerated transport
(4) changes in pattern of fisheries involving

- progressive abandonment of the traditional system whereby one and the same craft does the fishing and takes catch to port
- operational separation of these two phases, even in the case of vessels unsuitable for use independently

● adoption of practice of operation as a fleet aimed at

> maximum effective fishing time
> full utilization of available crew, including traditional type crews
> full utilization of catch aboard ships acting as collection centres for other boats in fleet

On the above premises, the problem of the development of the fisheries sector for the future amounts to:

● perfecting the machinery of the technological and economic development now underway

facilitating the changeover from "dispersed" to centralized production

coordination of these objectives with conservation of the biological resource, by enabling crews to have a wider deployment range and establishing possible alternatives among the various fishing grounds

reservation, one at a time, of adjacent areas (if possible, subject to their re-stocking) for fleets of low tonnage and practicing non-industrial fishing

co-operative organization of family-type fisheries

efficient management of the entire system with a view to maximizing production on a sustained-yield basis

REFERENCES

The figures in brackets are the page numbers of this book where the references have been quoted.
FBW — *In* Fishing Boats of the World. Fishing News (Books) Ltd., London. 1955. 600 pp.
FBW: 2 = *In* Fishing Boats of the World: 2. Fishing News (Books) Ltd., London. 1960. 781 pp.
MFGW — *In* Modern Fishing Gear of the World. Fishing News (Books) Ltd., London. 1959. 639 pp.
MFGW: 2 — *In* Modern Fishing Gear of the World: 2. Fishing News (Books) Ltd., London. 1964. 603 pp.

ABKOWITZ, M A   The effect of antipitching fins on ship
1959   motions. Trans. SNAME, Vol. 67, New York. (184)

ALEXANDER, J B   Basic stresses for wood. Forest Products
1949   Research Society Bulletin, No. 62. Madison, Wis., USA. (215, 219)

ALFERS-GRANER, J B   Glass reinforced plastic laminate in
1960   contact with sea water or fuel. Proceedings of the 1960 Conference of the Society of the Plastics Industry Inc., New York. (275)

ALLEN, R F   King crab pot fishing in Alaska. MFGW: 2.
1964   (546)

ALTON, LEONARD   Western Fisheries. Nov. 1959. Roy
1959   Wrigley Publications Ltd., Vancouver, BC, Canada. (495)

ALVERSON, D L   Trends in trawling methods and gear on the
1959   West Coast of the US. MFGW. (566, 570)

AMERICAN BUREAU OF SHIPPING RULES 1965. (261)
1965

ANONYMOUS   Luketa's astronaut in orbit. Pacific Fisherman,
1962   60(9): 15, 1. Seattle, Wash., USA. (546)

ARMSTRONG, F H   The strength properties of timber. Forest
1961   Products Research Laboratory Bulletin, No. 45. Her Majesty's Stationery Office, London. (219)

ASHTON, RANDOLPH   Effect of spray strips on various power-
1949   boat designs. Technical Memorandum, No. 99, Experimental Towing Tank, Stevens Institute of Technology, Hoboken, NJ, USA. (495)

ASIA KYOKAI (ED.)   Japanese fisheries—their development and
1957   present status. Asia Kyokai, Tokyo. (44)

BAEHLER, R H   Corrosion of metal fastenings in zinc-chloride-
1949   treated wood after 20 years. American Wood Preservers Association, Washington, DC, USA. (225)

BARTZ, F   Fischgründe und Fischereiwirtschaft an der
1942   Westküste Nordamerikas. (Fishing grounds and fisheries economy of the West Coast of North America.) Geographische Institut der Universität Kiel, Germany. In German. (35, 36)

BEACH, D D   Commercial outboard fishing craft. FBW: 2.
1960   (334)

BEEVER, C   Economic influence on design of fishing craft.
1955   FBW. (33, 37, 41, 48, 50)

BEEVER, C and RUUD, K   Financial assistance schemes for the
1960   acquisition or improvement of fishing craft. FAO Fisheries Studies No. 9. Rome. (43)

BEGHTEL, S C and NORRIS, C B   Strength of wood beams of
1949   rectangular cross section as affected by span depth ratio. Forest Products Laboratory Report No. 1910, Madison, Wis., USA. (218)

BENFORD, H and KOSSA, M   An analysis of US fishing boats—
1960   dimensions, weights and costs. FBW: 2. (40, 237)

BIRKHOFF, C   Stern trawling. (A record of the stern trawling
1963   conference at Grimsby, UK, 1963.) Fishing News (Books) Ltd., London. pp. 61–63. (568)

BLACK, CLINTON V   History of Jamaica. (1st edition.)
1958   Collins Cleartype Press, London. (434)

BOGUCKI, D   The determination of optimum characteristics
1964   for fishing vessels. FAO Meeting on business decisions in fishery industries, 1964, FAO Fish. Rep. (22.2). Rome. (116)

BOSCH, J J VAN DEN and VUGTS, J H   Roll damping by free
1966   surface tanks. Report No. 134, Shipbuilding Laboratory, Delft, Netherlands; or Report No. 835, Netherlands Ship Research Centre. (159)

BRITISH STANDARD   British-made plywood for marine craft.
1957   British Standard No. 1088. British Standard Institution, London. (212)

BROSENIUS, H   (HSB-Girder utilized in building of wooden
1947   vessels of the order of 150–300 GRT.) Discussion contribution to Unda Maris, 1947 1948. Göteborg, Sweden. In Swedish. (227, 228)

BRUHN, J   The transverse strength of ships. Trans. INA,
1901,   London. (215)
1904

BURDON, T W   A report on the fishing industry of Malta.
1956   Government Printing Office, Valletta, Malta. (38, 44)

BUREAU OF SHIPS JOURNAL   Wooden hulls and decay preven-
1953   tion. May. pp. 35–38. US Navy Department, Washington, DC, USA. (212)

BUREAU VERITAS Rules for the construction of fishing boats.
1963a Paris. (215, 294)

BUREAU VERITAS Nouveau réglement du Bureau Veritas pour
1963b les navires de pêche en bois. (New regulation of
Bureau Veritas on construction and classification of
wooden fishing vessels.) Bulletin technique du
Bureau Veritas, Apr. Paris. In French. (215, 297)

CARTWRIGHT, K S G and FINDLAY, W P K Decay of timber
1958 and its prevention. Her Majesty's Stationery Office,
London. pp. 55-57. (220, 222, 289)

CHADWICK, J H and KLOTTER, K On the dynamics of anti-
1954 rolling tanks. Schiffstechnik 8. C Schroedter and
Co., Hamburg, Germany. (189)

CHAPELLE, HOWARD I Some American fishing launches.
1955 FBW. (41, 56)

CHAPELLE, HOWARD I Comments on hull design of fishing
1960 boats. FBW: 2. (50)

CHAPMAN, W M Politics and the marine fisheries. Address
1965 delivered to North American Fisheries Conference,
30 Apr. to 5 May 1965, Washington, DC, USA. (44)

CHARBONNIER, D and CHEMINAULT, R Traitement et com-
1964 mercialisation du poisson pêché dans le Delta Central
du Niger. (Processing and distribution of fish taken
in the Central Delta of the Niger River.) A study
carried out by the SCET—Coopération et la SNDES
Ministère de la Coopération, République Française)
for the Republic of Mali. In French. (35, 37, 38)

CHRISTENSEN, A N How costings rationalize construction.
1955 FBW. (209, 210)

CLEMENT, E P and BLOUNT, D L Resistance tests of a syste-
1963 matic series of planing hull forms. Trans. SNAME,
New York. Vol. 71, 1963. (495)

COBB, B JR A report of long term durability of fibreglass
1962 boats. Yachts and Yachting, Eden Fisher Ltd.,
Southend-on-Sea, Essex, UK. (256, 275)

COLVIN, THOMAS E Gillnet fishing: deck design and equip-
1960 ment. FBW: 2. (46)

COPES, P St. John's and Newfoundland—an economic survey·
1961 The Newfoundland Board of Trade, St. John's,
Newfoundland, Canada. (34, 39, 42, 43, 46, 47, 48)

COUTY, PH Le commerce du poisson dans le Nord-Caméroun.
1964 (The fisheries trade in the Northern Cameroons.)
Office de la Recherche Scientifique et Technique
Outre-Mer (ORSTOM), Institute de Recherches
Scientifiques du Caméroun, Paris. In French. (36)

COUVERT, M Études de problèmes posés par la com-
1963 mercialisation des produits de la pêche à Madagascar.
(A study of the problems of distributing fishery
products in Madagascar.) SATEC, Paris. (36, 50)

CRUTCHFIELD, J and ZEI, M Draft report of mission to
1964 Ghana—Fisheries Research Unit. Unpublished
manuscript, prepared for UNSF, New York. (43, 51)

