TRANSACTIONS

OF

THE SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS

1921

VOL. XXIX 1921

TRANSACTIONS

OF

THE SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS

EDITED BY THE SECRETARY

PRINCIPAL OFFICE OF THE SOCIETY
ENGINEERING SOCIETIES BUILDING
29 WEST 39TH STREET, NEW YORK, N.Y., U.S.A.

ROBERT GIBSON
DIRECTOR OF PRINTING
WASHINGTON, D. C.

NOTICE

The Society as a body is not responsible for any statements of fact or opinion contained in the following papers and discussions, such responsibility resting entirely with those making the statements.

CONTENTS

INDEX TO PAPERS AND DISCUSSIONS

OFFICERS OF THE SOCIETY

President.

WALTER M. McFARLAND.

Past Presidents and Life Members.

FRANCIS T. BOWLES, STEVENSON TAYLOR,
WASHINGTON L. CAPPS.

Past President and Life Associate Member.

ROBERT M. THOMPSON.

Honorary Vice-Presidents.

F. E. KIRBY, D. W. TAYLOR,
W. F. DURAND, W. J. BAXTER.

Vice-Presidents.

Term expires December 31, 1922:

A. P. NIBLACK, H. D. GOULDER,
R. M. WATT, C. P. WETHERBEE.

Term expires December 31, 1923:

H. L. FERGUSON, F. L. DuBOSQUE,
H. A. MAGOUN, W. A. DOBSON.

Term expires December 31, 1924:

LEWIS NIXON. C. H. PEABODY,
H. I. CONE, J. W. POWELL.

Members of Council.

Term expires December 31, 1922:

J. H. LINNARD, W. L. R. EMMET, W. J. DAVIDSON,
C. A. McALLISTER, J. H. GARDNER, H. P. FREAR.

Term expires December 31, 1923:

H. C. SADLER, C. F. BAILEY, E. H. RIGG,
D. H. COX, W. H. TODD, WM. McENTEE.

Term expires December 31, 1924:

ANDREW FLETCHER, W. G. COXE, ROBERT HAIG,
R. H. M. ROBINSON, J. H. MULL, C. W. DYSON.

Associate Members of Council.

Term expires December 31, 1922:

R. A. C. SMITH, A. W. GOODRICH.

Term expires December 31, 1923:

H. L. ALDRICH, H. H. RAYMOND.

Term expires December 31, 1924:

E. M. BULL, J. N. PEW, JR.

Executive Committee.

WALTER M. McFARLAND, *Ex-Officio.*

STEVENSON TAYLOR, F. L. DuBOSQUE, H. L. FERGUSON,
WASHINGTON L. CAPPS, E. M. BULL, J. W. POWELL,
ANDREW FLETCHER, D. H. COX, *Ex-Officio.*

Secretary-Treasurer.

DANIEL H. COX.

Assistant to the Secretary-Treasurer,

THOMAS J. KAIN.

ARTICLES OF INCORPORATION

THE SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS

State of New York,
City and County of New York.

We, the subscribers, Wm. H. Webb, Chas. H. Cramp, George E. Weed, H. Taylor Gause, William T. Sampson, Horace See, Frank L. Fernald, Francis T. Bowles, Washington L. Capps, Edwin D. Morgan, George W. Quintard, Harrington Putnam and Jacob W. Miller, being persons of full age and citizens of the United States, of whom a majority—namely, William H. Webb, George E. Weed, Horace See, Edwin D. Morgan, George W. Quintard, Harrington Putnam, Frank L. Fernald, and Jacob W. Miller are citizens of and residents of and within this State, desiring to associate ourselves for scientific purposes under and pursuant to, an Act of the State of New York providing for the incorporation of benevolent, charitable, scientific and missionary societies, passed April 12, 1848, and the several acts amending or supplementing the same, do hereby, in accordance with the requirements thereof, certify as follows:—

First. The name of title by which the Society shall be known in law is The Society of Naval Architects and Marine Engineers.

Second. The particular business and objects of such Society are the promotion of practical and scientific knowledge in the arts of shipbuilding and marine engineering and the allied professions, and in furtherance of this object, to hold meetings for social intercourse among its members, and the reading and discussion of professional papers, and to circulate by means of publication the knowledge thus obtained.

Third. The number of directors, trustees, or managers to manage the Society shall be seven, and shall consist of a President, a Secretary, and five Members of Council.

Fourth. The names of the trustees, directors, or managers of the Society for the first year of its existence are:—President, Clement A. Griscom; Secretary, Washington L. Capps; Members of Council, Francis T. Bowles, H. Taylor Gause, Chas. H. Loring, Lewis Nixon, Harrington Putnam.

Fifth. The business of the Society is to be conducted, and its place of business and principal office is to be located, in the City and County of New York.

In Witness Whereof we have made, signed, and acknowledged this Certificate, this 28th day of April, 1893.

WILLIAM H. WEBB.
CHAS. H. CRAMP.
H. T. GAUSE.
GEORGE E. WEED.
W. T. SAMPSON.
HORACE SEE.
F. L. FERNALD.

FRANCIS T. BOWLES.
W. L. CAPPS.
E. D. MORGAN.
GEORGE W. QUINTARD.
HARRINGTON PUTNAM.
J. W. MILLER.

City and County of New York, *ss:*

On this 28th day of April, 1893, before me personally appeared William H. Webb, Charles H. Cramp, H. Taylor Gause, George E. Weed, William T. Sampson, Horace See, Frank L. Fernald, Francis T. Bowles, Washington L. Capps, and Edwin D. Morgan, to me known and known to me to be the persons described in and who executed the foregoing certificate, and severally acknowledged to me that they executed the same.

James Forrester,
Notary Public, Kings Co., Cert. N. Y. Co.

City and County of New York, *ss:*

On this 1st day of May, 1893, before me personally appeared George W. Quintard and Harrington Putnam, to me known and known to me to be the individuals described in and who executed the foregoing certificate, and they severally acknowledged to me that they executed the same.

James Forrester,
Notary Public, Kings Co., Cert. N. Y. Co.

City and County of New York, *ss:*

On this 9th day of May, 1893, before me personally appeared Jacob W. Miller, to me known and known to me to be one of the individuals described in and who executed the foregoing certificate, and he duly acknowledged to me that he executed the same.

James Forrester,
Notary Public, Kings Co., Cert. N. Y. Co.

(Endorsed.)

Upon reading the within Certificate for the Incorporation of the Society of Naval Architects and Marine Engineers, I hereby approve and consent to the incorporation thereof and the within Certificate and filing thereof, and direct that the same be filed in the office of the Clerk of the City and County of New York.

Dated New York, May 10, 1893.

Edwd. Patterson,
Justice of the Supreme Court in the State of New York
in and for the City and County of New York.

CONSTITUTION AND BY-LAWS OF THE SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS

Article I.

Name and Object.

1. The name of the Association shall be "The Society of Naval Architects and Marine Engineers."

2. Its object shall be the promotion of the art of ship building, commercial and naval.

3. In furtherance of this object, annual meetings shall be held for the reading and discussion of appropriate papers and interchange of professional ideas, thus making it possible to combine the results of experience and research on the part of shipbuilders, marine engineers, naval officers, yachtsmen, and those skilled in producing the material from which ships are built and equipped.

Article II.

Membership.

1. The Society shall consist of Members, Associates, Juniors, Honorary Members and Honorary Associates.

2. *Members.*—(1) The class of Members shall consist exclusively of Naval Architects, Marine and Mechanical Engineers, including Professors of Naval Architecture or Mechanical Engineering in colleges of established reputation.

(2) A Candidate for this class must not be less than twenty-eight years of age and comply with the following regulations: He shall submit to the Council a statement showing that he has been engaged in the practice of his profession, in a responsible capacity, for at least five years, and setting forth the grounds upon which he bases his claim to membership. This statement shall be signed by three Members, who shall certify to their personal knowledge of the candidate and approval of his statement.

(3) In the case of persons not American citizens, the signatures of three Members shall be required in confirmation of their personal knowledge of the candidate's scientific attainments.

(4) If three-fourths of the members of the Council present are in favor of the admission of the candidate his name shall be submitted to the Members of the Society at the next meeting; the voting to be by ballot, should a ballot be demanded.

3. *Associates.*—(1) The class of Associates shall consist of persons, who, by profession, occupation, or scientific attainments, are qualified to discuss the qualities of a ship.

(2) Candidates for this class shall submit to the Council a written statement of their qualifications for membership; this shall be signed by two Members or Associates who shall certify to their personal knowledge of the candidate and approval of his statement. If considered by three-fourths of the Council present duly qualified for associate membership their names shall be submitted to the Society at the next meeting, to be voted upon by the Members and Associates; the voting to be by ballot, should a ballot be demanded.

4. The proportion of favorable votes for deciding the election of Members and Associates shall be at least four-fifths of the number recorded.

5. *Juniors.*—(1) The class of Juniors shall consist of graduates of technical schools of established reputation, or persons who have had not less than two years' practical experience in marine engine works or shipyards.

(2) Candidates must be at least eighteen years of age and certify their intention to continue in the profession and become naval architects or marine engineers.

(3) Juniors shall be eligible for transfer to the class of Members or Associates after fulfilling the necessary conditions; when they are twenty-eight years of age they shall be offered the option of being transferred to the class of Members or Associates in conformity with their qualifications; but if they do not accept such offer or do not qualify, they shall be dropped from the rolls of the Society.

(4) The admission of Juniors shall be by a favorable vote of three-fourths of the members of the Council present.

(5) Juniors shall have no voice in the government of the Society or admission of members.

6. *Honorary Members and Honorary Associates.*—The Council may elect Honorary Members and Honorary Associates, the total number not to exceed twenty-five. They shall be persons of acknowledged eminence in their profession upon whom the Council may see fit to confer an honorary distinction.

7. *Benefactors and Permanent Members.*—The Council may establish a list of Benefactors. It may also elect as Permanent Members of the Society such Members or Associate Members as shall, in the opinion of the Council, by reason of notably liberal contributions to the Society, merit special recognition. Permanent Members shall, from the date of their election, be relieved from annual dues, and shall have the right, subject to the approval of Council, to designate, by will or otherwise, their successors. The conditions to be met before placing any name on the list of Benefactors and the regulations governing the election of Permanent Members shall be prescribed by the Council.

Article III.

Dues, Suspension and Expulsion of Members.

1. The entrance fees, payable on admission to the Society, shall be as follows:

Members and Associates, fifteen dollars; Juniors, ten dollars; Honorary Members and Honorary Associates, no fees.

2. The annual dues shall be as follows:

Members and Associates, fifteen dollars; Juniors, ten dollars; Honorary Members and Honorary Associates, no dues.

3. A member transferred from one grade to another shall pay the difference between the entrance fees of the two grades, and his annual dues shall be those of the grade to which transferred.

4. The annual dues shall be payable in advance on the first day of January. The Secretary shall notify each member of the amount due for the ensuing year at the time of giving notice for the annual meeting. On notification of his election each member shall pay his entrance fee. If he desires to receive the published transactions of the Society for the meeting at which he is elected, he shall pay ten dollars in addition to the entrance fee.

5. Members and Associates can compound for all future dues and become Life Members or Life Associates by making a single payment of three hundred dollars and signing an agreement to conform to any future amendments to the Constitution and By-Laws.

6. Members are entitled to no return of fees upon severing their connection with the Society.

7. Any member whose dues are more than three months in arrears shall be notified by the Secretary. Should his dues become six months in arrears he shall be again notified by the Secretary and his rights as a member suspended. Should his dues become one year in arrears the delinquent member shall forfeit his membership in the Society unless the Council may deem it expedient to extend the time of payment.

8. The Council may, in its discretion, temporarily suspend the annual payment of dues by any member whose circumstances have become such as to make such payment impossible, and may, under similar circumstances, remit the whole or part of dues in arrears.

9. No name shall be entered on the rolls as Member, Associate or Junior, nor shall the privileges of membership be enjoyed until the payments required in paragraphs 1 to 4 of this article have been made; if the payment be delayed for more than six months from the date of election, the same shall be void unless the Council otherwise direct.

10. (1) Should the expulsion of any member be adjudged expedient by five or more members, they must draw up and sign a proposal requesting such expulsion, delivering the same to the Secretary, to be laid before the Council.

(2) If the Council do not find reason to concur in the proposal, no entry thereof shall appear in the minutes, nor shall any public discussion thereon be permitted.

(3) If, however, the Council find the charges contained in the proposal for expulsion substantiated, the accused member shall be notified and given an opportunity to resign. If he avails himself of this privilege, no entry shall be made on the minutes nor public discussion of the case be permitted. But if he declines to resign and offers no satisfactory explanation of the charge, the whole case shall be submitted to a special meeting of the Society.

(4) If two-thirds of the members at this special meeting (providing there be not less than twenty present) vote for expulsion, the Chairman of the meeting shall cause the accused to be expelled from the Society and direct the Secretary to notify the accused of this action.

Article IV.

Officers.

1. The officers of the Society shall consist of a President, Past Presidents, Honorary Vice-Presidents, twelve Vice-Presidents, twenty-four Members of Council, and a Secretary and Treasurer.

2. Both Members and Associates are eligible for the offices of President, Honorary Vice-President, Vice-President and Member of Council, but three-fourths of the Council shall be Members.

3. Prior to the date of the annual meeting of the Society of the year with which the term of the President expires, the Council shall nominate a candidate for the office of President, whose name shall be presented to the Society for election at the annual meeting. Any other candidate whose nomination, signed by at least sixty Members and Associates, shall have been submitted to the Secretary prior to the annual meeting shall also be presented. The candidate receiving the highest number of votes shall be the President for the ensuing

three years. The first President under this rule was elected at the annual meeting in 1906 and his term of office began January 1, 1907. The President shall not be eligible for election as his own successor.

4. (1) The term of office of the Vice-Presidents shall be three years. The terms of the Vice-Presidents which, under a previous provision of the Constitution, should have expired in 1911 and 1912 are regarded as having expired on December 31, 1911. Those terms which, under the same conditions, should have expired in 1913 and 1914 are regarded as having expired on December 31, 1912; those which should have expired in 1915 and 1916 are regarded as having expired on December 31, 1913. Beginning with the four Vice-Presidents elected for the term ending December 31, 1914, there shall be four Vice-Presidents elected each year to take the place of those whose terms expire. The Vice-Presidents to fill the vacancies occurring each year in any class shall be elected by the Council from their own membership. Retiring Vice-Presidents shall be eligible for re-election.

(2) Honorary Vice-Presidents shall be chosen from the list of Vice-Presidents who have had at least ten years' service as Vice-President. They shall be chosen at the meeting of the Council next prior to the annual general meeting of the Society and must be the unanimous choice of all members of Council present. Not more than two Vice-Presidents may be elected Honorary Vice-Presidents in any one year.

5. (1) The term of office of the Members and Associate Members of Council shall be three years. Prior to August 1st of each year the Secretary shall mail to each Member and Associate a list of the names of the Members and Associate Members of Council whose terms expire with the current year, and shall enclose a blank on which each Member may, if he so desires, nominate one additional candidate for Member of Council and one additional candidate for Associate Member of Council; and each Associate Member may, if he so desires, nominate one additional candidate for Associate Member of Council. No nominations received by the Secretary after August 31st shall be considered.

(2) Prior to September 1st of each year the President shall appoint a nominating committee of five, at least three of whom shall be Members. This committee shall scrutinize the nomination slips sent in by Members and Associates and prepare a ballot. This ballot shall contain the names of all the retiring members and Associate Members of Council who shall not have declined re-election and a sufficient number of additional names to make a total of nine candidates for Member of Council and three candidates for Associate Member of Council. The names listed on the ballot, other than those of retiring Members and Associate Members of Council, shall be chosen by the nominating committee from those who have received the highest number of votes on the nominating lists returned by members of the Society.

(3) Should the number of names which have received at least ten votes in the case of nominees for Members of Council and five votes in the case of nominees for Associate Members of Council be insufficient to complete the number on the ballot list above provided for in sub-paragraph (2), the nominating committee shall add enough names to bring the total on the ballot up to nine candidates for Member and three candidates for Associate Member of Council.

(4) The ballots shall be sent by mail as soon as possible after September 1st of each year to all Members and Associate Members of the Society. Each Member may vote for not more than six Members of Council and two Associate Members of Council, and each Associate may vote for not more than two Associate Members of Council. The ballots

shall be returned by mail to the Secretary and canvassed by a committee of three members appointed by the President. This canvassing committee shall report the results of the election to the Council at its meeting immediately prior to the Annual Meeting of the Society.

(5) When the ballots have been sent out by the Secretary, should there be a desire on the part of Members or Associates to suggest another list of candidates for the Council, any twenty Members and Associates may unite in submitting another list to the Secretary which shall also be sent out to the membership to be considered in connection with the list already sent. In any event, the six Members who receive the highest number of votes shall be declared elected Members of Council and the two Associates receiving the highest number of votes shall be declared elected Associate Members of Council, in each case for a term of three years.

6. A vacancy in the office of President shall be filled by ballot by the Council from the list of Past Presidents, Honorary Vice-Presidents and Vice-Presidents until the end of the year in which it occurs. At the annual meeting of that year a new President shall be elected for three years in the manner prescribed in paragraph 3. A vacancy in the office of Member of Council shall be filled by the Council for the unexpired portion of term of the Member or Associate causing the vacancy.

7. The President, Past Presidents, Honorary Vice-Presidents and Vice-Presidents shall be *ex-officio* members of Council.

8. The Council may hold meetings subject to the call of the President, as often as the interests of the Society may demand.

9. At all meetings of Council seven members shall constitute a quorum.

10. The Secretary and Treasurer shall be elected annually by the Council, but may be removed at any time by a majority vote of the Council after due notice has been given.

11. The Secretary must be a Member of the Society.

Article V.

Management.

1. (1) The President shall have general supervision over the affairs of the Society, appoint special committees, and preside at the annual general meetings. He shall be *ex-officio* member of all committees.

(2) In the absence of the President, one of the Past Presidents, Honorary Vice-Presidents or Vice-Presidents, in the order of seniority as determined by original accession to, or election, in, their respective grades, shall preside and perform all the duties of the President; where there is the same date of seniority, the alphabetical order will govern. Provided, however, that for the Annual Meeting of the Society or for any other special occasion when it is known that the President cannot attend and preside, the Executive Committee shall, in its discretion, select and designate as Acting President any one of the Past Presidents, Honorary Vice-Presidents, Vice-Presidents or members of Council, who shall act for the President in his temporary absence and shall perform all the duties which would devolve upon that officer during such Annual Meeting or on such special occasion.

2. (1) The direct management of the Society shall be vested in an Executive Committee of nine, composed of seven members of Council, elected annually by the Council, and the President and the Secretary of the Society *ex-officio*. At least five of the seven elective members of the committee shall be Members of the Society.

(2) Meetings of the Executive Committee may be held at any time, subject to the call of the Chairman; and four members shall constitute a quorum for the transaction of any business that may be properly brought before the committee.

3. The Executive Committee shall manage the affairs of the Society in conformity with the laws under which it is incorporated and the provisions of this Constitution. It shall direct the investment and care of the funds of the Society; make appropriations for specific purposes; arrange for the reading and publication of professional papers; take measures to advance the interests of the Society, and generally direct its affairs under such regulations as the Council may from time to time prescribe.

4. The Executive Committee shall make an annual report to the Society, transmitting the report of the Secretary and Treasurer, and of any special committee which may have been ordered.

5. (1) The Secretary shall be the Executive Officer of the Society under the immediate direction of the President and the Executive Committee.

(2) He shall prepare the business for the annual meetings and record the proceedings thereof.

(3) He shall be responsible for all expenditures and certify the accuracy of all bills or vouchers upon which money has been paid, and he shall conduct the correspondence of the Society and keep full records of the same.

6. The Treasurer shall see that all money due the Society is collected and carefully invested in such manner as the Executive Committee may direct. If considered advisable by the Council, the duties of Treasurer may be performed by the Secretary.

7. The accounts of the Secretary and Treasurer shall be audited annually in such manner as the Executive Committee may direct.

Article VI.

Meetings.

1. There shall be at least one annual general meeting of the Society for the reading and discussion of professional papers, election of officers for the ensuing year, and transaction of such other business as may be brought before it. The time and location of this meeting shall be determined by the Council at least three months prior to the date fixed.

2. Special meetings may be called by the Executive Committee at the request of twenty members, which request shall state the purpose of the meeting. The call for such meetings shall be issued ten days in advance, and shall state the purpose thereof. At these meetings thirty members shall constitute a quorum.

3. The Society may adopt, from time to time, such rules at it may think proper for the order of business at its meetings.

Article VII.

Regulations and By-Laws.

1. The Council shall have authority to establish such by-laws and regulations as may be necessary for the government of the Society in the conduct of its affairs, provided that such by-laws and regulations do not conflict with the provisions of this Constitution and that they are approved by a two-thirds vote of the members of Council present at any meeting regu-

larly called for the consideration of same. If, however, objection be made by any member of Council to a by-law or regulation so proposed, it must be submitted in writing for the action of the entire Council and will not be finally adopted unless a majority of the Council signifies its approval.

Article VIII.

Amendments.

1. Proposed amendments to the Constitution must be reduced to writing and signed by not less than ten members. They shall be forwarded to the Secretary at least ten days before the annual general meeting, and shall be immediately forwarded to the Council for its consideration. If a majority of the Council approve the proposed amendment it shall be presented to the Society at the next ensuing general meeting for discussion; if approved by two-thirds of the members present, voting by ballot, if a ballot be demanded, it shall be adopted.

REGULATIONS

(See Article 2, paragraph (7), and Article 7, paragraph (1) of Constitution).

ADOPTED BY THE COUNCIL OF SOCIETY, NOVEMBER 18, 1921.

Benefactors.—Before becoming eligible for enrollment as Benefactors, candidates must have evidenced special interest in the objects for which this Society was founded and have contributed at least five thousand dollars toward a scholarship, a special fund, or the general endowment fund of the Society. For those who are already Permanent Members, this contribution will be not less than four thousand dollars.

Permanent Members.—Those eligible for Permanent Members must have the qualifications prescribed by the Constitution for candidates for Members or Associates and have contributed at least one thousand dollars towards a scholarship, a special fund, or the general endowment fund of the Society. For those who are already Life Members, this contribution will be not less than the difference between one thousand dollars and the amount of the Life Membership fee previously paid.

The names of all Benefactors and all Permanent Members will be placed in special lists and will be published in perpetuity in the annual Transactions of the Society, the names of the deceased members being appropriately designated.

Benefactors and Permanent Members shall have the right, subject to approval of Council, to designate by will or otherwise their successors, to whom shall be sent the published Transactions of the Society. This privilege of designation of successors shall pass from original beneficiary to his successor in due course, subject in all cases to the approval of the Council.

SPECIAL MEETING OF THE SOCIETY HELD AT THE ENGINEERING SOCIETIES BUILDING, 29 WEST 39th STREET, NEW YORK CITY, MAY 26, 1921.

SPECIAL MEETING OF MAY 26, 1921.

Past President Stevenson Taylor, in the chair, called the meeting to order at 8.25 p. m.

THE CHAIRMAN:—Gentlemen, at the request of the secretary it is my privilege to open this meeting. As I recall it, this is but the second mid-season meeting that this Society has ever held, for I recall only the one held at Detroit a number of years ago, under the lead of the then president, Admiral Bowles, and which was very successful.

I think we are greatly indebted to the three distinguished gentlemen who have prepared, at the request of the secretary, the two papers on the subjects that are to be presented to you tonight. These men have taken especial interest in this mid-season meeting because there seemed to be a demand for it, a demand that is shown by the presence of so many of you. I congratulate you on this meeting and on having the pleasure of listening to these papers. It has been proposed that both papers be presented before there is any discussion; then those who are to discuss the papers can discuss one or both as may seem best to the individual.

As there are no regular business proceedings, we will take up at once the business of the evening.

I wish to call to the attention of those who will present the papers that an abstract will be better for that purpose than to read the entire paper. The papers have been well distibuted, and considerable discussion is not only expected but desired. At the same time the authors will please not omit any points they have in mind, for these two subjects are of the utmost importance.

Paper No. 1 is entitled, "The Internal-Combustion Engine as Applied to Marine Propulsion," by Mr. John F. Metten and Mr. J. C. Shaw.

Mr. Shaw presented the paper.

THE INTERNAL-COMBUSTION ENGINE AS APPLIED TO MARINE PROPULSION.

By John F. Metten, Esq., Member, and J. C. Shaw, Esq., Visitor.

[Read at a special meeting of the Society of Naval Architects and Marine Engineers, held in New York, May 26, 1921.]

The fall in ocean freight rates in recent months to prewar levels should bring forcibly to the attention of American shipowners the great economic importance of the internal-combustion engine for ship propulsion, although it is not claimed that the Diesel engine is a complete remedy for the present predicament of the American merchant marine.

The situation in which American shipping now finds itself is analogous to the early transition from sail to steam. This country then failed to keep pace with Great Britain, who gained a lead which was only partly overcome, due to the condition brought about by the late war.

In the recent shipbuilding emergency, efficiency of type was subordinated to the expediency of rapid construction and quantity production. Many warnings were sounded to those in authority at the time in regard to the danger of entirely ignoring the larger motor ship in the emergency construction. However, this defect in building could have been greatly remedied by recasting the uncompleted program immediately after the armistice, as carried out by other countries, to meet the inevitable competitive conditions of peace.

Contrasted with our past policy in reference to motor ships is that of Great Britain and Scandinavian countries, in particular, who fostered the motor ship during the war, and, since the armistice two and a half years ago, have rapidly built motor ships almost to the exclusion of the less efficient steam cargo vessels.

As matters now stand we find ourselves in the possession of a large government-owned fleet, almost wholly steam driven, which private owners are reluctant to purchase or operate. The question accordingly is presented to us, as naval architects and marine engineers, as to the best method by which the inadequacy of the situation can be met, whether to advocate the conversion of the most inefficient of the existing steam vessels to Diesel drive or build new motor ships, and the best systems to be recommended.

It is hardly necessary to state in detail the particular advantages of the motor ship over the steamer which are fairly well conceded and undoubtedly well known to the members of the Society. More in regard to detail of the application of the internal-combustion engine, pointing out the various advantages and the defects of the different systems, will be attempted to be presented. A critical analysis of two vessels of a given size, propelled by steam turbines and Diesel engines, will also be given to show the economic importance of the latter. It is to be hoped the authors will be pardoned if undue reference is made to Burmeister & Wain, of Copenhagen, with whose work they are mostly familiar. As commonly recognized, this pioneer company has been mostly responsible for the present accepted high standing of the motor ship. There will be completed this month sixty-seven vessels to their system representing 580,000 tons deadweight and 214,000 Diesel indicated horse-power, totaling more tonnage than all the other makers combined for this class of vessel.

Of other continental builders who have done much also to promote development of the motor ship with their respective designs may be mentioned Werkspoor, Sulzer, Ansaldo San Gorgio, Krupp, Polar Diesel and Vickers of England.

A brief review of Burmeister & Wain's work in this field will be given as best illustrating the development of the art. This maker, like Werkspoor, has always held to the four-cycle engine as best suited to this class of service, where utmost reliability combined with economy is of first consideration.

Their epoch-making first vessel, the Selandia, was put into service in February, 1912, being 7,400 tons deadweight, having twin screws, and designed for 10½ knots. The two main engines, which have eight cylinders each, develop 2,500 total indicated horse-power when running at 140 revolutions per minute. This vessel, now entering her tenth year, with a total mileage of nearly 500,000, has proven the same unqualified success as her successors and is today in steady service in the Far Eastern trade, while hundreds of steamships completed eight years later are laid up on account of their greatly inferior operating economy. Eight cylinders were used to limit the diameter to 530 mm., or 21 inches, which was the same as Burmeister & Wain's largest land engine at that time. Later the number was changed to six, which is cheaper to build, requires less engine-room length and has fewer parts to take care of. The size of the cylinders was increased by degrees to meet the power requirements of the larger vessels employed. The largest cylinders so far built by this company are 740 mm., which in six and eight cylinders give respectively 4,500 and 6,000 indicated horse-power for two screws, turning at 115 revolutions per minute, and suitable for cargo vessels of, say, from 11,000 to 14,000 tons deadweight and 12 to 12½ knots speed. The six-cylinder engine is the same as is being installed by the Cramp Company in the United States Shipping Board's motor ship William Penn, shortly to be placed in service.

It might be mentioned that the same Danish builder has drawings completed for engines having cylinders of 800 mm. or 31½ inches diameter, and 500 indicated horse-power per cylinder adaptable to intermediate liners.

As with the steam engine, there is a limit in size of cylinder for a Diesel engine, and it would appear that the 31½-inch is nearing this limit, due principally to liner thickness required. Considerations of convenience for handling the parts on board vessel are also involved. It would seem that the next logical step with the four-cycle engine for increasing the power to more than 500 indicated horse-power per cylinder is to resort to the double-acting piston. From the standpoint of elimination of heat troubles, the condition is believed to be more favorable for the double-acting four-cycle engine than for the single-acting two-cycle engine, as the maximum temperature at the first part of the power strokes is alternately distributed to the two ends instead of continually to one end of the cylinder as with the two cycle.

The adaptability of the motor ship in having its auxiliaries electrically driven and the advantages resulting from the same were at the beginning recognized by Burmeister & Wain and incorporated in their first vessel. As the internal-combustion engine by nature requires an external source of power for starting and maneuvering, the same power can be effectively used for other purposes as for driving pumps in engine-room and deck machinery. The saving in fuel thus made, being about one-tenth that of a steam vessel when in port, it should be observed, is due primarily to the efficiency of the Diesel engine driving generators and not so much to the electrical transmission as some have been led to assume.

In the earlier installations two large auxiliary engines were used, each driving a generator and compressor in tandem, the latter being uncoupled when in port. This was soon replaced by three, and now, as in some of the larger vessels, by four, small sets having generators only. The compressors on the main engines at the same time were changed from single high-stage compressors, taking their air from the maneuvering air system to independent three stage compressors. For the two low-pressure air compressors, one of which was always operated at sea, was substituted one motor-driven compressor for maneuvering purposes only. This latter arrangement is better in that the high and low-pressure air systems are not interdependent and the auxiliary power plant is more flexible. From an operating standpoint it is also better, as, by having more than two sets and being small in size, they can be overhauled in turn at sea, relieving the work of the engineers' personnel in port, whose time should then be given to more important port duties.

There has been much discussion as to whether the two or four-cycle engine is better. Judged in the light of the number of motor ships in successful operation, at present the four cycle has the decided advantage.

The special claims made for the two-cycle engine is that more power can be obtained per cubic space of cylinder, from having double the power strokes of a four cycle, and hence less weight and space occupied; also that the two cycle, having no exhaust valves to cause trouble, can burn the lower grade oils of high sulphur content.

The four-cycle advocates dispute these claims by saying that the two-cycle engine cannot run with as high mean pressures in the cylinders as the four cycle if internal heat troubles are to be avoided, and that the combustion is not apt to be as complete as in the four cycle. They also point out the lower mechanical efficiency, resulting from negative work required for scavenging, and hence higher fuel consumption. With the rings passing across the open ports wearing conditions are not so good as with the unbroken liner surface of the four cycle, and the cylinder lubricating oil consumption is much higher than the four cycle due principally to the oil being scraped into these ports and blown out through the exhaust. It is also stated that with the long pistons required, scoring is apt to result from misalignment caused from wear at crossheads and guides. The two cycle originally dominated the field of the light high-speed submarine engine, but after some ten years have been spent in its development it has been superseded in this field to a great extent by the four cycle. This would not have been possible if there is any inherent advantage in the two cycle as to weight for a given output. Moreover, in the long trade routes, which is the merchant motor ship's chosen field, it must be obvious that the conceded superior economy of the four cycle will give an advantage in deadweight cargo capacity more than sufficient to offset the advantage in weight of machinery claimed, but not yet proved, by the two-cycle advocates.

Some makers, who originally built four-cycle engines and changed to two cycle, have in recent years changed back to four cycle, and others, who have always built the four cycle, are known to be experimenting with the two cycle. All experienced builders are fairly well agreed, however, that the Diesel engine works best at low speeds due to the nature of the injection and burning of the oil, and that the large cylinder engines better burn the lower-grade oils. Oil of higher sulphur content, though, as commonly used under boilers, is not to be recommended, as the sulphuric acid formed in the burning not only affects adversely the exhaust valves of the four-cycle engine but attacks impartially the exhaust pipes and other parts of either the four or two cycle.

Some makers have advocated the solid injection or injection of the fuel by pressure alone, with which Vickers has been most successful. The chief difficulties encountered with such a system are in getting good combustion at all running speeds and loads and the elimination of the shock in the cylinder, which is apt to occur with the sudden rise in pressure when fuel is injected. The advantage claimed is that compressor troubles are entirely eliminated with a correspondingly higher mechanical efficiency obtained than with air injection. The fuel consumption, often erratic, however, under the most favorable conditions, is no better than the air injection full Diesel. It is also questioned if an oil pressure from 2,500 to 4,000 pounds per square inch is more to be preferred than an air compressor and its corresponding air system having a pressure of 850 to 900 pounds.

The Diesel electric drive has been suggested by some, using direct current supplied by several high-speed engine sets working in series. The sponsors of this system apparently have either taken their cue from the turbine electric drive or are more familiar with the electric end than the shortcomings of the high-speed Diesel engines. To reduce the weight of the engines and space occupied sufficiently to compensate for the additional electrical equipment involved, the engines must necessarily be high speed and of the trunk-piston type. The engines would correspond in design to that halfway between land and submarine practice.

The disadvantages of such a system compared with the direct drive are as follows:

1. Loss in reliability in the prime movers.

2. More major overhauls, as lifting of cylinder covers and drawing of pistons, due to poorer combustion and passage of lubricating oil from crank case.

3. About 30 per cent more fuel per knot, 15 per cent chargeable to higher fuel consumption of engines and at least 15 per cent electrical losses with the small-size generators used.

4. Lighter grade and more expensive fuel oil required.

5. Much higher lubricating oil consumption associated with high speed and trunk pistons.

6. Possible vibration troubles associated with high revolutions.

7. Necessity for using objectionably large motors of the commutator type for transmissions of power from engines to propellers.

8. Greater complication of controls and more expert knowledge required of the engineer personnel.

9. Tendency to overwork the personnel with the frequent overhauls required with high-speed engines when operated continuously at full power.

10. Danger of short circuits.

11. Short life of high-speed engines compared with slow-speed engines.

12. Higher first cost and maintenance charges.

With the higher consumption of fuel and lubricating oil per indicated horse-power combined with the electrical losses involved and the better quality of fuel oil required, the total expenditure for these items will be about 50 per cent more than with the direct-drive system.

The Diesel electrical system has been specially recommended for converting existing steamers. It is believed by the authors that this can be far better accomplished by using a long stroke engine turning at the low revolutions required. Work has been done along these lines by Doxford and Cammell-Laird, using the doubled opposed piston, and also Burmeister & Wain have developed a line of long stroke engines, with a stroke bore ratio of two to one, specially adapted to single-screw vessels. These latter engines are to be recommended for new vessels, as well, of 5,000 tons deadweight and less, on account of less engine-room personnel required, important in small vessels, and the dispensing with one shaft alley, which is also important in this size ship.

For new motor ship construction, over 5,000 tons deadweight, two screws are to be recommended. In smaller vessels there is little difference in propulsive efficiency between single and twin screws. For larger ships, however, the efficiency is more favorable with the two-shaft arrangement due to well-known conditions affecting propeller performance, including the better immersion of the two smaller propellers under all conditions of draught. In the larger vessels, also, the saving in space by having only one shaft alley is not so important, and the length of engine room will be less with the higher-speed standard-stroke engines.

A comparison will be given showing the estimated increased earning capacity of a motor ship over a corresponding oil-burning steamer as can be anticipated in actual service. The size of vessel chosen has the same general dimensions as the motor ship Afrika, owned by the East Asiatic Company, and which is similar to the William Penn and the two motor ships building for the United American Lines.

The steamer is single screw with double reduction gearing and compound turbines and Scotch boilers. The revolutions for the vessel is taken as seventy, which is conservative practice, to favor propulsive efficiency which for convenience here is assumed the same as the twin-screw vessel.

The ships are of the awning-deck type having a nominal deadweight carrying capacity of 13,000 tons when loaded to 31 feet 5 inches draught. They are 445 feet between perpendiculars, 60 feet beam and 42 feet moulded depth, with a block coefficient of .782. The shaft horse-power of the turbines is taken as 3,500 which is equivalent to the 4,500 indicated horse-power of the Diesel engines. The cost of the vessels to build, based on probable cost of labor and material in the immediate future, is assumed $150 per ton for the steamer and $165 for the motor ship. The $200,000 additional cost of machinery for the motor ship, including deck machinery, is considered fair where the Diesel work is well standardized.

The fuel oil consumption at sea for the steamer with 16° Beaumé oil is taken as .95 pound per shaft horse-power, all purposes, which should be realized in service with properly designed turbines and double reduction gears and coordination of auxiliaries. For the motor ship, with oil of 22° Beaumé, the consumption is taken as .31 pound per indicated horse-power all purposes, which is usual with motor ships belonging to the East Asiatic Company. The cost of oil in American port, per recent quotations, is $2 for fuel oil for steamer and $2.30 for Diesel oil of gravity indicated. It is necessary for the steamer to take on additional oil in a foreign port which is assumed double that in an American port.

The route chosen is from San Francisco to the Far East and return, calling, for example, at Yokohama, Hong Kong, Manila and Honolulu, with a total distance of 15,500 knots. The number of days at sea and in port is taken from percentages for similar vessels operating over similar routes, and the number of days in port include that for loading and unloading, repairs and docking, holidays, etc.

The cost of personnel is based on scale of wages in effect the first part of this year with sustenance at $1.25 per man. This is estimated with 27 for the deck officers and crew for either vessel, and for the engine room 19 and 14 men respectively for the steamer and motor ship.

The freight rate for bulk cargo is estimated as $27 per 100 cubic feet and for deadweight cargo as $13.50 per ton which is fairly well in accordance with present rates.

The itemized figures are as follows:

	Steamer.	Motor ship.
Displacement, tons	18,690	18,730
Gross tonnage, tons	9,050	9,050
Actual mean sea speed, knots	11.5	11.5
Revolutions per minute	70	115
Indicated horse-power	.....	4,500
Shaft horse-power	3,500	.....
Total weight of machinery (tons), including pipes, ventilators, ladders, floor plates, spares, tools, outfit, propellers, shafting, etc.	690	911
Water in system, tons	115	14
Weight of deck machinery, tons	140	155
Weight of hull, fittings, equipment, etc., tons	4,575	4,600
Light displacement, tons	5,520	5,680
Capacity deadweight, tons	13,170	13,050
Capacity (bales) cubic feet	590,000	620,000
Oil bunker capacity, tons (double bottoms)	1,320	1,350
Oil bunker capacity, tons (tank between tunnels)	.....	120
Oil bunker capacity, tons (settling tanks)	80	20
Total oil bunker capacity, tons	1,400	1,490
Oil consumption per shaft horse-power, main engines all purposes, pounds	0.95	....
Oil consumption per indicated horse-power, main engines, all purposes, pounds	....	0.31
Oil consumption per day at sea, tons	35.65	14.95
Oil consumption per day in port, tons	5.5	0.7
Number of days at sea, per annum	220	220
Number of days in port, per annum	145	145

15,500-Knot Voyage.

	Steamer.	Motor ship.
Days at sea	55.5	55.5
Days in port	36.5	36.5
Total oil consumption at sea, tons	1,980	830
Total oil consumption in port, tons	200	26
Reserve oil bunker (for about six days), tons	220	90
Total oil carried outbound, tons	1,400	946
Total oil burned on trip out, tons	1,090	428
Total oil necessary, homebound, tons	1,310	518
Oil to be purchased abroad, tons	1,000	0
Weight of crew and stores, tons	50	50
Fresh water on board at start of each leg, tons	300	75
Total weight of vessel, including fuel, water, etc., outbound, tons	7,270	6,751
Total weight of vessel, including fuel, water, etc., homebound, tons	7,180	6,323
Cargo capacity, outbound, tons	11,420	11,979
Cargo capacity, homebound, tons	11,510	12,407
Cargo capacity, average (two ways), tons	11,465	12,193

Cost of Operation Per Voyage.

	Steamer.	Motor ship.
Insurance (4%); depreciation (5%), 92 days	$44,200	$48,800
Brokerage, at $0.15 per ton cargo capacity	3,440	3,660
Overhead and general expenses at $20 per gross ton, per annum	45,600	45,600
Fuel oil	45,900	15,260
Water, at $1 per ton	600	150
Deck officers, crew, stewards	12,200	12,200
Engineer personnel	9,300	7,600
General stores, deck, engineers and stewards	5,000	5,000
Totals	$166,240	$138,270
Loading and discharging of deadweight tons at $1 per ton and 75% of cargo capacity	17,200	18,280
Total cost for deadweight cargo (per voyage)	$183,440	$156,550
Loading and discharging of bulk cargo at $2 per 100 cubic feet at 75% capacity	$17,700	$18,600
Total operating cost for bulk cargo (per voyage)	$183,940	$156,870

Comparison of Earnings With Deadweight Cargo Carried.

	Steamer.	Motor ship.
Tons per voyage outbound at 75% capacity	8,580	8,980
Tons per voyage homebound at 75% capacity	8,640	9,300
Rate per ton	$13.50	$13.50
Gross revenue per voyage at 75% capacity	$232,500	$246,780
Cost of operation per voyage	$183,440	$156,550
Net revenue per voyage	$49,060	$90,230
Net revenue per annum	$195,000	$358,000
Per cent earned on investment	10	16.65

Comparison of Earnings With Bulk Cargo.

	Steamer.	Motor ship.
Cubic feet of cargo carried out and return at 75% capacity	885,000	930,000
Rate per 100 cubic feet	$27	$27
Gross revenue for bulk cargo	$239,000	$251,100
Cost of operation per voyage	$183,940	$156,870
Net revenue per voyage	$55,060	$94,230
Net revenue per annum	$218,500	$374,000
Per cent earned on investment	11.2	17.4

From the foregoing it will be seen, for the particular conditions chosen, that the motor ship has an increased earning capacity over the steam vessel of 66 per cent on deadweight and 55 per cent when bulk cargo is carried. In addition to the bulk cargo, there can be carried on the outbound trip 544 tons of oil, which, at $13.50 per ton, will increase the amount earned on investment from 17.4 per cent to 18.73 per cent or 67 per cent better than the steamer.

The above figures can be used as a basis for working out a comparison for any route which will vary directly with length of voyage and the size of the vessels employed.

A brief description of the motor ship William Penn will be given, as it was the first large vessel of this kind owned by the United States Shipping Board. The performance of this vessel in service will be of particular interest, as it is to be operated over the same route and by the same operating company as the electrically driven ship Eclipse, recently put into service.

The hull, having been originally intended for a 3,000 shaft horse-power single-screw turbine installation, is not exactly suitable to the Diesel engine installation of 4,500 indicated horse-power, or 3,500 shaft horse-power. For best efficiency, due to its high block coefficient, the vessel should not be driven over 10½ to 11 knots in service. The screws have accordingly been designed for lower turns than that for which the engines were intended, so that the designed mean indicated pressure, upon which the efficiency of engines somewhat depends, will be maintained.

The William Penn has a length between perpendiculars of 439 feet 6 inches, beam of 60 feet, depth moulded to shelter deck of 36 feet 8 inches, and draught of 28 feet 4¾ inches, corresponding to 12,375 tons deadweight The length of engine-room space was maintained the same as for the steam-driven sister ships. A built-up column was added to tie the middle of the engine-room double bottom to the shelter and bridge decks, to prevent possible synchronous vibrations being set up between the main engines and the hull's structure.

The main engines are, as previously stated, six cylinders, each of a bore and stroke of 740 mm. and 1,150 mm., respectively. Along the port side are arranged the three auxiliary engines each driving 65 kilowatt generators, and along the starboard side the maneuvering compressor and bilge and ballast pumps. The lubricating and salt-water cooling pumps are placed near the forward bulkhead and the fuel oil pump and reserve air compressor aft, between the main engines. In this vessel a fresh-water closed cooling system, with cooler and fresh-water pump, has been added for the cooling of the cylinders and covers. This is a precaution against mud being deposited in the spaces, which is liable to occur with deep-draught vessels when navigating shallow waters and rivers. The salt cooling water is maintained for the main compressors and piston cooling, which is also used for cooling the fresh water.

THE CHAIRMAN:—For the benefit of those who have come in since we opened these proceedings, let me say that it was thought desirable to have both papers before there was any discussion; that the discussion should then take in both subjects. At the close of the discussion some pictures will be thrown upon the screen by Mr. Shaw, by Mr. Warriner and by some others.

Paper No. 2, by Mr. Robert Warriner, is entitled, "Reduction Gears for Ship Propulsion."

Mr. Warriner presented the paper.

REDUCTION GEARS FOR SHIP PROPULSION.

By Robert Warriner, Esq., Member.

[Read at a special meeting of the Society of Naval Architects and Marine Engineers, held in New York, May 26, 1921.]

The past ten years have seen rapid development of the reduction gear for ship propulsion and something like one thousand merchantmen so fitted have been built or are building. The venture has not been an unqualified success, but the proposition is attractive enough to warrant careful study and discussion so that the faults can be eradicated and a reliable manufacture arrived at.

The turbine, perhaps, is the simplest machine for turning the energy of steam into power but its best efficiency and simplest construction are obtained with high speed of revolution; on the other hand, the best efficiency of screw propeller is attained with comparatively low revolutions and to take advantage of the best in these two it is necessary to use some means of reduction, either electric, hydraulic or gearing.

The first application of reduction gear for ship machinery was on the S. S. Vespasian by Sir Charles A. Parsons, and following this there were a few applications to special steamers and cruising turbines for war vessels and the main drives for some destroyers. It was not, however, until the shipbuilding activity which resulted from the war had attained full swing and the urgent need for all kinds of machinery was felt, that the reduction gear drive was made a leading type of propulsion machinery.

The development was so rapid that most of this machinery was designed and built with scant knowledge of the real requirements for sea service and with none of the essential experience which comes from actual practice under continued service conditions. It should also be remembered that the number of gear cutting machines was very limited and those in use, with a few exceptions, were rather small, and no doubt this led to some reduction gears being designed to meet the existing facilities for machining and cutting teeth. There was also considerable trouble in getting special material and it was necessary to use what was available. As a consequence there have been some unfortunate experiences which have raised doubts in the minds of many engineers as to their ultimate success. On the other hand, there are a number of examples where reduction gears are giving good service and showing better economy than reciprocating engines under the same steam conditions, and there is no doubt that by adopting a conservative design and manufacturing on sound lines this type of machinery can be made more reliable, economical and easier to handle than other kinds of steam machinery.

The Neptune, built by the Sparrow's Point Plant of the Bethlehem Shipbuilding Corporation, was the first vessel of the U. S. Navy to be fitted with turbines and reduction gears for main propelling machinery. The equipment was manufactured by the Westinghouse Machine Company (since consolidated with the Westinghouse Electric and Manufacturing Company) and the boat was put in commission in August, 1911.

The economy of the machinery was not satisfactory and the contractor offered to replace the machinery with turbines of much higher revolution. This necessitated, also, changing the gears, although they were quite satisfactory. This new machinery was fitted and put into operation November, 1915, and has been in successful operation ever since, the ship having sailed over 180,000 miles since November, 1915.

The U. S. S. Wadsworth, built by the Bath Iron Works, Ltd., was the first destroyer of the U. S. Navy to be fitted with reduction gears for the main drive. She was authorized in March, 1913, and completed June, 1915. The machinery is twin screw and develops 16,000 shaft horse-power, that is, 8,000 shaft horse-power for each set and 4,000 shaft horse-power per pinion. The turbines are compound, the high pressure on one side and the low pressure on the other side of the large wheel, and the revolutions are: Propellers 450 revolutions per minute, high-pressure turbine 2,494.5 revolutions per minute, and low-pressure turbine 1,509.8 revolutions per minute. One peculiarity of this gear is that there is only one helix. The steam thrust of the turbine acts against the propeller thrust and any difference between the two is taken by a Kingsbury thrust bearing. This vessel was a remarkable advance on any previous destroyer of the U. S. Navy, both as regards speed and efficiency, and during the six years of service has operated in a very satisfactory manner.

There are now about two hundred and fifty destroyers fitted with geared-turbine drives. These are all single reductions of various makes and no trouble is being experienced with them.

The double reduction gear was introduced for the turbines of the battleship Nevada. They were built by the General Electric Company and were distinctly novel. There is a single high-speed turbine in each set and the pinion engages two wheels which in turn are coupled to the two pinions of the second reduction and engage in the large driving wheel. The shaft horse-power developed by each of these cruising sets is 1,750 and the speed reduction 23.35 to 1. These gears were tried out November 9, 1915, and proved very satisfactory, the efficiency of the vessel from 10 to 15 knots being improved some 30 per cent at 10 knots to 10 per cent at 15 knots.

The same type of double reduction was further developed and fitted on the Pacific, built by the Union Iron Works, and on the Sucrosa and Mielero, built by the Fore River Shipbuilding Company. These sets were what is known as the "two-plane" type (Fig. 5, Plate 5), the first stage or high-speed gear being comparatively small and carried above the center of the main drive. This allows the latter to be as large as can conveniently be housed in the ship and lends itself to sturdy, short second speed pinions.

After making a few of the two plane gears, the single-plane type of double reduction (Fig. 4, Plate 5) was introduced as a means of increasing production. The change led to a rather cramped design as the low speed wheel has to be contained between the centers of the high-speed train and cannot be increased without increasing the latter, and this limitation led to a very considerable increase of tooth pressures. The units so designed are small and showed a saving in weight and, as they performed well at the outset, the manufacture of this type was generally adopted.

We have now a variety of reduction gears in service and enough running has been done to show that some types are good for continuous service and to point out some of the defects in design, handling or manufacture.

Lack of knowledge of gears and their requirements on the part of the engine-room staff, improper lubrication, failure to keep the oil clean and free of water, especially salt water, are some of the causes of wear and complicate the task of distinguishing between the good and bad of design or material, but this is a condition which is rapidly improving and there are now plenty of engineers experienced in the handling of turbines and gearing.

The lubricating oil systems of most of the later boats have been standardized on the lines set forth in a paper by Messrs. Smeltzer and Fernald, read before the Society in November, 1919.

The gravity system insures a constant pressure of oil to all parts of the engine, and the increased capacity of drain and gravity tanks allows for a slower circulation of the oil and provides a reserve supply which will last a few minutes after the pumps stop and allows the turbine to be safely shut down. The settling arrangements are greatly improved and the use of the DeLaval separator will do much to improve the condition of the lubricating oil.

There is still frequently encountered the misconception in regard to lubrication that the lower the temperature of the oil fed to the machine, the better will be the lubrication. The gears would, of course, run better with cool oil or oil of high viscosity, providing it is not too cold to reach the wheels from the spraying nozzles, but bearings require oil of low viscosity, and as it would be cumbersome to have two oiling systems it is necessary to compromise between these two, and it has been found from experience that, with oil of 500 seconds Saybolt viscosity, good results are obtained on both gears and bearings when the inlet oil temperature is between 100° and 110° F., that is to say oil at a viscosity of about 450 seconds Saybolt. Bearings fed with oil of low temperature are found to generate more heat and wear rapidly, whereas with oil of proper viscosity the wear, over considerable periods, is practically negligible.

Accuracy in the cutting of the teeth and machining casings, assembling and setting up of parts is absolutely essential for insurance of good running. The clearance in the bearings must also be uniform so that in whatever direction the pressure is to be taken they will maintain the pinions in a true line with the wheels. The casing should be made as stiff as possible and will be better if it is so designed that it is rigid enough to hold its form when placed on the ship seatings for the process of fitting the packing blocks. The two-plane and three-plane types are specially advantageous in these respects as the depth is so great as compared with the area covered by the gear. Ship seatings should also be designed so that they will add to the stiffness of the casings. A ship is generally quite flexible and alters considerably with change of trim and works due to the action of the sea. It seems, therefore, desirable to make the seatings so that they will not be influenced by the movements of the ship, that is to say, they shall be substantial structures set down on the ship's bottom and free of all connections to the ship's side or bulkheads which would have the effect of transferring to the gears the movements of the ship. They should be arranged to maintain the alignment of the gears and turbines, and not, as is so often the case, to add strength to the ship's structure.

The maintenance of the contact of the pinions and wheels along the whole face is a matter of one or two thousandths of an inch and unless this alignment is strictly maintained it means that the work has to be done by only a part of the face and that the part which actually does the work is subject to increased pressure.

Undoubtedly some gears have been manufactured with tooth pressures greater than present day materials and manufacture will stand. Devices for giving flexibility and to compensate for misalignment have been tried out in the test house and have shown the capacity of gearing to work under loads far in excess of those used in service. These tests would be carried out under the best conditions with little to distort the casings or to upset the alignment. The conditions at sea, however, are entirely different and it is difficult to estimate what may have to be taken into account. Apart from the alteration in a ship's structure due to loading or trim and running light there is the occasional disturbance due to heavy weather, the effect of which cannot be calculated. With the reciprocating engine the results are apparent and it is necessary to ease down and stand by, but with the turbines and reduction gears considerable variations may take place in the revolutions without making themselves felt except by a change in the hum of the engine. The constant change in inertia has all to be taken up by the teeth and it has been noted that gears which are heavily loaded wear rapidly in stormy weather.

The tables (Plate 4) show the principal dimensions of gears by different makers, Fig. 1 for double reduction gears and Fig. 2 for single reduction. These are by no means complete but are representative of what has so far been made. Plate 5 shows diagrammatically the arrangement of wheels and pinions for a variety of reduction gears and is explanatory of some of the terms used in the paper.

The single reduction sets are generally satisfactory and out of the large number fitted there have been very few failures. The tooth pressures are not excessive; those for war vessels may be fairly high, but they have only to work at full power occasionally and for very short periods. The turbine speeds are usually moderate and the inertia of the moving parts correspondingly low. It is easy to estimate the load on each pinion due to the turbine, and the difference between mean and maximum torque is much smaller than in the case of double reductions with their high-speed turbines. In the latter (Figs. 4 and 5, Plate 5), where a single turbine is used to drive two sets of wheels and pinions, it is difficult to assemble them so that work is divided evenly between the two sets, and any uneven wear or adjustment of the bearings will throw most of the load on one side or the other with an increase of the tooth pressure on that side.

Some of these gears are also solidly coupled together so that there is no give in the gears themselves to compensate for this uneven loading.

The single reduction gears under column 9, Fig. 2, Plate 4, have given considerable service. They were installed on the Orizaba and Sibboney and were manufactured by the DeLaval Company. Both of these vessels were operated under very severe overload conditions during the war. The Orizaba has steamed, to date, over 225,000 miles and the Sibboney 175,000 miles. It is stated that when the gears were last examined they were in excellent condition. All the other gears of this sort, tabulated, are, so far as can be learned, operating well, though the mileage is much less than in the case of the two ships quoted.

Amongst the double reduction gears there are some cases of extended running which point to the loads which gearing will stand safely. The S. S. Pacific in service since December, 1915, still has the original low-speed gears, which, on last report, had made 240,000 miles. The S. S. Sucrosa in service since July, 1916, also has the original low-speed gears after running 225,000 miles. The high-speed train was renewed after 120,000 miles. The S. S. Mielero had the original gears still in use after three years running during which she made 160,000 miles. These are all of the two-plane type (Fig. 5, Plate 5) and were made by the General Electric Company.

The design tabulated in column 1, Fig. 1, Plate 4, has given an excellent account of itself and there have been no break-downs or repairs. Some of these units have been in service over two years and show little sign of wear. Those tabulated under column 3, Fig. 1, Plate 4, have also given excellent service. Both of these are Falk gears.

In regard to double reduction gears of the single-plane type the results are various, but there are few which have seen 100,000 miles of sea service, and this type is not likely to be repeated to any great extent.

After studying the results obtained on various types the author suggests the following table of tooth pressures as being the maximum which it is safe to use:

$$K = \frac{P}{\sqrt{D}}$$

P = Pressure per inch of working face
D = Diameter of pinion in inches

		K	D
Double reduction gear with a single turbine where a single pinion meshes with two high-speed wheels coupled to two low-speed pinions driving one low-speed wheel	High speed	120	6″ to 9″
	Low speed	180	9″ to 16″
Double reduction gear, single or compound, where each turbine drives a single wheel and pinion	High speed	150	6″ to 9″
	Low speed	220	9″ to 16″
Single reduction gears, constant service	....	175	
Single reduction gears where full power is only used occasionally	....	250	

One further important item is the length of helix in proportion to the diameter of the pinion, and the constants quoted are based on the assumption that this ratio does not exceed 2 to 1 and should be reduced to 1.5 to 1 whenever possible.

The material of the casing and bearings is practically standard. The oil well and the gear-case cover are sometimes made of cast iron and sometimes are built of steel. The cast iron serves to deaden the noise of the gears and is to be preferred, but good results have been obtained with the steel covers by lagging them with felt and sheet iron. The general construction for the wheels has been either cast iron or cast steel spiders with rolled rims of mild steel shrunk on and pinned and in which the teeth are cut. Gears of the Alquist type are formed of steel plates (laminated) bolted together on a hub or disc, the plates being separated from each other to a depth of a few inches. This gives a certain amount of flexibility when new, but it is found that the teeth rapidly grow together. Some of the gears we have now in service have solid steel spiders with teeth cut in the rim. They are made by a special process and come out quite sound. Those tried have given good results, and the structure being finely granular it is believed that they will wear better and be less subject to pitting than the mild steel forged rims.

Difference of practice is found in the material for the pinions; some prefer high carbon steel and others nickel steel, chrome nickel or chrome vanadium steel. It is believed that the alloy steel will be found to give the best results as the structure is so different from that of mild steel and the material appears to have better qualities. The pinions are made as hard as they can be cut and they are usually heat treated to secure the necessary degree of hardness.

In some of the gears which have passed through our hands which have been manufactured ahead of requirements and have had to lie in storehouses for a few months it has been found that the pinions have distorted. Some of these had to be removed on account of noise or vibration, and on inspection it was found that both bearings and teeth had altered so much that it was necessary to regrind the bearings and recut the teeth. This would seem to show that when first made there were stresses in the material which annealing had failed to remove or which had been left by the heat treatment. It is suggested that it would be advisable to make casings, wheels and pinions ahead of time and allow them to stand out in the weather so as to get rid of these internal stresses, before machining.

Considerable difference has been found in the life of gears of the same design, between those fitted amidships and those fitted in the stern of the ship, the latter wearing more rapidly. The inertia of the turbine is much greater than that of the propeller and shafting, and the turbine will run with practically uniform angular velocity while the motion of the propeller will be uneven due to the different conditions of water, depths, etc. This variation will have little effect on the gears when transferred through the long, flexible shaft of the machinery fitted amidships, but with the short shaft for those fitted in the stern of the vessel this variation of torque will be reflected on the teeth without any damping due to the shaft. When reduction machinery is fitted in the after end of the ship it is better to fit the turbines aft of the gears so as to make the line shaft as long as possible.

A number of gears have been fitted with a flexible shaft between the turbine and pinion or between the high-speed wheel and second-speed pinion. This device was patented by Mr. Day of the Falk Company for use on reduction gears where the torque from a single pinion has to be delivered through two wheels and pinions to a single wheel. The device is illustrated on Fig. 10, Plate 5. The pinions are made hollow and a flexible shaft passes through the center and is made just large enough to carry the load safely. It is attached to a turbine or high-speed wheel by a solid coupling and to the after end of the pinion by means of an extensible pin coupling. The weight of the shaft is taken in an easy fitting bearing at the end of the pinion. These torsion shafts are admirably placed for taking up the variation between the propellor speed and that of the turbines and eliminate to a great extent the turbine vibration being communicated to the gears.

The superheater has, so far, not found much favor in America for marine purposes, and considering the number of turbine-driven vessels that are being built it is surprising that so many are working without superheat. The turbine under the same steam conditions gives an efficiency of 10 to 15 per cent better than the reciprocating engine. From the actual service results of three steamers of the same capacity and in the same trade and running 55,000 miles a year, the one with triple-expansion engines used 335.3 pounds of oil per knot and the other two with turbine machinery used 281.5 pounds and 282.5 pounds of oil respectively. This could have been improved considerably by the use of superheat with very little increase in the cost of the turbines. Practically all that would have been needed would be to make the high-pressure end of the casing of cast steel instead of cast iron.

There is shown in Table I a comparison of machinery for 20,000 deadweight tons combined ore and oil vessels, showing the relation as to the weight, space, cost and operating expense for reciprocating engines, turbines and reduction gears, Diesel and electric drive on these particular vessels. In this the Diesel engine is rather at a disadvantage owing to the necessity of fitting considerable boiler power for heating the cargo oil. All the sets are twin screw.

TABLE I.

	Reciprocating	Turbine	Diesel	Electric drive
Speed of ship, knots	11.5	11.5	11.5	11.5
Diameter of propellers	17′ 6″	15′ 8″	15′ 8″	15′ 8″
Revolutions per minute	76	105	105	105
S. H. P. for 250 sea miles per day	4,135	4,350	4,350	4,350
S. H. P. maximum	4,600	5,800	5,000	5,800
Weight of machinery and water-tons	1,060	914	1,267	981
Weight of machinery in lbs. per max. S. H. P.	517	353	567	379
Space occupied by machinery, cubic feet	171,826	171,826	192,251	171,826
Total weight of hull and machinery, tons	9,350	9,200	9,700	9,267
Net carrying capacity of ship bunkered for 20 days' steaming and 8 days' reserve fuel, tons	18,775	19,220	19,482	19,153
Comparative cost of machinery	100	98.3	123.5	128.3
Fuel consumption per day, 250 sea miles, tons	60	48	24	48
Estimated cost of operating per day*				
Crew	13.33	13.33	14.46	13.33
Repairs	11.34	11.34	11.34	11.34
Stores	4.82	4.82	7.89	4.82
Provisions	3.97	3.97	4.26	3.97
Depreciation	27.10	27.00	29.83	30.10
Insurance	17.60	17.53	19.40	19.67
General	1.42	1.42	1.42	1.42
Fuel oil	20.42	16.34	8.18	16.34
Total	100.00	95.74	96.38	100.99
Per deadweight ton	100	90.7	93.2	99.3

* Based on total of 100 for reciprocating machinery.

The reciprocating engines are triple expansion $\frac{25'' \times 41'' \times 68''}{48''}$ and there are three cylindrical boilers 17 feet 6 inches diameter by 12 feet long, operated at 190 pounds per square inch and 20 degrees superheat, oil fired and with heated air forced draft.

The turbine machinery is cross compound with single reduction gears, turbine revolutions 1,930 per minute to 105 at the propellers. The boilers are the same size as for the reciprocating set and arranged for 220 pounds per square inch working pressure and 200° F. superheat. The water rate for the turbines will be 9.6 pounds per shaft horse-power per hour.

The Diesel machinery consists of two engines, each with six cylinders 25½ inches diameter by 48-inch stroke, two cycle. In this ship all the main and auxiliary deck machinery is driven electrically.

The electric drive consists of one turbo-generator with an auxiliary generator to give a speed of about six knots, and two large motors, one on each propeller shaft. The boilers are the same as for the turbine drive.

This comparison was not made out to favor any particular engine and is probably a fair representation of the relative weight, space and costs of the different types of machinery for these vessels. With the cheap rate for oil which it is possible to secure on the particular service for which the vessels are designed it is found that the turbine machinery makes the most attractive proposition, but as regards the mere cost of operation this advantage would swing to the Diesel engine with an increased cost of fuel, that is, providing the Diesel engine would operate satisfactorily on the same low grade of oil as is contemplated for firing the boilers.

It is considered that the turbine installation is the simplest to operate and will entail far less repair at the end of each voyage, so that the turn around can be made in quicker time, and that is of the greatest importance when special arrangements are made for loading and unloading, so that the time for this is counted in hours and not days. The turbine set has the further advantage of great flexibility and can be driven up to 15 per cent over normal full power when required.

It is interesting to note that the cost of the turbine installation is somewhat less than that of the reciprocating machinery, and if the boilers had been reduced to the extent warranted by the decreased steam consumption of the turbine there would have been a still further reduction in weight and cost. It was, however, considered to be an advantage to have the boilers operating under easier conditions for the normal full power and to have available, when required, the extra power and speed.

The arrangement of the turbine and gears is shown on Plate 6.

When comparing the efficiency of turbines and reciprocating engines it is usual to consider the best steam consumption of both. The turbine having good clearances and no wear on the parts affecting economy should maintain its efficiency, but the reciprocating engine falls off rapidly, due to the wear on valves and piston rings, liners and cylinders.

The question of gear efficiency has been much debated and various factors have been given from time to time. The Falk Company devised a means of testing them under full load, for bearings and teeth, with a motor large enough to supply the amount lost in friction only. This was further extended so that they could be tested for efficiency and tests were subsequently made on a number of gears, the results of which the Falk Company have kindly allowed me to add to this paper.

The first of these was on two sets of single reduction gears for one of the 35-knot destroyers built by the Bethlehem Shipbuilding Corporation at Fore River. The method is shown on Plate 7. The two gears, port and starboard, are placed back to back with a space of 10 or 12 feet between them. The main shafts and pinions are coupled together, the latter by means of torsion shafts with large couplings so that the twist on the shaft can be varied at will. By this means it is possible to put the same load on the bearings and to run the gears at the same tooth pressures and under the same conditions as when operating on board ship. The two sets are driven by a D. C. motor at the required speed and the power developed by the motor represents the friction of all the gears and bearings in the two units. The thrusts are not loaded, but these are not a part of the gears, and as they are only located in the casing for convenience of manufacture they should not be included in the gear losses. The results are corrected for motor efficiency. The oil service and lubrication are the same as for actual service.

In the case of the destroyer gears a number of tests were run with various loads and speeds so as to obtain a curve for the efficiency over a range of speeds and powers. The curves for the actual tests are shown for one-quarter, one-half, three-quarters and full power torque, each over a range of speeds (see Fig. 4, Plate 8), and from these further curves have been developed showing the efficiency at various speeds, powers and revolutions at which the machinery would work in the ship, Fig. 5, Plate 8. It will be seen that the maximum efficiency is 98.3 per cent at full torque and about one-half speed. In a ship, however, this condition is not used and the maximum efficiency is only 97.3 per cent. The bearings of these sets are very ample and account for the major part of the friction loss. Further experiments were made with shortened bearings and showed a gain in efficiency, but the curves are given for the actual gears as installed.

A summary of other tests is contained in Plate 9.

Test No. 2 was made on units of single reduction gears for the passenger ships for the U. S. Shipping Board. These units were designed for a normal horse-power of 10,000, but the test was made at 12,000 shaft horse-power as shown with a gear efficiency of 98.1 per cent.

Test No. 3 was made on units for passenger ships similar to No. 2, but designed for 12,000 shaft horse-power. These were made at a later date and the improvement is shown by the increased efficiency.

The fourth test was made on a pair of double reduction gears with compound turbines and was carried on continuously for eleven days. The conditions were maintained very nearly constant and the efficiency, 96.8 per cent, is very good for this type of machine.

Column 5, Plate 9, is for a similar set of gears with improved bearings, an arrangement which resulted in increasing the efficiency to 97.3 per cent.

The author is indebted to Mr. P. C. Day for the information on these reduction gear tests and to the Falk Company for permission to use them; also to the DeLaval Company, Westinghouse Manufacturing Company and the General Electric Company for the information and data furnished by them.

DISCUSSION.

The Chairman:—Gentlemen, I think it is sufficient for me to say that you have been favored with the presentation of two papers as simple, as complete and as understandable as any papers that have been heretofore presented on these same subjects.

The field is open to you all now for discussion. You can discuss both papers at once if you please, and it is advisable for the speakers to come to the front, in order that they may be more easily and readily understood in all parts of the hall. The floor is open.

Mr. Donald Mathieson, *Member* (Communicated):—I wish to convey to Mr. Metten and Mr. Shaw my regrets not being able, owing to strike trouble, to be at the meeting and my congratulations for their excellent, practical paper which offers shipowners just the right kind of information.

Mr. John Martin, *Member:*—Mr. Chairman and members, it is not so much a discussion as it is a tribute I would like to offer for a moment. About ten days ago it was my good fortune, representing the American Bureau of Shipping, to attend the sea trial of the motor ship William Penn, equipped with Diesel engines by Mr. Metten and Mr. Shaw for the Cramp Company.

The trip was notable in the marine-engine history of this country inasmuch as we have just learned from the authors that the William Penn is the largest American ship fitted with Diesel engines, and its successful trial performance marked another blaze in the trail the end of which may be our ability to meet the lower operative costs of foreign ships and get our share of the world's trade.

On this trial the ship was stopped, started, run at different speeds over measured miles, maneuvered in various ways such as ahead with starboard propeller and astern with port, with helms alternately with and at variance with propellers, and finally a many-hour endurance run, during all of which the engines and auxiliaries functioned perfectly with a noticeable absence of vibration in all parts of the ship.

I take this occasion to felicitate Messrs. Metten and Shaw upon their accomplishments, and believe it would be of great interest to the members present to know how closely the ship's performance met their estimates. Of this latter Mr. Shaw enlightened us tonight, and I am sure you were very much interested to learn that the ship's performance met very nearly their estimates. (Applause.)

Mr. Chester B. Mills, *Visitor:*—With the chairman's permission I will endeavor to throw a ray of hope into the hearts of the naval constructors of the coming generation.

The advantages of the Diesel engine in economy of fuel over other prime movers has long been recognized, and this type of engine is rapidly moving to the forefront where economy of fuel is a prime consideration. The disadvantages of the Diesel engine in its present conventional form, however, are its complexity, great size and weight per brake horsepower developed. A tremendous amount of energy and skill has been expended in attempts made to simplify the design, eliminate the air compressor and lower the manufacturing cost.

It will be of interest to members of the Society to know that one of the workers in this field, Mr. E. A. Sperry, has struck out on a pioneer trail in the direction which will produce a heavy oil engine with a number of new characteristics, chief among which is its low capital charge because of the greatly simplified construction, low weight per brake horsepower, great economy of operation, and noticeable gain in space occupied by the engine and machinery. The weight of this engine for the same power and revolutions is between one-tenth and one-twentieth that of the conventional engine, and it will require approximately one-fourth the floor space. What this means in the powering of a ship will be readily appreciated by naval constructors.

This engine as constructed is more efficient through the carrying out of compression and expansion in two stages, with expansion to practically atmospheric pressure. It is noiseless and burns, without carbon or smoke, ordinary bunker oil. Having fewer parts, its mechanical efficiency is higher. High speeds are practicable through the employment of new methods of burning the fuel, and rotational speeds up to 1,500 revolutions per minute are perfectly practicable and have been demonstrated. The engine is high compression and auto-ignition.

This new engine is not limited to the use of the higher priced Diesel oils but runs on the cheapest grade of boiler fuel oil. It does this without the use of a spray air compressor. The combustion chamber being about 30 per cent of the piston displacement and approaching a hemisphere in shape, makes possible the use of the simplest form of solid injection system.

It will be seen from the above statements that a real, serious attempt is being made to produce a light, compact and efficient prime mover, the commercial introduction of which will mark an epoch in the development of the Diesel engine in this country. This engine is in an advanced stage of development, and commercial construction on several applications is already under way.

In connection with the development of this engine, and in order to provide any Diesel type of engine with speed flexibility approaching that of the steam engine, there has been developed an electro-magnetic clutch operating on an entirely new principle, rugged in design and construction, consisting of but few parts and capable of being built to transmit practically any range of horse-power. This new type of clutch transmits torque entirely through air gaps and has no mechanical contact whatever between the driver and driven. It is capable of remote control and may be operated at any speed from zero to full engine speed, the torque being under full control. The power required to operate the clutch at full load is but a fraction of 1 per cent of the power transmitted. On direct drive the clutch has a unique feature of being magnetically locked together and transmits full engine power without slip and with an enormous increase in pull-out torque.

Mr. Benjamin G. Fernald, *Member:*—This discussion was prepared jointly by my associate, Mr. C. O. Tappan, who is not a member, and myself.

The Society is to be congratulated on having secured the presentation of these two papers. The authors of both papers occupy a leading position in the marine engineering field and are connected with companies which either build or furnish all types of propelling machinery, and are therefore well qualified to discuss the subject authoritatively and without bias.

Relative to Mr. Warriner's paper, we are in substantial accord with the author's conclusions throughout, and our only criticism of any of his statements on the foregoing points is that in the last paragraph of page 14 he limited his imputation of "lack of knowledge of gears and their requirements" to the engine-room staff. In our opinion the trouble experienced with marine reduction gears was due as much to "lack of knowledge of gears and their requirements" on the part of the designers and constructors as to the operating staff, although the latter certainly contributed their quota. It would be possible to discuss the whys and wherefores of gear troubles at sufficient length to fill a volume of the Society's transactions; however, we believe that those who have been in close touch with the situation are satisfied that geared turbines of both the single and double reduction type, which will operate with reasonable reliability and quietness, are now procurable for any type of vessel for which such equipment could be considered.

The ultimate efficient life of reduction gears is not as yet established, and we believe it is doubtful if either turbines or gears of any type can be expected to furnish useful service for such periods of time as slow-speed reciprocating engines. This deficiency, however, could be taken care of by applying a more liberal amortization percentage to such installations when comparing them with more durable types of propelling machinery.

Mr. Metten and Mr. Shaw in their paper have covered much the same ground in treating Diesel engines, and we agree with their conclusions as to both reliability and fuel economy of certain types of Diesel engines. The Diesel engine has unquestionably established its right to fair and equal consideration on its merits.

We believe, however, that the most valuable feature of both papers is the analysis of operation of specific ships in specific routes with various types of propelling equipment. In the case selected by Mr. Warriner he analyzed the operating cost of the same ship equipped with different types of propelling machinery and concluded that the geared turbine will make the best showing. Mr. Metten and Mr. Shaw have carried their operating analysis further and have furnished more details and reduced their comparison to the basis of net annual revenue for the ship and the percentage earned on the investment. Their comparison is also based on a specific ship in a specific route and shows the motor ship to be a better investment than a turbine-operated steamship. Superficial consideration of such opposite conclusions does not necessarily indicate that either of the authors is wrong. They both may be and probable are right for the ships and trade route selected.

The advocacy of any particular type of propelling machinery for all classes of vessels and for all trade routes, without a searching analysis of probable operating results and the compilation of comparative operating balance sheets, is a very short-sighted policy. Very few designing and constructing engineers have been in a position to secure information from actual operating records enabling them to apply to their theories the acid test of performance. On the other hand, operators of vessels and their superintending engineers have in many cases been too willing to let well enough alone. There is seldom that degree of cooperation between the builders and operators of ships which is necessary to accomplish the ultimate end of all commercial activities, viz., earning the highest return on a given investment.

After being without a merchant marine for many years, this country has by force of circumstance become possessed of a huge tonnage which eventually must pass from governmental control to that of corporations and individuals. Whether we continue to have a merchant marine will depend on the profitable operation of our ships by the owners.

Mr. Metten and Mr. Shaw infer that this result can be achieved only by the wholesale conversion of the propelling equipment of these ships to Diesel engine drive or the building of new motor ships. In our opinion such a conclusion is not warranted by a critical analysis of one ship for one trade route.

Assuming equal reliability and flexibility in operation, the only advantages which one type of propelling equipment can have over another are:

(*a*) To deliver a unit of power with less fuel and supplies.

(*b*) To have a lower first cost installed (including any extra cost of hull to accommodate).

(*c*) To weigh less.

(*d*) To occupy less space.

(*e*) Require lower operating labor cost.

(*f*) Lower maintenance cost.

No type of machinery which does not have an advantage over all others on all of the six points mentioned above can be recommended for universal application. The Diesel engine is by no means a new device. Its theoretical and actual saving of fuel has been generally known and admitted for approximately twenty years. Its general adoption has been retarded because of the slowness of designers and builders in achieving reliability in operation. The real reason, however, for the abnormal delay in its development is because it is inherently weak on first cost and weight.

A factor working in favor of the Diesel engine will be found in the uncertainty of obtaining a fuel supply at reasonable prices at all world ports. Because of its fuel economy it has been possible with the motor ship to make a complete round trip of almost any duration with one bunkering, and bunkering could be done at the port of call where fuel prices were lowest.

Economic conditions may bring about a reduction in the cost of coal and the wages of firemen without a corresponding decrease in the price of Diesel fuel oil, in which case it is not only conceivable but probable that an application of the same method of analysis, which today indicates the wisdom of selecting Diesel propelling machinery, will tomorrow give its verdict for reciprocating engines and coal-fired boilers.

Perfection of the electric drive, including electric auxiliaries, by whatever type of prime mover operated, may reduce the necessity for labor to a point where a modification of the navigation laws may be secured and the use of this type of equipment justified by the reduction in operating labor costs in spite of its higher fuel cost. Another point to be considered is that progress has been made not only in improving reduction gears, but the highly efficient Ljungstrom type turbine which has already been applied to the electric propulsion of ships has recently been applied by the Stal Works of Sweden to a special reduction gear so that its economy is now available for gear drives.

In November, 1919, we investigated for a foreign client the Diesel-engine situation as existing at that time and reported the following conclusions:

1. The Diesel motor ship has demonstrated its reliability, high fuel economy and the advantage of its use on long trade routes, especially in the Far East where suitable cheap crude oil is obtainable and the long cruising radius makes it independent of coaling stations.

2. The designs of Diesel engines are still in the formative stage, and developments may be expected within a short time that will greatly increase the brake horse-power per cylinder with no serious sacrifice of efficiency and with a marked decrease in weight, cost and space occupied.

3. The 4-cycle Diesel engine at the present time (this was at the date I mentioned, in 1919) has more fully demonstrated its reliability than any other type of marine internal-combustion motor.

As a part of the same investigation a complete operating analysis was made for the purpose of determining the best type of propelling machinery for a standardized 8,800-ton vessel for the run between San Francisco and Tokyo, and the operating balance sheet showed an advantage in net annual operating surplus of 10 per cent for geared turbines over reciprocating engines and 9 per cent over Diesel engines. The investigation was completed in about three weeks. We did not have available detail figures for costs of construction and operation such as would be available in a conference between a shipyard and an operating line, and many of our figures were necessarily estimated. The figures for crew wages and maintenance, cost of vessel, cargo rates, etc., were furnished by the superintending engineer of our client. Certain other items included in the balance sheet of Mr. Metten and Mr. Shaw were omitted from our report, some through oversight and some through intention, because our client preferred adjusting the figures later from his own records rather than to delay the report.

We are submitting a copy of this balance sheet for printing in the transactions of the Society, thinking that it may be of some use in arriving at a correct basis for comparison. (Plate 10.)

At the time this work was done we could not discover in the technical press or transactions of the engineering societies on file in the libraries any complete comparative operating balance sheet, although there were many half statements, misleading from their incompleteness, contained in publications seemingly conducting a propaganda in favor of certain types of propelling machinery.

Shortly after our report was completed the Division of Operations of the U. S. Shipping Board prepared a most exhaustive analysis of the propelling machinery situation from the standpoint of operating costs and return on investment.

If it may now properly be made public, we hope that this report of the Division of Operations, or the essential features of it, may be included in this discussion either by the Shipping Board or by Mr. Robert L. Hague and Mr. A. P. Allen, who, we believe, were responsible for its preparation when they were connected with the U. S. Shipping Board.

In view of the fact that there is no recognized standard form for the preparation of an operating balance sheet and such arbitrary percentage charges as interest, depreciation, etc., are also not standardized, it seems to us that this Society could to advantage appoint a committee selected from members active in the design, construction and operating ends of the shipping business, to prepare a standardized form and method of comparing different types of propelling equipment. Similar work has been done by other engineering societies in standardized specifications, methods of testing boilers, other machinery, etc. (Applause.)

Mr. William W. Smith, *Member:*—The paper contributed by Messrs. Metten and Shaw is of timely interest, since many owners and shipbuilders have been investigating this subject with the view of obtaining higher economies in operation.

Referring to page 5, where the authors point out that the policy in Great Britain and the Scandinavian countries differs from our own, it should be borne in mind that the economic conditions there are somewhat different. The price of oil is considerably higher than here, and labor is cheaper. Also, most of the motor ships, as far as I know, are employed on long trade routes, where the cost of oil is much higher than here. These conditions are more advantageous for the motor ship. In general, the character of the service has a large influence in determining the most economic type of machinery.

The authors' remarks on page 8, in connection with high-speed engines and electric transmission, are of especial importance and are entirely concurred in. My conclusion is that high-speed engines are particularly undesirable for marine installations, which, first of all, must be reliable. The speed of the direct-connected engine is as high as it should be, and it seems unwise to go to higher speeds. Speeds between 250 and 350 revolutions, such as have been proposed for the generator engines, seem to be far beyond the limit for reliability under marine conditions.

It may be noted that the piston speed of the engine used in the comparison is 867 feet per minute, and that the revolutions are 115, which is high enough already for this type of installation.

On page 8, reference is made to converting steamships by installing Diesel engines. The entire replacement of a machinery installation is a very expensive proposition, and consequently the savings due to the new installation would have to be very large indeed to justify this. In some cases, depending on the machinery and the character of service, a complete replacement possibly will be of advantage, but in most cases I think it would not be profitable, considering that the average book value of vessels is considerably below the first cost. In the average steam engine or turbine vessel, I believe it would prove more profitable to install superheaters. This can be done at comparatively small expense and will result in a saving of fuel of between 15 and 17 per cent.

On page 9 the authors recommend twin screws for new vessels of over 5,000 tons deadweight. Considering the types of oil engines in general service at present, this view is concurred in; but if a satisfactory engine is developed for single-screw propulsion, this type will no doubt be preferable, for the reason that the installation will be considerably lighter, less expensive, and the operating staff will be reduced. Our investigation of this subject shows a marked advantage for a single-screw installation for the usual cargo vessel.

Referring to the difference in cost between the motor and turbine vessel on page 9, the relative values given are considerably different from what we have found. The cost per ton as given is 10 per cent more for the motor vessel; it is not stated, but I presume this is per deadweight ton. We found a difference of about 40 per cent more per deadweight ton, and about 28 per cent more per ton of average cargo capacity, allowing for fuel, etc., based on a long voyage.

In this connection, it may be noted that there are differences in the two vessels which influence these values. The vessel in the table has 3,000 tons more deadweight, smaller engines, and apparently lighter auxiliary machinery.

With reference to the cost of fuel oil, the authors use a difference of 15 per cent. Our information, which was obtained about a year ago, showed an average difference of about 25 per cent between 12 to 16 degree steam oil and 18 to 22 degree Diesel oil.

The voyage selected by the authors for the comparison is a long one and is therefore more favorable to the Diesel engine. It should be kept in mind that this comparison cannot be applied generally and only holds good for the particular conditions given.

The speed of the turbine propeller is quite low, whereas the engine speed is quite high. The weight of the turbine installation is therefore greater relatively than it should be. We made a comparison for a 12-knot vessel using 90 revolutions for the turbine and 105 for the oil engine. The weight given in the table for the turbine installation wet is 515 pounds per shaft horse-power, or 27 per cent more than the weight of our turbine installation, which is 405 pounds per shaft horse-power. The weight given by Mr. Warriner in his paper is 470 pounds, and if allowance is made for boilers and auxiliaries which are too large, and considering the fact that this is a twin-screw vessel, his figure would be reduced considerably. It would therefore appear that the turbine weights as given are rather high.

The oil consumption of our turbine was 1.08 pounds per shaft horse-power, with the following conditions at the turbine: Steam pressure 200 pounds gauge, superheat 25 degrees, vacuum 28½ inches.

The authors give a consumption of 0.95 pound of oil for the turbine, the steam conditions not being mentioned. I presume, however, that a moderate degree of superheat is used. This is a good performance for the turbine, but it is not the best which can be obtained by using a higher degree superheat of about 200° F.

The oil consumption of the Diesel engine is 0.40 pound per shaft horse-power for all purposes. This is a good average performance for the main engines only and is the value which we used in our comparison. For all purposes we allowed 0.45 pound per shaft horse-power, which includes the auxiliary engines and donkey boiler.

The figures for the cost of operation, on page 11, are considerably less for the steamer and very much less for the motor ship than we found. It appears that both the operating costs and the earnings for both vessels are optimistic for the freight rate specified.

The table shows that there is a saving in the cost of the engine-room staff, but we did not find this to be the case. It should be remembered that the Diesel vessel has twin screws and requires more routine work and attention when in port. Fifteen men were allowed by us in both cases.

The comparisons which we have made show that the earnings per year are about as follows, based on conditions which prevailed some time ago:

1. Voyage from New York to Hong Kong via Panama Canal—

	Steamer.	*Motor ship.*
Net earnings in per cent of first cost	11.32	13.47
Net earnings in per cent of steamer	....	119

2. Voyage from New York to Seattle, via Panama Canal—

	Steamer.	*Motor ship.*
Net earnings in per cent of first cost	14.73	11.4
Net earnings in per cent of steamer	....	77.4

This illustrates the fact that the earnings will differ with the character of the voyage. The first voyage was based on the price of oil as given in Table I herewith; the second was based on steam oil at $18.26 per ton and Diesel oil at $23 per ton.

TABLE I.—*Comparison Between Geared-Turbine and Diesel-Engine Machinery for Cargo Vessel.*

Length—425 feet; speed, three-quarters loaded, 12 knots; displacement, full load, 14,050 tons; deadweight capacity, about 10,000 tons.

	Turbine.	*Diesel.*
S. H. P. for 12 knots, ¾ loaded	3,100	3,020
Weight of machinery, dry, tons	470.5	1,052
Weight of machinery, wet, tons	560	1,060
Weight of machinery, wet, per S. H. P. lbs	405	785
Deadweight capacity, tons	10,050	9,500
Bale capacity, cubic feet	497,000	493,000

Voyage from New York to Hong Kong via Panama Canal.

	Turbine.	*Diesel.*
Oil consumption for all purposes, lbs. per S. H. P.	1.08	0.45
Fuel consumption per year, tons	8,978	3,468
Fuel consumption, per cent of turbine	100	38.7
Cost of fuel per ton (dollars)	23.85	29.90
Cost of fuel per year (dollars)	214,000	103,700
Cost of fuel per cent of turbine	100	48.5

In connection with our comparison, the following may be noted:

1. Cheaper oil will be more favorable to the steamer.
2. The steam plant is not the most economical and the lightest type, and further im-

provement to the extent of about 20 per cent could be made in fuel consumption by using steam superheated to 200 degrees and by other improvements.

3. The oil engines run at a lower speed than those used by the authors. A reduction in weight and cost can be effected by the use of higher speed engines, if this is considered advisable.

4. The engine-room and deck auxiliaries are based on British practice and are more liberal than those used on Danish type motor ships. We considered this was desirable to meet American requirements.

5. Changes in costs and economic conditions will also modify the comparison.

I desire to point out two important characteristics of the Diesel installation, the first being favorable and the second unfavorable.

1. The fuel consumption and the cost of fuel are extremely low.

2. The weight and first cost of the installation are extremely high.

It would seem that the trend of development should be towards reduction of weight, and it is believed that not until a substantial reduction of weight is effected will the Diesel engine have material advantages for American conditions, sufficient to induce its general adoption.

In general our conclusions in regard to Diesel engines are:

1. That Diesel engines are not advantageous for all services, and the most economic type of machinery will depend on the particular conditions to be met.

2. Turbine machinery with high superheat will prove more advantageous for ordinary voyages and moderate fuel prices.

3. The Diesel engine will be advantageous for long voyages and high fuel prices.

4. From the information available, it appears that a successful single-screw installation will have a considerable advantage for most cargo steamers. (Applause.)

The Chairman:—Mr. Smith wishes now to speak on the Warriner paper.

Mr. Smith:—Mr. Warriner has contributed a very valuable paper, which is of especial interest at this time. There are a large number of geared-turbine vessels in service, and the present trend, more especially in Great Britain, is toward the general adoption of geared turbines for marine propulsion.

Geared turbines have been adopted by our Navy Department for all surface vessels except battleships and battle cruisers. Great Britain and Japan have adopted this type for all surface vessels. The British battle cruiser Hood is equipped with geared turbines which develop 150,000 horse-power. The machinery of this vessel has been a marked success and has advantages in weight, space and economy in steam consumption which it will be difficult to surpass under similar conditions. The machinery of this vessel is of especial interest in comparison with our electrically driven vessels.

Geared turbines have been adopted by many British steamship companies for the largest and finest of their recent passenger steamers, including the Cunard liners Scythia and Samaria, the Anchor liners Cameronia, Tiburnia and Tyrrhenia, and the Pacific Navigation liners Orduna, Orbita and Oropesa. This type has also been widely adopted by British owners for cargo and channel steamers.

American owners have not been as progressive as the British in adopting geared turbines, although several have apparently adopted this type. There are, however, many geared-turbine vessels under the American flag, most of which were built for the Shipping Board during the war. Unfortunately, the geared-turbine installations of many of these vessels were defective and naturally gave trouble, as Mr. Warriner points out. Unfortunately, also, the operation of many geared-turbine installations has been so unspeakably inefficient that the machinery could not be expected to survive.

There is nothing especially difficult about the operation of geared turbines. They have characteristics which are peculiar to them, like all kinds of machinery, and, if the precautions necessitated thereby are not observed by the operating engineers, trouble results. Nearly all of the trouble with geared turbines has been caused by ignoring absolutely these essential precautions. In this connection I may say that, if an owner does not intend to have geared turbines operated strictly in accordance with their requirements, he will be unwise to put them in his vessel. On the other hand, if he desires to effect large economies and increase the earning power of his vessel substantially, he can do so by using geared turbines, but in such cases he must see to it that they are operated properly. Perhaps this may be a little more trouble to start with, but he will be repaid handsomely for his pains.

Referring to the troubles experienced with geared-turbine vessels due to improper installation and operation, and especially to the conditions during the war and subsequent thereto, I would suggest to owners that these troubles are not a proper criterion from which to judge the merits of geared-turbine machinery. There are numerous successful geared-turbine installations both here and abroad, and both merchant and naval, which show conclusively the possibilities and advantages of good geared-turbine installations when properly operated.

The advantage of the geared turbine for merchant vessels is economic—that is, its use results in larger earnings. The chief features which produce this advantage are the following:

1. Less steam and fuel are consumed and the cost of fuel is less.

2. The weight of the geared-turbine unit is about half that of the steam engine. The boilers and other auxiliary machinery are smaller and lighter, since less steam is produced and used.

3. The first cost of the installation is less, due largely to smaller boilers and auxiliaries. The cost of repairs depends considerably on the size and first cost.

4. The cargo carried is greater, due to less fuel and lighter machinery.

These economic advantages are well worth the consideration of the owner, and especially during the pinch of present conditions, where high operating costs make it difficult to compete successfully.

Mr. Warriner has properly emphasized the great importance of accuracy and rigidity of construction. While some concerns are very efficient in this respect, others are not quite so. It will pay the owner to examine into these features carefully in selecting machinery and while having it built and installed. Guarantees will not cure inaccurate work.

The foundations for geared turbines should, as pointed out, be extremely rigid. In this connection it seems best to err on the safe side by allowing a very large factor of safety; for in spite of designs and instructions, the riveting of foundations is not always as solid as it should be.

Due to the flexibility of the vessel, perfect alignment of the shafting abaft the gear is not possible under all conditions of loading. The shafting, when out of line, tends to force the low-speed gear out of one of its bearings. Should this occur, the gear teeth will be thrown out of alignment, which will cause heavy local pressures on the gear teeth. For this reason the low-speed gear bearings should be made very ample, and the clearances should be made as small as possible.

In a number of recent ships, principally British, the thrust bearing is located well abaft the gear and is carried on a heavy foundation which forms part of the gear foundation. This arrangement has the advantage that the steady bearings contained in the thrust bearing will, if closely fitted, help considerably in preventing the shafting from throwing the gear out of line. The same result can be obtained by using one or two heavy steady bearings with closely fitted caps carried on strong foundations abaft the gear. Where the machinery is located in the stern, this precaution is of still greater importance.

Referring to page 15 of his paper, Mr. Warriner observes that heavy weather conditions at sea are very different from the normal conditions and that the pressures on the gear teeth are greatly increased under such conditions. This statement was fully borne out by actual observation on the Neptune, which was equipped with a Westinghouse hydraulic dynamometer which indicated continuously the load on the teeth of the gear. In heavy weather it was observed that the average pressure increased considerably and that there was a constant and large fluctuation in pressure, which varied with the rolling and pitching of the vessel.

In ordinary heavy weather the average dynamometer pressure increased to 84 pounds, which was 24 per cent above the pressure of 68 pounds at the same revolution per minute, with a light wind and a fairly smooth sea. The variation in pressure was about 20 pounds above and below the average. In very heavy weather the increase was still greater, and, as I recall, the maximum pressure was well over 50 per cent above normal. In both cases, however, the revolutions were from 15 to 20 per cent below the designed.

It is my conclusion, from the observation of gear operation in heavy weather, that conservative tooth pressures should be used and that gearing should be able to stand continuous operation at pressures well above the designed maximum. This allowance will of course depend on the type, speed and service of the vessel. For ocean merchant vessels I would suggest an allowance of about 50 per cent based on continuous land operating conditions.

Referring to Mr. Warriner's remarks on page 16 and to Figs. 4 and 5 on Plate 5, the requirements for dividing the load equally between the low-speed pinions are very difficult, and for this reason a very large margin of flexibility should be allowed. This type of gear has given a great deal of trouble, a large part of which appears to have been due to inadequate flexibility for the proper division of the load.

In general a single turbine with these types of gears is not desirable for large vessels. Cross compound turbines with gears as shown in Figs. 6 to 9 have advantages in safety, reliability and economy which make this type of unit desirable in all except vessels of small power. This type has been used in most recent vessels and in general may be regarded as the standard type for practically all ocean merchant vessels.

On page 17 Mr. Warriner advocates the use of cast-steel wheels with teeth cut in the rims. I seriously doubt the advisability of this type of construction. It is believed that a cast-iron center with a rolled steel rim is more reliable and preferable. One of our vessels recently had a serious breakdown at sea due to a defective cast-steel wheel. A section of the wheel rim 20 inches on the chord broke off from the high-speed gear wheel when the vessel was approaching the Panama Canal en route to New York. Fortunately the low-speed gear and the starboard high-speed gears were not damaged, and the vessel proceeded to New York under the high-pressure turbine only, the speed being reduced from 11 to 9.4

knots, due to cutting out the low-pressure turbine. The load carried on the starboard gearing was, of course, higher than it should have been; but, on the other hand, this further emphasizes the importance of conservative tooth loading. The unit pressures on the teeth of this gear under normal conditions are 52 pounds for the high-speed and 58 for the low-speed pinion. Under the emergency conditions the load on the teeth was increased about 30 per cent. The above pressure is the pressure per inch of face per inch of diameter.

This accident also emphasizes the importance of cross compound turbines. As it was, the loss of time was only about two days. With a single turbine the loss of time would probably have been over a month and with the possibility of a salvage claim in addition.

Attention is called to Mr. Warriner's observations in regard to superheated steam, which are fully concurred in. In Table II herewith a comparison is made between the ordinary type of steam-engine installation and a steam-turbine installation using superheated steam. This table shows that the saving in weight is 133 tons; that the cost of the turbine installation is about three-fourths of the engine, and that there is a saving of 32 per cent in fuel consumption. The economic advantages of the turbine are very great and are too important to be ignored by American owners, and especially so since foreign owners are rapidly adopting turbines with superheated steam.

TABLE II.—*Comparison Between Steam Engine with Saturated Steam and Steam Turbine with Superheated Steam.*

For a cargo vessel of 11 knots speed, and 2,900 S. H. P. Deadweight capacity 10,000 tons.

	Engine.	*Turbine.*
Weight of machinery installation, net, tons	596	463
Same, lbs. per S. H. P.	461	358
Cost of machinery installation in per cent	100	75.5
Steam pressure at engine, lbs. gauge	200	200
Superheat at engine, deg. F.	0	200
Vacuum, inches	26	28¼
Steam consumption for all purposes per S. H. P., lbs	16.8	11.5
Fuel oil consumption per S. H. P., lbs.	1.25	.85
Same in per cent	100	68

It is also possible to reduce the steam consumption of steam engines by using superheated steam. By using 200° superheat in the steam-engine vessel given in the table, the fuel consumption would be reduced about 17 per cent.

The comparison given by Mr. Warriner on page 19 is of great interest. We have made a number of comparisons of this kind which verify closely the data given, with due consideration to the type of installation. It should be noted, however, that this comparison is based on a twin-screw installation, which is considerably different from the single-screw installations of most cargo vessels. In addition to this the comparison, as pointed out, is unfavorable to the geared-turbine machinery, since the boilers and auxiliaries are considerably larger than required.

It should also be noted that the oil engines are of the two-cycle type. The weight of this installation is less and the fuel consumption greater than for the four-cycle type.

The length of the round voyage is not given, but I presume it is about 10,000 miles. This feature has a considerable influence on the expenses and earnings.

In general, our comparisons between geared turbines and Diesel engines, and our conclusions from them, are in close agreement with Mr. Warriner's figures. Briefly, our conclusions are that the turbine installation will give higher earnings for all ordinary voyages, but for long voyages the Diesel engine will yield higher earnings. These conclusions are based on present conditions and machinery, without regard to future developments, which may be important.

Our comparisons between geared-turbine and turbine-electric-drive machinery show that the electrical installation is 90 per cent heavier, that the cost is about double, and that the steam consumption is about 6 per cent more. These figures refer to the main propelling units only. They include the main turbines, gears and pipe connections for the former. For the latter, they include the main turbo generator, main motor, fans, exciter sets, switching gear, etc.

It is obvious from these figures that there is no economic advantage in the electrical transmission. In this connection it seems rather futile to advertise and argue advantages which are not substantiated by the facts. It may also be noted that this type of transmission is not being fitted in British vessels, either merchant or naval.

The efficiencies of reduction gears as determined by careful tests are of especial interest in view of the conflicting statements which have been made recently in regard thereto, especially by advocates of electric transmission. It is evident from these tests that efficiencies of 94 and 95 per cent, which have been given for double reduction gearing, are entirely too low for normal operating conditions.

These tests confirm the tests and efficiency values which have been given by the Parsons, De Laval, and Westinghouse companies.

For normal operation under the usual conditions the reduction gear losses may be safely taken from 1¾ to 2¼ per cent for a single reduction gear, with 2 per cent as an average value. For double reduction gears they may be taken from 2¾ to 3¼ per cent, with 3 per cent as an average value. (Applause.)

MR. ALEXANDER SCHEIN, *Member:*—Mr. Warriner, in his paper, has presented us with very valuable data and numerous suggestions for securing successful operation and has pointed out important requirements to be considered when designing reduction gears.

I must use again the same paragraph that Mr. Smith used, but I think our deductions are rather different. On page 16 the author refers to the following: "The conditions at sea, however, are entirely different, and it is difficult to estimate what may have to be taken into account." In conjunction with this, I wish to take the liberty of pointing out a very interesting experiment which was carried out on the S. S. Coronco sometime during the past winter, an account of which was given in several of the technical periodicals.

A test in measuring the distortion of the reduction gear casing was carefully carried out under various conditions of the wind and for different headings of the vessel. The results clearly indicate that either rolling or pitching causes a very marked distortion of the gear casing. However, a combination of roll and pitch results in the greatest distortion and accordingly the greatest misalignment in teeth at the line of their contact.

No doubt some of the distortion of the gear casing is not only due to the ship's deformation under severe action of the sea but also due to the inertia of the oscillating masses that are in continuous cycles of acceleration and deceleration in synchronism with the roll of the vessel. This action is more pronounced in twin-screw vessels.

In a vessel that is stabilized against roll, it is quite evident that the distortions in the ship's structure, and also in the gear casing, are considerably reduced, which is conducive to decreased wear.

Automatic records taken upon several vessels in a heavy sea indicate that an increase in roll occasionally increases the angle of pitch. This peculiar phenomenon is self explanatory if careful consideration is given to the action of a vessel when pitching without rolling or when pitching with a marked angle due to heavy roll.

Another point of very important magnitude is to be considered when diagnosing the trouble in reduction gears, particularly in the high-speed double reduction type, due to the effect of pitching, and especially in vessels with a quick period and large angles of longitudinal oscillations. The gyroscopic effect of large gears, revolving at a high angular velocity, when possessing considerable inertia, is of great importance. The resultant pressure on the bearings, supporting the pinions and gears, no doubt changes under the influence of gyroscopic effect.

Bearings naturally must and do have considerable clearance between the babbitted surface and the revolving journals. This clearance varies with the diameter of the journal, method of lubrication, etc. The direction of the maximum pressure upon the bearing will be disturbed by the gyroscopic effect and will have the tendency of changing the parallelism that existed between the teeth of the gears in contact.

Gyroscopic effect on many occasions, under the influence of unfavorable sea conditions, will express itself in additional distorting strain in the large gears and also in the shaft or spindle carrying them. No matter how minute this distortion is, it will effect the misalignment of the two faces of the gear and pinion, and possibly this misalignment in some instances will pass the region of prescribed safety. The gyroscopic effect is co-periodic and proportional to the angular velocity of the pitch.

I may recall a case. Two years ago I passed on a transport to France, studying the conditions of the sea, and found that the vessel was pitching 7 degrees on either side of the horizontal—that is, about 14 degrees total, with a period of pitch of about 8½ seconds. Of course there are vessels that have a very much slower period, and naturally the gyroscopic effect with a slower period would not be as large, because the angle of velocity is a function of the amplitude of pitch and the period of oscillation.

In conclusion I will refer to the well-known fact that the torsional pulsations in a heavy sea are transmitted from the propellers laboring under constantly varying conditions, especially in twin-screw ships. The torsional pulsations are due, among other things, to the constant change of hydrostatic pressure in the vicinity of the propeller, due to roll, pitch and the rotation of blades. Efficiency of the propeller is very much effected when air cavities are encountered, this, in turn, increasing the torsional unbalance.

Extreme cases of a combination of a heavy roll and pitch will force the propeller partially out of the water, even on a properly loaded vessel.

It is quite evident that the elimination of roll will reduce the major element of distortion in any vessel and will also provide the best possible conditions for the propeller to work in, thus insuring the highest efficiency and proper performance of not only the gear reduction unit but also all the other apparatus aboard ship. (Applause.)

MR. J. T. DALCHER, *Member:*—As previously pointed out by Mr. Smith, the Federal Shipbuilding Company has quite extensively investigated the question of comparison between a steam and a motor vessel, and in our case we assumed vessels with a displacement of 14,050 tons and a normal sea speed of 12 knots, based on the following assumptions:

Steam Vessel.—The machinery consists of oil-fired Scotch boilers, fitted with superheaters to give a superheat of 50° F. at the boilers. The propelling machinery consists of a set of compound turbines and double reduction gear developing 3,100 shaft horse-power at 90 revolutions per minute of the propeller. All auxiliaries and deck machinery are steam driven.

Motor Vessel.—The machinery consists of two main engines of the 4-cycle type, having six cylinders each with a bore of 29 inches and stroke of 46 inches, developing normally 3,870 individual horse-power at 105 revolutions per minute of the propellers. Auxiliary engines are provided for supplying power to the electric driven auxiliaries in the machinery spaces and on deck. An oil-fired donkey boiler is installed in the engine room for heating quarters, engine room, etc. Means are also provided for heating the fuel oil in settling and storage tanks.

It will be noted that the above engines are designed to develop their normal power under ordinary seagoing conditions based on a piston speed of 800 feet per minute and a mean effective pressure of 80 pounds per indicated horse-power. The engines as described by Messrs. Metten and Shaw are rated somewhat higher, the piston speed being 867 feet-minutes and the mean effective pressure 85.6 pounds per indicated horse-power. This gives a total increase in power of about 15 per cent based on the weight of the main engines over the design as contemplated in our proposal.

The weight of the main engines was fixed at 670 tons or 388 pounds per indicated horse-power, the total weight of machinery being 1,052 tons or 610 pounds per indicated horse-power of main engines, as compared with 454 pounds deduced from the weight given in the paper under discussion.

In order to allow for sufficient space to handle the machinery efficiently, we had to increase the length of the machinery spaces 7 feet over the corresponding steam plant.

Attention is called to the fact that the design used in connection with our comparison is based on more conservative ratings throughout, but taking into consideration that this was to be our first venture in the particular field, we believe we are fully justified.

The fuel oil consumption for the main engines was taken at 0.312 pound per indicated horse-power, for the auxiliary engines 0.007 pound, and for the donkey boiler 0.031 pound per indicated horse-power of main engines, making it a total of 0.35 pound per indicated horse-power or 14.55 tons per day. The thermal efficiency of the total plant based on shaft horse-power output and 19,000 British thermal units per pound of oil figured 29.7 and 33.5 per cent for main engines only. As will be noted, the efficiencies are in no way excessive and should be maintained in service under ordinary care.

The total fuel oil consumption as given by Messrs. Metten and Shaw is 0.31 pound per indicated horse-power, and making an allowance of 2 per cent for auxiliary machinery and 8.85 per cent for donkey boiler (percentages given correspond with those as applied in our own comparison) leaves a net amount of 0.277 pound per indicated horse-power of main engines and a thermal efficiency based on 19,000 British thermal units per pound of oil for total plant of 33.7 per cent and for main engines alone 37.7 per cent.

A comparison of net earnings on initial investment between the two types of vessel based on a return voyage of 22,670 miles gives the following result:

	Steam ship, single screw.	*Motor ship, twin screw.*
Length, feet	425	425
Beam, feet	56	56
Depth of shelter deck, feet	38	38
Displacement, tons	14,050	14,050
Gross tonnage, tons	7,100	7,100
Deadweight, tons	10,050	9,500
Capacity (bales), tons	497,000	493,000
Total oil bunker capacity, tons	1,479	1,215
Oil consumption per day at sea, tons	35.9	14.55
Oil consumption per day in port, tons	5.0	0.75
S. H. P.	3,100	.....
I. H. P.	.....	3,870
Speeds in knots	12	12
R. P. M.	90	105
Fuel oil consumption per S. H. P. of main engines, all purposes, pounds	1.08	.....
Fuel oil consumption per I. H. P. of main engines, all purposes, pounds	.....	0.35
Total weight of propelling machinery, per cent	100	223
Total cost of propelling machinery, per cent	100	209
Total operating expense per year, per cent	100	94
Total gross earnings, per cent	100	105
Total net earnings per year on initial investment, per cent	100	119

Mr. W. M. Huskisson, *Member:*—I would like to make a few remarks respecting the first paper which has just been read. The authors have mentioned the solid injection of fuel by mechanical pressure without the aid of air blast. This system has been invented by Sir James McKechnie and used by Messrs. Vickers since they abandoned the use of the air blast injection.

I would like to call your attention to the sentence in the paper which reads as follows: "The chief difficulties encountered with such a system are in getting good combustion at all running speeds and loads and the elimination of the shock in the cylinder, which is apt to occur with a sudden rise in pressure when fuel is injected."

This is a remarkable statement, because no difficulties such as those mentioned have occurred. Fortunately, one of our ships happens to have arrived in this port today, so I took the opportunity of ringing up the chief engineer and speaking to him on this point. He stated that during the voyage out they ran into a fog and had to reduce the revolutions from 118 to 80 revolutions per minute for over one day, and he also mentioned that in coming up the Manchester Ship Canal it was necessary to reduce the revolutions to 40 revolutions per minute (this run takes about eight hours), and the combustion was perfect as shown by the transparent exhaust at all speeds. I cannot understand why any sudden rise in the pressure of the fuel should be anticipated, as special means are taken to avoid this, and I think that the authors' fears of trouble on this score are born of ignorance.

The authors further go on to say that the advantage claimed is that the compressor troubles are entirely eliminated with a correspondingly higher mechanical efficiency obtained than with air injection. This is quite true.

Now one would think from this that the advantage mentioned was the only advantage that is obtained by the use of this system, but as a matter of fact there are many, and it was because of these advantages that Messrs. Vickers some years ago decided to abandon the use of the air blast system. Since that time every single engine that they had previously built fitted with this air blast system has been altered to the mechanical injection system.

I may briefly mention the advantages of the mechanical injection which the authors have dismissed so lightly:

1. *Saving in weight.*—In a high-duty light-weight engine of 600 brake horse-power a total net saving in weight of 4,887 pounds is effected by the substitution of the small fittings required for the mechanical spraying system, for the air compressor and its attendant complication of fittings and pipes.

2. *Saving in space.*—In the case of the above engine, the overall length of the engine is reduced by 3 feet, while further space is saved by the omission of the high-pressure and low-pressure cooler pipes and their connections.

3. *Reduced cost.*—The air compressor is an expensive auxiliary to the engine, and in view of the simplicity of the mechanical injection system, it follows that the relative cost of manufacture of the engine is less than that of the other type.

4. *Economy of fuel.*—Consumptions down to 0.38 pound per brake horse-power per hour, or 170 grammes per *force de cheval,* have been obtained on ordinary official trials. This figure has not been attained in any other type of engine of which we have knowledge.

5. *Number of fittings and pipes reduced.*—Less attention and adjustment of the engine are required as compared with the air spraying system, due to the elimination of the valves and pipes in connection with the air compressor, relieving the engineers in charge of the engine and reducing the cost of upkeep and repairs.

6. *Economy of air for starting the engine.*—Experience has demonstrated that the engine will get under way more rapidly with mechanical spraying than with air spraying, this effecting a considerable saving of starting air. Greater certainty is also obtained when maneuvering the engine.

7. *Blast action on pistons.*—There is a complete absence of blast or blow-pipe action on the piston top, and of local heating of the piston, both of which faults have a tendency to crack the pistons.

Not the least of these advantages is the perfect safety of this system over and above the chances of an accident with the air-blast injection system.

I have in my hand a report of an accident to an air-blast injection engine which occurred at the beginning of this year. The accident occurred to a large six-cylinder engine in an ex-German vessel. I will not weary the meeting by reading the whole of this report, but I will mention that the engine was started on fuel and made about 50 revolutions ahead. It was then reversed and it made a few revolutions astern when an explosion took place in No. 1 spray valve. The damage done was as follows:

No. 1 cylinder.—The top cast-iron casting of the spray valve body was burst into about thirty pieces and scattered over the engine room. The nozzle end of the spray valve was blown off into the cylinder. The forked lever for lifting the needle valve was broken off and two 1¼-inch nuts were split and the studs broken off next to the spray valve.

Nos. 2 and 5 cylinders.—The nozzle ends of the spray valves were blown off into the cylinders.

No. 6 cylinder.—The nozzle end of the spray valve was blown off into the cylinder. The forked lever for lifting the needle valve was broken at the collar. The explosion was of a very violent nature, pieces being projected in all directions, a steam pipe of 1½ inches diameter being cut in two about 8 feet away from the explosion by one of the pieces of the spray valve body.

Fortunately this explosion was not attended by fatal results, but I think most practical engineers will agree it is better to get rid of a system where there is liability of such occurrences.

The authors do not seem to realize that the mechanical injection of fuel is obtained by the use of very small and simple pumps and fuel pipes, which are also very small, and have an enormous factor of safety.

With regard to the high-speed Diesel engines for the electric drive, the consumption of these engines is as small as that on the larger type. On looking through the official trials of over twenty submarine engines running at 380 revolutions per minute, the figures are in the neighborhood of 0.382 to 0.386 per brake horse-power per hour; therefore I think that part of the disadvantage under the heading of 3 on page 8 should be eliminated.

Of course everyone must quite agree with the authors that, if American shipowners desire to run their ships in competition with European companies, they must employ internal-combustion engines.

Mr. Edgar D. Dickinson, *Member:*—Many of the thoughts that had occurred to me have been expressed so much more ably by others, especially one remark Mr. Fernald made about what we are doing to develop apparatus, that I will not say anything on the subject.

There are, however, a few points in the paper read by Mr. Shaw which I think we should mention here. Referring to page 6 saving on auxiliaries, possible only with electric transmission of power: The alternative, as I read this paragraph, would mean—I cannot believe the authors meant it—to recommend a separate Diesel engine for each winch, capstan, starting engine, pump and compressor. In practice, the advantage of the oil-engine driving auxiliaries can only be secured by the use of electrical means. Regarding the auxiliaries, I am glad to see that this has been given prominence, because the same means and therefore the same saving can be realized on any ship, and it is in no way affected by the kind of propulsion machinery.

On page 7 the argument in favor of more than two sets of auxiliary Diesel engines—that is, the auxiliary engines—applies to an even greater extent when considering Diesel electric propulsion with several generating sets as compared with direct drive. I will not go into detail here; of course there is a loss in transmission with Diesel electric drive and there are arguments pro and con that we cannot touch on.

Trade Routes.—The field for merchant ships is wherever a cargo can be profitably carried. The long trade should be the favored route, in that the percentage of time in port is less, but it is sometimes the case that the short route is the more profitable.

On page 7 I note that cheaper oils are not recommended for oil engines. That, of course, is of interest in making comparison with other drives. I do not know of any particular troubles now being experienced with Diesel engines of the best types applied to the duties for which they are designed.

I would like to inquire what the authors mean by high speed. The studies of Diesel electric drives with which I am familiar are based on using engines of established design, moderate speed, rugged construction, and of design and general proportion that long experience has shown to be the most reliable. In that particular connection, on the Fordonian, which is now being equipped, the engines were run at 200 revolutions per minute and the complete equipment weighs about 20 pounds per horse-power less than the original engines. In both cases they are two cycle; the propeller speed is not altered.

Referring to the twelve disadvantages of electric drive: Nos. 1, 2, 3, 4, 5, 6, 9, 11 and 12 are based on the erroneous assumption that flimsy and inefficient engines are being used; Nos. 7 and 8 must have been written without investigation. (Laughter.)

Referring to No. 10, if this is to be construed in its broadest sense to cover all possible troubles from grounds or short circuits in generators, motors, control and wiring, investigation will show that with the low voltage and high class of marine insulation which is being used, there is less liability of trouble than may be expected with a high-pressure air system.

For the reason that Diesel electric drive has been referred to, I would like to take the opportunity of mentioning a few points that have been given most serious consideration by shipowners. There are several, but, unfortunately, I have not time to go into all of them.

The Chairman:—They can be printed, Mr. Dickinson.

Mr. Dickinson:—Yes, sir.

Some authorities of international reputation maintain that single-screw cargo ships are more efficient than twin.

I note that the authors figure on only 15 per cent more for Diesel oil. From some recent quotations it would seem that the difference is greater than this by probably 30 or 40 per cent.

When apparatus of equal quality is being compared, the same personnel should be required for a turbine ship as for an engine ship.

It is noted that the authors allow the same depreciation and general expenses for the steamer as for the motor ship. It would be right to expect somewhat higher maintenance on reciprocating machinery.

With regard to the general use of electricity, Mr. Smith made a remark that it is not being done in England. Well, that is interesting if true, but it is being done in England. One of the biggest shipbuilders in the north of Ireland is actually building and equipping an electrically driven cargo ship at the present time.

The sum and substance of the matter has been said several times, that for each class of freight the proper ship must be put in service. The English had shown us this before the war. One company would have several classes of ships, more expensive and more efficient machinery for the longer routes, and less expensive and slightly less efficient machinery for the shorter routes. The whole subject of electric drive is altogether too much for this evening. (Applause.)

The points of particular interest which should be given special study when propelling machinery for ships is under consideration are the following:

1. *Reliability.*—Several engines of moderate size and of proportions and speed which experience has demonstrated to be most reliable instead of one or two large direct-connected engines each having many cylinders. The failure of any one of these cylinders would cripple the engine.

2. *Maneuvering Ability.*—Propeller can be reversed rapidly and continuously (fewest motions to maneuver ship).

3. *Simple Engines.*—Engines not reversed nor run at reduced speed; may be started

electrically, simplifying valve and operating gear. Maneuvering air bottles, air compressors, reverse mechanism and much other mechanical complication are eliminated.

4. *No Propeller Racing.*—Engines run at constant speed and motor speed under control in rough seas. No vibration transmitted to engine.

5. *Fewer Auxiliaries.*—Only one auxiliary generating set required, if any. With electric starting, no starting air tanks or compressors required.

6. *Flexibility.*—Efficient operation at all speeds—at reduced speed only enough engines operated to supply the required power.

7. *Space Savings.*—Machinery space 25 to 30 per cent less, due to small moderate speed engines.

8. *Weight Saving.*—Diesel electric weight considerably less per horse-power than direct Diesel.

9. *Single Screw.*—Single-screw construction can be used, reducing hull cost and increasing propeller efficiency.

10. *No Shaft Tunnel.*—With engine amidships and motor in stern, shafting and tunnels are eliminated; saves weight and gives undivided cargo space.

11. *Bridge Control.*—Duplicate control station may be located in the pilot house; of great value for certain classes of ships for particular service.

12. *Special Cases.*—Diesel electric drive has particular advantages in double-ended ferries, tugboats, yachts, self-propelled barges, fishing trawlers, fire-boats, submarines, etc.

Mr. W. J. Flanders and Mr. E. F. Clark, *Visitors:*—In connection with the third paragraph of the paper by Mr. Warriner we would like to call attention to Mr. Hodgkinson's closure of the discussion of his paper presented before this society at its Philadelphia meeting, November 14, 1918, in which he states:

"I think there can be no doubt but that the present great expansion in the adoption of high-speed gearing, whether for shipboard or land use, was pioneered by Melville and Macalpine. Their first large reduction gear was tested in 1909, the patents having been applied for in 1907. The result of their work was published quite generally and was common knowledge both in Europe and the U. S. A. at the time of the Vespasian in 1910. Sir Chas. A. Parsons had experimented with gearing previous to this, but we learn from the Transactions of the Institute of Engineers and Shipbuilders in Scotland, vol. 44, page 216, that he had given up hope of success."

In regard to the development of marine gears one must agree that it was too rapid for best results, but it is to be feared that the bad results obtained in certain cases were due to oversight rather than lack of proper knowledge of the requirements.

The oil must, of course, be of good quality, but a viscosity of 450 seconds at the actual running temperature seems to be higher than is desirable. The gear teeth as well as the bearings will generate more heat with oil of low temperature and high viscosity than they will with the higher temperature with the correspondingly lower viscosity. As the frictional loss will vary very nearly as the viscosity, it is obvious that this viscosity should be kept as low as possible consistent with safe operation, and there does not seem to be any reason to doubt that, with properly designed gears accurately cut, viscosities as low as 200 seconds Saybolt under actual running conditions should be employed.

I think everybody will agree with the author that a ship is generally quite flexible and that it is practically impossible to design a gear casing which will not be affected by the movements of the ship's hull. A casing which could be actually supported on only three points and possessed of a high degree of rigidity within itself, such as may be approximately with the two or three plane gears, with the additional precaution of very accurately machined bearings and journals with practically perfect alignment, would undoubtedly operate successfully under the varying conditions to which this ship's hull is subjected. It would seem much simpler, however, to recognize the fact that the gear casing is prone to distort and that it is practically impossible to obtain, to say nothing of maintain, the desired degree of alignment between pinions and gears, and to employ a structure which in itself compensates for these factors. Several instances have been reported where the bearings have been seriously worn, due to failure of oil supply or dirt in the oil, causing change in alignment between pinion and the pinion supporting structure of as much as one-quarter of an inch without any noticeable effect upon the gear tooth. It is needless to say that these cases were where the flexible pinion support was employed. This particular device for giving flexibility, as pointed out in Mr. Hodgkinson's paper above referred to, has been tried out in service in many instances since 1911 and should, therefore, be considered as somewhat more than a laboratory experiment. Practically every gear designer at this time recognizes the inherited difficulties in connection with the design of marine gearing and is making a strong effort in one way or another to introduce some form of compensating flexibility.

While it is true that comparatively few single-plane type double-reduction gears have traveled over 100,000 miles, a large number employing the flexibly supported pinion frame have traveled in excess of 70,000 miles and show no evidence of not being able to operate many times this distance without replacement. By incorporating the flexible support, this type of gear is reliable; and it offers the very great added advantage of accessibility. In Mr. Hodgkinson's paper of November 14, 1918, Fig. 4, are shown curves of tooth pressures in pounds per inch of face for varying diameters of pinions, and all the gears noted on this curve by the circles show no evidence of requiring replacement within many hundreds of thousands of miles. The tooth pressures for the rigid bearing gears on this curve correspond with those proposed by the author of this paper, and the question would seem to arise: Why limit the tooth pressures for the larger size gears to approximately half of what may safely be allowed?

The question of noise with the steel gear covers was one that was active with the Westinghouse Company some time ago. Tests were made in steel, cast-iron, wooden and lagged steel covers, and while the lagged covers gave some relief from a rather excessive noise, the final solution of the problem permitted the use of the bare steel covers with quieter gears than had heretofore been considered practical. A surgical operation was found to be better than the "application of a poultice." The experience with gears built by the Westinghouse Company does not bear out the author's contention that gears fitted in the stern of the ship deteriorate more rapidly than those fitted amidships. Out of many examples of both types it has been found that there is apparently no difference in choice with respect to the two locations. The satisfactory operation of these gears when placed in the stern is undoubtedly due to the flexible support of the pinion frame.

We would add here that in the case of one gear, the steamer Hisco came part way across the Atlantic with the tail shaft down in the stern tube 1⅝ inches. The machinery was located aft, with one section of the line shaft between the tail shaft and the gear, the turbines being located aft of the gear, so as to permit of drawing the tail shaft. No damage was done to the gears.

A flexible shaft with gearing was used in the first Melville and Macalpine gear built in 1909 and has been used by the Westinghouse Company ever since.

We would like to add something to the information available with regard to gear efficiency. The Westinghouse Company conducted a large number of tests on a pair of 1,500 horse-power double-reduction gears designed to be driven by a single, complete expansion turbine. These gears were coupled together, and the high-speed pinion of one driven by a carefully calibrated steam turbine, and the high-speed pinion of the other was connected to the water brake. Readings were taken, over a wide range of load and speed, of the steam conditions on the turbine and the horse-power absorbed by the brake. The turbine was then again directly connected to the brake and the horse-power measured under identically the same steam conditions as when operating with the gears. Sufficient observations were made so that the errors of observation could be corrected by means of suitable curves. The accompanying curve (Plate 11) shows the net result of these tests corrected for a single double-reduction gear. These tests check quite closely with those reported by the author, although we believe the light load efficiency should be somewhat higher, as indicated on this curve.

Another test was made in a similar manner on a pair of 5,000 horse-power double-reduction gears designed to be driven by a cross-compound turbine (Plate 12). These tests show an efficiency at full load and full speed of 97¼ per cent. The tests on the 1,500 horse-power gear indicated that the loss in power in this gear could be very nearly approximated by the formula:

$$\text{H. P. loss} = \frac{\sqrt{\text{H. P. load} \times \text{R. P. M.}}}{60}$$

R. P. M.=revolutions per minute of high-speed pinion.

A pair of 15,000 horse-power single-reduction gears for destroyers was tested in a manner similar to that shown on plate 7. A 1,500 horse-power turbine was used for a drive through the third gear of the same type as those under torque, but unfortunately the power required to drive this equipment at full speed was so light that it could not be accurately determined on this turbine. A careful estimate indicated about 500 horse-power for the two gears under load and the one gear running with that amount of load at full speed, giving a net probable efficiency per gear of 98½ per cent or better. (Applause.)

Mr. L. V. Armstrong, *Member*:—With reference to the paper by Mr. Metten and Mr. Shaw, it is interesting to note that the Ingersoll-Rand Company, after approximately fifty years of successful building of air-compressing machinery when they decided to enter the oil-engine field, saw fit to reject the licenses of certain well-known air injection Diesel engines and adopted a mechanical injection engine. They certainly must have had some very good reason for doing this.

Mr. Hubert C. Verhey, *Member* (Communicated):—The critical analysis as tabulated in the paper of Messrs. Metten and Shaw is worthy of notice and should arouse intense interest as coming from men with acknowledged experience in marine steam installations.

From actual and practical personal experience obtained during a trip to the Orient and return on board of one of the modern vessels as described in the paper, I may declare that the performance was splendid and in harmony with figures given. The reliability of such installations is illustrated by the course followed during the last years of manufacture, by standardizing on a general construction, which speaks for itself.

America has already entered the field of motor-ship construction to a limited extent. Foreign-type engines are and have been duplicated and Americanized at the same time, as far as production methods are concerned, but much is yet to be done and should be done for the benefit of the American industry in general. In this respect, I wish to offer comments on the remarks regarding four versus two-cycle engines, as commercializing splendid performances of four-cycle engines as referred to is legitimate, but at the same time does not picture the actual situation from a heavy oil-engine engineering standpoint.

The limit set in this paper for the diameter for cylinder units of 500 indicated horse-power and pronounced to be 31½ inches seems justified, as it is known to the followers of the constructional end of the game that the conventional shape and design of cylinder heads does not render further increase of the bore practicable. It should be borne in mind that all four-cycle engines are subject to unequal heat distribution throughout the cylinder-head casting, in particular the lower disc, for the reason that the exhaust valve or valves are located on one side of the head while the air-intake valve or valves are at the other side, thus unavoidably disturbing the uniformity of the all-round heat problems—the larger the engine, the greater they become.

The next step advocated in the paper in order to increase the power of four-cycle cylinder units to more than 500 indicated horse-power by resorting to double-acting units is at least problematical. The belief expressed about heat problems of the double-acting four-cycle engine holds good only in case the authors intended to point out that a four-cycle cylinder head receives half the number of heat applications in a given time as compared with a two-cycle engine. Assuming that the general construction of cylinder heads had to be the same for both types, there is no question left as to the more favorable condition under which the four-cycle engine works, but it should not be overlooked that the two-cycle cylinder heads can be and are made much simpler in shape, tending to offset the known disadvantage. Furthermore, improvements are possible above the conventional practice followed for the effective cooling of parts subject to high heat.

Built as double port-scavenging engines, the cylinder head contains only one boss, thus allowing a very symmetrical casting, while, built as a top-scavenging engine, this casting can also be made absolutely symmetrical, and care should be taken to provide efficient means to allow for undisturbed expansion and contraction. Heat applications, although twice as many in a given time, do effect the cylinder disc more uniformly, and in case of a properly designed cooling agent system there is no reason why the two-cycle principle should receive undue criticism.

There is much misunderstanding on the subject indeed, and the truth is sometimes sidetracked for commercial reasons, which in turn does not add to the possibility of more rapid progress than thus far obtained. Controversies about weight and sizes of various designs of engines such as are found in practical magazines are sometimes one-sided and published to advertise a specific make.

Assuming that the reduced weight for a given horse-power in a ship means a direct gain in carrying capacity, I may illustrate a way to impartially look upon the question.

If we had a conventional type of engine of a given horse-power working on the four-cycle principle and the valve gear coud be so arranged that the valves proper could either serve as inlet and outlet valves in case of the four-cycle engine or as top-scavenging valves in case of the engine working on the two-cycle principle, we would be able, assumably and conservatively speaking, to develop 65 per cent more horse-power using the same bore, stroke and revolutions. Account is taken of the power required to drive a direct-driven scavenging pump and a somewhat larger air compressor, which means additional length for the engine in question. The weight thereof can be made less than the weight involved to increase the four-cycle engine in size to aid the additional horse-power, as it also should be understood that no increase in the proportion of stress carrying members or increase of wall thicknesses becomes thus necessary, because the peak loads do not vary enough to make it a serious point of consideration—in particular if we realize that the factor of safety assumed for materials used is very much on the safe side, especially in engines of the commercial type.

Rather than go to double-acting four-cycle engines building higher than single-acting engines, also having a complicated lower cylinder head and gear in addition to a stuffing box, it is suggested that the two-cycle single-acting engine be given serious consideration as well. The latter engine, for that matter, can also be converted to a double-acting engine with equal chances for success if properly designed, although for all practical purposes the balance of a two-cycle six-cylinder single-acting engine is effective and sufficient for good operation. In fact we cannot help keeping an eye on the development now going on in England and Germany with opposed piston type engines, all of which work on a two-cycle principle.

Another factor which should not be overlooked is that general arrangements as now commonly adopted are more or less duplicates of practices followed by the pioneer concerns, and the desirability and merits of independent driven auxiliaries such as air compressors and scavenging air pumps were simply sidetracked for good reasons prevailing at the time. Further development along the lines of the last points mentioned is bound to show considerable advancement in motor-ship construction and, rather than criticize such advancement from the start, we should keep a watchful eye on the future in full appreciation of the performances of the past in behalf of our American fleet.

High-speed engines for electric drive are being developed and eventually may demonstrate their usefulness in the unavoidable reconstruction of part of our emergency war fleet. There is, furthermore, no reason why high-speed units should be limited to the trunk-type engines, as the problem of height involved is in most cases negligible, particularly with reference to cargo ships so that high-speed crosshead engines could be considered.

Mr. Ernest H. B. Anderson, *Member:*—The paper by Messrs. Metten and Shaw is a valuable contribution to the Transactions of the Society, and Messrs. Wm. Cramp & Sons Ship and Engine Building Company are to be congratulated in commencing to manufacture this class of engine.

I do not quite agree with some of the statements made in the opening paragraphs of the paper, and it does not seem to me that the progress in the construction of large motor-ship machinery in this country warranted shipowners, or the U. S. Shipping Board, awarding contracts to engine builders on any large scale, and after perusing the paper it will be seen that the authors to a large extent review the progress made by foreign builders.

The engine builders in Great Britain are experimenting to some considerable extent in the construction of these engines and, except in one or two cases, where certain firms have scrupulously followed continental practice, the results have not been altogether successful, and it has been anything but a money-making proposition. Only one or two shipowners have fleets of motor ships, while, on the other hand, firms who adhere to steam-driven ships are alive to the situation and are considering the whole matter from every point of view.

Very few references are made in the paper regarding the actual manufacture of these engines, but accuracy in workmanship is of the most vital importance, and unless this is clearly realized the chances of success are materially lessened.

It can be stated with certainty that this type of engine cannot be regarded in the light of a manufacturing proposition; many of these engines are most complicated in every respect and are still in the experimental stages of development.

Turning to the tables of figures comparing a steam-driven ship with a motor ship, after considering the data it would seem to me that the figures are properly made to show that the motor vessel is more economical in every respect. For instance:

1. The mechanical efficiency of the motor ship is about 80 per cent of that of the steamer, yet both vessels make a voyage of 15,500 knots in the same number of days, whereas the authors must realize that with bad weather conditions at sea the motor ship cannot maintain full speed, and estimates covering a number of days should make allowances for such conditions.

2. The oil consumption per shaft horse-power of the steamer is about right for saturated steam conditions, but with superheat of 150° F. this will be reduced by at least 10 per cent.

3. The oil consumption per indicated horse-power per hour, all purposes, of the motor ship—namely, 0.310 pound—is based on good trial-trip conditions, and a more conservative figure for a usual sea performance would be somewhere between 0.330 and 0.370 pound of fuel per indicated horse-power per hour, all purposes.

For further information dealing with the results of Burmeister & Wain motor vessels, I refer you to *Engineering* of February 15, 1915, where trial data and sea-going results are tabulated in various lists.

I have read over the paper by Mr. Warriner with a great deal of interest and also had the pleasure of listening to the discussion, but did not have an opportunity of taking part, due to the large number of speakers. It seems to me that the statement of the author in the first paragraph is hardly in order.

Mechanical reduction gears for turbine-driven vessels have fully justified all that the original promoters claimed for this system, and up to the outbreak of war, in 1914, there had been no serious breakdowns or setbacks with turbine reduction gears. During the first two years of the war a large number of geared-turbine contracts for freight vessels were secured by one or two builders in this country, and at that time these firms had practically no experience in manufacturing gears, with installing same in vessels, or in taking care of them whilst in operation. This abnormal condition resulted in bringing about many failures and breakdowns, and some of these would undoubtedly have been avoided if the gear designers and builders had been more conservative in their proposals.

On the other hand, it should not be overlooked that the chief reason for installing mechanical reduction gears in such a large number of vessels was probably due to the successful results obtained with this form of drive in vessels built in England. Many of the designs built and completed here were somewhat complicated as compared with those successfully in operation, practically all of which were of the single-reduction type.

With regard to the destroyer Wadsworth, referred to on page 14, the information regarding this installation is not quite correct. The two sets of geared-turbine machinery were designed to develop 17,500 shaft horse-power, with propeller revolutions of 450 per minute, corresponding to a speed of 30 knots for the vessel. The horse-power transmitted by the four pinions is not equal, and whilst each high-pressure pinion transmits about 4,000 shaft horse-power, each low-pressure pinion transmits the remainder, about 4,750 shaft horse-power.

Full particulars of this vessel, together with complete trial data records, were published in the *Journal of the American Society of Naval Engineers,* volume 27, 1915, pages 640 to 662. During the standardization trials the vessel attained a mean speed of 31.64 knots during five runs across the measured mile, with propeller revolutions of 486 per minute and shaft horse-power of 18,005.

With regard to the author's figures outlining a table of tooth pressures for various types of gearing, it seems to me that these figures should be used with caution. I have looked up a number of papers on gearing and the empirical formula, where pressure in pounds per inch of tooth face divided by the square root of the pinion diameter is a constant was introduced by Sir Charles Parsons and his associates, Mr. R. J. Walker and Mr. S. S. Cook.

Reference was made to this method of treating problems in gearing during the discussion of Mr. R. J. Walker's paper on "The Application of Geared Turbines to Merchant Ships," before the Northeast Coast Institution of Engineers and Shipbuilders, December 19, 1919.

Engineer Commander H. B. Tostevin, D. S. O., R. N., also made use of this formula in a table of gear proportions for naval vessels in his paper, "Experience and Practice in Mechanical Reduction Gears in Warships," before the Institution of Naval Architects, March 26, 1920.

More recently, Mr. R. J. Walker and Mr. S. S. Cook have thrown further light on this subject, and the particulars of actual data given in their paper, "Mechanical Gears, of Double Reduction, for Merchant Ships," before the Institution of Naval Architects, March 19, 1921, are most valuable.

I should like to mention that it is the practice of the Parsons Marine Steam Turbine Co., Ltd., to make the load per inch of tooth face directly proportional to the diameter of the pinion for sizes up to 10-inch P. C. D., and for larger pinions the load is proportional to the square root of pinion diameter.

With designs prepared in connection with my own work, I have suggested that for pinions up to 8-inch P. C. D., the value of the constant $\frac{P}{D}$ may vary between 60 and 65 for maximum loads, and for larger sizes of pinions the constant $\frac{P}{\sqrt{D}}$ should be 170 for maximum loads.

The proportions of the gear teeth, and the helical angle, should also be given consideration in connection with using constants of this nature.

The foregoing constants apply to installations which are operated at full power for long periods, but for naval vessels considerably higher constants can be used with absolute safety.

MR. MARTIN L. KATZENSTEIN, *Member* (Communicated):—On page 8, Messrs. Metten and Shaw, referring to the Diesel electric drive, enumerate disadvantages which such a system suffers when compared with the direct drive. As regards the electric equipment and its functioning, I shall enter no discussion, leaving that to the manufacturers of that equipment, who are more familiar with the transmission and control of electric current as applied to shipboard use, but concerning the Diesel engine running at moderately high speeds, I believe that it is the opinion of many reputable engineers that the solution of the problem of re-engining many of the present Shipping Board vessels will be brought about by the use of the moderately high-speed Diesel engine transmitting its power through electricity or some other means to the existing single-screw shaft.

The disadvantages named by the authors, while applying possibly to engines running at such high speeds as would bring them near to submarine practice, are no doubt justified, but when applied to moderate-speed engines will not hold in the face of current experience.

Taking up the objections as named, I should say that No. 1 as to loss in reliability in prime movers is answered by the authors' reference to the motor ship Selandia, which, they state, was put into service in February, 1912, and is still going strong. The auxiliary engines on that vessel consisted of two four-cylinder 200 horse-power at 225 revolutions per minute, and so far as I have been able to find, they are still running. The William Penn, I believe, is fitted with auxiliaries of 100 horse-power, operating at 320 revolutions per minute, and I doubt whether the three-year limit placed on the life of high-speed engines by Mr. Shaw will be found to apply to those units after that period. Even when run up to speeds as in submarine practice, the German submarine engines certainly showed reliability under the tremendous stress to which they were subjected.

No. 2, as to more major overhauls, such as lifting of cylinder covers, etc., and discharge of lubricating oil from crank case—these appear to be questions of design which improvements of the art are overcoming.

No. 3, concerning 30 per cent more fuel per knot, of which 15 per cent is chargeable to the higher fuel consumption of the engines—this might apply to very high-speed engines, but not to the moderate-speed engine of comparatively large size as applied to main propelling units.

No. 4, as to lighter grade and more expensive fuel oil required—the oil that is burned in auxiliary engines certainly should not differ from that burned in the main engines, and there is no reason why just as heavy a grade of oil cannot be burned in the moderately high-speed engine as in the slow-turning engine used by the authors.

No. 5—the same answer as for No. 2 applies.

No. 6 depends upon the number of cylinders used and the design.

No. 9—if the engines are not run at too high a speed, there is no reason to expect that the personnel will be overworked any more than they would on direct coupled twin-screw installations. A subdivision of the total power for electric drive, if not carried too far, should give satisfactory results if the engines are properly designed.

No. 11—the same answer would apply here as to No. 1, and in addition I might add that the Worthington Pump and Machinery Corporation has over one hundred successful Diesel-engine installations of the horizontal type operating at moderately high speeds, such as I have in mind; they are driving oil line pumps, electric generators, and have provided power generally for many years, and apparently they are entirely satisfactory. In vertical designs the operation at moderately high speed can certainly be accomplished to better advantage than with the horizontal type.

No. 12, as to higher first cost and maintenance charges—the figures that I have seen do not bear this out, and as a matter of weights the Diesel electric drive shows weights that run from 65 to 70 per cent of the weight per shaft horse-power of the direct coupled Diesel twin-screw installation.

In the statement that follows No. 12, reference is made to the higher consumption of fuel and lubricating oil, which, combined with electrical losses, calls for a total expenditure of about 50 per cent over the direct-drive system. While there may be the 15 per cent of electrical losses, the latest designs do not show such excesive consumption of fuel and lubricating oils to justify this figure, and I should say that this item, instead of 50 per cent, should be reduced to a maximum of 20 per cent.

The authors refer to the oil consumption of the direct-drive as 0.31 pound per indicated horse-power of the main engines. Would it be possible to state what shaft horse-power was developed?

I would appreciate very much the authors' comments on the foregoing.

Mr. H. B. Oatley, *Member* (Communicated):—Mr. Warriner's paper has been read with much interest, and he is to be congratulated on the interesting facts brought out and the progressive ideas advanced.

With particular reference to that part of the paper which refers to the infrequent use of superheated steam in marine practice in the United States, it may not be out of place to mention that in Europe there recently have been constructed, or are on order at present, 147 vessels equipped with geared turbines of several different makes, which total 754,000 shaft horse-power and 28 vessels with reciprocating engines, developing 86,000 indicated horse-power. These geared-turbine vessels range from the small converted sailing vessel of 750 horse-power to the 20,000 horse-power passenger vessel Guilio Cesare. All of these vessels are or will be fitted with superheaters, the majority of which are capable of delivering from 200 to 225 degrees of superheat at the throttle.

The almost universal adoption of highly superheated steam on the vessels now under construction by European builders is proof that the vessel owner has found it profitable to specify its use and that such procedure has the full approval and cooperation of the turbine builders. With geared turbines it usually is thought necessary to use saturated steam on the reversing turbine on account of the increased temperature generated, as the result of the work done upon the steam by the rotor's movement in the opposite direction to the flow of steam when the astern throttle is opened. There may be some slight action of this kind, but the European turbine builders have not found it of enough importance to provide a means of reducing the temperature of the steam to the astern turbine, and in all of the above-mentioned cases the full degree of superheat will be used on the astern turbine.

In all, there have been approximately 2,000 vessels equipped with superheaters which deliver steam within the temperature range above mentioned. About 75 per cent of these vessels have reciprocating engines, and the use of superheated steam on reciprocating engines dates back nearly twenty years.

While theoretically a little economy may be experienced by the adoption of 20 degrees of superheat on reciprocating engines, as Mr. Warriner mentioned, it must be appreciated that approximately 150 degrees superheat are required to eliminate the initial condensation in the high-pressure cylinder. The present practice in the leading maritime nations with which the vessels of the United States are in competition (this includes England, Holland, Denmark, Norway, Sweden, Japan and Germany) is toward the use of high-degree superheat on all steam-propelled vessels, regardless of the type of the steam-propelling unit, and the performance of these vessels is very favorable when compared with the performance of the saturated steam vessels of the United States.

It is pleasing to note that Mr. Warriner has designed and is building a vessel which may be operated at a reduced cost and thus place the owner in an advantageous position with relation to his foreign competitors, and that another progressive step has been made towards the successful realization of an efficient merchant marine in the United States.

Mr. J. W. Atkinson, *Member* (Communicated):—In reference to the latter part of Mr. Warriner's paper dealing with the testing of gears for efficiency, it is stated that, by the method adopted, "it is possible to put the same load on the bearings and to run the gears at the same tooth pressures and under the same conditions as when operating on board ship."

I should like to ask what revolutions were obtained on the tests, with the full power tooth pressures and bearing loads, since it is also stated that the power developed by the motor represents only the friction of all the gears and bearings in the two units.

Messrs. Metten and Shaw:—The Sperry oil engine is very interesting, and the authors only hope the rather unusual claims that have been made can be made good on commercial engines. The high-speed experimental model shown is not considered justly comparable with proven performance of engines designed for low revolutions to meet the particular requirements of the motor ship. To prove his statement that this experimental engine is lighter per horse-power than a Burmeister & Wain engine, two slides were shown by Mr. Smith illustrating the two types coupled to a generator, with the remark that the generator so coupled to the B. & W. engine "absorbs the whole power of the engine." This is incorrect, as the generator shown was used for absorbing the power of three cylinders out of the six at one time to save purchasing a new generator of sufficient capacity for the full brake load.

Mr. Fernald has furnished an estimated performance of a comparatively small vessel having triple-expansion engines, geared turbines, and Diesel engines, and for the last has selected engines of the B. & W. type. He states that his comparison was worked up some time ago when he was connected with the Shipping Board, and from which we are led to infer the Shipping Board based its decision not to embark on motor ship construction at that time. If this is correct, this important decision was based upon incorrect data, as the B. & W. engines used in the comparison are two sizes larger than those in service on vessels of the same size and speed. The size assumed for the comparison is known as B. & W. type 6-275 and designed for 4,000 indicated horse-power (total). The engine size that should have been employed in the comparison is actually two sizes smaller and known as B. & W. type 6-200, designed for 2,800 indicated horse-power (for the two engines). These latter engines are the same as installed on the motor ship Oregon and several similar vessels which have the same designed sea speed as the Fernald vessel but have 5 feet more between perpendiculars, 1 foot more beam, and 6 inches more draught. The total weight of machinery, therefore, including spares, engineer's stores and water in the system, is thereby reduced by using the proper installation from 795 tons to 540 tons. Also, the fuel oil consumption is reduced from 13½ tons to 9½ tons per day, as actually obtained on the motor ship Oregon. For the motor ship the cargo-carrying capacity, both cubic and deadweight, will be correspondingly increased, which taken with the decreased cost of machinery will show a decided economical advantage for the motor ship over the steam vessels for the particular route in question. Mr. Fernald has failed to take cognizance of the fact that the twin Diesel vessel will have a better propulsive efficiency than the single-screw vessel, due to the revolutions assumed for the latter. The results arrived at by him are therefore incorrect and extremely misleading.

Messrs. Smith and Dalcher, of the Federal Shipbuilding Company, have also investigated what advantages there may be in the motor ship and have furnished an estimated comparison by them of a vessel with geared turbines and Diesel engines. From the data given, the Diesel installation is apparently based on an experimental engine, which is unusually heavy for the power. The shaft horse-power estimated as required for the motor ship is about right, but the power used for the geared-turbine vessel is considered too small, due to the high turns of 90 revolutions per minute employed for the single screw, and which should not exceed 75 revolutions per minute for the particular conditions if the propulsive efficiency of the two vessels is to be kept the same. Had B. & W. engines, type 6-275 (erroneously used in Mr. Fernald's comparison, and exactly suitable for the present vessel) been employed, the machinery would have been reduced from 1,052 tons, as given in Mr. Dalcher's figures, to 795 tons, or a saving of about 25 per cent. Mr. Dalcher has used 0.35 pound of fuel oil per indicated horse-power, all purposes at sea, giving 14.55 tons per day. If this is corrected to 0.31 pound, as obtained on B. & W. vessels, the consumption per day is reduced to 13 tons. Had a more suitable Diesel-engine installation been selected for the comparison, the 19 per cent net earnings per year on the initial investment, as given, would have been very greatly improved and would conform more with the figures of the authors in their comparison.

Referring to Mr. Huskisson, of the Vickers Company, it was not the intention to criticise the Vickers engine in particular, which is known to be of fairly high compression and is about the only marine engine of the solid injection type to date that has met with any degree of success for marine purposes. As to the Vickers engine being entirely free from the troubles enumerated, reference is invited to some comments by Mr. David P. Peel regarding his experience with Vickers submarine engines, in which he discusses the smoking and knocking in cylinders. This is to be found in the Transactions of the Institute of Marine Engineers, volume 31, February, 1920, pages 566-572. The authors can also speak from experience gained with a four-cylinder 500 horse-power experimental engine of this type, and the company with whom they are associated is building very satisfactory solid injection stationary engines for lower powers. It should be pointed out that Vickers' experience has been mostly with submarine work, and, to the knowledge of the authors, they have only three merchant vessels in operation, which are of comparatively small power. Submarine engines are operated only for short periods at full power and frequently come into special bases prepared for their overhaul, while merchant motor ships must operate a long time at full power and away from home without any special attention. We fail to see wherein the accident cited by Mr. Huskisson as occurring to an ex-German vessel has any logical bearing on the matter in the absence of trouble of this kind with standard air-injection engines.

Mr. Katzenstein, representing the Worthington Company, has advocated and defended the proposed Diesel-electric drive on the ground that the higher-speed trunk-type engine has been satisfactory as auxiliary engines on B. & W. vessels. It should be noted that the function of auxiliary engines and their operation is entirely different from the main engines as they are very seldom operated at full power, and then only for a specified time, when each in turn is shut down and another started up in its place. It might be stated in this connection that there is a strong tendency at present, on the Continent in particular, to replace the larger sizes of trunk-type engine for land purposes by the crosshead type, due to the generally recognized superiority of the latter, although the weight and cost are higher. For the main drive in a motor ship it cannot be too strongly emphasized "that the best is none too good" for reliability and continuity of operation, which are of the utmost importance. Mr. Katzenstein has also referred to their land engine of the horizontal type, commonly used for driving pumps of oil lines, which are known to be quite heavy and not permissible in a Diesel-electric drive, where the high-speed light-weight engine is a requisite to keeping the total weight of machinery and the space occupied within reasonable bounds.

Mr. Anderson, representing the Parsons Company, states that the motor ship cannot make as good an average speed in bad weather as the steamer, when, as a matter of fact, the motor ship has a considerable advantage in this respect. The larger diameter single screw employed with the steamer has a tendency in bad weather to be longer out of the water than the smaller diameter twin screws of much greater immersion in the motor ship, and it is apparently only when the screws are in the water that the power can be effectually applied to driving the vessel. Furthermore, there is no throttling of the power in the Diesel engine, as with the turbines for the steamer, in rough weather. This is accounted for in the oil engine being able to have all the power instantly cut off when the revolutions exceed a certain determined value, reached when the screws are out of water, and is instantly cut in again when the screws are returned to the water. The average all-year propulsive efficiency will also be better for the twin screws as a result of their better immersion under all conditions of draught. Mr. Anderson considers the oil per shaft horse-power of 0.95 pound, all purposes, for the geared turbine, as used by the authors, can be improved on some 10 per cent with 150 degrees superheat. We are, however, dealing with operating conditions, and higher economy implies a very good vacuum for the turbines, and it is a known fact that it is chiefly due to not realizing the designed high vacuum in actual service that accounts for the discrepancies between trial data and actual performance of turbine vessels. This is particularly noticeable when the vessels are run over tropical routes. The efficiency of the steamer also has a tendency to fall off in service as the boiler heating surfaces deteriorate. The above conditions do not affect the Diesel engine, which actually improves in economy and which in no way is affected adversely by tropical conditions. Mr. Anderson questions the 0.31 pound per indicated horse-power for main engines, all purposes, used by the authors, and has referred to figures published in *Engineering* of February 15, 1915, which give a mean of about one-third of a pound of oil per indicated horse-power for B. & W. installations up to that date. The explanation for this is that the consumption then published represented the earlier design of B. & W. engines, in which the compressor for the injection air had its first two stages driven by separate auxiliary engines, which is a less efficient arrangement than now used, where a three-stage compressor is driven by the main engines alone. Some development in the art is to be expected in that time contributing towards improved economy, as likewise noted in the steam turbine.

Mr. Dickinson, of the General Electric Company, has misinterpreted the meaning of the authors in reference to the importance of electrically driven auxiliaries for motor ships, especially in regard to deck machinery. The individual Diesel drive for the winches, as suggested by Mr. Dickinson, would no doubt be the most efficient arrangement if such were practicable, as there would be no electrical losses involved. In a motor ship, however, the electrical link is necessary to make the power of the auxiliary engines, primarily an accessory to the main engine, available for deck use. This does not imply, as we are led to suppose, that the electrical system, *per se,* is accountable for the low port consumption with a motor ship, as by replacing the auxiliary Diesel sets by a steam-driven set this oil consumption in port will be more than trebled. Mr. Dickinson's strong defense of the Diesel-electric drive can readily be understood, but the Diesel-electric drive, which is quite a parallel case to the steam-electric, runs contra to the history of all engineering development, which shows that efficiency, simplicity and cost are the deciding factors. The electric drive is deficient in each respect, and the fact that twelve of the Shipping Board's geared-turbine vessels are being changed over to turbo-electric drive is due to good salesmanship and not good engineering. The first of these installations has been in service since November, 1920, and has steamed approximately 20,000 miles with the electric drive, during which her logs show that she actually consumed 10 per cent more fuel than when equipped with her original geared turbines, which, by the way, operated with 50 degrees superheat while the turbo-electric drive operated under 200 degrees superheat.

Mr. Warriner's figures for a motor-driven ore ship are of particular interest on account of being of two-cycle design, and we presume are based on the Cubore installation. It again furnishes an illustration of the superiority of the four-cycle engine, had such been used in the comparison. By replacing the two-cycle engines with four-cycle of same cylinder dimensions as the motor ship William Penn, but of eight cylinders each, the normal shaft horsepower would be increased 7 per cent and the total weight of machinery, including boiler, reduced at least 100 tons, since the total installation without boiler for the four-cycle will be 1,050 tons. The fuel consumption per day becomes 19 tons instead of 24 tons, with a corresponding increase in cargo capacity of 140 tons. Accordingly, the total increased cargo carrying capacity will be 240 tons more than with the two-cycle vessel. Using the same basis of comparison as used by the authors in their comparison, the cost of crew per day for the motor ship becomes 12.3, with repairs and provisions same as for the steamer. The cost of fuel is reduced to 6.48, giving a total operating cost per day of 89.56 compared with the 96.38 for the particular two-cycle installation. The four-cycle will be seen to be better than any of the three other drives used by Mr. Warriner in his comparison. It can be safely stated that on the long trade routes the large direct-driven motor ship, where proper care is made as to proven types, will show a greater earning capacity on the investment over all other drives, irrespective of variations in freight rates and fuel prices.

Mr. Warriner:—I wish to thank the members who have taken part in the discussion for their very interesting contributions.

Owing to the nature of the two papers, these have resolved themselves somewhat into a debate of Diesel vs. reduction gears; it was not, however, the intention in writing the paper to make out a case for the reduction gear at the expense of the Diesel engine and, personally, I am very much in favor of the Diesel engine because it means economy in fuel consumption, and economy is the goal that engineers are always striving for.

As brought out in the papers and in the discussion there is a difference of opinion as to the relative economy of the two types of machinery, not on the score of fuel consumption, but of the operating costs, and at the present time, with the high cost and the limitation in power of the Diesel engine, both types of machinery have their proper fields; for one service it will be found that the Diesel engine is more adaptable, and for other services the reduction gear will give the best results. It is advisable, before settling the type of machinery, to take into consideration all the circumstances and to select that which furnishes the best results.

Mr. Fernald, in his paper, remarks that Great Britain and Scandinavia have, for the past few years, swung over to the motor ship almost exclusively. So far as Great Britain is concerned, this is not an altogether fair remark. According to the *Shipbuilding and Shipping Record* of April 21, the following is the proportion of steam and motor ships building in Great Britain and the United States, on March 31, 1921:

	Description.	*Gross tonnage.*	*No. of ships.*
Great Britain	Steamers	3,530,364	794
	Motor ships	263,180	66
United States	Steamers	1,048,914	142
	Motor ships	34,232	8

Mr. Smith states that the oil consumption for the two-cycle Diesel quoted in Table I is 0.515 pound of fuel oil per shaft horse-power, which is correct for all purposes, but the actual figure used in the calculations was 0.42 pound of oil per shaft horse-power for the main engine. The remainder is for auxiliary purposes—heating cargo oil, running cargo pumps and allowance for bad weather.

Regarding the use of the gravity system for lubricating oil, it is believed that this is the best installation and that it is now generally adopted. Those who have had experience with both systems prefer the gravity system.

Mr. Clark's contribution is particularly interesting, and the results of the test on efficiency by the Westinghouse Company, though taken in an entirely different manner, generally confirm the test made by the Falk Company.

In reply to Mr. Atkinson's remarks, as will be seen from the curve sheet, Fig. 4, Plate 8, the gears were run up to full speed or 450 revolutions per minute with the full-power tooth pressure and bearing loads, the results being shown on the top curve.

Mr. Anderson takes exception to the statement in the first paragraph of the paper, but the discussion on gears was intended mainly for those built in the United States. The author was unable to obtain first hand information on other gearing, and it would, no doubt, be interesting to all concerned if Mr. Anderson would furnish particulars of gearing data he may be able to obtain for gears built in Great Britain, including length of operation. The author is at one with Mr. Anderson on the subject of single-reduction gears, and would prefer these instead of double-reduction gears, wherever the circumstances allow.

In regard to the formulae for tooth pressures, it does not seem very material whether $\frac{P}{D}$ or $\frac{P}{\sqrt{D}}$ is used, providing the constant is properly selected. It is believed that the figures given are fairly conservative and would produce good results with properly constructed gears.

The following lantern slides were shown at the meeting:

1. 1,500 S. H. P., double reduction, three-plane type. Single turbine 3,600 to 90 R. P. M. No. 1 in list.
2, 3, 4. 3,100 S. H. P., double reduction, three-plane type. Compound turbines, 3,200 to 90 R. P. M. No. 2 in list, and No. 4 in test.
5. Gear wheels for the above.
6. Same gear on test.
7. Machine shop of the Falk Company at Milwaukee.
8. Large double-headed hobbing machine at the Falk Company's works.
9. Two sets of gears for destroyers on efficiency test.
10. Two sets of single-reduction gears for passenger boats on test. 12,000 S. H. P., 1,793 to 125 R. P. M., 10-inch pinion, 143.14-inch wheels.
11, 12. Solid cast-steel gear wheel.
13. Single-reduction gear, 6,000 S. H. P., Nos. 12 and 13.
14. Plan view of reduction gear, 6,000 S. H. P.
15. Assembly of reduction gear, 6,000 S. H. P.
16. 1,500 S. H. P., double-reduction, three-plane type, single turbine.
17. Another view of double-reduction, three-plane type, single turbine.
18. Showing the same gears with cover removed.

The Chairman:—Just a few words in closing. There is not a man in this room, indeed I doubt if there is a member of the Society, who can say as I can, that my first trip across the Atlantic and return was made on an iron single-screw steamship having a two-cylinder low-pressure engine geared to the propeller and run with a maximum steam pressure of 25 pounds per square inch.

When I went an as apprentice in the old North River Iron Works on West Street in this city, an old feed store changed into a machine shop, there was under way the engine of the steamer John L. Hasbrouck—following the one in the Daniel S. Miller built two years before—a beam engine placed athwartships and geared to the propeller.

Now, as one who has come from those primitive years and has seen the simple engine, the compound engine, the triple, the quadruple and even the quintuple expansion engine down to the great advances in other forms made within recent years, I can truly say the papers and the discussion we have had presented to us tonight excite my highest admiration.

You are all to be congratulated that you see progress in the making and can look forward to still further progress.

Feeling that the men who have taken the time and trouble to prepare these particularly interesting papers, also those that have so carefully prepared their discussions, are fully entitled to an expression of your appreciation, I now, on your behalf, extend to them sincere thanks.

The meeting is now adjourned. (Applause.)

Whereupon at 11.25 p. m., the meeting adjourned *sine die.*

TWENTY-NINTH ANNUAL MEETING OF THE SOCIETY, HELD AT THE ENGINEERING SOCIETIES BUILDING, 29 WEST 39th STREET, NEW YORK CITY, NOVEMBER 17 AND 18, 1921.

INTRODUCTORY PROCEEDINGS

MINUTES OF THE TWENTY-NINTH ANNUAL MEETING OF THE SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS, HELD AT THE ENGINEERING SOCIETIES' BUILDING, NEW YORK CITY, THURSDAY AND FRIDAY, NOVEMBER 17 AND 18, 1921.

FIRST SESSION.

THURSDAY MORNING, NOVEMBER 17, 1921.

The president, Rear Admiral W. L. Capps (C. C)., U. S. Navy, called the meeting to order at 10.30 a. m.

THE PRESIDENT:—The meeting will please come to order. We will begin by the presentation of the Secretary's report, which will be read by our former secretary, Captain W. J. Baxter (C. C.), U. S. Navy, in the enforced absence of the Secretary, Mr. Cox.

REPORT OF SECRETARY-TREASURER.

NOVEMBER 16, 1921.

To the Council of The Society of Naval Architects and Marine Engineers:

GENTLEMEN:—I have the honor to submit the following report showing the condition of the Society at the close of the fiscal year ended October 31, 1921.

The membership of the Society as at October 31, 1921, was as follows:

Class of Members	Membership, October 31, 1920	Elected at 1920 Meeting	Promotion, Associate to Member	Promotion, Junior to Member	Promotion, Junior to Associate	Membership at Close Annual Meeting, 1920	Promotion, Members to Life Members	Deaths, 1920-1921	Resignations, 1920-1921	Suspended, 1920-1921	Membership, October 31, 1921
Members	1095	152	+8	+8	—	1263	−1	15	23	12	1212
Associates	336	79	—	—	+5	420	—	1	16	7	396
Juniors	63	10	−8	−8	−5	52	—	—	3	4	45
Life Members	17	—	—	—	—	17	+1	—	—	—	18
Life Associates	8	—	—	—	—	8	—	—	—	—	8
Honorary Members	1	—	—	—	—	1	—	—	—	—	1
Honorary Associates	1	—	—	—	—	1	—	—	—	—	1
Totals	1521	241	—	—	—	1762	—	16	42	23	1681

Deaths (16).

Members (15).

Ellsworth P. Bertholf.
Martin C. Erismann.
William D. Forbes.
Frank L. Fernald.
William E. Francis.
Emilio S. Godoy.
Maury P. Gregg.
William N. Howell.
Samuel S. Jordan.
John McInnes.
Hugo J. Norman.
Hugo B. Roelker.
James P. Sneddon.
Peter Cooper Hewitt.
Henry Lysholm.

Associates (1).

F. J. Renz.

Resignations (42).

Members (23).

Frederick W. Allan.
A. G. Anderson.
George A. Andrews.
Henry Black.
Ernest W. Blocksidge.
Alexander de Bretteville.
Loren Bugbee.
George E. Burd.
Richard V. Cowley.
Thomas C. Desmond.
Wyllys E. Dowd.
William A. Ebsen.
Alfred H. R. Jackson.
Gustav Kaemmerling.
Harry G. Knox.
James McDermott.
James H. Mancor.
Everett M. Matthews.
Harrie R. Parish.
Lyndon B. Taylor.
Joseph B. Weaver.
Jay M. Whitham.
Evan C. Williams.

Associates (16).

Gilbert C. Dohm.
Charles Halcomb.
Lawrence L. Henderson.
John H. Hyde.
Robert L. Ireland.
Washington Irving.
Harry L. Katz.
Preston Lincoln.
Thomas I. Miller.
Otho M. Otte.
August Nagelvoort.
John R. Russell.
Thomas M. Searles.
William M. Stanton.
Henry M. Toch.
Elisha J. White.

Juniors (3).

Leon C. Bibber.
William G. Brown.
David J. Howard.

THE SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS.

BALANCE SHEET.

October 31, 1921.

EXHIBIT "A."

RESOURCES.

Cash on hand and in bank		$2,623.01
Certificate of Deposit—Bank of America		3,000.00
U. S. Certificate of Indebtedness, $5,000.00		5,034.38
U. S. Certificate of Accrued interest		23.93
Accounts receivable—dues		5,705.00
Accounts receivable—dealers, etc.		343.50
Publications—inventory		5,272.52
Furniture and fixtures		940.50
Total general resources		$22,942.84
ENDOWMENT FUNDS:		
Corporate Stock, City of New York, $7,000.00—4½s	$7,000.00	
Bonds $5,000.00 Brooklyn Public Market 3½s	5,000.00	
Bonds 4,000.00 Baltimore & Ohio R. R.—Conv. 4½	3,925.00	
Bonds 2,000.00 Morris & Essex R. R.—1st Ref. 3½s	1,732.50	
Bonds 3,000.00 Central Pac. R. R.—1st Ref. 4s	2,651.25	
Bonds 1,000.00 U. S. Liberty—first Convb. 4¼	1,000.00	
Bonds 3,500.00 U. S. Liberty—second Conv. 4¼s	3,500.00	
Bonds 2,800.00 U. S. Liberty—third 4¼	2,800.00	
Bonds 5,350.00 U. S. Liberty—third 4¼s	4,936.81	
Bonds 6,750.00 U. S. Liberty—fourth 4¼s	6,750.00	
Bonds 1,000.00 U. S. Victory—fifth 4¾s	1,000.00	
Cash in bank	235.28	
Total endowment funds		40,530.84
		$63,473.68

LIABILITIES.