CURRY, W T Working stresses for plywood. Forest Products
1957 Research Laboratory Bulletin No. 42. Her Majesty's
Stationery Office, London. (225)

DAGET, J La pêche dans le Delta Central du Niger. Journal
1949 de la Société des Africanistes, 19. In French. (37)

DANISH GOVERNMENT RULES Draft DS-recommendations
1965 M 314/Oct. 1965. Dansk Standardiseringsråd,
Copenhagen, Denmark. In Danish. (294)

DE SILVA, G B Socio-economic survey of fisher families,
1964 1958-59. Bulletin of the Fisheries Research Station,
Ceylon, 17(1), Colombo, Ceylon. (37, 47)

DICKSON, W and MOWAT, M J D Measuring seine net warp
1963 tension. Scottish Fisheries Bulletin, No. 19, Jun. (91)

DIGBY, MARGARET Cooperation for fishermen. International
1961 Cooperative Alliance and FAO, Rome. (47)

DOKE, C and CHIGUSA, S Tuna freezing. FBW: 2. (416, 554)
1960

DOUST, D J Optimized trawler forms. NECI, 79 (preprint),
1962a Newcastle-upon-Tyne, UK. (123, 148)

DOUST, D J The statistical analysis of FAO resistance data
1962b for trawlers and related hull design considerations.
FAO Report 23 Aug. (second draft—Restricted).
Rome. (123)

DOUST, D J Optimized trawler forms. NECI, 79, Newcastle-
1963 upon-Tyne, UK. (119, 120)

DOUST, D J The relative importance of trawler design in the
1964 economics of fishery operations. FAO Meeting on
business decisions in fishery industries, 1964. FAO
Fish. Rep. (22.2), Rome. (116)

DOYLE, D V Diaphragm action of diagonally sheathed wood
1957 panels. Forest Products Laboratory, Report No.
2082. Madison, Wis., USA. (227)

ERICKSON, E C O Mechanical properties of laminated
1959 modified wood. Forest Products Laboratory Report
No. 1639. Madison, Wis., USA. (225)

ESTLANDER, E (Discussion on beach landing boats.) FBW.
1955 p. 253. (518, 519, 520)

EVANS, K G Design of wooden naval vessels. Trans. INA,
1957 Vol. 100, 1958. London. (223, 228)

FAO EPTA Reports Nos. 403, 706, 945, 1096, 1409, 1518,
1953- 1535, 1710, 1711, 1846, 2004 and 2107. FAO, Rome.
1965 (437, 438)

FAO Report of the third conference on wood technology.
1954 FAO Forestry Development Paper, No. 7, Rome.
(218, 220)

FAO Report of the fourth conference on wood technology.
1958 FAO/WTC/58/8, Rome. (218, 220)

FAO Economic effects of fishery regulation. Report of an
1962 FAO Expert Meeting at Ottawa, 1961. FAO Fish.
Rep. (5). Rome. (44)

FAO FAO Yearbook of Fishery Statistics, Vol. XV. Rome.
1962 (327)

FAO Report of the fifth conference on wood technology,
1963 in Madison, Wis., USA. (218, 220)

FAO Report of the meeting on business decisions in fishery
1965 industries. FAO Fish. Rep. (22), Vol. 1. Rome. (34)

FAO UNDP Report No. TA 2217, FAO, Rome. (437, 438).
1966

FARMER, R H Corrosion of metals in association with wood.
1962 Wood, Aug. pp. 326–328, 443–446. Tothill Prees
Ltd., London. (225)

FISH TRADES GAZETTE Stern trawler fleet study at Aberdeen,
1965 17 Apr. 1965. Retail Journals Ltd., London. (39)

FLETCHER, R and POWELL, M J D A rapidly convergent
1963 descent method for minimization. Computer Journal,
6, 163. British Computer Society, London. (141)

FLODIN, J An analysis of the Isherwood system of ship
1919 construction. Trans. SNAME, Vol. 27, New York.
(228)

FRAHM, H Results of trials of the anti-rolling tanks at sea.
1911 Trans. INA, Vol. 53, London. (184)

FREAS, A D Studies of the strength of glued laminated wood
1950 construction. ASTM Bulletin No. 170. American
Society for Testing Materials, Philadelphia, Penns.,
USA. (299)

FREAS, A D and SELBO, M L Fabrication and design of glued
1954 laminated wood structural members. Technical
Bulletin No. 1069, US Department of Agriculture,
Washington, DC, USA. (225)

FREAS, A D Factors affecting strength and design principles
1956 of glued laminated construction. Forest Products
Laboratory Report No. 2061, Madison, Wis., USA.
(225)

FRIED, N Laboratory Project 6152, Supplementary Report.
1962 US Naval Applied Science Laboratory, Naval Base,
Brooklyn, NY, USA. (256)

GENERAL DYNAMICS CORPORATION, CONVAIR DIVISION
1963 Development of a telemetering oceanographic buoy.
Sponsored by the US Navy Office of Naval Research.
Progress Report GDC-63-060. (197)

GERMANISCHER, LLOYD Vorschriften für Klassifikation und
1964 Bau von hölzernen Seeschiffen. (Regulations for the
classification and construction of wooden seagoing
ships.) Hamburg, Germany. In German. (294, 297)

GIANESI, G Deep freezing on tropical seas. Paper read at the
1963 XI International Congress of Refrigeration. Munich
1963. (418)

GIBBS AND COX, INC. Marine Design Manual for Fiberglass
1960 Reinforced Plastics. McGraw-Hill Book Co. Inc.,
New York. (258)

GIBBS AND COX, INC. Marine Survey Manual for Fiberglass
1962 Reinforced Plastics. Gibbs and Cox, Inc., New York.
(258, 259)

GNANADOSS, D A S (Discussion on comparison of wooden
1960 scantling regulations.) FBW: 2. pp. 171–172. (293)

GOLDSWORTHY, E C New materials for construction and
1955 operation. FBW. (40)

GOODMAN, J R and HAYGREEN, J Problems and possibilities
1964 of a post-tensioned wood panel. Forest Products
Journal, Sept. Madison, Wis., USA. (226)

GOULAEFF, E E On circular ironclads. Trans. INA, Vol. XVI,
1876 pp. 29–61. London. (195, 196, 197)

GOULAEFF, E E On the Russian imperial yacht Livadia.
1881 Trans. INA, Vol. XXII, pp. 256–264. London. (196,
197)

GRANHOLM, H Chalmers Technical University Report No.
1954 154. Göteborg, Sweden. pp. 89–92. In Swedish with
English summary. (227)

GRANHOLM, H Chalmers Technical University Report No.
1961 239. Göteborg, Sweden. pp. 114–118. In Swedish
with English summary. (226, 227)

GRIGORE, J JR et al Catamaran survey vessel. The Military
1962 Engineer for May–Jun., Vol. 54, No. 359. pp. 192–
193. Washington, DC, USA. (193)

GRIM, O Berechnung der Festigkeit eines Schalenschiffes.
1952 (Calculation of strength of a vessel of laminated shell
construction.) Schiff und Hafen, Hamburg, Germany.
pp. 524–527. In German. (215)

GRIM, O Berechnung der Festigkeit eines Schalenschiffes.
1953 (Calculation of strength of a vessel of laminated shell
construction.) Schiff und Hafen, Hamburg, Germany.
pp. 11–13. In German. (215)

GURTNER, P Development of a boat for India's surf coasts.
1960 FBW: 2. (519)

GURTNER, P FAO Third Report to the Government of India
1963 on fishing boats. Rep. FAO/EPTA (1535). Rome.
(52)

HAJIMU, M The effect of rise of floor on longitudinal strength
1961 of wooden ships. Journal of the Society of Naval
Architects of Japan, Tokyo. No. 109, pp. 41–49.
(215)

HAMLIN, C Glued strip construction. Yachts and Yachting,
1954 Eden Fisher Ltd., Southend-on-Sea, Essex, UK.
(226, 227)

HAMLIN, C (Discussion on new type of construction (strip-
1960 building)) FBW: 2. pp. 172–175. (226)

HAMLIN, C The catamaran as a seagoing work platform.
1965 Ocean Science and Ocean Engineering Conference,
Washington, DC, USA. (191)

HAMLISCH, R and TAYLOR, R A The demand for fish as
1962 human food. In Fish in Nutrition, Fishing News
(Books) Ltd., London. (81)

HANSON, H C Pacific combination vessels. FBW. (535, 563)
1955

HANSON, H C Steel and wood scantling tables (West Coast of
1960 USA). FBW: 2. (293)

HARADA, M et al Strength investigations concerning
1950 European-type wooden ships, 25 test reports. Fishing
Boat Laboratory of Japan 1950–1960, Tokyo. In
Japanese with English summary. (226, 227)