Annual Banquet 1921			$1,512.00
Dues and fees, paid in advance, etc.			492.00
Total general liabilities			$2,004.00
PRESENT WORTH:			
Endowment Funds		$40,530.84	
General Funds—Balance November 1, 1920	$14,431.16		
Gain—see Exhibit "B"	6,507.68		
Balance, October 31, 1921		20,938.84	
Total			61,469.68
			$63,473.68

Income and Expenses for the Twelve Months Ended October 31, 1921.

Exhibit "B."

INCOME.

Dues accrued for year	$25,435.00	
Less amounts written off	1,317.50	
Net		$24,117.50
Annual banquet—1920		1,743.68
Publication—sales		1,657.50
Interest		255.41
Pamphlets and year book—sales		16.54
Total		$27,790.63

EXPENSES.

Publication—Inventory, November 1, 1920		$7,249.24	
Preliminary papers—1920		2,591.97	
Volume No. 28—1920		6,652.85	
		$16,494.06	
Inventory, October 31, 1921	$7,030.03		
Less 25 per cent deducted for depreciation	1,757.51		
		5,272.52	
Cost of publication		$11,221.54	
Annual meeting—twenty-eighth		1,350.44	
Special meeting—May, 1921		653.22	
Rent		1,002.00	
Office salaries		4,074.92	
Office expenses		2,006.48	
Miscellaneous printing, membership list		611.90	
Storage		112.00	
Bank collection charges		6.56	
Transportation		54.39	
Donation to Industrial Training Congress		85.00	
Depreciation on furniture and fixtures—10 per cent on $1,045.00		104.50	
Total			21,282.95
Excess of income over expenses for the twelve months ended October 31, 1921			$6,507.68

Endowment Funds—For the Twelve Months Ended October 31, 1921.

Exhibit "C."

November 1, 1920, balance		$36,379.05
Interest Earned on:		
Bank deposit	$6.10	
Liberty and Victory bonds	817.44	
Municipal bonds	490.00	
Railroad bonds	370.00	
Total	$1,683.54	
Membership, entrance fees	2,375.00	
Membership, life	200.00	
	$4,258.54	
Less: Bank commission charges	106.75	
Net income for the twelve months ended October 31, 1921		4,151.79
October 31, 1921, balance		$40,530.84

The financial statements and books of account have been audited by Wm. J. Struss & Co., Certified Public Accountants, 93 Nassau Street, New York, N. Y.

Respectfully submitted,

Daniel H. Cox,
Secretary-Treasurer.

Acting Secretary Baxter:—Gentlemen, it gives me great pleasure to be of service to the Society at any time. Following the example of many distinguished men, I shall serve as Secretary without compensation; and, furthermore, my salary as Honorary Vice-President is hereby donated to the Society.

This report has been distributed throughout the room. It shows a very satisfactory condition as regards the members and financial position of the Society. We came to the meeting last year with 1,521 members, and this report shows that we elected 241 new members at the last annual meeting. Since that time we have lost 81 members by death, resignations, etc., making our net increase 160, and the present total membership is 1,681. Despite present conditions, we are coming to this meeting with 122 new applications, with many more still expected from recent appeals to members to bring in at least one new member.

The report shows that we have increased our resources by the addition of a $5,000 U. S. Certificate of Indebtedness and a $3,000 Bank of America Certificate of Deposit. The depressing effect of business conditions at the present time is shown in the amount owing for dues, a total of $5,705, but a considerable number of those in arrears have written expressing their intention to remit at an early date.

The Secretary-Treasurer and the Committee on Papers have endeavored to effect a reduction in the cost of printing the preliminary papers and the volumes. The cost of the papers and the volume for 1920, when compared with the cost of the papers and volume for 1919, shows a reduction of nearly $2,800.

It will be noted under Exhibit "B" that 25 per cent has been deducted for depreciation of the value of the publications on hand. Undoubtedly the older volumes have depreciated in selling value and some reduction should have been made.

The increase in rent is due to the fact that we were required to move to a larger office in June, 1920, in readjusting space in the Engineering Societies Building.

The increase in salaries was incidental to the appointment of an assistant to the Secretary-Treasurer, with some clerical assistance in the office, which is also the reason for the increase in office expenses over last year; but this latter item includes a large amount of circularizing made in an effort to sell publications on hand and to procure new members.

Exhibit "B" shows a surplus of income over expenses amounting to $6,507.68, which means that our present worth has increased from $14,431.16 to $20,938.84, whereas the last report showed we suffered a loss of nearly $2,000 in this respect.

A most gratifying feature of the report is the steady advance shown by the increase of the Endowment Fund from $36,379.05 to $40,530.84, being an increase of $4,151.79.

The President:—Gentlemen, you have heard the report of the Secretary-Treasurer, which was approved by the Council at its meeting yesterday, and accepted as the report of the Council to the Society.

Motion was made, seconded and adopted that the report of the Secretary-Treasurer as approved by the Council be accepted.

The President:—During the past year, the Society, as noted by the Secretary, has lost by death a substantial number of its members. Following our usual custom, the members present will please rise while the Secretary reads these names.

Acting-Secretary Baxter then read the following list of names, the members standing: Ellsworth P. Bertholf, Martin C. Erismann, William D. Forbes, Frank L. Fernald, William E. Francis, Emilio S. Godoy, Maury P. Gregg, William N. Howell, Samuel S. Jordan, Henry Lysholm, John McInnes, Hugo J. Norman, Hugo B. Roelker, James B. Sneddon, Peter Cooper Hewitt, F. J. Renz.

The President:—Gentlemen, among these names you will all recognize many of those of members who have achieved high place in their profession. One of them is that of a scion of a family greatly distinguished in its patronage of art and science, who himself greatly advanced the world's knowledge in pure and applied science and placed it under special obligation to him. I refer to Peter Cooper Hewitt.

Another achieved the highest place in his chosen profession, was given special recognition by his government for the saving of many lives under difficult conditions, and, on his retirement from active service, accepted a high office in our principal Classification Society. Commodore Ellsworth Price Bertholf was well known to many of you, and his passing from the scene of his activities is a matter of deepest regret.

Another distinguished member, who perhaps was not so well known to the younger generation, was William D. Forbes, a man who gave to the earlier deliberations of our Society the benefit of his ripe judgment. And though, in later years, deprived of the power of vision, he always maintained his interest in the welfare and activities of this Society.

Proper recognition will be made, in our published transactions, of all of our departed associates, but it would be quite inappropriate if the Chair did not make special allusion to another name on this list, the name of a man who was an incorporator and one of the original Members of Council of this Society and who, almost up to the very moment of his death, maintained an active interest in it. I need hardly say that I refer to the Nestor of our profession, Francis Lysander Fernald; a man of high professional attainments, rare personal simplicity and charm, and beloved by all who knew him. A slight incident in his official career will quite well illustrate his point of view. Many years ago—more than thirty now—when graduates of the Naval Academy were not an "old story" in the Construction Corps of the Navy, one of the comparatively recent graduates was assigned to duty under Captain Fernald. This officer was a man very much younger than Captain Fernald and was, of course, a man lacking in practical experience, but he had had excellent theoretical, professional training. Captain Fernald, instead of receiving him casually or critically, made the following comment: "Well, my young friend, I have lived very much longer than you, and am, perhaps, at some disadvantage so far as theoretical training goes, but I have acquired certain practical experience. You, on the other hand, have had the best scientific training that the United States Government can give. I think that, together, we will make a very fine working team. I welcome you cordially to our official family." Nothing could have been finer, nothing could have illustrated more perfectly his generous point of view. Gentlemen, we deeply regret the passing of all these dear friends, but they have left behind them hallowed memories, and we must accept the inevitable as best we can.

Yesterday afternoon at a meeting of the Council, held in conformity with the provisions of the Constitution, the filling of vacancies or prospective vacancies in the offices of the Society was considered. The first on the list of prospective vacancies was the office of President. After very thorough consideration, the Nominating Committee made its report to the Council. It had selected a gentleman whose name when presented was immediately recognized as that of a man who had been closely associated with the Society from its very beginning, and the gentleman in question had, as we all know, given the very best thought that was in him to the well-being of the Society—and that, we all know, meant a great deal. I take great pleasure in announcing that the Council unanimously recommended for the presidency of the Society for the ensuing term of three years, Mr. Walter M. McFarland. (Applause.) It seems quite unnecessary to put his election to formal vote. Your reception of the announcement indicates quite clearly that his election is made by acclamation.

The Council also recommended for election the following gentlemen as Vice-Presidents for the term expiring December 31, 1924: Lewis Nixon, H. I. Cone, C. H. Peabody, J. W. Powell.

For Members of Council for the term expiring December 31, 1924: Andrew Fletcher, J. H. Mull, C. W. Dyson, E. H. M. Robinson, W. G. Coxe, Robert Haig.

For Associate Members of Council, for the term expiring December 31, 1924: E. M. Bull and J. N. Pew, Jr.

For Executive Committee: Stevenson Taylor, W. L. Capps, Andrew Fletcher, F. L. DuBosque, J. W. Powell.

For Committee on Papers: F. L. DuBosque, J. Howland Gardner, H. L. Aldrich.

For Secretary and Treasurer, last but never least, Daniel H. Cox.

Gentlemen, what is your pleasure with reference to the recommendation of the Council, regarding the names of officers which have been presented to you?

Mr. Mason S. Chace:—I move that the recommendations of the Council be accepted.

The President:—It is moved and seconded that the recommendation submitted by the Council be accepted by the Society. All in favor say "Aye," contrary-minded, "No." The "Ayes" have it. The officers whose names have been presented are unanimously elected.

The Secretary will now read the list of the new members recommended by the Council.

Acting-Secretary Baxter then read the following list of names:

Members (68).

Lloyd V. Armstrong, Oil Engine Department, Ingersoll-Rand Co., 11 Broadway, New York, N. Y. P. O. address, 319 Fairmont Avenue, Jersey City, N. J.

Charles H. Bateman, Hull Estimator, Staten Island Shipbuilding Co., Mariners Harbor, Staten Island, N. Y.

Guy L. Bennett, Marine Surveyor, Governor Apartments, Charles and Reed Streets, Baltimore, Md.

Robert F. A. Benson, Assistant Superintendent, Jahncke Dry Dock and Ship Repair Co., New Orleans, La.

John L. Bogert, Consulting Engineer to Providence Engineering Corporation. P. O. address, 203 Greene Avenue, Brooklyn, N. Y.

Leon B. Bozardt, Sales Engineer, American Engineering Co. P. O. address, 100 Broadway, New York, N. Y.

John C. Braislin, Surveyor, United States Salvage Association. P. O. address, 425 Clinton Avenue, Brooklyn, N. Y.

George Brown, Surveyor, American Marine Insurance Syndicates. P. O. address, 1918 Avenue H, Flatbush, Brooklyn, N. Y.

Hadley F. Brown, Works Manager, Globe Shipbuilding Co., Baltimore, Md. P. O. address, 3418 Norwood Avenue, Baltimore, Md.

Frederick G. Brownlie, Naval Architect and Marine Surveyor. P. O. address, Baltic Chambers, 50 Wellington Street, Glasgow, Scotland.

George L. Buchanan, Surveyor, American Bureau of Shipping. P. O. address, 419-21 Hoster Building, Havana, Cuba.

George S. Bull, Surveyor, American Marine Insurance Syndicates, 44 Beaver St., New York, N. Y.

William Butler, Lloyd's Register of Shipping, 17 Battery Place, New York, N. Y.

Harold D. Campbell, Marine Superintendent, Sun Shipbuilding Co., Chester, Pa.

William Compton, Surveyor, Salvage Association of London, 68 Broad Street, New York, N. Y.

William J. Deed, Naval Architect. P. O. address, 160 Cedar Hill Avenue, Nyack, N. Y.

Joseph E. Dorward, Chief Estimator, Lord Dry Dock Corporation, 25 Broadway, New York, N. Y. P. O. address, 106 West 78th Street, New York, N. Y.

Robert Douglas, Engineer Inspector, Construction Department, International Mercantile Marine Co., New York, N. Y. P. O. address, 312 Devon Street, Kearny, N. J.

Arthur L. du Busc, Naval Architect, J. M. Sullivan Co., Ft. E. 9th St., New York, N. Y. P. O. address, 476 Jefferson Avenue, Elizabeth, N. J.

Edwin A. Ernest, Inspector of Hulls, Merchant Shipbuilding Co., Chester, Pa. P. O. address, Langdon, Minn.

William C. Foley, Chief Surveyor, American Marine Insurance Syndicates, 44 Beaver Street, New York, N. Y.

James Forsyth, Superintendent, New York and Porto Rico Steamship Co., Pier 35, Atlantic Basin, Brooklyn, N. Y. P. O. address, 37 Howard Place, Brooklyn, N. Y.

David Galloway, Superintendent Engineer, International Mercantile Marine Corporation, New York, N. Y. P. O. address, P. O. Box 191, Hoboken, N. J.

Eugene G. Grace, President, Bethlehem Shipbuilding Corporation, Ltd. P. O. address, "N" and Prospect Avenues, Bethlehem, Pa.

Alexander Guidoni, Lieut. Colonel, Royal Corps of Naval Constructors, Italian Navy, and Air Attaché, Italian Embassy. P. O. address, 1400 New Hampshire Avenue, Washington, D. C.

Herbert D. Haverfield, Marine Engineer, Chas. Cory & Son, 183 Varick St., New York, N. Y.

Frederick D. Hesley, Surveyor and Contract Writer, U. S. Shipping Board, 45 Broadway, New York, N. Y. P. O. address, 709 Foster Avenue, Brooklyn, N. Y.

William M. Huskisson, Engineer Assistant to Messrs. Vickers' Agent in the United States, 2550 Woolworth Building, New York, N. Y. P. O. address, 15 Wildwood Road, Larchmont, N. Y.

Robert Jacob, Ship and Yacht Builder, City Island, N. Y.

Patrick S. Jolly, Surveyor, American Marine Insurance Syndicates, 44 Beaver Street, New York, N. Y. P. O. address, 1554 Richmond Turnpike, West New Brighton, Staten Island, New York.

Waldo L. Kraemer, Sales Engineer, Kearfott Engineering Co., Inc., 95 Liberty Street, New York, N. Y. P. O. address, 305 8th Avenue, Brooklyn, N. Y.

George F. Lynn, Fleet Engineer, Great Lakes Steamship Co., 1007 Kirby Building, Cleveland, Ohio.

John A. McKeown, Surveyor, U. S. Shipping Board, 45 Broadway, New York, N. Y. P. O. address, 485 6th Street, Brooklyn, N. Y.

Martin McLeod, Dockmaster, Montreal Dry Dock and Ship Repairing Co. P. O. address, 88A Durocher Street, Montreal, Quebec.

John R. McRae, Chief Inspector, North Atlantic District, U. S. Shipping Board, 45 Broadway, New York, N. Y. P. O. address, 1571 77th Street, Brooklyn, N. Y.

William H. Magee, Resident Engineer (New York District), American Engineering Co., Philadelphia, Pa. P. O. address, 100 Broadway, New York, N. Y.

Edward T. Malloy, General Superintendent, Jahncke Dry Docks and Ship Repair Co., New Orleans, La.

Julius E. Marwitz, Superintending Engineer, Transatlantica Italiana America, Mediterranean S. S. Co., and Maru Navigation Co. P. O. address, 5 State Street, New York, N.Y.

Cornelius W. Middleton, Engineer, Marine Department, Babcock & Wilcox Co., 85 Liberty Street, New York, N. Y.

Charles P. Minning, Marine Superintendent, American Fuel Oil and Transportation Co. P. O. address, Room 1700, 111 Broadway, New York, N. Y.

Charles E. Montgomery, Assistant Superintending Engineer, Panaman R. R. S. S. Line, 24 State Street, New York, N. Y. P. O. address, 25 Fort Washington Avenue, New York, N. Y.

George L. Moore, Marine Engineer, Service Department, The Superheater Co., 17 E. 42d Street, New York, N. Y. P. O. address, 94 Riverside Drive, New York, N. Y.

John H. Moore, Superintendent Engineer, United Fruit Company, Pier 9, North River, New York, N. Y.

Leslie R. Oliver, Port Engineer, J. S. Emery & Co., Inc., 114 State Street, Boston, Mass. P. O. address, 22 Albion Road, Wollaston, Mass.

John D. O'Meara, Draughtsman, New York Shipbuilding Corporation, Camden, N. J. P. O. address, 344 Carteret Street, Camden, N. J.

George E. Pendergast, Marine Superintendent, Union Petroleum Steamship Co., 26 Broadway, New York, N. Y.

Walter E. Pommer, Naval Architect. P. O. address, 711 Majestic Building, Milwaukee, Wis.

Frederick A. Resch, Hull and Engine Draughtsman, Tietjen and Lang Plant, Hoboken, N. J. P. O. address, 589 Bramhall Avenue, Jersey City, N. J.

Charles C. Roberts, Marine Inspector in British Isles for the U. S. Shipping Board. P. O. address, 36 Van Winkle Street, Boston, 24, Mass.

Alexander Robertson, Port Engineer, Ore Steamship Corporation at Sparrows Point. Md., also 11 Broadway, New York, N. Y. P. O. address, 64 Admiral Boulevard, Dundalk, Md.

James Robertson, Contracting Naval Architect and Marine Engineer, 24 California Street, San Francisco, Cal.

John Sanders, Jr., Representative U. S. Shipping Board at Submarine Boat Corporation. P. O. address, Box 456, Newark, N. J.

Daniel Sawyer, Superintending Engineer, Norfolk & Washington Steamboat Co., Washington, D. C. P. O. address, 1926 Kearney Street, N. E., Washington, D. C.

Thomas Service, Engineer, Fuel Oil Burning Department, Bethlehem Shipbuilding Corporation, Bethlehem, Pa. P. O. address, Bethlehem, Pa.

James C. Shaw, Assistant to Chief Engineer, The Wm. Cramp & Sons S. & E. B. Co., Philadelphia, Pa.

Carl D. Smith, Chief Inspector, Steamship Zulia, Red D. Steamship Lines. P. O. address, 36 Tompkins Place, Brooklyn, N. Y.

William Snoswell, Marine Inspector, Standard Oil Co. of New York. P. O. address, 51 Four Corner Road, Dongan Hills, Staten Island, N. Y.

Elwin L. Stewart, Naval Architect, Standard Oil Co. of N. J., 26 Broadway, New York, N. Y.

Daniel A. J. Sullivan, Commodore of Black Diamond Steamship Corporation. P. O. address, 349 Garden Avenue, Mount Vernon, N. Y.

Howard N. Tait, Superintendent Engineer, C. H. Sprague & Son, Boston, Mass. P. O. address, 141 Milk Street, Boston, Mass.

Thomas M. Tait, Superintendent of Repairs, New York and Cuba Mail Steamship Co., Pier 13, East River, New York, N. Y. P. O. address, 8204 Ridge Boulevard, Brooklyn, N. Y.

Charles M. Taylor, Chargeman Draughtsman, Navy Yard, Boston, Mass. P. O. address, 363 North Street, East Weymouth, Mass.

Walter E. Thau, Engineer, Westinghouse Electric and Manufacturing Co., East Pittsburgh, Pa. P. O. address, 567 East End Avenue, Pittsburgh, Pa.

Anthony Vandenheuvel, Superintending Engineer, New York Canal and Great Lakes Corporation, 27 Pearl Street, New York, N. Y. P. O. address, 20 Jennings Street, Elmhurst, L. I.

Robert H. Wager, President, Wager Furnace Bridge Wall Co., Inc. P. O. address, 149 Broadway, New York, N. Y.

Oscar Wahlquist, Senior Engineer, U. S. Shipping Board. P. O. address, 232 Brookline Boulevard, Philadelphia, Pa.

Robert D. Whittaker, Combustion Engineer, White Fuel Oil Engineering Corporation, 742 East 12th Street, New York, N. Y. P. O. address, 161 68th Street, Brooklyn, N. Y.

Roger Williams, Manager, Operating Department, International Mercantile Marine Co., 9 Broadway, New York, N. Y. P. O. address, 40 Ingram Street, Forest Hills, Long Island, N. Y.

Associates (13).

Robert Colston, Member Marine Department, The Griscom-Russel Co., 90 West Street, New York, N. Y. P. O. address, 36 Wendt Avenue, Larchmont, N. Y.

William J. Du Bree, Secretary and Treasurer, Du-Fo Products Company, 1018 Harrison Building, Philadelphia, Pa.

John Englis, Vice-President, C. M. Englis, Inc., Grand Central Terminal, New York, N. Y. P. O. address, 340 Park Avenue, New York, N. Y.

Peter R. Foley, President, Du-Fo Products Company, Harrison Building, Philadelphia, Pa.

Philip A. S. Franklin, President, International Mercantile Marine Company, 9 Broadway, New York, N. Y.

Henry Frielinghaus, Jr., Assistant Treasurer, Tietjen & Lang Dry Dock Co., Hoboken, N. J.

James A. Hargan, Draughtsman, Robins Dry Dock and Repair Co., Erie Basin, Brooklyn, N. Y. P. O. address, 154 Richmond Street, Brooklyn, N. Y.

Charles H. Mallory, Assistant Manager, Operations Department, Munson Steamship Line. P. O. address, Port Chester, Pa.

Chidley D. Mears, Hull Estimator, Federal Shipbuilding Co., Kearny, N. J. P. O. address, 95 Walnut Street, Bloomfield, N. J.

William G. Post, Assistant Marine Manager, Sinclair Navigation Co. P. O. address, 139 Wegman Parkway, Jersey City, N. J.

George A. Tomlinson, President, Buffalo Dry Dock Co., Buffalo, N. Y. P. O. address, 1229 Kirby Building, Cleveland, Ohio.

Elisha Webb, Jr., President Elisha Webb & Son Co. P. O. address, 136 South Front Street, Philadelphia, Pa.

Joseph S. Wood, Marine Superintendent, Wilson Transit Co., Cleveland, Ohio. P. O. address, 2994 Scarborough Road, Cleveland Heights, Ohio.

Juniors (7).

James L. Dobson, Superintendent of Marine Work, Pennsylvania Flooring and Coating Co. P. O. address, Bulletin Building, Philadelphia, Pa.

Philip W. Clark, Instructor in Naval Architecture at Lehigh University. P. O. address, Lehigh University, Bethlehem, Pa.

George L. du Busc, Assistant in Sales Department, Bethlehem Shipbuilding Corporation, 111 Broadway, New York, N. Y. P. O. address, 476 Jefferson Avenue, Elizabeth, N. J.

George W. Grove, Sales Engineer, Bethlehem Steel Co., New York, N. Y.

Amos S. Hebble, Jr., Marine Draughtsman, Tietjen & Lang Dry Dock Co. P. O. address, 31 Vernon Terrace, East Orange, N. J.

Jacob Mesnick, Marine Engineer. P. O. address, 713 Courtlandt Avenue, Bronx, N. Y.

Harry Neilson, Marine Draughtsman, Tietjen & Lang Dry Dock Co. P. O. address, 253 Emerson Place, Brooklyn, N. Y.

Junior to Member (3).

William Nelson, Assistant Naval Constructor (C. C.), U. S. N., Bethlehem Shipbuilding Company, Union Plant, San Francisco, Calif.

Hendrik C. Snethlage, Naval Architect, Christensen & Snethlage. P. O. address, 9 Portsmouth Place, Forest Hills, Long Island, N. Y.

Thomas H. Soyster, Marine Draughtsman, Standard Oil Co. of New York, 26 Broadway, New York, N. Y. P. O. address, 79 Florence Avenue, Bloomfield, N. J.

Junior to Associate (1).

Carl E. Peterson, Naval Architect, U. S. Lines, 120 Broadway, New York, N. Y.

Associate to Member (7)

Reuben E. Bakenhus, Captain (C. E. C.), U. S. N., Assistant Chief, Bureau of Yards and Docks, Navy Department, Washington, D. C.

Edmund D. Bistline, Works Accountant, Federal Shipbuilding Co., Newark, N. J. P. O. address, 338 Roseville Avenue, Newark, N. J.

Hans A. Christensen, Naval Architect, Christensen & Snethlage, 25 Broadway, New York, N. Y.

Joseph M. Kiernan, Lieutenant (j. g.) (C. C.), U. S. Navy, Hull Division, Navy Yard, New York, N. Y.

George C. Manning, Lieut. Commander (C. C.), U. S. Navy, Production Superintendent, Hull Division, Navy Yard, Charleston, S. C.

Henry E. Rossell, Commander (C. C.), U. S. Navy, Engineering Superintendent of Hull Division, Navy Yard, Philadelphia, Pa.

Albert E. Eldredge, Treasurer, George Lawley & Sons Corporation, Neponsit, Mass.

The President:—Gentlemen, you have heard the list of names read by the Acting Secretary. What is your pleasure?

Professor Herbert C. Sadler:—I move that the applicants whose names have been read by the Acting Secretary, and whose applications have been approved by the Council, be accepted by the Society, and that they be elected to membership in the various classes indicated.

The motion was duly seconded, put to vote and carried.

The President:—At yesterday's meeting of the Council, an amendment which had been duly proposed in conformity with the Constitution was unanimously approved by the Council. It is now ready for final action by the Society. This amendment is brief, and deals with the composition of the Executive Committee, increasing its membership from a total of seven to a total of nine. This increase was found desirable in order that we could more easily have a quorum when a meeting was held at the headquarters of the Society in New York. The Acting Secretary will please read the proposed amendment.

The Acting Secretary then read the proposed amendment as follows:

"The direct management of the Society shall be vested in an Executive Committee of nine, composed of seven members of Council, elected annually by the Council, and the President and the Secretary of the Society *ex-officio*. At least five members of the seven elective members of the committee shall be Members of the Society."

The President:—Gentlemen, you have heard the proposed amendment. What is your pleasure?

Mr. Howard C. Higgins, *Life Member:*—I move the adoption of the proposed amendment to Article 5 of the Constitution.

The President:—It has been moved and seconded, that tne amendment, as recommended by the Council, be adopted by the Society, and incorporated in the Constitution. All in favor say "Aye"; contrary-minded "No." The "Ayes" have it and the amendment is adopted.

We have now come to the point in our preliminary proceedings, gentlemen, when the President is expected to make an address. On this particular occasion "a few remarks" would much more fittingly describe what the President is going to say. These few remarks, if taken by themselves, might give cause for sadness, because many things are happening in the world at the present time, and the shipbuilding profession is not at the head of active industrial pursuits. I think, however, in this great country of ours, we can always afford to be optimistic, and if, temporarily, the shipbuilder and the ship operator are not enjoying a high degree of prosperity, they can well afford to remember that possibly it is for the best good of the greatest number, and that their day will surely come in the future.

PRESIDENT'S ADDRESS.

Twice during the past three years, the Annual Meeting of our Society has been coincident with events which are epochal in the world's history. These events must necessarily have a profound effect upon the "promotion of the art of shipbuilding, commercial and naval," the object, as stated in our Constitution, for which this Society of Naval Architects and Marine Engineers was founded.

On November 11, 1918, was concluded an armistice which virtually ended a war greater in magnitude and in world significance than pre-war historians would have dared imagine.

This gigantic struggle had dislocated practically all industrial effort, over-expanding in some directions, ruinously contracting in others. The shipbuilder and the ship operator were no exceptions in this general upheaval. They were both subjected to unusual demands. They both responded in a manner too well known and of too recent occurrence to require extended comment. Suffice it to say that the tonnage for the transportation of millions of men and many million tons of supplies was forthcoming in sufficient quantity, and the menace of the submarine, which at one time threatened disastrous results to the Allied cause, was overcome by the efficiency and gallantry of the Allied and Associated Navies and Merchant Marine, the gallantry of the personnel being fairly matched by the efficiency of the matériel.

But, in those desperate efforts to combat enemy operations and to replace the tonnage sent to the bottom by enemy submarines, shipbuilding, both naval and commercial, was stimulated to an abnormal degree. The result is known to all. The world's naval and commercial tonnage today, despite the World War's losses, are both far greater than they were in 1914, while the world's trade, reacting from the stimulus of war and the months succeeding the armistice, has been decreasing.

There is nothing abnormal in the comparative confusion and lack of stability in industrial and trade conditions now confronting the world. History is in reality repeating itself. Conditions which prevailed at the end of the Napoleonic wars, as well as those which have developed at the conclusion of other great conflicts, are being paralleled at the present time, although on a vastly greater scale.

Great as has been the industrial upheaval due to the World War, serious as may now appear the conditions which prevail in that industry which is the especial concern of the members of this Society, it is hoped and believed that the return to normal conditions will be much more rapid at this time than at the conclusion of any of the other great world crises.

While it is always difficult for those directly affected to keep in true perspective developments which so vitally concern their interests, there is little doubt that the history now being made in the capital of our country will be epochal in character, and, in the final analysis, the decisions now being formulated will be beneficial to all mankind.

While it would not be appropriate at this time and in this place to do more than refer to the possible effect of these decisions, it would not seem out of place to note the tremendous changes which have taken place in world shipping and ship construction and world trade during the last few years. The effect of those changes in shipbuilding and ship operating in the United States is obviously most important.

It will, therefore, be worth our while to note briefly some of these changes.

From data compiled from latest reports of the U. S. Commissioner of Navigation and Lloyd's Register, it appears that:

In 1914, the world's gross tonnage in vessels of 100 tons or more was approximately 49,000,000 tons. Of this, more than 42,000,000 tons was *steel steam* tonnage. In 1921, the gross *steel steam* tonnage alone had increased to nearly 55,000,000 tons. Of the total world ship tonnage of 49,000,000 tons in 1914, the United States had, in overseas trade, only 1,100,000 tons, while the gross United States *steam* tonnage engaged in overseas trade in 1921 was practically ten times the 1914 figure. Of this enormous expansion of U. S. ocean-going tonnage, approximately 8,000,000 tons were contributed by the Government of the United States through its authorized agency, the United States Shipping Board Emergency Fleet Corporation, and the cost of this additional tonnage, due largely to war conditions, was virtually equal to that of the entire pre-war world tonnage.

As opposed to the great increase in *overseas* tonnage, it is worthy of note that the increase in U. S. tonnage engaged in *domestic* trade in the 7-year period from 1914 to 1921 was comparatively insignificant, being less than 5 per cent.

It is also interesting to note that the total increase in world tonnage in the 7-year period preceding and following 1914 was approximately 10,000,000 tons, the percentage increase for the 7-year period 1907-1914 being really greater than that for the 7-year period which included the war expansion.

Nor were the increases in American trade in American bottoms less significant than the increases in American overseas tonnage.

The entries and clearances of U. S. vessels in North American trade had increased from 26,000,000 tons in 1914 to 46,000,000 tons in 1921, while the trans-oceanic or overseas trade had increased from 1,700,000 tons in 1914 to 22,000,000 tons in 1921. The corresponding United States trade carried in *foreign* bottoms decreased from 31,000,000 tons of entries and clearances in 1914 to 25,000,000 tons in 1921, while the *overseas* entries and *clearances* of U. S. trade in *foreign* vessels *decreased* from 48,000,000 tons to 45,000,000 tons in the same period. We thus had, during the 7-year period, 1914 to 1921, a tremendous increase in *overseas* entries and clearances in *U. S. vessels,* with a slight decrease for foreign vessels, the net result being, of course, a very great increase in U. S. world trade.

In further illustration of the great change which has taken place in recent years in American steel steam tonnage, it is worthy of note that while the increase in this tonnage for the period 1907-1914 was approximately 50 per cent, the increase for the following 7-year period was nearly 300 per cent. Moreover, in 1914, the U. S. had less than 10 per cent of the world's steel tonnage; it now has approximately 26 per cent of the total.

When we note the variations in quantity of steel ship *construction* for the period in question, the facts are even more startling. In 1915, the total tonnage of ocean-going steel vessels of more than 1,000 tons gross register, constructed in the U. S., was approximately 112,000 tons. In 1920, this had increased to nearly 2,900,000 tons, or more than 2,500 per cent. Now, however, building programs are nearly completed and the actual merchant ship steel steam tonnage under construction, as reported by Lloyd's Register for the quarter ending September 30, 1921, is approximately 420,000 tons for the United States and 4,550,000 for the rest of the world.

The foregoing brief reference to abnormal changes in conditions with respect to ships built and building and cargoes carried, especially in their relation to the U. S., is illustrative of the extraordinary character of the revolution which went on during the 7-year period in question. Of course, no one who has considered carefully the trade economics of the situation has doubted for an instant that serious readjustments must, sooner or later, take place and that those readjustments would, temporarily at least, involve many difficulties. Those readjustments are now in the making, and temporary stagnation in U. S. shipbuilding and a decrease in overseas commerce are inevitable until the abnormal developments due to the war have been placed in their proper relation to normal peace-time conditions.

In passing, it may be well to note that there were great losses of high-class passenger vessels during the war and that much of the war-time construction and service of all vessels was of a character which would greatly shorten their period of usefulness; it may, therefore, be anticipated that sometime in the not far distant future shipbuilding will profit from these conditions.

The membership of this Society is, of course, profoundly interested in the developments which have taken place and are now proceeding. The effect upon the shipbuilding industry as a whole, at the present time, is serious. The effect upon ship operation is also serious. Highly developed shipbuilding plants are, in great part, idle. Hundreds of comparatively new steel vessels are tied up with no immediate prospect of obtaining cargoes. That these conditions are temporary may well be true, and the period of readjustment must be accepted, with as much equanimity as possible, as a necessary part of the aftermath of the stupendous struggle through which the world has recently passed.

Passing, now, from this brief survey of world conditions which indirectly, and even directly, affect the future of those interests in which the membership of this Society is so deeply concerned, it is a pleasure to record that the condition of the Society itself, both as to membership and income, is very encouraging. It is interesting to note that the membership has increased from 762 in 1916 to 1,762 in 1921, or more than 125 per cent, and there are 122 candidates for admission whose applications are to be acted upon at this meeting. The increase in annual dues adopted at the last meeting has relieved, in large measure, the financial embarrassment with which the Society was then confronted. It is too soon yet to assume, with prudent regard for the future, any unusual additional financial obligations. The establishment of scholarships at technical colleges is one of the extensions of the Society's activities which is still a cherished hope of the future since the proper education and training of younger members of our profession has been and must continue to be one of the most effective lines in which this Society can "promote the art of shipbuilding, commercial and naval." On the first occasion on which I addressed you as President, it was noted that the Society is "a great educational institution whose standards and ideals must be maintained and whose powers of instruction and professional helpfulness should be constantly developed," and that "upon the maintenance of high standards for the art of shipbuilding depends, in large measure, the satisfactory solution of the many great problems connected with ocean, lake, and inland water transportation with their consequent beneficent results for humanity. To aim at less would be to miss our greatest opportunity for good."

These statements are as true today as they were three years ago. Therefore, during the difficult period of readjustment through which nearly all industrial activities, and particularly the shipbuilding industry, are passing, we should be encouraged by the reflection that character of performance will, in the final analysis, be the measure of our success. No matter how difficult may seem the future, skill, integrity, and high standards of performance will, even under the keenest international competition, achieve the results most to be desired.

As in the days of the sailing clipper ship when the American shipbuilder excelled all others and the American Merchant Marine was at the forefront in tonnage and efficiency, we may confidently look forward to a period when efficiency of design, construction and operation of the power-driven cargo and passenger vessels of the future will place the United States again among the leaders of maritime development, and it is to be hoped that the rivalry through which such results may be accomplished will be of an entirely friendly character largely as represented by efficient passenger and cargo vessels rather than by vessels primarily designed for destructive purposes.

The reading of the President's address was greeted with applause.

The President:—I am requested to announce that arrangements have been made for visiting the Leviathan. Full information can be obtained through Captain McAllister, at the entrance to the hall, or his accredited representative.

We will now proceed with the reading of papers. Obviously, several papers on this program were prepared well in advance of the meeting. Some of these papers deal with naval matters. Even the naval papers, however, deal with tactical or technical subjects. They will be presented by the various authors in abstract. It is hoped that the discussion which will ensue will throw light upon the tactical and technical features involved in these papers. The discussion should not, of course, in the slightest degree, touch upon subjects which are within the special province of the International Conference now in session in Washington.

It is a very real pleasure to the Chair to announce that the first paper will be contributed by a distinguished officer of the United States Navy, who himself occupies a very important relation to that conference, and who bears a name which is especially distinguished in the annals of the United States Navy. I take great pleasure in presenting to you Rear Admiral W. L. Rodgers, U. S. N., an Associate Member of the Society. His paper is entitled, "The Tactical Relations between Different Clases of Men-of-War and Their Embodiment in Design."

Rear Admiral Rodgers presented the paper.

THE TACTICAL RELATIONS BETWEEN DIFFERENT CLASSES OF MEN-OF-WAR AND THEIR EMBODIMENT IN DESIGN.

By Rear Admiral W. L. Rodgers, United States Navy, Associate.

[Read at the twenty-ninth general meeting of the Society of Naval Architects and Marine Engineers, held in New York, November 17 and 18, 1921.]

A paper for the Society of Naval Architects on the subject of the relation of the battleship to other types of combatant ships is one which I am able to discuss only from a tactical point of view. In the relation existing between the different classes of ships there are several fundamental principles, controlling factors, which are embodied in history and experience. As to the steps by which the designing constructor embodies these principles in an acceptable design, I shall have nothing to say, as it would be beyond my capacity. But some of the fundamental rules of war are of interest to us all, both as citizens and as members of technical professions, and an understanding of one another's requirements and limitations can only be mutually helpful in showing the interlocking of design and of tactics.

OBJECTIVE OF NAVAL EFFORT.

As a first point of inquiry we may ask what a navy is for. Except for fisheries the sea is uninhabitable and unproductive. It is used by mankind only as a highway of commerce; as a highway its control by a dominant merchant fleet enables one power to secure its own economic prosperity at the expense of rivals without such control of trade routes. A dominant merchant fleet in peace enables a nation to take a middleman's monopolistic profit of world business in peace and throttle the development of a rival. In war, such a fleet supplies a nation, while its lack may reduce a nation to want and economic defeat. We have seen this exemplified very recently.

Contrary to popular belief, combatant fleets are not built for the purpose of enjoying a national championship fight to the finish. They are built for the ultimate purpose of driving hostile commerce from the seas and controlling neutral commerce as far as they can. As a means thereto, they seek to destroy the protecting and opposing fleets of their enemy to the end that, after a decisive sea battle, economic pressure on the enemy will become severe, and greater military effort will also be possible through the use of the sea for military transportation. Thus a combatant fleet should be so built that its main fighting strength is in such form as may be best fitted to sweep an opposing combatant fleet from the seas. This is the first step towards the goal of economic control of ocean commerce and maritime trade.

With this object we have our main body of the fleet seeking a decision by force. But our strength must be exerted intelligently. We cannot let it be ruined by surprise or misled into futilities. Knowledge must precede action.

As a distinguished German military writer says: "From knowledge to action it is always a great leap, but from ignorance to action the leap is a still greater one." Our fleet must not leap from ignorance into an abyss. The main strength must be guarded from surprise by "speed" ships screening it. It must be guided truly by speed ships reconnoitering and seeking for correct information, fighting for it as necessary.

Thus a strategic necessity forces us to develop our combatant surface fleet along two lines, "strength" ships for the ultimate battle reliance and "speed" ships for auxiliary and preliminary service of screening and scouting.

Yet these speed ships as against each other must be strength ships, for they must live through their own preliminary hostile contacts to do their duty towards their main body previous to the great fleet action; and after it they must combine sufficient strength with their mobility to sweep up hostile commerce and so accomplish the naval objective.

If one asks why these speed ships, which accomplish the final step of destroying the hostile merchant fleet are not themselves also the strength ships for the main battle, the answer is that concentration for battle, and the battle itself, must precede the dispersion which reaps the fruit of battle. The strength ships must fight and control the seas before the speed ships are wholly free. If we try to combine the two functions, we have design and counter design each accentuating strength, till we arrive at the typical battleship attaining the utmost tactical battle endurance and are obliged to start design anew with a speed ship suitable to cooperate with the battleship.

To compare the tactical use of the various types of ships we have first to look at the combatant elements embodied in all fighting ships and understand their relationship. These elements comprise means of attack, of defense and of mobility, all resting on the elements of seaworthiness (sea keeping, buoyancy, habitability) as their basis and support.

RELATIONS OF ATTACK AND DEFENSE.

The general relations of attack and defense need attention. Passive defense may always be overcome in time; what man has made, man can destroy. In delaying destruction, the defense finds the limit of its powers.

Defense is useful only in so much as it gives time and opportunity for a fighting man or group of men to develop their own counter attack and destroy the lives of enemies. The aggressive fighting spirit is the soul of warfare. Without it a combatant will attain only defeat at the end.

As an extreme example of a passive defense we may take the safety vaults of Wall Street. The valuables in the vaults are as strongly protected as steel and cement can protect them, but the real defense is in the watchman and his gun, his honesty and courage. If the watchman fails to take the opportunity to fight when the burglar alarm rings, the strongest vault cannot protect.

The public was too liable to draw false lessons from the recent bombing attacks on the ex-German battleship Ostfriesland. Her passive defense was as strong as the art of the day could accomplish. This ship was required to be sunk by treaty, and the Navy Department decided to do so by bombs from the air. The essential in the matter was that there was no one either on board or elsewhere to resist by force the department's resolution to destroy her. The attacking force was uninjured, and so she was destroyed. A bull fight is interesting to sporting people because the bull has a chance of injuring his enemy, who must do his best or be killed himself. But the Ostfriesland bull went to a slaughter house for anatomical vivisection ending by butchery.

Combatant strength or endurance as a whole is not the sum of defensive and offensive powers, but more in the nature of a product of these two factors. This has long been known practically. Theoretically it may be pointed out that the defensive strength measures and prolongs the time element during which the offensive aggressive power is doing its work of destroying the enemy.

DEFENSIVE STRENGTH.

Defense, or the attainment of safety, may be accomplished in three ways—by protection, by concealment, and by flight or evasion.

A ship is defended by protection in two ways—namely, by armor in some form against projectiles and other explosive attacks above water and by compartmentation against invasion by water. The first form of protection is afforded directly to life, as well as to the ship herself. The second form of protection is directly to the ship as a carrier but only indirectly to the lives of those on board.

It is in the battleship that we find the greatest development of protection. The weight of armor is about 20 to 25 per cent of the displacement. Compartmentation is carried to the highest practicable degree. But, as we have seen, combatant endurance is the product of offensive strength and defensive strength. We must therefore get our full value out of the battleship by making her strong in attack also. We do not know precisely what relative weights of armament and protection will give the maximum yield, but the empirical solution which the best efforts of designers of all powers seem to have arrived at is that the protective weights in battleships should be not far from twice that devoted to the armament and ammunition.

For obtaining a defense by concealment we have two methods. One, the latest in point of time, is the smoke screen, but the application of this method calls for no attention in this paper. The second method of concealment is that of submergence, and its practice requires a special type of vessel, the submarine, radically different from all others. In all surface ships the design is such that it provides for a very large factor of safety by ample reserve buoyancy. In all ordinary conditions the law of gravity is friendly to surface ships. But in a submarine the combatant defense by concealment is gained only by the sacrifice of navigational safety. In passing from the cruising to the diving condition, reserve buoyancy is lost, and the law of gravity is turned from an attitude of benevolence to one of indifference bordering on unfriendliness. The preservation of this neutral condition of no buoyancy becomes the chief preoccupation of all on board; it influences every movement and controls efficiency in very great degree. Moreover, it tends, to some extent, to limit the size of submarines.

To make full use of the power of concealment inherent in her design, a submarine must practice in peace and utilize in war what are known as "crash" dives, when the order to close up openings is followed almost instantly by the dive. The life of the boat and safety of all depend on every responsible man doing his whole duty with little time for the captain to assure himself that his order has gone through and has been properly executed.

As boats grow larger the difficulties of communication and opportunities for errors and negligence by operators increase, and the law of "diminishing returns" so well known in business comes into play. Difficulties in administration tend to become dangers in this type and offset the advantages in design which are offered by increase in size of submarines.

The submarine has not been a welcome development to all powers. It is the weapon of the weak powers. To a navy, dominant, as is England's, a new invention can only threaten its supremacy. England is therefore very slow to take up new things whose success would threaten her present supremacy. England opposed the submarine till other powers made it a success and then England was obliged to accept it.

We may now come to defense by evasion or, less euphemistically, by flight.

As we have seen, a ship's combatant power or battle endurance to live longer than her enemy and accomplish her ultimate purposes is the product of her defensive by her offensive strength. If either factor becomes very small, the other must become impracticably great in order to give a probability of ultimate survival. Hence, if a type of ship sacrifices defense by protection or by concealment, she must either secure herself by enormous armament or she must get a reasonable measure of defense by her speed and consequent ability to run away.

As a principle of design, we may then take it that sacrifice of protection normally calls for speeds superior to those of better protected types of ships. And so, taking battleships as setting the standard speed for combatant ships, we find that all surface ships less thoroughly protected should be faster as their armor grows thinner, whereas to submarines, whose defense lies in concealment, a submerged speed much less than battleship speed is all that is necessary.

OFFENSIVE STRENGTH.

Next we may take up the subject of offense. The oldest form of attack now important is artillery fire, chiefly aimed at the upper works and crew, using explosive shell and, recently, poison gas. With these latter may be classed deck bombs dropped by fliers. A more recent form of attack is that of the torpedo directed against the underwater body of the ship.

The essential difference in the manner of employment of these two weapons is that the velocity of the gun's projectile is such that, once within range of a gun, its projectile cannot be avoided or parried by the target ship. The gun is the weapon best fitted for heavy "give and take" and for the exercise of stern resolution to win by endurance to outlast the enemy.

The torpedo, however, has a speed which at best is little greater than that of the fastest ships. It cannot overtake a ship unless the range is short, for it does not run far; it is preferably fired to meet an advancing enemy. Hence the torpedo is eminently a weapon for fast ships. Further, ships having a defensive element in their speed, if properly armed, find in their speed also an offensive element as against slower ships, owing to their ability either to gain desirable position or else force the enemy to maneuver disadvantageously under gun fire.

MOBILITY.

We have already discussed speed as an element in attack and in defense from a tactical point of view. We must further consider it from a strategic point of view and the consequent influence on design.

Fuel endurance as a strategic factor must be increased as ships are expected to operate in wider waters. The light cruisers operating against each other in the late war across the North Sea were of from 3,000 to 5,000 tons and were quite effective. To operate equally effectively across an ocean, the size of individual ships should be much larger. The Karlsruhe and other German raiders in the broad ocean were much preoccupied by the question of finding fuel. Some years ago this matter was the subject of marked divergence of views between officers of the submarine flotilla and the Navy Department.

After the beginning of the recent war, but before the United States entered it, the General Board of the Navy under Admiral Dewey, charged with the duty of recommending to the Secretary the characteristics of ships, urged submarines of about 500 tons. Officers of the submarine service did not agree to this view but wanted larger craft of 800 tons. Now, however, the Navy Department favors the large type. At the time I wrote a paper for this Society favoring the smaller size. The reason for this change of view by the Navy Department is worth examining. German submarines were coming out to sea to operate west of the British Islands. They were entering the Mediterranean and making long voyages, and their performances were spectacular. Hence our submarine service was chiefly impressed by German performance and requirements and wanted the United States to adopt the large type. The Navy Department, however, looked to American requirements if we entered the war as allies of western Europe and realized that with bases always near at hand, long radius based on large size was not called for. Moderate size with handiness, although requiring frequent returns to port, would be preferable. We built such craft and used them with good results both on our own coast and abroad.

But for general use now, without the certainty of allies, and separated by great oceans from all serious adversaries, such small, short-radius boats are no longer the best type, and the Navy Department has changed its plans to suit the requirements of any field of action. A large boat is utilizable near home and also overseas.

The advantages of size are obvious in all classes of ships. We know that they increase faster than the displacement, and hence the constant tendency towards bigger and bigger ships.

AVIATION.

Aviation as a new arm deserves attention. It is spectacular and romantic and attracts popular regard on these grounds as well as on account of its inherent value.

It is the most speedy means of locomotion known. Hence aircraft are specially indicated as suitable for reconnaissance and screening. Their speed makes them available as carriers for weapons of position such as the torpedo and bomb. Further, like the torpedo boat and other speed craft, the reply to seaplanes should take the form of counter attack by similar craft. It is unlike the submarine in this respect, whose slow speed causes it to rely on concealment for protection. To the submarine the hostile reply is by search and the use of a short-range water projectile—the depth bomb.

The airplane has a disadvantage belonging to the submarine—it is ceaselessly struggling against gravity; but, on the other hand, it can sometimes find defense by concealment in the clouds. Yet its short radius and light weight prevent it at present from assuming a major rôle, unless and until it is unopposed by its like.

COMBINATIONS OF DIFFERENT CLASSES OF WEAPONS.

We have examined the reason for various types of ships, each specializing in weapons suitable to them. It lies in relative mobility. But each weapon's method of attack calls for a correspondingly suitable method of defense. Where a single weapon of one type is opposed by a single weapon of another type it is desirable to develop the battle into a tactical form suitable to our weapon and unfavorable to the enemy's weapon. Hence, if we can induce the enemy to accept a certain form of attack and then pass to another, he is at a disadvantage by the surprise. We supplement brute force by intelligence and skill—a most satisfactory arrangement. Thus we saw, in the recent war on shore, artillery and infantry mutually aiding each other—the artillery making a position untenable and the infantry taking possession. At sea, the torpedo attack by the Germans at Jutland caused Admiral Jellicoe to yield his superiority of artillery position. Thus every new weapon adds to the possible tactical combinations and enables skill to economize in bloodshed and money with greater expense to the enemy. But on the other hand, however a ship may specialize in any direction as to armament, it has never seemed wise to arm any ship with one weapon only.

Every new weapon involves new methods of attack, and it requires some time for the opposing force to find the appropriate way of defense. This delay raises hopes of the new weapon as a decisive one. But after a little the appropriate defense is found, and when it is thoroughly worked out the new weapon becomes less effective and remains as a tactical auxiliary only.

The fast ships of "position" when fighting against heavier ones, clearly need the weapons of position—torpedoes, bombs—but against their equals, they need the weapon of endurance—the gun—for in the end it is grit and heavy pounding, physical courage and endurance that win in sea battles just as in prize fights.

This combination of strength and endurance in attack is reached to the greatest extent in battleships, yet in them it has always been thought advisable to add other arms as auxiliary to the gun, rather perhaps as a defensive element, checking and cramping the adversary's tactical style, than as an aggressive element.

Thus, in battleships, an anti-aircraft battery will not protect against air attack, but it will weaken the vigor of the attack from the air and give time for support from friendly aircraft. The torpedo battery may frequently be used by battleships, but perhaps more often its potential influence upon the enemy will be of tactical value.

CONCLUSION.

Thus, in the last analysis of ship design, we see battleships, as the most potent embodiment of combatant strength, led, screened and informed by lighter and faster auxiliary surface craft—cruisers, torpedo boats. These are further supported by the ships using the third dimension of space, at the sacrifice of maneuvering safety, but gaining concealment and surprise in the case of the submarine, and speed and surprise in the case of the air craft. None of these auxiliaries can become dominant because they cannot remain in the field of battle when properly opposed.

The tactical principle controlling the course of the battle is fairly well fixed, although variations in methods of execution will be almost infinite. The lighter speed ships will reconnoiter and screen till in touch with each other. Then they will fight each other as strength ships developing their greatest volume of fire. Next, the victorious speed ships will seek to assume a "position" advantage with regard to the main body of the enemy, using their speed weapons in aid of their own strength ships, and the decision will come by the endurance of the strength ships.

When the great battle is done, the battleships may go home to await another call while the auxiliaries remain active to subdue hostile commerce and throttle the enemy's economic life. These are the objectives which the naval seaman asks you to enable him to reach by suitable embodiment of tactical features in the three main types of ships, namely, "strength" ships and "speed" ships, and auxiliary ships movable in the third dimension.

DISCUSSION.

The President:—Gentlemen, you have heard the presentation of paper No. 1, by Rear Admiral Rodgers, entitled "The Tactical Relations between Different Classes of Men-of-War and Their Embodiment in Design." This paper is now open for discussion. We have a contributed discussion which the Acting Secretary will read.

Captain W. C. Watts, U. S. Navy (Communicated):—It has been a great pleasure to me to read this excellent treatment of a difficult question, and I feel flattered to have been given an opportunity to comment on it. Naturally, I approach the subject with diffidence and preface my comment by expressing my full agreement with the various general principles and conclusions of the author. My brief remarks are more in the nature of amplifying certain phases of the discussion and may seem unnecessary where perhaps only an enlargement upon the author's views.

In considering the subject of "defensive strength" of ships, it seems that some mention should be made of the fact that in some types of vessels a part of the battery is essentially of a defensive character, though the act of using it is of course offensive and the degree of defense derived from it is in proportion to the vigor of its offense. For example, in a battleship the anti-aircraft battery is essentially for protective purposes, and to a less extent the same applies to the secondary battery, as is indicated by the term "torpedo defense battery" frequently applied to it. This point is brought out by the author in another part of the paper, immediately before the "conclusion," but it is believed to be appropriate to emphasize the fact that these batteries would hardly be installed on a capital ship if the possible menace from such craft as destroyers, submarines, torpedo planes and offensive aircraft did not exist. Battleships are essentially "strength" ships, to use the author's apt expression, and the sacrifice of weight to a battery designed to stand off an enemy that the battleship, in fulfillment of its mission, would not seek, is as truly a concession to the requirements of protection as is the weight of armor. Thus, in considering the whole question, it might clarify the situation if we recognize that guns, from the viewpoint of the discussion in this paper, may be of offensive or defensive character, although naturally the latter are freely used to assist the former, when in special circumstances this is possible and when the necessity of their employment for their primary mission is not present.

The torpedo is spoken of by the author as an offensive "weapon of position," eminently adapted for fast ships. This is borne out by its inclusion in the armament of most vessels of this type in all navies, where it becomes in some instances the primary weapon of offense. When carried by battleships, however, the controlling principle is not so clear as to the purpose for which installed, whether offensive or defensive. In fact, it must be regarded as partaking of both these characteristics for employment in certain special circumstances, and is therefore in the nature of a compromise in this respect. To include torpedoes in the armament of a battleship has involved submerged tubes and the necessarily very large torpedo rooms that constitute a striking exception to the system of subdivision elsewhere insisted upon in the structure of the ship. This is, of course, a weakness and a lessening of the protective properties of the ship, which, to be justified, must be more than offset by the advantages, as either an offensive or defensive weapon, of the torpedo itself. This is an example of how sacrifices must invariably be made to include additional weapons, and when these weapons are of an auxiliary character it becomes of great importance to weigh carefully how far a sacrifice of any vital characteristics should be tolerated.

The battleship is the purest type of naval vessel, and the principles of the embodiment in its design of its tactical relations to other classes are more simple than in other cases. As the possible missions of ships increase, more and more weapons suggest themselves as desirable, with resultant complications in determining upon the design. The author has spoken of the gun, the torpedo and the bomb, and in addition the mine and the depth charge must also be considered, for in some types these weapons are a most important, if not primary, feature of the armament and exercise their natural influence upon design.

The President:—Is there any other discussion I think that this paper presents, in most admirable form, tactical considerations involved in warship design. It is the sort of paper that is not likely to provoke impromptu discussion. It is quite possible, however, that there may be those who desire to submit written comment later on. If such should be the case, I take it for granted that the Society will follow its usual custom in permitting such discussion to be passed upon by the Executive Committee and incorporated in the proceedings.

Rear Admiral W. A. Moffet, U. S. Navy (Communicated):—The paper prepared by Admiral W. L. Rodgers is one of the best of its kind that I have ever read. It presents the situation concisely, it states clearly the essential factors entering into sea power, and in such a way that no one can fail to understand.

The present position and possibilities of aviation are well stated, although it is probable that even the admiral does not appreciate its far-reaching possibilities and effects. Specific mention is not made of the design of aircraft carriers, which may be so designed as to make them fully as formidable as battle cruisers and battleships.

It is believed that the time will come when the battleship and carrier will be merged into one, and the battleship of the near future may be a ship carrying a few of the largest practicable caliber guns with a great many planes of all types.

It would be a great advantage to the country if this paper could be given the widest circulation possible.

Rear Admiral Rodgers (Communicated):—This paper was written with a view to suggesting to engineers that the fundamental engineering principles of force and time operating against resistance to produce useful work are also involved in the fundamental principles of military and naval tactics where the work done is that of destruction.

The destructive forces of warfare, like all other forces, need time for them to do a given amount of work. But the destructive forces can be destroyed only by counter-destructive forces. The passive elements of defense (or resistance) serve only to secure time for the attacking forces to do an appreciable amount of work. Passive defense alone may sometimes deny victory to the enemy, but even this half success is possible only when the defense secures more time than the enemy has available for the accomplishment of his task. Passive defense never secures complete victory.

Thus in ship design we classify our ships into two main classes, the "strength" ships combining force to overcome the enemy with protection to secure time to exert that force, and "speed" ships whose attack is comparatively light in force, but either so quickly delivered or from so favorable a point that the enemy lacks time to develop his resistance and so to absorb the attack.

The submarine, relying on concealment to deliver its sudden attack is tactically akin to fast-moving surface craft and air craft in that suddenness of approach and attack in them all deprives the enemy of the time he needs to establish his defense and counter-attack.

THE PRESIDENT:—It remains for the Chair to express, on behalf of the Society, its very great appreciation of the time and trouble taken by Admiral Rodgers in preparing this paper.

The next paper, No. 2, is by Mr. Mason S. Chace, a life member of the Society. It is entitled "Development of the Three-Plane Navy, with or without Battleships." We will ask Mr. Chace to read an abstract of his paper.

Mr. Chace presented the paper.

DEVELOPMENT OF THE THREE-PLANE NAVY, WITH OR WITHOUT BATTLESHIPS.

By Mason S. Chace, Esq., Life Member.

[Read at the twenty-ninth general meeting of the Society of Naval Architects and Marine Engineers, held in New York, November 17 and 18, 1921.]

During the World War, following predictions made by those best informed as to military and naval matters, many means of attack and defense were used and developed, both for fighting on land and at sea; also, there were other important developments in means and methods of fighting which were unforeseen, unpredicted and even not to be expected, judging by the experiences of previous wars.

The difficulties and liabilities of error in making predictions as to what shall be the most efficient methods of attack and defense to be used in the next war are as great, or greater, than they have ever been, owing to the number of new arms and methods produced during the World War. The next war may take place under conditions so different that predictions based on experiences of this last war will be seriously in error.

Today, probably the most important questions which can be asked as to the future development of naval means of offense and defense are: Has the present type of battleship survived the test, and does it remain as before, the backbone of navies, with all other types of fighting ships composing a naval offensive and defensive force existing only as essential aids or auxiliaries to battleship operations, but with the battleship supreme as the most powerful sea fighter yet devised by man and still indomitable? Does the development of means of attack from the air jeopardize the existence of the battleship in such a new way that this additional menace cannot be overcome? Can the battleship be so modified that its powers of resistance, combined with those of the various types of auxiliaries, including additional ones, permit it to remain supreme and to decide the question of naval victory or defeat? In other words, in the new three-plane navies, with means of fighting in the air and attacking ships from above, which three-plane navies will certainly be rapidly developed by all the great powers, will the battleship be able to maintain its supreme position or must it be abandoned as obsolete; and, if abandoned, what new type of fighting machine will replace it?

It would seem to be most important to discuss now, without delay, and to answer these difficult questions and then to shape our naval policy and program of construction to meet not only the situation of today but what is to be expected years hence. I believe that such investigation and discussion as has already taken place in connection with bombing tests of surrendered German ships both in this country and in Europe is only preliminary to much more important investigations and discussions which will have to follow before all the facts and elements in the situation can be correctly presented and analyzed and before the lines of development to be followed can be decided upon. Complete and expensive tests made on the latest and most powerful new ships would be cheap in actual cost, in comparison with the final cost, which might be the result of being satisfied with what we have, or of watchfully waiting for somebody else to do something, or the attitude that we should jump into something quite new without full investigation. The results of tests made on old units are open to the serious question as to how different the results would have been had improved units been subjected to the tests. It is difficult to sufficiently well assume and adopt in tests the conditions of real warfare, and consequently to have the results of peace-time tests accepted as applicable under war fighting conditions, especially if these tests are made on obsolete units.

I believe that the opposition of ultra-conservatism to seriously consider the possibilities and probabilities of aerial fighting as may affect naval developments of the near future is strong, because it is difficult to boldly face new developments which mean radical changes and the acceptance of the responsibility accompanying a revolution in point of view, as well as in means and methods to be employed. We know that it was many years after the introduction of steam propulsion before the necessity of completely abandoning sail for fighting ships was realized, and that the importance of the evolution to follow the introduction of iron as a material of construction for ships to replace wood was not quickly accepted.

A radical change, such as a decision to immediately abandon battleship construction, would seriously affect enormous vested interests and would bring forth the strong opposition of a great industry fighting for its existence. Many advocate the immediate adoption of air forces to replace the battleship and maintain that aerial means of attack and defense will be at the same time more effective and much less costly than building and keeping up battleships. Evidently, the burden of proof will rest heavily on those who advocate taking steps which may lead to abandoning battleship construction. It cannot be imagined that an investigation and discussion of such a question will be confined to getting at the facts unless special group interests and politics are omitted.

I will briefly summarize the naval experiences of the World War, as many of them have a bearing on the possibilities and probabilities of future developments.

The unrestricted submarine warfare launched by Germany, which included the sinking without warning of passenger vessels and hospital ships, as well as freighters, was for many reasons a great surprise to the allied powers, and it took considerable time before methods and means of successfully combating this kind of warfare were developed and effectively applied. So destructive of merchant tonnage was this use of the submarine that Germany was nearly successful in destroying sufficient tonnage to stop supplies from going to England and in that way probably to win the war. This destruction reached a maximum rate of about 875,000 tons per month in April, 1917.

These results are recorded to have been accomplished with a comparatively small number of the U type of submarines of from 750 to 950 tons submerged displacement, 11 knots or more surface speed, 6 to 8 knots submerged speed, carrying eight to twelve torpedoes, capable of keeping at sea three or four weeks and with a cruising radius of about 5,000 to 6,000 miles. The last and largest boats of the U type built are reported to have a surface displacement of 900 tons, with a submerged displacement of 1,300 tons and to be of greater speed and increased radius of action. The records of submarine boats operating to sink merchant vessels in the best merchant vessel hunting grounds on the approaches from the west, to the Irish, English and French coasts would show that a daily average of eight to ten, and always less than twenty, of the U type of submarines accomplished these sinkings; also, that it was necessary for Germany to possess, in commission, either being overhauled and prepared for a cruise or going back and forth between the home bases and the hunting grounds, at least ten submarines for every one submarine which was engaged in making sinkings.

War records, and records obtained since the termination of the war, indicate that at no time, in all fields of operation, did Germany have at sea, on any day, more than thirty submarines. In 1914 the German navy possessed in commission less than thirty submarines, with ten more being completed. Germany built and put into commission during hostilities about 300 submarines, and at the termination of hostilities had about 100 more under construction. About 200 German submarines were sunk by the Allies. Taking into consideration the time elapsed before the successful operation of effective means of stopping the tremendous losses from submarine sinkings, it is evident that had Germany, in the beginning, possessed four or five times as many submarines she would have had sufficient to have been successful in her aims.

Even Germany did not realize how effectively submarines could be used in destroying merchant shipping, for before the outbreak of hostilities she did not plan and prepare for the unrestricted submarine warfare subsequently undertaken. That campaign was an outgrowth of the helplessness of the German fleet in the face of the British fleet, and was launched as a last resort rather than as a campaign that had been planned. Germany had been notably slow in taking up the construction of submarines in the years previous to the war, during the period when other nations were experimenting with and building them. The first German submarine built was finished in 1907, a vessel with a submerged displacement of about 240 tons. In 1911 Germany commenced to build boats with a surface displacement of 550 tons, submerged displacement 750 tons, with 14 knots surface speed and 8 knots submerged speed. The last vessels built before the war had a surface displacement of 700 tons, submerged displacement 950 tons, with designed surface speed of 16 knots and submerged speed of 8 knots.

After the commencement of the war Germany continued to incease the size, the designed speeds and the radius of action as different series of the U type were constructed. Surface displacement increased from 750 to 800 and then to 900 tons, with the corresponding submerged displacements of 1,000, 1,150 and 1,300 tons. Designed surface speeds were increased from 16 knots to 17.5 knots, with an increase in submerged speeds from 8 knots to more than 10 knots. The radius of action, on the surface, was increased from 5,000 to 8,000 miles up to 10,000 miles. The number of torpedo tubes remained about the same, being from four to six 20-inch tubes. In the last boats the number of torpedoes carried was increased from twelve to sixteen.

While the first small U type of submarine was armed with a 50 millimeter or 2-inch gun, the caliber and number of guns carried were increased with the increase in the size of the submarines. The next size of gun supplied was the 88-mm. gun of 30 calibers in length, followed by guns of 105 mm. or 4 inches, of 40, also of 45 calibers in length. Then came the 105-mm. or 6-inch guns, of 50 calibers in length, mounted on submarine cruisers which were larger vessels than the ordinary U type of submarine.

The German submarines comprised three types: The U type, different series of which have been described above, and which includes the larger submarine cruisers yet to be described; the UB type which was smaller than the U type, of smaller radius of action, designed to be built in sections to facilitate transportation on land, and intended to be economically built in large numbers; and the UC type of mine-laying submarines. Although the first series of the UB type, consisting of seventeen, had a surface displacement of only 127 tons, the second series of thirty had a surface displacement of 260 tons, and the third series of seventeen boats had a surface displacement of 500 tons, which shows that the displacement of the UB type of submarine was progressively increased until the last of this type built had become as large as were the vessels of the prewar U type.

The first fifteen of the UC type of mine-laying submarines were small boats, built in sections to facilitate land transportation, of 180 tons surface displacement, less than 2,000 miles cruising radius, and carried twelve mines. The next series of the UC type had a surface displacement of about 430 tons, 6,000 miles cruising radius and carried eighteen mines. The UC type continued to increase in size until the last boats had attained a surface displacement of 600 tons and carried twenty-five mines. It may be mentioned that some of the UC type of submarines were provided with three 20-inch torpedo tubes, that about ten boats of the U type were mine layers, also that all German submarines carried rapid-fire guns and that the boats of the UB and UC types were armed with either one 88-mm. or one 105-mm. gun.

I will terminate this summary of the German types of submarines with a brief description of the largest of the cruising type of the U boats, the first series of seven of which were transformed into so-called freight-carrying or merchant submarines, one of which, the Deutschland, visited the United States in 1916. These boats were not all alike, as changes were made while under construction and while being transformed from freight carriers to armed submarines. These first seven cruising submarines were about 230 feet long, with a surface displacement of 1,750 tons, a submerged displacement of over 2,000 tons, with 11 to 12 knots surface speed, and 7 to 8 knots submerged speed. They were armed with two 150-mm. and two 88-mm. guns and several rapid-fire guns; they had also six torpedo tubes and carried about twenty torpedoes. They had a capacity of 250 tons of oil fuel, sufficient to permit them to cruise for four or five months. The Germans recognized that the speed of this first series of cruiser submarines was insufficient to permit these vessels to overhaul merchantmen.

The second series of cruiser submarines was composed of boats of increased dimensions, with a length of about 350 feet, a surface displacement of about 3,000 tons, a designed surface speed of 16 to 17 knots, and 8 to 9 knots submerged speed. The construction of these vessels was commenced late in the war, and this last series of twelve cruiser submarines was not ready for service until 1918. They were heavily built, so heavily that they may be considered as being lightly armored. I will not go into the question of the equipment of periscopes, wireless installations, etc., of the different types of submarines, except to say that all German submarines were provided with excellent material of the kind and which was being constantly improved; also that range finders, listening devices, etc., were generally provided.

The Allies succeeded in organizing a successful anti-submarine campaign and in preventing Germany from winning the war through the unforeseen, unrestricted submarine campaign. Means were found and adopted by the Allies which made the sinking with submarines of merchant vessels not only unprofitable but also an occupation which although in the beginning was considered by the German sailor as a safe one and probably as agreeable, later on as one that had become extremely dangerous and was to be avoided rather than sought. As the anti-submarine campaign progressed, the nerve and morale of the crews of the submarines were wrecked to a point of first causing a serious loss of efficiency and finally mutiny.

To overcome the menace of defeat from the destruction accomplished by the comparatively few German submarines engaged each day in sinking merchant vessels, the total number in commission at any time being only about 150, it was necessary for the Allies to make use of from 4,000 to 5,000 vessels, large and small, operating to find and destroy these German submarines, to destroy mines laid by German submarines, and to protect ships against their attacks. The vessels of the allied navies engaged in this work included 500 destroyers, 3,000 auxiliary patrol vessels, such as trawlers and yachts; about 100 allied submarines; 400 subchasers; about 30 "mystery ships" or decoy ships, these being armed merchantmen manned by naval crews and so disguised that they could not be distinguished from the unarmed merchantmen; numbers of mine layers; also many mine sweepers used to destroy the numerous mines which were constantly being laid by German submarines. To the above list of vessels might be added other large naval vessels which escorted convoys across the ocean until these convoys were met by the destroyers which accompanied them during the last part of their voyage, except for the fact that these large naval vessels should be considered rather as serving to protect against possible attacks of German surface raiders than as vessels which could protect against German submarines.

Some of the work of going to sea and escorting ships to port was carried out by airships and seaplanes, operating either alone or with destroyers. Aircraft must be included in the forces which combined to defeat the German submarine campaign. Aircraft were extensively used in patrolling to locate or spot submarines which were perhaps subsequently destroyed through information obtained by the aircraft; aircraft also successfully bombed submarines, made bombing raids on submarine bases, etc.

Of all of the vessels and means used against German submarines the destroyers using depth bombs and gunfire accomplished the greatest number of sinkings. The allied submarines operating against German submarines sank more of the latter, in proportion to their number so engaged, than did any other anti-submarine craft. The depth bomb was one of the most important factors in fighting submarines, from actual sinkings and from the demoralizing effect of the explosion of such bombs in the vicinity of submarines which were not destroyed by them. The use made of allied submarines and "mystery ships" in this anti-submarine warfare had a demoralizing effect which was probably more important than the number of sinkings made by these two types of vessels. Local mine fields and various forms of nets, either moored or towed, accomplished some of the sinkings; also, the very extensive North Sea mine barrage between the coast of Norway and the Orkney Islands resulted in some sinkings of submarines, but its demoralizing effect was perhaps of greater importance than these sinkings. This mine barrage, with a length of about 250 miles and a width of from 15 to 35 miles, contained about 70,000 mines when work on it was stopped by the armistice. Had the war continued, this barrage would probably have contained several times as many mines. Its construction was made possible by the invention of a mine which could be placed at different depths and was exploded by a vessel striking a copper cable supported above the mine by a buoy near the surface. One of these mines did the work of four mines of the old type which were exploded only by contact.

Among the important devices used to detect the presence of submarines and to locate them were the radio-direction finder, used to determine the direction from which wireless messages sent by submarines were coming, and the improved microphones, or under-water listening devices, which made it possible to detect the presence of submarines and to follow their movements by sound. The microphones were made good use of by the small subchasers operating principally in restricted waters. These vessels were armed with 3-inch guns and depth bombs. They did excellent work within the limits imposed on them by their comparatively small dimensions. Their work did much to keep submarines away from the waters patrolled by them and to prevent the submarines from making sinkings and from laying mines.

Lastly, but of great importance in this anti-submarine warfare, I must add the use of the convoy system to this list of the means adopted to combat the German submarine and to reduce the sinkings of merchant vessels. This system was started experimentally in May, 1917, and was in complete operation three to four months later. Its adoption was made possible by the addition of American naval vessels, particularly destroyers, to the naval forces of the Allies. The convoy system permitted the successful transportation of supplies and troops from the United States to Europe; it was also a direct attack against German submarines inasmuch as it forced them to attack merchant vessels in the presence of protecting destroyers or other craft, and consequently to run the risk of a fight and of being sunk themselves. By use of the convoy system and information as to the whereabouts of the German submarines at sea, it was often possible to route convoys around these submarines in safety. Comparatively few vessels, when in convoy, were sunk by submarines.

In the preceding paragraphs are listed, as briefly as possible, the vessels and means employed against the German submarines and which were finally successful in the anti-submarine campaign. It is evident that the German unrestricted submarine warfare was difficult and expensive to combat. It required much time to develop and to put into operation means of defeating this method of attack. In spite of the fact that the British Grand Fleet, to which, in the latter part of the war, were added some American naval vessels, held the control of the surface of the sea by keeping German surface naval vessels in German harbors, the control of the waters under the surface of the sea was but slowly taken away from the German submarines.

The different uses made of the submarine by the Germans and by the Allies in this war demonstrated that it has many uses which previously had not been considered possible. It was found that submarines could remain at sea for long periods, on extended cruises of thousands of miles, without the assistance of mother ships or tenders; that submarines could fight with torpedoes against other submarines; that a submarine armed with 4 or 6-inch guns, especially under favorable conditions of light, could shell surface vessels with little danger to itself owing to the small target it presented, combined with the fact that, while the surface vessels were easily seen by the submarine, the low-lying submarine was practically invisible to the surface vessels. The submarine can do effective patrolling or scouting in the immediate vicinity of the ports of the enemy, while submerged, which no other type of craft can do.

The extensive and effective use of submarine mine layers at long distances from their bases was quite unexpected. Submarines made long submerged runs, through mine fields and other obstructions, which previous to this war had been considered impossible. For example, we may refer to work of this kind done by British submarines in the Dardanelles as well as to that done by German submarines. The use by the latter of artillery of increasing caliber up to 6 inches and the adoption of 12-inch guns in the case of British submarines are developments of the World War.

The torpedo equipment of submarines today is far behind its possibilities of development. The torpedoes supplied to submarines are of shorter range than those supplied to surface vessels, in consequence of the incorrect assumption that submarines will always fight at short range. Large submarines can and should be provided with especially large, long-range torpedoes carrying explosive charges up to 1,000 pounds or more and thereby increase their power of attack, particularly against large naval vessels, even when escorted by a protecting screen of small, fast vessels. Although the great advantage of transverse torpedo tubes in facilitating attacks, as compared with bow tubes in combination with the practically useless stern tubes, is generally realized, yet little has been done to develop the transverse torpedo tube for large submarines. Although the submarine has been in existence many years, the World War demonstrated that the navies of the world had failed to recognize its possibilities.

We must recognize the defects of the submarine as follows: The two separate systems of propulsion, one for surface running and the other for submerged running, combined with the heavy hull necessary to give strength for submergence, result in producing a vessel which is of low surface speed for its length and displacement and of low speed and small radius of action when submerged. Increases in surface speed and in radius of action, on the surface, demand considerable increase in displacement. Large sized submarines require great depth of water for maneuvering and are also much more difficult to handle than small submarines. Owing to their comparatively small reserve buoyancy and the danger of damage to the watertight hull, submarines cannot safely receive much punishment from artillery fire.

Conditions of stability and weight considerations make it impossible to armor small submarines, except to give them an armored conning tower. The largest submarines yet constructed are only lightly armored. Some protection can be obtained by the use of transverse watertight bulkheads in vessels of medium and of large size. Owing to low submerged speed, the generally poor arrangement of torpedo tubes and the equipment of short-range torpedoes, the submarine is a poor torpedo boat compared with surface vessels such as the destroyers, except for the fact that a submerged submarine is invisible. Consequently, speed and zigzagging on the part of the surface vessel are among the best defenses against being torpedoed by a submarine. The air bubble wake of the torpedo fired by a submarine shows the direction of the submarine to its enemies. It is now expected that inventors will eliminate this tell-tale wake.

I believe that the experiences of the war will lead to the construction of many mine-laying submarines and large submarines of both the commerce-destroying or raider type and of the "fleet" type. It may be found in developing these two types that they can be merged into one. Submarines of these two types must have a high surface speed of 23 to 25 knots and a large cruising radius when on the surface, in order to be able to do the work of commerce destroyers or to keep up with large naval vessels at sea.

I will not take up the question of any other characteristics except that of displacement. I believe that the displacement of vessels of these two types will not much exceed 5,000 tons as a maximum. The experiences of the war would not justify an attempt to build either extremely large submarine armored cruisers or submarine battleships, both of which types have been proposed by enthusiasts.

The extensive use made of mines, particularly in restricted waters, was to be expected. The use of mine-laying submarines was something new and which will now be further developed.

Torpedoes and mines sank and damaged many naval vessels, although the German submarine torpedoing operations were principally directed against merchantmen. The Germans made few attempts to torpedo large naval vessels when those vessels were screened by destroyers. Such attempts were unsuccessful. In the beginning of the war Germany did not avail herself of opportunities to use submarines to torpedo ships of the British Grand Fleet when means of protecting that fleet were yet undeveloped. In all fields of operation, about forty large naval vessels of the older types, built five to ten years before the war, were sunk by torpedoes and mines. This number includes cruisers, armored cruisers, and predreadnaught battleships. In most of these sinkings the ship was sunk by the explosion of a single mine or torpedo. In many instances these ships lost stability and capsized before sinking. The damage inflicted by mines and torpedoes to naval vessels during the war was of such importance that it was found necessary to improve the protection against torpedoes and mines of even the latest of the new ships still under construction.

The destruction wrought by torpedoes and mines emphasized the value of a good margin of initial stability, the importance of transverse watertight subdivision and the necessity of increasing lateral protection. This lateral protection includes the use of several longitudinal bulkheads, in proximity to the outer shell, and of exterior "blisters" or "bulges." Increased initial stability and increased lateral protection call for increased beam. The beam of the largest superdreadnaughts which have been built, or are now to be built, can be but little increased unless the width of dry-dock gates is increased. The last of the superdreadnaught battleships designed for the United States Navy have a beam of about 105 feet, and the width of the locks of the Panama Canal is only 110 feet. The war has shown the importance of the influence of the increasing menace of the torpedo and mine on the design of naval vessels.

The Battle of Jutland shows the advantage which ships with guns of the largest caliber and longest range have in fleet action over ships provided with smaller guns of less range, also the advantage of a high angle of elevation of gunfire over smaller angles of elevation. Increasing the angle of elevation increases both the range and the destructive effect of plunging fire. Exactly what happened in the case of the destruction and sinking of three British battle cruisers of recent design is not known, but it is supposed to have been from the effects of gunfire. The battle cruisers were called upon to receive more punishment from artillery fire than they could withstand. In fact, in this sea fight the battle cruisers of both sides bore more of the brunt of the fighting than did the battleships. The part played by the battle cruisers is considered as fully justifying their existence as an essential part of a fleet of capital ships, also as having proved the value of high speed in such vessels. The latest superdreadnaught battleships, British and German, showed their ability to withstand much punishment from artillery fire and still continue to fight. The predreadnaught type of ships was found to be too vulnerable to be of use when fighting with ships of recent design.

Previous to and during the Battle of Jutland the Germans attempted to use dirigibles, principally for scouting, to locate the British fleet. The British seaplane carrier was not with the fleet during the battle, but one British seaplane was called upon to scout and locate the ships of the enemy during the battle. Owing to low hanging clouds, fog and mist, the German dirigibles were unable to locate the British ships or to keep in contact with them. The British seaplane, under similar conditions, found it impossible to do the work assigned to it. Low hanging clouds forced it to fly so low that it came under the fire not only of the German anti-aircraft guns but also of other guns of the German ships. These experiences are cited by those who claim that we must not expect that forces of the air will become an important part of navies, as experiences which conclusively demonstrate the unreliability of air forces under atmospheric conditions frequently lasting for days at sea. It is advanced by them, that, while under such conditions the surface fleets can fight and decide the question of naval supremacy, meanwhile the air forces must be inactive and useless.

I do not consider that the attempts to utilize air forces in this battle were made on a large enough scale to make it possible to draw such general conclusions. Certainly there will be atmospheric conditions affecting visibility which will seriously handicap or prevent the operations of both surface craft and aircraft. Other atmospheric conditions will favor one or the other. There are conditions of low-lying fog which give aircraft advantages over surface vessels. In night fighting the advantages would seem to be more often with the aircraft than with the surface vessels.

Aviation stands today as a new, powerful arm of offense and defense which can only be made dependable through development and use.

During the war much more attention was given to the development of aircraft with the forces fighting on land than with those fighting at sea. It was only through constant competitive use that the utility of different kinds of aircraft became recognized. Improvements were made in the machines, their armament, and the methods of using them. It was learned that the only real defense against aircraft is other aircraft. Anti-aircraft batteries were useful at times, but very inefficient. The records show that the most efficient of such batteries made one hit out of 1,000 shots fired. As the speeds of aircraft increased, the probabilities of hitting them with anti-aircraft guns diminished. Anti-aircraft guns, firing from the deck of a moving and rolling ship, will be less efficient than similar batteries installed on shore.

Bombing from the air was first done by small machines which could carry only small bombs. Finally, large bombing machines, capable of making long flights with bombs of several thousand pounds, were developed. It was realized that the big bombing planes were comparable to long-range guns. The bombs carried have a capacity of explosive, of poisonous or other gas, many times the capacity of the explosive shells of the largest guns built. The range of the bomb-carrying aircraft is today 150 to 200 miles. The flight to the objective and return can be made at a speed of more than 100 miles an hour.