HARADA, M *et al* The longitudinal strength of wooden ships.
1950   Journal of the Society of Naval Architects of Japan, Nos. 74, 1952: pp. 33–52; 75, 1953: pp. 43–68; 82, 1960: pp. 1–13. Tokyo. In Japanese. (226, 227)

HARADA, M *et al* Suggestive design of nails and a method of
1954   design of nails. Journal of the Society of Naval Architects of Japan, Nos. 76, 1954: pp. 85–98; 77, 1955; pp. 155-164, 147–154. Tokyo. In Japanese. (226)

HARTLEY, C and MAY, C Prevention of decay of wood in
1960   boats. Forest Pathology Special Release No. 8. Department of Agriculture, Beltsville, Md., USA. (224)

HAYES, J G The optimum hull form parameters. Symposium
1963,   on Numerical Method Applied to Shipbuilding.
1964   Central Institute for Industrial Research, Oslo, Norway. (123, 148)

HEADY, E O Basic economic and welfare aspects of farm
1949   technological advance. Journal of Farm Economics, 31 (2). American Farm Economic Association, Menasha, Wis., USA. (45, 56)

HILLMAN, H J Wood for small boat construction. Inter-
1956   national Shipbuilding Progress (10) Vol. 3, No. 26, pp. 551–559. International Periodical Press, Rotterdam, Netherlands. (224)

HIRT, R R Moisture content of wood boats. Forest Pathology
1944   Special Release, No. 18. Department of Agriculture, Beltsville, Md., USA. (222, 223)

HISHIDA, I, YAMACHIKA, I *et al* Conducting experiments on
1957–   models and actual ships of double layer planking and
1959a   obtained design data. Technical Report of Hitachi Zosen 18.4 (11), pp. 9 12; 20.1 (16), pp. 9–17; 102 (10), pp. 111-116. Osaka, Japan. In Japanese. (227)

HISHIDA, I, YAMACHIKA, I *et al* Conducting experiments on
1957–   models and actual ships of double layer planking and
1959b   obtained design data. Journal of the Society of Naval Architects of Japan, Tokyo. 104 (14), pp. 163-174. (227)

HISHIDA, I *et al* Experimental research with aluminium alloy
1959   frames and wooden planking. Technical Report of Hitachi Zosen. 20.1 (15) pp. 31 35. Osaka, Japan. In Japanese. (227)

HOLLIMAN, E S Financial assistance policies and administra-
1962   tion for fishery industries. FAO Fisheries Studies, No. 11, Rome. (43)

HUGHES, G Tank boundary effects on model resistance.
1961   Trans. RINA, Vol. 103, London. (124, 125)

HUSE, H V Hydraulic deck equipment. FBW. (415)
1955

HUSE, H V Hydraulic deck equipment for research vessels.
1961   Research Vessel Design, FAO, Rome. (415)

ICHIKAWA, S Investigation of strength of scarfed joints.
1955   Journal of the Society of Naval Architects of Japan, No. 77 (5), pp. 139-146. Tokyo. In Japanese. (224)

IPFC/FAO Proceedings, 7th Session, Indo-Pacific Fisheries
1957   Council, Section I. IPFC Secretariat, FAO Regional Office for Asia and the Far East, Bangkok, Thailand. (45)

IPFC/FAO Proceedings, 8th Session, Indo-Pacific Fisheries
1958   Council, Section I. IPFC Secretariat, FAO Regional Office for Asia and the Far East, Bangkok, Thailand. (44, 49, 50)

IPFC/FAO Proceedings, 9th Session, Indo-Pacific Fisheries
1961   Council, Section I. IPFC Secretariat, FAO Regional Office for Asia and the Far East, Bangkok, Thailand. (38, 40, 45)

IPFC/FAO Proceedings, 10th Session, Indo-Pacific Fisheries
1963   Council, Section I. IPFC Secretariat, FAO Regional Office for Asia and the Far East, Bangkok, Thailand. (39, 45, 49, 50)

IPFC/FAO Intersession Report (1963-64) of Technical
1964   Committee II and Craft and Gear Sub-Committee and Food Technology Sub-Committee to the 11th Session of the IPFC. IPFC/C64/WP7. IPFC Secretariat, FAO Regional Office for Asia and the Far East, Bangkok, Thailand. (39, 40, 47, 48, 49)

ISHERWOOD, J W A new system of ship construction. Trans.
1908   INA, Vol. 50, London. (228)

INUI, T A study of wave-making resistanceless hull forms.
1961   Research Vessel Design, YOK-8 Appendix. FAO, Rome. (633)

JABLONSKI, O A method to determine freeboard in relation to
1960   stability. FBW: 2. (474)

JAKOBSSON, JAKOB Recent development in Icelandic purse
1964   seining. MFGW: 2. (578)

JOHNSON, M New Development in the hull design of wooden
1953   ships. Paper presented at the Feb. 1953 meeting of the New York Chesapeake Section, SNAME, New York. (227)

JOHNSON, N V Experience with straight framed ships. Trans.
1964   RINA, Vol. 106, London. (531)

KEMPF, G Stabilitatsgranzen für Schiffe. Schiffbau, 41 (1940)
1940   Jan. Hamburg, Germany. In German. (155)

KETCHUM, V Glued laminated wood. Forest Products
1949   Research Society Bulletin, No. 87. Madison, Wis., USA. (225)

KNAKE, B O, MURDOCK, J E and CATING, J P Double rig
1958   shrimp trawling in the Gulf of Mexico. Commercial Fisheries Review (615), Washington, DC, USA. (596)

KOLLMAN, F Technologie des Holzes und der Holzwerk-
1951–   stoffe. (Technology of wood and wood materials.)
1955   Band 1 and 2. Springer Verlag, Berlin. In German. (216, 222, 225)

KOREAN FISHERIES Ministry of Agriculture and Forestry,
1962   Republic of Korea, Seoul, Korea. (36)

KRAUSE, R L Iron stain from metal fastenings may accelerate
1954   decay in some woods. Journal of the Forest Products
        Research Society. Vol. IV (2), p. 103. Madison, Wis.,
        USA. (224)

KRISTJONSSON, H (ED.) Modern Fishing Gear of the World.
1959   Fishing News (Books) Ltd., London.

KUPRAS, L K Analysis of main dimensions, displacement,
1964   block coefficient and speed of a stern factory trawler.
        FAO Meeting on business decisions in fishery
        industries 1964. FAO Fish. Rep. (22.2). Rome. (122)

LA PÊCHE AU TCHAD (Fisheries in the République du Tchad.)
1965   Contribution prepared by the Ministère des Eaux et
        Forêts, Pêches et Chasses, République du Tchad, for
        the Seminar on Fisheries Administration and Develop-
        ment Planning, Abidjan 1965. FR SS/WP-45. In
        French. (36)

LERCH, D W The application of hydraulic power to fishing
1964   gear. MFGW: 2. (356, 415)

LEVY, F The freezing time of fish. Journal of Refrigeration,
1958   Mar.-Apr. (418)

LEWIS, E V and GERARD, G A long range research program
1959   in ship structural design. US Ship Structure Commit-
        tee, Report No. SSC-124. (213)

LINDBLOM, J Byggnadsteknik vid seriet.llverkning av 300
1947   tons skonare. (Building techniques for the mass
        production of schooners of 300 tons.) Unda Maris
        1947-1948, Göteborg, Sweden. pp. 211-256. In
        Swedish. (225)

LINDBLOM, J Om limmade träkonstruktioner i fartygs-och
1963   båtbyggeri. (Laminated wood construction in ship
        and boatbuilding.) Scandinavian Ship Technical
        Meeting Proceedings, 1963. In Swedish. Teknisk
        Förlag, Copenhagen, Denmark. (227, 300)

LISKA, J A Effect of rapid loading on the compressive and
1950   flexural strength of four wood species. Forest
        Products Laboratory Report No. R1767, Jun.
        Madison, Wis., USA. (218)

LLOYD'S REGISTER OF SHIPPING. Provisional Rules for the
1965   Application of Glass Reinforced Plastics to Fishing
        Craft. London. (261, 263, 306)

LORD, LINDSAY Naval architecture of planing hulls. Cornell
1963   Maritime Press, 1963. (495)

LUXFORD, R F and KRONE, R H Laminated, bolted and solid
1946   keels for 50 ft. navy motor launch compared for
        strength. Forest Products Laboratory Report No.
        R1625. Madison, Wis., USA. (226)

LUXFORD, R F and KRONE, R H Laminated oak frames for a
1956   50 ft. navy motor launch compared to steam bent
        frames. Forest Products Laboratory Report No.
        1611. Madison, Wis., USA. (225, 226)