The navies of the world are now face to face with the necessity of developing aerial means of offense and defense. There would seem to be nothing which the surface fleet can do to defend itself against the attacks of air forces except to use other air forces. Preliminary to a naval battle between surface fleets, we can expect that a battle between the fighting air forces of these fleets will take place. It remains to develop for naval use the several different kinds of aircraft suited for different purposes such as fighting, scouting, bombing, launching aerial torpedoes, distributing gas, etc.; also, the necessary ships to house, repair and transport this fleet of the air. Perhaps some of the aircraft will be transported by other aircraft.

The report of the Joint Army and Navy Board, which report has been approved by the Secretary of War and the Secretary of the Navy, gives us interesting information, although we may not agree with the conclusions of this board. The most striking among these conclusions, and the only ones which I will present here, are to the effect that aircraft carrying high-explosive bombs can sink, or seriously damage, any naval vessel at present constructed, provided such projectiles can be placed in the water alongside the vessel; that it will be difficult, if not impossible, to build any type of vessel of sufficient strength to withstand the destructive force that can be obtained with the largest bombs that aeroplanes may be able to carry from shore bases or sheltered harbors; that aeroplane carriers will probable be able to transport planes with these heavy bombs in the future; also that the aeroplane carrier will require the support of the battleship, the battleship remaining the backbone of the fleet.

It would seem to me that, when we have acquired and developed the use of air forces which can be depended upon to deliver attacks so destructive that battleships can be sunk, these forces of the air will have become supreme over those on the surface of the sea. Apparently we have a weapon which will make the battleship an auxiliary of the aeroplane carrier. I believe that the supreme position of the battleship is more threatened today than it has ever been, if that position is not already lost. On the supposition that a small number of the largest bombs carried by aeroplanes can destroy a battleship, we may conclude that, in the naval battles of the future, victory will go to the forces which control the air.

The aeroplane carrier ships which transport the scouting, fighting and bombing planes will become the ships from which the naval engagements of the future will be carried on and directed. It remains to further develop the submarine, which in the World War surprised us by its work and development. The surface forces can be but little developed, and the greatest possibilities and probabilities of development are in the air forces, which air forces are to become of supreme importance.

DISCUSSION.

The President:—The paper presented by Mr. Mason S. Chace is now before you for discussion. I understood that there were several gentlemen who wished to make comment on this paper. If no one present desires to discuss the paper at this time we will proceed to the next paper.

Commander Stevenson Taylor, U. S. N. R., *Past President:*—It seems to me only fair that notice should be taken of the fact that if the meeting had been held a week earlier there might have been much comment and discussion on these two papers. The subject of naval disarmament having been taken up by a much greater conference than ours, there is not much opportunity for this body to interject its opinions into the world's field.

The President:—The sentiments just expressed by Commander Taylor are undoubtedly shared by everyone present. The desire to keep entirely out of a field of discussion which might be, even in the slightest degree, detrimental to the best development of the deliberations now in progress in Washington is very much upon the mind of everyone. That, undoubtedly, accounts for the lack of desire to project oneself unnecessarily into such a field at the present time. I think it well, however, that the remarks of Commander Taylor be published in our Proceedings so that the status of this Society with respect to the vastly important matters now in progress should be clearly understood.

I am sure that the members are desirous of expressing their thanks to Mr. Chace for bringing his admirable paper before us. The thanks of the Society are therefore extended to him.

The next paper on our program, No. 3, is by Mr. W. A. Dobson, Vice-President of the Society. It is entitled "American Classification of American Vessels." In the unavoidable absence of the author, the paper will be read in abstract by Professor Herbert P. Sadler.

Professor Sadler presented the paper in abstract.

AMERICAN CLASSIFICATION OF AMERICAN VESSELS.

By W. A. Dobson, Esq., Vice-President.

[Read at the twenty-ninth general meeting of the Society of Naval Architects and Marine Engineers, held in New York, November 17 and 18, 1921.]

CLASSIFICATION OF VESSELS A NATIONAL ASSET.

Classification of vessels built for the merchant marine is fundamentally a matter of national importance. This view is justified by the fact that the certificate of class issued by a registration society is a guarantee that the vessel so classed is properly constructed. Such a certificate assures the owner and the insurance underwriter that the strength of the vessel is unquestionable and that its character of construction is in accordance with the standards of the classification society. The enormous risk, therefore, incidental to an inferior construction is eliminated, and only the hazards common to sea service remain to be considered. The result, therefore, of building to the rules and survey of a classification society, in so far as providing for and obtaining a proper construction goes, is the assurance that the lives of those who travel by sea, in vessels so constructed, and the vessels themselves with their cargoes are to that extent safeguarded. Life and property, so safeguarded, become a part of the nation's assets.

OBJECT.

The purpose of any society for the registration of vessels is to classify them in accordance with their strength and seaworthiness, with proper regard, on the one hand, for the safety of life and property, and, on the other, to obtain the necessary strength and seagoing qualities without impairing the earning power of the vessel by carrying around for its lifetime an unnecessary weight of structure that reduces the cargo-carrying capacity. It would, then, appear that, among other responsibilities, a moral obligation rests upon the classification society, as representing the owners, to use every endeavor to prevent the incorporation of unnecessary weight, thereby assuring a vessel of the maximum earning capacity combined with satisfactory strength. From the time of Noah to within the last two centuries, vessels were constructed either by inspiration or from experience gained by a long series of observations on vessels built from prototypes, whose characteristics, good and bad, were carefully noted and incorporated or eliminated, as the case might be, in following designs.

STUDY OF STRESSES ON FLOATING STRUCTURES.

With the introduction of iron as a building material, it became practicable to consider the hull proper as a girder and to closely approximate the stresses brought upon a vessel floating in a highly disturbed medium. The art of arranging the scantlings for safely meeting such stresses became the study of naval architects of all nations, and, while new combinations are constantly being developed, the general principles involved are well known and carefully considered in any standard arrangement of scantlings. As a result of such investigations, combined with many years of sea experience, tables or rules have been prepared by the classification societies which insure that vessels built in accordance therewith will have the required strength to successfully meet the varying conditions of ocean traffic. It is to be noted that such rules are not on a purely academic basis but are the result of mathematical investigation applied to sea experience with all types of construction, wherein stresses are kept within well-defined limits.

MERCHANT MARINE ACT.

The salient features of such rules were well known to the framers of the Merchant Marine Act of 1920, which, having been signed by the President of the United States, is now a law.

This act provides for the classification of vessels, other than military, owned by the United States, and for such other purposes in connection therewith as are the proper functions of a classification bureau. The act directs that all departments, boards, bureaus and commissions of the Government recognize the American Bureau of Shipping as their agency, so long as that bureau continues to be maintained as an organization which has no capital stock and pays no dividends. This being the case, it is deemed proper and opportune to review the history of the only existing American classification society and to show its growth and present condition.

HISTORY.

On April 22, 1862, the legislature of the State of New York incorporated the American Shipmasters' Association, the incorporators being men well known in shipping and maritime insurance.

The purposes of the association were those of collecting and disseminating information upon subjects of marine or commercial interest, of encouraging and advancing worthy and well-qualified commanders and other officers of vessels in the merchant service, of ascertaining and certifying the qualifications of such persons as shall apply to be recommended as commanders or officers, and of promoting the security of life and property on the seas.

The last-named purpose necessarily carried with it the preparation and adoption of rules for construction and survey which, when complied with in the construction of a vessel, entitled it to classification in the association.

The association continued to function under the title of "The American Shipmasters' Association" until the first of November, 1898, when, by order of the Supreme Court of the State of New York, the Association was authorized to assume another corporate name, namely, "The American Bureau of Shipping."

The Bureau affairs are administered by representatives of shipping interests in its broadest sense, and, although the Bureau is incorporated, it has no shares upon which dividends are payable. In other words, it has no capital stock and pays no dividends.

During the period which had elapsed from its original incorporation as The American Shipmaster's Association and its continuation as The American Bureau of Shipping, the work of classification had been chiefly confined to American built coastwise vessels. At one time the shipping interests of the United States under Federal aid, in the shape of wise legislation and encouragement, had assumed large proportions, but upon the withdrawal of such aid, and acquiescence with treaties decidedly favorable to foreign shipping, these interests gradually declined. This shrinkage, resulting in the relatively small amount of merchant shipbuilding done here, combined with the lack of vision on the part of the Bureau in not making alliances outside of this country, caused its power and influence to parallel the downward tendency of American shipping. In the meantime foreign classification societies, from large and extended experience, had so built up their staffs of advisers and surveyors, had so revised their rules and broadened their activities in all phases relating to building, insuring and salvaging vessels, that the American shipowners found their interests best served by building under foreign classification rules. This tendency became so pronounced that, prior to the Shipping Board assuming control of the building facilities of this country, 96 per cent of the United States seagoing vessels was built under the rules of foreign classification societies. Therefore, in 1915, the American Bureau found it necessary to reorganize and to consider the advisability of making connection with a foreign registration society in order to enlarge its operations and usefulness.

DECLINE OF AMERICAN SHIPPING.

Before entering further upon the history of the Bureau, it may be well to allude briefly to some of the causes of decline of American shipping and its reaction upon shipbuilding in the United States.

First and foremost of the reasons was the withdrawal of the discriminatory duties enforced by the Government in favor of American bottoms. This legislation had been so instrumental in building up the American marine that at one period American vessels carried by far the larger part of the world's commerce. Another cause of the downfall of the American merchant marine was the entering into of treaties which, to say the least, placed American shipping at a decided disadvantage with the carriers of other nations. The result was that little interest was taken by Congress in furthering the interests of the shipping of the United States from before the Civil War until the beginning of the Great War, the only aid extended being in the shape of mail-carrying subsidies. The shipbuilding interests naturally followed the decline in shipping. The good effect of discriminating duties in the past may well be closely studied in connection with the enforcement of recent legislation. Another feature was the development of internal transportation facilities which greatly influenced and held in financial subjection the natural development of the United State as a shipping power.

This influence is to be found in the rapid construction of the railway systems of this country. We have a tremendous area whose development depended upon means of communication one part with the other. This led to the building of great transcontinental railways, as well as lines connecting the northern and southern portions of our country. This and other necessary internal developments absorbed the financial energies of the country, and, while vast sums of money were raised and expended in the building of great railways, shipping, being of greater risk and its future to a great degree dependent upon congressional action, was not looked upon with favor as an investment nor given the consideration its importance demanded, by the financial powers of the country.

REORGANIZATION.

By the year 1915, or the second year of the Great War, shipbuilding in the United States becoming much more active, the American Bureau of Shipping, through its board of managers, called a special meeting for the purpose of considering the reorganization of the Bureau, of enlarging its usefulness by establishing faithful and accurate classification and register of mercantile shipping, and to aid in developing the merchant marine of the United States of America.

Looking to this end, a committee of reorganization was appointed at the meeting on October 8, 1915, consisting of P. A. S. Franklin, Chairman; Antonio C. Pessano, Walter Wood Parsons, Charles Skentelberry, Harvey D. Goulder, and William A. Dobson.

A number of meetings of this reorganization committee were held in the latter part of 1915 and the early part of 1916. At these meetings various maritime matters were discussed, including the renewal of negotiations contemplating an amalgamation of the Bureau with Lloyd's Register of Shipping, as well as one with the Great Lakes Register. Ultimately it was determined not to make the contemplated arrangement with Lloyd's but to continue the American Bureau of Shipping as a vital force in American shipping, it being the judgment of the committee that such course would be for the best interest of American shipowners, builders and underwriters, and from the fact that people in this country began to have a belated sense of national pride in the affairs of the merchant marine which called for the classification of American vessels by an American society and to desire insurance of American vessels and cargo, by Americans for the benefit of America.

At the meeting January 13, 1916, Mr. Stevenson Taylor was invited to attend, and on the following day he was made chairman of the reorganization committee at the request of Chairman Franklin, who resigned the office for that purpose.

GOVERNMENT AUTHORITY FOR CLASSIFICATION.

Advance in connection with American shipping developed very rapidly from that date on, and congressional action, taken in connection with vessels owned by the United States, made it absolutely necessary that there should be an American Bureau of Classification, recognized as the authority for the proper classification of its vessels. It can be seen clearly that no foreign classification society, or an American committee of a foreign classification society, could be accepted as an authority under which the interests of the American Government could be properly served. The recognition by Congress of the American Bureau of Shipping as the American authority placed it at once in an official position for the classification of government vessels and established it as a body capable of advising on kindred subjects; to this end, matters such as the determination of load line and freeboard were referred by the Government to the Bureau for advice and cooperation in considering legislation for a government load line for American vessels. It thus became necessary for the Bureau to come at once into the field so largely occupied by foreign classification societies, fully equipped to assume the requirements and duties of an American classification society.

FOREIGN CLASSIFICATION SOCIETIES.

It must be recognized that the Bureau had to contend with foreign registration societies, some over a century and a half old, whose growth had been marked by affiliation with insurance and salvaging companies which gave them a commanding position in maritime affairs. It must also be recognized that but five years had elapsed since the American Bureau of Shipping began to strengthen its forces and affiliations and to make a faithful and accurate classification of vessels and registry of mercantile shipping contributory to the development of the merchant marine of the United States of America.

The record as now compiled is a compendium of the general characteristics of the vessels admitted, in which are given the vessel's name and official number; the signal letters; the material of which the vessel is constructed; the number of bulkheads and decks; whether vessel is built with water bottom or not; whether fitted with wireless outfit and submarine signal apparatus; the hailing port; the registered dimensions; the gross and net tonnage; when built, and by whom; the owners; the particulars of engines, boilers and propellers and the class the vessel is given; so that by referring to the record the general information concerning any vessel is at once obtainable.

PURCHASE OF THE GREAT LAKES REGISTER.

In this country alone is to be found a chain of great cities located on interconnecting inland seas of fresh water, where vessels up to 600 feet and over in length are common carriers. Seasonal storms of great violence occur throughout the area of the Great Lakes, but the waves, while steeper than ocean waves, are not as long. Therefore the stresses on the main structure are not as severe, but weather deck structure and fittings are required to withstand the pounding effect of seas breaking on deck. A type of lake structure has thus developed that requires special treatment by the rules of a classification society.

To meet these requirements the Great Lakes Register was purchased in 1916 from its owners and incorporated with the Bureau as the Great Lakes Department.

ALLIANCE WITH BRITISH CORPORATION.

In the year 1917 the Bureau was convinced that the rules adopted by the British Corporation for the survey and registration of shipping were the most scientific of the rules in force for the construction of steel vessels, and after conference with said corporation an alliance was made whereby the British Corporation represents the Bureau in the United Kingdom, and the Bureau represents the British Corporation in the United States, on terms mutually satisfactory.

ALLIANCE WITH ITALIAN AND JAPANESE SOCIETIES.

Following this alliance in 1917, one of the same nature was made with the Registro Navale Italiano, and in 1920 one with the Imperial Japanese Marine Corporation. It will thus be seen that working arrangements have been made by the American Bureau of Shipping with the British Corporation, the Registro Navale Italiano and the Imperial Japanese Marine Corporation, by which each society represents the others in its home country. In the Japanese corporation, Mr. Fred F. Perris, long with the British Corporation, serves as technical adviser of the Japanese corporation. Prince Higasji Fushimi is honorary president, and Dr. Seichi Terano, of the Engineering College, Imperial University, Tokio, is vice-chairman. The head offices are in Tokio, and surveyors will be established in Yokohama, Kobe, Nagasaki and Osaka.

SURVEYORS PLACED ABROAD.

At the present time it can be said that all these alliances have been very satisfactory. During the past year offices and exclusive surveyors have been placed in Hamburg, Antwerp, Havre, Brest, Bordeaux, Rio de Janeiro, Buenos Aires and Valparaiso, and additional nonexclusive surveyors in Spain, Portugal and all important Mediterranean ports, including Constantinople.

ACTIVITIES OF THE BUREAU.

A table follows showing that for the past five years, or from 1916 to 1920, inclusive, the service furnished by the Bureau has grown in importance and has proved worthy of the confidence of the Government and of shipowners, as well as underwriters.

	1916	1917	1918	1919	1920
No. of ships classed	194	262	218	898	514
Gross tonnage classed	228, 539	550, 285	535, 232	3, 030, 962	1, 918, 007
No. of surveys made	572	780	795	1, 729	4, 122
No. of executive officers	2	3	3	5	5
No. of office employes	8	15	35	58	43
No. of surveyors (exclusive)	8	69	176	179	138
No. of offices	3	12	19	21	25

ACTION OF THE ATLANTIC COAST SHIPBUILDING ASSOCIATION.

The registration of American vessels by an American society has been considered so important that the Atlantic Coast Shipbuilders' Association, representing all the shipyards on the Atlantic coast, appointed a committee to cooperate with the American Bureau of Shipping in extending its efficiency in every way possible.

The following statements, made by the Bureau in response to suggestions of that committee, are quoted from the committee's annual report to the Shipbuilders' Association:

"In general the several suggestions which you sent us related to improving the efficiency of our surveyors wherever possible, the 'handling with greater speed of the review and criticism of plans in our New York office, and the possible granting of larger salaries to surveyors in order to secure the best talent.

"To all of these matters we have given most careful attention with a view of remedying conditions along those lines wherever possible so to do.

"As you well know, the shipbuilding business has undergone a great slump since your letter was received. This has necessitated the discharge of a number of our surveyors, and we have endeavored to retain the most competent. The lull has relieved the pressure in our technical branch at the New York office, and we feel quite sure that there can now be no just complaint concerning the celerity with which we handle all plans submitted.

"We wish to assure your committee that we will welcome any further suggestions it may care to make and that we are continuing our endeavors constantly to keep up our standards and improve our efficiency in every way feasible."

From this it will be seen that the Bureau is working in full harmony with the shipbuilders of this country and is rapidly gaining the confidence of shipowners, builders and underwriters.

GENERAL OUTLOOK.

One of the most important features of a classification society is that its surveyors shall be men in whom the shipowner, the shipbuilder and underwriter have confidence as to their experience, judgment and technical knowledge. From the above report it is apparent that the Bureau, by the process of selection and elimination, is acquiring a staff with the desired qualifications.

The technical committee of the Bureau is headed by no less an authority on hull construction than Admiral D. W. Taylor, U. S. Navy, than whom no expert speaks with greater weight on matters of construction and design. There is much to be accomplished by the Bureau in strengthening its forces and making affiliations for appraisal of damages and salvaging, but the record of the past five years argues well that these matters will be fully and ably dealt with. It has been well said by Mr. Walter B. Norris that "though the western frontier is gone, and with it the historic incitements of democratic character which it offered, the sea remains with its majesty, its independence and its call to imagination and courage, to keep alive the democracy and idealism which it helped to create in the typical American."

The typical American is returning to love of the sea and the opportunities it affords for advancement and accumulation of wealth. The American Bureau of Shipping has awakened to its opportunities and is strengthening its forces and enlarging its borders to meet the revival of interest in the merchant marine of the United States.

There can be no doubt that it is the patriotic duty of American shipowners, underwriters and builders to aid and encourage the Bureau in its efforts to build up an organization which, with its affiliations, shall be second to none in the world in the service rendered in classing, surveying, appraising, underwriting and salvaging vessels owned by the shipping interests of this country. If we are to have a prosperous growing merchant marine, we must also have an American classification society, capable of rendering aid of the best class to every phase of the shipping industry.

DISCUSSION.

The President:—Mr. Dobson's paper, "American Classification of American Vessels," is now before the Society for discussion. We will be glad to hear from any member. Due to the apparent reluctance of members to discuss naval and related matters this morning, we are comparatively well ahead of schedule time. Those who wish to submit their comment upon this entirely safe and important subject will have plenty of time in which to present their views.

Professor Herbert C. Sadler, *Member of Council:*—I would like to say, in connection with the American Bureau of Shipping, that frequently we have come across certain criticisms of the rules. These criticisms generally take the form that the rules lack simplicity as compared with the rules of some other organizations. I think it has been the experience of a good many men that it is a little easier to get out scantlings or midship sections from the rules of some other societies. That point, I believe, is being taken up by the American Bureau now in the endeavor to make the rules as workable as possible, and I would also like to point out this fact—that fundamentally the rules of the American Bureau of Shipping are more logical than some of the other societies, they are more flexible, and give the designer a little more scope, as the steps are not so great as in some of the others. If the Society would do a good deal of the work of tabulating instead of every individual having to do it, it would be of great advantage.

Mr. Hugo P. Frear, *Member of Council:*—I regret to say that I have not read Mr. Dobson's paper and did not anticipate making any remarks on it, but in view of the apparent lack of discussion, reference might be made to a point we are sometimes up against in dealing with classification societies; not to any greater extent, however, with the American Bureau of Shipping than with Lloyd's or any other society.

In cases of special construction, not covered by the rule where the scantlings have to be calculated, a much higher stress seems permissible for transversely framed vessels than is allowed for vessels on the Isherwood longitudinal system of framing. Stresses of 10 tons are common with transverse framing, whereas corresponding stresses for longitudinally framed vessels are confined to the neighborhood of 5 or 6 tons.

It has frequently been maintained that just as light vessels could be designed on the transverse system as on the longitudinal system if the same process of calculating the scantlings throughout was used. This could only be accomplished by increasing the stresses on the transverse system. If the same stresses were used in both cases, there would be a greater difference in the weights.

The President:—Is the present status of the American Bureau of Shipping such that no one desires to make any comment whatever as to its excellencies or possible shortcomings? There is a list of several names which have been handed to me.

Commander Stevenson Taylor, *Past President:*—That remark of yours, Mr. President, calls me to my feet, although I had no intention to say anything on this particular subject, being so personally interested in it. I have been rather waiting for something of this nature to be said. I recall being in Mr. Hurley's office some few years ago when he was the head of the Shipping Board, and he asked me that question directly: Were we perfect? Naturally, I hesitated, and then he said, "You are not perfect?" I replied, "No, not any more than your organization is." The American Bureau of Shipping only wants to do the right thing, first in the matter of making the ship safe, and next to help shipowners, shipbuilders and underwriters principally. I have taken many opportunities in the last five years to repeat that statement, and we are always ready to receive from anyone any hint or suggestion that will make the service better. There have been many criticisms of the service. Well, on March 1, 1916, we had five surveyors in the service, and one office; and a year ago we had 185 surveyors and about twenty-five offices—a very great growth in a very short time, particularly at a time when the sort of men needed to carry out the work of the American Bureau of Shipping was required in the many shipyards in this country. We are not perfect; we are not immaculate; and it would be easy to find some criticism, and I only urge on the friends of the American Merchant Marine the necessity of taking these criticisms to the headquarters of the American Bureau of Shipping rather than to go outside to talk about them. A day or two ago I had occasion to try to offset some criticism by getting at the facts. I asked the gentleman who made the criticism if he had ever called our attention to his complaint at all, the source of it, and the cause of it, and he said, no, he had not. I said. "Do you not think you should have done so?" His reply was: "Thinking about it, I believe I have been remiss, but I hated to butt into another man's business." This is everybody's business; it is no one man's business.

As indicated in the paper, the American Bureau of Shipping is a corporation without any capital stock, and every man who works for it earns his salary, and the total amount of salaries has been very materially increased in the last five years. For the first month after the reorganization of the bureau on March 1, 1916, the rate per annum for the payroll for every employee, from the president down to the office boy, was only $28,000. Last month I had the pleasure of signing checks amounting to very nearly $60,000 for the payroll of October only. That shows how the institution has grown. Next year will be our very bad year. Undoubtedly we shall lose some of the surplus we have been aiming to obtain in the last five years, because during the year 1921 there have been but two ships contracted for in the United States—one a Sandsucker out at Manitowoc, of 1,200 tons displacement, and another small ship, which is not classed at all, so that next year, should there be a revival in shipbuilding, there will not be any increase in the returns until a year after, and I am looking for a decline in the extent of ourservice, but not by any means any decline in the matter of the efficiency of it, and any hint which can be given to us, where our service can be improved, will be taken with a great deal of pleasure.

The President:—The Chair felt quite sure that the distinguished president of the American Bureau of Shipping would not let pass the opportunity to spurn the suggestion of their being immaculate or not being willing to accept suggestions for improvement. It is a very great pleasure for the Chair to state personally and on behalf of the Society, that the present standing, the present efficiency of the American Bureau of Shipping, is due to the devoted and efficient work of the president, its Board of Managers, and its executives, practically all of whom are members of this Society. When Commander Taylor says that the Society has no capital stock, he is quite correct; when he says the Society pays no dividends, I rather take issue with him. The dividends do not take the form of checks received, but they do take the form of giving protection to the entire merchant marine and affording an American method of giving the highest certificate of efficiency to American-built vessels. That is a dividend which is shared, not only by the merchant marine, but the whole American nation.

Will any other gentleman discuss this paper which Mr. Dobson has presented? If not, the Chair desires to express to the author the thanks of the Society for his contribution. While papers of this kind are not very provocative of discussion, they are very important to have in our records, and will be read with great interest by those who are not members.

I am requested to make the following announcement: The coast-guard cutter Tampa, equipped with a synchronous motor drive, is at Pier 59, foot of 18th Street, North River, and is open for inspection by members of the Society. She will remain there all today and tomorrow. It is understood that Colonel Simmons has made arrangements for taxicab service to the dock in connection with the Annual Marine Exposition of the Marine Equipment Association of America.

On Saturday, through the courtesy of the Shipping Board, the Victorious, latest freighter to be converted to electric drive, also the Leviathan, will be open for inspection to naval architects and marine engineers.

Tugs leave Pier 59, foot of West 20th Street, at 10 a. m. The Victorious is of 12,000 tons deadweight, 3,000 shaft horse-power, revolutions per minute, 100, magnetic and manual control, 3 Scotch boilers, 200 degrees superheat.

Complimentary tickets for visiting the ships may be had upon application at the enrollment desk in the lobby of the Central Mercantile Building.

The Marine Equipment Association has arranged to enroll members of the Society if they will stop at the registration table at the rear of the hall. Enrollment will admit members to the exhibition at the Central Mercantile Building without charge.

Due to the celerity with which the morning program has been disposed of, through no fault of the chairman, I hope, we are through well in advance of the usual time. It is important to call your attention to the fact that this afternoon at 2 o'clock there will be a joint meeting under the auspices of this Society and the American Institute of Electrical Engineers, at which two very important papers will be read, dealing with electrical propulsion and electrical auxiliaries. Unless all guesses fail, the time will not be sufficient this afternoon to permit all gentlemen who so desire to express their views, either for or against this method—at least that is a prediction based upon the experience of the past. Therefore please bear in mind the meeting at 2 p. m. This is a joint meeting, at which the president of the American Institute of Electrical Engineers will preside, and I hope there will be a full attendance and a complete discussion. If there is no further business, we will now adjourn until 2 o'clock this afternoon.

SECOND SESSION.

THURSDAY AFTERNOON, NOVEMBER 17, 1921.

The President, Admiral Capps, called the meeting to order at 2.15 o'clock.

THE PRESIDENT:—Appearances indicate very strongly that we are going to have quite a lively session. It is not well to begin with an excuse, but I do wish to apologize for being a little late for reasons which I could not personally control. I had to leave behind me thirty good men and true, who are very important members of this Society, and whom we hope to have with us in a short time. We are going to have presented to the Society this afternoon two very important papers on subjects that are interesting alike to the American Institute of Electrical Engineers and the Society of Naval Architects and Marine Engineers. With that condition before us, it was considered very desirable to have a joint session. The president of the American Institute of Electrical Engineers very kindly consented to preside. I therefore have great pleasure in presenting to you Mr. William McClellan, president of the American Institute of Electrical Engineers, who will please act as chairman of the meeting.

PRESIDENT MCCLELLAN:—Gentlemen, it gives me a very great deal of pleasure to be here personally and also officially, to take part in this meeting which expresses the cooperation of the electrical engineers with the naval architects and marine engineers in carrying forward one of the greatest pieces of work in connection with modern progress. Electricity gradually gets into almost every phase of our existence, and sooner or later it was bound to get into the great work of marine propulsion.

I always like to think, in connection with every engineering problem, that there is a social aspect to it, and that engineers do well to look upon that social aspect. We can always find it, because engineering is always done for the benefit of people in general. In this case, we find it because it has to deal with the easier exchange of goods, with the more frequent meeting of peoples, and the ease of getting from one place to the other, over the great natural highways provided for us. In connection with this great meeting which is being held in Washington today—of course, I have seen comments in the papers as to what it will do, and the effect it will have on certain activities in the world—fortunately for us, while there is great spectacular interest in a warship coming up the bay on a successful trial trip, nevertheless, after all, that is only one phase, even though the most spectacular and perhaps the most interesting phase. The activities of shipbuilders and shipowners are not going to be taken from them, and we shall have a great opportunity, as much as any group of engineers could demand, to bring this great work of ship propulsion by electricity and by every modern device to the greatest possible point of advance.

You know that we are accustomed to have certain things interrupt our plans at times, and we ought to get used to it. There is a man in this audience today—I think he will talk to you before the meeting closes—who has been spending much time on certain devices, to keep the ships on an even keel, making use of an old toy we were all familiar with at one time, the gyroscope. I understand that not very long ago he was hard at work on a device to be hung on the end of a watch chain, so that as long as you had that on your watch chain in your pocket, you yourself would remain on an even keel. An inconsiderate Congress passed a prohibition amendment, and that poor fellow finds himself obliged to turn entirely to some other field of activity. Meanwhile we are on an even keel, and not likely to go off it. That is a common experience we have all had, and the way to overcome such interruptions is to direct our energies towards the overcoming of them.

Today we have two very interesting papers, and I am going to call first, according to the program, for the paper by Mr. W. E. Thau, a member of the American Institute of Electrical Engineers, on "Electric Propulsion of Ships." Before doing so, however, I will remind you that, under the rules of the Society of Naval Architects and Marine Engineers, twenty minutes are allowed for the presentation of a paper in abstract, including lantern slides. Those who discuss the paper will have ten minutes for discussion, including lantern slides, and I ask each member who wishes to discuss the paper, when he starts to do so, to come forward so that he can face the audience, and his discussion will be much more attractive, more easily heard, and therefore much more effective. I have great pleasure in presenting Mr. W. E. Thau. Mr. Thau is connected with the Marine Department of the Westinghouse Company.

Mr. Thau presented an abstract of the paper.

ELECTRIC PROPULSION OF SHIPS.

By W. E. Thau, Esq., Member.

[Read at the twenty-ninth general meeting of the Society of Naval Architects and Marine Engineers, held in New York, November 17 and 18, 1921.]

This paper will deal primarily with the electric propulsion of ships, except wherein a comparison of some particular feature or characteristic warrants a reference to some other type of drive. In dealing with electric propulsion, it is necessary to consider all classes of ships, and this leads to two broad, general classifications, such as merchant ships and war vessels.

MERCHANT SHIP PROPULSIVE EQUIPMENT.

General Requirements.—The ultimate purpose of a merchant ship is to earn money. From this standpoint, the factors of reliability, economy, weight, space, cost, operation and maintenance are involved in the propulsive equipment. Therefore the type of drive best suited is that which excels in all or the most important of these factors. The relative importance of these items varies with different ships, depending upon the trade route, cargo, etc., with the result that there is a definite and logical field for each of the principal types of drives, such as reciprocating engine, geared turbine, turbine electric, Diesel and Diesel electric. Since many general comparisons of the principal types of drives in regard to these factors have been given in recent articles in the technical press, it is not the intent of the present paper to take up this phase of the subject, but rather to analyze the principal types of electric propulsive equipments and to show in general how they fulfil these requirements.

Reliability.—The universal use and the indisputable success of electrical apparatus on land is sufficient testimony in behalf of its reliability. The absence of reciprocating parts makes electrical apparatus with its simple rotation as reliable as can be desired. It can almost be said that there are no mechanical troubles with electrical machinery. Broadly speaking, there are no new principles involved in the application of electrical apparatus to ship propulsion. It is true that ship conditions differ from land conditions in certain respects, but there is no phase of the application which presents any really serious difficulty. The most important adverse condition is the deleterious effect of salt and moisture, which is easily surmounted by proper insulation of the windings and circuits, as is obvious from the several successful years of operation of present electric installations. There can, therefore, be no question as to the reliability of electrical propulsive equipment.

Economy.—Economy is an important factor and must be given due consideration. To properly analyze this item, it is necessary to consider all equipment involved in the propulsion with respect to fuel, water, lubricant and supplies. The relative proportions of these items vary considerably in the different types of propulsive equipments. The turbine electric and the geared turbine compare very closely in economy when all items are considered. The losses in the reversing elements of geared turbines, the losses in the gears and the power required to circulate the additional lubricating oil detract appreciably from the gain which the geared turbine would otherwise have over the turbine electric because of the inherent electrical losses in the latter. Generally speaking, the net economy of a properly designed and constructed geared-turbine drive should be better than a turbine-electric drive, even though full advantage is taken of every practical source of gain in the latter. The difference, however, is perhaps hardly of sufficient magnitude to be the dominating factor in arriving at a final selection. The economy of a reciprocating engine drive is obviously poorer than that of a properly designed turbine drive of either type, for the reason that the reciprocating engine cannot utilize the same expansion of the steam.

It has been advanced that the turbine for the turbine-electric system, being a one-direction rotation machine, can utilize higher superheat than the geared turbine, because of the reversing element of the latter, thus resulting in better overall economy. With the present installations this condition is true to some extent. However, with proper attention given to this factor, geared turbines can be designed to operate without detriment with steam superheated 150° F. to 200° F., which is fairly close to the practical limit of superheat on board ship, as there are other items aside from the turbines which are affected by high superheats to the extent of fixing limitations.

Obviously from a fuel-consumption standpoint, the direct Diesel and Diesel-electric propulsive equipments offer by far the best economy. Of these two types, it would appear offhand that the direct Diesel drive is decidedly superior to the Diesel electric; however, it will be shown later that there are certain limitations in the direct Diesel drive which offset its advantage in fuel per brake horse-power hour over the Diesel electric. Here again it is obvious that all items related to the propulsive equipment must be taken into consideration to obtain the ultimate answer.

Weight.—The item of weight would probably show more variance than other items owing to differences of arrangement, design, foundations, etc., in the practice of the several shipbuilders. The importance of weight depends upon the type of ship, cargo and trade route. Usually, however, weight is an important item as it has a direct effect upon the total fuel consumption and the amount of cargo that can be carried with a given displacement. Here again it is necessary to consider all items related to the propulsive equipment. A correct comparison of weight necessitates that the equipments under consideration be on the same basis relative to overload, factor of safety and arrangement. This is particularly important in comparisons between electric-drive equipments. Where one equipment affords an advantage in flexibility of reserve, however, it is usually at some sacrifice in weight, and an allowance must be made.

Space.—Space is important in that it has a direct bearing upon the bulk of cargo that can be carried. Its relative importance depends somewhat upon the location of the machinery, *i. e.,* whether the machinery is located amidship or aft, or both. Space is affected by the distribution of machinery, and the relative saving depends somewhat upon the practice of the various shipbuilders in that respect. General analysis of the space factors which have been made thus far gives the advantage to the direct-connected Diesel and Diesel-electric types of propulsive equipment, the saving being effected by the elimination of the boilers and reduction of fuel and water tanks. Of the turbine-electric and geared-turbine types, the space factor is in favor of the geared turbine, except in special cases. The general arrangement of the engine-room, number of propellers and the beam of the ship have a direct effect upon the space occupied as a result of machinery distribution. By locating the condensers underneath the turbines in electric drives, the total floor space can be greatly reduced.

Cost.—A definite comparison of costs is still a difficult task, owing to the continued unsettled conditions. On the basis of equal performance in regard to propeller torque and speed, the cost, including all items related to the propulsive equipment, should run in the order of direct Diesel, turbine electric, geared turbine and Diesel electric, the latter being the cheapest. The paradox in the relative cost of direct Diesel and Diesel electric is explained by the condition that small Diesel engines and generators for Diesel electric drives can be manufactured ultimately on a large production basis and stocked, whereas the engines for direct Diesel drive and, to a large extent, the two types of turbine drive, because of their large size and weight, must almost of necessity be a building proposition. On the basis of standardized drives there should not be a great deal in favor of the geared turbine as compared with the turbine-electric drive. This comparison will vary somewhat with the different manufacturers.

The initial cost of the propulsive equipment has a direct effect upon the net earning power of the ship, because of interest, depreciation and insurance charges, and therefore cost is an important item.

Operation.—In regard to operation, it is realized that the present operators are largely men who are more familiar with reciprocating engines than with other types of machinery, and that for this reason certain difficulties are likely to be encountered in placing electrical equipments in their hands. The author believes that this thought should not be a consideration, as it is a temporary condition only. The horse-car driver became the motorman of the electric car, the reciprocating plant operator became the turbine plant operator in the central station, the steam locomotive engineer became the electric locomotive engineer (engineers now operating electric locomotives are reluctant to return to the steam locomotive), and similarly countless examples may be mentioned to show that change in machinery represents no obstacle. Successful operators of electrical machinery need not have sufficient knowledge of it to understand the details of its design. This is not the case on land, and there is no greater reason for it on the sea. The operator should, however, know the operating characteristics of electrical apparatus and how to take care of it.

The same question was raised in the case of geared turbines only a few years ago, yet today there is nearly a sufficient number of competent geared-turbine operators to take care of all the geared-turbine ships. The same will be the case with operators for electric ships. It is merely a matter of training and education, and it is certainly a reflection upon the intelligence of the age to classify the present limited knowledge as an obstacle for consideration.

On page 110 is a probable list of the operating personnel for the principal types of drives. The cost of operating personnel as based upon this list would therefore be in the order of direct-connected Diesel, turbine electric, geared turbine, reciprocating engine, and Diesel electric.

Maintenance.—Although there are practically no data available on the maintenance of electrical propulsive equipments (except battleships), there is no reason to anticipate any great difference between sea and land practice. As a matter of fact, there is reason to anticipate less maintenance for the reason that the load conditions and control operations are less severe than is the case with most land installations involving large machinery. If the equipment is given proper care and inspection, the maintenance item will be low, as the absence of rubbing parts (except for the bearings) leaves little to get out of order. Electrical machinery does not wear as is the case with other machinery. Furthermore, all probable repairs are such as can be made aboard the ship without the use of an elaborate machine shop.

Performance Characteristics.—The inherent performance characteristics of electrical machines are particularly well suited to ship propulsion. Having identical operating char-

Table of Probable Operating Personnel.

	Reciprocating engine*	Geared turbine*	Turbine electric*	Direct-connected Diesel	Diesel electric
Total crew					
Chief	1	1	1	1	1
1st assistant	1	1	1	1	1
2nd assistant	1	1	1	1	1
3rd assistant	1	1	1	1	1
Junior engineers	0	0	0	3	0
Electricians	0	0	1	1	1
Oilers	3	3	3	6	6
Firemen	6	6	6	0	0
Total	13	13	14	14	11
On each watch					
1st, 2nd or 3rd	1	1	1	1	1
Junior engineers	0	0	0	1	0
Electricians	0	0	0	0	0
Oilers	1	1	1	2	2
Fireman	2	2	2	0	0
Total	4	4	4	4	3

* Based on oil-burning ships. For coal ships, the operating personnel would be augmented by three coal passers.

acteristics in either direction of rotation, all types of electric drive inherently afford, or can be made to afford, full torque and power for reversal. For reasons of economy, space and cost, the reversing element of a geared turbine is designed to give only 40 to 60 per cent power in the reverse direction. It has been claimed that full reverse power is not essential to a merchant ship, and this is true under ordinary conditions. In emergency, however, it is desirable to stop the ship very quickly, and in this connection it might be pointed out that the electric ship can be stopped in considerably less time than a geared-turbine ship. This is not altogether the result of less backing power but is due to a great extent to the inefficiency of the reversing element of the geared turbine causing an enormous draft on the boilers which greatly reduces the steam pressure.

In reversing, the energy put into the screws by the action of the water and the stored energy in the rotating parts attached to the propeller shaft must be dissipated in some manner. In the case of the geared turbine this energy is consumed in doing work on the steam. In the case of A. C. electric drives, the energy of reversal is dissipated in the motor and generator windings, the rotors of the motors, or in external resistors connected to the rotor circuits, depending upon the type of motor used. In D. C. electric drives the reversal energy must be absorbed elsewhere in the system. The amount of energy to be dissipated or absorbed in the case of a given ship depends entirely upon the time taken to stop the screws.

The instant the screws commence to turn over in the reverse direction, the system must supply the energy and all further stopping energy is dissipated at the propellers. There are two factors to be considered in stopping, namely, the energy returned through the propellers and the stored energy in the propellers and the motor armatures. Analysis shows that reversing even at full speed is not a serious problem and that it does not place as severe requirements upon the electrical machinery as does turning with hard-over rudder. The details of the distribution and absorption of the energy of reversal would occupy too much space to be discussed at this time. Suffice it for the present to say that the inherent facilities afforded by electrical systems for dissipating energy and for giving full power in either direction are what make the electric drives ideally suited for stopping. The time required to stop an electric ship is the same as, or less than, that of other drives.

DESCRIPTION OF ELECTRICAL PROPULSIVE EQUIPMENTS.

General Classification.—Electrical systems for ship propulsion may be classified into two general types from the standpoint of the prime movers, namely, turbine electric and Diesel electric. Due to the inherent performance of these two types of prime movers, both kinds of electric machinery are used—A. C. machinery with turbine electric because the A. C. generator is inherently suitable for direct connection to the economical high-speed turbine; and D. C. machinery with Diesel-electric drive because the inherent characteristics of the D. C. generators are ideally suited to Diesel engine performance.

The electrical equipment for turbine-electric drive may be further subdivided as follows, in regard to the type of motor:

1. Induction.
    - Wound secondary
        - Ordinary, and with power factor correction.
    - Squirrel cage.
    - Combined squirrel cage and wound secondary.
2. Synchronous.

In the case of the Diesel-electric drive there is no broad subdivision. As a minor classification, this type of drive might be subdivided with respect to the method of generator operation, *i. e.,* series and parallel. However, series operation is so vastly superior that parallel operation can be disregarded except for the purpose of comparison.

Units Involved.—A complete turbine-electric drive involves the following apparatus: Boiler plant, evaporation plant, condenser plant, turbine, generator, motor, oiling system, exciter set, control.

A complete Diesel-electric drive involves the following apparatus: Diesel engines, generators, motors, small auxiliary air compressors, air bottles, exciters, fuel pumps (if not attached to engine), lubricating pumps (if not attached to engine), control.

Turbine Electric.—With turbine-electric drive, the electrical equipment is of the A. C. type, principally for the reason that A. C. turbo-generators are inherently better suited for the high economical speeds of turbines. The speed at which the turbine operates is influenced by the propeller speed because of the limitation in the number of poles of the motor. Theoretically, an A. C. motor can be built for any even number of poles, but in practice such factors as power factor (induction motor), diameter and assembly fix the upper limit in the neighborhood of 60 to 72 poles. As the motor speed and number of poles fix the generator and turbine speed, there is consequently an approximately fixed limit to turbine speeds. Incidentally, in the case of practically all merchant ships this speed is lower than the most economical speed of the turbine. As the propeller is most efficient when designed and operated at low speeds, it is advisable not to exceed 90 to 100 revolutions per minute for the ordinary merchant ship.

Assuming a propeller speed of 100 revolutions per minute, a 60-pole motor and a 2-pole generator, the generator and consequently the turbine would operate at 3,000 revolutions per minute (neglecting the slip in case of the induction motor). This gives a reduction from the turbine to the propeller of 30:1, which is approximately the same irrespective of the type of motor used.

Fig. 1, Plate 13, shows a diagrammatic scheme of connections for an induction-motor drive of the wound secondary type. Power is supplied from the turbine-driven generator to the induction motor through one of the reversers. The generator is excited from one of the auxiliary geared-turbine D. C. sets. Whether the auxiliary set would supply generator excitation only or simultaneously furnish ship's auxiliary power depends principally upon the electrification of engine-room auxiliaries, winches, etc.

The turbine is under the control of a governor capable of maintaining constant speed over about 75 per cent of the entire speed range. The governor speed-control valve is regulated from the control stand by an oil relay valve or system of rods and levers, depending upon the type of governor used. The propeller speed is adjusted by throttling the turbine as in the case of a geared-turbine drive. The turbine is started and brought up to its "idling speed" by the throttle valve at the turbine.

Similarly, the generator field switch and rheostat and the ahead and back switches are controlled from the control stand by means of levers. These levers are mechanically interlocked, so that it is necessary to follow the proper sequence of operations in starting, stopping and maneuvering.

Usually the reversers are interlocked with the field lever so that the field lever must be in the "off" position before the reversers can be opened or closed. Similarly, the field is interlocked with the turbine speed-control lever so that the control valve must be set for low speed before the field can be opened or closed.

The secondary control is automatic, being either of the solenoid contactor or motor-operated contactor type. The actuating means is energized through contacts on the field lever near the end of its stroke. This arrangement insures the establishment of voltage at the motor before closing the secondary accelerating switches. Similarly, moving the field lever to the "off" position opens the secondary switches.

The operating levers and a complete complement of electrical instruments and steam gauges are arranged convenient to the operator, the instruments and gauges being mounted on a panel directly above or in front of the levers. By observing the instruments, the operator will be kept informed at all times of the performance of all machines, even though the machines be obscured from his view.

By a suitable arrangement of the switches and control levers, the entire maneuvering of a ship of any size and any number of screws can be under the complete control of one operator.

The interlocking system necessitates the following sequence of operation:

A. Starting Ahead (Turbine Idling):

1. Close reverser in "ahead" position,
2. Close field and establish excitation,
3. Adjust turbine speed to desired value after secondary is completely short-circuited. (Indicated by pilot light.)

B. Stopping:

1. Move turbine speed control lever to idling position,
2. Move field lever to "off" position,
3. Move reverser to "off" position.

C. Starting Back:

1. Close reverser in "back" position,
2. Close field and establish excitation,
3. Adjust turbine speed to desired value after secondary is completely short-circuited.

D. Reversing (from Ahead Operation):

1. Move turbine speed control lever to idling position,
2. Move field lever to "off" position,
3. Move reverser from "ahead" to "back" position,
4. Move field lever to full excitation,
5. Bring up turbine speed after motor has pulled into step.

The above description applies to a single-screw drive having but one turbine set. For a multiple-screw ship having generating sets for port and starboard sides, the operation would be the same for each side of the ship, as just described.

The above operations are based upon switching when the current in the circuits has been reduced to very low values, or nearly dead circuit conditions. This arrangement is not really necessary, as with such small powers it is not essential to open the generator field; however, it may be justified in the light of conservatism. In any event, the reversers are so designed that they are entirely capable of opening full power.

The salient features of the wound secondary induction motor drive are its inherent torque characteristics and the ease of handling. While the secondary control necessitates a few additional switches, this is fully compensated for by the fact that the propeller energy of reversal and the slip energy of reversal and starting are dissipated in resistors external to the motor. The importance of this is dependent upon the amount of reversing that is done, particularly from full speed. This system, therefore, represents the most conservative arrangement of turbine-electric drive.

The squirrel cage motor system is shown in Fig. 2, Plate 13, and it will be noted that the electrical connections are the same as for the wound secondary motor system, except that there is no secondary control. This system is therefore somewhat simpler than the wound secondary motor system from an electrical connection standpoint, both inside and outside the motor. It also has a slight advantage in cost in that the motor is less expensive to build. The squirrel-cage motor is shorter because of the absence of collector rings. It has a disadvantage in conservatism and torque characteristics.

The power factor of either of the induction motor systems is less than unity, the exact value depending upon the number of poles and certain design features. For the ordinary merchant-ship requirements these motors would have power factors of approximately 70 per cent, the wound secondary motor having the higher power factor of the two by a small amount. The induction motor drive therefore requires a generator with KVA. capacity in excess of its KW. capacity, which adds somewhat to its weight and size, and which detracts a very small amount from its efficiency.

The efficiency of the squirrel-cage induction motor of ordinary design is slightly less than that of the wound secondary motor, for the reason that sufficient permanent resistance must be incorporated in the rotor windings to obtain the required torque for reversal without excessive current. In motors with special double secondary windings, the required torque can be obtained without excessive current, and the running efficiency can be improved somewhat. Such motors are in use on propeller drives at the present day.

Turbine Electric (Synchronous).— Fig. 3, Plate 14, shows a diagrammatic scheme of connections for a synchronous motor drive. Power is supplied from the turbine-driven generator to the synchronous motor through one of the reversers. The generator and motor fields are excited from a three-wire D. C. exciter set. The synchronous motor system differs from the induction motor system only in so far as the synchronous motor itself affects the details of control and generator capacity, the main features of turbine-electric drive being otherwise the same.

Although the characteristics of the ordinary synchronous motor are not suitable for ship propulsion, the synchronous motor can be modified to give characteristics which meet the requirements. The modification consists in providing the rotor with a substantial induction winding of such design and arrangement as will not seriously detract from certain purely synchronous motor characteristics which are desirable.

The maneuvering operations can be accomplished in more than one way. If appreciable torque is required to reverse, the method which appears to be most favorable is to utilize the synchronous characteristics and the induction characteristics at different stages of the reversing cycle. The motor is stopped as a synchronous generator loading into the generator windings which form a dead load (generator field not being excited), then is brought up to nearly synchronous speed in the reverse direction as an induction motor, and finally is pulled into step with the generator as a synchronous motor. With this method, the sequence of operation for reversing would be approximately as follows:

1. Reduce turbine to idling speed (25 per cent),
2. Open generator and motor fields,
3. Reverse motor connections,
4. Apply motor field excitation bringing motor to rest,
5. De-energize motor field,
6. Energize generator field to double value, bringing motor to nearly synchronous speed as induction motor,
7. Apply normal excitation to motor field, pulling motor into synchronism with generator,
8. Adjust speed to desired value.

The method described above is preferable where appreciable torque is required during reversing. Usually, however, sufficient torque will be developed by the simpler method of reversing as an induction motor, in which case the cycle of operation will be as follows:

1. Reduce turbine to idling speed (25 per cent).
2. Open generator and motor fields.
3. Reverse motor connections.
4. Energize generator field to double value, bringing motor to rest and reversing it to nearly synchronous speed, as an induction motor.
5. Apply normal excitation to motor field, pulling motor into synchronism with generator.
6. Reduce generator field to normal.
7. Adjust speed to desired value.

This method, therefore, simplifies the sequence to the extent of omitting one step and eliminating the generator action of the synchronous motor.

Although 8 and 7 steps respectively have been indicated in the sequence, as a matter of fact some of the steps are combined so as to reduce the actual number of levers and operations to a reasonable amount.

Although the synchronous motor requires special design and introduces additional complications in the control, it has the important inherent characteristics of unity power factor. The unity power factor results in slightly decreased weight and size, and consequently less cost of the motor and generator. Taking the drive as a whole, and considering that both motor and generator must be excited from a separate source at a cost of at least twice the steam per KW. hour as the main turbine, the efficiency improvement over the induction motor drive is more apparent than real. Therefore the principal advantages of the synchronous motor drive as compared with the ordinary induction motor drive are a slight saving in cost, weight and space, with a possible inappreciable margin in efficiency. A somewhat larger air gap and greater ease of repair are claimed by some as additional advantages.

Turbine Electric (*Induction with Power Factor Correction*).—The unity power factor advantage of the synchronous motor system is also available with a wound secondary induction motor system in which the low lagging power factor is corrected to unity. This arrangement not only provides a system of the same weight, space and cost of the synchronous system, but in addition possesses the superior torque characteristics and simplicity of control of the wound secondary induction system.

The diagrammatic scheme of connections is shown in Fig. 4, Plate 14. It will be noted that this is the same as the wound secondary induction motor system shown in Fig. 1, except that power factor corrective apparatus has been added. The scheme functions in the same manner and sequence as that shown in Fig. 1 until the motor is in step with the generator, and at this point the power factor corrective apparatus is caused to function. The corrective apparatus consists of a Le Blanc phase advancer driven by a small D. C. motor, the speed of which may be varied to suit the power factor correction desired. The function of the phase advancer is somewhat similar to that of the D. C. exciter in the case of the synchronous motor in that it supplies excitation to the induction motor. The connection is made to the secondary or rotor winding, and thus excitation is supplied through the secondary instead of through the primary, with the result that the primary current is all "power" current, which means "unity" power factor.

The phase advancer is a small commutating machine of very simple construction. The losses in the phase advancer consist of the internal copper loss due to the secondary current, almost negligible iron losses, friction, windage and brush drop. The total of these losses is very little and compares very favorably with the excitation power of the synchronous motor.

The induction motor used with this system is simple in construction, smaller, lighter and consequently less expensive than the motor used with the ordinary wound secondary induction motor system. The generator is the same as that for the synchronous motor drive. Thus the induction motor drive with the phase advancer not only provides the advantages resulting from unity power factor, but in addition provides the superior torque characteristics of the wound secondary induction motor for maneuvering, and also obviates the necessity for synchronous operation with the generator. In fact, it combines all the really desirable features and characteristics of both systems, without complications.

Diesel Electric.—For practical reasons, direct current only is feasible with Diesel electric drive. This will be evident by a proper analysis of the performance of Diesel engines in connection with the characteristics involved in applying A. C. and D. C. machinery, due consideration of ship requirements being taken into account. To obtain the best results with Diesel electric drive, it is necessary to provide several relatively small and moderately high-speed generating sets for supplying power to single or double-unit direct-connected propelling motors. Not only must the generated power divide evenly or proportionately between the generating units, but the system must also be such as will conveniently and economically lend itself to speed control.

In the case of alternating current it would be necessary to operate the generators in parallel. To operate A. C. generators in parallel necessitates the very closest speed regulation and practically identical angular velocities of all prime movers. To properly visualize this exacting requirement it must be remembered that satisfactory parallel operation of A. C. generators necessitates that the angular displacement of the field poles of one machine with respect to another must not vary more than approximately ± 3 electrical degrees, or a total of 6 electrical degrees. Since 360 electrical degrees constitute the space between adjacent like poles, the total variation in mechanical degrees, for example, in the case of a 20-pole machine must not exceed 0.6 degree. While succesful operation under such requirements is carried out in several land installations where the prime movers operate at constant speed, it is not considered safe practice on board ship where the necessity for varying the speed of all sets simultaneously introduces another very serious difficulty. To overcome this condition successfully would require absolutely perfect engine governors which would function 100 per cent perfect at any speed setting. The speed of the motor could be varied by the rheostatic method, thus allowing the engines to operate at constant speed; however, this method is extremely wasteful at reduced speed operation and at best offers a solution for only one of the many difficulties. It is for these reasons that alternating current is not suitable for Diesel electric propulsion.

Direct current not only obviates all of the above difficulties but possesses many advantages in the way of operation, control and reserve power. With direct current we have the choice between two methods of generator operation, *i. e.,* parallel and series. From the standpoint of engine performance only, parallel operation of D. C. generators is entirely feasible and easily accomplished. However, when considering economical methods of speed control of the propeller motors, another factor enters which makes parallel operation difficult, even with D. C. machines. This is explained below.

With direct current we have a choice between two methods of motor speed control, *i. e.,* armature rheostatic and generator voltage control. Armature control is not only unjustifiably wasteful at reduced speed operation but also adds complication to the control. On the other hand, the voltage control method is practically 100 per cent economical and provides an ease and a flexibility of control unapproachable by other systems. In the case of very small drives, armature rheostatic control might be selected because of factors not related to the propulsive equipment making it preferable to have a constant voltage system which is common to the propulsion and auxiliary circuits. For a drive of any appreciable size, the best results are obtained by isolating the propulsive equipment so that immediate maneuvering can be done without affecting non-related circuits. Therefore, having an isolated plant for propulsion only, voltage control is obviously the method to use.

With parallel operation of generators, voltage control is not simple of accomplishment. To satisfactorily vary the voltage of two or more generators simultaneously over the full range from zero to maximum necessitates very closely and very carefully adjusted field rheostats, generators with practically identical saturation curves and engines with practically identical regulation, or some complicated and delicate automatic voltage balancing instrument.

The series arrangement of generators, however, is ideal from every standpoint such as operation, control, economy, simplicity, flexibility, reserve, etc. The series arrangement, in eliminating parallel operation of generators, obviates the necessity for close regulation, and hence simple engine governors and simple field rheostats are entirely satisfactory. In other words, satisfactory operation is independent of variation in voltage between the different generators.

Besides the operating advantages, the series arrangement inherently provides for full power from each of the remaining generators in case of casualty to one or more of the generating sets without providing additional capacity, and consequently additional weight in the motor. To obtain full power from each of the remaining sets with parallel operation would necessitate increasing the motor field in order to lower its speed to such a value as would require the total capacity of the remaining units, thus necessitating a larger and heavier motor.

Fig. 5, Plate 15, shows a diagrammatic scheme of connections for a single-screw Diesel electric drive. In this particular case there are six generating sets and one double-unit direct-connected motor. The six generators and the two motor units are connected in series. The machines are distributed electrically as follows: 3 generators, 1 motor unit, 3 generators and 1 motor unit, to reduce the voltage strain, or the maximum voltage to ground at any two points to one-half the total voltage of the system. The voltage of each generator being 250, we have in effect a 1,500-volt system with only 750-volt insulation requirements. The advantages of this arrangement are obvious, especially in the case of large capacity drives and where there are several generators involved. The diagram shows an arrangement for using as many as may be desired of the main generating sets for supplying power to the ship's auxiliaries when in port. Although the generators (and motors) operate as pure shunt machines when driving the ship, series windings on the generators are automatically placed in circuit when the generators are connected to the auxiliary bus, and therefore the generators operate as compound machines when supplying the auxiliary load, and when used for this purpose the generators are operated in parallel. Arranging the generators for supplying power to the ship's auxiliary bus determines the voltage of the individual machines (250 volts).

The motors and generators being pure shunt wound machines, the motor speed is adjusted to any value within the requirements by the voltage control system. In this system the generator and motor fields are separately excited (preferably from the same excitation source). The motor fields are excited at constant potential, and in one direction, whereas the generator field excitation is varied to obtain the motor speed desired. With this arrangement the speed of the motors is directly proportional to the generator voltage, and therefore any motor speed from zero to the maximum in either direction is obtained by merely manipulating the generator field rheostat (a common rheostat is used for all generators). Since the rheostat handles only the generator field current, which is 1 to 1½ per cent of the generator rating, the simplicity and economy of the control are obvious. With the type of rheostat used, the excitation of the generators may be varied from full excitation in one direction to full excitation in the opposite direction, without opening the field circuit, and therefore the ship can be brought from full speed ahead to full speed astern without opening a single circuit.

Reserve power in the event of casualty to prime movers is greater with this type of drive than with any other. On the basis of the power varying as the cube of the speed, a three-engine unit Diesel electric ship can make 88 per cent speed with two generators and 70 per cent speed with one generator.

The Diesel electric has the greatest range of application of any of the economical drives (geared turbine and turbine electric not excepted). Because of the inherent merits of this drive, it is very suitably applied to merchant ships, barges, river boats, lake boats, ferry boats, small coastwise vessels, yachts, fishing boats, coastguard cutters, cable-laying ships, and any ship within its capacity requiring refined control and economical operation over a wide range of speed.

As compared with any type of steam drive, the principal advantages of the Diesel electric are: Fuel consumption; weight; control; considerably more reserve power in case of casualty to prime movers.

The principal advantages of the Diesel electric drive as compared with direct Diesel drive are:

Reliability.—Cylinder parts being thinner are not subjected to such high temperature strains in heads and liners as are the large slow-speed engines, and consequently there will be fewer breakages of these parts. Years of application and service demonstrate beyond a doubt the full reliability of electrical machinery.

Maneuvering Ability and Control.—The control is extremely simple, easily understood, and can be placed anywhere on the ship. The engines run at constant speed, and hence the engine reversing gear is eliminated.

Weight.—On a very conservative basis, the Diesel electric should show at least 100 pounds less per propeller shaft horse-power.

Propeller Application.—Propeller speed not restricted, and in the case of large ships one propeller would be used for Diesel electric, whereas, because of engine conditions, two would be used with direct Diesel.

Reserve Power in Case of Casualty.—Very much greater with Diesel electric.

Maintenance.—For reasons under "Reliability," the maintenance should be less. Furthermore, due to smaller parts and reserve power, repairs to Diesel electric engines can usually be made on board ship while under way, providing sea conditions permit. The engines for Diesel electric are designed and built on the same conservative basis as direct-drive Diesels and are not the high-speed, short-lived submarine type.

Less Starting Air.—Diesel electric requires starting air only during the initial start in port. Subsequent engines may be started electrically. No air is used during reversing, and consequently the air problem is reduced to simplest terms.

Fuel Consumption.—There would be little difference in the net fuel oil and lubricating oil consumption as the increased efficiency of screw and the reduced strutt losses, with the low-speed single-propeller Diesel electric, offset the twin-screw arrangement of the direct Diesel. From a standpoint of piston speed, the engines used for Diesel electric drive are no different than direct-connected engines. (The former exceeds the latter only *in revolutions per minute.*)

Cost.—The cost of Diesel electric in some cases is less than the cost of direct-connected Diesel drive on present-day figures and will generally show a greater gap when fully developed along standardized lines.

GENERAL SUMMARY FOR MERCHANT-SHIP ELECTRIC DRIVES.

In the way of a summary relative to all types of electric propulsive equipments for merchant ships, the following salient features may be reviewed:

1. Electric drive is as reliable as any drive suitable for ship propulsion.

2. Maintenance and repairs should not exceed those of other drives, and in some cases should show a saving.

3. Electric drive is ideal for ship propulsion and will soon be recognized, if it is not already recognized, as a standard type along with the reciprocating-engine, geared-turbine and Diesel-engine drives.

4. Electrical machines have longer life than engines or geared turbines (drives) and do not decrease in efficiency with age.

5. Electric drive (Diesel electric) is as reliable as any economical drive, generally weighs less than any other drive, is as economical as the best, in most cases costs less than any other drive,* provides more reserve power in case of casualty to prime movers, and affords simplest and most flexible control.

WAR VESSELS.

The electric propulsive equipments for war vessels have been described and discussed in many articles in the technical press, and therefore only the principal phases will be dealt with here.

The fact that the last nineteen capital ships of the U. S. Navy are or will be equipped with the electric drive is sufficient testimony in behalf of what the builders and users of war vessels think of its merits. The prime requisite of reliability in any type of machinery designed to propel war vessels was recognized in the electrical machinery at the time of the first installation. Also the calculations showed that the unit fuel consumption over a wide range of operating speeds should be better than anything yet proposed. Service operation of two 30,000-horse-power electrically propelled battleships has indisputably proven that the reliability is all that was claimed, and that the fuel economy, as compared with other ships of the same type using direct-connected turbines with geared cruising turbines, is vastly superior.

Two other factors in which the electric drive shows a marked improvement over other drives have been emphasized since the first battleship was built, namely, the superior protection from torpedo attack afforded the machinery by virtue of the arrangement of the electric plant and the superior maneuvering qualities of the electric drive. The large horse-power requirements of the present war vessels (60,000 horse-power and 180,000 horse-power) preclude the use of reciprocating-engine drive, and this leaves electric drive with a decided maneuvering advantage over any other form of turbine drive.

Of the two types of electric propulsive equipments, only the turbine electric is suitable for propelling war vessels, because of the large capacities required. The nineteen drives installed and building employ essentially the same system in that induction motors are used in all cases. In details, the systems differ in regard to the type of induction motor. Of the three ships in service (the Maryland having been recently commissioned), the New Mexico motors have the double squirrel-cage rotor winding, the Tennessee motors have the form-wound rotor with external starting and maneuvering resistance, and the Maryland motors have combined single squirrel-cage and form-wound rotors. Each of these arrangements has its advocates. However, continued service alone will decide which method is the most suitable, all factors being considered.

Because of limitations in weight and space factors, electric drive is not well suited to small, high-powered, fast craft such as destroyers and scout cruisers. In the case of ships where conditions are suitable for electric drive, the following discussion of the more important factors will be of interest:

*It is predicted that future developments will bring the item of cost below that of any other drive.

Reliability.—In all phases of the industrial field where electricity has entered, it has proven its reliability. With a good record for reliability behind it, electricity has set out to establish a similar record on the sea, and the experience of the two large battleships thus far equipped with electric propelling machinery, and in service, shows that there will be a duplication of past satisfactory performance. The electrical machinery will be found to be in good condition long after the ship has become obsolete.

The arrangement of units and distribution of power make it possible to supply balanced power to all screws in the event of casualty to one of the prime movers. In other words, the electric drive possesses an inherent advantage in regard to reserve power.

Economy.—Regardless of calculations, the recorded performance of the electrically propelled battleship New Mexico has proven the superiority of the electric battleship in respect to fuel consumption. Recently published figures in the *Marine Review* show that the Idaho and Mississippi use 20 per cent more oil at 10 knots than the New Mexico, 42.7 per cent more at 13 knots, 48 per cent more at 16 knots, 40.1 per cent more at 19 knots, and 32 per cent more at full power. This superiority in fuel consumption is not altogether due to the main units, as the figures include the oil consumed by the auxiliaries. There is enough difference, however, to show conclusively that the comparison is very favorable to the electric ship.

That the advantage in fuel consumption demonstrated by the New Mexico is not a mere incident, it is well to note that the Tennessee, which is a later ship, is showing even better results than the New Mexico, as was indicated when the two ships steamed together during recent maneuvers of the Pacific fleet. Accurate measurement of unit fuel consumption during the official trials of the Tennessee showed that the actual steam consumptions were less than the guaranteed figures by amounts varying from approximately 3 to 8 per cent. Thus the art of electric propulsion is still progressing. The answer is found in the use of only a sufficient number of turbines for the load conditions and in the two speed motors, the combination of which maintains a higher average load on the turbines at a higher average speed.

Maneuvering.—Owing to the availability of full backing power in the case of the electric-drive ship, the latter possesses a marked advantage over the turbine ship in maneuvering qualities. As these were referred to under "Merchant Ships," it is sufficient to merely mention at this time that the electric battleship can be stopped in considerably less time than is required to stop a turbine ship. The advantage of this feature is obvious in the case of a war vessel. This is due to the combined action of quicker "set-ups" and greater backing power.

Further maneuvering advantages of the electric drive are apparent from recent publications. These advantages are chiefly concerned when entering and leaving ports and maneuvering therein. By operating the ship from one turbine set, the other, or others if there are more than two, can be held in readiness for immediate service in case of necessity such as would arise from a mudded condenser or other cause. When maneuvering to get under way, operation from a single generating set inherently enables exactly the same speed—but of opposite direction—to be obtained on the port and starboard screws. This is very desirable for the reason that the ship can be turned on its heel without making any headway. With different prime movers supplying power to the various screws, it would be difficult to maintain all the screws at the same speed and thereby turn in the same space.

Control.—The control for the propelling machinery is centralized in one compartment and can be easily arranged to be operated by one operator. The flexibility of the control is such that almost any emergency resulting from casualty to any equipment connected with the propulsive machinery proper can be taken care of in brief time by disconnecting the disabled unit from the source of power.

Maintenance.—The maintenance and repairs should show to advantage because of the inherent reliability of electrical machines and the absence of wearing parts. Repairs of considerable magnitude can be made aboard the ship without removing the machinery. It is difficult to imagine a casualty to any one of the electrical units which could not be repaired on board the ship if circumstances warranted it.

Study of Performance.—The electrical instruments enable accurate and convenient observations to be made of the performance of the screws at any instant. The electrical instruments also provide a means for quickly detecting improper performance of the screws due to excessive shaft friction or damaged blades. The performance of all units as indicated by the instruments is under the observation of the watch officer and control-room attendants at all times.

ELECTRICALLY PROPELLED WAR VESSELS IN SERVICE AND BUILDING.

Ship	Kind	Total S.H.P.	Type of drive	Tonnage	Date
U. S. S. Jupiter	Collier	7,000	Turbine-electric	20,000	1912
U. S. S. New Mexico	Battleship	28,000	Turbine-electric	33,000	1918
U. S. S. Tennessee	Battleship	28,000	Turbine-electric	33,000	1920
U. S. S. Maryland	Battleship	28,000	Turbine-electric	33,000	1921
U. S. S. California	Battleship	28,000	Turbine-electric	33,000	1921
U. S. S. Colorado	Battleship	28,000	Turbine-electric	33,000	Building
U. S. S. Washington	Battleship	28,000	Turbine-electric	33,000	Building
U. S. S. West Virginia	Battleship	28,000	Turbine-electric	33,000	Building
U. S. S. South Dakota	Battleship	60,000	Turbine-electric	43,000	Building
U. S. S. Indiana	Battleship	60,000	Turbine-electric	43,000	Building
U. S. S. Montana	Battleship	60,000	Turbine-electric	43,000	Building
U. S. S. North Carolina	Battleship	60,000	Turbine-electric	43,000	Building
U. S. S. Iowa	Battleship	60,000	Turbine electric	43,000	Building
U. S. S. Massachusetts	Battleship	60,000	Turbine-electric	43,000	Building
U. S. S. Lexington	Battle cruiser	180,000	Turbine-electric	43,500	Building
U. S. S. Constellation	Battle cruiser	180,000	Turbine-electric	43,500	Building
U. S. S. Saratoga	Battle cruiser	180,000	Turbine-electric	43,500	Building
U. S. S. Ranger	Battle cruiser	180,000	Turbine-electric	43,500	Building
U. S. S. Constitution	Battle cruiser	180,000	Turbine-electric	43,500	Building
U. S. S. United States	Battle cruiser	180,000	Turbine-electric	43,500	Building
Japanese fuel ship	Collier	8,000	Turbine-electric	20,000	Building
4 coastguard cutters	Cutter	2,600	Turbine-electric	1,600	Building

ELECTRICALLY PROPELLED MERCHANT AND MISCELLANEOUS SHIPS IN SERVICE AND BUILDING.

Ship	Kind	Total S. H. P.	Type of drive	Tonnage displaced	Date
2 ice-breakers at Niagara Falls	Tug	50	Trolley or cable fed, D.C.	......	1906
Joseph Medill	Fireboat	400	Turbine-electric D.C.	......	1908
Graeme Stewart	Fireboat	400	Turbine-electric D.C.	......	1908
Electric Arc	Experimental launch	25	Petrol-electric A.C.	......	1911
Tynemount	Cargo	500	Diesel-electric A.C.	......	1912
Mjolner	Cargo	950	Turbine-electric A.C.	......	1912
Wulsty Castle	Cargo	1,500	Turbine-electric A.C.	......	1918
Aquila, etc.	Cargo	1,200	Turbine-electric A.C.	......	1918–9
Mariner	Trawler	400	Diesel-electric D.C.	500	1919
Eclipse	Cargo	3,000	Turbine-electric A.C.	16,000	1920
Cuba	Cargo and passenger	3,000	Turbine-electric A.C.	3,580	1920
Elfay	Schooner yacht	90	Diesel-electric D.C.	313	1920
Guinevere	Schooner yacht	550	Diesel-electric D.C.	1,160	1921
Invincible	Cargo	3,000	Turbine-electric A.C.	......	Building
Archer	Cargo	3,000	Turbine-electric A.C.	......	Building
Independence	Cargo	3,000	Turbine-electric A.C.	......	Building
Alcyone	Schooner yacht	350	Diesel-electric D.C.	......	Building
Velero II	Yacht	215	Diesel-electric D.C.	......	Building
Fordonian	Cargo	850	Diesel-electric D.C.	2,200	Building
8 cargo carriers	....	3,000	Turbine-electric A.C.	16,000	Building
Poughkeepsie-Highland Ferry	Ferry	200	Diesel-electric D.C.	640 DWC.	Building

DISCUSSION.

PRESIDENT McCLELLAN:—Paper No. 4, by Mr. Thau, on "Electric Propulsion of Ships," is now open for discussion. We have a number of pinch hitters on the list, and if there is anybody who is in a hurry to discuss this paper, and cannot wait, I will give him an opportunity now. (A number of members rose to discuss the paper.) As three or four men got up at once, I think perhaps I had better call on the men who are on the list which has been handed to me, in the order in which their names are entered. The committee first gives me the name of Mr. W. L. R. Emmet, of Schenectady. If he is present, we would like him to speak on this paper.

Mr. W. L. R. Emmet, *Member of Council:*—Before discussing Mr. Thau's paper, I want to call attention to something that has just occurred, something that was told me a few minutes ago. I spent a few days on the battleship Maryland last week and was very favorably impressed with the operation of the machinery, and there were various complimentary remarks from others on that subject. I have been told that there was an article in the newspaper this morning saying there had been some sort of trouble with the machinery on the Maryland. I have just been told by two officers at this meeting, who have just come ashore from the Maryland, that she is lying at Tompkinsville and that there is no trouble in connection with her. I thought I would mention that fact.

Mr. Thau, in discussing this subject, has done so in a manner which I should say was very impartial. He has worked on the machinery of these ships, and gives a good idea as to the various methods which are applicable to the electric drive of ships and of the character of apparatus used in their varied service.

There are one or two points in Mr. Thau's paper where I think the case has been a little understated. In the matter of reliability I have always been of the opinion that the electric method of doing anything was the most reliable, and where anything was broken or damaged, electrical apparatus was easy to repair. I do not simply think it is on a parity with other methods.

The question of the economy of the electric drive, as compared with gears, is a subject concerning which I will say a few words later.

As to weight and space. In Mr. Thau's statement about merchant ships, he has not called attention to the fact that in certain electric drive merchant ships already equipped, and possibly in many others, a very large amount of space, weight and cost can be saved by leaving out shafts and shaft alleys, and the arrangement of the ship can be made more convenient.

Cost is a question which I think could generally be decided about as Mr. Thau has decided it, but there are many contradictions in that respect. Some little time ago we bid on equipments for some 12,000-ton transports that were being constructed in considerable number. We were the lowest bidders on electric drive and offered the best guarantees. We also made our electric bids on exactly the same profit basis that our gear proposition was based upon, in the case of these ships, and the electric was the cheaper. There have been only a few electric-drive ships equipped, and a great many geared ships, and when these two methods are reduced to a basis of comparison it has in many cases been found that the electric drive is not much more expensive than a conservatively proportioned gear drive.

There is a suggestion in the paper of a possible difficulty through lack of training the men. I know Mr. Thau does not consider, any more than any other electric man does, that there is any such disadvantage in the electric drive, because I know that he is an enthusiast on the subject, and our whole experience with electrical application on land is that everybody is afraid of it before the apparatus is started, but it is very popular the first day after the apparatus is started, with the whole operating force, and that has been the experience on ships. The Jupiter started with a set of green men, and they were all enthusiastic about the apparatus immediately, and that has also been the experience with the different warships.

In the matter of maintenance, the impression is given in this paper that electrical machinery is on a parity in the matter of maintenance. The Jupiter has been operating for seven years without any maintenance expense, I am informed—at least, I do not know of it. I do not think there is much to wear out in an electrical ship, so far as the electrical apparatus is concerned. You might have to replace a bearing occasionally, but normally, electrical apparatus of that type is virtually everlasting. In other forms of drive it is not always so.

Another matter that I would take exception to, or at least state a little differently, is the matter of the efficiency of the synchronous motor, as compared with the induction motor. We have applied synchronous motors to several ships and what Mr. Thau says is in a way justified, because if you waste enough power on excitation, you may equalize the differences which exist between the efficiency of the two systems, but my idea of the electrical drive is a little different from anything that has ever been actually produced, because I would like to see the ship equipped with sufficient means for making electricity for auxiliary purposes, and if all the auxiliary operations in a ship were done electrically, and your electric power is made efficiently, the excitation would be secured at a very low cost.

If power is obtained of proper efficiency for excitation in connection with other auxiliary purposes, in the case of the synchronous motor it will be something like 3 per cent better than the induction motor, and the apparatus will be materially lighter.

Another point is that the synchronous motor apparatus has an air gap on the order of three or four times as much as that which is practicable with the induction motor.

Furthermore, the synchronous motor can be made with removable poles, so, without disturbing the position of the machinery itself, you can take off a pole, get at the windings of the stator, and replace the windings without removing or lifting anything, and such operations are very simple and easy. The synchronous motor is of rather simpler mechanism than the induction motor, because there are simple solenoids for field windings, the movable parts; in other words, there is a more easily repaired structure.

As to some of the remarks about the Diesel electric, I do not pretend to know much about Diesel engines or the possibilities of electric drive with them, but I am very much interested, or should be, being an electric man. I would like to push the Diesel electric along if it is a good thing, and for the sake of bringing out discussion I want to state that certain people, who are well informed in the Diesel engine business, have given me the impression that the records to date indicate that the slow-speed Diesel engines were rather more practicable than the high speed. I do not see any very inherent reason why the high-speed Diesel engine might not be made good, but combustion takes time and it may be that there is something in this point.

I do not think I could quite agree there with Mr. Thau's statement that the alternating current Diesel electric drive is out of it. I would not go so far as to say that, although I might possibly agree with him if I really gave more thought to the thing, and had his reasons.

One other thing which has not been mentioned in this paper is the advantage afforded by interchange ability in electrical ship installations. On board the Maryland, the other day, we ran at 19 knots with one generator, a 21-knot ship; we ran 17 knots with only one generator and two motors. I say two motors—I mean two propellers trailing. I think this is very valuable. In a passenger ship with two turbines designed to run 22 knots, you could run at 18 knots with one generator. That is very desirable in many merchant ships—to be able to run economically at lower speed.

Another matter which Mr. Thau has not mentioned is the advantage afforded in warships of the change of ratio in the electrical motors. That is done in existing warships. I have heard statements to the effect that the Tennessee gained nothing through that change of poles. I do not understand the cause for that. The question was raised on board the Maryland lately, and trials were made at 15 knots, the maximum speed at which low-speed connection can be run. At that speed the oil consumption was 10 per cent lower; and the water consumption, as reported to me, was 7 per cent lower with the low speed connected than with the high, and at lower speeds than that there is, of course, a greater gain. In a warship this is a very important matter.

Mr. Charles F. Bailey, *Member of Council:*—I feel sure that the Society appreciates the excellent and comprehensive paper presented by Mr. Thau.

This discussion and investigation has been prepared in an impartial spirit with the purpose of emphasizing a few of the outstanding facts and conditions apparent in a comparison of the following types of marine propelling machinery, including Diesel electric and steam electric-driven machinery, as covered in Mr. Thau's paper. Let us consider the following:

Group I. 2,000 S. H. P.

(*A*) Diesel electric, twin screw.

(*B*) Direct Diesel, twin screw.

(*C*) Single-reduction geared turbines, single screw, oil fuel, Babcock and Wilcox boilers, also Scotch boilers.

(D_1) Triple expansion reciprocating engine, single screw, oil fuel, Babcock and Wilcox boilers, also Scotch boilers.

(D_2) Triple expansion reciprocating engine, twin screw, oil fuel, Babcock and Wilcox boilers, also Scotch boilers.

Group II. 2,600 S. H. P.

(*A*) Diesel electric, single screw. (Fig. 1, Plate 16.)

(*B*) Direct Diesel, twin screw. (Fig. 2, Plate 17.

(*C*) Geared turbines, single reduction, single screw, oil fuel, Scotch boilers, also Babcock and Wilcox boilers. (Figs. 3 and 6, Plates 18 and 21.)

(*D*) Quadruple expansion reciprocating engine, single screw, oil fuel, Scotch boilers, also Babcock and Wilcox boilers. (Figs. 4 and 6, Plates 19 and 21.)

(*E*) Turbine electric machinery, eclipse type, single screw, oil fuel, Scotch boilers, also Babcock and Wilcox boilers. (Figs. 5 and 6, Plates 20 and 21.)

Babcock and Wilcox boilers for installations (*C*), (*D*), (*E*), Fig. 6, Plate 21.

These comparisons are based on merchant marine requirements. Small powers have been selected as more data for comparisons are available, and as installations of such powers would be practicable with each type of machinery.

It has been the endeavor to make the comparisons as carefully and fairly as would have been the case if they had been estimated upon for a proposed order.

The ratio of shaft horse-power to indicated horse-power is assumed as follows: Diesel electric, 0.65; direct Diesel, 0.72; reciprocating engines, 0.92.

The installations of Group I are smaller than would usually be adopted in merchant service, but the comparisons will hold fairly closely. The information from which these comparisons were made was largely taken from detailed estimates and are closely approximate. The principal elements of each installation are tabulated in Tables I and II from which it will be noted in Table I covering Group I and Table II, covering Group II, comparisons are made with both Babcock and Wilcox watertube boilers and Scotch boilers, allowance being made for some increase in heating surface of the watertube boilers. In a merchant vessel the installations, Group I, could occupy more space athwartships, as the beam would be greater than here shown.