MACCALLUM, W A The fish room, engineering and architec-
1960   ture. FBW: 2. (40, 223)

MACLEAN, J D Effect of steaming on the strength of wood.
1953   American Wood Preservers Association, Washington,
        DC, USA. (225)

MANDEL, P A comparative evaluation of novel ship types.
1962   SNAME, New York. (191)

MANNING, S F Fishermen weigh the benefits of stern trawling.
1964   National Fisherman/Maine Coast Fisherman 44 (2),
        pp. 8-9, 6 illus. Journal Publishing Co., Belfast, Me.,
        USA. (538)

MARIN, J Mechanical behaviour of engineering materials.
1962   Prentice-Hall, Englewood Cliffs, NJ., USA. (216, 217)

McCOY-HILL, M The marine borer problem. Wood, Jan.
1964   1964. pp. 40-43. Tothill Press Ltd., London. (223,
        224)

MEAD, M (ED.) Cultural patterns and technical change.
1953   UNESCO, Paris. (36, 37, 42, 47, 48)

MOAL, R and LACOUR, J P Quelques reflexions pratiques sur
1964   les perspectives du développement des pêches
        maritimes dans les pays en voie de développement.
        (Some commonsense observations on the develop-
        ment prospects of marine fisheries in developing
        countries.) Paper submitted to the FAO meeting on
        business decisions in fishery industries 1964. FIBD-
        W/35. FAO, Rome. In French. (50)

MÖCKIL, W Behaviour of trawlers at sea - II. FBW: 2.
1960   (155, 474)

MÖCKEL, W and HATTENDORF, H G Stabilitäts- und Schwin-
1963   gungsversuch mit zwei Lotsenversetzbooten. (In-
        vestigation of stability and roll tests with two pilot
        boats.) Hansa, No. 22, Hamburg, Germany.
        pp. 2179-2184. In German. (274)

MOE, J Strength and stiffness of glued laminated timber
1961   beams. Norsk Treteknisk Institutt Meddelse, No. 15.
        Trondheim, Norway. (219, 225)

MOLTENO, C J The possibilities of a mixed fishermen settle-
1962   ment in Northern Chile. Division of Migration
        Programs and Development Activities, The Inter-
        governmental Committee for European Migration,
        Rome and Geneva. (44)

MORGAN, P G The chemical deterioration of wood in the
1962   presence of iron. Wood, Dec. 1962. p. 492. Tothill
        Press Ltd., London. (224, 225)

MORGAN, R World Sea Fisheries, Methuen, London. (34, 35,
1956   36, 37, 39, 40, 41, 42, 46, 48, 49, 50)

MOTOR CRAFT (PLEASURE AND COMMERCIAL) Publication
1964   No. 302. National Fire Protection Association,
        Boston, Mass., USA. (401)

MURRAY, A The theory and practice of shipbuilding. Edin-
1851   burgh, UK. pp. 89-93. (212, 228)

MURRAY, ALLAN B The hydrodynamics of planing hulls.
1950   Trans. SNAME, Vol. 58, New York. (495)

MYRDAL, GUNNAR McDougall Memorial Lecture delivered
1965   at the opening of the 1965 FAO Conference. FAO,
        Rome. (81)

NETHERLANDS ECONOMIC INSTITUTE   The development of
1958   offshore fisheries and economics of choice. Publica-
        tion No. 16/58.   Division of Balanced International
        Growth, Rotterdam, Netherlands.   (35, 38, 39, 41,
        42, 44, 46, 48, 50)

NEWLIN, J A Structural timbers, defects and their influence
1924   on strength.   Forest Products Laboratory Report No.
        R1041. Madison, Wis., USA. (219)

NEWLIN, J A Bearing strength of wood at angle to the grain.
1939   Forest Products Laboratory Report No. R1203.
        Madison, Wis., USA. (220)

OEHLMANN, K Holz als Bootsbaustoff. (Wood as material for
1963   boat construction.) Hansa (16), Hamburg, Germany,
        pp. 1603-1605 and Schiff und Hafen, 7, Hamburg,
        Germany. pp. 603-605. (215, 227)

OTSU, Y et al Structural testing of small craft. FBW: 2.
1960   (212, 226)

PACKMAN, D F Electrochemical corrosion of fastenings in
1961   wooden boats. Forest Products Research Laboratory
        Bulletin No. 31.   Her Majesty's Stationery Office,
        London. (225)

PAIN, H E H et al Discussion on deck machinery and control.
1964   MFGW: 2. (538)

PECK, E C Bending solid wood to form. Agriculture Hand-
1957   book No. 125, US Department of Agriculture,
        Washington, DC, USA. (225)

PEDERSEN, G   Skalkonstruktioner i traekutterbyggeriet.
1964   (Shell construction in design of wooden fishing boats.)
        Ingeniøren No. 5, Mar. Copenhagen, Denmark. In
        Danish. (215, 226, 227)

PEERY, D J Aircraft structures. McGraw-Hill, New York.
1950   p. 279. (216)

PILLOW, M Y Selecting white oak trees for bending lumber.
1951   Forest Products Research Society Bulletin No. 152.
        Madison, Wis., USA. (225)

PRODUCTION OF FISH IN THE COLONIAL EMPIRE (REVISED
1954   EDITION) Colonial Office. Her Majesty's Stationery
        Office, London. (47, 50)

RABL, SAMUEL S Multiconic development surfaces. Problems
1959   of Small Boat Design. Sheridan House, New York.
        (529)

REED, E J On the injuries sustained by the Livadia in the Bay
1881   of Biscay. Trans. INA, Vol. XXII, London. pp.
        265-283. (196, 197)

REPORT OF THE COMMITTEE OF INQUIRY INTO THE FISHING
1961   INDUSTRY. Her Majesty's Stationery Office, London.
        (37, 38, 39, 41, 43, 44, 45, 49)

REPORT OF THE DEPARTMENT OF GAME, FISH AND TSETSE
1962   CONTROL FOR THE YEAR ENDED 31 DEC. 1961 Ministry
        of Natural Resources and Local Government,
        Zomba, Malawi (formerly Nyasaland). (41)

RICARDO, H R High-speed diesel engines for marine service.
1933   Proc. Institute of Mechanical Engineering, Vol. 125,
        London. p. 293. (398)

RINGHAVER, L C Design and mass production of shrimp
1960   trawlers. FBW: 2. (40)

ROBAS, JOHN S Seining with a shrimper. Fish Boat, 6 (6),
1961   pp. 27-29, 39. H L Peace Publications, New Orleans,
        USA. (542)

ROBINSON, JOAN   Economic Philisophy.   Pelican edition,
1964   London. (77)

ROPELEWSKI, A Wies Rybacka Rewa W Powiecie Puckim.
1962   (Fishing Village Rewa in the Puck District.) Gdanskie
        Towarzstwo Naukowe. Institute of Nauk Spoecznych
        i Humanistycznych, Gdansk, Poland. In Polish with
        English summary. (34)

SAUNDERS, HAROLD E   Hydrodynamics in ship design.
1957   SNAME, New York. (495)

SAVITSKY, DANIEL   Hydrodynamic design of planing hulls.
1964   Paper presented at the Jan. 1964 meeting of the New
        York Metropolitan Section, SNAME, New York.
        (495)

SAVORY, J G Prevention of decay of wood in boats. Forest
1961   Products Research Laboratory Bulletin No. 31. Her
        Majesty's Stationery Office, London. (223, 224)

SCHMIDT, P V The puretic power block and its effect on modern
1959   purse seining. MFGW. (570)

SCHMIDT, P V Purse seining: deck design and equipment.
1960   FBW: 2. (546)

SCHNIEWIND, A P A look at wood engineering since 1957.
1962   Forest Products Journal, Vol. XII, No. 8, Aug.
        Madison, Wis., USA. pp. 343-353. (299)

SCHUSTER, S   Beitrag zur Frage der Kanalkorrektur bei
1955   Modellversuchen.   (Contribution concerning the
1956   question of restricted water corrections in model
        tanks.) Schiffstechnik, 3. Schroedter and Co.,
        Hamburg, Germany. In German. (125)

SELBO, M L and GRØNVOLD, O Laminering av trykkimpraeg-
1956   nert furu.   (Laminating of preservative-treated
        Scotch pine.) Norwegian Institute of Wood Working
        and Wood Technology, Blindern, Oslo, Norway. In
        Norwegian and English. (300)

SELBO, M L   Laminating of preservative-treated wood.
1957   American Wood Preservers Association, Washington,
        DC, USA. (225, 300)

SELBO, M L A few brief comments on laminated ship and
1964   boat timbers. Communication presented at a meeting
        on fishing vessel scantlings arranged by the Danish
        Wood Council, Copenhagen, Denmark. (300)

SETNA, S B Bombay fishing boats. FBW. (38)
1955

SHIP AND BOAT BUILDER INTERNATIONAL   140 footers in
1965   glassfibre. John Trundell (Publishers) Ltd., London.
        (257)

[646]

SIMPSON, D S Suggested standard scantlings. FBW: 2. (280)
1960

SNAME, Hull Structure Committee, Panel HS-6, Task
1965   Group HS-6-3 (structural plastic) Bulletin 2-12, dated
       Mar. 1965 "Guide for the selection of fiberglass
       reinforced plastics for marine structures". SNAME,
       New York. (259, 265)

SPAULDING, K B and DELLA ROCCA, R J Fibreglass reinforced
1965   plastic minesweepers. Trans. SNAME, Vol. 73, New
       York. (256, 259, 260, 267, 269)

SPICER, E H (ED.) Human problems in technological change—
1952   a casebook. Russell Sage Foundation, New York.
       (36, 47)

SQUIRE, J L, Jr New England commercial Bluefin tuna purse
1959   seining.   Commercial   Fisheries   Review,   21(2),
       Washington, DC, USA. pp. 1–5. (541)

STENSTROM, L Agricultural engineering development of
1963   agricultural equipment. Summary of proceedings on
       agriculture of the UN conference on the application
       of science and technology for the benefit of the less
       developed areas, prepared for First World Food
       Congress, 4 to 16 Jun. 1963. WFC/63/BP/UNSCAT,
       FAO, Rome. Also in Mechanization of Small
       Fishing Craft. Arthur J Heighway Publications Ltd.,
       London. 1964. (45, 50)

SUMMERSON, T J et al Organo-tin-based antifouling coatings
1964   for aluminum boats. Materials Protection. Kaiser
       Aluminum and Chemical Corp., Oakland, USA.
       (237)

SUNLEY, J G Working stresses for structural timbers. Forest
1961   Products Research Laboratory Bulletin No. 47.
       Her Majesty's Stationery Office, London. (220)

SWIECICKI, JERZY Choice of boat type and size for Polish
1960   deep-sea fisheries. FBW: 2. (43)

SZCZEPANIK, E F (ED.) The economic role of middlemen and
1960   cooperatives in Indo-Pacific fisheries. FAO, Rome.
       (36, 38, 42, 48, 49)

TAKAGI, A Japanese pelagic fishing boats. FBW. (603)
1955

TAKAGI, A Standard costs of fishing boats from 1956–1964.
1965   Journal of the Fishing Boat Association of Japan,
       No. 135, 1965, Tokyo. (248)

TAKEHANA, M Dynamic deflection gauge for long span.
1960   Journal of the Society of Naval Architects of Japan,
       Tokyo. No. 108. pp. 177–181. In Japanese with
       English summary. (226)

TELFER, E V Miscellaneous notes. International Conference
1933   of Tank Superintendents. The Hague, Netherlands.
       p. 133. (124)

THODE, H Rollzeitmessung und Stabilität. (Period of roll and
1965   stability.) Hansa, 102 Jahrgang, No. 18. Hamburg,
       Germany. In German. (474)

THOMAS, A J The economic and social effects of public credit
1960   in the fishing industry of Jamaica. Paper No.
       FIFA/WP/19 presented at the FAO technical meeting
       on credit for fishery industries 1960. (435)

THOMAS, A V Timbers used in the boatbuilding industry.
1964   Forest Products Research Laboratory, Aylesbury,
       UK. pp. 33–38. (224)

THOMAS, E B This Business of Boating, Cambridge, Md.,
1949   USA. (205)

TIMBER DESIGN AND CONSTRUCTION HANDBOOK Prepared by
1957   the Timber Engineering Company, Washington,
       DC, USA. (224)

TIMBER RESEARCH AND DEVELOPMENT ASSOCIATION Glued-
1960   laminated timber. High Wycombe, Bucks., UK.
       (225)

TRAUNG, J-O (COMPILER) Fishing Boat Tank Tests, Parts 1
1955, and 2. FAO, Rome. (123, 136)
1959

TRAUNG, J-O (ED.) Fishing Boats of the World. Fishing
1955   News (Books) Ltd., London. (155)

TRAUNG, J-O (ED.) Fishing Boats of the World: 2. Fishing
1960a News (Books) Ltd., London. (37, 38, 40, 155, 256,
       261, 264, 265, 266, 267)

TRAUNG, J-O (Discussion on the fishing boat of 1975.)
1960b FBW: 2. pp. 755–759. (33)

TRAUNG, J-O Outboard mechanization in fisheries. Proceed-
1960c ings of the International Economic Conference on
       Small Craft for Fisheries and Transportation held
       in New York in May 1960. Outboard Marine
       International SA, Nassau, Bahamas. (387)

TRAUNG, J-O and FUJINAMI, NORIO (ED.) Research Vessel
1961   Design. FAO, Rome. (407, 638)

TRAUNG, J-O Overcoming problems on boat design, servicing
1964   and fuel costs. Mechanization of Small Fishing Craft.
       Arthur J Heighway Publications Ltd., London.
       pp. 19–24. (387)

TRUAX, T R et al Production and preservative-treated
1953   laminated timbers. American Wood Preservers
       Association, Washington, DC, USA. (300)

TSUCHIYA, T A report of hull deflection test of wooden
1963   research boat Wakataku-Maru (Rep. No. 1). The
       hull deflection test with Chidori, 3.67 GT semi-
       European type wooden boat. (Rep. No. 2.) Tech-
       nical reports of Fishing Boat Laboratory No. 17.3,
       Tokyo, Japan. In Japanese with English summary.
       (226)

TSUCHIYA, T Report on the statistical analysis of FAO
1964   fishing boat tank tests. FAO report dated 11 May
       1964 (Restricted). FAO, Rome. (123)

US BUREAU OF SHIPS Wood, a manual for its use as a ship-
1957– building material. Vols. I, II, III, IV: Nav-Ships
1962   250–336. Washington, DC, USA. (220, 225, 291)

US Department of Defense   Design of wood aircraft
1951   structures. Report No. ANC-18, Jun. pp. 14, 18. Washington, DC, USA. (217, 218)

US Forest Products Laboratory   Wood Handbook,
1955   No. 72. pp. 67-81, 88. (215, 216, 219, 220, 225)

Vanneste, O and Hovart, P   La pêche maritime Belge—
1959   étude économique. (Belgian sea fisheries—economic study.) Bureau d'Etudes du Conseil Economique de la Flandre Occidentale, Bruges, Belgium. In French. (37, 42, 47)

Verhagen, J H G and Wijngaarden, L van   Non-linear
1965   oscillations of fluid in a container. Journal of Fluid Mechanics, 22.4; p. 737. Cambridge University Press, London. (189)

Verhoest, J and Maton, A   Double rig shrimp beam trawling.
1964   MFGW: 2. (576)

Verrall, A F and Scheffer, T C   Control of stain, mold and
1949   decay in green lumber and other wood products. Forest Products Research Society Bulletin No. 58. Madison, Wis., USA. (222)

Vossers, G   New perspectives in sea behaviour. FBW: 2.
1960   (159)

War against the Teredo   Fishing News International 4 (2).
1965   p. 135. London. (224)

Vathne, Fred   Pacific Coast drum trawling. Commercial
1959   Fisheries Review 21 (12). US Bureau of Commercial Fisheries, Washington, DC, USA. pp. 34-36. (536)

Watts, P   On a method of reducing the rolling of ships at sea.
1883   Trans. INA, Vol. XXIV, London. p. 165. (186)

Watts, P   The use of waterchambers for reducing the rolling
1885   of ships at sea. Trans. INA, Vol. XXVI, London. p. 30. (186)

White Fish Authority, Committee for Scotland and
1960   N. Ireland   Standard specifications for the construction of Scottish wooden fishing vessels (overall length 30-90 ft.), Edinburgh, UK. (294)

Wilson, P G   Review of the development of the Atlantic
1965   Coast tuna fishery. Commercial Fisheries Review 27 (3), US Bureau of Commercial Fisheries, Washington, DC, USA. pp. 1-10. (542)

Wilson, T R C   The glued laminated wooden arch. Tech-
1939   nical Bulletin No. 691. US Department of Agriculture, Washington, DC, USA. (299, 300)

Wood, L W   Relation of strength of wood to duration of load.
1951   US Forest Products Laboratory Report No. R1916. Department of Agriculture, Washington, DC, USA. (219)

Wood, L W   Factor of safety in design of timber structures.
1960   Trans. American Society of Civil Engineers, 125 (part 1), p. 1033. Paul A Parisi, New York. (219)

Yamagata, M   Standard of stability adopted in Japan.
1959   Trans. INA, London, Vol. 101. (104)

Yokoyama, N   Study on the development of fishing boat
1961   design based on the waveless hull form theory. Scientific Report No. 5. Fishing Boat Laboratory, Tokyo. (184)

Yoshiki, M and Takehana, M   (Investigated strength of
1956   double-sawn frames.) Journal of the Society of Naval Architects of Japan, No. 98 (7), Tokyo. pp. 103-111. In Japanese. (224, 226)

Yoshiki (wrong in paper, should be Yuchi) M and
1957   Takehana, M et al (Calculated necessary and adequate amount of material based upon the assumption that material was homogeneous and distributed in the traditional manner of the European-type ship.) Journal of the Society of Naval Architects of Japan, No. 98 (8), Tokyo. pp. 113-119. In Japanese. (226)

Yoshiki, M. and Takehana, M (Research on the joints in
1959   wooden ships: vibration damping of joints.) Journal of the Society of Naval Architects of Japan, No. 105, Tokyo. pp. 185-191. In Japanese. (224)

ADVERTISEMENT SECTION

AS stated in the preliminary pages, this advertisement section is included because it is appreciated that practical, commercial information should be readily available for all interested parties concerning fishing vessels, fishing gear and equipment that can be procured from various sources for the betterment of fishing practices.