TABLE I, GROUP I—*Particulars of Machinery.*

	(*A*) Diesel electric	(*B*) Direct Diesel	(*C*) Geared turbines	(D_1) S. S. triple	(D_2) T. S. triple
Main Engines	4–600 B. H. P. Engs. 4–410 K. W., 250 V., 250 R.P.M. gens 2–1000 H.P. D. C. Motors	2–1000 B.H.P. 6 cyls. 4 cycle	1–H.P. & 1–L.P. turbine driving one single reduction gear	1–2000 S.H.P.	2–1000 S.H.P.
Main Boilers—No.	....	....	2	2	2
Type	....	....	B. & W. or S.	B. & W. or S.	B. & W. or S.
Steam press., lbs., B. & W.	....	....	250	200	200
Steam press., lbs., Scotch	....	....	220	200	200
Donkey Boiler—No. and type	1 Scotch	1 Scotch	1 Vert.	1 Vert.	1 Vert.
Type of auxiliaries	Electric	Electric	Steam	Steam	Steam
R. P. M.—propeller	120	125	90	70	100
S. H. P.	2000	2000	2000	2000	2000
M. E. P.—based on I. H. P.	....	96.5	....	31.8 ref. L.P.	30.4 ref. L. P.
Ratio $\frac{\text{S. H. P.}}{\text{I. H. P.}}$	.65	.72	....	.92	.92
Oil per S. H. P. per hr., lbs. (all purposes)	.55	.50	.95	1.10	1.20
Weight and space:					
Propel. mach., dry tons	571	436	325 (*b*) 370 (*s*)	375 (*b*) 429 (*s*)	362 (*b*) 425 (*s*)
Propel. mach., lbs., per S. H. P.	640	488	364 (*b*) 415 (*s*)	420 (*b*) 480 (*s*)	406 (*b*) 476 (*s*)
Propel. mach., wet tons	582	447	344 (*b*) 422 (*s*)	394 (*b*) 493 (*s*)	382 (*b*) 492 (*s*)
Propel.mach.,wetlbs.,perS.H.P.	650	500	385 (*b*) 472 (*s*)	441 (*b*) 552 (*s*)	428 (*b*) 550 (*s*)
Length machy. space, fore and aft	60′ 6″	55′ 0″	53′ 6″	53′ 6″	51′ 3″
Relative mach. costs	1.70	1.58	1.00	875 (*b*) 876 (*s*)	86 (*b*) 86 (*s*)

(*b*) With Babcock and Wilcox boilers.
(*s*) With single and Scotch boilers.

TABLE II, GROUP II—*Particulars of Machinery*

	(*A*) Diesel electric	(*B*) Direct Diesel	(*C*) Geared turbines	(*D*) S. S. quad.	(*E*) S. S. turbo-electric
Main Engines	5-600 B. H. P. Engs. 5-410 K.W., 250 V., 250 R.P.M.gens. 1-2600 H. P. D. C. Motor	2-1300 B. H. 6 cyl. 4 cycle	1-H.P. & 1-L.P. turbine driving single red. gear	1-2600 S. H. P.	1-Gen. 3000 R. P. M., 2300 V. 1 induction motor
Main Boilers—No.	....	....	3	3	3
Type	....	....	B. & W. or S.	B. & W. or S.	B. & W. or S.
Steam press., lbs., B. & W.	....	....	250	250	250 at 150° F. S (*d*)
Steam press., lbs., Scotch	....	....	220	220	220 at 150° F. S (*d*)
Donkey Boiler—No. and type	1 Scotch	1 Scotch	1 Vert.	1 Vert.	1 Vert.
Type of auxiliaries	Electric	Electric	Steam	Steam	Electric
R. P. M.—propeller	90	115	90	70	100
S. H. P.	2600	2600	2600	2600	2600
M. E. P.—based on I.H.P.	....	90.5	....	25.5 ref. L. P.	
Radio $\frac{\text{S. H. P.}}{\text{I. H. P.}}$	.65	.72	....	.92	
Oil per S. H. P. per hr., lbs.	.55	.50	.95	1.00	.90
Weight and space:					
Propel. mach., dry, tot. tons	640	626	373 (*b*) 461 (*s*)	497 (*b*) 585 (*s*)	387 (*b*) 475 (*s*)
Propel. mach., lbs. per S.H.P.	550	540	321 (*b*) 397 (*s*)	428 (*b*) 504 (*s*)	333 (*b*) 409 (*s*)
Propel. mach., wet, tot. tons	652	638	397 (*b*) 528 (*s*)	521 (*b*) 653 (*s*)	410 (*b*) 539 (*s*)
Propel. mach., lbs. per S.H.P.	563	550	343 (*b*) 455 (*s*)	450 (*b*) 563 (*s*)	354 (*b*) 465 (*s*)
Length machy. space, fore and aft	82′ 9″	86′ 9″	85′ 3″ (*b*) 82′ 9″ (*s*)	85′ 3″ (*b*) 82′ 9″ (*s*)	85′ 3″ (*b*) 82′ 9″ (*s*)
Relative mach. costs	1.90	163	1.00 (*b*) .97 (*s*)	1.09 (*b*) 1.10 (*s*)	1.23 (*b*) 1.21 (*s*)

(*d*) Service conditions—superheaters designed for 200° F.
(*b*) With Babcock and Wilcox boilers.
(*s*) With single end Scotch boilers.

The principal points of total propelling machinery weights, which include auxiliaries, piping, engine and fire room floor plates, ladders and gratings, water, etc., weight per S. H. P., relative costs, fore and aft, space required for the machinery installations, fuel consumptions, etc., are plotted as indicated in Fig. 7, Plate 22.

These data, it will be seen, vary somewhat from those of Mr. Thau, particularly in regard to weight and costs for Diesel electric machinery. Table III, compiled from Tables I and II, indicates that the comparison of wet weights, costs, fuel per day and space required, based on the geared turbines with watertube boilers, all as outlined under groups I and II, are as follows:

TABLE III.

Relative Data, Group I.

	(*A*)	(*B*)	(*C*)	(D_1)	(D_2)
Wet weight	1.69	1.30	1.00 (*b*) 1.23 (*s*)	1.15 (*b*) 1.43 (*s*)	1.11 (*b*) 1.43 (*s*)
Cost	1.70	1.58	1.00	0.875	0.86
Fuel consumption at sea	0.58	0.53	1.00	1.16	1.26
Fore and aft space	1.13	1.03	1.00	1.00	0.96

Relative Data, Group II.

	(*A*)	(*B*)	(*C*)	(*D*)	(*E*)
Wet weight	1.64	1.61	1.00 (*b*) 1.33 (*s*)	1.31 (*b*) 1.64 (*s*)	1.03 (*b*) 1.36 (*s*)
Cost	1.90	1.63	1.00 (*b*) 0.97 (*s*)	1.09 (*b*) 1.10 (*s*)	1.23 (*b*) 1.21 (*s*)
Fuel consumption at sea	0.58	0.53	1.00	1.05	0.95
Fore and aft space	0.97	1.02	1.00 (*b*) 0.97 (*s*)	1.00 (*b*) 0.97 (*s*)	1.00 (*b*) 0.97 (*s*)

(*b*) With Babcock and Wilcox boilers.
(*s*) With Scotch boilers.

It is of course known that the weights and other characteristics of machinery constructed by different builders vary considerably, which doubtless accounts for much of the difference between the conclusions of Mr. Thau and the above.

These tables also indicate what is well known but often overlooked—that small engines and machinery generally weigh less per horse-power than large machinery. These figures, for the entire machinery installations, also generally correspond in this respect.

With the conditions in merchant work such as to permit of building machinery on a manufacturing basis, development would take place resulting in many improvements, and it is conceivable that the relative improvement would favor the Diesel electric installation.

The above outline installations are conservative in design and follow moderate practice. We know that some features of value might be incorporated to show more favorable results in a discussion of this character, such, for example, as greater steam pressures, higher superheat, double reduction gears, etc., but such installations require more careful operation, and while they may show theoretically better results, under the ordinary prevailing conditions, we would not now recommend them except where they are to be operated with the required knowledge and care.

In regard to fuel, with the present development and conditions it is frequently necessary to pay from 40 to 50 per cent more for Diesel engine fuel than for steaming oil fuel, depending upon the trade. New advances are modifying these conditions.

It will be understood that other arrangements in dissimilar vessels will work out somewhat differently, but the foregoing indicates substantially the condition in the arrangements described.

It is quite apparent that the comparative advantages of Diesel propelling machinery or Diesel electric machinery are considerably less in installations for oil tankers, owing to the large amount of steam required for heating heavy oils during the voyage and when discharging.

There are many other vital points brought out in Mr. Thau's paper upon which I have not had time to prepare a discussion.

I consider that the Society is fortunate in being able to incorporate in its proceedings the valuable paper presented by Mr. Thau.

Mr. William W. Smith, *Member:*—Mr. President and gentlemen, on page 108 the author states that economically a geared turbine drive is generally more efficient than an electric drive. I have also found this to be true, the saving in steam consumption in favor of the geared-turbine machinery being from 4 to 8 per cent. This feature is of especial importance, because statements to the contrary have been made frequently.

It is also pointed out on this page that geared turbine machinery can use high degree superheat. This is also a fact. Some fairly large passenger steamers with geared turbine machinery using 200 degrees superheat have recently been put in service by the Cunard and other leading British steamship lines. It is important to point out here, also, that misleading statements as to the inability of geared turbines to use high degree superheat have frequently been made.

We have made a number of designs for different types of machinery, but have not found the differences in space referred to by the author. We have found that all of the types referred to occupy about the same space except the turbine-electric machinery, which requires more space, and especially when the motor is located aft. I might add that where the motor is located aft, I do not think it is permissible to eliminate the shaft alley. I do not quite agree with some other gentlemen in this respect. I think it is essential for the engineer to be able to visit the motor room easily and frequently without having to go up on deck and make an excursion such as I had to make on an electric ship not long ago.

The author refers to the saving effected by eliminating the boilers, but neglects to say that Diesel machinery is far larger and heavier than the remaining machinery. The picture of eliminating boilers, and pointing out the rest of the machinery as comparable with Diesel engines as to weight, space and cost, is often described. This, however, is far from the facts, since the Diesel engine installations occupy about the same space, and weigh nearly twice as much as a complete steam installation including boilers.

On page 109, the author's statement as to the cost of the various types of installations is at variance with my experience. I have found the cost per shaft horse-power of complete machinery installations of cargo vessels of ordinary size to be relatively about as follows:

1. Geared turbine vessels—50 degrees superheat	$122
2. Steam engines—saturated steam	132
3. Diesel engine—direct drive, twin screw	240
4. Diesel engine—electric drive, twin screw	260

Variations in designs and conditions would modify these figures somewhat. This would apply to modifying item 4 to single screw. As the size of vessel decreases, the direct-drive Diesel installation works out to better advantage.

Referring to the table on page 110 and to the number of men allowed for the Diesel electric, I should say that this class of machinery would require at least as many men as other types.

I understand from the paragraph on maintenance that the Diesel electric is supposed to be less expensive. This, I think, is very doubtful. My experience with marine machinery is that high-speed reciprocating engines are more expensive in maintenance and are avoided for this reason. Certainly the slow-speed engine is the one most favored for reliability and low maintenance. I do not think many marine engineers will accept the author's appraisal of this item, which at best is a very uncertain one.

Referring to performance characteristics on page 109, I wish to call especial attention to one feature of electric drive machinery which I think is very much over-rated and over-advertised—that is, its backing and maneuvering qualities. (It may be noted here that direct-turbine drive installations are not considered in the following or at all in this discussion.)

About the only time when the full backing power of the ordinary ship is required is when stopping in emergency at full speed or nearly full speed. I will therefore consider only this latter condition, because the ordinary requirements of backing are fully met by all of the types of machinery under discussion.

Many persons seem to have a misconception as to the backing power of the ordinary steam engine. It is supposed that the engine develops 100 per cent full power when stopping at full speed. This is not the fact; only about half of the full power is developed. (See tests of U. S. S. Delaware, Birmingham, Salem, etc.)

This is due to the fact that, when wide open in either direction, the m. e. p. and the torque of the engine are approximately the same. Dut to the characteristics of the propeller in reversing, the full torque gives an average r. p. m. in stopping only half of the ahead r. p. m. Consequently, the astern power is only half of the ahead power. In this connection, it would appear better to refer to backing torque instead of backing power.

The torque of turbine increases as the speed decreases, and it is also possible to allow an increased steam flow for emergency reversal, which, as is well known, is required very seldom indeed; consequently properly designed astern turbines will develop from 75 to 100 per cent of the ahead full torque when required. This has been proven to be quite ample; which is a point which is well to keep in mind before making assertions to the contrary. The above refers to compound reversing geared turbines.

It is also well to keep in mind that the thrust of the propeller under such conditions depends as much on the size of the wheel as on the torque applied to it. Consequently the large, slow wheel of a geared turbine may retard more than a smaller and faster wheel of an electric drive. I mention this because we are nearly always urged to use from 20 to 40 per cent higher propeller speed for electric motor drives than for other types to reduce the size, weight and cost of the motor.

I believe that the motors of electric drives are good for a reversing torque of one and one-half times the ahead full torque, the pull-out torque being double. In order to obtain the superior performance referred to by the author and others a torque of one and one-quarter to one and one-half times the full torque is imposed on the motor in reversing. This results in one of two effects: Either the normally designed shafting, propeller, etc., are stressed beyond the safe limit; or the shafting, etc., must be increased in size, weight, and cost to allow for about 50 per cent more strength.

It is my opinion, from careful observation and study of this subject, that this feature is unnecessary and undesirable for ordinary vessels. I think the shafting, etc., should be designed as usual and the motor torque limited so as not to exceed the maximum designed stress. With such an installation, there would be practically no difference in the possible backing torques of different types. In this connection, I may call attention to the fact that the full backing power of steam engines and steam turbines is seldom used, and especially on vessels of high power, for the reason that heavy vibrations are set up. In very high-powered vessels these vibrations are unusually violent; so much so that I doubt the wisdom of applying even the full torque to vessels such as scout and battle cruisers.

In general, the backing power of steam engines and compound geared turbines is ample; it meets the requirements, and no more has been called for. Consequently, I fail to see the advantage of giving more than is needed or used.

On page 119, also, the author refers to the superior maneuvering qualities for naval vessels. Rapidity of reversal is a point often referred to in this connection. This advantage does not appear to be of great importance, since all types can be handled quicker than they usually are. Also, all types can be reversed in 10 to 20 seconds, which is satisfactory, considering that the propellers must act for a considerable period of time to overcome the momentum of the ship.

In general, I consider the superior backing and maneuvering qualities of electric drive as largely theoretical, and believe there is little if any real practical advantage for ordinary vessels.

On page 118, the author states that the Diesel electric is superior in fuel consumption weight, etc., to other types. I have not found this to be the fact, and am giving particulars in Table I to show that there is a wide difference between this data and the author's opinions. In general, I think the author's claims and conclusions would be more convincing if specific data had been given. Specific and accurate comparisons are the best methods of determining which is the best type of machinery for a particular vessel and service, and this method is suggested to the shipowner who has to choose a new type of machinery. Also, if fair and reliable comparisons of this kind are published, there will be much less room for differences of opinion.

Referring to page 118, the author's views as to the advantages of the Diesel electric over the direct-drive Diesel are not concurred in. I should say that the direct drive is more reliable due to the lower r. p. m. I cannot see the alleged advantage in maneuvering. The absence of engine reversing gear is more than made up by switchboards, switching gear, etc. I find no advantage in propeller application except the additional complication when twin screws are used. In this connection, the trend seems to be towards single-screw engines. I also fail to see the advantages in reserve power and maintenance. In the designs which I have handled, the reserve power of the Diesel electric has been more closely limited than in any other type.

The author states that the engines are designed and built on the same conservative basis as direct-drive Diesels. His views in regard to conservative designs and revolutions are evidently at variance with those of most marine engineers. It is the general view that low-revolution engines are the more reliable. I do not think engines at 250 to 350 r. p. m. will be accepted as equally as conservative as engines at 75 to 125 r. p. m. In general, the use of high-speed engines is regarded as questionable, and they are considered as not sufficiently conservative.

If a high-speed engine should prove desirable because of weight, cost, etc., it would seem that the mechanical gear offers a better solution of the speed-reduction problem than the electrical. It is far lighter, cheaper and more efficient. I note that a new vessel for the Hamburg-American Line (the Havelland) is being equipped with such an installation. It may be pointed out, however, that there may be special reasons for making this selection.

In connection with the use of high-speed Diesel engines, two of the oldest and most experienced builders of marine Diesel engines do not advocate this application, although they build high-speed engines.

Referring to page 118, we estimate that the fuel consumption of the Diesel electric will be from 12 to 15 per cent more than the direct drive, and that the propulsive efficiencies will be approximately equal.

In the general summary, page 118, the author states that the Diesel electric weighs less and costs less than any other type, which, as pointed out above, does not agree with our data.

On page 119 the author states that geared turbines are better for destroyers and scouts than electric drive. Since the former type of machine is superior for such vessels, it is not clear to me why this superiority disappears when it comes to battleships and battle cruisers. The following seems to be established:

1. The electric-drive machinery weighs from 75 to 100 per cent more than the corresponding geared turbines and costs about in the same proportion.

2. The steam consumption of the electric drive is from 4 to 8 per cent more at full speed, the boilers and auxiliaries being heavier to a slightly less extent.

To offset these, the advantages claimed for the electric machinery do not seem to be very substantial. The above are measurable and tangible advantages for the geared turbine, which are opposed to a number of rather intangible ones for the electric drive, which to me do not seem to be of equal importance.

In this connection it is interesting to note that the British battle cruiser Hood is equipped with geared turbines which develop 150,000 horse-power. The machinery of this vessel has been a marked success. It would be of special interest to compare the machinery of this vessel with the electrically driven machinery of our vessels.

As noted in the beginning, the essence of this paper is electric drive. Electric-drive machinery is a splendid engineering achievement, and its mechanical operation is, without doubt, superior to mechanical gearing. The absence of meshing teeth and the smooth, flexible operation appeal to the engineer. However, these features are not the chief ones in deciding the type of transmission. The selection of the best type is largely a matter of economics. We must be guided by comparative data and statistics as to first cost, weight, fuel consumption, cost of operation, etc. These hard, cold facts will largely decide the best type.

I have made a great many investigations and comparisons of these transmissions, and so far the results have always shown the mechanical-gear machinery to be superior to the electric. In fact, the advantage has been found to be very large, so much so that the elimination of electric transmission except in special cases is indicated.

Personally, and as an engineer, I like the operation of electric transmission and will advocate its use whenever it is warranted. I am not opposed to electric drive, but I am opposed to attributing to it advantages which it does not possess.

In closing, I may say that American ships must have the most economic type of machinery so as to meet competition, and our purpose in the analysis and selection of machinery should be the accomplishment of this end.

TABLE I.

	Steam engine	Geared turbine	Direct-drive Diesel	Diesel electric
1. Number of screws	1	1	2	2
2. S. H. P. *	2,700	2,600	2,600	2,000
3. R. P. M.—propeller	80	80	115	120
4. Fuel consumption, lbs. of oil per S. H. P. (all purposes)†	1.30	1.08	0.45	0.53
5. Weight of all engines and boiler-room machinery—wet, tons	627	449	786	571
6. Weight per S. H. P.—lbs	509	386	676	671
7. Cost of machinery	$355,650	$319,000	$625,700	$526,000
8. Cost of machinery, $ per S. H. P.	132.0	122.5	241.0	263.0

* Good for 10 per cent more continuously.
† Represents good average performance; 5.7 per cent can be deducted for high performance.

CAPTAIN Q. B. NEWMAN, U. S. Coast Guard, *Member:*—I wish to speak briefly on one application of the electric drive with which the Coast Guard has recently had, and is now having, some new experience—the turbo-electric synchronous motor drive. The coast-guard cutter Tampa was the first ship in the world for which a synchronous motor was ever proposed. When this type of drive was first suggested to us, and we began to look into it, we found that it appeared doubtful whether the synchronous motor would maneuver under the conditions that are met with in a ship—that is, whether it would start under a heavy load. In order to determine that point we asked the General Electric Company to build an experimental set and simulate ship conditions as nearly as they could. They built a 300-kilowatt set, which they coupled to a direct-current generator, and by that means they could put on any load they pleased. This apparatus was subjected to all the tests we could think of, and it maneuvered perfectly. Then we tried to wreck it by doing things wrong, but found it impossible to do any damage, and so we decided it was a pretty good motor. We had no way of determining whether, in a seaway with a racing propeller, when the load is suddenly thrown off and suddenly reapplied, the motor might not fall out of step. So far we have not had an opportunity to determine that. The Tampa was built in Oakland, California, at the works of the Union Construction Company, and has made only one cruise, from San Francisco to New York, and the captain says he encountered no bad weather on the voyage to test that. However, we have no apprehension on that subject.

The Tampa is 240 feet long over all, 39 feet beam, and about 14 feet mean draught, 1,640 tons displacement, and has a block coefficient of 0.4765. She has 16 knots speed, and will do better than 2,600 horse-power.

The chief advantage of the synchronous motor (which Mr. Emmet has already mentioned) is the matter of accessibility for repairs. By the removal of the pole pieces on the rotor, any part of the motor can be repaired without lifting anything heavier than one single pole piece. I do not anticipate that we shall have to repair the motor, but in case we should have to do so, all parts are easily accessible without lifting any weights.

The matter of weight was the determining factor in our selection of this type of motor.

We looked into the induction motor, but the lines of the ship were all fine, and she would not carry the weight; and the lines of the appropriation were still finer, and they would not carry the cost, and the synchronous motor was automatically selected. The results we have obtained are not at all conclusive so far as fuel consumption is concerned. The results vary radically. We hope in the course of time to get some reliable information, and that will be published. As a basis of comparison, I will say on this ship we have installed two Babcock and Wilcox boilers built for installation in mine sweepers. The mine-sweeper contracts were cancelled, and the Navy then sold us the boilers for installation in these ships. We put on superheaters, and I believe we used higher air pressure than the Navy intended to be used on the mine sweepers. They were designed to develop 1,400 indicated horse-power on triple expansion, which I think is about 1,300 shaft horse-power. The Tampa has developed 2,900 shaft horse-power, a good deal more than 100 per cent over the estimated power of the mine sweepers. There is a difference to be expected in the economy of reciprocating and turbo-electric drive, but whether we should take this as a basis of comparison between the reciprocating engine and the turbo-electric ship, I am not prepared to say.

Our first requirement in the Coast Guard, I should say, is responsiveness, because the matter of maneuvering is of the first importance. It may not be so with the merchant ship, but we were very much interested to know how quickly we can get a response to a signal from the bridge. It has been found on a number of occasions, with the ship going at 15 knots speed, the motor will reverse in eleven seconds from the time the signal is given from the bridge. At that speed the ship can be brought dead in a little more than her own length. In backing and filling the response is instantaneous—you cannot tell when it starts.

There is one point that Mr. Thau brings out, in connection with synchronous motors, that I do not quite agree with. He says that the synchronous motor is a more complicated mechanism. If you eliminate the ordinary squirrel-cage induction motor, which I have never heard proposed for ship propulsion, the synchronous motor seems to me simpler than any other type of induction motor—that is, a motor in which you have external secondary resistance. You have a squirrel-cage winding for maneuvering, and for a full power run you have an ordinary direct-current field, the same, in most respects, as the generator field. Where it differs at all is in the line of being more readily repaired, but the same sort of connections and switches and apparatus in general applies to both the generator and the motor. I believe the synchronous motor to be a simpler machine than the induction motor with external resistance.

The Tampa, as was announced this morning, is now lying at Pier 59, at the foot of 18th Street, North River, and she will be open all today and tomorrow for inspection, and we hope as many as can will go down and inspect the ship.

A few words on the control. The handling gear consists of two levers, one being the direction lever and the other the steam lever. A man who can take charge of an installation with ordinary reciprocating engines can go on board and handle this ship without additional instructions.

The switches are operated on solenoids, but provision is also made for manual operation in case the solenoids are thrown out of operation. It is impossible to perform any operation out of its order. You cannot throw on or off the main circuit when the fields are excited, and you cannot throw on or off the fields if the main circuits are open; and so it is a very safe sort of thing so far as a man's being excited in an emergency and doing the wrong thing—you cannot do the wrong thing.

Mr. Ernest H. B. Anderson, *Member:*—This paper has resulted in bringing out many interesting points during its discussion, but it seems to me that Mr. Thau has given the Society no definite information regarding the fuel consumption performance of steam electric-geared vessels.

There must be a great deal of data available, and there is too much doubt about the fuel consumption performance of such ships; this applies to naval vessels and also to ships of the merchant marine.

For instance, there are eleven freighters which are having the original mechanical geared turbines replaced by electric gearing. The first of these, the Eclipse, has completed a voyage of 26,000 miles and, as far as one can learn, the machinery worked splendidly throughout the voyage, but nothing reliable has been published regarding the fuel consumption. Competent authorities who have had an opportunity of studying the "engine-room log" state that the oil fuel consumed by the main engines and auxiliary machinery averaged about 1.30 pounds per S. H. P. per hour. Further, it should not be overlooked that the boilers were equipped with superheaters giving 200° F., and in view of this the reported performance of the machinery is poor.

A double-reduction geared steam-turbine vessel operating under the same conditions has a fuel consumption of 0.90 pound of oil per S. H. P. per hour for all purposes.

It seems to me that the builders of the electrical machinery in these freighters did not quite do justice to the system they were advocating, for it was necessary to increase the revolutions of the propeller from 90 to 100 per minute, which is hardly suitable for a freighter of 16,000 tons, displacement and sea speed of 10.50 knots. Shaft revolutions of 75 to 80 would have ensured a much better performance, but to accomplish this mechanical gearing of the single-reduction type would require to be arranged between the propelling motor and line shafting. This arrangement was adopted by Llungstrom in the vessels Mjolner and Wulsty Castle, where two motors are in parallel, each driving a pinion in mesh with one gear wheel.

Dealing with warships, in view of the great interest taken in the machinery installations of the battleships New Mexico and Idaho, Nos. 40 and 42, respectively, Plate 23 shows a plan view of the propelling machinery, and it will be seen that the engine-room spaces in these two ships are alike, but the propeller revolutions at the designed power and speed in the New Mexico are 170 per minute, whereas in the Idaho they are 240 per minute. Needless to say, the slow-turning propellers of the former have a considerable advantage over the latter.

Whilst bids for battleships Nos. 40, 41 and 42 were in hand during 1914, geared-turbine machinery was making rapid progress, and we submitted alternative proposals with this type to the shipbuilders, and two firms offered to build these battleships with geared turbines driving four shafts, as shown on Plate 24.

Battleships Nos. 43 and 44, Tennessee and California, were designed during 1915, having a four-shaft arrangement of "electric gearing" for the propelling equipment, in which the machinery arrangement is absolutely novel as compared with all previous battleships.

We submitted alternative propositions to the Navy Department, but it is almost impossible to install or arrange mechanical geared steam-turbine machinery in spaces specially designed to suit "electric gearing."

Plate 25 shows a plan view of the Tennessee and California arrangement of machinery and a proposal having twin screws, driven by two sets of Parsons single-reduction geared steam turbines. The revolutions of the electric-geared ships are 170 per minute, whereas in the twin-screw turbine proposal they are 125 per minute.

On referring to the plan view of the electric geared machinery, it will be seen that there are two central compartments, each of which contains a complete turbo-generator and the various auxiliary machinery. There are eight boilers divided into two groups, four being arranged in separate compartments on each side of the turbo-generator spaces, the total width of the machinery spaces being approximately 61 feet. The uptakes from the four boilers are led to two funnels, arranged on the center line of vessel and directly above the turbo-generator compartments.

Multiple shaft arrangements of machinery came into use solely to suit direct-driven steam turbines, and it is rather curious that the electrical firms merely copied a type that was never considered suitable for battleships of 28,000 S. H. P. to 32,000 S. H. P. by many naval constructors and naval engineers in Washington.

Referring again to Mr. Thau's paper, electric gearing has its limitations just as well as all other forms of propelling machinery; among these may be mentioned:

Backing qualities. Experience has shown that it is not necessary to have more than 60 per cent astern power, and it is overlooked by many that it is "stopping qualities" which are required. In other words, two large-diameter slow-turning propellers will bring any large vessel to rest quicker than four fast-turning propellers which at all high speeds of revolution do not take a grip on the water but tend to cavitate in a vortex.

The electric-geared battleship does not maneuver or go-astern with full "ahead" shaft horse-power. I believe it is now an official order in the Navy that all maneuvering has to be carried out with one turbo-generator transmitting current to the four propellers in parallel.

This limits the maneuvering capabilities to a large extent, for all propellers must revolve at the same speed, if in operation. For instance, the two port propellers cannot run at maximum speed "ahead" whilst the starboard propellers revolve "slow astern." A complete explanation for this limitation when manuevering will be found in a paper published in the Journal of the American Society of Naval Engineers, August, 1921, in the article "Propulsion Wiring Circuits, U. S. S. New Mexico," under the sub-title "The Steam Limit Device" on pages 509-511.

Weights, space and economy are all in favor of mechanical geared turbine machinery, but until further data are available regarding these items in connection with electric gearing in war vessels, it is useless to attempt to discuss these features.

The battleship North Dakota, built in 1909, has had the original direct-driven twin turbines replaced by twin sets of single-reduction Parsons geared turbines, and the new machinery has resulted in a gain of 31 per cent in fuel consumption at all speeds. For further information on this point, reference should be made to the report of the Engineer-in-Chief, U. S. N., for 1919.

I should also like to mention that this new machinery effected a saving of at least 50 per cent in the weight, went into the same engine-room space with very few changes, and has done very well ever since the vessel went back into commission. Further, this replacement could not have been carried out with any of the present forms of electric gearing.

Referring to the data accompanying the performance of the New Mexico and the so-called sister ships, I think the author cannot have realized that these figures were quoted in a paper read by Mr. Eskel Berg at a meeting of A. I. E. E. during May of this year. Mr. Berg gave the source of his information; the data were submitted to the editor of *Marine Engineering* and published in an editorial in the issue of May, 1920, entitled "Two Years of Electric Propulsion on New Mexico."

I shall not comment further on this point but suggest that anyone who is interested in the question obtain the August, 1920, issue of that journal and see the other view, in the article "U. S. Battleships of the Year 1914 and Later Classes."

I was much interested in listening to Captain Newman's remarks regarding the performance of the new coast guard cutters, but unfortunately very little was said regarding the actual fuel performance of the electric geared machinery.

The *Army and Navy Register,* in its issue of September 10, gave particulars of the trials of the U. S. S. Tampa. It was a short article and one paragraph read as follows:

U. S. S. TAMPA.

STANDARDIZATION RUNS.

Knots.	*Revolutions.*
8	60
10.50	80
11.80	90
14.20	110
16.20	128

"The total fuel consumed on the four-hour run was 2,008 gallons. The consumption was high on account of unsatisfactory pump operation." That is all. As Captain Newman stated, the contract conditions of the vessel were as follows: Knots, 16.00; S. H. P., 2,600; revolutions, 130. There are superheaters also installed on these vessels, and if you use the design figures as a basis, you will find that the fuel consumption averages about 1.35 pounds of oil per S. H. P. per hour for all purposes.

President Capps in the chair.

MR. ELMER A. SPERRY, *Member:*—The Society is certainly to be congratulated upon the paper by Mr. Thau as making a substantial contribution to our Transactions.

The paper devotes considerable space to Diesel-electric transmission. We all appreciate the suitability of the turbo-electric drive, where the turbine needs assistance in the fact that it will only run one way and is almost impossible when asked to go through severe maneuvers. But with the Diesel or oil engine the matter is entirely different. Here we have an arrangement which will run one way as well as the other, and in quick reversing may be made about the equal of the reciprocating steam engine.

In the case of the oil engine the greatest problem is simplified over the turbine in two ways. The speed is lower, and the other important difference is that the oil engine gives full and quick reversing, so we do not need the electric plant for the purpose of reversing, as we do with the turbine.

We should look at this matter squarely. The electric propulsion of ships is good and should be used if we do not know any better way. However I, for one, believe that there is a better way in the heavy duty air-gap drive that has now been under test for upwards of two years, and I give fair warning that this may be found to entirely supersede the electric propulsion of ships. It makes a number of substantial contributions, not the least of which is the opening up of new fields of usefulness for reciprocating oil engines by permitting gearing, and comparatively inexpensive gearing, to be directly driven therefrom under conditions of practically no wear and with entire success.

Many attempts have been made to drive gears with reciprocating engines, but the crank-whip and general thrash due to the irregularities in the crank effort have intervened and over-stressed the material at the surface of the teeth, causing pitting and peening and early destruction of the gear. The thrashing soon causes them to run so roughly as to become impossible. Examination indicates that not only the positive side, but also the negative faces of the teeth are pitted and peened and receive serious wear. After years in which the struggle was practically given up, it has suddenly reached a complete solution in the endeavor to secure extreme lightness in very large aircraft engines of 1,000 horse-power or more, where engine speeds have had to be pushed considerably beyond the economic speed of the air propeller.

At this juncture an Italian engineer, Pomellio, found a very complete solution. He divorces the pinion from the mass moments of the crank and allows the latter to "run wild," the pinion being driven through an elastic link (see Fig. 1, Plate 26). This is found to completely smooth out the action so as to make the gear drive perfectly successful. The elastic link does not require highly organized gears, simply spiral toothed spur gears of rather coarse pitch which are found to show no wear, contact on the positive side only, the negative faces not even indicating contact.

Fig. 1 shows the crank shaft of a heavy airplane motor below and the short, hollow propeller shaft above. The engine shaft operates a broad-faced pinion driving the gear, plainly to be seen on the upper shaft. The peculiarity of this drive is that, rigidly mounted on the conical end of the engine shaft is a slender hub terminating at the extreme right in a thin disc with deep gear teeth of peculiar shape cut in its broadened periphery, shown also in elevation in the detailed quadrant in the little view below and to the left. The pinion is mounted independently of the crank shaft on heavy ball bearings, plainly to be seen in the lower part of the figure, and the only connection between them are 172 broad, highly tempered steel springs entering the teeth in the shape of radial hairpins, each held on two pintles. The thrash of the crank shaft is taken up completely by the springing back and forth on the part of the 172 sheet steel leaves, allowing the pinion full freedom to accommodate itself entirely to its master gear on the upper shaft. The smoothness of the operation of this arrangement leaves little to be desired.

There are two forms of the elastic link available for this purpose—the magnetic and the mechanical. The latter, though extremely highly organized and made up from a great many pieces, is lighter and better suited for aeronautical work. So entirely successful are these geared reciprocating sets in the larger geared engines that one is now coming forward of 1,600 horse-power, all rendered possible by a complete separation of the crank shaft and the pinion teeth, which are thus safeguarded completely from the thrashing of the crank shaft.

The above method is not the one used in power plants of ships, because we have a better and more complete elastic link in the magnetic air-gap drive. Besides, this drive makes a number of other important contributions in connection with ships' plants, but I have dwelt in some detail upon the above hairpin drive to emphasize the point that whenever the pinion is given full freedom, gears operated by reciprocating oil engines are perfectly successful and are now available, this having received complete demonstration under service conditions.

The magnetic form of the elastic link is much simpler, having two as compared to some 260 parts in the mechanical drive. It also gives more complete and smoother operation. This is quite outside its important two-fold contribution in case of oil-engine ship propulsion, because, while for the first time it renders comparatively inexpensive gearing entirely successful with reciprocating engines, it goes still farther and takes care of all fractional speeds in the lower range, where the Diesels are found to draw too heavily on the starting air reserves. They run with good reliability at, say, one-quarter speed or below. Why go lower when the magnetic air-gap clutch takes care perfectly of all fractional speeds even down to complete stopping of the tail shaft?

The provocation for use of electric propulsion existing with turbines which will not reverse and are involved in such destructive superheating troubles whenever they are forced to go through this maneuver, does not exist with Diesels. The Diesel will run in either direction equally well and responds perfectly and instantly to the reversing maneuver.

As we all know, the reciprocating steam engine, barring foaming boilers and condensation troubles, makes by far the best engine for ship propulsion. It maneuvers perfectly and, while it has complete flexibility, yet it will give instantly full power astern or ahead at will. Compared with this performance, for instance, just what is supposed to be the contribution of Diesel-electric propulsion?

1. It is supposed to give both the naval architect and engine builder complete freedom in design to employ the best speed for propeller and engine. This would be realized were it not for the fact that both the electric generators and motors are too heavy and expensive if these speeds are kept low, so there is a constant urge toward too high speeds and the actual plants are a compromise at best. This is not at all true with gears, where the lower speeds are encouraged.

2. It gives divided prime mover units. Should an emergency arise, a part only of the plant is crippled. This is true with the gears and the air-gap clutches at a very great saving of weight, expense and space. Here a plurality of engines is always present. (See Fig. 5, Plate 27.)

3. *Flexibility.*—The Diesel will run with as great reliability as steam at all speeds but the lowest. Here the Diesels are found to draw too heavily on the starting air reserves, as stated, so they may be left running at full or fractional speeds while the electric transmission does the rest and allows the propeller shaft full range down to just turning over if necessary for slow headway. This is precisely the function of the loaded secondary in the air-gap clutch. The continuous operation at all fractional speeds is provided for and at many times the efficiency of the electric drive and without its weight and expense; and as to the important matter of space, with a plant located within the flywheel of the engine itself.

4. It is supposed to make the farther doubtful contribution of avoiding reversing oil engines. Reversing Diesels were formerly so complex that there was little wonder that reversing relief was sought in the electric plant, but this has now been done away with. For instance, the 32 cams for each four cylinders for full air starting and reverse has in the new engines been reduced to 5 and the problem no longer exists.* The maneuverability with these engines and the air-gap clutches accomplishes all that the full electric plant does, at a very great saving of plant and control equipment.

Taking up the detailed construction of these clutches, a brief statement might be made as follows:

The clutch is characterized by two kinds of torque operating by opposite phenomena; the greater the differential or relative velocity between the driver and driven parts (so indicated in Figs. 2 and 3, Plate 27), the greater the torque available for starting and for bringing up to synchronism. This phenomenon also provides for slipping and continuous operation at all fractional speeds by means of the loaded secondary effect acting as an induction motor. The electrical conductor in the loaded secondary is indicated by the large light masses in the driven rings separating the blackened masses, which indicate the magnetic inserts. (Fig. 3.)

The air-gap clutch drives by means of magnetic flux. There are four elements in the

*See author's A. S. M. E. paper, "Compound Combustion Engines," Annual Meeting, 1921.

form of rings in the magnetic circuit, two of which are driving and two of which are driven. The flywheel proper accommodates an exciting coil (shown in Fig. 2) producing the magnetic flux. At all fractional speeds, or while this clutch is slipping, large currents are generated in the driven elements by magneto induction, which are now acting as short-circuited secondaries, producing heavy drag torques under perfect control by varying the amount of coil excitation. This is plainly seen by the height of the curve at the right in Fig. 4, Plate 27. However, when the speed comes up in the vicinity of synchronism, shown at the extreme left in Fig. 4, locking occurs and the parts assume the relative position shown to the right in Fig. 3, where enormous pull-out torques are present, as indicated by the height of the curve at the extreme left, as stated.

In Fig. 5 the casing containing the low-speed gears is an entity by itself, especially with respect to any extreme alignment requirements with the engine. The air gaps in the flywheels allow of considerable leeway, both endwise and laterally. The pinions are mounted on hollow quills, and complete flexibility is assured by the steel plate coupling located at the after end of each pinion. No amount of "weaving" of the foundations forming a part of the ship's structure, in changing the alignment, will disturb the perfectly smooth running of these low-speed gears.

With this clutch and the engine combination shown in Fig. 5, several very important advantages are secured:

1. We have available on a single propeller all the advantages and flexibility of a multiple engine equipment, where one engine may be shut down and completely disconnected for inspection, valve grinding, etc., and yet the ship is going forward at three-quarters its normal speed.

2. We have the complete flexibility of the electric drive without the expense, weight and space of the electric generators and motors, as stated, and the cumbersome electric control equipment for handling the heavy currents in maneuvering, and the double losses of generators and motors which are of substantial amount and a constant drag on plant and fuel economy.

3. The simplest form of gear drive may be employed because the magnetic clutch allows the pinion to be a complete "floater." The pinion may thus accommodate itself to any want of precision and all sorts of idiosyncrasies of the main gear and teeth without shock. Any irregularities existing in either main gear or pinions thus have to deal only with the small masses of the pinion itself and its stub shaft, being completely isolated from the large mass moments of the engine.

4. The torque, being under complete control, can be lowered so as to safeguard the equipment against overloading, especially when sailing in obstructed harbors, near derelicts, and where floating obstacles are likely to be encountered by the propeller blades, thus providing an important emergency disconnecting gear breaking away from the large revolving engine masses and allowing the propeller to "stop in its tracks" through the self-interruptibility of the magnetic clutch when reduced to fractional underload condition. In this way many disasters to the propelling machinery and interruptions to the service may be avoided.

5. Most revolving machinery is subject to periods, sometimes running into severe "criticals." These criticals always develop from the torque irregularities in the revolving masses within the engine pitted against outside mass moments aft. This can occur only when these are solidly coupled with each other, but if instead they are isolated, as by the air gap of the magnetic clutch, these troublesome criticals with their excessive stresses are completely suppressed and can never develop.

Important ships that would be much better equipped with the single screw have gone to the trouble, weight and expense involved in using twin screws to secure the advantages of the divided unit and to obtain sufficient power while avoiding the expense of the larger engines required with the double efficiency losses of the electric drive.

As to larger powered engines, with the new compound much larger units are possible without approaching the size and space occupied by the simple Diesel engines. Through compounding the combustion engine (see author's paper on this subject before the 1921 Annual Meeting of the American Society of Mechanical Engineers), tail shaft powers up to 12,000 horse-power are available with the present cylinder and cylinder wall limitations, with only six combustion cylinders in line in each engine, utilizing the arrangement of Fig. 5. If a similar pair of engines is used aft of the gear, then a shaft horse-power of 24,000 can easily be secured, and the weight can be held to a point far below the present weight per shaft horse-power of combustion engines or steam plants for continuous heavy duty service.

With the simple device of the heavy duty air-gap drive, everything claimed to be accomplished by the electric drive is accomplished, and much better and with greater economy. The efficiency of the air-gap drives alone is better than 99.5 per cent. They weigh less than 2 per cent of the weight of the electric drive, and as to valuable space occupied, they are moved into the small flywheels of the engines themselves, where they are accommodated perfectly, and from which point they make their varied and most important contributions to ship propulsion.

The following table gives the percentage of clutch excitation for fractional tail shaft speeds below the engine speed, the first half when the oil engine is running at one-half normal speed, the second when running at one-third normal speed:

No. 50 ELECTROMAGNETIC CLUTCH OR AIR-GAP DRIVE APPLIED TO A 900 HORSE-POWER DIESEL ENGINE, 140 R. P. M. GEARED TO PROPELLER AT 90 R. P. M.

Engine	R.P.M.	Propeller				Air-gap drive	
		R. P. M.	Per cent engine speed	H. P.	Torque lb.–ft.	Torque lb.–ft.	Per cent of normal excitation
Full speed	140	90	100	900	53,000	70,000	100.0
One-half speed	70	45	100	112.5	13,200	17,000	100 to 50.0
One-half speed	70	33	75	47.5	7,300	4,780	Slipping 50.0
One-half speed	70	22.5	50	14.0	3,260	2,120	Slipping 11.5
One-half speed	70	11	25	1.76	820	530	Slipping 2.0
One-half speed	70	5.5	12.5	0.22	206	133	Slipping 0.43
Full speed	140	90	100	900	53,000	70,000	100.0
One-third speed	46.7	29.5	100	33.3	5,900	7,560	100 to 33.0
One-third speed	46.7	22.5	75	14.0	3,300	2,120	Slipping 33.0
One-third speed	46.7	15	50	4.15	1,470	945	Slipping 7.4
One-third speed	46.7	7.1	25	0.52	366	236	Slipping 1.3
One-third speed	46.7	3.7	12.5	0.07	91.5	59	Slipping 0.27

Full or normal excitation of magnetic drive = 1.4 kw. or 0.2 per cent efficiency = 99.8 per cent.

Mr. W. McClelland, *Visitor:*—I would first of all like to thank you for the honor and privilege which you have shown me in calling upon me to say a few words to this gathering. I have been a member of the American Institute of Electrical Engineers for, I think, very nearly twenty years, but this is the first opportunity I have had of attending one of their meetings, so it is, indeed, a pleasure to be able to say just a few words. I am interested in electric propulsion and also the electrical auxiliaries, so will touch briefly on both papers.

In the British Navy, as you know, we have always pinned our faith on the geared turbines rather than the electric drive for capital ships. I think, Mr. President, at this point I ought also to say that a free discussion of this subject at the present time is rather difficult, owing to the very high-minded and worthy proposals dealing with the limitation of naval armament, which have been made by your Secretary of State in Washington. (Applause.) These proposals are under discussion at the present moment, and in my opinion history will show that they are epoch-making; I believe that the blessings which will flow to mankind from these proposals are yet not only untouched but are at present unknown. (Great applause.)

I said in the British Navy we pinned our faith in the geared turbine with the single-reduction drive. I think the author of the propulsion paper has stated the case exceedingly fairly. He has not gone in for any of the extravagant claims for electric propulsion which I have seen published in certain papers from time to time, but there is one statement in the paper to which I should like to refer, and that is the comparison of the economies claimed by the United States warship New Mexico over the Idaho and Mississippi. In that connection, while the author, I believe, states facts—the Idaho and Mississippi are direct-turbine drives with an auxiliary turbine-geared drive.

That installation is now somewhat behind present practice and would not be repeated in any modern ship, and therefore I feel that a comparison which shows such marked economy by the electric drive is not one which should be passed over without reference in the discussion. I believe that a practical trial of the latest practice in steam-turbine geared work would show that there was very little difference between the electric drive and the turbo-geared drive. At various points on the curve, you would find that the electric drive gains considerably, whereas at other points on the curve I think you would find that the steam-geared drive gains. The steam gearing, I believe, will gain at maximum speed. The electric drive will gain at cruising speeds, and it is a matter of policy, I think, for the various governments designing these ships, as to whether maximum speed is required or alternatively economy at cruising speed. That the electric drive is economical over most of the range of speed of a capital ship, that it is reliable and generally free from breakdown, is admitted.

The discussion has turned in large measure on the Diesel electric drive. Whilst I am not a Diesel expert, there is one question I would like to put to the gentlemen who advocate Diesel drives, either geared or electric, in the present stage of development, and that is this—if you have a single-screw ship, is there any owner who would rely on, say, a single 3,000 to a 5,000-horse-power Diesel engine, and send that ship to sea on a scheduled service? I do not know whether there is in this country or not. I am rather doubtful as to whether there is in our country. In this respect the reliability of the Diesel appears to be regarded as much less than either the turbine or the reciprocating engine.

Several remarks were made about the different classes of main motor machinery. It was my good fortune to come to America in the fruit ship referred to by the last speaker.

In that ship the drive is by means of a synchronous motor, and one speaker particularly referred to the question of the racing of electric motors when the propeller of the ship was out of the water. We had very heavy seas—at one stage of the crossing we ran into a hurricane, and the propeller was out of the water over and over again, and there was no racing whatever—the motor stood up perfectly to its work, and I believe that with a properly designed synchronous motor, you will get, in addition to high efficiency, equally good results as with any other type of motor.

Mr. E. A. Stevens, Jr., *Member* (Communicated):—Before discussing this paper in detail, I think it would be well to consider the question of transmission in general, whether it be electric, mechanical gear, or hydraulic. The only advantage of any of these is the ability to run the main machinery at a different speed than that of the propeller, thereby obtaining greater economy than what would be possible if the two were operating at the same speed. With this in view, the Diesel electric (excpt in a few special cases) would be eliminated. As the Diesel engine is more reliable as well as more economical at the lower speeds, it is far better to connect direct to the propeller than to use any of the transmissions mentioned above. It has been argued that when the cylinders reach a certain size trouble occurs. This can be eliminated by increasing the number of cylinders up to eight to one shaft, or by the use of twin or even triple screws. When the power required is greater than what would be practicable with three screws, it would be better to use steam, as the weight, first cost, and complications of the Diesel electric system would offset any advantage, if any, that this system would have in economy.

Mr. Thau states: "The economy of a reciprocating engine drive is obviously poorer than that of a properly designed turbine of either type, for the reason that the reciprocating engine cannot utilize the same expansion of steam." This is true for high powers, but for a slow ship of 3,000 horse-power or less, the reciprocating engine has shown as good economy as the average geared turbine and better than the electric drive, in spite of the fact that no superheat was used with the engine while 50 degrees superheat was used with the geared turbine and 180 degrees with the electric drive. The cost of the electric drive outfit installed is over double that of the reciprocating engine, while the geared turbine is about the same or a little less than the latter.

The horse-car driver who became a motorman and the steam locomotive engineer who became an electric locomotive engineer cannot be classed with the marine engineer, as neither the motorman nor the locomotive engineer does his repair work or keeps his machines in condition. These men are merely drivers. All the repair work and care of the apparatus are done by the repair gang or round-house foreman.

If three junior engineers are required for the direct-connected Diesel as shown in the table on page 110, why are they not required for the Diesel electric, which is more complicated?

The fact that the U. S. Navy has adopted the electric drive for battleships and battle cruisers speaks well for it, but cannot the same thing be said about the geared turbine which is being used by the British Admiralty in the above-mentioned classes?

The protection against torpedo attack afforded by the electric drive is not much greater, as the motors on the outboard shafts are as near the skin of the ship as the geared turbine would be; besides, the ship fitted with the latter could be better protection against gun fire as machinery is lighter, while the maneuvering ability of the geared turbine is all that is desired.

It is hardly fair to compare the New Mexico and Tennessee with the Idaho and Mississippi, as the two latter are fitted with direct-drive main turbines and geared cruising turbines. A considerable amount of the saving was due to the propellers.

Mr. Thau neglects to state that, while the battleships and battle cruisers of our Navy are, or are to be, fitted with the electric drive, the light cruisers and destroyers are being equipped with geared turbines. The U. S. Navy refrained from using the latter in the battle cruisers where weight is of great importance, because they did not believe that gears could be built that would transmit the necessary power (45,000 S. H. P. per shaft). However, the British Admiralty has been able to transmit 39,000 S. H. P. per shaft successfully.

Commander S. M. Robinson, *Member* (Communicated):—Mr. Thau's paper has so completely covered the range of subjects involved in a discussion of electric propulsion that there are not many new points that can be added, but I think some of them might be emphasized in order to bring out their very great importance.

Turbo-electric propulsion is being used to such an extent at the present time and is so well known to the marine engineering world that it hardly seems necessary to dwell much on this subject, but Diesel-electric propulsion is a comparatively new art and still has its way to make in the marine field. It seems to me to be an ideal system of propulsion for cargo vessels. By its use it should be possible to greatly increase the reliability of Diesel engines, since it will not be necessary to start them up under load nor reverse them. The importance of these two points is very great and cannot be emphasized too much in any comparison of direct-connected Diesel engines and Diesel electric propulsion; submarine experience has shown that many of the troubles with Diesel engines are directly traceable to these causes and, while air starting is still fitted on these engines, it is only used in case of emergency when the motors are out of commission.

With Diesel electric propulsion it will be possible to use multiple units, thus keeping down piston diameters; this will add greatly to the reliability and will also operate to reduce the maintenance cost. It also makes it possible to carry out engine repairs on one engine at sea without suffering any very great reduction in the speed of the ship.

Diesel electric propulsion is frequently criticized as being about 12 per cent less efficient than the direct Diesel drive. No general statement can be made which will cover all types of ships, but for cargo vessels of the usual low horse-power it can be said that there will be little difference in the overall economy of the two systems, and what difference there is will generally be in favor of the Diesel electric. This arises from the fact that it is necessary to use twin screws running at comparatively high propeller speeds for the direct Diesel, while a single screw of lower speed can be used with the Diesel electric; with the latter arrangement the losses in the struts are done away with and a more efficient screw is provided due to the lower speed at which it runs.

I believe that the voltage proposed by Mr. Thau is somewhat higher than should be used on board ship, and this will not be necessary if the number of units is reduced; a three-generator and two-motor installation would seem to give all the flexibility desired and at the same time obviate the necessity for the use of such a high direct-current voltage. This will give three combinations of generators and motors, the first being all units in use, the second being two generators and two motors, and the third being one generator and one motor. At the maximum capacity of each of these conditions the motor and generator efficiency will be practically the same as at full power.

In connection with the flexibility of the series system of Diesel electric propulsion, Mr. Thau points out the simplicity of the speed control which is obtained by varying the generator field strength; this method can be combined with that of variation of motor field strength so as to give the most efficient operating condition for any of the various combinations of motors and generators.

PRESIDENT CAPPS:—Owing to unavoidable absence of the author, who cannot be here until tomorrow afternoon, paper No. 8, which was to have been read tomorrow morning, will be read by Mr. Bailey, the author, tomorrow afternoon, taking the place of paper No. 12, by Profesor Hovgaard.

MR. PIERCE:—In view of the fact that there has been considerable discussion relative to the Diesel electric drive, I might say that we are all familiar with the specifications sent out for a tender on a ship for Diesel electric. The Diesel electric equipment for that ship was 58 per cent heavier, 20 per cent more fuel consumption, and 10 per cent more cost than the direct Diesel.

PRESIDENT CAPPS:—It is hoped that in making their replies, the authors of the papers will be able to throw more definite light on the subject of weight of machinery and fuel consumption, because the differences per shaft horse-power, when translated into terms of cargo capacity, or fuel which can be carried, are very important indeed. If there is no further comment, we will bring the discussion on these papers to a close.

MR. EMMET:—As to the question of the relative economy, the turbine being the same for both, the difference must be small. In a large ship, for which we have recently designed electrical transmission machinery, we would only lose 4.5 per cent. The San Bonito, which just came over, and which ran in the Mediterranean for a long distance, had a rate corresponding to 1 pound of fuel per shaft horse-power. Any of these other electric ships will do pretty nearly that. The difference is, in any case, small, provided the turbine is equally good. I have tested a large number of ship gears by actually running them on generators at a given load, and I have actually found the efficiencies of a double reduction ship gear as low as 96. I have tested 6,000 horse-power gears and two 3,000 horse-power gears, and know the losses are considerable in the gears alone.

I think it quite probable that Mr. Anderson's criticism of the 100 R. P. M. propellers in the Shipping Board boats equipped may be correct, although, when these jobs were undertaken, statements to the contrary were given us by the best authorities.

MR. THAU:—Before replying to the discussions which have been made on my paper, I desire to take this opportunity to extend my appreciation and thanks to the authors of the discussions for the thorough manner in which they have gone into the subject. The majority of the points brought out in the discussion are very beneficial to the progress of the art. There are, however, a few instances where the meaning of the author's statements in the paper have been misconstrued, and also some instances where some of the discussions have digressed from the points at issue in the paper, in an endeavor to discuss claims for electric propulsion systems which have been made in other articles in the technical press. It is hoped that the interested persons reading the paper, the discussions and the author's reply to the discussions will take these points into consideration.

Mr. Emmet says that I have understated a few of the points of advantage or of attraction in regard to electric drive. I can merely reply to this by saying that I endeavored to be ultra-conservative throughout the entire paper, so as not to invite undue criticism from gentlemen who oppose electric drive or who are not yet prepared to accept it. This is one reason why I placed maintenance on not worse than a parity with other drives. I am sure that the electrically driven ships in operation have already shown a surprisingly low maintenance cost.

I have given considerable thought to the efficiency of a synchronous drive, as compared with an induction drive, and have always concluded that there can be only a very inappreciable difference in efficiency. The suggestion by Mr. Emmet that the adoption of electric auxiliaries throughout will enable the installation of larger auxiliary turbines which would be conducive to lower steam consumption for excitation is, of course, correct, but I think that, considering everything, the ultimate difference in efficiency of the two drives would be inconsequential. The largest attraction of the synchronous drive is in the weight, space and cost saving resulting from unity power factor. As I have shown later in the paper, these advantages can be obtained with the induction drive, using the power factor corrective apparatus.

The larger air gap and better access of the synchronous motor were mentioned in the last paragraph of my description of the synchronous motor drive.

By "high-speed Diesels" I do not have in mind high piston speeds. The matter of piston speed must be treated with conservatism in high R. P. M. engines, as well as in low R. P. M. engines. The reciprocating parts being smaller, the cylinder walls and cylinder heads thinner (this being conducive to quicker heat transfer and lower temperature strains), and the absence of water cooling on the pistons should decrease rather than increase the maintenance of the engines. Repairs are easier to make because of the smaller parts to be handled. There are engines of 200-horse-power capacity at 250 R. P. M. that have been operating continuously, except for periodic valve grinding, since 1914, and during this time the maintenance was practically negligible. Mr. Smith has also questioned the reliability of the higher R. P. M. engines.

Regarding the application of alternating current for Diesel electric drive, I am quite sure that the flexibility in control advantages alone of the direct current would go a long way to favor the direct current, even though parallel operation of a multiplicity of alternating current units were entirely feasible. It has been shown definitely in the case of land installations that Diesel driven alternators do work satisfactorily in parallel, but it must be remembered that these engines operate at constant speed instead of at adjustable speed, as would be necessary in the case of ship drives. Where the Diesel engine units are sufficiently large so that one unit would supply one motor, as in the case of a twin-screw drive, alternating current is feasible and will undoubtedly be used under certain conditions.

Mr. Emmet mentions that the interchangeability of electrical units in a ship installation was not brought out in the paper. I did not deem it desirable to go into this matter in detail, as the principal part of the paper was on merchant ships, whereas such opportunities are only offered on high-powered ships having two or more generators. Reference was, however, made to this feature under the captions of "Reliability," "Economy" and "Control" in the section covering war vessels. This advantage was also referred to in connection with the Diesel electric drive. For large ships these advantages are important, as is perfectly obvious, for the reason that balanced power can be obtained on all screws, regardless of the number of generator sets in operation.

The advantage resulting from the change in ratio in motor speeds for a given frequency is also mentioned in the paper under the caption of "Economy" in the section covering war vessels. This item was not discussed in detail, as it has been given considerable airing in recent technical publications. Mr. Emmet brings out the comparison that the advantage resulting from the change in pole ratios of the motors is more pronounced on the Maryland than on the Tennessee. This is true for speeds between 13 and 15 knots, but for lower speeds the larger number of poles show better economy. This characteristic can only be explained by the combination of turbine and motor and generator efficiency performance. I think the performance of the Tennessee is more or less incidental, as such a condition would not be anticipated. The turbines installed on the Tennessee are particularly economical at a very wide range of speed.

Three of the discussions, at least, dwelt at considerable length on weights and submitted some data which are at variance with the author's analysis of weights, space, cost, etc., for the different principal types of propulsion. Any data of this nature must of necessity be considered upon its hypothesis, as there are several ways of comparing such items relating to propulsive machinery. There is, however, only one correct way, and that is to include every single item which by virtue of its function is directly related to the propulsive equipment, such as engines proper, boilers, condensers, propulsive equipment auxiliaries, shafting, foundations, seatings, water in machinery, reserve water for machinery, stacks, piping, ladders, platforms, thrust bearings, shaft alley bearings, propellers, generators, motors, control, cable, exciters, fuel, lubricating oil, etc. A comparison of the bare machinery weights means nothing.

The analysis of the Diesel electric propulsive machinery in the paper is based upon a single-screw drive in which the propeller R. P. M. is uninfluenced by the motor speed limitations, because with Diesel electric drive, using direct current, the propeller speed can very conveniently be made to suit the preference of the propeller designer, as there is absolutely no fixed relation between the generator speed and the motor speed.

Because of the well-known fact that practically all of the direct-drive Diesel ships today are twin screw, this arrangement has been considered in the case of such ships.

It is probably unfortunate that a table of comparative weights showing all items considered was not incorporated in the original paper. The author's statements in comparing the different factors of the various drives were of a general nature, and this system was used purposely to avoid contention on details. To substantiate the statements in the paper, particularly in connection with weight, the table on page 148 which forms the basis of the author's analysis, is included in this reply for reference.

A brief discussion of this table will reply to several points raised by Mr. Bailey and Mr. Smith. It will be noted that at least every essential item on which there is any difference in the various types of drives has been included. Unfortunately, I have no reliable data on foundations which must be made a part of the ship's structure for supporting the propulsive machinery. However, I believe that these items should just about balance in the various types of drives, and what little difference might exist would certainly be of little influence in the ultimate results, or might even favor the Diesel electric.

The Diesel engines considered in the table for the Diesel electric drive operate at 180 R. P. M., and complete with their accessories, generators, exciters, the motor and control, weigh 350 pounds per shaft horse-power. Of this figure, the electrical equipment consumes 104 pounds, leaving 246 pounds for the engines. Certainly no one will question the

TABLE OF DETAIL WEIGHTS FOR A 3,000 S. H. P., 90 R. P. M. DRIVE.

Item	Double reduction geared turbine	Turbine electric	Direct Diesel (twin screw)	Diesel electric
Prime mover	*100,000	*206,000	*1,200,000	*1,050,000
Boilers and superheaters	†360,500	†360,500	‡11,200	‡11,200
Condensers and auxiliaries	50,000	50,000	....	....
Water in machinery	200,000	200,000	45,000	45,000
Reserve water for machinery	250,000	250,000	....	....
Propeller shafting	115,000	115,000	135,000	115,000
Propeller shaft bearings	15,000	§30,000	§45,000	§30,000
Gratings, ladders, etc.	60,000	60,000	50,000	50,000
Control and cable	....	18,000	....	¶
Steam and water piping	100,000	100,000	32,000	32,000
Independent auxiliaries	32,000	32,000	130,000	20,000
Uptakes, air box, stack, etc.	70,000	70,000	11,000	14,000
Totals	1,352,500	1,491,500	1,659,200	1,368,200
Lbs. per S. H. P. total machinery	451	497.5	552.5	452.5
Ratio, geared turbine, unity	1	1.103	1.227	1.003

NOTE—Using watertube boilers, the two turbine drives would be reduced about 250,000 pounds. However, the installations using such boilers are relatively very few in comparison with those using Scotch boilers.
* 180 R. P. M. engines with exciters. † Scotch boilers. ‡ Vertical boilers.
§ Include thrust bearing. ¶ Included in prime mover.

conservatism of such an engine. This engine is available today in sizes suitable for electric drive.

Another absolutely reliable Diesel engine for electric drive is available, weighing 180 pounds per brake horse-power for the engine alone and operating at 250 R. P. M. The complete Diesel electric drive using this engine instead of the one used in the table is 402 pounds per shaft horse-power, and the ratio of this weight to the weight of the geared turbine drive is 0.892.

Developments will undoubtedly be undertaken by some present Diesel engine manufacturers to commercially produce a lighter Diesel engine which will be suitable for electric-drive units. The ultimate outcome of this development should produce a conservative engine weighing not more than 125 pounds per shaft horse-power and operating at 300 R. P. M. Using these engines instead of those in the table, the weight of the complete Diesel electric drive would be 328 pounds per shaft horse-power, and the ratio of this figure to that for the geared turbine is 0.727.

The weight of 400 pounds per brake horse-power for the direct-drive Diesel used in the table is lower than the average engine actually installed and operating today, which, according to authoritative data, is 483 pounds per brake horse-power. On the 483-pound basis, the weight per shaft horse-power for a complete direct Diesel drive is 635 pounds, and the ratio of this figure to that for the geared turbine is 1.41.

The analysis in the table does not include fuel. Taking the fuel consumption roughly at 0.55 pound per effective shaft horse-power hour for the Diesel and Diesel electric (which is very conservative), and twice this amount per shaft horse-power hour for the geared turbine (which is likewise conservative), and 5 per cent more for the turbine electric than for the geared turbine, and allowing sufficient fuel for a round trip of 3,300 miles each way, for a 3,000 S. H. P. ship, operating at 11 knots, the total fuel consumption would be as follows:

1,648,000 pounds for the geared turbine.
1,730,000 pounds for the turbine electric.
874,000 pounds for the direct Diesel.
874,000 pounds for the Diesel electric.

Adding these figures to the total weights in the table, we have:

3,500,000 pounds for the geared turbine drive.
3,221,500 pounds for the turbine electric.
2,533,200 pounds for the direct-drive Diesel.
2,242,200 pounds for the Diesel electric.

The corresponding ratios as compared with the geared turbine would then be:

Geared turbine	1
Turbine electric	1.07
Direct-drive Diesel	.845
Diesel electric	.747

The above results agree with the general statements in the writer's paper, but are at variance with the figures given by Mr. Bailey and Mr. Smith, particularly the latter. I am quite sure that if these gentlemen would have used the same engine for their Diesel electric drives, their figures would have been substantially in agreement with the table, provided all related items as listed were included.

The tables given by Mr. Bailey and Mr. Smith also show considerably higher cost figures for the Diesel electric than seem justifiable in the light of my experience. I feel quite certain that the price of Diesel engines is still higher than it should be. This is particularly true in the case of engines for Diesel electric drive. I have no figures on the installation of the machinery, shafting, propellers, etc., but I am sure that the engines, generators, exciters, motors and control can be bought today for $130 to $140 per shaft horse-power, provided the proper Diesel electric units are used. Previous quotations might run at variance with this statement, but until recently electrical manufacturers have been forced to quote relatively low-speed Diesels. My remarks on cost referred to future developments, except in a few present cases.

Rather than point out the detailed differences of the comparisons in the tables prepared by Mr. Bailey and the table given above in this reply, the reader is requested to review the tables for himself. I have stated the basis on which my table has been compiled, and, presuming that Mr. Bailey's table has been compiled in much the same manner, the largest discrepancy appears in the cases of the Diesel direct and Diesel electric. The probable reasons for this have been stated above. Mr. Bailey's analysis shows that, in the case of the single-screw Diesel electric, the space favors this type of drive slightly, and it is safe to say that with later developments in electric-drive Diesels the space factor will show greater favor in behalf of the Diesel electric.

In regard to relative fuel consumption, Mr. Bailey has used the same figure for the single-screw Diesel as for the twin-screw Diesel, and according to analyses of propeller performance that have come to my attention, I believe that the fuel consumption per ton-mile should be very nearly the same for the Diesel and the Diesel electric, for the reason that the twin-screw arrangement using the higher speed propellers and additional struts will require more effective horse-power to drive a given tonnage through the water. Furthermore, the fuel consumption figure for turbine electric is given as 0.95 as compared with the geared turbine of 1.0. Mr. Bailey, as stated, uses single-reduction geared-turbine drive in this analysis. I think the figure would have shown the reverse had double-reduction gearing been used. It is also probable that the figure of 0.95 in comparison represents guaranteed economy rather than actual performance. The above paragraph will also reply to similar remarks by Mr. Smith.

I believe that with machinery in proper working condition, the fuel consumption per shaft horse-power, or rather per ton-mile, should run in the order of 1 for the geared turbine, 1.04 to 1.05 for the turbine electric, and approximately 0.5 to 0.55 for Diesel electric and direct-connected Diesels (the latter being twin screw).

Such discussions as Mr. Bailey's are very constructive and will undoubtedly be very beneficial in the final solution of the selection of propulsion machinery. Just at present, it is expected to find considerable difference in the analyses made on Diesel and Diesel electric drive, owing to the wide variety of engines available, and since the engine forms a large portion of the weight of the Diesel electric drive, a considerable variation in this item would show a large difference in the total weight.

Mr. Smith and Mr. Stevens questioned the omission of the junior engineers. The reason why the junior engineers have been omitted from the list of personnel for the Diesel electric drive is because one man is sufficient to operate the control, and this man would always be one of the assistant engineers. In the case of the twin-screw Diesel, it is necessary to station an engineer at each engine, and this requires two men, whereas in the case of the electric drive one man is sufficient, regardless of the number of screws, as the controllers are easier to operate and require less manipulation than the ordinary surface electric car. This practice will vary with different operating concerns.

It will be noted that Mr. Smith takes considerable exception to the value of the backing qualities of an electric-drive ship. If a ship and its shafting, etc., will withstand only a definite amount of backing torque, surely it is inadvisable to apply an excessive amount. In this connection, the electric drive can be regulated to give any desired amount of backing torque from the minimum to the maximum, as it is merely a function of the control. The principal idea in incorporating in the paper a discussion on backing qualities of electrical machinery was simply to show that this type of drive is as good as any type of drive, and can be made better than some types. In regard to battleships, however, it has always been my understanding that quick stopping is essential and that the Navy Department lay some stress on this point. Whether or not the ships are so operated as to not utilize the full backing powers of any type of drive, it is of interest to note that, on the trials, tests are made to determine the quickness with which a battleship can be stopped. In this connection it is interesting to note that the Tennessee can be stopped from full speed in less than three minutes. I think it is plausible to conceive a condition where this difference in stopping time would avoid a wreck.

Mr. Smith mentions that the facts in his table of comparative weights, fuel consumption, etc., show a wide difference from the author's opinions. To substantiate the author's opinions, reference is made to the table given above where the facts on which these opinions were based are recorded. Mr. Smith takes exception to the author's statement and places direct Diesel above Diesel electric in regard to reliability. In this connection, it is interesting to note that present direct-drive Diesels are twin screws. Furthermore, obviously a ship having four engines is more reliable when considered from the "get there" idea than one having two. With a single-screw Diesel electric, the full power of any number of sets can always be utilized for effective balanced propulsion. This is not the case with any other type of drive. Certainly the control gear of a Diesel electric ship cannot be considered in the same category as the reversing gear of a direct-drive Diesel engine when it comes to complication. All control for a Diesel electric ship is effected through a simple, small-field rheostat which handles only a very small fraction of the total current, and which in going from the full speed ahead to the full speed astern positions, does not even open the circuit. In discussing reserve power, I clearly identified it as reserve power in case of casualty to a prime mover. In comparing the Diesel electric with the Diesel or any other type of drive, the Diesel electric is obviously superior to any of them in this respect. For instance, on a 3-unit Diesel electric, the failure of one engine would only necessitate the loss of 12 per cent in speed, and this cannot be approached by the other drives in case of failure of one of the units, and particularly the direct Diesel.

It is but natural for some Diesel engine builders to manifest a reluctant spirit in the advocation of high-speed Diesel engines for electric drive, because the net returns to their coffers are naturally going to be enormously reduced. Such recommendations are probably influenced by commercial analysis rather than engineering analysis. However, as a matter of fact, this reluctance might not represent the most expedient commercial analysis, as the manufacture of engines on a large production basis for an advantageous drive would eventually further the sale of engines, and thus result in greater and more profitable business.

The reason that turbine electric drive is not well suited to destroyers or scout cruisers is because of construction conditions. These conditions do not obtain in battleships and battle cruisers.

Following Mr. Smith's specifications for the selection of the most suitable drive, I think the analysis as given in the author's paper and reply will clearly show that the electrical apparatus fulfils his requirements which he classifies as the "hard, cold facts." In comparing the turbine electric with double-reduction gears there is very little difference, but what little there is in cost and weight favors the geared turbine. In the author's mind, however, these are not sufficient reasons to eliminate turbine electric drive, particularly in the light of past performance.

Captain Newman has given a very instructive description of the U. S. coast guard cutter Tampa and its propelling machinery. There is one point, however, in the discussion that I would like to clear up, and that is Captain Newman's reference to the writer's allusion to a synchronous motor as being more complicated than an induction motor. Possibly Captain Newman might have meant this for someone else, as certainly the author made no such statement in his paper. I did refer, however, to the additional complication of the control in connection with synchronous motor drive as compared with the induction motor drive, and I feel quite sure that those who visited ships containing both types of drive will bear me out in this conclusion.

I cannot agree with Mr. Sperry in his comparison of the electric clutch system with the Diesel electric system using motors and generators, as obviously the latter is considerably more flexible than the former and possesses distinct advantages that are not common to the two systems. The clutch, for instance, does not eliminate the reversing gear of the engine and does not eliminate the necessity for varying the engine speed in order to obtain speed control of the screw. Even assuming that the screw can be reduced by engine throttling to half speed, and controlled from there to zero by slipping the clutch, I am sure that if this were continued for any length of time it would be necessary to use special means for dissipating the heat resulting from the slip energy in the clutch, and this introduces a complication of some kind. The energy resulting from the slipping of the clutch below its synchronous speed is comparable to that which exists in the case of an induction motor, and with this type of machinery it has always been found necessary to dissipate excessive slip energy externally; for this reason, when adjustable speed induction motors are required, it is necessary to furnish the wound secondary type so that the slip resistance can be incorporated external to the motors. It is true that the slip energy at low propeller speeds is considerably less than at high propeller speeds, for the reason that the propeller power varies approximately as the cube of the speed, but the powers are hardly sufficiently small below half speed to enable slip energy to be absorbed in the clutch, without providing some means for dissipating the heat.

Mr. Sperry gives four items of performance contributed by the Diesel electric system of propulsion. In the first place, he endeavors to show that the propeller speed is compromised by the application of a motor. This, however, is not the case, as with direct-current motors we can accommodate any desired propeller speed. Furthermore, the generators can accommodate any engine speed, so that the selection of propeller speed is, therefore, not influenced. There are no limitations in D. C. motors and generators which influence their speeds for ship drive.

Second, the amount of reserve power in the case of the air-gap clutch drive, based on an equal number of engine units, is not as great as with the Diesel electric drive using generators and motors, as the engine speed in the case of the air-gap clutch drive must be reduced in proportion to the reduction in the speed of the ship, therefore reducing the available horsepower of the remaining engines.

Third, in varying the speed of an air-gap clutch drive, it is necessary to vary the speeds of all engines simultaneously, and the engines must govern at any speed; otherwise there will be an interchange of power between the engines and a waste of energy. With the Diesel electric using motors and generators, the generators run at constant speed for any condition of propeller speed and need have only the crudest type of governors, because with series operation it is not even necessary to have theengines running at the same speed. The motor speed is controlled by varying the generator voltage, which is effected through the operation of a simple field rheostat, so that in going from full speed ahead to full speed astern, it is merely necessary to move the lever from one extreme to the other extreme. Certainly nothing more flexible than this could be desired, and these advantages in flexibility do not obtain with the air-gap clutch Diesel drive. The operation at slip speeds of the air-gap clutch has been discussed previously. When the clutch is slipped, the losses vary directly with the speed reduction and power. This means poorer efficiency at low speeds than is the case with straight electric. The matter of cost is something which the author does not propose to know anything about, but it seems that the cost of generators, motors and control, which are all simple apparatus, should not be much in excess of the cost of the air-gap clutch, which is a refined piece of apparatus, flexible couplings, gears, larger air compressor plant, refined engine governors, and engine reversing gear. Another point to be remembered is that this apparatus requires very careful alignment.

Fourth, in addition to eliminating the necessity for reversing Diesel engines as viewed merely from a matter of reversing gear, the one-direction rotation, electric-drive Diesel engine offers considerable simplicity to the air problem, since it is only necessary to start one engine by means of air in getting under way, as the remainder of the units can be started electrically. Therefore, the compressor equipment, air bottles, etc., together with reversing gear, must be balanced against the cost of the electrical apparatus in the Diesel electric system. I am, therefore, not prepared to agree with Mr. Sperry in that the "maneuverability with these engines and the air-gap clutches accomplished all that the full electric plant does, at a very great saving of plant and control equipment." I think that if Mr. Sperry's clutch were reversible, however, it would represent an advance in the art of ship drive, particularly as related to Diesel engines.

Later in his discussion, Mr. Sperry gives five important advantages secured by the application of the air-gap clutch system, on which I would like to comment in numerical order:

1. As pointed out previously, such a system does not give all the advantages and flexibility of a multiple engine unit with as great reserve power as a Diesel electric system would.

2. As stated previously, the air-gap clutch system does not possess the complete flexibility of the electric drive, and it is questionable when all items which the electric drive eliminates are considered, together with the clutch, flexible coupling and gears, whether the expense would be an item for consideration. Mr. Sperry's allusion to the "cumbersome electric-control equipment for handling the heavy currents in maneuvering" is not well founded, as the only thing that is handled is the field rheostat in the generator excitation circuit, and this handles only a small fraction (not exceeding 1½ per cent of the total power), and at that does not even open the circuit. The notice taken of the double losses in motors and generators brings out, of course, a point which does exist when comparing the air-gap clutch drive with the electric system, as there is possibly 8 or 10 per cent additional loss with the electric drive when using the same number of propellers. If the electric uses fewer screws, this economy difference vanishes.

4. The safeguards due to the setting of the torque developed can be accommodated just as well by electric drive.

5. The subject of "criticals" as mentioned here will not exist with the type of units proposed for Diesel electric drive, as the generator armature furnishes the only rotational mass connected to the engine, and this has little, if any more, inertia than the fixed half of the air-gap clutch. The air-gap fluxes of the generators and the motor are comparable to the air gap of the clutch.

As Mr. McClelland states, the comparison of the New Mexico and Tennessee with the Idaho and Mississippi is not a comparison of what might be done with a full gear drive, for the reason that the two latter ships have direct-drive turbines with auxiliary cruising turbines. Nevertheless it will be noted that even at the cruising speeds the electric ships show better performance. Mr. McClelland's statements that the geared-turbine drive of an up-to-date installation would show slightly better economy at full speed than the electric drive, and that the electric drive would gain at the cruising speeds, is in fact the analysis that is conceded in this country, as far as economy is concerned. I am quite sure, however, that the concession must be given to electric drive when considering flexibility, both of arrangement of apparatus and reserve power in case of casualty to prime movers. There are other reasons substantiating electric drive which have been covered in recent articles in the technical press.

Mr. Anderson makes the inference that a geared-turbine drive, particularly for merchant ships, should show better steam consumption than a turbine-electric drive, and requests information on the performance of existing electric-drive cargo ships. I regret that I do not have authentic figures in these cases. It would seem to me, however, that with the turbines operating at the same speeds and other things being equal, or at least comparable, that geared-turbine drives should show a slightly better economy. The value of this small difference is questionable. Personally, I think there are other features of greater concern than a slight difference in efficiency. The figures which Mr. Anderson quotes for the electric drive of existing cargo ships seem to me to be rather high and out of proportion for the figure he quotes for the geared-turbine drive. At best, I cannot see more than 5 or 6 per cent difference.

I do not propose to reply further to the discussion regarding the selection of twin and four-screw ships and electric and geared drive, as this is a matter that concerns the Navy Department.

All the maneuvering that I have witnessed, particularly as concerns backing, has been done with all the engines in use at the time, and I know of no ruling to do all such reversing on only one machine. As far as I can see, there is no reason for it.

I do not agree at all with Mr. Stevens in his analysis of Diesel electric drive as given in the first paragraph of his discussion, and a reference to previous paragraphs of the author's reply to discussion will clearly show the reasons why I do not agree with him.

Referring to the second paragraph of Mr. Stevens' discusion, his statements regarding the comparable economy of the reciprocating engine in sizes of 3,000 horse-power or less do not agree with any figures that have ever come to my attention, and reference to Mr. Bailey's table of comparison will also show that both triple-expansion, single-screw, and triple-expansion, twin-screw engines consume 16 per cent and 27 per cent respectively more fuel than the single-reduction geared turbine in the case of a 2,000-S. H. P. drive. Mr. Bailey also gives a fuel consumption of 6 per cent more for a quadruple expansion reciprocating engine in the case of a 2,600 horse-power drive.

The writer's reference to the horse-car driver who became the motorman, etc., was merely done to show the little difficulty that electrical apparatus had in replacing other means of motive power on land. As far as repairs to electrical machinery aboard ship are concerned, owing to the reliability of such apparatus, there is nothing likely to occur that cannot be taken care of by an ordinary electrician, and furthermore, I do not believe the marine engineer would want to place himself in the position of saying that he could never learn to repair an electrical machine, as this would indicate that the height of progress for marine engineers was already attained. Also, due to the simple construction of electrical apparatus, repairs should be very infrequent.

The matter of electric drive and geared drive for war vessels and the manner in which the different layouts affect the protection of the ship, etc., have been covered in many previous articles, and a discussion of it will, therefore, not be entered into at this time. Mr. Stevens asks why I neglected to mention that, while battleships and battle cruisers are to be fitted with electric drive, the light cruisers and destroyers are being equipped with geared turbines. A reference to the fifth paragraph of the paper under the section of "War Vessels" will show that this matter was mentioned in the paper. Naturally, as an electrical man, I would prefer to pin my faith to a large electric unit, particularly in the light of past experiences.

Commander Robinson has given a very good discussion on the Diesel electric section of the paper and explains the reason for using the same fuel consumption with single-screw Diesel electric as exists with twin-screw Diesel direct.

I do not believe that a voltage of 750 is too high to be used aboard ship in connection with propelling machinery, as this constitutes an isolated plant and can be very easily insulated and protected. If the engines for the electric drive are sufficiently large, so as to reduce the number of units, the voltage, of course, can also be reduced in proportion.

President McClellan:—We will now have the paper entitled "Electric Auxiliaries on Merchant Ships," by Mr. Edgar D. Dickinson, a member of the Society of Naval Architects and Marine Engineers.

Mr. Dickinson then abstracted the paper.

ELECTRIC AUXILIARIES ON MERCHANT SHIPS.

By Edgar D. Dickinson, Esq., Member.

[Read at the twenty-ninth general meeting of the Society of Naval Architects and Marine Engineers, held in New York, November 17 and 18, 1921.]

When we discuss the merchant marine, or any feature thereof, we must not lose sight of the fact that we are dealing with a commercial undertaking which is probably more highly competitive than any other. From its very nature this must be the case, for while each country can make laws to assist the merchant shipowners of that country, every effort to help them and penalize foreign shipping can and undoubtedly will be neutralized by laws of the countries with which they are trading. The only assistance, therefore, that can be given by legislation, outside of providing good port facilities, is to enact laws that will assure a good standard for ships and at the same time not impose penalties in operation to which owners of other countries are not subject.

So we see that the answer to the question: "Who is to carry the merchandise which has to be transported between the various ports of the world?" rests in a great measure with the owners and operators of ships, and, because electricity makes possible many reductions in the cost of operation and at the same time enhances the earning power of a ship, it is being used to an ever-increasing extent for driving the machinery on ships.

On highly efficient new ships, especially motor ships, practically all the auxiliaries are driven by electric motors. In the motor ship the steam boiler becomes an auxiliary, and it is apparent that much of the gain in economy secured by the oil engine would be sacrificed if steam auxiliary machinery were retained. In the steamship, the losses incident to the steam auxiliaries are not so apparent; nevertheless, they are there, a constant drain on the boilers and a continual handicap to any operator or engineer endeavoring to attain efficiency in operation.

It is recognized that a somewhat greater gain in fuel economy is generally secured on a motor ship by the adoption of electricity for the reason that Diesel engines are employed to drive the generators. Oil engines might be used on steamships with a resultant reduction of fuel required for all purposes. However, there are certain good operating reasons why such an arrangement is not generally popular. It would be necessary to have an engineering force competent to operate and maintain the oil engine. As the pumps essential to the operation of the ship's main engine would be driven electrically, any interruption of the auxiliary oil engine might seriously interfere with the operation of the ship. Fuel oil would have to be suitable for the Diesel engine, and in some cases this might necessitate carrying two kinds of fuel oil on board with the incidental disadvantages. Duplicate equipments for heating, storing and filtering fuel oil would have to be installed. On a steamship, therefore, the most generally accepted practice is to install turbine-driven generator sets for auxiliary power.

At this particular time, with the ships of the world tied up owing to lack of cargo, with other countries bending every effort to improve their merchant fleet, and with all men in this country who have the interests of our merchant marine at heart endeavoring to see into the future and maintain such advantage as we have secured due to the large increase in American registry, it would seem that the opportunity afforded by this joint meeting should prove of inestimable value, as engineering advancement can only be secured when a thorough knowledge and understanding of all conditions are recognized by both the manufacturers and users of machinery.

The problem is entirely an economic one. It is only because investigations show that the electrically equipped ship can be operated more economically and can earn more that the question is being discussed. It is the intention of the writer to endeavor to show why this is the case.

Not much information has been published relating to the details of costs of operation of ships. Studies indicate that on new ships electric auxiliaries will show a marked improvement in the economy of operation and will increase the net earning capacity. The future will show that many existing ships can be operated profitably by the substitution of electric for steam auxiliaries. The reasons for expecting such big savings are not at once apparent. Investigations indicate that the losses are partly due to innumerable small leaks and to radiation; in other words, it is the steam which is generated in the boilers but not put to useful work that, in a great measure, accounts for the high fuel consumption of many steam-driven ships. When it is recognized that steam is kept on hundreds of feet of piping from the boilers to the steering engine all the time, and in many ships it is always on all deck lines, to avoid losses and leaks incident to expansion strains from alternately heating and cooling, and in the winter time there are often considerable extra losses incident to keeping steam on deck machinery to prevent freezing, it can be seen that it is not by any means entirely due to the inefficiency of steam auxiliaries themselves that we get a poor showing, but to the very nature of their application, which cannot be altered. The size of the evaporators fitted in many steamships is proof of the amount of steam that is made by the boilers and passed off into the atmosphere.

Auxiliary machinery on ships can be readily subdivided into two broad types: (*a*) For deck use; (*b*) for below-deck use. The motors most suitable are enclosed, weather-proof for above deck, and ventilated for below deck.

It is not the intention to describe a number of different pieces of electric machinery for ships. A study of the technical papers shows an ever-increasing amount of space being given to such descriptions. Thoroughly reliable, simple and substantial machinery of various designs has been developed.

DECK MACHINERY.

Deck machinery (Plates 29, 30 and 31), properly speaking—that is, all machinery which is exposed to the elements and which must be built with this in view—consists generally of cargo winches, anchor windlass, a certain number of capstans, mooring winches and sometimes special machinery on particular ships. It is true that the steering machinery is not generally exposed to the elements, but is, however, very often housed in an extremely damp compartment. Continuous operation is vital to the safety of the ship. It will be evident that only machinery designed and built for the service should be considered for the application. The service of deck machinery is of an intermittent nature except in some special ships, that is, certain tankers where the motors for driving the cargo pumps are mounted on deck.

Electric deck machinery has been developed along two fundamentally distinct lines: one in which the motor is mechanically geared to the drums, and the other where some form of hydraulic speed reducing gear is fitted between motor and drum. The latter class seems to have found considerable favor abroad, where certain well-known manufacturers have developed winches, using either the Williams-Jenney or Hele-Shaw hydraulic power transmission. Electric hydraulic power transmission is particularly well adapted for steering gear work and has been developed in this country. For general winch service the hydraulic pump and motor are excessively costly. A brief comparison of winches developed abroad and in this country would indicate as follows:

(*a*) That the speeds for given load are somewhat lower for the foreign-made winch. A drum speed of approximately 175 feet per minute for 5,000 pounds and 250 feet per minute for 2,000 pounds would seem to be good practice.

(*b*) Certain manufacturers abroad have developed very neat worm-driven winches. These, if properly built, should be very quiet and, from the descriptions, appear to be quite compact. The writer does not know of any winches of this type developed in this country. One particular merit of such a winch is that the gear is readily encased, lubricated and protected from the action of the weather.

(*c*) From several descriptions there appears to be a tendency abroad to operate the motors by contactors. While this arrangement has much merit, it takes up additional space and costs more to install. In one description it is stated that the contactor controller is below deck. This, of course, is possible only in certain cases. Where the winches are located over the cargo holds, special space must be provided on deck for the control panels, and this space, of course, must be properly enclosed.

(*d*) There would seem to be a tendency on the part of the foreign winch manufacturers to considerably complicate the motor and control by the addition of special safety devices. In the writer's opinion this will be found undesirable. One manufacturer in this country who has fitted about two hundred electric winches on ships during the past five or six years claims that special safety devices are not only unnecessary but are actually undesirable. For the reason that they must be kept in perfect operating condition at all times so as to function properly when called upon at infrequent intervals, it will be recognized that apparatus for such service is the most difficult of all to maintain. It must be remembered that winches are operated in various parts of the world by longshoremen at the ports and not by the personnel of the ship. Experience indicates that properly designed and substantial equipment is entirely suitable for the service and does not require complicated safety-guarding features.

(*e*) With the majority of foreign-built winches it would appear that a handwheel is used for operation. This necessitates a tiring and unnatural movement on the part of the winch man. The natural motion, and therefore one which can be carried on for hours at a stretch without unduly tiring the operator, is similar to working a pump handle—that is, to control by means of a lever, raised to raise the load and depressed to lower the load.

For gear winches the series motor or compound-wound with very small amount of shunt winding is the most desirable. Plate 28 shows how the natural characteristics of the series motor make it most suitable for winch service. It is found necessary to throttle the steam winch at light loads to reduce the speed. In practice, therefore, it approaches more nearly the speed of the electric winch. Many winches are fitted with winch heads. When handling cargo with these instead of the drum the revolutions per minute will run up somewhat. However, the winch head being of smaller diameter than the drum, it is generally found that the rope speed on the winch head will be about right.

For all service using hydraulic gear, constant-speed motors are used, either alternating-current or direct-current.

Of all the electric apparatus aboard a ship the winch is subject to the most abuse. Everything about it, therefore, should be designed, manufactured and installed in the most substantial and workmanlike manner.

Specifications for electric deck machinery should cover the following:

1. Insulation should be as highly moisture-resisting as it is possible to get by the use and treatment of the best materials. This applies not only to windings but to all bushings, brush holder collars, etc., which, if hygroscopic, are liable to result in grounds.

2. Motor frames should be thoroughly cleaned and painted on the inside to prevent, as far as possible, scale forming by corrosion.

3. Covers for inspection openings should preferably be hinged and arranged so as to clamp tightly. On all apparatus, motors, resistor boxes, controllers, etc., if impracticable to hinge the covers they should be attached by swinging bolts. Cap screws or cap bolts should not be used, as they are liable to be dropped into the motor or left on deck and lost.

4. Bearings should be designed to prevent, as far as possible, ingress of water and egress of oil due to rolling of the ship.

5. All apparatus should be provided with some form of drain. It must be recognized that, while machinery may be built in the factory so watertight that it can be submerged, there is no assurance that this condition will exist after it has been once opened on deck. Further, any totally enclosed electrical apparatus is liable to breathe under varying temperatures which may result in an accumulation of moisture by condensation.

The cost of good electrically fitted machinery installed should be little, if any, more than that of high-grade steam machinery. Of course, until apparatus reaches a stage of standardized production the costs cannot be materially reduced. It must be remembered that, while in steam machinery all kinds of economies may be practiced at the cost of quality, in electrical apparatus built to withstand marine conditions and severe service a departure from the highest grade is most certain to be followed by failure and consequent cost to the operator. The making and insulating of electrical machinery cannot be materially hastened, as the successive dryings or bakings of the insulation must be given proper time; otherwise, it may be imperfect. The insulation in a marine motor must be moisture resisting to the maximum practical extent; otherwise, it should not be deemed proper for the service.

Plate 29 shows a deck winch developed in this country, several of which type will shortly be installed on ships. This winch is a radical departure from the generally recognized designs using either spur or worm gearing.

Electric steering gears have been developed for mechanical control of the rudder. For these the service is extremely intermittent, operating from two to ten times per minute, which means that the motor would be started, stopped and reversed thousands of times during one voyage. Such gears require the installation of a motor of sufficient torque to swing the rudder to the extreme angle, whereas during most of the time a very small amount of power is required. This means loss in efficiency as the motor is operating nearly all the time very much underloaded.

For controlling the steering gear from the pilot house two electrical means are available—follow-up and nonfollow-up. The first entails considerably more wiring, a multiple switch in the wheel house, a more complicated control in the steering engine compartment, and has the disadvantage of moving the rudder step by step a definite number of degrees. By the nonfollow-up means the rudder can be moved by fractions of degrees in either direction; its use, however, calls for the installation of a rudder indicator in the wheel house. A device has been worked out to show positively the position of the rudder at any instant, using simple means already developed.

Special Deck Machinery.—There are many special applications of electricity to machinery for shipboard not normally included as part of the regular equipment of a cargo ship wherein the use of electricity is particularly well suited. By the proper application of principles already worked out, it will be found that towing engines, mooring winches and other special pieces of machinery can be built to operate electrically in a very simple manner and with as great, or greater, reliability than steam machinery already developed.

The following is a table of deck machinery which, with slight modification, would be applicable to ships of any tonnage between 8,000 and 10,000 tons dead-weight. It should be borne in mind that the size of the cargo winches is based upon the best practice for general cargo and therefore does not vary greatly with the size of the ship. The number of winches, however, has to be modified to suit the number of hatches and derrick booms of the different ships.

	No. units	Assumed motor horse-power	Duty
Anchor windlass........	1	70	Very intermittent, severe. Often submerged. May be stalled in operation.
Cargo winches..........	12	35	Intermittent. Fast cycle, severe duty. Sometimes submerged. Wide range in loads and speeds.
Steering gear...........	1	35	Seldom fully loaded. Severe intermittent duty with mechanical gear. Moderate continuous duty with hydraulic gear.

Types Developed (Electric Deck Machinery.)

	Drive	Motor	Speed control
Anchor windlass and capstan	Spur gear..... Worm gear.... Hydraulic.....	Reversing........ Reversing........ Constant speed....	Electric. Electric. Hydraulic.
Cargo winch	Worm gear.. Spur gear...	Reversing........ Reversing........ Constant speed.... Constant speed.... Constant speed.... Constant speed....	Electric with electric brake (general use) Electric with mechanical brake. Mechanical brake and clutch (free drum winch). Mechanical brake hoisting and lowering clutches. Reverse gear and brake. No speed control (winch head only).
	Hydraulic.....	Constant speed....	Hydraulic.
Steering gear..............	Spur gear..... Worm gear.... Hydraulic	Reversing........ Reversing........ Constant speed....	Electric. Remote. Hydraulic.

BELOW-DECK MACHINERY.

It should not be necessary to emphasize the importance of fitting equipment of proper design and of the highest grade material, particularly pumps vital to the operation of the ship and which must be relied upon to operate continuously day and night for weeks at a stretch.

The greater part of the electrical machinery below deck is naturally located in the engine room. The following table gives a list of below-deck auxiliaries suitable for a cargo ship of about 8,000 to 10,000 dead-weight tons and equipped with 2,500 to 3,000 shaft horse-power steam turbine. A motor ship requires somewhat fewer auxiliaries, and slightly less power is necessary for driving them. Tankers require a number of motor-driven pumps for discharging the cargo. These may be installed either in a special pump room or arranged with the motors on deck with vertical shafts to the pumps below. It will be noted that in the list there are only five sizes of motors. That is with the intent of simplification and to reduce the number of spare parts to be carried. A study of particular cases may show that it is possible to satisfactorily arrange the engine-room equipment so as to have still fewer sizes.

BELOW-DECK AUXILIARIES.

	No. units	Assumed motor rating in horse-power	Duty
Propulsion:			
1. Circulating pump ..	1	40	Continuous at sea.
2. Boiler feed.........	2	25	One continuous at sea.
3. Forced draft fan....	1	20	Continuous at sea.
4. Condensate	1	5	Continuous at sea.
5. Lubricating oil.....	2	5	One continuous at sea.
6. Oil cooler water....	1	5	Continuous at sea.
7. Fuel oil	2	5	One continuous at sea.
8. Fuel oil trans	1	5	Intermittent (assume 4 hours per day).
Service:			
9. Fire and bilge......	1	10	Intermittent (assume 6 hours per day).
10. General service.....	1	10	Intermittent (assume 6 hours per day).
11. Sanitary...........	1	5	Intermittent (assume 12 hours per day).
12. Fresh water........	1	5	Intermittent (assume 2 hours per day).
13. Refrigerating	2	5	One continuous at sea.
14. Evaporator	1	5	Intermittent (assume 3 hours per day).
15. Ballast............	1	10	Intermittent (assume 4 hours per day).
16. Workshop.........	1	5	
17. Oil purifier	1	5	
18. Galley	1	5	

Motors for these auxiliaries should be designed for continuous running, because, while certain pumps may be started and stopped frequently, the service cannot be considered intermittent.

In the engine room, and in fact even if placed in the lowest part of the ship, totally enclosed motors are not recommended. For continuous operation they would have to be excessively large. With the changes in the atmosphere that take place below the water line, enclosed motors would be more liable to sweat and accumulate moisture internally than if well ventilated. In general, enclosed self-ventilated motors are recommended for the reason that they are often located in congested places where, if open, they would be liable to mechanical injury and in addition would have to be protected from dripping water. However, as electrical machinery, when open, is more readily inspected and kept clean, it is not essential that the motors be enclosed if located, *e. g.*, on a gallery and properly protected from dripping water. Such motors should be screened to prevent rats eating the insulation. On tankers, if the cargo pump motors are of the direct-current type and are located in a special pump room, they must be provided with some means of ventilation which will insure all explosive gases being driven off before the motors are started.

The motors in the engine room should be insulated with the same care and the castings as thoroughly cleaned and painted as the motors on deck. The insulation on all marine electrical apparatus should be made as highly moisture-resisting as possible.

As illustrating the adaptability of electrical apparatus, the writer recently saw a report from a chief engineer which stated that when the steam engines on his circulating pump and dry vacuum pump broke down he replaced them by two deck winch motors. The drive was so satisfactory that he intended to recommend that it be made permanent, and incidentally the ship burned 1½ tons of fuel oil per day less after the change.

Control.—It would seem desirable that the means for starting and stopping each motor be located directly adjacent to it. Such starters are relatively inexpensive. They should be very substantial and moisture-resisting. Thin sheet iron should not be used, especially on any part of the construction which cannot be readily painted, as after a short time it is liable to rust and may be the cause of serious trouble.

On steam ships the motors on the circulating pump, lubricating oil pump, boiler feed pump, hot well pump, balancer set or lighting motor-generator set, if any, and steering gear, should be fitted with starters, so that when power is restored after an interruption these particular motors will immediately start up automatically. The other motors can be restarted by the engineer at his convenience.

Generating Units.—A study of the installations on a number of cargo ships of various tonnages indicates that on a steamship 150 kw. would give ample power for the deck machinery when in port and for the entire engine-room equipment when at sea. On a motor ship about 75 kw. are necessary at sea. Therefore, on cargo ships of about 10,000 deadweight tons, two 150 kw. steam turbines or on the motor ships three 75 kw. generator sets would give ample power with one unit for a standby at all times. The auxiliary power in many cases will be much greater than 150 kw. on refrigerator ships and on ships fitted in part for passenger service. The larger the amount of auxiliary power the greater the reason for highly efficient auxiliary turbines. Some studies have shown requirements for auxiliary power as great as 1,500 kw.

Small steam turbines should be rugged and simple, as they will be classed as part of the propelling machinery and therefore vital to the safety of a ship. In sizes of 150 kw. and even smaller, gear reduction would be recommended, as the best direct-current generator operation cannot be expected at the speed at which the turbine should run in order to get good economy. It is expected that these sets will be more substantial and rugged than sets of similar capacity for land service, where they are at all times readily accessible.

For the reason that on shipboard there is always possibility of scale or salt passing to the turbine from the boilers, it is preferable for the governor to control the speed by means of an oil Servo motor. All parts should be readily accessible. Even with the greatest care there is always liability that the lubrication may be momentarily interrupted, and as the bearings should be examined before the machinery is placed in service they should all be readily removable for inspection. An overspeed or emergency governor of the simplest and most reliable type should be fitted. Very specific and simple instructions should be issued to show the operating engineer the necessity of testing the governing mechanism periodically and assuring himself that it is in perfect operating condition.

THE MOST SUITABLE ELECTRIC POWER.

All references indicate that at the present time direct current is being generally adopted for auxiliary power on merchant ships. Some time ago there was considerable discussion as to the relative merits of alternating current and direct current. The following tabulation will show why direct current is being used to the greater extent:

Cargo Ships.

DIRECT CURRENT.

Arguments For	*Arguments Against*
1. Simple wiring.	1. Commutators require some attention.
2. Any speed control easily obtained.	
3. Equally suitable for continuous and intermittent duty.	

ALTERNATING CURRENT.

1. Lower cost of motors and generators.	1. Wiring more expensive.
2. Absence of commutators.	2. Unsuitable for variable speeds necessitating hydraulic or other gear for winches and windlasses.

Tankers.

DIRECT CURRENT.

1. Simple wiring.	1. Commutators require some attention.
2. Equally suitable for continuous and intermittent duty.	2. Little necessity for variable speed motors. Special cases could be fitted with hydraulic or direct-current power furnished from small motor-generator set.
3. Speed of cargo pump can be varied to suit pressures and most efficient rate.	3. Special precautions must be taken to ventilate motors in tank room.

ALTERNATING CURRENT.

1. Lower cost of motors and generators.	1. Wiring more expensive.
2. Absence of commutators, particularly desirable in pump room.	2. Special motors necessary to change speed.
3. Cargo handled by constant speed pumps.	

It would seem that for cargo ships direct current can be used to the greatest advantage. On tankers this is not so apparent.

Except in the smaller ships, it is desirable to use not less than 230 volts. The lower voltage necessitates large or more expensive control; also the cost of wiring and switches is greater.

For lighting, the arguments seem to be in favor of 115 volts. This necessitates the installation of a small 115/230-volt motor-generator set. The use of incandescent lamps for 230 volts is not recommended. They are of necessity built with a very fine filament and are, therefore, less substantial and, further, are not easily procured in seaports.

WIRING AND INSTALLATION.

It is impossible to speak too forcibly on this subject. A great deal of the criticism of electrical apparatus when thoroughly investigated has been found to be directly due to faulty, careless, slipshod methods of wiring and installation. Care and attention have been given to choosing apparatus, but the method of installation, the kind of wire, and many details of vital importance have been left to the wiremen's discretion with the inevitable result.

It is not the intention here to suggest that definite rules be laid down. Each engineer must work out his own particular problems. Certain underlying fundamentals, however, can generally be applied. The following are recommended:

That the wiring and distribution in the engine room be made as simple as possible, with relatively few circuits.

The switchboard should be largely a distribution panel designed with the idea of attaining maximum simplicity and occupying the least amount of engine-room space.

Circuits may be led from this distribution panel to different parts of the ship where they may be further subdivided, as, *e. g.*, five circuits for deck machinery, No. 1 to the steering engine, No. 2 to the after hatches, No. 3 to the forward hatches, No. 4 to anchor windlasses and forward capstans, No. 5 to after capstans. This will permit opening all the winch circuits when at sea and also allow for thorough inspection and try-out of the capstans, anchor windlass or steering engine when in port, even if cargo is being handled.

In the engine room a similar method may be applied, one circuit to the engine-room auxiliaries, port side, and another to the starboard side. By such simplification it will be possible to obtain low cost with maximum reliability.

Cables should not be run in conduits except, perhaps, for very short lengths where necessary for mechanical protection. Cables in the engine room should be run overhead. All cables should be thoroughly anchored so that the covering will not be chafed, due to vibration.

OPERATION.

To study the relative merits of ships' auxiliaries, it is necessary to consider the part which they play in the economic operation of the ship.

For certain special types of ships designed and built to operate for some particular service, such as tankers and lake ore carriers, it is not difficult to show definitely why a certain installation will give the best return on the investment.

In the cargo ship, however, the problem is not so clearly cut. While it is true that a certain number of ships may be designed with the intention of traveling particular trade routes and handling a special cargo, it is often found that their schedule must be modified.

Therefore the general cargo ship must be built to handle all kinds of cargo, and at best, therefore, the apparatus with which it is equipped is somewhat of a compromise.

It is not possible to make any exact general statement as to the proportions of the various items constituting the cost of operating merchant ships. They may, however, be listed as follows:

1. Fuel and lubricating oil at sea and in port.
2. Port charges including wharfage, lighterage, pilot fees, canal dues, stevedoring, tugboat charges, etc.
3. Salaries and subsistence.
4. Upkeep and repairs, deck department.
5. Upkeep and repairs, engine department.
6. Supplies, engine, deck and steward's departments.
7. Insurance.
8. Loss and damage.

If we assume a 7,800 deadweight-ton ship fitted with 2,500 horse-power steam turbine on a schedule for coastwise service between New York and Seattle, stopping at San Pedro to load and discharge cargo and making four round trips per year, the charges might be approximately as follows:

OPERATING DISBURSEMENTS.

	Loaded both ways	Percentage	Loaded going, one-half loaded returning
1. Fuel	$81,300	14.8	$81,300
2. Port charge	290,420	52.9	211,020
3. Salaries	60,490	11.0	60,490
4. Repairs, deck	10,000	1.8	10,000
5. Repairs, engine	20,000	3.7	20,000
6. Supplies	20,250	3.7	20,250
7. Insurance	62,400	11.4	62,400
8. Loss and damage	3,650	.7	3,650
Total	$548,510	100	$469,110

Many of these would be affected by electrification of auxiliaries, and the net reduction would be very considerable.

1. *Fuel, etc.*—In the usual marine geared turbine installation with steam auxiliaries, the pressures generally carried are as follows:

	Gauge
Boiler pressure	210 pounds.
Turbine bowl	200 pounds.
Auxiliary steam line	100 pounds.
Auxiliary exhaust	10 pounds.
Superheat	75° F.

The auxiliary exhaust steam is used to heat the feed water, and that which is in excess of feed-water heater requirements is by-passed to the main condenser.

Under full power, a fair operating average for this type of installation is as follows:

Steam Consumption Per Hour:

	Pounds
Main turbine, 2,500 horse-power	28,875
Steam auxiliaries at sea	12,500
Total steam consumption	41,375

Steam Per Shaft Horse-power Hour, All Purposes:

$$\frac{41,375}{2,500} = 16.5 \text{ pounds.}$$

Boiler Evaporation.—With water tube boilers, Howden draft system, feed water delivered to boilers at 220°, 210 pounds gauge pressure and 75° superheat, a conservative estimate of the actual evaporation per pound of fuel oil is taken at 13.5 pounds.

Fuel Consumption:

Fuel per hour $= \frac{41,375}{13.5} = 3,065$ pounds................ = 9.6 bbls.

Fuel per day, 73,560 pounds.......................... = 32.8 tons.

Fuel in barrels per day................................ 230

Fuel Per Shaft Horse-power Hour:

$$\frac{3,065}{2,500} = 1.23 \text{ pounds.}$$

Fuel in Barrels, Per Knot:

Assuming a speed of 10.5 knots, $\frac{9.6}{10.5} = 0.915$ barrel per knot.

The economy to be gained through the application of electrically driven auxiliary machinery, in fuel consumption alone, may readily be seen from the following estimates:

ELECTRIC AUXILIARIES.

Superheat, 75° F.

Heating Feed Water.—The proposed method would be to extract sufficient steam from the turbine for feed-water heater requirements.

Steam Consumption, Per Hour:

	Pounds.
Main turbine, 2,500 horse-power	30,600
Turbine generator	2,640
Air ejector	1,000
Total	34,240

NOTE:—3,600 pounds per hour steam will be extracted from main turbine at about 10 pounds gauge to heat feed water.

Steam Per Shaft Horse-power Hour, All Purposes:

$$\frac{34{,}240}{2{,}500} = 13.7 \text{ pounds.}$$

Boiler Evaporation.—Estimated for comparative purposes at 13.5 pounds per pound of fuel. With the lesser quantity of steam to generate, however, the boiler efficiency would be improved in actual practice.

Fuel Consumption:

Fuel per hour, $\frac{34{,}240}{13.5} = 2{,}536$ pounds $= 7.9$ barrels.

Fuel per day, 60,864 pounds = 27 tons.
Fuel per day, in barrels = 189 barrels.

Fuel Per Shaft Horse-power Hour:

$$\frac{2{,}536}{2{,}500} = 1.01 \text{ pounds.}$$

Fuel in Barrels Per Knot:

Assuming a speed of 10.5 knots, $\frac{7.9}{10.5} = 0.75$ barrel per knot.

The application of high superheat, well within the limits of present-day design, and electric auxiliaries present a very interesting and high economic value in ship propulsion.

ELECTRICAL AUXILIARIES.

Superheat, 200° F.

Steam Consumption, Per Hour:

	Pounds.
Main turbine, 2,500 horse-power	27,000
Turbine generator	2,400
Air ejector	1,000
	30,400

NOTE:—3,000 pounds per hour steam will be extracted from main turbine at about 10 pounds gauge to heat feed water.

Steam Per Shaft Horse-power Hour, All Purposes:

$$\frac{30{,}400}{2{,}500} = 12.15 \text{ pounds.}$$

Boiler Evaporation:

Assumed at 13 pounds per pound of fuel.

Fuel Consumption:

Fuel per hour $= \frac{30{,}400}{13} = 2{,}340$ pounds $= 7.33$ barrels.

Fuel per day, 56,200 pounds = 25.1 tons.
Fuel in barrels per day = 176 barrels.

Fuel Per Shaft Horse-power Hour:

$$\frac{2{,}340}{2{,}500} = 0.936 \text{ pound.}$$

Fuel in Barrels Per Knot:

Assuming a speed of 10.5 knots, $\frac{7.33}{10.5} = 0.698$ barrel per knot.

These estimates show the saving in fuel consumption by the use of electric auxiliaries, as follows:

Saving in Fuel Consumption (at sea):
Steam auxiliaries, 230 barrels.
Electric auxiliaries, 189 barrels, 17.3 per cent.
Electric auxiliaries, with 200° F., 176 barrels, 23.5 per cent.

Saving Per Year:
208 days at sea, oil at $1.50 per barrel.
Electric auxiliaries, 8,320 barrels at $1.50 = $12,480.
Electric auxiliaries, with 200° F. superheat, 11,250 barrels at $1.50 = $16,900.

In the estimate, an allowance was made of 40 barrels per day in port. With electric auxiliaries and economic engine-room machinery, it should be possible to reduce this by one-half.

157 days × 20 pounds × $1.50 = $4,710.

With a good system in the engine room, the lubricating oil required would be greatly reduced.

2. *Port Charges.*—In giving thoughtful consideration to improving the earning power of a ship, it will be recognized as essential to decrease its idle time, as certain charges are continuous, whereas the ship is actually earning money only when traveling between ports. When it is realized that the average cargo ship makes only about 36,000 miles per year and that at an average speed of 10 knots, which means that she is at sea only about 150 days out of a year, it is very evident that there is a big field for improvement.

Port charges estimated for the coastwise schedule mentioned above are as follows:

	New York	Colon	Los Angeles	San Francisco	Seattle	Total
(a) Wharfage	$7,800	....	$1,560	$3,120	$3,120	$15,600
(b) Lighterage	....	....	....	....	....	....
(c) Pilots' fees	202.56	....	200	250	....	652.56
(d) Stevedoring	7,800	....	1,560	3,120	3,120	15,600
(e) Tugboat charges	100	....	....	200	....	300
(f) Canal dues	....	$4,150	....	....	....	4,150
Total per trip						$ 36,302.56
Total per year (four round trips)						290,420.48

It will be evident that any means which will reduce the time a ship has to lie at the wharf loading or unloading cargo should lessen the two items, wharfage and stevedoring. The writer has been informed of specific cases where ships have been delayed at docks due to freezing of steam-deck machinery. He has also been informed of a specific case where with two similar ships loading and unloading the same kind of cargo at the same dock and with the same stevedore foreman, the electrically equipped ship loaded in very much less time. Another specific case was where a number of ships fitted with steam-deck machinery had to await the derrick to assist in loading heavy cargo, while a ship fitted with electric machinery was able to handle its own cargo and saved a number of days delay.

Delays have been experienced with steam machinery due to low steam pressure. This may not be due to drop in boiler pressure but to loss in piping. With electric equipment there is always ample power available for the winches.

By the use of the most suitable electric machinery, it should be possible to reduce the item of port charges 10 per cent. In the estimate given above this would mean approximately $30,000 per year saving.

3. *Salaries.*—In all probability the salaries would not be directly affected. In the larger ships and in those where there is a very large amount of auxiliary power it might be found desirable to increase the salary slightly for one of the positions, in order to secure a man with electrical experience.

4 and 5. *Upkeep and Repairs.*—Both of these items should be reduced. With properly designed electric machinery, the charges for repairs and maintenance would be less than with steam machinery. If compared with many existing ships, a 20 per cent reduction would in all probability be a conservative estimate. If we only allow 10 per cent, however, this would mean a saving of approximately $3,000 per year on the above estimate.

6. *Supplies.*—This item would not be appreciably affected in the deck department, but for the engine department there should be a material reduction. A saving of 10 per cent might be expected, which would amount to $2,000 per year.

7. *Insurance.*—The assured reliability of proper electrical machinery in the engine room, along with the elimination of a large amount of piping carrying high-pressure steam, should have a direct bearing on the insurance rate. Indirectly, by reducing the loss of steam it should be possible to maintain the water in the boilers in almost perfect condition. This should still further add to the safety of a ship. It would seem to be justifiable to expect that the insurance premiums can be decreased about 5 per cent; this would mean a saving of approximately $3,000 per year.

8. *Loss and Damage.*—This item in all probability would not be affected.

The sum of the different gains mentioned above totals $55,190 per year. The amount of saving that can be shown by other estimates will naturally vary with conditions. In any estimates the possibility of making a substantial gain in the earning capacity in a ship is a real one. Having in mind certain ships, there is every reason to believe that the figures mentioned above might be increased.

One of the latest British combined cargo and passenger ships is equipped electrically and is fitted with over 100 motors driving auxiliary apparatus. Needless to say, the owners of new foreign ships are fitting them with electrically driven machinery only because they have satisfied themselves that it is profitable to do so. We engineers in this country should combine our efforts and avail ourselves of every opportunity to improve the efficiency of our merchant ships to the end that they may be able to successfully compete with the modern ships being placed in service by the other countries.

DISCUSSION.

Mr. Fred C. Bates, *Visitor:*—In 1895 I made a trip from Germany to China on the North German Lloyd steamship Prinz Heinrich which was exclusively equipped with electrically operated cargo winches. In an incautious moment, I wrote a letter to Mr. Maxwell W. Day, of the General Electric Company, in which I outlined some of my old experiences, the letter having been prepared largely for the use of those unfortunate men who by force of circumstance are compelled to get their marine experience on land.

I believe that the Prinz Heinrich was the first ship that was ever exclusively equipped with electrically operated cargo winches, although the steamship Darmstadt of the same fleet had been partially equipped the year before. I spent about six months on board this ship in immediate charge of the electrical equipment, consisting of two 75-kw and one 35-kw direct-connected, direct-current, 125-volt generators and six cargo winches mounted on deck.

Many things have changed since 1895. Insulating materials have been vastly improved; protective devices now in common use were then unknown, and many other improvements, both mechanical and electrical, have been made. I would, however, venture to assert that the grim old sea is unchanged; that the weather conditions under which operation must be maintained are just as vicious in 1921 as in 1895, and that the tricks of the gentle stevedore, be he black, white, brown or yellow, are just as stupid and just as rough as ever.

The ship was built by Friedrich Schichan & Company at Elbing, near Danzig. She was 11,000 tons displacement, made about 14 knots,and was built for mixed cargo and passenger service in the tropics, hence the use of electricity in order to maintain a cool ship. The electrical equipment was furnished by the Union Elektricitats Gesellschaft, since absorbed by the Allegemeine Elektricitats Gesellschaft.

My data covering the winches have been long since lost or mislaid, but some old bulletins were found in the archives of the General Electric Company which reveal the fact that their capacity was 6,600 pounds at 1.64 foot-seconds or 3,300 pounds at double speed. The motors were from 10 to 15 horse-power capacity at 450 R. P. M. The winches were installed one forward and one aft on the upper deck, two forward and two aft on the main deck.

A merchant ship is only in port when unloading and loading cargo. The rest of the time she is at sea; therefore a winch that breaks down in service in port must be repaired at sea, perhaps with a rolling ship in a storm, in order to be ready for service in the next port.

The apparatus mounted on deck is exposed to extremes of temperature, making the problem of lubrication difficult and necessitating the greatest care in the design of armatures, fields and resistances.

Apparatus mounted on deck is exposed to all forms of moisture, rain, snow, sea water and fog. While at sea the apparatus can be protected by tarpaulins, but in port the apparatus must be uncovered and operate under any conditions of weather. The location with respect to hatches and overhead tackle determines the amount of protection that can be given to apparatus and operator, but as a general rule any sort of protection impedes operation. Complete housing would be expensive, as it would have to be strong enough to withstand winds and waves.

The duty of such winches is most difficult. Long pieces of cargo such as bar iron or fabricated steel, if unskillfully "slung," will jam across the hatch opening. The operators often run out 10 or 20 feet of chain and "break out" the cargo with a winch at full speed. All this abuse requires extraordinary strength in shafts, keys, couplings, gears, etc., and most careful selection of electrical protecting devices.

We sailed from Bremerhaven, having loaded ship with her own electric power. At Antwerp the hydraulic dock equipment was used for loading and unloading. Our electric power was used in Southampton and also for light duty at Genoa and very heavy duty at Naples, where all the winches broke down, and we sailed for the Far East with 4,000 tons of cargo and not a winch working. It was quite evident that this particular equipment was inadequate, and after having shared the responsibility with the officers of the ship by a letter in which this inadequacy was expressed, I had the most cordial, helpful cooperation from these splendid companions and shipmates.

The controllers were changed when we returned to Germany, but they were not successful and were changed again upon the second return. This time they were found to be entirely successful. I secured my acceptance of the equipment at Port Said and returned home on another ship.

We left Germany without spare parts of any kind. At every port we made vain efforts to secure electrical supplies; none of the big shipyards had such supplies, and none of the cities we visited had shops or stores for the sale of this material. When we got to Port Said a friend took me to his storehouse and loaned me a miscellaneous assortment of wire and switches.

The engines were very bad, and we were unable to obtain proper regulation. On an old English tramp built on the Clyde which came into port, we found some good governors built by a concern called Clark & Chapman. After the purchase and installation of these governors, we had no further trouble with the engines and, as far as we know, they are still in operation.

The operation of the electrical winches was alleged to be as simple as the operation of steam winches and, while this was true later on, it was by no means so at first. The North German Lloyd had contracts with stevedore gangs in different ports, and as they had been accustomed to the operation of steam winches we had a great deal of difficulty in teaching these stevedores to use the electrical winches. The Chinese operators were the best. All we needed to do was to tell "No. 1" what his men were to do, and they did it without variation hour after hour.

In 1896 the steamship Bremen was laid down in the yards of Blohm and Voss. She was equipped exclusively with electrical cranes which were very successful.

The Prinz Heinrich is now the steamship Porto belonging to the Portuguese government and sailing from Lisbon. Information received within a month through confidential sources is to the effect that the electrical cargo winches on this ship are still operating. We had no electrical failures. Our troubles were entirely mechanical, due to improper selection of material and a lack of knowledge of the sea, and of the service which the winches were to perform, but the outstanding fact still remains that this electrical equipment put into service in January of 1895 is still in commercial service in November of 1921.

Mr. G. H. Jett, *Visitor:*—In my invitation to present a discussion of the paper on Electric Auxiliaries I was advised that the time allotted for such discussion would be ten minutes. This, as you will understand, will prevent my going into any phase of the subject in detail, especially the very important subjects of costs of installation, operation and repairs.

It is very gratifying to me that an engineer of one of the leading electrical manufacturers should so strongly advocate the simplifying of wiring and control for electrical equipment on board ship, as Mr. Dickinson has done in his article. It would appear that, until recently, manufacturers have not fully appreciated the conditions on board ship as differing greatly from those in shore plants. There are many examples of ship installations where recommendations have been made by electrical manufacturers following closely the practice generally in use in power stations on shore, resulting in the use of unsuitable motors and equipment and in some cases a far too elaborate and complicated system of wiring and control apparatus. In general, I concur in Mr. Dickinson's opinions and recommendations and will attempt to discuss only certain particulars.

In our merchant ship installations, in my opinion, the following are the most essential points to be borne in mind:

First, that the proper type and capacity of motor be selected, particular attention to be paid to the waterproofing of motors for all deck equipment. Without question the characteristics of the series direct-current motor make it particularly well adapted for cargo winches, windlasses and capstans.

Second, that the control equipment for all electric motors and apparatus be limited to the very minimum consistent with safety, hand-operated devices being used wherever practicable to eliminate danger of failure through burned-out shunt coils or other parts.

Third, that all protective devices limiting current to motors or equipment be installed in engine-room compartments or at least where it will be under the supervision of the personnel of that department, eliminating the possibility of deck hands or stevedores having access.

Fourth, that in all wiring, as far as practicable, marine armored cable not enclosed in conduit be used and that the amount be limited to the minimum consistent with proper grouping of circuits.

In this connection I want to say it is not my idea to eliminate any particular thing being proposed by the electrical people, but I do think it is necessary to limit to the very maximum the amount of equipment, whatsoever, to simplify it as far as it is possible to do so. In Mr. Emmet's talk he called attention to the fact that—and I agree with him—the problem of training personnel for electrically driven ships is not what it is understood to be by many. However, I want to call your attention to the fact that in public service corporations, electric light and power plants, they do not have the engineers of these power plants make repairs to electrical equipment. They have specialized men for armature winding and winding of shunt coils who look after all the details of the equipment, and the steamship operator does not like the idea of facing the possibility of highly trained specialized men on shipboard, and for that reason I think it is most important, in view of the personnel going to sea at the present time, to eliminate to the very last degree the installation of unnecessary equipment. Every foot of wire and every shunt coil makes another possibility of trouble. The motors as now supplied for ships are rugged and will stand a lot of abuse, but they do need a certain amount of protection.

The subject of rope speeds in handling cargo with deck winches is a very important one, on which there is a great divergence of opinion, there being but little reliable data and records available. Many of the steamship companies contemplating new construction are frequently demanding rope speeds which, I am satisfied, are far in excess of the speeds at which it would be practicable to handle cargo. In most cases their demands are based on incorrect information as to speeds at which cargo is handled by steam winches. I have made an extensive study of this subject, and it is my opinion that only in exceptional cases is a rope speed of 250 feet a minute reached in handling sling loads of cargo even as light as 1,000 pounds, but the items of greatest importance are the acceleration and the speed of raising and lowering light hooks. In the design of electric cargo winches, in deciding on the size of the motor, you must take into consideration the speed at which the various weights of cargo are to be handled.

I do not agree with Mr. Dickinson's recommendations as to the size of motors required for deck winches on 8,000 to 10,000-ton cargo ships. In my opinion 25-horse-power motors are ample for any cargo winch except in case of very deep holds of the largest vessels. The majority of 8,000 to 10,000-ton deadweight vessels have but eight steam winches, usually with engine cylinders of 8¼ inches by 8 inches or the equivalent. It has been demonstrated to my entire satisfaction that an electric winch equipped with a 25-horse-power series direct-current motor will more than equal in every respect the performance of an 8¼-inch by 10-inch steam cargo winch. It is my belief that the load factor or ratio of average to maximum load, and consequently the size of winch motors required, is overestimated.

Referring to Mr. Dickinson's comparison between electric and steam operated auxiliaries as to fuel consumption, because of the many elements to be considered, it is very difficult to determine the possible fuel saving to be effected in the operation of the engine-room auxiliaries, this being a matter on which there are very little accurate data available. Advocates of steam equipment will no doubt take exception to the figures presented in Mr. Dickinson's paper. An important item to be considered in this connection is the fact that electrically operated equipment can be maintained at a higher operating efficiency than steam equipment. Electric motors will continue to operate at practically maximum efficiency as long as continued in service, as compared with steam equipment, which is subject to the usual adjustment and wear of steam valves, wear in cylinder liners, broken or loose piston rings, condition of steam packing, etc. The figures presented by advocates of steam equipment would of course be based on the equipment being in its most efficient operating condition, which is not generally maintained in service.

In my opinion Mr. Dickinson has been entirely too conservative in his estimate of the possible economy of electric deck winches over steam equipment, both in the case of fuel for operation and repair costs. There are considerable accurate data available on this subject.

The following data were obtained as a result of recent carefully conducted tests under actual operating conditions on a vessel of 11,600 tons deadweight equipped with three Scotch boilers, oil fired; main propulsion electric drive; engine room and deck auxiliaries steam driven; deck equipment included twelve cargo winches, steam cylinder sizes 7 inches by 10 inches:

Usual engine-room auxiliaries operating twenty-four hours and an average of ten cargo winches operating from eight to nine hours. Average fuel consumption per day, tons..........	11
Usual engine-room auxiliaries in operation twenty-four hours, no cargo winches or other deck auxiliaries operating. Average fuel consumption per day, tons....	4
One cargo winch in operation for five hours continuously handling 1,000 pounds sling loads of cargo from hold of ship to dock. Average steam consumption per hour, lbs.	1,200

Calculating boiler evaporation at 13 pounds per pound of fuel, to supply steam for this winch operated under above conditions would require a minimum fuel consumption per hours of (lbs.) 92.3

To determine the amount of steam consumed in the above operation, exhaust steam from this winch alone was condensed into a specially constructed measuring tank.

In comparison with the above, the following report on the performance of the motor ship Kennecott is quoted. The Kennecott is a 6,000-ton deadweight vessel equipped with Diesel engine main propulsion, all engine-room and deck auxiliaries being electrically driven from auxiliary Diesel engine-driven generating sets. Deck equipment includes eight 25-horse-power dynamic lowering type electric cargo winches:

Vessel was at Seattle pier for a period of ten days, during which time 3,000,000 feet of lumber were loaded. During this period of ten days the engineer's log shows that but 31 barrels of fuel oil were used for all purposes, including auxiliary Diesel engine generating set consumption for operating engine-room auxiliaries and cargo winches. Average daily fuel consumption (barrels) 3.1

Later reports of the Kennecott show that—

Under average operating conditions engine-room and auxiliary equipment in operation twenty-four hours per day, deck winches in operation from eight to nine hours per day. Average daily fuel consumption (barrels) 4½

The above data are evidence of the economy to be effected in the use of electrically operated deck auxiliaries, but of course cannot be used as a comparison of fuel consumption for engine-room or other auxiliaries.

In giving these figures I made no attempt to make a detailed comparison or make any deductions. You may make your own deductions, but the figures I have given are unquestionable evidence of the possibility of economy, and, taking these figures, you can work it out on any basis you wish, and it will result in showing very decidedly in favor of electric auxiliaries.

Mr. William W. Smith, *Member:*—Mr. President and gentlemen, on page 160 the author states that the cost of electrical deck machinery is little if any higher than steam machinery; I have found the reverse to be true to a very marked degree. For example, the cost of the steam deck machinery for a 10,000-ton cargo vessel was $33,000, whereas for electrical machinery, to perform exactly the same work, the cost was $80,000. It may also be pointed out that the cost of a 5-ton steam winch was about $1,500, whereas for an electric winch of the same capacity the cost was about $4,300. In view of these figures it is difficult for me to understand the author's assertion.

Referring to the comparison given on pages 167 to 169, I would suggest that the author add a brief description of these installations to give a better understanding of the comparisons.

On page 167 the author states that the excess auxiliary exhaust steam is by-passed to the condenser. Thus all of the available energy in this steam is wasted, which is not done in properly designed installations. Approximately 4,550 pounds of auxiliary steam are condensed in the feed heater. This leaves 7,950 pounds which could develop power in a low-pressure turbine under efficient conditions. Since there are no data for the turbine referred to, let us assume that this steam is passed into the low-pressure element of a Parsons turbine and expanded from 5 pounds gauge to 28¾ inches vacuum. It is assumed that superheated steam (75 degrees) is supplied to the auxiliaries; that it is approximately saturated upon arrival at the turbine; and that the exhaust pressure is reduced from 10 to 5 pounds. With saturated steam, the slow-pressure turbine will develop a horse-power on 23 pounds of steam, so that 346 horse-power could be developed by the steam which is wasted. This represents about 14 per cent of the total power of the turbine. It is needless to say that this is not a suitable basis for an accurate comparison.

The steam consumption given for the auxiliaries is about 50 per cent higher than I would estimate it to be for properly designed auxiliaries. It is also noted that this consumption is about 40 per cent of that of the main turbine. I would say that this figure would represent inefficient machinery or performance.

On page 167, the steam consumption per S. H. P. is given as 16.5 pounds. This is not representative of efficient machinery of this class, for which the consumption should be 14½ pounds or less. Also, the fuel consumption per S. H. P. is higher than it should be for such machinery with reasonably good operation.

It is not clear from page 167 whether the turbo-generator is condensing or non-condensing, and where the exhaust goes to. It would also be interesting to know the horse-power and other particulars upon which this performance is based.

On page 169, under "saving in fuel consumption at sea," the author has allowed the same quantity of auxiliary steam for both 75 and 200-degree superheat. This cannot be considered accurate, since the power and steam consumption of the auxiliaries should be approximately proportional to the turbine steam consumption in two equally well-designed installations. It is not clear, but it is assumed, that the main turbines for both steam and electrical auxiliaries operate under the same steam conditions. Otherwise the comparison would be of little value.

As pointed out above, 14 per cent in equivalent turbine power is wasted, and consequently this comparison cannot be considered as reliable. The same applies to the saving per year. Under this heading, also, no account is taken of depreciation, repairs, etc., which amount to about 12 to 14 per cent of the first cost, which is considerably higher for the electrical auxiliaries.

My conclusions after investigating the subject of electrical auxiliaries for cargo vessels were as follows:

1. Two large turbo generators were required.
2. We could not get electrical auxiliaries into the same engine room as used for steam auxiliaries, and additional space had to be allowed.
3. The electrical auxiliaries were heavier and more expensive than the steam auxiliaries.
4. The saving in steam and fuel consumption was not sufficient to justify the use of electrical auxiliaries.

I regret that I cannot give more specific data (including weight, cost, fuel consumption, etc.), since this would be desirable.

On page 170 it is implied that electric winches will handle cargo faster than steam winches. I do not think this can be considered as an accepted fact. For machinery of the same capacity, I do not believe there will be enough difference to be of importance in the usual class of cargo handling. In special cases there may be advantages of importance, which, of course, should be given due consideration.

Failure of steam to flow through pipes I do not believe can be considered as a very serious defect of steam machinery, and any failure of boiler pressure would affect both types in the same way.

Referring to the cost of insurance, the fact is that this is somewhat greater because the first cost is greater.

Referring to the other savings referred to on page 170, there appears to be no sound basis for these assumptions, which I should say were very doubtful. This also applies to the total saving of $55,190 on page 170, which is also rendered inaccurate by the engine-room comparison as mentioned above.

There is no doubt a substantial saving in fuel in port, and a minor one at sea. There may also be a slight saving in supplies, repairs, etc. Altogether, however, I do not believe the investment will pay.

Steam deck machinery is without question inefficient, and there are large heat losses in piping, etc. However, it is a great deal lighter and cheaper and so far appears to have the advantage for steam cargo vessels.

However, for motor ship and passenger vessels the conditions and considerations are different, and for such vessels, especially the former, electrical auxiliaries seem to be the more suitable. In motor ships no main boilers are available, as in steam vessels; and in passenger vessels the considerations are often other than economic.

In general, although electrical auxiliaries, and especially those outside of the engine room, are generally preferable mechanically and from an engineering standpoint, they cannot be used in all cases because of the economic requirements. I may say in closing that reduction in weight and first cost would greatly accelerate the use of electric auxiliaries on shipboard.

Mr. G. A. Pierce, *Visitor:*—The author is to be congratulated upon the clear and concise statement in paragraph one of his paper.

The equipment of modern motor ships answers the question of electrical auxiliaries as far as reliability and economy are concerned, and it is to be regretted that we are compelled to refer to foreign-built ships for the principal data of their performance. No less than sixty-six of one type are in successful operation and foreign yards are building motor ships today in greater number than our combined effort of all classes. The motor ship with steam auxiliaries is a failure, as was proven in the case of the S. S. California. This was the wrong application of an otherwise perfectly good auxiliary, as steam auxiliaries in many instances are to be preferred to electrical.

Paragraph 4 does not appear consistent with the remainder of the paper in endeavoring to establish operating economies by the use of electrical auxiliaries, as greater economy can be realized by the use of Diesel prime movers for generating current than by the use of electrical auxiliaries in place of steam, as the fuel for the Diesel engine would cost only one-third of that of the steam turbine. The adoption of electrical auxiliaries will involve trained men, the handicap mentioned in connection with the Diesel, and it is my opinion that at no remote date licensed engineers will be required to be familiar with steam, oil and electrical machinery, and there are, no doubt, many instances today of cargo ships which would not only warrant the expense of additional machinery and personnel but would show a substantial saving, and on the basis of the author's conclusions three times as much.

Referring to paragraphs 5, 6 and 7, relative to the cost of carrying cargo, the answer is not alone in electrical auxiliaries, as that cannot be a deciding feature, but in the motor ship which includes electrical auxiliaries.

Relative to deck machinery, we agree absolutely with the author in that none but the most careful design and the best of materials and workmanship should be used, as the apparatus is exposed to all sorts of weather and operated by unskilled men. The deck winches largely used in this country, using a series motor with a small shunt winding, have spur reduction gear and manual control which is simple and efficient and has been developed to a high degree of satisfactory operation, so that safety appliances other than over-load and no-voltage are unnecessary. Improvements can be made by the addition of automatic control, just as in land practice, thus eliminating the personnel element in operation. This, however, cannot be done with success until the ship operators are willing to pay for competent maintenance, men to keep the apparatus in repair, and the expense for competent men should be considered in any scheme of electrical auxiliaries. It may be of interest to many to know that on the recently built motor ship William Penn the 5,000-pound hook speed was 170 feet per minute hoist, 470 feet lower; 2,000-pound hoist 245 feet, lower 380 feet; no load hook speed, hoist 457 feet, lower 337 feet, which corresponds to the author's recommendations and which speeds are in excess of general practice for electric winches; and that with these speeds and with the general cargo handled it was impossible to make up and discharge loads sufficiently fast to keep the winches in operation, thus removing a common complaint that electric winches are slow. A vertical handle of a new type was used, which required less movement of the body and consequently less tiring effect than any other type previously used.

The author's specifications for deck machinery motors cannot be too strongly endorsed.

Relative to steering gear, it is questionable if a more satisfactory type, employing the electric motor, than the hydro-electric gear has been developed. This type is ideal for control and makes a minimum demand on the generating plant with an efficiency equal to that of any other type, and should be considered seriously for new ships. The electric motor for the steering gear offers the greatest saving of any single auxiliary on the ship and, no doubt, in many ships the steam steering gear could be replaced by a hydro-electric gear with considerable saving and without increasing the size of the generating sets.

There has been considerable discussion in the past relative to the use of follow-up and non-follow-up system of control; while the non-follow-up gear may serve the purpose, it depends on a rudder indicator, a separate piece of apparatus for proper operation, and for this reason I believe the follow-up system, which is self-contained, is to be preferred and its use will consume less power.

Relative to the horse-powers of motors for cargo winches and steering gear, if we are to realize the maximum economies for electrical auxiliaries these should be worked out for each particular vessel.

Referring to the list of engine-room auxiliaries and the horse-power required, in view of the statement, "A motor ship requires somewhat fewer auxiliaries and slightly less power is necessary to drive them," I believe the following comparisons should be made: Steamship 15 motors, motor ship 5 motors; steamship aggregate horse-power 160, motor ship 55; fuel consumption, steamship 41 barrels, motor ship 2.5 barrels.

Relative to the types of motors for shipboard use, the greatest enemy of electrical apparatus is foreign substances, and it is therefore essential that apparatus should be enclosed, particularly the rotating type with commutators. Therefore we are compelled to take issue with the author. The governing feature should be reliability; space, weight, and first cost should be secondary considerations. It is not so important that a certain frame size motor should develop so many horse-power and be assisted by some sort of ventilation to do it as it is that it should work continuously for long periods without repair. Further, we believe that ball bearings are a very essential feature for continuous operation. Realizing certain limitations for enclosed motors, we believe, motors for below decks and engine rooms should be enclosed except where the size prohibits, and then they should be open with protection against drip and condensation from pipes and other apparatus, and this practice has been followed on foreign-built ships with success.

Relative to the location of starters, I desire to emphasize the author's opinion that they should be as close to the motors as possible.

Relative to the most suitable electric power for cargo ships, this has been answered by a failure for almost every installation of A. C. current. For tankers the same troubles would be experienced with the delicate A. C. regulators as on cargo ships, and with most of the ships burning oil today the dangers in the engine room of a tanker would not be increased, and with A. C. current there will be the operation of the switchboard switches and the exciter must have a commutator.

With regard to the wiring and installation, it may be of interest to the author and those present to know that the A. I. E. E. have recently issued a set of marine rules which amply cover all phases of the question and for power wiring are the only ones in existence. I do not believe the author's insinuation relative to the wireman's discretion should pass by unnoticed. From personal observation, covering a period of twenty-eight years, I have seen more failures of generating sets than bus wires, more failures of motors, controllers and starting panels than feeder wires, and I do not believe the author's contentions can be proven except in isolated cases and those during the war period.

Relative to operation, this is most difficult to discuss, as the author has assumed certain fundamentals which cannot be reconciled and can be in keeping only with ships which are laid up due to their excessive cost of operation. I refer particularly to the figures of 12,500 pounds of steam for auxiliaries at sea, which is 30 per cent of the boiler capacity and 43 per cent of the main engines. These figures, to say the least, are ridiculous, and any deductions based on them are not only misleading, if used for comparison, but an injustice to the cause of electrical auxiliaries where they can be economically applied.

Electrical auxiliaries have a place in the steamship when the generators are driven by engines or turbines, namely, outside the engine room, for steering gear, windlass and deck winches. Electrical auxiliaries can only show a saving in the engine room when the generators are driven by oil engines. This arrangement would require extracting steam from the main turbine for all heating of feed water, which is extremely bad practice and is not recommended for shipboard use in any degree. The adaptability of electric motors has been proven beyond question, and the answer to who shall carry the merchandise of the world is—motor ship with electrical auxiliaries.

Mr. Charles Rettie (Communicated):—In reading Mr. Dickinson's paper on "Electric Auxiliaries on Merchant Ships," being an A. M. A. I. E. E., I thought I would like to take part in the discussion before the joint meeting of the Naval Architects and the A. I. E. E. on the 17th instant. Though I cannot attend personally I thought a letter from me would be of interest, especially as I have had a good deal to do with the fitting up of ships with the electric light and also repair work on many of our large liners, which dates back to 1889, with the exception of a few years before the war, and up to the present time.

It is only of recent years that electric auxiliaries have been introduced into ships. On the earlier ships that I worked on, which included the Empresses running out of Vancouver, which were built in 1890 in Barrow in Furness, no motors were installed though they were all fitted up with the electric light—the Empress of Japan and the Empress of China had each four dynamos which I worked on, the Empress of India having already been completed.

There is a large field for the use of electric auxiliaries on board our merchant marine; there are still a good many places on ships where the electric motor might be used with advantage and, as already pointed out by our leading electricians in this country, including Mr. Wordingham, late president of the I. E. E. and head of the Admiralty Electrical Department during the war for ship works, that while there is a doubt as regards the economy of using electric motors for driving our ships, there is no question of the advantage of the use of electric auxiliaries over every other system, and they should be immediately installed on all our ships; electricity should be used for all power purposes except the actual driving of the ship.

During the war I had a good insight into the fitting up of many of our latest warships and merchant vessels, being sent by the army authorities to work in one of our large shipyards.

With reference to Mr. Dickinson's remarks regarding the use of enclosed motors on deck and partially enclosed below deck, the latter being shown on Plate 32, I take it this would only apply in some cases, but surely not in the engine rooms and boiler rooms; it need not be necessary to be watertight, but all openings would have to be covered to keep out dirt, oil and dripping water, especially in the case of the turning motor, used for turning the main engines in port, where it has to be fitted low down in the engine room and subject to be covered with dirt falling and water and oil dripping.

I think the best power for use on board ship is unquestionably the direct current, as pointed out by the author, but as the tendency lately is to use submersible pumps on board ship, and as the same can only be worked by the alternating current, it will be necessary in all up-to-date plants to have a rotary converter to supply current; that is a point which has been omitted by the author. As is well known, the squirrel type of A. C. motor will work under water.

In the description of wiring systems, nothing has been said about the possibility of using ring mains; that is the only way to reduce the number of circuits as suggested by the author in another part of the paper; the number of circuits on a distributing system cannot be reduced with safety; a large number of circuits must be run to supply the different parts of the ship, either for the lighting or power.

I also notice the author does not recommend the use of conduits for carrying the wires and cables. In this country the tendency at the present time is to use screwed conduits galvanized wherever possible in the electric lighting of our ships; in fact the latest Cunarder being built on the Mersey, I understand, is mostly wired in galvanized steel tubes, solid screwed.

In most of the ships I have worked on recently the systems have been divided up. For instance, on one ship armored and lead-covered cables are used in the engine room and boiler room, casing on the passages, galvanized screwed conduits in the holds and portable fittings in emigrant quarters. The last ship I worked on was a refrigerator ship of about 7,000 tons for carrying bananas. She had three generators about 80 kw. each; most of the electric power was used for driving huge fans for cooling the holds where the bananas were stored; all the passengers' quarters, of which a few first class were carried, and officers' rooms were heated by electricity. The steering gear was steam. The hoist motors in the boiler rooms were worked with a lever up and down to start and stop.

In conclusion, referring to the question of salaries, there is another point I would like to raise, and that is the question of the status of an electrician on board ship. On one of the Norwegian-American liners, the Stavangerfiord, which I worked on, they had a very good arrangement. Instead of the electrical department being subject to the lowest graded engineer, as in this country, it was run on an entirely separate department. The chief electrician ranked with the chief machinist. There was a commander engineer over all. The chief electrician messed with the chief machinist, and the chief commander had his quarters with them. The junior electricians messed with the junior engineers. I think the above is a very important point to raise because, as the electric machinery used on board ship gets more complicated, a higher skilled man will have to be employed, and unless sufficient remuneration is given and more respect shown, it will be difficult to get a good man to go to sea on ships as an electrician.

Since writing the above I attended the opening meeting of the Liverpool Engineering Society, November 3, when a very interesting address was given by our new president, James B. Wilkie, M. I., Mech. E., M. Inst., N. A., on the "History and Progress of Marine Engineering." In his address he gave us some details of a new ship belonging to the company he is interested in and which is expected round next Tuesday from the builders. The name of the vessel is the Aba and she is about 7,000-tons, oil driven; all her auxiliaries are electrically driven. The generators, of which there are three in number, are 200 kw. each, and are driven by Diesel engines.

Mr. W. McClelland, *Visitor:*—As to the auxiliaries paper, I am in general agreement with the author. In the British Navy we have for many years run most of our auxiliary machinery electrically. We have winches, capstans, pumps, refrigerating machinery, fans, air compressors, almost every conceivable kind of machinery, running by electricity, and we have had very little difficulty with that machinery; I speak with some authority because, during my eighteen years of service with the Admiralty, fifteen years of that period was spent as head of the electrical repair department, and I have had to deal with all classes of electrical machinery, not only machinery connected with the British Navy, but, during the war, of the American Navy.

There is one point to which I would particularly like to refer, and that is the question of insulation. We hear a lot about water washing electrical machinery on the decks. I do not really think that in this country the importance of proper insulation for electrical work for deck machinery has as yet been appreciated. I have visited many of the works in this country, and I am quite sure most of them can make satisfactory material, but most of the materials used are composite materials, and these materials absorb moisture. This means breakdown sooner or later in moist atmosphere laden with salt.

I am giving you the result of our experience. We have found that the only insulation which stands up under salt water and sea atmosphere conditions is mica and micanite. For instance, with control gear, with the fingers clamped to a diamond shaped or square bar, which has been insulated with moulded micanite or wrapped micanite thoroughly baked and finished, you will have a thoroughly satisfactory insulating material; whilst at the present time we are carrying out tests on practically every known composite material, I have not yet met with the material which I should consider suitable for insulating electrical machinery on deck.

I was much interested in what Mr. Bates said about the winches on deck being washed with sea water and that they were not satisfactory; he then went on to say that the whole of the defects were mechanical, not electrical. I could not follow his argument, unless it was that the sea water damaged the mechanical parts, which speaks well for the electrical gear. Another speaker referred to the maximum speed of lift at which winches should be used. He stated they had standardized 250 feet per minute. I think that is a good speed for full load. Sometime ago we tried a speed of 300 feet per minute, but experience showed it to be too fast for a short lift, and we dropped our full load speed for winches to 200 feet per minute.

Another point referred to, although I must be brief, is the question of direct and alternating current. I believe in direct current work for ships, and also in the two-wire system rather than the three-wire system. Earths or grounds are so prevalent on a ship's electrical system that I think the simplicity of the two-wire system more than counterbalances any slight advantages which the three-wire system has. 220-volt incandescent lamps are now satisfactory on board ship, and there appears no necessity for the third wire.

With regard to submersibles, although it is a difficult problem, I think time will show that we shall get a satisfactory continuous current submersible pump—I am hoping so. Alternating current will not then be required for this service.

Mr. President and gentlemen, I thank you very much for the opportunity of addressing you.

Mr. H. L. Hibbard, *Member* (Communicated):—The two papers presented this afternoon cover subjects of the greatest importance to our merchant marine industry, but it is our own feeling that much the larger field for the application of electric drive lies in the direction of the ship auxiliaries.

Mr. Dickinson's very interesting paper has covered this subject of electric auxiliaries in an able manner, but we could wish that he might have been more specific with regard to a number of the detailed points which he has raised.

On page 158 he refers to the two types of electric steering gears now in use but does not mention the dividing line where the hydro-electric gears for this purpose would have a distinct preference. In our opinion, the direct application of motor drive to the steering gear can be used to the best advantage in horse-powers up to about fifteen. For twenty horse-power and beyond, the hydro-electric has unquestionable advantages.

In sub-paragraph (*c*) on page 159, reference is made to contactor equipments especially for deck winches but apparently questions the wisdom of this form of control in most cases. For the severe service met in the case of these auxiliaries, the contactor control, we feel, is especially suited, and foreign practice has already clearly demonstrated the feasibility of its use and of readily locating the contactor control below decks or in suitable housings.

Sub-paragraph (*d*) on page 159 touches upon the wisdom of omitting, as far as possible, all safety devices. While these should unquestionably be reduced to a minimum, we would ask Mr. Dickinson, for the benefit of the profession, what devices he would recommend for deck auxiliaries. In our opinion, stalling devices at least must be furnished in connection with anchor windlasses, capstans, steering gears, and overload contactors or circuit breakers for deck winches.

Pages 164 and 165 discuss the relative merits of direct and alternating currents for auxiliary purposes and state that while on the cargo ships direct currents can be used to the greatest advantage, on tankers it is not so apparent. On this latter point we would take some issue, as it is possible to furnish motors entirely enclosed, gas and watertight, or where location on tank vessels renders the same desirable to furnish forced ventilation through the enclosed motor casings. Several tank vessels in this country have already been equipped in this manner, and there are others under construction.

With regard to the question of economy of engine auxiliaries on steam-driven vessels, Mr. Dickinson has furnished some interesting figures, although we feel that perhaps his assumption for the steam required for auxiliaries at sea is a little too high a percentage of the total. The advantages obtained from the use of electric drive for all auxiliaries on motor ships is, we believe, now apparent, and similarly the advantages of the electric drive for deck auxiliaries on steam vessels as well as motor ships. The question, however, of the use of electricity for auxiliaries in the engine room on steam vessels furnishes the most debatable ground. A certain amount of exhaust steam from engine auxiliaries is always diverted to feed water heating, but beyond the point where exhaust steam can be used economically for this purpose lies considerable possibility in economy for electric drive as well as the advantages of convenient operation and freedom from leaking steam pipes, etc.

We heartily endorse the statement of the author in his last paragraph that engineers of this country should combine their efforts and avail themselves of every opportunity to improve the efficiency of our merchant ships to the end that they may be able to compete successfully with the modern ships of other countries. In this connection, we were much impressed on a trip this summer to the Pacific Coast, to find that numerous European and Scandinavian motor ships, electrically equipped, were making regular trips through the Canal to the Pacific Coast ports. In addition to the conducting of a satisfactory cargo-carrying business, these vessels were buying California oil on the coast at $1.50 per barrel, sufficient for a round trip, this same oil selling in their own home ports at $8 to $9 per barrel.

President Capps:—Before giving the author of the second paper an opportunity to respond, the Chair is of the opinion that it would add very much to the value of this discussion, if the Engineer-in-Chief of the Navy, who is with us, would make some comments on the papers and the discussions which have ensued. If he does not feel so prompted, of course, it is his privilege not to respond.

Rear-Admiral John K. Robison, U. S. N., Engineer-in-Chief:—About ten years ago I was called upon to discuss an article presented by Mr. W. R. L. Emmet on the subject of "Electric Drive," and I expressed then that I was from Missouri. Do you remember that, Mr. Emmet?

Mr. W. R. L. Emmet:—Yes.

Rear Admiral Robison:—Well, I have seen a few things since. Concerning the economy proposition, I can state for the benefit of the Society that on trial trips we have had figures that have given us in no case so much as 0.9 of a pound of fuel per shaft horsepower, under any speed between 10 and 21 knots. Within the last week, I attended a trial where that took place. The best performance we have gotten on the trial-trip conditions is on a geared-turbine drive, on a destroyer, which was 0.83; the best we have on the electric drive is 0.86.

Concerning the geared-turbine drive for the North Dakota, the current operating efficiency of the ship has not been so satisfactory as we had hoped. We do not lay that to the machinery. We lay it to conditions that are temporary. We lay it to the lack of skill of our own people on board the ship, and we expect in the future on the North Dakota a degree of efficiency that will become comparable with what we have been getting on the New Mexico; for example, the New Mexico burned about one-half to two-thirds as much fuel when steaming in squadron with the North Dakota as the North Dakota burned.

In port, on the electric auxiliary question, we have extended very considerably the use of electric auxiliaries. That has been done notably on the Tennessee. The fuel consumption of the Tennessee is less than 11 tons a day in port, and nothing is steam driven except an electric generator, condensing or non-condensing, forced draft blower, and a few pumps. The exhaust steam from the auxiliaries and the non-condensing generator is used for the operation of the evaporators; also when sufficient exhaust steam is available for heating the ship and in the galley. The pressure of the exhaust steam is maintained at 12 pounds gauge in order to provide sufficiently high pressure to operate the boilers in the galley. That ships is running with materially less fuel than any other battleship, and we figure that the electric auxiliaries on that ship are saving us approximately $165.00 a day.

Mr. Ernest H. B. Anderson:—May I make one comment in regard to the North Dakota in relation to the other ships? I do not know if it is clear to everyone here that the revolutions of the propellers on the North Dakota are 240 a minute, as compared with 170 for the Tennessee and sister ships.

Rear Admiral Robison:—That is true—the North Dakota has single-reduction gears.

Mr. Anderson:—She has single-reduction gearing, but when the change was made it was not possible to renew the shafting and reduce the propeller revolutions to 125, we will say—it could have been done so far as the geared turbines were concerned, but it was really a question of cost and structural limitations.

Mr. Emmet:—When we were figuring on the alterations for the North Dakota we were told it was not worth while to change the propellers, although I said that it would be a practicable thing to put new shafting and propellers into the ship, but I was told we would not gain much.

Mr. Anderson:—It could not have been done, Mr. Emmet.

President Capps:—The Chair wishes to suggest that in making responses to these remarks, which could not be covered in the rejoinder by the authors of these papers, that very great care be taken to reply only to questions which have been brought up in the main discussion of these papers; in other words, we cannot have a continued discussion of opinions interjected from time to time during the consideration of these papers after the main discussion has taken place. It is rather irregular to have that sort of discussion arise, simply because if every opinion expressed in the discussion is itself subject to indefinite discussion, there will be no end to it. That is just a word of caution. Mr. Dickinson, have you anything you desire to say?

Mr. Dickinson:—I do not think I would have time to go into the matter *ad infinitum.* I think, however, that you will, perhaps, bear with me for five minutes if I refer to one or two remarks which have been made. Mr. Pierce got at me rather hard. I deserve it, because I very carelessly on page 167, I think it is—that is a page referred to quite often this afternoon, referred to steam for auxiliaries. That is not quite true, but it is probably true that the steam is generated in the boilers and not all put to useful work. I have not a great deal of data. I had hoped that we would get some positive information this afternoon on the subject of operation. I have engineers' logs and reports on something like 500 voyages. Throwing out about half of these as unreliable and estimating the horse-powers as accurately as we can, reckoning on the vacuum and steam conditions under which the ship was operated, and also knowing approximately the power that would be necessary to drive the ship, between the ports stated in the log, we arrived at a fairly accurate figure for horse-power. Based on this we can estimate the fuel per horse-power hour. These figures will run, on similar ships with similar equipments, all the way from less than 1 pound to nearly 2 pounds. The figure of 1.23 pound which I took, so far as I can find, is fair. Assume a boiler efficiency of about 75 per cent, which means an evaporation under conditions of operation of approximately 13.5 pounds; this gives us the total amount of steam. We know that the turbine can pass only a limited and definite quantity of steam through its first stage nozzles. With operating pressure more will not go through. The difference, therefore, is the amount of steam generated by the boilers and charged to auxiliaries.

We are all looking forward to the time when we will have a steamship entirely equipped with electric auxiliaries. Comparison made between our merchant ships similar to the comparisons that have been made between naval vessels, I think, will vindicate the figures which I have used.

Mr. Anderson, in his remarks, seems to settle on 0.9 pound, which, with fair assumption, will allow only 6,500 pounds of steam for all purposes on the ship, including heating feed water. That sounds too good for a ship equipped with steam auxiliaries. I do not think that there is anything else I wish to bring out this afternoon, but as the chairman has pointed out, economy is the vital question, and we should get accurate studies and positive knowledge of the evaporation on our ships; then we will all be in a better position to discuss gains which are possible by the general application of electricity.

The author has been afforded the opportunity of reading the discussions of his paper and before proceeding to reply wishes to thank those gentlemen who have taken such pains to prepare constructive criticism, setting forth their views on the subject under discussion. The interest manifested on the part of so many able engineers in this all-important subject should be extremely gratifying and encouraging to shipowners in this country, who must take advantage of every means to reduce the cost of operation of their ships in order that they may profitably compete for the trade of the world. Without question, owners and operators are realizing to an ever greater degree to what extent the engineer can assist them in studying their conditions of operation with the view of improving the efficiency of their ships.

Mr. Bates' account of the electrical equipment on the Prinz Heinrich gives conclusive proof, if such be necessary, as to the reliability of suitably designed electrical machinery on ships. The apparatus, built twenty-five years ago, is still in service. This is what should be expected of properly designed and properly built electrical equipment. In other words, practically all the maintenance charge of suitable electrical apparatus will be covered in the first cost.

Mr. Jett's recommendations should be given the most serious consideration. He has devoted much time and thought to the study and investigation of electric deck machinery. Recommendations based upon his findings that a properly designed geared-electric winch with 25 horse-power motor is in every way the equivalent of a steam winch having two 8¼ by 10-inch cylinders will most likely be excellent practice to follow.

In making such comparisons it must be borne in mind that a cargo winch is at best a compromise; in other words, for the reason that winches will be called upon to handle miscellaneous cargo and that the length of the lift varies with the depth of the cargo in the hold and the height of the dock or lighter on which the cargo is being handled, it will be necessary for the owner or operator of the ship, with his naval architect and engineer, to arrive at a design of winch which, all things considered, will be the best for the average conditions. In larger ships with deeper holds it may be found desirable to somewhat increase the rope speed and fit a larger motor.

The horse-power rating of a winch motor is not definite. Electric motors are capable of considerable overload for short periods of time. The rating will be considerably less if based on a one-hour test rather than on one-half-hour test. Experience indicates that handling cargo on ships gives approximately the same heating as a rated full load for the half-hour.

Mr. Jett also points out the need for more accurate data on fuel consumption that may be charged against ships' auxiliaries. The author wishes that Mr. Jett had put even greater stress on this vital point.

A reply to Mr. Smith's criticism would become very lengthy. He has given the subject so much detailed thought and consideration that in the author's opinion a proper and fair reply could only be made by discussing a number of specific cases in like detail with Mr. Smith. In all fairness, however, it should be pointed out that, as stated in the introduction of the author's paper, the comparisons were based upon cost of electrical equipment installed. In all probability the individual units electrically driven will in many cases be somewhat more costly than steam-driven apparatus of the same quality and for the same work. On the other hand, the cost of installing the steam machinery with the extra piping will be considerably greater than the cost of installing the electrical machinery, which requires only cable to transmit the power from the engine room. The cost of $4,300, which Mr. Smith took as the cost of an electric winch, is very high. Further, the cost of suitable electrically driven ships' auxiliaries will be reduced as the demand increases.

The author would point out that on the earlier motor ships steam-driven auxiliaries were fitted, and it was found these required so much fuel that electric auxiliaries had to be fitted in order to realize the high efficiency expected from a motor-driven ship.

Mr. Smith's argument as to the amount of power that might be secured by admitting 7,950 pounds of exhaust steam to the low-pressure turbine is based on the assumption that this is steam. When it is considered that a great part of the heat in the 12,500 pounds of steam referred to in the author's paper has been given up to heating the atmosphere, that condensation has been going on continuously in the thousands of feet of piping with approximately 2,500 square feet of radiating surface, it must be recognized that there is a great deal of hot water returned to the engine room and that the theoretical advantage cannot be realized.

If Mr. Smith will refer to the comparisons, he will find that the author allowed somewhat less for the auxiliary turbine when using 200 degrees superheat than with 75 degrees.

It has not been the author's contention that steam machinery is of itself always inferior to electrical. It is a question of application, and the future will show that it is not economical to operate a number of small steam units distributed in different parts of a ship. When shipowners realize the gain that can be effected by substituting one steam engine driven, or even oil engine driven generating set, for the multiplicity of small pieces of steam machinery, they will fit their ships with electrically driven apparatus.

Particular attention should be called to Mr. Pierce's remarks, "in many ships the steam steering gear could be replaced by a hydro-electric gear with considerable saving and without increasing the size of the generating sets." Mr. Pierce is a man of experience; the hydro-electric steering gear is one of the most expensive single pieces of equipment on a ship; his recommendation therefore to a great measure vindicates the author's contention as to the desirability of entire electrification.

Referring to Mr. Pierce's recommendation that enclosed motors be used below deck except where the size prohibits, it would seem that if it be granted that enclosed motors must be used in order to assure reliability, this rule would apply with the greatest force to the larger motors, and in the higher ratings the size would be found to be impracticable. The author would point out that motors which are designed to run continuously become tremendously heavy and expensive when enclosed; further, if they are to be located in a damp place, they will become wet inside and are just as liable, or perhaps even more liable, to deteriorate when not running than are ventilated motors. Experience has shown that ventilated motors are entirely reliable on shipboard if designed for the conditions and built of suitable materials.

Referring to Mr. Pierce's remark that this practice (referring to the use of enclosed motors below deck) has been followed on foreign ships with success, the author would refer to an article in the *Electrician* (London) of July 29, 1921, on page 131, in which it is stated "but for all ordinary purposes a semi-enclosed and preferably drip-proof design is best." This article refers to British practice.

In making a general recommendation in favor of enclosed ventilated motors for below deck installation, the following points were given consideration:

Open motors would have to be protected from dripping water by shields which would cost the shipbuilder something to install.

In the smaller sizes the cost of such shields would be high in proportion to the first cost of the motor.

In many instances such shields would occupy valuable space and would interfere with accessibility of the motor and other apparatus located nearby.

The cost of the enclosed ventilated motor is slightly more than the open motor and very much less than the enclosed motor for continuous operation.

Motors suitable for marine service can be built with open frames. They would cost but little less than ventilated motors designed to keep out dripping water.

Referring to Mr. Pierce's criticism of alternating current for tankers, while it is true that troubles have been experienced, I believe the particular tankers referred to were a war product, and many details of application were responsible for the troubles. There are certain very definite reasons in favor of alternating current for particular applications on ships, and the fact that some installations have not been successful is due to improper application rather than to the fact that alternating current was used. The author is of the opinion that in most cases direct current will be found to be more suitable for auxiliary power on ships; he believes, however, that very careful consideration should be given to special applications where alternating current might be preferable.

Regarding Mr. Pierce's remark that the author was making insinuations relative to the wireman's discretion, it would seem that the author had been somewhat unfortunate in the way he expressed himself on the subject and that Mr. Pierce had been unfortunate in the experience he had had with generators, motors, controllers, and starting panels. What the author wished to bring out was the fact that a great deal of trouble had been experienced with wiring on ships and that the application of electricity suffered in consequence. It is essential, in order not to discredit the use of electricity, that the installation be well and carefully done, and that every precaution be taken to see that apparatus fitted on ships is in every way suitable for the application.

Mr. Pierce remarks that the figure of 12,500 pounds of steam per hour, which was charged to auxiliaries, is ridiculous. The author has knowledge of certain geared-turbine ships with steam-driven auxiliaries which are also showing approximately 1 pound of fuel consumption per shaft horse-power hour.

The author is in general agreement with Mr. Pierce that in all probability the greatest part of the saving will result from having deck auxiliaries electrically operated rather than steam driven. There are two apparent reasons for this—one, that a great amount of steam piping will be removed, and perhaps the most important reason, that the steam-driven auxiliaries in the engine room will be at all times under the direct observation of the engineer, who, if conscientious and competent, will be in a position to maintain them in better operating condition than can be expected in case of steam-driven deck machinery, which of necessity stands idle for long periods of time and is subject to considerable abuse when in operation; also, the length of the steam piping on deck makes it subject to considerable expansion strains which cause leak and loss of steam at joints.

The author agrees with Mr. Pierce's suggestion that great saving can be realized by the electrification of all ships' auxiliaries, power being furnished by reliable oil-engine generating sets.

In concluding, the author would gather from his critics that, with but one exception, there is a unanimity of opinion as to the desirability of electrifying merchant vessels to the end that greater economy of operation may be realized.

It will be recognized that each ship must be given special study, and all factors entering into its economical operation must receive due and proper consideration in order that the most suitable apparatus be fitted. So long as the art is advancing, it is to be expected that there will be a considerable divergence of opinion as to the best means of attaining the end in view. Much has already been done in this country, and it is gratifying to find that the question of reliability of electrical apparatus has been laid at rest.

The author felt that he was liable to certain criticism in drawing the comparisons in fuel consumption which he did between ships fitted with steam and electrical apparatus. We have available data as to the fuel consumption of ships, but very little published data as to how much of this fuel is required for the propulsion and how much should be charged against auxiliaries. Any engineer who is in a position to obtain absolutely reliable information on this important subject can materially assist shipowners and operators in this country in their endeavor to improve the efficiency of their ships. The data, of course, must be on ships actually in service. Trial trip information, when every valve and all fittings are in perfect condition, is misleading.

President Capps:—I think the Society is to be congratulated on the very illuminating discussion which has flown from these admirable papers. I know that you will wish that I should extend the thanks of the Society to Mr. Thau and to Mr. Dickinson for their painstaking preparation of the papers which have elicited such lively discussion. The hour is now a quarter past six, and I expect that many of you desire to go elsewhere. If there is no objection, this session will now stand adjourned.

THIRD SESSION.