The prime object of the Department of Fisheries, Food and Agriculture Organization (United Nations) in organizing these Fishing Boats Congresses is to bring together the leading experts from all major fishing countries and fishery administrators in order to give and exchange information calculated to improve the technical capacity and efficiency of the fishing industries in their territories.

To supplement that knowledge this section is designed to give commercial information of where and how fishing craft of various types can be most satisfactorily secured or built, reliable engines bought and particular gear and equipment purchased. The co-operation of the firms who thus advertise, renders a double service: in addition to giving information about their wares, their support enables this book to be produced at a lower figure than would otherwise be possible.

Therefore the publishers of this book bespeak for these firms such good will and support as can be given by appreciative fishermen and operators in the expanding industries of the countries of Asia, Africa, the Pacific, South America, North America and European areas.

Fishing News (Books) Ltd.
110 Fleet Street, London, E.C.4.

An index of advertisements included in this section appears overleaf

Index to Advertisements

Index to Advertisements

ARCO – PIONEERING NEW EQUIPMENT AND SERVICES.

The wide scope of Marco services is based on direct experience in many technical fields. Personnel include marine and mechanical engineers, naval architects, fleet managers, processing plant designers and managers, civil engineers, master fishermen, spotter-aircraft pilots, refrigeration specialists, project managers. These personnel have one area of experience in common: *a first-hand knowledge of fishing operations.*

The various areas of Marco's experience are made available through the Fisheries Development Division, in the form of economic and resource surveys, feasibility studies, consultation, design, construction, management and management assistance. Inquiries are invited concerning how these capabilities may be applied to comprehensive projects in newly-developing fisheries, or to special problems in advanced fisheries.

HYDRAULIC DECK MACHINERY—complete high-pressure systems for fishing, cargo handling, and oceanography, including full responsibility for all pumping and control functions. This Marco winch, shown on a Faroese seiner, is one of a series for seine, trawl and combination service. New designs are evolved from accumulated fishing experience, providing increased power, speed and convenience.

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ARINE CONSTRUCTION & DESIGN CO.

2300 W. Commodore Way, Seattle, Washington 98199, U.S.A.

| Cables: **MARCO** | Telephone ATwater 3-2680 |
| Telex: 32-298 | Area Code 206 |

HYDRAULIC MACHINERY ■ PURETIC POWER BLOCKS ■ SPECIALIZED GEAR FOR FISHING AND FISHERIES RESEARCH ■ NEW VESSEL DESIGN AND CONSTRUCTION ■ DESIGN AND MODIFICATION WORK FOR VESSEL CONVERSIONS ■ ENGINEERING OF INTEGRATED FISHERIES FACILITIES

COASTAL STERN TRAWLERS—holders of many production records for hake and shrimp. GRINGO, 22 meters l.o.a., produced 9700 tons of hake in 12 months. Designed and built by Marco, the vessel has an hydraulic deck machinery system of unusual refinement and efficiency. Trawl drum, combination winch and auxiliary winches enable the crew of only six men to perform all net-handling operations with ease.

JARCO MANUFACTURING LICENS

Scope of respective manufacturing program is indicated. In add these licensees, Marco distributors are established in most major centers of the world.

NORTHERN EUROPE—Marco / Rapp hydraulic machinery

RAPP FABRIKKER A/S
Nyholmen   Telephone: 21 091
Postboks 145   Cables: RAPPFABRIK
Bodoe, Norway   Telex: 4087

FRANCE—Marco hydraulic deck machinery

AYELLO & FILS S.A.
5, Rue Carnot
Boite Postale 1-016   Telephone: 66.52.00
Dunkerque   Cables: AYELLOFILETS

SPAIN—Marco hydraulic deck machinery

JUNASA
Julio N. Sancho
Apartado 582   Telephone: 15769
Vigo   Cables: JUNASA

SOUTH AFRICA—Marco fishing vessels

CAPETEX ENGINEERING WORKS (PTY.) LTD.
P.O. Box 3130   Telephone: 53-1386
Cape Town   Cables: COLLINSTEX
                                  Telex: C-7648

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PEACOCK BROTHERS, LTD.
P.O. Box 1040   Telephone: (514) 366-!
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FABRICACIONES METALICAS S.A.
Casilla 307   Telephone: 93202
Callao   Cables: FABRIMET

PERU—Marco hydraulic deck machinery

MARCO PERUANA S.A.
Apartado 415   Telephone: 93970
Callao   Cables: MARCO
                                  Telex: 0207

CHILE—Marco fishing vessels

MARCO CHILENA S.A.I.
Clasificador 116   Telephone: 66835
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Santiago   Telex: 299

RENK TWIN GEAR UNITS
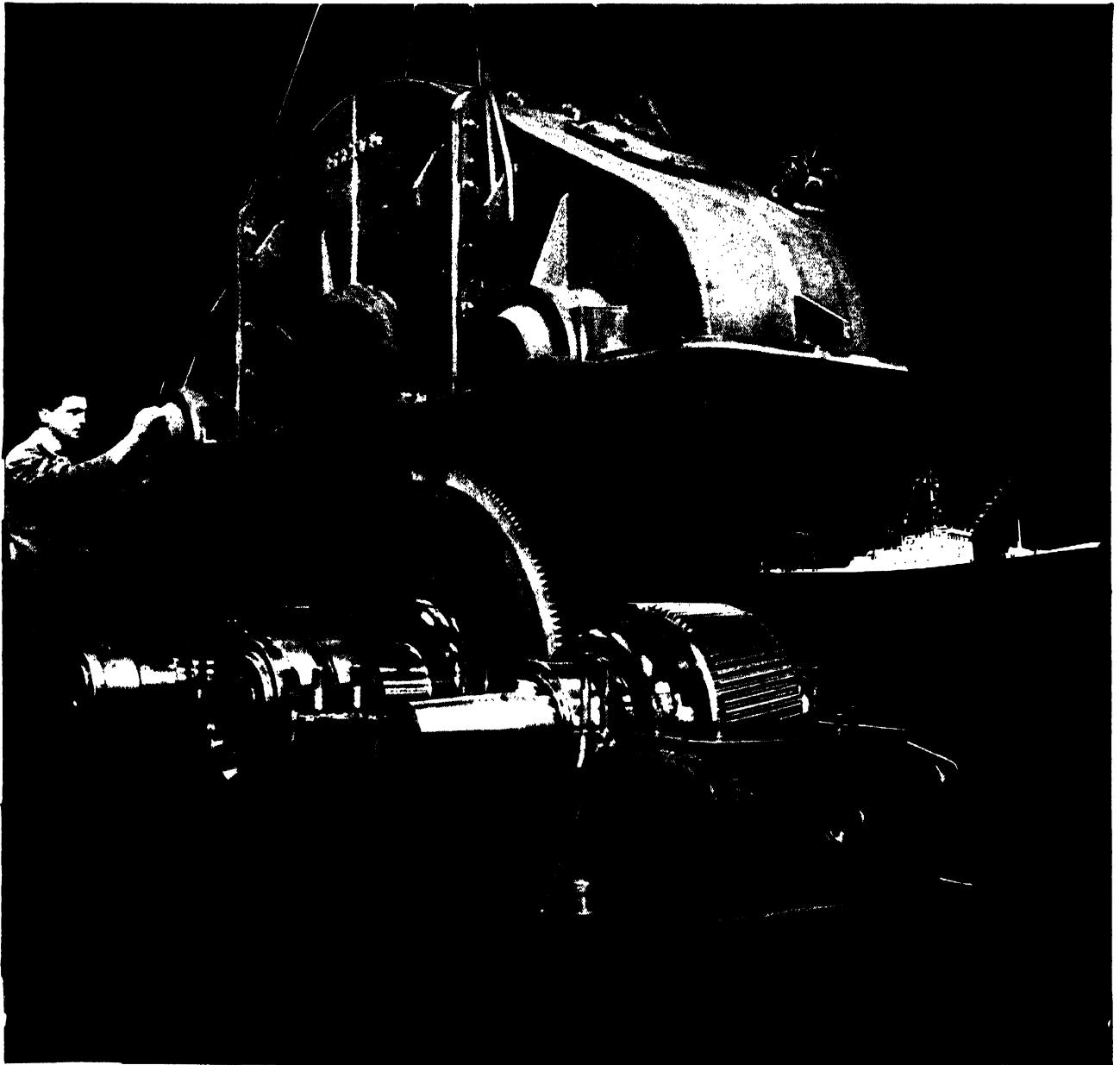
Want an outboard's fun with an inboard's go? Fit an Evinrude Stern-Drive.

The new Evinrude Stern-Drive can make any boat (your boat) get with it. These exclusive Evinrude features tell why:

Electric power shift - Gives smoother control than old-fashioned mechanical shifts.

Electric power lift - Provides dash-board (fingertip) control to raise the lower unit a full 75°.

Quiet mount system - Offers rubber mounts strategically located to isolate motor and outdrive for greater balance and quiet. You get maximum performance with minimum vibration.

Installation package includes: push-button, remote control. Dash panel and instruments consisting of ammeter, oil light, temperature light, ignition switch, tilt switch and tachometer

for single or dual installations and all mounting hardware. Also throttle and electrical cables, propeller.

In addition, you have the assurance that comes from owning an Evinrude - 60 years of experience plus holder of the world's speed record.

See your local Evinrude Distributor and choose your Stern-Drive from his selection of 5 different models - 90, 120, 155, 185 and 200 HP. Each one has a 2-year warranty.

the power of experience **EVINRUDE**

For complete information, write to: Outboard Marine Bruges, Belgium or Nassau, Bahamas.

| 90 HP | 120 HP | 155 HP | 185 HP | 200 HP |
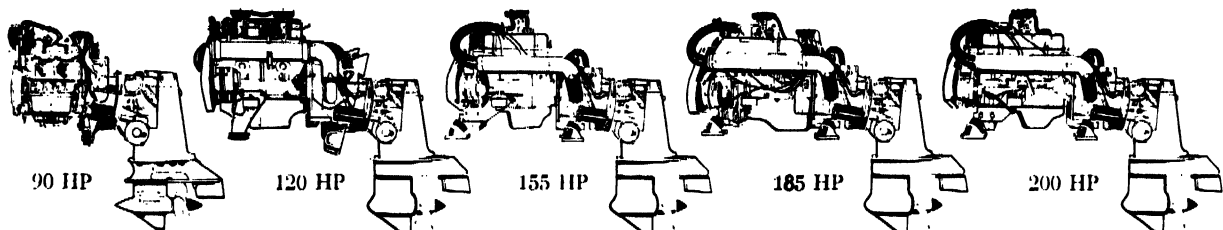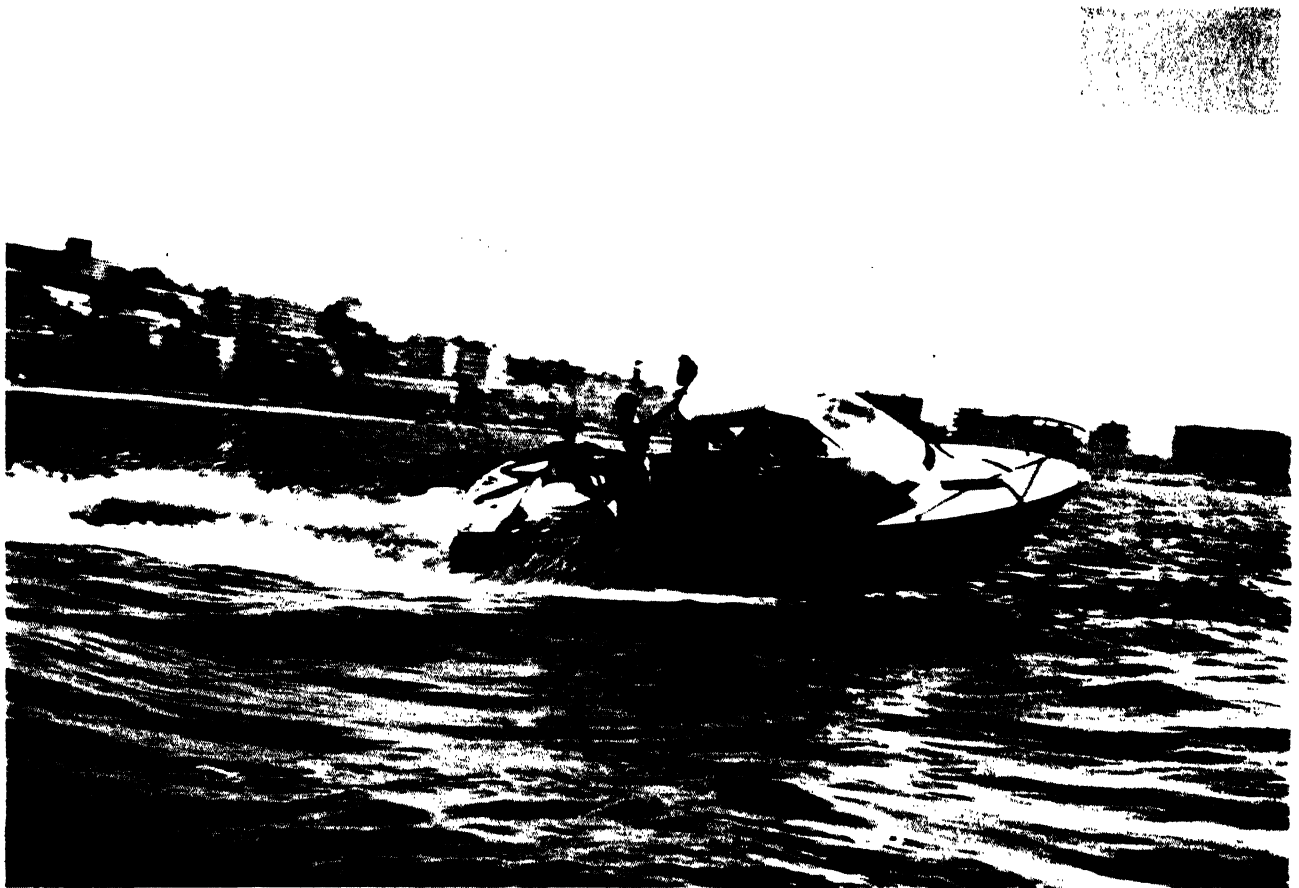
"Water Gods" can make a big splash with any of these magnificent Stern-Drives.

[vii]

Introducing the newest concept in marine power Johnson Stern-Drives.

The new Johnson Stern-Drives are loaded with all the features for which others charge extra *plus* some you can't buy anywhere dashboard control, electric powershift and electric power lift *are standard equipment* ! The new Johnson Stern-Drives give you smoother performance with a lot less vibration. Here is why: only the new Johnson Stern-Drives feature an exclusive rubber mounting system that isolates both the motor and outdrive. Applies all the thrust to the floor of the boat where it should be.

INSTALLATION PACKAGE INCLUDES : single lever shift remote control. Dash panel and instruments consisting of ammeter, oil light, temperature light, ignition switch, tilt switch and tachometer for single or dual installations and all mounting hardware. Also throttle and electrical cables, propeller.

You can choose from a range of 5 dependable Stern-Drives from 90 to 200 HP with 4, 6 or 8 cylinders. Each one comes with a 2-year warranty.

To get the newest concept in marine power plus the know-how that only Johnson can provide, see your Johnson dealer and select the new Stern-Drive which best fits your boat.

Johnson is first in dependability

For complete information, write to: Outboard Marine Bruges, Belgium or Nassau, Bahamas.