FRIDAY MORNING, NOVEMBER 18, 1921.

The President, Admiral Capps, called the meeting to order at 10.20 o'clock.

THE PRESIDENT:—We will proceed immediately to the program of papers. The first paper for the morning is entitled "How Can American Ships Compete Successfully with Foreign Ships?" which has been prepared by Mr. Winthrop L. Marvin, an Associate Member of the Society.

MR. WINTHROP L. MARVIN:—Mr. President and gentlemen, before going on with the presentation of my paper, I would like to take this occasion to express the admiration which the members of the American Steamship Owners' Association entertain for this technical society, and the high honor in which they hold its members. We regard it rightfully as a vital part of the American merchant marine and one of the tremendous agents for its success in the future.

During the reading of the paper, Mr. Marvin said: Wages have fallen about 15 per cent on American vessels through formal arrangements, and are still falling. We are assuming that the wages on American vessels, in the course of a few weeks, will be lower, by 30 per cent, generally. Foreign wages, of course, will fall also.

HOW CAN AMERICAN SHIPS COMPETE SUCCESSFULLY WITH FOREIGN SHIPS?

By Winthrop L. Marvin, Esq., Associate.

[Read at the twenty-ninth general meeting of the Society of Naval Architects and Marine Engineers, held in New York, November 17 and 18, 1921.]

How can American ships compete successfully with foreign ships? It is a far-reaching question that is stated in these words, a question that goes right to the root of the life of our present-day merchant marine. For unless American ships can compete successfully with the ships of foreign nations, which still manage to dominate our own overseas carrying, there can be no future for ocean shipbuilding and navigation under the American flag.

Therefore this question is one of as direct personal interest to naval architects and marine engineers of all grades and ratings in their profession as it is to the shipowners and managers themselves. The future livelihood and success of thousands of energetic and ambitious Americans hang upon a right solution of the problem of the ship in service.

Three main causes well known to men of our maritime industry were responsible for the inability of successful competition under the American flag with foreign ocean shipping previous to the great war.

For more than a hundred years the privilege of wearing American colors had as a general policy been reserved to ships of American construction. Coupled with this reservation, in the earlier years of our national life, was a vigorous national policy of encouragement to American ships—the discriminating duty policy, so called—which absolutely guaranteed to these ships a strong preference in employment. Under this policy, not completely abandoned until 1850 against our chief competitor, Great Britain, the requirement that American ships must be built solely in American yards was by no means an actual handicap. The building of wooden-hulled sail ships for a hundred and fifty years before the founding of our Federal Government had been a firmly established and successful industry in North America. Materials were abundant and relatively cheap, and the skill of our builders was unsurpassed—indeed unequalled. No American merchants of that era desired to purchase or use foreign-built ships, for there was generally no advantage in securing vessels from abroad.

While wooden sail ships were carrying the commerce of the world, this requirement that vessels of the United States should be American built was a just and prudent policy for the republic. This policy was not substantially weakened or abandoned until the Panama Canal Act of August 24, 1912, which for the first time in a general measure permitted the registry of foreign-built vessels for the purpose of engaging in the overseas but not in the coastwise trade.

Because of the absolute lack from 1860 onward of any comprehensive encouragement for the employment of American vessels in other than our coastwise commerce, there was only scant, precarious demand for the construction of such vessels, and American ocean shipbuilding became a weakened industry. I have long been convinced that in past discussion of the decline of the American overseas marine altogether too much emphasis has been placed upon the change from sail to steam and from wood to iron and then to steel. It is true that, in the period from 1840 to 1860, the British iron industry was greater than our own. British machine shops and steam shipyards were mightily encouraged and strengthened by the generous British policy of mail shipping subsidies, initiated in 1840 and maintained with vigor and persistence until competing American steam services were driven from the seas.

But American shipowners and builders were by no means so unmindful of the advantages of steam propulsion and iron hulls as some of the commentators upon the fate of our ocean shipping have contended. The iron propeller steamer Bangor was built on the Delaware in 1845, a thoroughly efficient vessel for that period. In the years between 1850 and 1861 good iron steamers were built on the Delaware, at New York and at Boston. Indeed, good American iron was found to be superior for shipyard purposes. The United States possessed admirable iron works and a substantial body of highly skilled mechanics, as was to be demonstrated later by the rapid and successful building of a fleet of monitors that proved a decisive factor in the Civil War. Not only monitors but broadside armorclads and iron cruisers were constructed in this country in the Civil War period, and a vast impetus was given to boiler and engine-making establishments at the northern seaports by the swift creation of a new fleet of the six hundred war steamers that constituted in 1865 the most modern and formidable navy in the world.

All these facilities for the building of steam, iron, seagoing merchant ships could readily have been turned to the construction of a new merchant tonnage in 1865 and after if there had been any positive aid and encouragement to the successful operation of these American ships after they were completed. But, though the dominant republican administrations of that period wrought a gigantic success in the protection and development of the manufacturing industries of the country, the overseas shipping trade of the United States was left wholly without any equivalent encouragement. What was more natural and inevitable, therefore, than that manufacturing should flourish and ocean shipping still further decline through those years when Great Britain, thanks to the depredations of Anglo-Confederate cruisers, had dealt a terrible blow to our sail tonnage and had possessed herself of that lion's share of our overseas carrying which she retained up to the outbreak of the great World War.

Without protection to the operation of American ships, the continued protection to the building of such ships of course proved wholly ineffective. Though iron ship construction, particularly in the Delaware district, made respectable progress in the years following the Civil War, these new iron steamships were designed for the protected coastwise trade, except for a few large passenger and mail steamers for the Pacific Mail, four excellent transatlantic liners for the Philadelphia and Liverpool service of the old American Line, and other good but smaller steamers for the nearby West India services.

Under the sharply contrasting conditions wherein British yards were building in swift succession twenty iron steamers while our yards were building one—that is to say while British yards were steadily manufacturing ships and our yards were producing irregularly a slender tonnage—what was more natural than that we should be seriously handicapped by a wide difference in the relative costs of construction? When in 1904-5 the Congressional Merchant Marine Commission under President Roosevelt made a careful survey of shipbuilding prices in this country and in Europe, the commission was constrained to report that steel steamships of the passenger and cargo type were costing from 40 to 45 per cent more on this side than on the other side of the Atlantic. Under the circumstances, with no aid or protection whatsoever for American shipowners and operators, it was hopeless to dream of employing any considerable numbers of American-built ships in overseas commerce.

How heavy was that handicap can be demonstrated by a comparison of the capital charges of a British-built ship produced at a price of $500,000 and an American-built ship produced at a price greater by 40 per cent, or of $700,000:

	British ship $500,000	*American ship* $700,000
Interest, 5 per cent	$25,000	$35,000
Insurance, 4 per cent	20,000	28,000
Depreciation, 5 per cent	25,000	35,000
	$70,000	$98,000

Here, without any allowance whatever for the higher American wage costs of operation, is a difference in the main capital or carrying charges of $28,000 a year, or in itself a fair rate of dividend upon the total cost of the British-built vessel. This fact alone would suffice to bar the American ship from competition.

Moreover, the wages and maintenance of the officers and men of the American steamer were at least 50 per cent greater than the wages and maintenance of the officers and men of the British steamer—a factor important of itself though of far less consequence than the handicap due to the higher cost of building as outlined above. It is not at all strange that from the building of the Ohio and her sisters for the Philadelphia American Line in 1873 the Stars and Stripes flew above no new American-built steamers exclusively employed in transatlantic trade until the keels of the St. Louis and St. Paul were laid by the power of a special mail subsidy in 1894 and 1895. Between far higher costs of original construction and higher costs of crew wages and maintenance, rivalry with European ships, often state-aided as they were, was accepted by American shipowners as impossible.

When the shrewd diplomacy of Europe from 1815 onward had succeeded in enmeshing our government in treaties that gradually prevented us from encouraging our ships through the historic policy of discriminating customs duties and tonnage dues, our competitors overseas lost no time in launching out on a new and effective expedient of their own—mail and admiralty subsidies and subventions. The first sustained British transatlantic steam service was created in 1839 by the grant of a mail subsidy of $425,000 a year to what is now world famous as the Cunard Company of England. Other subsidies, even larger in amounts, called into being the Peninsular & Oriental Line to India, the Royal Mail Line to the West Indies and South America and other British concerns, until finally thirty national steamship services reached all quarters of the world. France quickly followed suit. Germany put the powers of state aid, though in other forms than subsidy, behind the North German Lloyd and the Hamburg American. Our own Congress, in a fitful way, beginning with 1847, granted liberal mail pay to especial new American ocean steam lines, the best remembered of which are the Collins Line to Europe and the Pacific Mail to the Isthmus of Panama and on the Pacific Ocean. But while other nations were united in loyal zeal for the national interests, it happened, unfortunately for us, that this new and crucial steamship competition fell in a period that saw America rent by the sectional quarrels immediately preceding the Civil War. Southern statesmen, who at first had borne a full share in urging encouragement to our own national mail lines, turned against them when they saw how swiftly these new lines were upbuilding the sea power of the North. In the very crisis of the struggle between our American lines and their European competitors, a hostile Congress, dominated by sectional prejudice, struck down the American mail subventions and thereby destroyed every one of the American steamship services in the transatlantic trade.

At this time the American Collins Line, with the largest and swiftest ships, was receiving a subsidy of $858,000 a year, and the rival Cunard Line $856,871 for smaller and inferior steamers. Soon after the Collins Line was killed by the act of our national lawmakers the Cunard mail pay was reduced by Parliament, demonstrating clearly that it was an aggressive fighting subsidy and nothing else.

But the British and other European policies of generous aid to national shipping lines, and thereby to steamship building and navigation, continued steadily without a break. It is sometimes urged that these governmental aids were not applied to "tramp" steamers. Directly they were not until France and Italy began to subsidize their entire shipping forty years ago. But, as a matter of fact, in a broad, true sense these European subventions and other assistances in those earlier years did quicken and strengthen the then new arts of iron steam shipbuilding and boiler and engine building in such a way that even the "tramp" steamers that came afterwards were indirectly the beneficiaries of the system. Moreover, the subsidized national mail lines pioneered and created commerce a part of which the "tramps" subsequently carried.

Until the United States in the Ocean Mail Act of 1891 tardily renewed the subsidy system in America, the decline of our own shipping remained constant. This Ocean Mail Law, though sadly crippled by western agricultural opposition in its passage through the House of Representatives, did set the American flag again afloat on the great route across the western ocean and did permanently strengthen our steamship communications with the West Indies, nearby South America and Australasia. Services subsidized under the ocean mail law owned almost all the steam tonnage we had in ocean commerce when the great World War broke upon us in midsummer of 1914.

Turning from this survey of the past to the new present, what do we discover? Is there no more hope for successful American competition with foreign shipping than there was before the late great war?

For one thing, America has now what before the war it did not have—a large, actual, seagoing merchant tonnage available for immediate employment in overseas carrying. It has the ships and it also has the managers, the operators, the officers and the men. It is now conveying about one-third of our imports and exports, or three times the proportion of before the war. Moreover, the American people, even to a degree the long-indifferent middle west, have been shocked by the war into a realization that, for peace or war, a strong merchant shipping is absolutely indispensable to America.

The nation has 8,000,000 gross tons of newly acquired merchant vessels on its hands, ships in which all the American people are stockholders. These stockholders are unitedly determined that our ships worth having shall not pass out from under the American flag. Any political clique or party that consented to haul down the flag would be committing instant suicide.

So the general outlook of the present is immensely more favorable than that of before the war for the development of a great ocean shipping and shipbuilding industry. But the obstacles in the way are substantially the same obstacles—the higher cost of operation and perhaps of construction of American vessels, the fact that even now our foreign competitors are in possession of two-thirds of the field, and the further fact that these foreign competitors in some way or to some degree are all powerfully upheld by the active aid of their own governments.

It is not now possible to speak definitely and with authority as to the comparative cost of building ocean ships in America and in Europe. But it is true that shipowners who have made inquiry on the other side within recent months have found that British shipyard prices were lower than American prices by at least a margin due to the abnormal state of sterling exchange. On the other hand, the American yards could offer quicker completion and delivery, which in normal times is of itself a marked advantage. Altogether it will probably be found, when conditions in America and in Europe have again settled down, particularly with "tramp" cargo vessels, that foreign ship prices remain lower than our own, though by a narrower margin than before.

As to the costs of operation involved in at least the wages and maintenance of the crews, Europe retains an undeniable advantage as contrasted with America. The La Follette Seamen's Law, whatever else it may have done, has conspicuously failed to equalize sea wage conditions around the world. Individual foreign seamen have quit foreign vessels in our ports and have reshipped on other vessels at the American wage scale. But this process, though not without significance, has not of itself brought foreign wage scales, as a whole, up to American wage scales, as is demonstrated by the following comparative pay-rolls of American, British, Japanese and Norwegian cargo steamers of like character and tonnage previous to May 1, 1921:

Crew List and Wages on Selected American, British, Norwegian, and Japanese Vessels.

Crew List and Monthly Wages, Single-Screw Coal-Burning Cargo Ship, Atlantic and Gulf Coasts, 8,800 Tons Deadweight. Class "C"

American				
Deck Department	No.	Wages	Amount	Total
Master	1	$357.50	$357.50	
First officer	1	228.75	228.75	
Second officer	1	200.00	200.00	
Third officer	1	176.25	176.25	
Carpenter	1	100.00	100.00	
Boatswain	1	95.00	95.00	
Able seamen	7	85.00	595.00	
Ordinary seamen	3	65.00	195.00	$1,947.50
Engine Department				
Chief engineer	1	332.50	332.50	
First assistant	1	228.75	228.75	
Second assistant	1	200.00	200.00	
Third assistant	1	176.25	176.25	
Deck engineer	1	100.00	100.00	
Storekeeper	1	95.00	95.00	
Oilers	3	95.00	285.00	
Firemen	9	90.00	810.00	
Coal-passers	6	75.00	450.00	2,677.50
Steward Department				
Chief steward	1	135.00	135.00	
Chief cook	1	115.00	115.00	
Second cook and baker	1	100.00	100.00	
Utility man	1	70.00	70.00	
Mess men	2	70.00	140.00	
Mess boys	2	65.00	130.00	690.00
Total crew	48	Total wages per month.		$5,315.00

Crew List and Monthly Wages, Vessel of 8,800 Tons Deadweight

British				
Deck Department	No.	Wages	Amount	Total
Master	1	*$258	*$258	
First mate	1	165	165	
Second mate	1	129	129	
Third mate	1	109	109	
Carpenter	1	83	83	
Boatswain	1	78	78	
Able seamen	10	70	700	
Ordinary seamen	2	44	88	$1,610
Engine Department				
First engineer	1	233	233	
Second engineer	1	165	165	
Third engineer	1	124	124	
Fourth engineer	1	109	109	
Donkeyman	1	78	78	
Storekeeper	1	78	78	
Greasers	3	75	225	
Firemen	8	73	584	
Trimmers	4	70	280	1,876
Steward Department				
Chief steward	1	97	97	
Second steward	1	68	68	
Cook	1	92	92	
Baker	1	73	73	
Bedroom and mess steward	1	67	67	
Steward's boy	1	41	41	438
Total crew	45	Total wages per month.		$3,924

Basis of Compilation of Above Figures:

Exchange rate used to convert to American money—Pound, $4.86

Per cent of American scale 74

* Estimated.

Crew List and Monthly Wages, Vessel of 8,800 Tons Deadweight

Japanese				
	No.	Wages	Amount	Total
Deck Department				
Master	1	$255.00	$255.00	
First mate	1	148.00	148.00	
Second mate	1	110.00	110.00	
Third mate	1	98.00	98.00	
Boatswain	1	50.00	50.00	
Quartermasters	3	38.00	114.00	
Carpenter	1	35.00	35.00	
Able seamen	6	31.00	186.00	
Ordinary seamen	6	30.50	183.00	$1,179.00
Engine Department				
Chief engineer	1	220.00	220.00	
First engineer	1	138.00	138.00	
Second engineer	1	105.00	105.00	
Third engineer	1	98.00	98.00	
Storekeeper	1	58.00	58.00	
First oiler	1	58.00	58.00	
Oilers	6	48.00	288.00	
Firemen	12	32.00	384.00	
Coal-passers	8	25.00	200.00	1,549.00
Steward Department				
Steward	1	35.00	35.00	
Cook	1	26.00	26.00	
Rice cook	1	20.00	20.00	
Mess men	3	20.00	60.00	141.00
Total crew	59	Total wages per month.		$2,869.00

Basis of Compilation of Above Figures:

These are minimum wages paid by three largest Japanese steamship companies. There are higher wages and a bonus system in addition.

Exchange rate used to convert to American money—Yen, .50

Per cent of American scale 54

Crew List and Monthly Wages, Vessel of 8,800 Tons Deadweight

Norwegian				
	No.	Wages	Amount	Total
Deck Department				
Master	1	*$268	*$268	
First officer	1	195	195	
Second officer	1	143	143	
Third officer	1	104	104	
Boatswain	1	78	78	
Carpenter	1	78	78	
Able seamen	5	72	360	
Ordinary seamen	5	44	220	
Young man	1	29	29	$1,475
Engine Department				
Chief engineer	1	221	221	
First engineer	1	182	182	
Second engineer	1	143	143	
Third engineer	1	104	104	
Firemen	11	73	803	
Coal-passers	4	49	196	
Boy	1	23	23	1,672
Steward Department				
Steward	1	156	156	
First cook	1	52	52	
Boy	1	23	23	231
Total crew	40	Total wages per month		$3,378

Basis of Compilation of Above Figures:
Exchange rate used to convert to American money—Kroner = .26
Per cent of American scale 64
* Estimated.

On May 1 last the pay of engineers, sailors, firemen and stewards on American merchant vessels, government owned and privately owned, was reduced by an average of about 15 per cent. The ensuing strike was quickly and easily won by the Shipping Board and private shipping companies. On August 1, 1921, the pay of the deck officers of American merchant vessels was reduced about 15 per cent, so far as mates were concerned. The pay of masters, with their greater responsibility, was reduced less, or not at all. Early in May a reduction in the wage scale of British officers and men became effective without a general strike. New present wage rates of American and British officers and men for cargo steamers of the same representative type compare as follows:

Comparison of American and British Marine Wages for *Class C Steamers.

American Wages Effective from May 1, 1921, and British Wages Effective from May 6, 1921

Grade	American	British		
		£	£ at $4.86	£ at $4.00
First officer	$195.00	26/10	$128.79	$106.00
Second officer	170.00	21/10	104.49	86.00
Third officer	150.00	17/10	85.05	70.00
Carpenter	85.00	14/10	70.47	58.00
Boatswain	80.00	13/10	65.61	54.00
Able seamen	72.50	11/–	53.46	44.00
Ordinary seamen	52.50	7/10	36.45	30.00
Chief engineer	285.00	35/10	172.53	142.00
First assistant engineer	195.00	26/10	128.79	106.00
Second assistant engineer	170.00	21/10	104.49	86.00
Third assistant engineer	150.00	17/10	85.05	70.00
Donkeyman	80.00	13/10	65.61	54.00
Oiler	80.00	13/–	63.18	52.00
Water tender	80.00	13/–	63.18	52.00
Fireman	75.00	12/10	60.75	50.00
Coal-passer and wiper	65.00	12/–	58.32	48.00

*Class C, from 7,501 to 12,000 power tonnage—gross tonnage plus indicated horsepower.

Reductions in an equal or greater ratio have since become operative among officers and men of the Norwegian and Japanese merchant services, but the data for exact comparison with American schedules have not yet reached the United States. It can be said, however, that America is now paying wages far higher than those granted by any competing nations, and that the cost of food or maintenance is also markedly higher, so that in this respect there is no important change whatsoever from the economic conditions that prevailed before the great war. Sea pay, which rose during the war in Europe as well as in America, has since been somewhat reduced in Europe as well as in America, so that the difference between American ships and foreign ships in wage cost and operation remains substantially the same as it was before.

In fact, allowing for abnormal conditions of international exchange, the wage handicap against American ships is greater than ever. Foreign steamers plying in American trade demand their freight or charter hire in American money, but buy their supplies as far as possible and pay the wages of their crews in their own depreciated currency. The result is astonishing. A case just reported to the American Steamship Owners' Association is that of a Norwegian steamer of a deadweight capacity of 11,000 tons. Her total cost of crew, including officers as well as men, per month, taking the kroner at 12.65 cents, is $1,613 a month, while the total cost of crew of a submarine boat type steamer, with a deadweight capacity of 5,350 tons, is $3,302 a month.

Of course the abnormal difference in cost of operation, due to the present state of international exchange, is temporary; it will not last forever. But for the time being it has the practical effect of a profound discouragement to American shipping and of an actual subsidy to foreign shipping which will have to be met in some thoroughly effective way if American shipping is to live through the crucial ordeal of the three or four years to come.

Wages and maintenance together make up about 15 per cent of the total operating costs of a modern freight steamer. The present cost of wages and maintenance to our British and Norwegian competitors, largely because of upset rates of exchange, is nearly or substantially one-half our own cost. This exceptional difference, of course, will tend to decrease as financial conditions are restored, but for the present this extra cost of wages and maintenance is a grave handicap to American shipping in a period of unprecedented intensity of competition. The difference in wages and maintenance is all the heavier a handicap on the new American merchant marine because America still lacks the well-coordinated mercantile and maritime organization all over the world which enables British shipowners to meet the competition of continental nations having wage rates still lower than the British scale. The effect of this close British cooperation in every country, in every trade and in every port, of British agents, merchants and bankers in enforcing preference for British ships, makes that shipping in effect one of the most thoroughly protected industries of which there is any record in commercial history.

An excellent case in point has just been afforded in the effort of the United States Shipping Board to secure for American ships the carrying of Egyptian cotton from Alexandria to this country. American cotton mills are liberal users of the Egyptian fiber, practically every pound of which has for years been brought to the United States, either directly from Egypt or via the United Kingdom, in British steamers, through a close working agreement between cotton merchants in Egypt and the Liverpool conference lines.

When American steamship companies a year ago sought for their own vessels a share of the carrying of Egyptian cotton destined for the United States, their officials were told that this had been and would continue to be a British monopoly, and American vessels could not hope to have any share in it. For the time being the effort had to be abandoned, but last spring the Shipping Board forced the issue by offering a freight rate of 40 shillings a ton for Egyptian cotton brought to the United States and of 25 shillings a ton to the United Kingdom, while the bid of the Liverpool conference lines was respectively 60 shillings and 40 shillings per ton.

Yet so hard and fast was the combination which British merchants and shipowners had effected to monopolize the Egyptian cotton trade that the lower bids of the Shipping Board were immediately rejected, and rejected with the approval of the Liverpool and Manchester cotton exchanges. The characteristic intensity of the devotion of British merchants to their own country's shipping is shown in the insistence of these British business men in handling Egyptian cotton in their own country's ships, though it cost them a far greater price than if carried in American vessels. At last accounts the United States Shipping Board had been unable to obtain any concession whatsoever of any share of this American carrying trade, and the case was being transferred to the Department of State for diplomatic action.

From instances like these Americans can gather something of the exclusive, arbitrary methods by which Great Britain has developed her immense merchant marine, and something of the difficulties beyond mere wage scales which we must meet if we are to wrest from British carriers any part of the transportation to the United States of imports which American merchants and manufacturers have purchased.

All over the world British manufacturers and merchants and their representatives will be found demanding that British ships must secure all the cargoes which they can manage to control. There must be similar tenacious organization and cooperation of American manufacturers and merchants in the interest of their own country's ships and their own country's flag if our new merchant marine is to have the even chance to which it is honestly entitled.

Another important factor in the maritime situation, beyond the lower wage and maintenance cost of foreign ships and the disciplined activity of our competitors, is the generous direct or indirect national aid extended by all governments, particularly to their regular line steamship services. Just before the great war the United States Commissioner of Navigation published an analysis of the subsidies, subventions and bounties then being paid to the steamship interests of the world's chief maritime nations. These sums aggregated about $46,000,000 a year, of which Great Britain's own share was approximately $10,000,000. While the British and the Germans at that time gave direct state aid only for mail, passenger and fast freight services, it was significant that other governments, notably France, Italy and Japan, were subsidizing virtually their entire merchant marines and even giving direct bounties to shipbuilding.

As rapidly as possible, these subsidies, subventions and bounties are now being reestablished—they were not necessary during the continuance of the war. It is probable that when the total sums of these state expenditures are again recorded they will be found amounting to a great deal more than $46,000,000 a year, for the war itself most vividly emphasized to all governments and all peoples the tremendous value, indeed the imperative necessity, of a strong commercial shipping for defensive and commercial purposes.

What the American people must, therefore, prepare to do to enable American merchant ships to compete successfully with the ships of foreign nations is: (1) To find the most practicable form of equalizing American sea wages and costs of maintenance with the wages and costs of maintenance of foreign ships, by a system of preferential duties or subsidies and subventions, or some other still more effective method, if that can be found; (2) of organizing American manufacturers, merchants and bankers into a league as disciplined and powerful as the similar British league, for example, for securing the carriage of a greater share of our imports and exports to American ships; (3) of offsetting foreign subsidies, subventions, bounties and like national assistance given to the ships of our competitors. In addition, if it is discovered that the first cost of American-built ships is greater than the first cost of foreign-built ships, there must be full compensation for this factor also. In other words, the American merchant marine must be made what it has not been for more than sixty years, a nationally protected industry, as for most of the life of this republic manufacturing and agriculture have been protected industries. These things must all be done, or the new American merchant fleet, which is even now being beaten off the ocean by its competitors, will inevitably again decline and disappear exactly as the old merchant marine was declining from 1855 onward.

Moreover, it is essential that the classification and survey of American merchant shipping in the years to come be controlled by interests 100 per cent American. The success of the American Bureau of Shipping is absolutely essential to the prosperity and security of the new American merchant marine which must also find in American hands the resources for a major part of the underwriting of the ships themselves and of their cargoes. Only the other day British marine insurance companies were assisting the Liverpool conference lines to retain complete control of the Egyptian cotton trade by allowing British ships much lower insurance rates on cotton cargoes than were being granted to American ships. The protective value of classification, survey and insurance of our own is a point that cannot possibly be overestimated in any study of the future of the American merchant marine.

American shipowners must develop, as rapidly as possible, what their fathers possessed before them, a corps of the most efficient seagoing officers in the world, every one an American citizen, and the largest possible number of citizen seamen. The American people will never consent to protect and encourage American shipping as it must be protected and encouraged so long as any substantial proportion of that shipping is officered and manned by alien subjects of foreign countries, our rivals in trade and possible enemies in war. Who can justify a merchant marine as a naval reserve unless it is securely held in loyal hands, and not in the hands of those who in an hour of need might betray it to the enemy?

DISCUSSION.

The President:—The author of the paper just presented, "How Can American Ships Compete Successfully with Foreign Ships?" as you all know, is not only a writer, but a thinker along the lines of the subject which he has put before you. He also occupies a very prominent position as an executive of the American Steamship Owners' Association. I feel quite sure that the subject, presented to you in this way, will not only be of great interest but will elicit some illuminating and profitable discussion. The paper is before you, gentlemen, for action.

Mr. James Donald, *Member*:—Mr. President and gentlemen, on former occasions when I have appeared before this Society it was in the capacity of a naval architect for large American shipyards, and my remarks then related to the technical subjects after an experience of thirty years in the shipbuilding business.

I am now addressing you as a member of this Society and with five years' experience in the actual operation of merchant steamers.

Formerly I looked at the operation of steamers more from a naval architect's point of view and hope that I will be able to interest you now from another point of view, namely, the ship operator's.

We are all indebted to Mr. Marvin for his paper, and for bringing before us the question as to "How American Ships Can Compete Successfully with Foreign Ships." He has given you a scale of wages under the American and other flags and, even at the normal rate of exchange he has used, the cost of operating is more expensive under the American flag than under any other. To show the effect that the exchange has on these schedules, Table I herewith will show you the actual wages per month for a Norwegian vessel of 10,880 tons total deadweight, and the wages are as of August, 1921. This Norwegian vessel is larger than Mr. Marvin's type vessel of 8,800 tons, and you will notice that the total wages per month is $1,613.47, which should be compared with Mr. Marvin's total wages, per month, for an American vessel of 8,800 tons, $5,315, as shown on page 196 of his paper. This question of the labor on board the steamers of the various nationalities is the all-important question that the American shipowner has to contend with, and I would recommend that Mr. LaFollette, Mr. Gompers and Mr. Furuseth seriously consider these figures giving the comparisons of wages on vessels of all nationalities so that they may be able to pass laws and influence their unions so that the American shipowner may be better able to compete with the foreign.

TABLE I.—*Scale of Wages per Month for a Norwegian Vessel.*

Rate of Exchange figured at $12.65, as prevailing on August 8, 1921.

	Krons*		
Master	1169		$147.88
1st officer	500		63.25
2d officer	450		56.93
3d officer	325		41.11
5 A. B.'s	270 each	$34.16	170.80
5 O. S.	200 each	25.30	126.50
1 Boatswain	330 each		41.75
1 Carpenter	330 each		41.75
16 Deck department			$689.97
Steward	450		$56.93
Cook	350		44.28
2d cook	200		25.30
Messboy	115		14.55
4 Steward's department			$141.06
Chief engineer	700		$88.53
2d engineer	550		69.58
3d engineer	350		44.28
Two donkeymen	310 each	$39.22	78.44
Two oilers	310 each	39.22	78.44
9 firemen	300 each	37.95	341.55
3 coal passers	215 each	27.20	81.60
19 Engine department			$782.44
Total wages, 39 men per month			$1,613.47
Wages per man per month (average)			41.37
Wages per man per day (average)			1.37

* Norwegian

What the American merchant marine requires is more freedom as regards the nationalities of the crews, and American shipowners should be allowed to employ cheap alien crews the same as other nations do; otherwise, if an American merchant marine must be established this government will require to step in and pay the shipowner the difference in cost of wages between those existing on American steamers and those under foreign flags.

We have heard a great deal during these last few years regarding the possibility of the future American merchant marine, and too much general talk has been engaged in rather than in obtaining the actual facts.

My object today is to give you some exact figures showing the present cost of operation between vessels of foreign countries and those of the United States. The situation looks serious for the shipbuilder and also for the present owner of high-price tonnage, and as long as we have sufficient tonnage afloat I am afraid that it will be several years before there is a demand for new freight steamers.

Table II.—*Comparative Cost of Operation of 8,800-Ton Deadweight Steamer Based on a Value of $20 per Deadweight Ton, September 6, 1921.*

	British				American	
	Pre-war		Present		Present	
Crews' wages	$1,256	14c	$2,222	26c	$3,875	44c
Victualling	494	5c	883	10c	1,085	12c
Administration	277	4c	300	4c	1,000	11c
*Repairs	400	5c	1,000	11c	1,000	11c
*Drydock, etc.	400	5c	800	9c	800	9c
Deck and engine stores	350	3c	700	8c	700	8c
Depreciation, 5%	733	8c	733	8c	733	8c
Insurance, 6%	880	10c	880	10c	880	10c
Interest, 6%	880	10c	880	10c	880	10c
Loss hire, 10%	567	6c	840	9c	1,095	12c
	$6,237		$9,238		$12,048	
Cost per d. w. ton per month	70c		$1.05		$1.35	
Charter rate 5/6 at $3.70	....		1.0175		1.0175	
Loss	....		$0.0325		$0.3325	

* Includes periodical surveys, local inspection, etc.

The figures I am going to show you will prove to you that the present commercial value of freight steamers of an average tonnage of 7,500 tons deadweight is $20 per ton deadweight. In order to prove this I would refer you to Table II, where you will see that the cost to the owner of chartering a steamer of 8,800 tons deadweight, under the British and United States flags, as of September 6, 1921, when the exchange was $3.70 per £ sterling, was $1.05 per ton for the British steamer and $1.35 for the American steamer—please note that this is on a valuation of a vessel at $20 per deadweight ton. The charter rate at this date, 6th of September, 1921, in the open market was 5s. 6d., which, at $3.70 per £ sterling, equals $1.02. Therefore the British ship, as of September 6, 1921, is making a loss of 3 cents per deadweight ton; while the American ship at the same date is making a loss of 33 cents per deadweight ton, on a valuation of $20 per deadweight ton.

TABLE III.—*Comparative Cost of Operation of 8,800-Ton Deadweight Steamer Based on a Value of $20 per Deadweight Ton, November 15, 1921.*

	British				American	
	Pre-war		Present		Present	
Crews' wages	$1,256	14c	$2,222	26c	$3,875	44c
Victualling	494	4c	883	10c	1,085	12c
Administration	277	4c	300	4c	1,000	11c
*Repairs	400	5c	1,000	11c	1,000	11c
*Drydock, etc.	400	5c	800	9c	800	9c
Deck and engine stores	350	3c	700	8c	700	8c
Depreciation, 5%	733	8c	733	8c	733	8c
Insurance, 6%	880	10c	880	10c	880	10c
Interest, 6%	880	10c	880	10c	880	10c
Loss hire, 10%	567	6c	840	9c	1,095	12c
	$6,237		$9,238		$12,048	
Cost per d. w. ton per month	70c		$1.05		$1.35	
Charter rate 5/6 at $3.95	....		1.086		1.086	
	Profit		$0.024		Loss $0.264	

*Includes periodical surveys, local inspection, etc.

By referring to Table III, dated November 15, 1921, when the charter rate was 5s. 6d., but the exchange was $3.95 per £ sterling, the profit for the British steamer is 2 cents per deadweight ton, and for the American steamer there is a loss of 25 cents per deadweight ton. These two statements prove that the British steamship owner with a ship on a valuation of $20 per ton is just breaking even, while the American is losing $0.264 per deadweight ton per month, showing a loss at the end of twelve months of $27,878.40 or a loss per year per deadweight ton of $3.17. Assuming that the United States has 10,000,000 tons deadweight in steamers and it has been proposed that the Government should pay the difference in cost of operation, this would mean that there would be a yearly subsidy of $31,680,000 to overcome the difference in the cost of operation between an American vessel and a foreign one. It will be interesting to you to check up these figures from another point of view, shown on Table IV, where the time-charter rates and the owners' expenses in 1913 and 1921 for a British steamer are shown. It is there shown that the time-charter rate in 1913 was 84 cents and the owners' expenses were 75 cents, leaving a margin of profit of 9 cents per deadweight ton per month, which was quite a reasonable profit after paying all overhead. In 1921 a time-charter rate is taken at 6s., at $4.00 per £ sterling, and is therefore $1.20 per deadweight ton per month; the owners' expenses at the present time are $1.11, which again gives a margin of profit of 9 cents per deadweight ton per month, so that it will be seen that the British shipowner has now got his expenses and charter rate on the same basis as before the war.

TABLE IV.—*Time-Charter Rates and Owners' Expenses in 1913 and in 1921.*

BRITISH STEAMERS.

	1913.		
Time-charter rates..............	3s/6d	at $4.86	84 cents per deadweight ton per month
Owner's expenses...............	3s/1½d	at 4.86	75 cents per deadweight ton per month
Margin	0s/4½d	at $4.86	9 cents per deadweight ton per month
	1921.		
Time-charter rates..............	6s/–	at $4.00	$1.20 per deadweight ton per month
Owner's expenses...............	5s/6½d	at 4.00	1.11 per deadweight ton per month
Margin	0s/5½d	at $4.00	$0.09 per deadweight ton per month

Note that the margin over owner's expenses in each instance is 9c per deadweight ton per month

TABLE V.—*Hampton Roads, Va., to Genoa. Freight Rates and Cost of Transportation in 1913 and in 1921.*

On ship's value of $20 per d. w. ton—8,800 tons d. w.

BRITISH STEAMERS.

		1913.			
Coal rates.....................	15s/–	17s/6d	($4.86)	$3.60	$4.20
Cost of transportation	13s/3d	13s/3d	($4.86)	3.19	3.19
Margin	1s/9d	4s/3d	($4.86)	$0.41	$1.01
		May, 1921.			
Coal rates.....................	30s/–	32s/6d	($4.00)	$6.00	$6.50
Cost of transportation	28s/6d	28s/6d	($4.00)	5.70	5.70
Margin	1s/6d	4s/–	($4.00)	$0.30	$0.80
		November, 1921.			
Coal rates.....................	21s/3d	21s/3d	($4.00)	$4.25	$4.25
Cost of transportation	22s/9d	22s/9d	($4.00)	4.55	4.55
Loss........................	1s/6d	1s/6d	Loss........	$0.30	$0.30

AMERICAN STEAMERS.

		November, 1921.			
Coal rates.....................	21s/3d	21s/3d	($4.00)	$4.25	$4.25
Cost of transportation		......	($4.00)	6.07	6.07
Loss............................		......	Loss........	$1.82	$1.82

As the question of export of coal is important at the present time, it will be interesting to show you the comparison in operation between an American steamer and a foreign one. By referring to Table V, the freight rates and transportation costs in 1913 and 1921 are shown; first for a British steamer of 8,800 tons deadweight at $20 per ton deadweight value, and in 1913 the coal rates ran between $3.60 and $4.20; the cost of transportation at that time was $3.19 and the profit was an average of 70 cents. In May, 1921, the coal rates existing between Hampton Roads and Genoa were between $6 and $6.50—the cost of transportation had increased to $5.70, leaving a margin of profit of about 55 cents per ton. In November, 1921, the coal rates had been reduced to $4.25 and the cost of transportation for British steamers $4.55, leaving a loss of 30 cents per ton. For an American steamer, on the same value of vessel and of the same size, as of November, 1921, the coal rates are still $4.25 and the cost of transportation $6.07, showing a loss to the American steamer of $1.82 per ton and completely eliminating the American steamer from this trade.

We therefore conclude, from the above facts of the actual operation at the present time of American steamers, that it is impossible at the present time and under present conditions for American steamers to compete with foreign steamers. We also find from the above that if a subsidy is adopted it will mean an annual payment by the Government to overcome the extra wages of a sum amounting to $31,680,000 per year. It also shows that, if no financial assistance is given to the American shipowner, it will be necessary to employ foreign labor at the cheapest rate on board American steamers. These figures also indicate that the present value of tonnage is not more than $20 per deadweight ton as shown from the actual working of the ship and also from the record of the past year from the sale of ships in Europe which bears out this value, and therefore shows a very serious situation for obtaining new contracts for the shipyards, for selling the surplus steamers belonging to the U. S. Shipping Board, and for the possibility of American shipowners owning high-priced tonnage writing down their steamers at the present low freight rates.

We all should forget our own selfish points of view—the designers of vessels, the shipbuilders, the repairers and the suppliers of materials and equipment should all be represented in the same lifeboat, and strive to save ourselves from drowning. By steering the Senate, House of Representatives and the labor unions in the right course we may be able to reduce our costs to such an extent that the shipowner can operate his steamers successfully in competition with the foreigner and thus build up a merchant marine worthy of these great United States.

Mr. Marvin:—I would like to voice my own thanks for the very careful paper which has been prepared by our friend and neighbor. I think it is the most accurate statement of exact conditions which now confront American shipowners. The figures prove absolutely the contention that American vessels cannot live on the high seas today any more than they could before the great war. I think that Mr. Donald has rendered a great service to this Society and the whole American merchant marine by portraying the actual ship competitive conditions more graphically, and I think more fairly, than I have ever yet happened to see them presented anywhere.

On the matter of the suggestion that we employ foreign labor, Mr. President, I am not sanguine that we could permanently gain very much by that expedient, but I would like to impress upon the members of the Society that that expedient is entirely open to us at the present time, for except on a very few steamers provided for under the Act of 1891, all the crews below the rank of licensed officers can be of any nationality; they can even be all Chinese, but our experience is that, when we have used foreign labor, foreign labor, overnight, so to speak, demands and receives the American wage scale. Before the war, not 10 per cent, on the average of the unlicensed men—sailors, firemen and stewards—in the beyond-seas trade or American trade, were American citizens, and yet at that time the pay of the crews of the American ships was just as much higher as in the days when the law required two-thirds of the crews of American ships to be American citizens.

Moreover, I call your attention to the circumstance, that under the voluntary action of the American Steamship Owners' Association and of the United States Shipping Board, for some months past preference has been given to our own seamen, firemen and others, who are American citizens, and that has resulted in a great increase of the American personnel on our ships in general—it has been so great that the Sea Service Bureau of the U. S. Shipping Board has been able to announce in the last month that almost all the men shipping from that bureau have been American citizens. We now have the highest American personnel in the experience of any living American owner.

Sea wages are fixed by land wages. They are higher on sea in our case than they are in foreign countries, because land wages are higher, and that is an economic law we cannot dispense with in our day and generation.

Another point—we need a merchant marine, as you know, largely for naval reserve purposes. A substantial part of the crews must be American citizens for our own protection. During the war there were several instances of shameful conduct on the part of crews—nearly all foreigners—of merchant ships that were torpedoed and sunk by the German submarines, and the United States issued an order that no aliens should be shipped on vessels carrying troops from America to Europe. The Navy substituted green boys who had not been to sea before, and they did remarkably well.

I am in earnest in believing that we shall never have a merchant marine in this country if it is chiefly manned, as economical considerations might demand it should be manned, by foreign labor. The American shipowners must show that they are employing a very considerable proportion of American sailors and firemen before they can hope for any substantial protection or encouragement whatever from the Congress of the United States.

The President:—The remarks of Mr. Marvin can be considered as preliminary only. He is therefore privileged to reply to any other discussion, so that the discussion is still open for those who wish to express themselves.

Mr. Edwin C. Bennett, *Member:*—I had not intended saying anything in connection with Mr. Marvin's paper, for I am not a ship operator and therefore feel a certain hesitancy in entering a discussion upon one of the most vital problems facing the American people. I am, however, a naval architect and shipbuilder, and therefore the success or non-success of the American merchant marine reflects itself very materially in the business I am engaged in. It is a subject whose solution will be of the greatest influence upon the future welfare of this Society and every member connected with it. I feel that, of all the papers being read at this meeting, this is of the most vital consequence to all of us and should receive the greatest attention.

Mr. Donald, in the tables presented in connection with his discussion, very clearly shows the handicaps under which we are struggling even with ships carried at $20 per ton deadweight, and puts forth anything but a rosy outlook. Mr. Marvin also in his valuable paper refers to the first cost of the American ship as an item to be seriously considered. Now we know there are today something like 3,000 American ships, owned by citizens or the U. S.

Shipping Board, of which number the Shipping Board controls some 1,450 of 10,500,000 deadweight or practically 60 per cent of the gross tonnage. The Shipping Board is therefore the controlling factor in the shipping situation today, and, through its policy, will determine what the future of the American merchant marine shall be. I feel very strongly that little real progress can be made in stabilizing the merchant marine situation until the present market price of the vessels are determined upon a proper and logical basis and those prices used as the basic value in considering what remedies must be given to American shipping in order that it retain its proper position in world commerce.

We have recently seen in the public press advertisements by the Emergency Fleet Corporation offering its ships for sale on a private competitive basis, with a proviso stating that the board has set a minimum price upon these vessels. So far as I know, the minimum price has never changed from the previously announced $165 to $185 per ton deadweight. The latest advertisement offers certain specific vessels of varying types for sale—supposedly vessels of the highest grade—without, however, a minimum price but with the right of the Shipping Board to negotiate after the bids are in. In view of the unfortunate experience of the "pioneer" purchasers and the present deplorable condition of the freight markets, which make the ownership of a ship a liability rather than an asset, I feel the Shipping Board will get few bids that can be used for determining the basic value of the government fleet. The board will undoubtedly get a certain line of information—namely, the value of existing tonnage in an oversold market—but this is not the basis that should be used in determining the "capital cost" value of the Shiping Board tonnage. If the American merchant marine is to be given any hope of holding its own as one of the carriers of the world's sea-borne commerce, the Shipping Board will have to get the book value of the fleet down to a point where that value is comparable with the book value of the vessels operated by our competitors, and, to my way of thinking, the Shipping Board should immediately take steps to find out from the shipyards of Great Britain, Norway, Germany, France, Holland and others of our competitors exactly what the "replacement" cost of the existing fleet is; then use that information as a base on which to make the other adjustments called for in clause No. 5 of the Merchant Marine Act, and, in that way, get down to some basis of "book" value that will be comparable with that of our competitors.

Mr. Donald has shown that a capital cost of $20 per ton is too high in the present market without government aid, in competition with foreign tonnage. Well, if we cannot get any help from the Government we must bring down the book value to where we can compete. Say, for purposes of illustration, the cost works out at $15 per ton, then let the Shipping Board advertise the ships for sale from time to time by competitive bid, stating that they are offered at a minimum price of $15. A prospective shipowner could then value the particular ship he is interested in and determine how much more he can afford to bid in competition. Holding the present tonnage at $165 to $185 and without, so far, any apparent assistance from the Government either by subsidy or the enforcement of existing laws, is a situation that militates against the sale of the ships to any private ship operator.

The Democratic Administration formulated and passed the Merchant Marine Act of 1920, and, after it became a law of the land, promptly refrained from enforcing its provisions. It passed into the Republican Administration, who, I think, are quite as anxious as the Democrats to see an established merchant marine, but they, too, seem very reluctant to enforce the various measures included in that law to assist our shipping. Now, if that law is so "prickly" that our legislators are afraid to enforce it, let us get something that will be carried int , effect. It is a moral certainty that without some form of government assistance the existing handicaps under which our shipping operates are too heavy to be endured,

Not being a shipowner or operator, I feel a certain diffidence in expressing an opinion upon the wage rates given by Mr. Marvin. I believe, however, we must face the fact that the wages paid our seamen will always be higher than paid by our competitors, and it is one of the many factors to be taken into account in formulating any legislation for the help of our shipping.

The question of insurance rates on both hulls and cargo has a large influence in the operating costs of a vessel, and I am informed that it is cheaper to place such insurance abroad than in America. I am speaking from hearsay, but if it is a fact that insurance is more expensive when placed in this country and the situation cannot be altered through competition, then this fact also must be taken into account in future assistive legislation.

The Disarmament Conference now taking place in Washington, under which the number of capital ships of war will be limited, looks to me as tending to bring the merchant ship forward as a more necessary adjunct to the country's offense and defense. If the number of our capital ships is limited, and the country enters into a state of war, the first thing we must do to protect ourselves and our lines of commerce is to arm our fast merchant ships for use as cruisers and to protect our slower freight-carrying vessels. We will be in a most unenviable position and a most serious situation if, through lack of help and assistance through proper legislation, the American merchant marine is allowed to be dissipated and lost. A strong and effective merchant marine is, more than ever before, necessary for our future safety and protection, and the point I really want to stress is that the Shipping Board should face the situation squarely and, realizing it is the controlling factor, come out boldly with a program—even if it means a direct subsidy—for the support of our country's shipping and make it possible for American shipowners to purchase Shipping Board vessels at a price that, coupled with government aid, will allow us to compete with the ships of foreign nations.

One of the main factors in formulating this program is to find out the actual replacement value of our ships, make the necessary adjustments to that price to meet the provisions of clause No. 5 of the Merchant Marine Act, and, having determined a logical selling price, offer these ships to American citizens, and, after a certain length of time, to any foreign purchaser who can meet the terms of payment. By all means remove that menace of undigested shipping that is now overhanging the American market and which handicaps every private shipowner and deters him from venturing into new projects.

Commander Stevenson Taylor:—I think I can assure the meeting that it is not the idea of the Shipping Board to ask, for the ships they wish to sell, the old price of $165 per ton deadweight. I would like Mr. Bennett, as a shipbuilder, to tell us what is his opinion as to the price which should be asked for these ships, having due regard for the replacement value at the present time, and having due regard also to the proper business-like way of conducting such negotiations.

Mr. Bennett:—The replacement value in the American market today is very hard to say with any degree of definiteness——

Commander Taylor:—I thought you may have some idea——

Mr. Bennett:—I believe the best of the freight ships could be replaced today in American shipyards for from $90 to $110 per ton. That, however, is not the point I wish to make. It is not logical to set a replacement value of $100 per ton on Shipping Board vessels when we can go abroad to the shipyards of Germany, France, Norway or Great Britain and build the same ship for some $50 per ton.

Commander Taylor:—Is that so?

Mr. Bennett:—I believe it is. We have to compete with the foreign ships, and therefore we should bring the value of our ships down to the book value of our competitors, irrespective of whether it is different from what we can replace them for in the American market.

The President:—This discussion seems to bring out the salient points.

Mr. H. C. Towle, *Member:*—I wish to state that as far as shipbuilding costs are concerned I believe that the replacement value in this country today is lower than it is in England. Within two days I have received actual labor and material costs from England on a 10,000-ton tanker and also on a 9,000-ton freight ship. In both cases they were from $6 to $8 a ton higher than some shipyards in this country can do the work for.

The last speaker mentioned the Shipping Board vessels. We have in this country a large tonnage idle. If the ship operators—the American ship operators—can take these vessels and operate them profitably, let them take them, even though the Government sells them for $25 or $20 a ton, or less, and get them to work. These vessels then will establish trade routes and the shipyards will come in later on replacements, the same as British shipyards will come in on replacements of their tonnage at a later date.

Shipping men of other countries are afraid that the American Government will dump these ships on the open market, and that they will be absorbed by their competitors, and they are afraid more of that than they are of any other one feature in the situation. If the ships are to be sold soon, I see no reason why the American ship operator should not obtain the benefit of cheap prices.

Mr. W. H. Mackay, *Member:*—As an American of forty-five years' experience, born here in the City of New York, it is only natural that I should feel proud of being permitted by our government officials to operate as chief engineer, with a license of the kind stated. I merely mention these circumstances so that you will understand that I have had the experience and know what I am talking about. The question of operating ships under the American flag is a very vital question as to the success of the American merchant marine. If the shipbuilders and the ship designers continue to specify nickel-plated fixtures for the crews, in addition to enamel bath tubs, porcelain wash basins, beautiful mirrors, three or four systems of hot and cold water, and other accessories, such as linen sheets and linen pillow-cases that have been stolen off vessels and sold in foreign ports during the great war by the crews that we were compelled to sign on, most of them composed of the scum of Europe, then we might just as well close up shop and go out of business. During this World War I have seen sailors, firemen and coal passers carrying ashore almost everything that was movable and that could be sold in a foreign port, costing the owners thousands and thousands of dollars to replace the same. Another great expense to the shipowners that could be eliminated is the waste of fresh water. It was almost impossible to prevent the crew forward wasting the fresh water, due to the fact that they frequently opened the valves and permitted tons and tons of fresh water to run overboard and into the sea. Furthermore, tons and tons of coal mixed with ashes were lost by being allowed to go overboard, with the ashes, no care being taken to separate the same. Oil waste and other supplies, including silverware, dishes and table cutlery, disappeared in the same manner. Nothing like it ever occurred on any other vessels but ours, due to the fact that our laws are written in such a way that it is practically impossible to compel obedience to the captains and the chief engineers of the ships flying the American flag.

Many of the men making up the crews in our vessels during the war were tramps and slackers of the worst kind, of all nationalities, seeking a place of safety on board our vessels where they could get plenty to eat and a good place to sleep, safe from any possible chance of being drafted to a field of danger, and receiving large pay for a small amount of work. In a number of cases, after these men were well fed and recovered their strength which they had lost through inferior food and poor housing quarters ashore, they refused to work on our vessels when at sea, claiming that they were sick. According to law, an officer of a ship, when a man is reported sick, is compelled to make an examination of the man, take his temperature, count his pulse beats, respiration, apply a stethoscope to his heart and ascertain if the man is normal or abnormal. If we find that he is in first-class health and order him back to work, he will say, "I am sick" and you can go to ——." In a number of cases we were compelled to put such seamen in double irons and feed them on bread and water for five days. In some cases it was a permanent cure; in other cases the cure was only temporary. If we logged these men and deprived them of their wages, on return to port they put up an awful fight and, rather than have the ship delayed, all parties interested acquiesced and agreed to pay them their wages to get rid of them. But the next crew was just as bad, and sometimes worse, demanding, on certain holidays, such as Sundays, etc., their chicken and their turkey and their jam and their fruit, and if they did not get it they refused to work, claiming that the law gave them the right to demand all these things.

The sooner the La Follette law is changed so that it is reasonable and gives the owners, the captains and the chief engineers a little more authority over the crews on board ships flying the American flag, insisting that they must obey the officers without question; then we will have a merchant marine that we can be proud of.

Men with a college education will never be attracted to the merchant marine service as a life profession, due to the fact that it takes a different type of man to pass coal, fire boilers, oil the bearings, make repairs in general on the boilers, engines and auxiliaries, from time to time as they need them, at the wages that the steamship companies pay. A man with a college education may eventually become chief engineer, but when he arrives at that point in his profession he then seeks a position ashore where he can get a salary of $6,000 to $10,000 or $12,000 a year, which he is entitled to with his education and if he has the executive ability. A man does not spend four years in college at an expense of $6,000 to $7,000 or $8,000 for his education for the purpose of preparing himself for a job or position that would not pay him more, even at the very most over $300 a month for the balance of his life. Therefore it is necessary for us to train the native-born American boy from the bottom up, but the first thing to teach him is obedience and respect to the officers of the ship, who are held responsible for the safety of the vessel, the safety of the cargoes, and the safety of the lives of those who are traveling on that ship. Until all these matters have changed as suggested by me, until that time our merchant marine will be a source of great expense with very little profit for those who have invested their money in our ships.

The watchword, therefore, in the future, shall be 100 per cent American crews, the highest economy, reasonable living quarters and, above all, obedience.

Mr. Howard C. Higgins, *Member:*—I desire to say a word in defense of the American crew, not in the way of discussing the paper which is now before us, but in answer to the remarks of the gentleman who has just spoken. I have dealt with American crews, especially the engine department personnel, on American ships for the past twenty-five years, and the statements this gentlemen has made, as far as my observations go, are wholly unfounded. I believe there are no more faithful, loyal, hard-working crews on any ships afloat than the crews on American vessels, and in view of the remarks previously made it is my feeling that a word should be stated in their defense.

Captain D. J. Sullivan, *Member:*—I happen to be a master of a ship under the American flag, a graduate engineer who first started to sea as an engineer. I have been nineteen years in the service, and what has caused me to speak on this subject this morning is the question of foreign crews.

I have had in my day mongrel crews. I have had complete crews of Chinese, of Japanese, of Swedes, and of negroes. I have had crews made up of all American-born seamen. I have found by actual experience that the American-born crew, provided you pick them, provided you weed out those who do not wish to work, though they are paid, Mr. President, 100 per cent more than the next best paid crew, is the most efficient and in the end the most economical. (Applause.)

I stand before you today the master of a privately owned American ship, for which the owner paid $225 a ton, at the peak prices, and purchased it from the United States Shipping Board. At the time—which is now a year and a half ago—when he selected me to take command of the ship, conditions were bad and were rapidly growing worse. The cost of loading, the cost of detention, the cost of demurrage, the cost of repairs—and I hope there are a few shipyard men here who are listening to what I have to say about repairs—the cost of repairs were and are simply exorbitant.

From the time that I assumed the command of that ship, a year and a half ago, until the present day, there has been less than $4,000 expended in repairs for maintenance. The chief engineer, the master and the chief officer are specially paid men. The crew is American, selected. Of the eight licensed officers on board that ship, six are college graduates. Seven of the eight served abroad. We have reduced the fuel consumption on that ship from 42 tons a day to 28. We took the ship with an average speed for the transatlantic voyage of 9.4 and brought it up to 10.8. We have reduced the cost of the crew to about half Mr. Marvin's figures which he gave for the Shipping Board vessel—the cost of my crew today is $3,007.50 a month, or $2,300 less than the cost of the crew on a Shipping Board vessel on May 1. The cost of subsistence for the crew is 50 cents a day per man, from master to mess boy.

Our ship, unfortunately, is equipped, as the gentleman said, with nickel-plated fixtures for the bathtubs and nickel-plated faucets in various parts of the ship. We have seen fit to remove on that vessel all of the fancy patented equipment which the architects placed on board, and instead of having a steam pump with which to pump the water we put in hand pumps. The crew used 162 tons of water on the first voyage, and today we use 14 tons for ship's use, and we employ the immersion for cargo capacity.

As to the comparison in the operation of vessels—that has been a debated subject with me for some time, and I have studied it for years—I was trained under my old uncle, and we realize that the main item in the cost of operation is overhead expense.

There are very few steamship organizations the president and general manager of which are on intimate terms with the masters of their ships. The ship can be in distress, the ship can be sorely in need of essential repairs, which will reduce the cost of operation, and the blue pencil works automatically. In some cases you have repairs approved and you proceed to the shipyard, and you have certain repairs made in accordance with how much you yourself are on the job, watching it, watching each and every turn—and every member here present today knows that to be a fact, that it is necessary to do this—and on board my ship we insist on at least 99 per cent of the time being devoted to the work of making the repairs and allow the repair gang only 1 per cent of the time in which to shoot craps.

One of the most important considerations in steamship operation, and one that is least considered by American operators, is the question of turn around. Your ship is costing you just so much per day in port. It is costing you just so much more per day when steaming at sea. When that ship is steaming at sea, she is immediately forgotten. She is turned over to the master from the time she clears the custom house in New York and leaves the dock, and the office force throw their hands up and say, "Thank God, she's gone."

Now, as just a simple, rough comparison, depending on my memory, which sometimes fails, I will try to call attention to some of the features which run into money. For example, it took fourteen working days and two Sundays, overtime, and six nights all night long to load my ship one voyage, and we discharged in eight working days and two hours' overtime. The next voyage it took just exactly twelve days, with five days working all night long, to load her, and we discharged in nine working days. You have the added expense of your vessel lying idle, loading, plus the overtime of your longshoremen and the overtime of your stevedores.

One of the important considerations in American steamship operation is the analysis of its cost. I got into that, gentlemen, when I was port officer of the United States Navy, located in France, in charge of the movements of 300 colliers, and at that time we found out what operating costs were. Admiral Sims and Captain Long would camp on our trail, and there was an effort made to constantly keep these costs down, and we certainly did, from time to time, make great reductions in those costs.

With what I learned in that capacity abroad, and from other data which I have had access to, much to my surprise we can show that the ships can be made to pay, but the overhead is the blooming thing—that is the thing which makes it physically impossible for our operators to surmount their troubles, both in the original cost, the cost of your port facilities, not only at the Port of New York but all ports; and without going into detail, I will say if we can get 100 per cent honest men in the steamship business, I think we could reduce the cost of operation 25 per cent.

The President:—The expressions of views which we have heard are most interesting, bearing particularly in mind the comments of the last speaker. I think we can sum the whole situation up in one single word—efficiency. That is largely true of every operation in life, and if you have men whose principal concern is to see how much they can draw down per day or per month, and how little energy they can put out for that amount, you necessarily have disastrous results. If, on the other hand, you can develop an *esprit de* *corps* resulting in sympathetic relations between the master of the ship, the officers of the ship, and the men, they will take a keen interest in what is going on, and there will be instilled into the minds of all the feelings which should actuate loyal workers in any field of endeavor. You are then sure to get the efficiency which the last speaker has so forcibly put before us.

Mr. Marvin, do you wish to say anything in closing this discussion?

Mr. W. L. Marvin:—I have only a few brief words to say on two points. In what I presented in my paper, I urged the protection of the American shipowning industry; but I want to say, Mr. Chairman, that the American shipowning industry has no right to ask to be protected against any remediable extravagance or inefficiency of its own. It does not ask so to be protected. The American ship, particularly if it is carefully manned by such men as we have in this country, and it has been shown that it can be, ought to be operated as efficiently as any foreign ship in the long run, and I believe, if the proper effort is made, that result can be secured.

I want to say, Mr. Chairman, that I was intensely interested in what was said by Captain Sullivan just now. I think his message is one of immense encouragement. He has an American ship and a carefully selected American crew. He is an officer, apparently, of the kind that we want to send to sea—the kind of officers, Mr. Chairman, that controlled our ships in the heyday of the clippers and packets, thorough-going Americans, better educated than their competitors, and able to render efficient service in their various capacities.

I have appreciated very much this opportunity of speaking on this subject, and I also appreciate the discussion which has ensued upon my paper.

The President:—I am sure the Society desires to express its thanks to Mr. Marvin for his very interesting paper, and for the very effective way in which he presented it.

The next paper, No. 7, is entitled the "Importance of Port Facilities in the Development of a Merchant Marine and Commerce," by Rear Admiral H. H. Rousseau, C. E. C., U. S. Navy. In the absence of the author, the paper will be presented in abstract by Captain Linnard.

Captain Linnard presented the paper.

THE IMPORTANCE OF PORT FACILITIES IN THE DEVELOPMENT OF A MERCHANT MARINE AND COMMERCE.

By Rear Admiral H. H. Rousseau (C. E. C.), U. S. Navy, Visitor.

[Read at the twenty-ninth general meeting of the Society of Naval Architects and Marine Engineers, held in New York, November 17 and 18, 1921.]

Commerce involves transportation on a large scale, and the vessels comprising our merchant marine are the necessary vehicles of and serve the needs of our sea-borne foreign and domestic commerce. Commerce of these two classes involves at least three major transportation movements or stages, which for outgoing shipments are as follows:

First Movement: On land (or water) from the point of origin to the port of departure.

Second Movement: On water, from the port of departure to the port of destination.

Third Movement: On land (or water) from the port of destination to point of delivery.

While the first and third stages may each be made up of several minor movements and may be by canal, river, ocean, highway, or railroad, or any combination thereof, railroads are by far the greatest transportation factor from a tonnage standpoint, and these two movements may therefore be considered to be made on land. In some foreign countries water carriers are employed to a greater extent than in ours for inland transportation. For goods and merchandise produced or originating in the immediate vicinity of a port, the first transportation movement may consist merely of a short haul to the water-front by truck, and this would also hold for the third movement when the point of delivery is in the immediate vicinity of the port of destination.

In addition to the foregoing three major transportation movements, each shipment also requires at least two transfers, which for outgoing traffic are as follows:

First Transfer: From land carrier to water carrier at the port of departure, between the first and second stages of the journey.

Second Transfer: From water carrier to land carrier, at the port of destination, between the second and third stages of the journey.

In export business, the second transfer and the third transportation movement are, of course, not under the jurisdiction of the country making the shipment. For incoming business the foregoing description applies also, except for changes in numbering the movements and transfers, etc., due to reversing the direction of traffic.

The end of any transportation line is its terminus, while a terminal has been defined as the end of any transportation movement. For freight, a terminal means any point where delivery is made to the consignee or where transfer is effected to another carrier for another stage of a journey. Terminals take their names from the character of service and from the carrier. For example, there are freight terminals and passenger terminals; also railroad terminals, canal terminals, steamship terminals, water terminals, and marine terminals. In its usual meaning a port terminal, or marine terminal, is a water terminal that is located at a seaport. The word "port" is variously employed. It is commonly used interchangeably with "harbor," meaning a protected body of water, natural or artificial, that is suitable for use by vessels as a haven of refuge from the elements. In law, a port indicates a gateway where persons and merchandise are allowed to pass in and out of a country, and where customs officers are stationed. In this sense it is termed a port of entry, and such a port can be inland. In commerce, the word "port" is used to designate a harbor where vessels are loaded and discharged, and this is the meaning intended in connection with any discussion of ports and port facilities. A simple definition would therefore be that a port is a harbor provided with terminal and transfer facilities that enable it to be used in commerce. In this sense, there can be harbors without ports; but there cannot be ports without harbors.

Leading writers on ports have recently proposed a more specific and restricted meaning in discussions pertaining to port administration, viz., that for each port the established pierhead lines shall form the boundary between the harbor and the port—the channels, anchorage ground, and everything else outside of the pierhead lines being the harbor, and everything inside of the pierhead lines being the port, including piers, slips, wharves, railroad tracks and yards, warehouses, and all other plant and equipment, such as tugs, lighters, floating cranes, fueling facilities, ship-repair plants, drydocks, and marine railways, that are necessary to transfer passengers, merchandise, and goods between land and ocean carriers and from one ocean carrier to another, and to maintain and repair vessels. Facilities for salvaging vessels have also become a necessary and important part of the equipment located at some of the larger ports. While this plan has not yet received official recognition as demarking ports and harbors, and while it may be contrary to the preferred usage at some ports, it would seem to be logical inasmuch as this boundary line also divides the area under the jurisdiction of the Federal Government (the harbor) from that which comes under state and municipal authorities (the port).

From the standpoint of commerce, therefore, a port is merely a connecting link between two major transportation movements, where transfers of passengers and freight between land and ocean carriers are effected; and port terminal facilities—or, more simply, port facilities—comprise all those physical elements with which a port is equipped for the convenient transfer of passengers and freight between carriers, for the storage of freight and for the maintenance and repair of merchant vessels.

Ports have been likened to a funnel through which flows the sea-borne commerce of a country; also to a reservoir that should have storage capacity sufficient to accommodate itself at all times to the variations in the volume and speed of traffic of connecting carriers. Ports should perform functions similar to those of the flywheel of an engine, in regulating the mighty commerce that passes through them so as to secure the most regular and uniform movement of traffic and the maximum efficiency of operation of connecting carriers.

It is an accepted traffic law, advanced by the late James J. Hill, that the volume of traffic a line can carry cannot exceed the capacity of its terminals. Dr. R. S. MacElwee, in his well-known work on "Ports and Terminals," says that the conclusion to be drawn from this law is that the commerce that flows through our ports is limited by the capacity of the terminal facilities of our ports, and that "the commerce of the United States overseas is therefore hampered or limited by the lack of development of the terminal facilities of our American seaports." Anything that affects our commerce affects our merchant marine. Therefore, unless and until our ports and port facilities are further developed and put on a thoroughly efficient operating basis, the growth of our merchant marine will be much retarded and the difficulties connected with its successful establishment and operation will be immeasurably increased.

On the land side of any of our ports, the capacity of the combined carriers—principally railroads—is generally much in excess of that of the connecting ocean carriers that ordinarily frequent that port. This is a condition incidental to the advanced development of our railroad transportation system and is accompanied by ability on the part of land carriers to increase greatly and almost instantly the normal volume of traffic. Therefore, if the terminal facilities at any port are well proportioned and arranged, with a capacity equal to the normal requirements of the ocean carriers that ordinarily use that port, satisfactory results from the standpoint of port operation should be secured. The allocation, however, of vessels from one port to another can be changed practically overnight, and so, if a large additional number of vessels should be suddenly sent to a port, congestion of port facilities and delays to traffic will immediately occur, due to the inherent fact that ports, like all other terminals, are not able to accommodate themselves to great fluctuations in the volume of traffic as well as, and as quickly as, their connecting land and water transportation lines. Under such circumstances, any port not provided with a liberal excess over normal requirements of berthing space alongside suitably equipped wharves or piers, and of tracks and railroad yards, together with other necessary facilities in proportion, will immediately become the "neck of the bottle" under an increasing volume of traffic; and the particular transportation movement of which that port is a link will be slowed down, causing increased cost of operation to all carriers connecting at that port, and delays to shippers—all of which would be to the detriment of our merchant marine and our sea-borne commerce, including both foreign and coastwise domestic commerce. Increasing port facilities cannot be accomplished overnight and is an operation that requires time. The construction of permanent wharves, piers and accessories for a project of even moderate size may require several years, and the furnishing of even temporary wooden piers requires months. The undivided use of and free access to the site of any new works during construction is always essential.

Delays in port mean lessened revenues and increased expense to ocean carriers. The increased cost due to unusual delays—which may in general vary from $1,000 to $5,000 per day per vessel—cannot be passed on to shippers, and has to be borne by the steamship companies themselves. If such unusual delays at any port happen for a number of successive voyages, and the steamship companies attempt to recoup themselves by increasing rates, it usually happens that either the traffic diminishes so that the net returns are not increased, or the traffic becomes diverted to other routes, to the detriment of the steamship companies concerned.

We recently had an example of how our principal eastern ports, and the port facilities thereat, functioned under the rising tide of wartime traffic, and no one connected with transportation during that period will readily forget the far-reaching consequences of the congestion at those ports, a condition that at times seemed liable to break down the greater part of our transportation system east of the Mississippi River. It is to be hoped that such an "accelerated" test of our ports will never come again. If it does, however, our ports and port facilities must be found to be in a condition that will enable them better to stand the strain. Such a test always accentuates defects, and if we take advantage of the opportunity that is now offered to improve our port system and eliminate the defects that we are now aware of, the lesson will have been well worth while. Aside from the matter of inadequate capacity and equipment, our ports and port facilities proved unsatisfactory during the war in methods and cost of operation, and in organization and control. Of course these defects have always existed, but they had not been brought home to us quite so sharply, and we perhaps had failed to realize how much they mean during peace in reducing our foreign and coastwise domestic commerce and in retarding the establishment on a sound business basis of our merchant marine; for practically every dollar of the cost of operating our port facilities in connection with our sea-borne commerce is ultimately paid by the consumer.

Therefore, the higher the price of our products abroad the more easily will foreign competitors undersell the American producer and manufacturer and reduce our export business; and similarly, the higher the price of imported merchandise the less will be the demand at home, which will result in fewer return cargoes for American vessels as well as smaller customs revenues.

As for our coastwise domestic commerce, the higher the cost of the operation of port facilities the more closely will the cost of water transportation approach the cost of transportation by land, and the greater will be the volume of traffic diverted from steamships to railroads. Any lessening of sea-borne traffic from the foregoing causes will thus lessen the tonnage of American merchant vessels that can be profitably employed.

On August 1, 1921, our merchant marine consisted of the following documented seagoing vessels of 500 gross tons and over:

Engaged in	*Number*	*Gross tonnage*
Foreign commerce	2,518	10,567,909
Coastwise commerce	1,216	2,767,163
Total	3,734	13,335,072

In addition to the above there were 35 vessels of 500 gross tons and over, having a total gross tonnage of 266,125, adapted for merchant service, that have been transferred to the War and Navy Departments since April 6, 1917, and not yet reconveyed and documented. Included in the 3,734 vessels were 836 sailing vessels (or 22 per cent) having a gross tonnage of 1,021,287, and 1,172 wooden vessels (or 31 per cent) having a gross tonnage of 1,790,897.

On August 1, 1921, our seagoing merchant vessels of 500 gross tons and over were owned as follows:

Ownership	*Number*	*Per cent*	*Gross tonnage*	*Per cent*
Government (U.S.S.B.)	1,804	48	8,048,759	60
Private	1,930	52	5,286,313	40
Total	3,734	100	13,335,072	100

The vessels now owned by the U. S. Shipping Board, as listed above, have been acquired as follows:

	Number	*Per cent*	*Gross tonnage*	*Per cent*
Purchased	21	1	105,593	1
Seized (German and Austrian)	50	3	338,556	4
Requisitioned	252	14	1,133,587	14
Built by contract	1,481	82	6,471,023	81
Total	1,804	100	8,048,759	100

The following tonnage of documented U. S. Shipping Board vessels is not included in the immediately preceding table:

	Number	*Gross tonnage*
Vessels lost	80	269,236
Vessels sold to aliens	33	85,702
Vessels sold to citizens	158	622,898
Total	271	977,836

On July 1, 1917, shortly after we entered the World War, our merchant marine consisted of the following documented vessels of 500 gross tons and over, engaged in foreign and coastwise commerce:

Ownership	*Number*	*Per cent*	*Gross tonnage*	*Per cent*
Government (U.S.S.B.)	19	1	76,160	2
Private	1,552	99	3,564,160	98
Total	1,571	100	3,640,320	100

In a period of four years and one month, therefore, the net increase in our sea-going merchant vessels has been as follows: 2,163 vessels, which equals 138 per cent, or an average increase of approximately 10 vessels per week. The increase in gross tonnage has been 9,694,752, or 266 per cent, an average increase of approximately 45,600 tons per week. This gives some idea of the rapid increase in the size of our fleet and of the increased demands that have been made upon our ports and port facilities within that period. The large increase during that period in our sea-borne foreign commerce is shown by the following table, together with the percentage of this commerce carried in American vessels:

For year ended	*Total exports and imports*	*Per cent carried in American vessels*
June 30, 1917	$7,819,495,133	18.6
June 30, 1918	7,703,700,456	21.9
December 31, 1919	10,503,658,855	36.4
December 31, 1920	11,983,164,252	43.0

Due in part to governmental control over ship construction during the war, the increase in our privately owned merchant marine during the past four years has not been large, for if the Shipping Board vessels sold to citizens are excluded there has been a net increase from July 1, 1917, to August 1, 1921, of only 220 vessels, or 14 per cent. The increase in gross tonnage was 1,099,255, or 30 per cent. This shows that the real problem today in connection with our merchant marine is to transfer from government ownership to successful operation under private ownership the large tonnage we have built since 1917; for the sudden injection into the world's foreign commerce of such a large amount of new tonnage cannot be accomplished without jarring the commercial fabric of the whole world, as foreign vessels cannot be expected to relinquish their business without a vigorous struggle. Similarly, any sudden great increase in the tonnage of our merchant marine that is engaged in coastwise domestic commerce cannot but cause an appreciable and perhaps serious loss in the revenues of our railroads. This is not stated as a reason for not proceeding with our plans for a large merchant marine as quickly as possible, but only in order to point out that the shorter the time allowed for the establishment of our merchant marine the greater will be the difficulties to be overcome, and the greater will be the dislocation caused existing world trade, as well as that of our own railroads. The adoption of a time factor in executing any national policy of this kind, therefore, becomes a matter of great importance to the success of the undertaking.

The Merchant Marine Act of 1920 declares "that it is necessary for the national defense and for the proper growth of its foreign and domestic commerce that the United States shall have a merchant marine of the best-equipped and most suitable types of vessels sufficient to carry the greater part of its commerce." This may be taken to establish definitely as a national policy what has generally been accepted for some time past, viz., that not less than 50 per cent of the sea-borne foreign commerce of this country should be carried in American bottoms. Inasmuch as our coastwise commerce is protected against foreign competition, it should be excluded, of course, from any calculations determining the 50 per cent limit. This percentage has not been reached since the Civil War, and from that time to 1901 there was a gradual decline to 8.2 per cent. For the following ten years the percentage was nearly stationary. Since 1911 there has been a gradual and encouraging increase from 9.7 per cent to the figures in the above table. It should be fully appreciated by all that, unless we can reach and maintain permanently the 50 per cent standard, it will be a confession that we are unable to put into effect an announced national policy.

The Merchant Marine Act of 1920 also announces that "it is hereby declared to be the policy of the United States to do whatever may be necessary to develop and encourage the maintenance of such a merchant marine," and recognizes the important part that ports and port facilities play in such matters by stating that it shall be the duty of the Shipping Board, in cooperation with the Secretary of War, with the object of promoting, encouraging and developing ports and transportation facilities in connection with water commerce over which it has jurisdiction, to investigate territory, regions and zones tributary to such ports; to investigate the causes of the congestion of commerce at ports and the remedies applicable thereto; to investigate the subject of water terminals with a view to devising the types most appropriate for the most expeditious and economical transfer of passengers and freight between water and land carriers; to investigate the practicability of port improvements in connection with foreign and coastwise trade; and to investigate any other matter that may tend to promote and encourage the use by vessels of ports adequate to care for the freight which would naturally pass through such ports. The Federal Government exercises its supervision over our ports under the constitutional power to regulate foreign and interstate commerce, which gives it control of all navigable waters within its boundaries. The enforcement of laws relative to the use of our waterways is vested in the Secretary of War, under whom the Chief of Engineers directs all works undertaken for their improvement. Since the first appropriation was made by Congress for this purpose in 1802, for public piers costing $30,000 in Philadelphia, government assistance for the improvement and maintenance of rivers and harbors has totaled a billion dollars, and these appropriations have naturally greatly increased the influence of the National Government in port affairs. Comparatively recently, Congress has seen fit in several instances to require localities asking government assistance for the improvement of their harbor or other waterway either to pay a portion of the cost or to increase the commercial usefulness of the improvement by providing terminal facilities for public use at their own expense, and the River and Harbor Act, approved March 2, 1919, contained the following provision that formally adopted the latter procedure as a permanent policy:

"It is hereby declared to be the policy of the Congress that water terminals are essential to all cities and towns located upon harbors or navigable waterways and that at least one public terminal should exist, constructed, owned and regulated by the municipality, or other public agency of the state and open to the use of all on equal terms, and with the view of carrying out this policy to the fullest possible extent the Secretary of War is hereby vested with the discretion to withhold, unless the public interests would seriously suffer by delay, monies appropriated in this act for new projects adopted herein, or for the further improvement of existing projects, if, in his opinion, no water terminals exist adequate for the traffic and open to all on equal terms, or unless satisfactory assurances are received that local or other interests will provide such adequate terminal or terminals. The Secretary of War, through the Chief of Engineers, shall give full publicity, as far as may be practicable, to this provision."

At one of the meetings on national port problems held by the American Society of Civil Engineers in New York, in September, 1921, Maj. Gen. Lansing H. Beach, Chief of Engineers, in the course of an address on "Terminals" said that the power given by this Act to suspend work on current projects has not as yet been exercised, for it has been found that interests favoring the growth of some ports have endeavored to have the law used to further their own ends, by causing the suspension of the improvement of rival ports. This Act of Congress establishes the important principle that the improvement of ports at public cost may be expected hereafter to be largely confined to those ports that conform to established national policies pertaining thereto.

Congress reaffirmed its general interest in promoting all kinds of water transportation as an important factor in commerce by stating in the Esch-Cummins Railroad Bill that "it is hereby declared to be the policy of Congress to promote, encourage, and develop water transportation, service and facilities in connection with the commerce of the United States."

In any comparison or classification of our ports, the question arises at the outset: What yard-stick shall be used? Is the importance of a port to be gauged by the volume of foreign commerce only that passes through it, or by its combined foreign and coastwise domestic commerce; and shall the volume be measured by its value in dollars, by its weight in tons, or by the tonnage of the vessels that use it? Or shall ports be arranged in the order of their capacity as determined from the size and character of their facilities—that is, by their potential ability to handle business? Also, should not great weight be given in any classification to such vital matters as speed and economy of port operation, to port organization, and especially to the degree of conformance to national policies regarding public terminals, and assistance rendered in promoting our merchant marine? It would seem that mere size or volume of business should not be the controlling criteria, but that the true measure of a port should be the extent to which it is useful in promoting both commerce and the merchant marine of our country.

The Chief of Engineers publishes as part of his annual report the most complete commercial statistics of our ports that are available. These are compiled by the Board of Engineers on Rivers and Harbors. They include the tonnage and value of the commerce of each port that is under improvement by the United States, and show, for the calendar year 1919, that the foreign and coastwise commerce of twenty-seven of our continental ports exceeded either one million tons in weight, or one hundred million dollars in value, or both. These limits are entirely arbitrary. Sixteen of these ports are on the Atlantic Coast, six on the Gulf of Mexico, and five on the Pacific Coast. The business of several additional ports approached these limits. These figures indicate that at the present time we have in the neighborhood of thirty important seaports, actively competing with each other for business. There is a considerable number of additional potential ports, standing by, as it were, anxious to be given an opportunity to show their value as links in our overseas trade. Approximately 75 per cent of our sea-borne commerce passes through a dozen of our ports. New York stands pre-eminent in both foreign and coastwise domestic commerce, and is followed, at some distance, by Philadelphia, New Orleans, and Norfolk.

With the existing fierce competition between ports, both for business and for appropriations from the national treasury for the further improvement thereof, it would seem to be proper and consistent that Congress should now give definite notice that hereafter preference will be given in making any appropriations for harbor improvements to those ports that show themselves most interested and most successful in carrying out our national policy that the greater part of our foreign commerce—*i. e.,* both freight and passenger business—shall be carried in American vessels. Compliance with any such policy by a port, or the giving of satisfactory guarantees to fulfil any condition like this, could be best undertaken by an organized and unified port authority, and the matter of efficient organization is perhaps our ports' greatest need today. Such a measure as the foregoing would therefore have the additional advantage of accelerating steps to secure the best type of port organization, an outcome that would result in untold advantage to our merchant marine. It would seem advantageous that for this purpose the percentage should be measured by comparing the gross tonnage of vessels rather than the tons or value of freight or the number of passengers carried, as the former basis is more closely identified with the operation of our merchant marine since it would include allowance for both passengers and freight, and as any change in the number of vessels—and accordingly tonnage—would be more easily subject to the control of the port interests.

Such an act of Congress, based on the hereinbefore quoted law of March 2, 1919, relative to water terminals, reiterating the policy that the greater part of our foreign commerce should be carried by American vessels, and vesting the Secretary of War with discretion to delay or suspend expenditures for the improvement of any port unless at least 50 per cent of the gross tonnage of vessels engaged in foreign commerce entering and clearing from that port is American tonnage, or until satisfactory assurances are received that that percentage will be secured within a reasonable time and will be thereafter maintained, would instantly broaden competition between our ports beyond the present mere unorganized scramble for business on the part of individual carriers and other interests, and would initiate a competition that would bring concrete results in promoting steps to obtain a unified port authority and in assisting our merchant marine to get much needed cargo, as well as passenger business, that at present is going to foreign vessels.

Should Congress, in pursuance "of the policy of the United States to do whatever may be necessary to develop and encourage the maintenance of such a merchant marine," also direct the Interstate Commerce Commission to exercise its rate-making power so as to give due preference and assistance to those ports where at least 50 per cent of the gross tonnage of vessels engaged in foreign commerce, using that port, is American tonnage, the effect would be striking in enabling our merchant vessels to cope more successfully with foreign competition. Should any expenditure, also, of public funds for the overseas transportation of government freight and passengers other than by American vessels be prohibited by Congress, unless no suitable American vessels are available, it would especially assist our struggling transatlantic passenger lines that are greatly handicapped by the superior attractions offered at the present time by foreign steamships.