90 HP   120 HP   155 HP   185 HP   200 HP
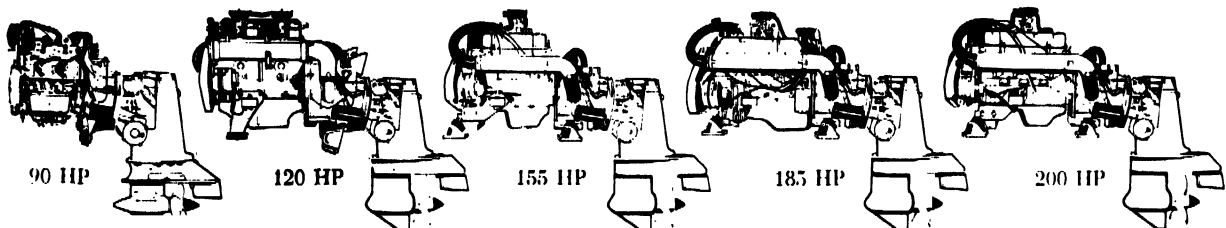
Any of these dependable Stern-Drives can give you real boating pleasure.

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ASTILLEROS UNIDOS DEL PACIFICO, S. A.

Tomás de Rueda Jr. General Manager.
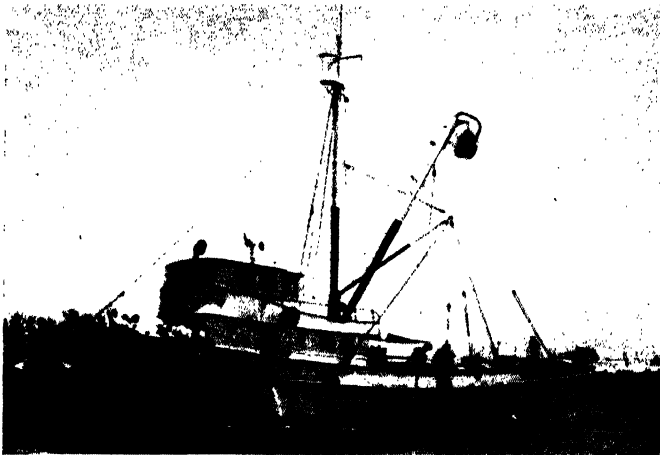
COPASA I Tuna Purse Seiner
Shipowners: Conservas del Pacifico, S.A., Ensenada, B.C.

The Astilleros Unidos del Pacifico, S.A., of Estero del Infiernillo, Apartado Postal 80, Mazatlán, Sinaloa, Mexico, have up to now built 350 fishing boats.

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Over fifteen years experience in shipbuilding.

UNDER CONSTRUCTION:

3 boats for Chile
10 boats for Central America
6 boats for Venezuela
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MORISHITA FISHING NET MFG. CO., LTD.
P.O. BOX 36, MINAMI OSAKA, JAPAN

HIDROSTAL MEANS FISHPUMPING EFFICIENCY

For equipping your fishing vessel with a Hidrostal fishpump you should know the following different size characteristics applicable to each pump.

Type of Pump	Capacity dewatered fish	Recommended largest fish specimen to be handled by this pump
E 8D	100 tons/hour	HERRING
F 10D	200 tons/hour	MACKEREL
I 12D	300 tons/hour	TUNA
L 16D	500 tons/hour	Any up to 4 ft. long and 10 in. diameter

For detailed information contact your nearest Hidrostal Distributor, or:

Head Office: **HIDROSTAL S.A. P.O. Box 5734   Av. Argentina 2842   LIMA . PERU**
Tel : 44485   Cables: Hidrostal Lima   Telex : WLA-5298

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SAN GIORGIO

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FAO YEARBOOK OF FISHERY STATISTICS

Trilingual.   First published in 1948

The most important internationally-published source of world-wide statistical tabulations covering, on a calendar year basis, catches and landings, disposition of catches, and production, imports and exports of preserved and processed fishery commodities. Special efforts are made to publish within approximately 10 months of the close of the last calendar year covered. The YEARBOOK data for many countries appear months before the data are released nationally.

Until the end of 1963 the **Production and Fishing Craft** volume appeared annually and the **International Trade** volume biennially. Since 1964 two volumes have appeared annually. The latest volumes are:

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The YEARBOOK is supplemented by a trilingual series of **Bulletins of Fishery Statistics.** Numbers are issued from time to time and are available in a limited number of copies from the DISTRIBUTION AND SALES SECTION, FOOD AND AGRICULTURE ORGANIZATION, VIA DELLE TERME DI CARACALLA, ROME, ITALY.

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Handbook of Mutual Insurance Systems for Commercial Fishing Vessels and Gear
by C. A. Theodore, 1966, 117 pp.   **Price: $2.00 or 10s. or FF7,00**
Scheduled for publication in 1967.

FAO FISHERIES STUDIES No. 11

Financial Assistance Policies and Administration for Fishery Industries
by E. S. Holliman, 1962, 121 pp.   **Price: $1.00 or 5s. or FF3,50**

This is the third FAO publication on financial aid schemes in fishery development. The study is based on discussions and papers contributed to the FAO Technical Meeting on Credit for Fishery Industries, held in Paris in 1960. Drawing on his experience as Assistant Chief Executive of the White Fish Authority, in London, Mr. Holliman covers many of the finer points of administrative decision-making in fishery industries.

FAO FISHERIES STUDIES No. 10

Costs and Earnings Investigations of Primary Fishing Enterprises
by A. E. Ovenden, 1961, 60 pp.   **Price: $0.75 or 3s. 9d. or FF2,70**

A study of the main concepts and definitions of the principal elements of primary fishing economies, with definition of terms commonly used in costs and earnings studies and with the application of those definitions to practical work. The book resulted from the FAO Technical Meeting on Costs and Earnings of Fishing Enterprises, held in London in 1958, which noted that lack of uniformity in fisheries organization seems to act as a barrier to agreement on many fishery concepts.

A limited number of the following earlier FAO Fisheries Studies is still available:

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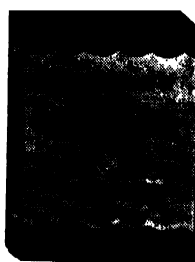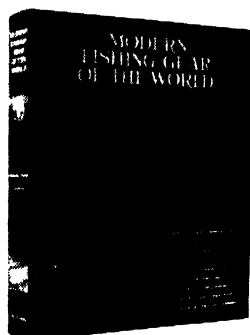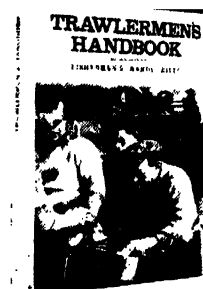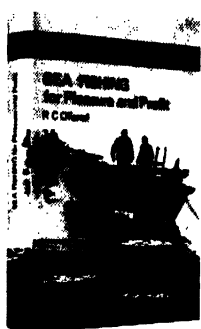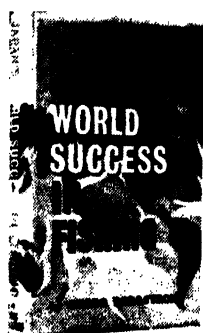
Information on specific world areas:

The Proceedings and Technical Papers of the General Fisheries Council for the Mediterranean have been published biennially since 1952 in bilingual English-French editions. The proceedings of the seventh session (1964) are available at **$10.00 or 50s. or FF35,00.** The eighth session proceedings are in press.

The Proceedings and Technical Papers of the Indo-Pacific Fisheries Council have been published in English since 1949. Proceedings (Section I) of the eleventh session (1964) is the latest available at **$1.00 or 5s. or FF3,50.** Complete sets of proceedings are still available for the sixth, seventh, eighth, ninth and tenth sessions. Both the GFCM and IPFC have additional documentation for specific fisheries problems in their areas.
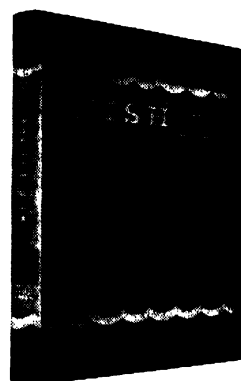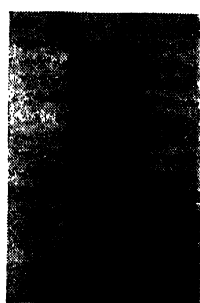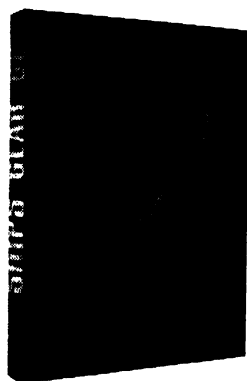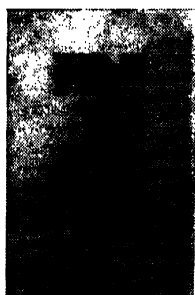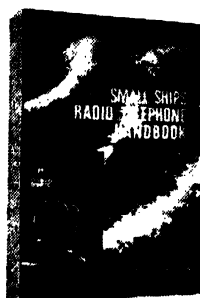
Aside from its publications, the FAO Fisheries Department also produces documents in the following series: Fisheries Reports; Synopses; Technical Papers; Technical Assistance and Training Centre Reports.