If government statistics on commerce and shipping should regularly include a table listing our ports in order by the percentage of the gross tonnage of American vessels engaged in foreign commerce to the total tonnage of vessels engaged in foreign commerce that enter and clear from each port; by giving same proper publicity, the wheels would automatically be set in motion in each port that falls below the 50 per cent standard, actuated not only by patriotism, but also by local esprit, to remove such port, through the united effort of all of its interests, from the undesirable "less than 50 per cent" class. At present, while we are all in sympathy with, and even enthusiastic over the idea of having a merchant marine that will carry the greater part of our foreign commerce, very few of us are taking any steps to accomplish that end, and it is doubtful whether the commercial interests at any individual port or any persons residing thereat, at present know or care particularly what proportion of that port's foreign commerce is being carried in American bottoms; and if our national policy in this matter is to succeed, the responsibility for making it a success must be shared in an important degree by each one of our ports, and they must each be made to feel the necessity of doing their part. The feeling of indifference at our ports that permits, without restraint by effective competition, foreign lines to run to and fro between the United States and countries other than the country whose flag the foreign steamship line flies, should be made to disappear through the increased activities of the port authorities, backed by an aroused public sentiment, at each port where that condition exists; and the feeling of satisfaction and even complacency over the establishment of new steamship lines that call at our ports, regardless of their nationality, should continue only in those cases where new lines fly the American flag.

Similarly, each port must cultivate closer relations with the shippers that use it, with the view of arousing their interest and securing their assistance in matters pertaining not only to the port but also to our merchant marine. Each port should determine from careful investigation the boundaries of the hinterland from which its business is derived, and a feeling should be inculcated in all communities in that region of their responsibility for the welfare of their port and of our merchant marine.

It would seem appropriate also that the Government should give each year, through the U. S. Shipping Board or other agency, fitting recognition to the port that attains during the year the highest percentage as regards gross tonnage of American vessels engaged in foreign commerce, using that port, compared with the total tonnage of both American and foreign vessels that used it. Such recognition might appropriately take the form of the presentation, with proper ceremonies, of a suitably inscribed certificate, describing and extolling the port's accomplishments; and if the President should see fit to be present to make the presentation on behalf of the nation on the first of these occasions, and to inspect the port with members of his Cabinet, it would focus the attention of the entire country on the importance of rendering assistance to our merchant marine in every way as a patriotic duty and would spur the efforts of other ports to make the highest percentage the following year.

The fact that much more than half of our government-owned merchant marine is unemployed at the present time is a reason strong enough to justify almost any step undertaken for its relief. Our important ports are not only the gateways of our sea-borne commerce but are also populous cities, having many interests other than those intimately connected with overseas commerce, and in some cases there is serious conflict between the municipal interests and those of the port as an outlet for our foreign commerce. The interests of the port, being those of the territory that uses it and partaking of a national character, are of greater importance than and should have preference over the interests of the municipality; but this is not likely always to be the case if the municipality owns or controls the port facilities, as it does at many of our ports. These municipal interests, including the furnishing of food supplies, materials and goods required for the support of its population and its industrial establishments, may be termed the local or industrial interests as distinguished from the commercial interests of a port; and a large number of our ports are suffering from the encroachment of industrial interests.

The following may be given as some of the important characteristics that our ports and port facilities should possess from the standpoint of the interests of our merchant marine and our commerce:

1. The use of deep-water frontage should be restricted to the commercial business of the port.

2. At least half of the deep-water frontage should be publicly owned or controlled.

3. Berthing, handling, transferring, switching, and storage facilities should be convenient, efficient and economical; they should be ample to carry any probable peak load.

4. There should be complete flexibility of movement between any and all water carriers and any and all land carriers, and *vice versa,* as well as from any water carrier to another, in order that the movement of commerce through the port may be as free as possible and may be accomplished in a minimum time and at minimum cost.

5. The port charges should be reasonable; should be as similar as practicable, both in manner assessed and in amount, for all of our ports; and should be based upon actual cost of the service performed, including interest on investment and overhead. For ports under unified public control, the charges should be without profit.

6. All the facilities of the port should be under one control, which preferably should be independent of the local government. The port authority should be animated solely by the aim to conduct the port business as an efficient link in our sea-borne commerce and in thorough sympathy with our national policies for a merchant marine.

With our interests centered upon our domestic affairs and internal development during the latter half of the last century, our ports and our merchant marine were neglected, and our port facilities, like Topsy, "just growed." In the absence of public interest and appreciation of the important function of ports in national commerce, there were no general plans for port development and management, and for financing the cost of port facilities. As a result, the affairs of each port were handled as a local problem with little or no attempt at coordination between ports, and with little or no thought given to the development of our port system in accordance with broad economic principles. This led in many cases to the local municipality, and in other cases to private interests, assuming responsibility for furnishing necessary piers and wharves, and taking control of the water frontage and improvements. The railroads were quick to grasp the opportunity afforded to attract to themselves sea-borne commerce by constructing and operating marine terminals at their own expense. Usually each so-called railroad port was dominated by a single railroad. Where more than one railroad constructed a water terminal at a port, these terminals were operated as independent and separate facilities, with little or no interchange of freight, thus affecting the movement of commerce and dividing the port, to all intents and purposes, into as many separate ports within a port as there were railroad terminals.

Due to the same lack of foresight and any general conservation of that must valuable port asset, deep-water frontage, cities have been permitted to encroach on the water front of most of our ports; industrial establishments that could have been satisfactorily located inshore have appropriated for their own use much valuable deep-water frontage; and no attempts have been made to restrict the growth of the city upon land now found to be required for port facilities and port operations. As a result, we are now paying the penalty through the difficulty experienced in increasing our port facilities, in the increased cost thereof, and in carrying on port business in an economical manner.

Our awakening to a realization of this situation has come within the last fifteen years. It began during the construction of the Panama Canal. The desire to be prepared to take advantage of the opportunities that were expected to accompany its completion was responsible for arousing many of our ports and commercial bodies to action. A report on Transportation by Water, made in 1910 by the Bureau of Corporations, first opened our eyes to some of our port deficiencies, including the lack of public ownership of water frontage at the great majority of ports in this country. This condition has since greatly changed for the better. This growing interest also resulted in the organization of the American Association of Port Authorities, which, with its large membership and through its annual meetings and the publication of papers on port matters, has been a powerful factor in securing the improvement of our ports and an understanding of our necessities. This was followed, in 1916, by a very complete and comprehensive report by Grosvenor M. Jones on "Ports of the United States," including terminal facilities, commerce, port charges and administration at sixty-eight selected ports, which was published by the Department of Commerce.

With the establishment of the U. S. Shipping Board, the importance of ports and port facilities to the development of our merchant marine was recognized by the organization, in May, 1918, of a Port Facilities Commission, that was authorized to make a survey of the ports of the United States and undertake investigations that would enable the Shipping Board to make the best use of existing port facilities and would further the construction of new facilities. The survey made by this commission showed that the ship-repair and docking facilities of our ports were inadequate, and steps were immediately undertaken to supply the deficiency. The commission made a study of handling appliances, transit sheds and warehouses, and of a zoning system under which exports and imports would flow through those ports within economical transportation distance of the points of origin and destination. For, as stated by J. R. Bibbins, in his report on port facilities, presented at the First Congress of the International Chamber of Commerce, held in London, June, 1921: "The elements of time and cost ultimately control most competitive movements of international commerce, and internal transportation exercises a relatively controlling influence not only upon shipping capacity and allocation, but upon port development and the trans-shipment facilities there required." It is largely for this reason that, aside from the matter of sufficient depth, ships themselves do not determine the character of a port, and that the railroads have played such an important part in the past history of most of our ports. Among the other investigations undertaken by the Port Facilities Commission was one to determine economies effected by the more rapid turn-around of vessels in United States ports, and the result of this investigation clearly indicated the considerable savings that would accrue to our steamship lines through quicker turn-arounds, made possible by increased efficiency of port operation.

When the Merchant Marine Act went into effect in 1920, in order to carry out that portion of the law enjoining the U. S. Shipping Board to cooperate with the Secretary of War, with the object of promoting, encouraging, and developing ports and transportation facilities in connection with water commerce, arrangements were made between the Shipping Board and the War Department whereby the work of that character that had previously been performed for the Shipping Board by the Port Facilities Commission should be transferred and thereafter performed under the Chief of Engineers by the Board of Engineers for Rivers and Harbors, and that Capt. F. T. Chambers (C.E.C.), U.S.N., Chief Engineer of the Port Facilities Commission, would continue his work in an advisory capacity under the Shipping Board and should also serve as consulting engineer in connection with port facilities with the Board of Engineers on Rivers and Harbors. This board has performed valuable work already, and its program includes the preparation and publication of reports in separate pamphlets upon the facilities of each of the important ports of the United States. These pamphlets will contain all information needed by vessels and will enable the charges of different ports to be compared. The board has reported that its investigations "show that the terminal charges and practices at railroad terminals at South Atlantic and Gulf ports have exercised an injurious effect upon the commerce of the United States, by rendering it impracticable for private and municipal terminals to handle through business, thereby restricting port growth and development." In reporting these matters to the Interstate Commerce Commission, the Secretary of War, in March, 1921, endorsed the significant statement of the Chief of Engineers that the success of our merchant marine depends largely on the economical operation of our ports.

In accordance with the River and Harbor Act of July 18, 1918, the Board of Engineers for Rivers and Harbors has prepared for the Chief of Engineers a very comprehensive and valuable report upon water terminal and transfer facilities of the United States. This report will include, when printed, a separate pamphlet with numerous illustrations, giving descriptions and general plans of terminals and appropriate types of construction for harbors and waterways of the United States, suitable for various commercial purposes and adapted to the varying conditions of tides, floods, and other physical characteristics.

An important contribution to our port facilities was made by the War Department during the war, through the construction of extensive terminals costing over $150,000,000, at Boston, South Brooklyn, Port Newark, Philadelphia, Norfolk, Charleston, New Orleans, Hoboken, and San Francisco, many of which are now available for commercial use.

The importance of public terminals and the public control of water frontage at each port cannot be overestimated. The day has passed when control of water terminals by railroads is advantageous or necessary. As shown by C. O. Ruggles in his report on "Terminal Charges at United States Ports," made to the U. S. Shipping Board in 1919, railroad control of water terminals has several important disadvantages. Government control over railroad rates has increased railroad competition in terminals and terminal construction, resulting in duplication of expensive terminals by the railroads operated independently, and causing unnecessary plant expenditures. Competition of this character in our ports has also resulted in the railroads offering gratuitous service at terminals in order to obtain additional freight. When charges are made by the railroads for dockage and wharfage, they are usually merely nominal. The investigation of the Board of Engineers for Rivers and Harbors of our South Atlantic and Gulf ports showed that the terminal charges at those ports averaged only from one-fourth to one-half the actual cost of same to the railroads. While the railroads may justify this practice to themselves from their methods of accounting, there is no question but that the practical effect of this procedure is detrimental to the growth of our ports and to our merchant marine, for terminals at those ports, constructed by either private capital or from public funds, cannot operate profitably in competition with railroad terminals that furnish free or practically free dockage to vessels and free wharfage to cargo. Many specific examples could be cited in support of this statement. The third unsatisfactory result of railroad ownership of water terminals is lack of coordination. Railroad tariffs applying to terminals commonly specify that the railroad does not obligate itself to provide wharfage, storage or handling for freight which is not to be transported over its lines. This restriction is undoubtedly due to the fact that railroad competition in terminals has made the terminal charges such that a railroad cannot afford to permit the practically free use of its terminal facilities by any freight from which the railroad cannot earn, through a line haul, enough to reimburse it for the cost of terminal operation.

The most important matter confronting our ports, and on which the welfare of our port facilities and our merchant marine depends in large degree, is the type of administration that shall exercise control over our ports. Of course, for our smaller ports and for those ports where the commerce is confined to a few commodities shipped in bulk, and where port facilities have been amply provided by railroads or by other private interests, the need today for a special administrative organization to exercise supervision over the affairs of such a port is not especially important. No one can say, however, whether these smaller ports in time will not become important ports with diverse interests, and from this viewpoint, even these smaller ports should be so administered that their growth will be along correct lines. The principal types of port administration or control are as follows:

1. Municipal department control.
2. Harbor board control, either municipal or state.
3. Independent or public control.

The most common type of control of our ports is the municipal department control, in which the port comes under a department of the city government, such as the Department of Public Works. At New York and Philadelphia the interests of the port are so large that there is a separate Department of Wharves and Docks. This type of port control is best adapted for small ports and places the entire control of port development and operation under the municipal authorities; in some cases it is operated as a revenue-producing department. New York City is often cited in this connection, because the revenue that New York City derives annually from the rental of its piers runs into the millions.

New York has been thoroughly aware of the serious situation confronting it through the increase in its terminal costs, due not only to the tremendous volume of its overseas commerce but also to the great concentration of population and industrial establishments which have congested the space required for port operations; and as a consequence the flow of commerce has been becoming more irregular, terminal costs have risen, and the situation has become more unsatisfactory from year to year. As an outcome of the appointment, in 1917, of the New York-New Jersey Port and Harbor Development Commission, by the concurrent action of the legislatures of New York and New Jersey, a report was submitted in 1920 by this commission, from which much is expected. In the opinion of the commission the vital matter lacking in New York is port organization, and in a progress report in 1919 the commission recommended the creation of a port authority with adequate powers to carry out a comprehensive plan, when adopted by the legislatures of the two states. Agreement has finally been reached upon a grant of power to the "New York Port Authority," which provides an agency to proceed with the work, at the same time leaving the local authorities with large freedom. This agreement has been ratified by both states and by Congress. The commission was very urgent in stating that the creation of a port authority with powers to go forward is absolutely necessary.

The method of municipal department control may be discarded from consideration as an approved permanent type of port administration. From this type of control was evolved the harbor board or commission type. In some cases these harbor boards are creations of the municipality; in others, of the state. Some of our leading ports have the municipal or state harbor board type of administration. Of the two, the latter is preferable; and three of our largest ports—viz., Boston, New Orleans, and San Francisco—have this type of port government; and New Orleans and San Francisco are being pointed out as the most efficiently operated ports in the United States. In either of these commission forms of port government, however, the members of the commission often serve without compensation, and in some cases act in an advisory capacity only. In some cases the control exercised by the commission is limited to the city boundaries, while in other cases it extends some distance beyond. In both San Francisco and New Orleans the harbor boards own practically all of the water frontage under their jurisdiction. They have the right to take over water frontage by condemnation or by use. The revenues are required to pay the cost of improvements and operating expenses. At San Francisco the harbor board has control of all port facilities, including the harbor belt-line railroad.

The ideal type of port government is the so-called independent port authority type, which is comparatively new in this country, though it has been adopted with great success in Great Britain, where the right to construct or control ports is vested in the Crown, and where, by special acts of Parliament, public corporations or trusts are organized with boards of commissioners to manage them. All grants give the right to the public to use the port facilities and to the state to control them. Under this form of administration in the United States, a municipal corporation, entirely independent of the municipal government of the port city, is created by act of the legislature. This corporation is vested with large powers, including that of eminent domain and of raising money by the sale of bonds and by tax levies. This type of organization is ideal and, if generally adopted by our ports, would accomplish more than any other one thing for their betterment, and indirectly for the benefit of our merchant marine; and in selecting the membership for the governing board we might well follow the example of Liverpool, Manchester, London, and other great ports in Great Britain, and give representation thereon to all port interests, including steamships, labor, railroads, commercial bodies, financial interests, the local municipal government, etc. It would be a part of the business of each port under this type of organization to collect all port statistics in a uniform manner, as required by the national government and other interests. The states of Washington and of Florida have enacted legislation which has resulted in port organizations of this general type at Seattle and Grays Harbor, Washington, and at Jacksonville and Tampa, Florida. With the best form of port control established, all other port problems may be considered as being solved through its agency, for any such port authority would have power to solve satisfactorily all such questions as ownership of water frontage, establishment of public terminals, coordination of all port facilities into one homogeneous operating organization, elimination of undesirable features, such as independent control of railroad terminals, elimination of profiteering, and the establishment of equitable port charges, as well as the progressive development of the port along sound economic principles and in accordance with the best engineering practice.

While all port charges ultimately lodge against cargo, they may be divided into charges that are primarily borne by the water carrier, by the cargo, and by the land carrier. The percentage of expenses of a vessel while in port to the total expenses of a steamship company varies considerably with different lines and depends not only on the size, speed, and type of steamships, whether passenger or cargo, but also on length of voyage. The following are the actual percentages of expenses of different kinds of a steamship company running out of New York, doing passenger and freight business, for the past six fiscal years. The vessels of this line vary in gross tonnage from 2,500 to 9,300:

	1916	1917	1918	1919	1920	1921
Port charges	3.3	1.2	2.6	3.7	1.8	3.5
Stevedoring and handling	25.0	24.2	17.4	19.1	18.7	14.2
Rental of terminals	2.5	3.5	3.6	2.6	3.5	3.9
Repairs and depreciation	9.8	10.8	18.4	18.3	14.1	13.9
Fuel, water and lubrication	11.5	12.0	14.3	13.9	11.3	14.8
Feeding passengers and crew	7.9	7.3	6.5	5.6	6.6	7.1
Loss, damages and injuries	1.8	2.2	1.1	.9	1.5	3.5
Equipment and stores	3.9	4.7	4.8	4.2	5.2	3.5
Wages, officers and crew	14.1	14.1	14.0	13.3	14.1	16.6
Miscellaneous	.7	.6	.5	.5	.5	.8
Undistributed expense	14.1	15.2	13.7	11.7	16.2	14.0
Administrative expense	5.4	4.2	3.1	2.4	3.2	4.2
Charter hire	..	...	...	3.8	3.3	...
Total	100%	100%	100%	100%	100%	100%
Tons of freight carried	577,686	546,660	630,055	1,103,587	634,256	408,060
Number of vessels operated	8	13	11	28	20	10
Number of trips (one way)	135	141	177	221	170	147

The above figures indicate that the percentage for each item of expense in general has varied between rather narrow limits. The unit costs, however, such as cost of stevedoring per ton of freight, average operating cost per steamer day, etc., have nearly doubled since 1916.

In an article such as this, it would be impossible to give a detailed description of port facilities. It is sufficient to say that the principal port facilities include necessary piers and wharves equipped with transit sheds, overhead cranes, and other necessary handling devices. The distribution of freight to and from each wharf is attained by tying up the railroad terminal yards with each other and with the water front by the means of a so-called outer belt-line railroad. Communication between piers themselves should be attained by an inner belt line, which may be on land by railroad or on water by lighters, or by both. The port should be equipped with sufficient warehouse and storehouse facilities, for reservoir purposes, and to eliminate the uneconomical expedient of using freight cars as storehouses when they are required for their proper purpose, to meet traffic demands.

Private enterprise may be expected to provide the proper docking and repair facilities. Private enterprise may also be looked to for salvage facilities, but it cannot be estimated that any given port with reasonably fixed tonnage movement will support a proportionate investment in salvage equipment. Frequency in marine disasters does not necessarily follow the greatest traffic but depends to a great degree on the navigation hazards existing in a given region. From the business standpoint, a salvor has to determine the ports which will offer the best market for employment on work other than salvage for appliances and trained personnel that are necessary in any well-organized salvage unit. The salvage facilities in this country are considerably in excess of those which could be maintained by salvage operations alone, and the continued maintenance of such facilities depends entirely upon the amount of work obtained by the salvage company other than rescue work.

Alexander Hamilton wrote considerably over one hundred years ago: "A prosperous commerce is now perceived and acknowledged by all enlightened statesmen to be the most useful as well as the most productive source of national wealth, and has accordingly become a primary object of their political cares." And President-elect Harding, less than a year ago, summed up our present needs in a speech as follows: "We are tardily alert to the imperative need of a merchant marine to widen commerce, world influence, and national safety. We have ships now; we have the commercial foundations; our future lies in policies and practices. We need the simple, practical understanding that commerce is the life blood of material existence; and no nation in the world ever has been or ever will be eminent in influence until it establishes eminence in commerce."

The attainment of these our ideals can be reached in no surer and quicker way than by the development of our ports, and by making them entirely suitable for the very important part they have to play, as our national gateways, in fostering the growth of our commerce and of our merchant marine.

DISCUSSION.

The President:—This paper, on "The Importance of Port Facilities in the Development of a Merchant Marine and Commerce," is now before you for discussion, gentlemen. The Chair appreciates that the subject treated of by Admiral Rousseau is one which is of tremendous importance to shipping. It has directly to do with the economics in ship-operation which have been mentioned frequently this morning. I hope, therefore, there will be definite and precise comments with respect to the features brought forward in the paper.

The discussion will begin by the reading of communicated discussions presented by various gentlemen who were unable to be present. The written discussions will be presented by Mr. Horace Holden Thayer.

Mr. Thayer presented the following discussion:

Captain F. T. Chambers, C. E. C., U. S. Navy (Communicated):—The importance of port facilities in the development of a merchant marine and commerce cannot be too greatly emphasized. Admiral Rousseau's presentation of the case is an excellent one, and no criticism is offered. It seems well, however, to emphasize several of the points which he has made.

While the principal European maritime nations have given the subject of port facilities real study for many years, it is only recently that port authorities in the United States have begun to give the matter the study which it deserves. The narrow piers commonly used in our harbors are probably the result originally of projecting street ends into the navigable waters, and such piers were probably of sufficient capacity for most of the old wooden sailing vessels. As pointed out by Admiral Rousseau, however, the terminal is almost of necessity the bottle neck of the transportation system, as even under the best of circumstances the capacity of the railways and ships serving the ports is likely to be greater than that of the pier or wharf which forms the connecting link between land and water carriers. In order that the greatest economies in ship turn-around may be effected, the terminal itself must have sufficient capacity for the assemblage and classification by commodities and marks of the cargo necessary for the particular ship to be loaded, and if piers are to be designed for the purpose, with ships' berths on both sides, the width will of necessity be large. The city of New York, for instance, is apparently content to use valuable water front for the construction of a series of new piers only 125 feet wide and 1,000 to 1,300 feet long, with inadequate provision of railroad trackage. Should piers be designed for this same locality with adequate railroad tracks upon each apron and down the center of the structure, provision for the quickest ship turn-around would require that the width be fully 500 feet, and this with a two-story transit shed.

This matter has been expanded on a pamphlet on the subject of water terminals suitable for various purposes, about to be issued by the Board of Engineers for Rivers and Harbors of the War Department. This publication cites examples to bear out its contention, among the most notable of which is the design of the quay and transit sheds along Dock No. 9 of the Manchester Ship Canal, where the available floor area per foot of berth is considerably greater than the figures just stated.

Admiral Rousseau has stated that delays in port mean lessened revenues and increased expenses to ocean carriers, which may in general vary from $1,000 to $5,000 per day per vessel. This is an important truth which should be brought home to all those interested in shipping.

About two years ago the Port Facilities Commission of the Shipping Board took up the subject of economies to be effected by the more rapid turn-around of vessels in United States ports. Endeavor was made to find the complete expense account of a typical ship. It was not practicable to get exactly what we wanted, but the record was found in the Shipping Board files of a 6,450 deadweight-ton, coal-burning vessel, which came into New York harbor from Genoa, Italy, carrying 2,713 tons of miscellaneous cargo, consisting of wines, hats, cherries, marble, etc., and departed fifteen days later for Archangel, Russia, with 3,783 tons of miscellaneous supplies, such as sugar, cocoa, canned goods and Red Cross articles. An analysis of the charges showed that the daily expenses against the vessel, inclusive of such overheads as interest on investment, depreciation, insurance, etc., and such other charges as stevedoring, wharfage, vessel supplies, port pay roll, clerking, winchmen, watching cargo, lighting and watching ship, amounted to $2,066.26 per diem. It was felt that no records would have been broken if the complete port turn-around of the ship had been six instead of fifteen days. Under these circumstances, the saving in expenses was estimated at $18,596.34. The complete argument as drawn up in this case was shown to a prominent ship operator, who was much interested. He stated that he had not been in the habit of looking at the subject in just the same way, but that a ship of the size and type that we had used should at the time have produced a profit of $2,000 per diem. Under such conditions, it is plain that we should add the profit to the expense to show the actual loss of keeping the ship nine unnecessary days in port. In other words, the total loss, inclusive of expense and profit, was over $36,000 for this particular voyage.

It has repeatedly been demonstrated on the Great Lakes that with special type vessels, and with proper equipment designed to suit these vessels, bulk cargo can be handled so rapidly that a 10,000 ton ore carrier can be turned around in the upper lake ports in a few hours, and the average for the season kept at something like twelve hours per ship turn-around.

The problem of handling miscellaneous cargo is not so simple, but proper design of our port terminals, plus efficient operation and management, will unquestionably produce results that are well worth while, and those interested in ship operation should give the subject of port facilities their best attention if they would effect all possible economics in ship operation.

The President:—The next written contribution is from the American Association of Port Authorities, through its president, Mr. Benjamin Thompson.

Mr. Benjamin Thompson (Communicated):—The paper by Rear Admiral Rousseau on "The Importance of Port Facilities in the Development of a Merchant Marine and Commerce" is a valuable contribution to the literature on the subject. The admiral has honored me, as president of the American Association of Port Authorities, by suggesting that I submit some discussion thereof. Appreciating the courtesy extended, and the opportunity thus placed before me, I will take up a little of your time in discussing certain features.

As the admiral says, "Our port facilities, like 'Topsy,' just growed." The same may be said about the several types of administration, and it seems to me that until the people living and having business at the several ports are led into an intelligent discussion of what must be done at the terminals to make them successful in every sense of the word, and how this shall be done, it will be futile to anticipate, with any degree of certainty, such development and such commercial success at them as it is within the bounds of reason to realize under the best conditions.

It seems to me that the business and administration of a port should be conducted the same as any other business involving the use of as much capital, at least in the application of elementary business principles. Would investors of money in the stocks and bonds of large mercantile, manufacturing, or transportation organizations not hesitate a long time before investing, provided they ever invested, if they knew that the management was to be changed continually every year or two, or three, and new men be placed in control whom previously they had never heard of, in all possibility? Is there any reason whatever why the business of a port and its facilities should not be conducted as carefully as of any other business?

It seems to me that the Congress by the enactment of the River and Harbor Act approved March 2, 1919, and the passage of the Merchant Marine Act of 1920, has made a very important beginning of what it is hoped will eventually result in port administration throughout the country being placed upon a strict business and accountable footing. The work being done by the Board of Engineers for Rivers and Harbors, under the Chief of Engineers of the U. S. Army, will supply information that will be available very soon, such as the majority of the ports of the country could not otherwise have at hand, on account of the expense attendant.

With that information available, will it not be possible to formulate conclusions as to some general form of port organization and administration that will be calculated to provide for satisfactory results? That done, can a way not be found to impress upon the business men of the several ports, and through them upon the majority of the people, the vital importance of having each port conform thereto? Then, and not till then, perhaps, will the several houses be put in order. This all will require leadership and systematic organization. Have the American people ever failed to find good leaders or determine upon a satisfactory organization to accomplish anything they thought should be accomplished? They will not fail in this most important matter if the issue is placed fairly and clearly before them. So far as it can possibly be done, there should be an absolute separation of port administration from what is commonly known as "politics."

Business opportunities will not wait. On that account, if for no other, it is vitally essential to the success of any port that exporters and importers should be in close touch with those who administer port affairs. In no other way can the latter so satisfactorily aid the former in securing prompt attention to their needs in shipping, thereby doing all that can be done to increase the importance of the local port. It all requires mutual effort if the greatest success is to be achieved in accomplishing those things which contribute to "The Development of a Merchant Marine and Commerce."

The admiral has spoken very complimentarily of what has been done by the American Association of Port Authorities. That organization stands for "service" if it stands for anything. The problems of the many ports are so many and so great that, while the association has been in existence for ten years, it has only begun the work that lies before it. I am glad to say that its efforts have been approved by those high in authority, and that its influence, and an understanding of what may be accomplished through its efforts, are spreading, so that now it has representatives in many lands. The association is ready and willing to do its share in helping to solve the problems that confront every port administration, and invites all of them to join with it in determining what is best to be done that transportation by water, export and import commerce may be conducted most quickly, most economically and most satisfactorily, for that is the crux of the whole matter.

I thank you for the opportunity to be heard before your organization and wish you the greatest success in your deliberations on this very important subject, so well put before you by Read Admiral Rousseau.

The President:—We have two more communicated discussions, which will be abstracted by Mr. Leo S. Blodgett.

Mr. Blodgett presented the following discussion:

Rear Admiral F. R. Harris, C. E. C., U. S. Navy, *Member* (Communicated):—Rear Admiral Rousseau's paper on the importance of port facilities in the development of a merchant marine and commerce is a very thorough and comprehensive discussion of the subject and one for which he is entitled to considerable credit. He is particularly well fitted by actual experience for the task he has undertaken, both on account of his general familiarity with various types of port improvement and also on account of his connection with the United States Shipping Board Emergency Fleet Corporation during the war, and in connection with that same organization, as a member of the important Port Facilities Commission which he refers to.

It is of course conceded that a large and prosperous foreign commerce is of vast importance to a country such as is the United States, both as an element of its general commercial and economic prosperity and as a means whereby its production, agricultural and industrial, above its own requirements, may be maintained through shipment to foreign users and, in the same way, make good its shortages in various staples and manufactures through foreign imports. Both from a commercial and economic standpoint it is highly desirable that the bulk, or surely at least half, of this ocean-borne commerce should be carried in our own merchant marine flying the American flag. This last statement would at first appear to be so evident as to require no elucidation. We all have a very general idea, which we consider patriotic, that we want an American merchant marine capable of carrying the bulk of our exports and imports; but I think very few of us either know exactly why we want such a merchant marine or how its possession would be of value to us, nor do many realize what are the obstacles to our attaining our national aspirations in this regard.

We need a merchant marine to carry our exports and imports for very much the same reason that animates a great merchant in desiring his own delivery wagons and service. For by possessing a thoroughly well-equipped transportation and delivery service, making prompt and efficient deliveries, he has one of the important elements that enables him to compete successfully with other merchants and thereby maintain and enlarge his sales. A merchant would undoubtedly consider it suicidal from a business standpoint to entrust the delivery of his own products or merchandise to the delivery service of a competing concern. Besides this, the merchant's efficient delivery service has a great advertising value and, if this is combined in suburban routes with the solicitation of orders, it becomes an important adjunct of the sales department.

Of course we can always export and sell our agricultural and industrial products where they are absolutely necessary to foreign customers and cannot be secured from other sources, and even export such products in foreign bottoms successfully. But to build up a large foreign trade we must not alone sell what no other country can supply, but also what other countries can supply, by selling in competition with them by means of their excellence, cheapness and availability, which means delivery of them. Having a great American merchant marine entails shipping agencies in all parts of the globe and exchange of information as to what our foreign customers require and prefer, and active competition in remote countries and with foreign competitors and knowledge of what their goods are—not alone their quality but their terms and commercial credits; in other words, all the facilities and machinery which seek for and find business.

We cannot expand foreign trade if terms and prices at which we can afford to sell are higher than foreign competitors can sell for, always assuming that the products are about equal in quality. In these prices from our foreign customers' standpoint are always included, and must necessarily be absorbed as an overhead, handling and terminal costs together with freight rates. The American merchant or transporter would for various reasons prefer to use American ocean carriers but, as a matter of business, rather than lose the opportunity for sale entirely, he will, and with justice, employ foreign bottoms if the freight charges are lower than in American bottoms. No idealism in the form of patriotism can long sustain an American merchant in employing American bottoms at a cost higher than in foreign bottoms. Such course would eventually result in bankruptcy. Therefore if we want an American merchant marine—and we realize that we do want it, not for general reasons of vague and indefinite type but for the specific reasons that in the long run we cannot hope for a large and increasing foreign trade without it—we must seek to establish this merchant marine on a firm and solid basis by all of the various means outlined by Admiral Rousseau in his able paper, and by striving to make the cost of transportation in American bottoms at least no higher than would be the case in foreign bottoms. This must be done by an actual reduction in cost of the various items that go into making transportation costs, or, failing in this, we inevitably face either some type of national subsidy to overcome the difference or the abandonment of our ambition for an American merchant marine, and with it eventually a large and increasing foreign trade. If we can only build, maintain and operate ships at cost much in excess of those of foreign builders and operators, we must either abandon the building and operation of ships, make up the difference by some type of national charge—in reality a subsidy—or ships will be built and operated under foreign flags.

The obstacles to our maintaining a large and successful American merchant marine with its consequent foreign commerce is very ably set forth in Paper No. 6, "How Can American Ships Compete Successfully with Foreign Ships," by Mr. Winthrop B. Marvin. Mr. Marvin's detailed analysis of the situation leaves nothing to be added to it. We must find a way to equalize the cost of ship construction and operation, either directly or indirectly or by government aid; if we are to maintain successfully the great American merchant marine it must become a government protected institution, and every piece of legislation such as the La Follette Seaman's Act must be considered from the aspect of its desirability to be enacted, how much the Government will have to pay in the way of subsidies to counteract its effects.

A not unimportant element in the item of cost is that of handling and terminal charges—port facilities; and even in this we cannot be too careful in attempting to avoid the evil of over-expansion and extravagance. Large and expensive works of construction of an elaborate character involve high first costs, high fixed charges, both of which must in turn be distributed on the terminal and handling charges. The question of proper terminals and port facilities is therefore in each case and in each port a special problem of balance between business and expected business, seeking the proper balance of cost and consequent distribution of fixed charges. It might easily be made too expensive to use the most elaborate and complete terminal facilities, causing the operator to seek more primitive and less complete facilities involving less charges.

There is undoubtedly an opportunity in American port and terminal problems to materially increase the capacity by a more efficient and economical utilization of these facilities. Such is the case regarding results in not alone more rapidly and economically loading and unloading vessels, but in capacity of the terminal as regards number of vessels and cargoes unloaded and a possible reduction on terminal charges. The great port of New York undoubtedly affords a fertile field for improvements of this character. The evil and expense of its lighterage system and drayage or truck transportation are well known. The condition of its waterfront and congestion westward during periods of normal commercial prosperity form one of the visible explanations of its constantly mounting costs of shipment through this port.

A glaring example of what the keen commercial competition for business expansion will do is well illustrated in a recent disclosure made by Senator Jones relative to agreements between various of our railroads and foreign steamship companies. To look at this disclosure impartially simply shows that various railroad officials seeking business have sought alliances that would bring them the most business and that, of course, would permit them to expand their railroad business, although apparently at the expense of the American merchant marine. It is human nature for the average business executive, who feels first his responsibility to his own corporation, to seek for its prosperity first; although he may be and is very likely at heart just as patriotic as any of us and would, all things concerned being equal, prefer to make his alliances with American steamship companies. The answer to such course of action is, first, to improve the American merchant marine service, so that it will offer and afford everything that foreign services offer and afford, so that it can offer freight rates as cheaply as foreign lines can offer them, thus removing the elements of temptation as far as possible. In addition to this, passing the necessary laws and regulations prohibiting any such alliances and forming the proper organization that will vigilantly, aggressively and tenaciously enforce these laws to guard against their evasion.

Thus far we have spoken largely of foreign trade, exports and imports, and why it is desirable that the United States should have a large and great foreign trade. We must not overlook the all-important fact, however, that foreign trade is dependent to a large extent on a balance between exports and imports. This condition is not alone desirable but necessary. It is absolutely necessary financially and, if not absolutely necessary, very nearly so from the standpoint of the ship operator. Ship operators have had many lessons in the last few years that it is expensive to export where the ship is sent out in cargo and returns in ballast—no imports available; just as the financier has found that it is expensive—in fact, ruinous—to sell goods on credit where your customer, when bills become due, asks for extensions of credit, and so on indefinitely. Much as a merchant desires to sell, he loses this desire if he is fairly well convinced that the customer cannot under any possible conditions pay for the goods he has bought.

The United States may be considered as a single, large merchant. We have a productive capacity in many lines beyond our requirements. We wish to dispose of this excess and continue to do so, keeping our industrial population at work to their full capacity or near capacity in producing. However, we only want to do this and continue to do this if we are paid for what we sell. The only way we can be paid is by people outside of the United States who buy and use our products, working and producing other products that we want and will buy from them or practically exchange with them. If they will not work and produce, or cannot work and produce, we not only cannot have a foreign trade but, I think, do not want a foreign trade. Credits, not matter how long extended, are merely a distinct promise for future foreign production, not alone sufficient to pay the accumulated debt in products but all of their future purchases and interest on the credits besides. Therefore, while I think we want to export, we also must want to import, and we must be especially careful not to export where there is little or no chance of repayment. There is no use sending good money after bad.

An analysis of this condition, I fear, will make many of us pause and conclude that, irrespective of our personal interests and desires, we must look forward for some years to come to a foreign trade much smaller than we would desire—a safe and conservative export and import business of such a character that it will sustain and pay for itself and grow year by year, and what the world has to offer us in this respect in purchases of our products on a sound basis we must be in condition to compete for with foreign sellers more keenly than has ever been the case before. This will involve not alone a matter of competitive price and conditions of delivery but put us on our mettle as regards an adequate delivery service, namely, a merchant marine. If we abandon the idea, we will end up, when trade is again resumed on the pre-war scale, with our foreign competitors having both the trade and the merchant marine.

There are certain commodities and staples, and always will be, which we do not produce and must import, such as rubber, coffee, cocoa, sugar, etc., and also certain manufactured articles and products which can be better or more advantageously secured from foreign sources that will be desirable imports. Eventually, with our constantly increasing population, we will consume most of our agricultural products that we have been in the past exporting, and we must, looking to the future, either expect to find outlets for our excess industrial producing capacity or else materially reduce this productive capacity, which in turn means a material curtailment of our growth and prosperity as a nation. It cannot be too strongly emphasized how important an American merchant marine, as well as proper port and terminal facilities, will be in locating a successful solution of this very important problem.

The whole matter of foreign trade, merchant marine, and port facilities is much involved and very complex and is a single problem, not three separate ones. We must be cautious and careful in our capital expenditures as regards productive plant, vessels, port works and terminals. We will be very fortunate in most cases to be able to utilize even what we have in part capacity for some years to come, and will have to scrutinize with the greatest care and discretion any new expenditures of money for enlargement of any of the three facilities. This does not mean that extensive works and improvements in the matter of port facilities are not warranted but merely that in each individual case there are special problems requiring study and analysis from all standpoints; and the sooner we give up idealistic statements and glittering generalities and come down to an analysis of facts and figures in special cases, the better.

The President:—It seems desirable to add that the contribution which has just been presented in abstract was prepared by Admiral Harris, who, as Chief of the Bureau of Yards and Docks in the Navy Department, and subsequently as General Manager of the Fleet Corporation of the Shipping Board and in charge of very important port development work, speaks with authority on the subject.

Mr. Charles Evan Fowler (Communicated):—The paper by Admiral Rousseau is such a thorough and comprehensive one that to properly discuss it would require much time and study. Therefore the writer will only attempt to call attention to some few points that should be most carefully considered, and some others that should be introduced as pertinent.

The seven postulates of the Montreal Harbor Commission, as given in their original report, cover the situation as to any important harbor most comprehensively, but the first two should be repeated here.

"The ports that are doing the biggest business, and doing it most efficiently, are the ports that have kept their facilities ahead of actual requirements."

"The ports that have remained stationary or lost prestige are those which neglected to provide facilities before business was forced to seek elsewhere the same facilities provided by rival terminals. Business follows the facilities."

The writer spent some four years, as an engineer member of the Seattle Harbor Commission, which evolved the present Port of Seattle scheme, to overcome the handicap imposed by private and railway ownership of ocean terminals, and he sees no reason, from the working out of the Seattle plan, to change his views, that the port authority must be divorced from any connection with municipal government, or politics if you please. The detail development of the port has also in the main been most satisfactory; and such things as the great jetty piers, as built, have undoubtedly met with great approval by all authorities on ports.

The whole project has, however, demonstrated that it is impossible to divorce the hinterland facilities, the port proper, and the harbor. The port will be a failure if the hinterland does not produce and consume products conducive to ocean commerce, and it must have the necessary connecting or feeder railways. Then, too, our railway managers must be of the broad-gauge type who can sense the welfare of their roads in terms of cooperation with the ports they serve. They must study such examples as the Puerto Mexico, Salina Cruz ports and railway, and the railway and port facilities of the Argentine. Such details, for example, as the roof doors of box cars to facilitate loading and unloading must be copied, if perforce we cannot attain to efficiency in any other manner. The steamship operator, on the other hand, must equip his ships with cargo booms and freight-handling machinery like the ships of the old American-Hawaiian Line, to supplement dock cranes, and also to serve such ports as have no dock cranes or freight-handling machinery.

The table on page 231 of the paper makes it easy to pick out those features of ocean commerce that cost the most in percentage in the handling of the world commerce. We can immediately attack the item of stevedoring as a fruitful point to improve upon, and one where such improvements will quickly tell on the reduction of cost. Repairs, fuel and wages are the other items where improvement would show most quickly.

Stevedoring and handling cost must be greatly reduced by the use of machinery by both the ship and the port. Repairs and depreciation must be reduced by better construction of vessel and port facilities and by better equipment on shipboard for the crews to effect more of their own repairs and upkeep.

Fuel cost must be reduced by using the most efficient type of machinery, both for handling cargo on the ship, on the piers, and in ship propulsion. Ships driven by Diesel engines must be more largely used, and for certain classes of ocean commerce we must again use sailing vessels, with auxiliary engines.

The wage question is the one which is paramount, because it brings up the question of the welfare of the human race, and more particularly the welfare of a small portion of our own countrymen. We may rest assured that our merchant marine will not be a success until there has been a radical revision of our shipping laws, to enable us to compete with England, France, Japan and other countries engaged in world commerce. There need be no hesitancy in doing this, because in normal times American labor can find plenty of congenial and remunerative work in other lines of endeavor.

The major problems of port location and arrangement of facilities, together with the general design of harbors, are ones which have not been given sufficient attention in the United States, with the result that many of our ports are most inefficiently arranged. Some of our older ports have grown by the process of accretion, and only the most drastic treatment will make them efficient world tools; but we may rest assured that desperate diseases require desperate remedies, and in the end most severe reconstruction from start to finish will prove to have been the only cure.

Much new harbor work has been placed in inexperienced hands; and it is only to be expected in such cases that the results will be far from satisfactory and the port be far from the required efficiency. The port must be specially planned for the class of ships and traffic that it will attract and handle.

The fact must not be lost sight of, that while an independent port authority has been found the best and only means for economy and efficiency in handling all port and harbor problems, the ships must be privately owned to effect a like result with the means of ocean transportation. Such a statement may seem paradoxical, but upon reflection it will be seen that a unified and independent port authority is necessary for the proper correlation of the many separate land and water transportation systems.

The task of forming a real merchant marine out of such a heterogeneous mass of land transportation systems, ocean transportation systems and port or harbor facilities is a herculean one, but one worthy of the best minds among engineers, business men and statesmen.

The President:—That ends the contributed written discussion. Is there any oral discussion to follow? I think we can undoubtedly get a much better conception of the subject and the written contributions by reading them in the Transactions later. It is a large subject, most intimately bound up with the whole commercial development of the country, and as we discovered very early in the transportation of troops and supplies during the war, the facilities for loading and unloading were vital in facilitating quick "turn-over" during those days. In fact, it is a matter of record that in some cases the time in port was cut down to one-tenth of the original time, simply by having up-to-date methods of handling supplies and adequate port facilities.

Before passing to the next paper, I am sure you will desire that the Chair make, on behalf of the Society, an acknowledgment to Admiral Rousseau for his preparation of this most interesting paper.

As you were advised yesterday afternoon, the next paper on the program, "American Shipyard Apprenticeships, Evening Schools and Scholarships," will be presented at the afternoon session in view of the unavoidable detention of Mr. Bailey. He cannot be present this morning. We will therefore pass to Paper No. 9, entitled "Cost Accounting and Estimating," by Mr. H. H. Schulze, a member of the Society. This is perhaps a rather dry subject, but it is an exceedingly vital and interesting one; also, one that all of us known a great deal more about now—at least we think we do—than we did five or six years ago. One of the serious and worrying problems during the war was to catch this somewhat elusive item of "cost" and find out exactly what were its true constituent parts.

Mr. Schulze:—I can hardly agree with the Admiral that this is a dry subject and not interesting.

The President:—You misunderstood my remark, I fear. It is an exceedingly interesting subject.

Mr. Schulze:—What we have tried to do in our work is to carry out what the Admiral presented in some previous remarks—that is, efficiency.

In this paper we have endeavored to reduce estimating to a scientific basis and bring it to such a point that, by giving engineering condition, we shall have one answer for the size of the auxiliary, and for a given size we would obtain but one answer for the price. It seems almost impossible to do it, yet I believe we have accomplished much in that line. In order to save the time of the Society, I have made an abstract of the paper and will therefore read it.

Mr. Schulze then read his paper in abstract and at its close said: "If there are any here who later wish to see any details of any portion of the work, I will be glad to show it to them."

COST ACCOUNTING AND ESTIMATING.

By H. H. Schulze, Esq., Member.

[Read at the twenty-ninth general meeting of the Society of Naval Architects and Marine Engineers, held in New York, November 17 and 18, 1921.]

Cost accounting and estimating are so closely allied that it is not possible to treat of one without the other. In early days, cost accounting as applied to ship work did not receive careful thought or attention but was considered more in the nature of clerical work; during later years, and especially since the cost plus form of contract came into being, cost accounting has become better understood and is today considered among the most important departments of the shipbuilding business.

Cost estimating occupied much the same position as cost accounting, and few shipyards reduced their cost estimating to a systematic basis. It is therefore the intention of this paper to treat mainly of the second portion of the title and to describe the methods adopted in the effort to obtain, as nearly as possible, uniform results.

COST ACCOUNTING.

There are really three main functions of the accounting: First, for determining the profit; second, for submitting statements during construction to the operating manager, so that he can anticipate or investigate the overrunning of estimated costs; third, for estimating—that is, to determine the basis upon which to submit bids for similar work. The financial statements required for each of the above purposes are entirely unlike.

For determining profit but one figure is required, namely, the completed cost; for use of the operating manager the statement should be divided into groups corresponding with the division of his operating department; for determining the cost for future work the statements should be divided by groups represented by physical quantities so that unit rates can be determined, to be applied to similar physical quantities calculated for the proposed work. A good accounting system should provide means to indicate all the above.

The number of groups in the accounting system depends largely upon the variety of work constructed. It is understood that, should but one type of commodity be constructed in which the relation of each operation to the other is always constant, but one factor would be necessary to determine the rates for similar commodities. In ship work, however, because of the varying relations of the many items and trades entering into the numerous types of vessels, it becomes necessary to subdivide the return cost into the correspondingly numerous items, which broadly may be classified in groups of hull and machinery.

The hull is usually divided into general items such as bonds, insurance, watching, temporary electric service, plans, trials and delivery; steel hull, including loft work, staging, launching, hull castings and forgings, and structural hull; woodwork, including joiner and carpenter work; also painting, hull piping, ventilation, electric work, steering gear, warping gear, boat gear, doors and hatches, airports, inside and outside fittings, handrails, deck covering, masts and rigging, and outfit. In naval work there must be such additional items as ammunition handling, turrets, installation of ordnance and armor.

The machinery is generally divided into main engine, condenser, pumps, boilers, stacks and uptakes, forced draft system, fuel oil system, piping, lagging, shafting, bearings, propellers, floors and gratings, tanks, and auxiliaries, including feed heaters, evaporators, distillers, oil coolers, auxiliary condensers, refrigerating, heating, fire extinguishing and disinfecting plants, together with tools and spares.

The above groups are more or less subdivided, according to the nature of the work constructed at the particular plant.

The return cost for each of the above items should be given in the three divisions: material, labor, operating expense, termed overhead.

Material is comprised of purchased material, *i. e.,* items requisitioned and purchased directly for a particular ship; and storehouse material, *i. e.,* material drawn from the general storehouse and applied directly to the vessel. The latter consists of such items as standard pipe, fittings, bolts, nuts, etc.

Labor, sometimes termed direct labor, is that portion of the labor which is charged directly to the vessel.

Operating expense, or overhead, consists of both material and labor and constitutes just as much a part of the cost as either the direct labor or material. It consists of material and labor which is more accurately distributed by prorating than by the direct charge.

The division between direct labor and indirect labor is by no means uniform at all plants. The general principle which determines the division is that direct labor should include all labor where little or no judgment is necessary by the operator in the division of his time. Where it becomes necessary for the foreman or quarterman to estimate the division of his time between the several vessesl or jobs, such labor should be classified as indirect labor. An ideal system would be one where all the labor could be accurately distributed directly to its appropriate job. Unfortunately, much of the labor entering into ship construction cannot be charged direct without the arbitrary distribution by the employee, and it must therefore be included in the operating expense.

The material charges in the operating expense embrace such items as light, heat, coal, water, etc., and the labor includes the compensation of foremen, leading men, inspectors, clerks, messengers, cleaners, timetakers, etc. In addition to the above there is included, as administration, selling and general expense, a proportionate part of the cost of the office of the manager, sales department, treasurer, accounting department, purchasing department, plant engineers, service department, etc.

The distribution of the overhead in some businesses can be apportioned according to the units manufactured, where such units are all the same character, but in shipbuilding it has generally been customary to apportion the indirect expense as a percentage of the direct labor. Each department in the shipyard should have an account to which the expense of the department is charged, so that it may be possible each month to prorate the expense of that department among all of the direct labor which it performed for that period.

Since the distribution between the direct and indirect labor is not uniform at various shipyards, it can be seen that direct costs of one yard are not comparable with another yard. To make a proper comparison, it would be necessary to adopt not only a uniform cost system, but a uniform force report so that the distribution between the direct and indirect labor would be the same at all shipyards.

ESTIMATING.

Cost estimates are prepared primarily to form the basis of a bid or a selling price, and secondarily for the information of the general manager so that he may be advised what allowance has been made to each department so as to assist in the reduction of operating costs. The importance of the latter function is being recognized more and more, and an excellent paper on this subject, entitled, "How the Cost System Assists the Management in the Reduction of Operating Costs," was presented by Mr. William B. Ferguson, assistant to the president, Hog Island, before the Society of Industrial Engineers, on March 26, 1920.

While the selling price is determined by the amount the consumer is willing to pay and the manufacturer willing to accept, few lump-sum contracts are taken without some form of estimate. The acceptance of a contract on a competitor's bid involves the dangerous assumption that the competitor has not made an error and that the purchasing power and manufacturing efficiency of both plants are equal.

The builder usually prepares his estimates on the same basis and, after submitting several bids, soon ascertains what allowance must be made over the estimates prepared by him to compete with other bidders. Thus, if he is consistently high, with a constant percentage as margin, he knows that, if he desires to obtain the contract, it is necessary to correspondingly reduce the amount of margin.

All estimating—in fact, the solution of all engineering problems—is performed by comparison. A formula is merely an expression endeavoring to reconcile by functions all the various conditions entering into the problem, and the closer the functions and formula represent the condition the more uniform will be the coefficients in the formula. The personal element in the selection of factors to represent the proposed condition is one of the reasons for erratic results in estimating.

Designing and estimating would be reduced to a more scientific basis if, under the given engineering condition, the same dimensions would be obtained at all times, irrespective of the person who is solving the problem. Again, after the size has been determined, if the same weight and cost would be obtained, then estimating would be reduced to somewhat of an exact science. The solution of this problem has been attempted by the method described herein, and, as far as it has been applied, has been found to be very successful.

There is usually a time limit to every estimate, and the problem is to make the best use of this time. One essential is to proportion the time according to the money value of the item, and another is to avoid repeat operations in every succeeding estimate. For example, it is unwise to devote a large amount of time to the calculation of structural foundations and then hurriedly figure the shell plating, merely because this portion is easy to calculate. Again, it is not desirable to devote a large amount of time to an intricate iron casting and to approximate the weight of a composition casting costing several times as much. Repeat operations are avoided by the standardization of particular items, as will be described later.

A good estimating system should be flexible enough to make the best use of all the particulars specified by the purchaser, and where these particulars are not specified it should provide means for determining the sizes according to the best standard practice.

Since estimating consists largely of a comparison with past practice, it is of importance that items to be compared should be on exactly the same basis; otherwise the estimator must make the proper adjustment in his mind before applying the new rates. In former years, when there was no great fluctuation in the material and labor market, it was sufficient to use the price-per-pound method for both material and labor, making slight modification as found necessary. When large fluctuations in material cost and labor rates occur, the mind cannot readily compensate for the varying rates, and comparisons with previous returned cost and with previous estimated costs become of no practical use; therefore a method should be adopted of placing all estimates on the same basis, viz., uniform base for material and labor rates.

By an adoption of a standard schedule of material unit rates for the various commodities, and by reducing labor to hours, estimates can be placed on a uniform basis and would not only be comparable one with the other, but would also be available for use at any period by applying current rates to the quantities and to the labor hours which, combined with the current expense rate, produces an estimate on current rates. The relation of the current estimates to the standard estimate should be very nearly constant for the same period.

It is not alone sufficient that details be calculated accurately, but every estimate should be subjected to a check method to determine whether the total represents a reasonable figure. To accomplish this, resort is made to check summary cards, which indicate the quantities and costs combined in large groups, together with appropriate weight factors, and unit rates of material and labor.

The character of the estimate depends largely upon the character of the inquiry. Frequently inquiries do not give any particulars, and sometimes not even the general dimensions. This probably means that the prospective purchaser is merely feeling the market, and in such cases approximate estimates are prepared in condensed groups, using as a basis the check cards of the nearest similar vessels. In the hands of an expert with good judgment, such check-card estimates will give results which compare quite favorably with the detailed estimates.

While space will not permit describing in detail the method of determining the dimensions of vessels and their horse-powers to fulfil required conditions, it might be briefly stated that recourse is made to design cards bearing lineal ratios, displacement and weight coefficients, also to the freeboard tables and to model experiments conducted by Admiral Taylor and Constructor McEntee. The freeboard tables have been reduced to curve form, making the determination of depth for any draught, length and extent of erections a very simple operation. By reducing the model results of Taylor's Standard Series to a mechanical operation and plotting curves of the relative performance of known models, the horsepower can be quickly determined, and with a reasonable degree of certainty.

In cases where only the general particulars are given, an estimate is prepared by the condensed groups without going into great details, except for the larger groups, such as structural steel hull.

When complete plans and specifications are submitted, or when it is probable that the prospective purchaser seriously contemplates construction, estimates are prepared in full detail. One of the first steps in preparing such detail estimates is the determination of the sizes of auxiliaries purchased from subcontractors and the submitting of the necessary inquiries. The subcontractor, before he will quote, will require complete information regarding the auxiliary, which necessitates not only the engineering knowledge for determining but also knowledge as to how this material is furnished by the subcontractor. In most cases the time required to prepare the estimate is governed by the time necessary to receive prices from outside contractors. This is particularly true when the auxiliaries are not of their standard manufacture.

Having briefly described the general principles and the several kinds of estimates, a description of the procedure in preparing a detail estimate will now be given.

In a large company the work of estimating is divided among men who become specialists in their particular line. For instance, it is very desirable to have the quantities for woodwork, both carpenter and joiner, calculated by someone who has had practical experience in this character of work; piping should be determined by an expert piping man. The material is generally calculated in the same units as it is purchased—that is, steel by the pound, lumber by the board foot, floor covering by the square foot, etc.

The costs of construction bonds and insurance depend upon the time of construction and the amount of the contract and are estimated on this basis. The cost of the trial trip and delivery depends upon the horse-power, duration of the trial, size of the vessel and the point of delivery, and where this amounts to a considerable item a detail estimate is prepared, taking into account the consumption of fuel, lubricating oil, stores, number of crew, commissary, transportation charges, compass adjustment, docking, towboat charges, etc. In cases where it does not involve a considerable item the cost is merely based upon similar vessels.

The cost of plans is based upon the number of hours required in the draughting rooms, and it has been found that the best criterion for determining these hours is the total hours of direct labor for constructing the hull and machinery separately. Staging and launching depend upon the size of the vessel and the duration of the construction period, and, based upon these factors and the return cost of similar work, proper allowance is made for these items.

The weight of structural castings and forgings is calculated after the sizes have been determined from the registration rules. Practically all vessels are classified in one of the society rules, such as the American Bureau of Shipping, Lloyd's, or Bureau Veritas, and if not classified the scantling and sizes are usually obtained from the above rules.

The structural hull is by far the largest item of cost and weight in the vessel, and it is therefore essential that the quantities be determined with the greatest accuracy possible. Coefficient methods have at times been adopted, but the use of such methods is dangerous, particularly in the hands of the inexperienced or when a complete knowledge of their derivation is lacking. Usually the approximate lines are sketched, from which curves of shell expansion, floor areas, areas of bulkheads, decks, and the length of frames and reverse frames are obtained. From the above information and the scantlings obtained from the Classification Rules, quantities are calculated in detail. The grouping is always done in the same manner so that comparisons can readily be made. This is very essential and applies to other jobs as well.

The steel hull is calculated in three groups, each divided into regular classified subgroups. The first group consists of the continuous running members below the topmost structural deck, namely, transverse framing, longitudinal framing, keel plates, shell plating, inner bottom plating and decks. The second group consists of the other members below the structural decks and includes bilge keel, engine, boiler, and miscellaneous foundations, transverse and longitudinal bulkheads, chain lockers, shaft alleys and miscellaneous trunks and ducts. The third group consists of all the erections above the continuous deck, including structural work for the poop, bridge and forecastle, bulwarks, casings, etc.

The steel has been classified in the above logical groups in order that the result can be checked by coefficients obtained from similar work. The quantities are net weight, calculated in pounds, and are classified as to plates, angles, channels, bulb angles, half rounds, tees, etc. The net quantities are transferred to the cost sheets and due allowance made for wastage, to obtain the gross quantity or amount to be purchased. To these gross quantities current unit rates are applied, obtaining thereby the estimated purchase price of this material.

The labor on steel, as in all the other jobs, is estimated in hours, being based upon the returned hours on similar work; to these hours are applied the current averaged hourly earnings of the particular plant, giving the labor in money value.

Joiner work is calculated in board feet and necessitates a knowledge of the kind of materials and dimensions ordinarily used for carlins, studs, sills, plates, internal and external sheathing, straight and diagonal bulkheads and for the various items of furniture. Hardware, fastenings, glass, etc., are listed and priced, unless the time is insufficient, when they are taken by comparison with other work. As with steel, the quantities of lumber are transferred to the cost sheet, due allowance made for wastage, current unit rates of lumber are applied, giving the estimated cost of this material. The labor in hours is estimated, based upon the corresponding prices per board foot obtained in similar work.

Carpenter work is calculated in the same manner as joiner work, but, in addition to the number of board feet, lineal feet are calculated, since the labor is best applied on the basis of the lineal feet as laid by the carpenters.

The amount of paint is calculated in pounds, based upon the extent of the surface covered, treating separately the under-water body, the ordinary steel work, the joiner work and the varnishing and decorating. While cement amounts to a considerable item in the displacement, it does not involve much cost, and this is usually approximated, taking into consideration the size of the vessel.

The hull piping, including cargo oil mains, fire main, drainage and plumbing, is calculated in detail from a single line sketch plan made to suit the special requirements. The number and weight of flanges, fittings and valves are listed and the pipe is calculated in pounds, separate quotations being received for the plumbing fixtures themselves.

A similar procedure is followed in ventilation where this is an elaborate system; otherwise, the ordinary engine fire-room and hold ventilators are obtained by applying quantities derived from similar work. The costs of doors, hatches, airports, hand rails and deck coverings are obtained by counting, or calculating the number and size from the plans, and applying to the quantities, so obtained, prices and weights derived from similar work. After applying to such systems as steering gear, warping gear, anchor gear, boat gear, etc., the prices of auxiliaries received from the subcontractors, the remaining items are estimated by comparison with similar work. Masts, spars and rigging are calculated in detail—that is, the number of pounds of structural steel, the number, diameter and length of booms, the lineal feet of wire rope, the pounds of running rigging and the number and size of various blocks required.

The galley and deck outfit in some cases is very elaborate, and complete schedules are often forwarded to subcontractors for silverware, glassware, linen, bedding, etc., and these prices are applied.

The machinery quantities are figured in detail and in the same units as the material is purchased. Within the time limit it is of course impossible to calculate the weights of each casting, such as cylinders, columns, bedplates, condenser heads, etc.; and in some shipyards the weights of such items are derived from an empirical formula, applying coefficients from the nearest similar work. For those shipyards which have a sufficient staff to enable weights and quantities to be classified and standardized, excellent results are obtained with a minimum amount of time. Curves are developed for the various types of cylinders giving the weights for any diameter and stroke one series for high pressure cylinders with piston valves; another series for intermediate pressure cylinders with one piston valve, with two piston valves, and with slide valves; and a similar series for low pressure cylinders with various types of valves. Similar curves are developed for all parts of the main engine, including bedplates, bearings, columns, guides, all items of the reciprocating group, the valve gear, etc., so that it is possible without detailed calculations to obtain the weights which meet the required engineering conditions. This same procedure can be adopted for all portions of the machinery estimates, including condensers, boilers, stacks and uptakes, shafting, bearings, etc.

One of the largest and the most difficult item in steam engineering is the steam engineering piping. The best procedure for calculating steam piping is to make a quick layout of the machinery with a single line sketch plan of the various piping systems, including main and auxiliary steam, main and auxiliary exhaust, suction and discharge piping, and to calculate from this layout all the valves, flanges, pipe and fittings in the same manner as for hull piping. Where the time limit will not permit of such detailed layout, piping is estimated in separate groups, as described above, by comparison with the nearest similar job; but here again great care must be exercised, since the several owners' requirements vary to such extent. One company might require copper pipe and composition valves for the system, whereas ordinary good practice would consist of wrought-iron pipe with cast-iron valves; and realizing that the former would cost several times as much as the latter it will be at once seen that the greatest care must be exercised in making assumptions in this group. The deck steam pipes, smothering pipes and heater coils for oil steamers sometimes consist of very large quantities, and, being comparatively simple, they are calculated separately.

The specifications cannot specify all sizes, dimensions and character of material, and therefore the estimator must have a complete knowledge of the character of the material and the size required for any portion of the machinery; for instance, in piping, it will be necessary for the estimator to know what connections are made to the various pumps, their size and character of piping. If the sizes of the condenser, air pump, and circulating pump are not specified, it will be necessary for him to know the best practice to determine these sizes. In reciprocating pumps he is required to know not only the size of the pumps, but whether they would be composition end, composition fitted, or with cast-iron cylinders—whether or not soft packing or metallic packing is required. The same detailed knowledge is required for determining all sizes and dimensions where not definitely specified. Having determined the net quantities, they are transferred to the cost sheet; due allowance for wastage, current unit rates are applied, obtaining the estimated cost of the material.

The labor, as with the hull, is estimated in hours, and in most of the groups is based upon the weight, though in some cases better results are obtained by applying unit rates, following the method of manufacture. Thus it has been found that in a condenser it is better to base the hours upon the number of tubes.

A summary of the hull and machinery is prepared from these detailed figures, and on this sheet is applied the current rate of expense. This is not constant for hull and machinery nor even for the separate jobs, since the expense rates of the various departments differ greatly, as described above.

The sum, then, of the material, labor and expense for the hull and machinery gives the estimated cost of the vessel. Throughout the process of estimating, check methods are continually applied, so that there is little possibility of a large error appearing in the process.

STANDARDIZATION.

To avoid repeat operations and to obtain uniform results, the various groups should be standardized. The general method of standardizing a group is, first, to ascertain the theoretical calculation by which sizes are determined; second, tabulate from practice the various sizes; third, apply the theoretical calculations and from practice obtain the coefficient so that the result may coincide with those usually adopted; fourth, calculate and tabulate results throughout the entire range of requirements. A few examples are as follows:

The size of the circulating pump depends upon the amount of steam to be condensed, the temperature of the sea water, the vacuum, and the percentage of the rated capacity of the pump in actual service. After having determined the amount of steam used by the various types of engines, the amount of water required by the theoretical calculation is determined and this amount compared with the rated capacity of the pump indicating that, in normal running condition, the pump is working at a certain percentage of its rated capacity. Tabular statements are then prepared for several temperatures of sea water and for predetermined water rates and vacuums for the several types of engines. Without calculation it is then possible to ascertain from this tabulation the normal size of a circulating pump for compound, triple, quadruple, turbine or electric drive, for several temperatures of sea water, the instructions giving the temperature to be used for the various routes.

The same method applies equally well to the hull jobs. In anchor gear, for instance, the size of the hawse pipe must be sufficient to prevent the chain shackles from fouling under all conditions. From practice, the clearance over the diagonal length of the chain shackle is plotted, to which is added the diagonal length of the shackle for determining the diameter of the hawse pipe. The length of the hawse pipe must be sufficient to permit of the proper housing of the stockless anchor. The top and bottom thicknesses and the dimensions of the lips are plotted from practice. With the standardized dimensions, hawse pipes are determined for all sizes of chains and the weights calculated. The dimensions of chain pipes, devil claws, cable clenches, hawse-pipe covers and anchor davits are similarly determined and placed in tabular form. The weights and costs throughout the entire range are carefully calculated and tabulated, so that for any size vessel or any size chain the weights and standard costs of not only the above fittings but the windlasses, anchors and chains themselves can be immediately obtained either in detail or in total.

A brief description of the method of applying the standardized information is given by an example for determining the size of the main engine when not specified. A tabular statement is prepared, giving the minimum, normal and maximum horse-power; the size of the engine; the minimum, normal and maximum revolutions; together with reference plans, hull numbers, and condition of patterns for the various engines constructed, with intermediate sizes where the sizes constructed are not sufficient to cover the entire range of horse-powers. Based on propeller performance, a tabular statement is prepared, giving the normal revolutions for varying speeds and drafts. Following the direction of the typewritten instructions, it is merely necessary to ascertain from the latter table the normal revolutions for any given draught and speed, and from the tabular statement of engines pick out the proper size. Reference is then made to a weight and cost folder for this particular size of engine, from which can be obtained at once the total net weight, the total gross weight, the standard cost of material and hours of labor. Current cost is obtained from the above by factors.

Similarly, the proper size of the condenser may be determined, and reference is made to the weight and cost folder which contains a list of condensers advanced by intervals of 100 square feet. This is accomplished by increasing or decreasing the length of the condensers actually constructed. The weights and costs are carefully calculated from bills of material, actual casting weights being used for gross weights and scale or calculated weights for net weights.

The principal weight factors for propellers are the diameter of the tail shaft, diameter of propeller, and area of developed surface. In determining the developed surface, the indicated thrust-per-square-inch method was adopted, using the information as published by Admiral Dyson, together with the actual practice used on merchant ships.

Similar methods can be applied to nearly all other jobs, such as forced draft systems, boilers, stacks, uptakes, lagging, shafting, auxiliary condensers, feed water heaters, refrigerating plants, and even tools, instruments and spares.

While the machinery jobs lend themselves better to standardization, similar methods may be applied to the hull jobs, and a few of these will be described.

The determination of the weight of the structural hull resolves itself into two operations: First, the determination of surfaces and lengths according to the dimensions and model; second, the determination of unit weights for those surfaces and lengths. The surfaces and lineal dimensions can be determined directly from a series of standardized lines somewhat similar to those described in the very instructive paper by Mr. A. J. C. Robertson, appearing in the Transactions of 1920. These standardized lines were developed by making use of the experiments of Naval Constructor McEntee appearing in the Transactions for 1919, and also from the various other model experiments. Investigations were also made regarding wetted surface formulae in order that the wetted surface for any particular model could be quickly and accurately determined. Taylor's formula was adopted as being the simplest formula, the accuracy being dependent only upon the accuracy of the coefficient. A series of curves of coefficients has been developed so that for any length, for any breadth, for any draught, and for any block coefficient, the surface coefficient could be obtained within the desired degree of accuracy.

The results of the standardization of lines have been incorporated in a folder with typewritten instructions so that a complete set of lines can be at once drawn up for any condition without fairing, or that a particular cross-section can be obtained without the use of a set of lines; also, that the areas of any particular cross-section to any height and the girths of any cross-section to any height can be obtained without the necessity of drawing lines or that the entire surface can be obtained by a simple calculation.

The unit weights are established by the classification society under which the vessel is constructed, and tables of coefficients have been established for laps, butts, straps, rivets, etc.

In joiner work standard drawings are made for the various items of portable furniture, such as berths, lockers, transoms, etc., and the number of board feet of lumber of various kinds, together with the amount of hardware for each of these items, have been tabulated. The various kinds of bulkheads and joiner decks have been standardized for dimensions and the quantities reduced to lineal or square-foot basis. The quantities for complete pilot houses and rooms for the various officers have been tabulated, so that it is unnecessary to make these detailed calculations for each estimate.

The work of standardization is performed during the intervals between estimates, and, when once started, the time saved on jobs already standardized can be utilized for further standardization. It is believed that the time-saving element and the uniformity and accuracy of results well warrant the labor expended; certainly, after the standardization is complete, the time required to prepare an accurate estimate is very much reduced.

DISCUSSION.

THE PRESIDENT:—The paper on "Cost Accounting and Estimating" embodies the result of a great deal of experience. Mr. Schulze quite naturally, but quite incorrectly, thought that the chairman was referring to various meetings which he himself had with the chairman, in the chairman's official capacity as a naval officer. That thought was not at all in the chairman's mind. What the chairman really referred to was the very difficult task throughout the period of the war of determining equitably and with reasonable accuracy the actual amounts of money which the naval department had contracted to give to those who were engaged in the naval construction program, the total costs involved approaching very closely to $1,000,000,000. It was that particular class of work which the chairman had in mind, and all of us have learned a great deal about costs, especially *overhead costs,* during the past five or six years. We will be glad to hear any comment upon this paper contributed by Mr. Schulze.

PROFESSOR HERBERT C. SADLER, *Member of Council:*—I think that Mr. Schulze has given us a very clear and concise method of procedure for getting out estimates, and on that I have no criticism to make at all, but I do feel that the value of the paper would be greatly enhanced if he could see his way to give us the values of some of the coefficients he refers to. (Applause.) Perhaps I am asking a little too much, but it seems to me that in the long run everybody is going to gain, if they are willing, up to a certain point, to give information that may appear somewhat confidential. I think the profession as a whole will gain because there is an incentive for the next man also to give his experience and data.

I think that any of us who have done estimating know that it is an extremely valuable thing to have a few coefficients, even though they do not apply exactly to the case we have under consideration, as a basis from which to start on our own estimate. I just throw that out as a hint, because in his last remarks Mr. Schulze mentioned that he would be glad to show us some of his information. If he would include that in an appendix to his paper, I think it would be very valuable. (Applause.)

MR. JOHN T. DALCHER, *Member:*—The paper in question is one that has particularly appealed to me, and its importance is readily recognized in view of the large evolutions regarding cost of manufacture through which we are passing at the present time.

The chief function of the estimator is to work out as accurately as possible the factory cost of a proposed ship based on previous cost records obtained from the accounting department. Where such records are not available the estimate is based entirely upon previous experience and good judgment of the estimator, and it is therefore quite apparent that his qualifications must be based on a sound training in the shipbuilding field and, if it covers both theoretical and practical knowledge, is so much more advantageous.

Having in view the fact that cost records vary in the different yards due to variety of methods and labor conditions, the estimator must be guided primarily by these records, and if none are available his judgment must be based on general conditions of the particular shipyard.

Although the primary function of the accounting department is to furnish information to the management, the fact should be emphasized that the more accurate the data turned over to the estimating department the more accurate and reliable the estimates will be. A general tendency of the accounting department has been to neglect this item, and it is to be hoped that in the future more attention will be paid to the return costs both from the heads of departments in the yard and the accounting department, so as to render the basic information for the estimating department more concise.

As is well known in shipbuilding practice, the time allowed for an estimate varies to suit circumstances, and it is therefore essential that the estimator be prepared to make a quick and reliable estimate based on information usually available in the form of specifications. If these are not available or if they consist only of a meager outline, it is to be recommended that, whenever time permits, they be accompanied by an outline specification upon which the actual estimate is based.

In order to render a quick and reliable estimate the method of computing curves to cover the cost of the various details such as piping systems, etc., is essential. They are generally based on a standard practice in force at the particular yard, and if the specifications in question demand a higher or lower type of vessel the points on the curve will be chosen accordingly above or below.

The efficiency and standard of an estimating department is directly based on the amount and quality of information in the form of tables and curves on hand, and the methods proposed to attain that end by Mr. Schulze are to be highly recommended.

Mr. T. M. Cornbrooks, *Member* (Communicated):—This paper is very interesting to one who has spent a number of years in developing a similar scheme for estimating and who was enabled to develop a system at Sparrows Point which was very much on the lines laid down by Mr. Schulze.

It has always impressed me that, considering the magnitude of the undertaking and the large sums of money involved, there had been no definite attempt made, until a few years ago, to properly analyze costs and to work up factors which would be valuable for estimating purposes, so that an estimate could be quickly and accurately made. The old rule of 3B or the "guess method" was used by most estimators and the wonder is that, considering such crude methods, the yards were able to exist.

The scheme which we used was to analyze every ship which had been built, both to determine factors for estimating the materials involved in a ship of similar design and for labor involved, also to tabulate all standards, such as side lights, deck scuttles, valves, fittings, flanges, furnace fronts, etc., so that an estimate of materials could be worked up very quickly or the costs entered per unit.

We analyzed the returned costs of each ship as completed by first checking the materials as charged on the drawings and orders and then from this analyzing the labor cost on the unit basis. We found in some cases it was necessary to use an empirical formula which we tested out on a number of different types before adopting as a standard. This applied principally to such matters as painting steel hull and other kindred jobs.

In analyzing the labor costs we used both the hour and dollar costs as a unit, as we found that in ordinary times when the wages did not fluctuate it was much quicker to use the dollar unit, and when wages began to fluctuate, due to the late disturbance, it was necessary to use the hour unit rather than the dollar. We were also able by this method to determine the effect of overload and underload on the various shops and to have some judgment as to the most efficient condition for the different shops.

In addition to the value derived for the estimator from this analysis there is another feature which is not touched upon by Mr. Schulze but which the writer has found to be extremely valuable; regardless of the difference in the design, by comparing the unit hour or dollar cost of various ships we were enabled to judge the efficiency of the various trades on the various contracts. One point which I have mentioned is extremely important in any analysis, and that is to determine first that the base figure, such as the amount of material which is charged to a contract, is correct; otherwise the unit is of no value whatever. This, we decided, required the service of an experienced designer who could take the return weights and check the same by the original design and the orders before using it as a base.

For the factors used in determining the coefficient to be used in working out the hull steel weights we had our line man, who worked on the marble slabs, determine this as part of the job of laying down and fairing the lines so that our data were always up to date.

From the prices which are quoted by some shipbuilding companies at various times, it would appear that some of our shipbuilders are still using the antiquated 3B method.

Too often the attitude of the accounting division is that the accounts should be kept in such shape as will satisfy their own requirements only. This is a very serious mistake. To secure full advantage of the money spent in keeping costs they should be so kept that the management can always analyze them and determine the efficiency of the various departments, also the various designs. This can easily be arranged without going into too many small detail divisions.

In regard to comparing costs and data from different yards, there is no standard subdivision of costs in use. For instance, some yards keep the steel hull complete, including cargo ports, hatches, doors, etc., in one division, while others keep only the main structure in one item and lump the doors, hatches, etc., in with other miscellaneous fittings.

The President:—Is there any further discussion? If not, we will ask Mr. Schulze to make his rejoinder, covering the remarks which have been made in the discussion.

Mr. Schulze:—In regard to Professor Sadler's remarks, one object of the paper was to place before the various shipyards, particularly the later ones, the methods which have been adopted by the larger yards, in order that they may profit thereby. It is one of our objects to have the bids as nearly uniform as possible, based upon the actual conditions which exist at that yard. Too many bids have been put in upon the erroneous assumption that they might be able to do something better than they could, and probably forgetting an item, and one of the objects of this paper has been to let the other yards know the system we have adopted.

The actual coefficients themselves would hardly apply to other yards, particularly those relating to costs. The weights themselves are a design factor, which would be very valuable, but I would hardly feel at liberty to place the actual figures officially before the Society. If, however, any member desires to see the details of the methods which are pursued, I would be glad to show them to him. The coefficiencies of weight depend on the particular boat.

I might inject here that, in some of the previous papers presented, it has been remarked that the architect puts in these fancy items. I think almost everybody who figures on a boat desires to figure it as cheaply as it can be done, and these requirements are generally the owner's requirements and not the architect's. We try to figure the boats as economically as possible. We do not figure on nickel piping where we think the owner will stand for the galvanized piping, but we have to contend with the specific requirements of the owner, and we know that in certain cases some owners will require a higher grade of finish than others. I desire to disabuse the minds of the members that the architect of his own accord puts in a higher grade article than he thinks the owner is willing to pay for.

THE PRESIDENT:—Mr. Schulze's comments are very pertinent. As to the coefficients, I imagined he would not be in a position to give you much help in that direction, because the method of keeping costs in nearly all the yards is quite different.

I take this opportunity, on behalf of the Society, to thank Mr. Schulze for his very complete and interesting paper.

Paper No. 12, entitled "Calculation of the Transverse Strength of Submarines by Marbec's Method," by Professor William Hovgaard, member of the Society, is next on the program. In the absence of Professor Hovgaard, the paper will be presented, in abstract, by Professor Sadler.

Professor Sadler presented the paper in abstract and at its conclusion said:

"A paper like this will cause very little discussion as it is beyond some of us, but I would like to point out the fact that a fundamental investigation of this kind cannot be other than of great benefit in advancing our knowledge of the stresses that will possibly occur in structures of this character, and in the end a purely practical man will benefit by this rather fundamental investigation."

CALCULATION OF THE TRANSVERSE STRENGTH OF SUBMARINES BY MARBEC'S METHOD.

By Professor William Hovgaard, Member.

[Read at the twenty-ninth general meeting of the Society of Naval Architects and Marine Engineers, held in New York, November 17 and 18, 1921.]

The French naval constructor Marbec in 1905 contributed an essay on "Dilatation des Tuyautages" to *Mémorial du Génie Maritime,* in which he dealt with the strength of closed elastic rings of uniform section and of relatively small transverse dimensions by a method based on the fundamental work of M. Maurice Lévy. In Bulletin de l'Association Technique Maritime for 1908, in a paper entitled "Théorie de L'Équilibre d'une Lame Élastique," he developed the method further and applied it not only to a simple closed ring but also to arches. The method was for the first time, I believe, explained in English by Marbec himself in 1911, when he read a paper before the Institution of Naval Architects, "Notes on the Collapsing of Curved Beams and Curved Elastic Strips"; and in 1921 Mr. W. R. G. Whiting published the results of an application of the method to elliptical forms in a paper, "The Strength of Submarine Vessels," read before the same institution. In Germany Marbec's method was explained and applied to arches by Dr. Rudolph Mayer in *Zeitschrift für Mathematik und Physik,* 1913.

I shall endeavor to explain the method as briefly as possible, without following all the interesting side issues of M. Marbec, including only the steps necessary to an understanding of the method and its intelligent application to problems occurring in the design of closed frame rings, and more especially of frames in submarines, in cases where the resultant effective forces can be assumed to be equivalent to a uniform pressure all around the circumference. The proof here given is direct and simple and is essentially that given by Dr. Mayer. The method of application I have developed into a form which I believe is suitable for practical purposes and is exemplified in the accompanying plates.

Marbec's method is based ultimately on the same fundamental formula as that used in my work on "Structural Design of Warships" in the treatment of the closed frame ring:

$$d\,\theta = \frac{M}{EI} \tag{1}$$

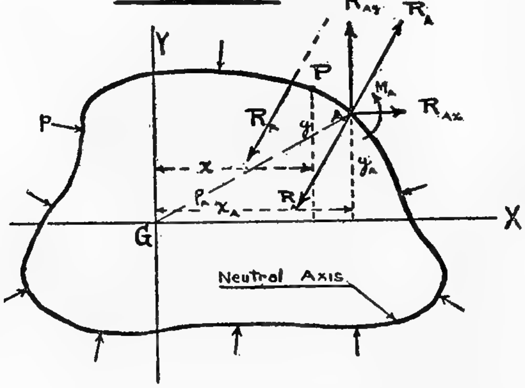
where $a\theta$ is the change in curvature. Marbec also makes use of the same equations of condition based on the principle of continuity. This must necessarily be so, but in determining the unknown bending moments and reactions Marbec follows a different path and by an elegant graphical method arrives at a solution which exhibits the results in such a form that it is easy to visualize the general distribution of the moments and reactions. The method appears to be simpler in application than any other, but, as I have not had an opportunity to compare it thoroughly with other methods, I am not certain that it is in all cases and for all purposes superior.

The reason why Marbec's method has not become better known than it is today, ten years after it was explained in the Institution of Naval Architects, is probably the abstract form in which it was then presented.

Mr. Whiting's presentation of the method is brief and cannot well be understood without a study of Marbec's papers.

Marbec deals first with an independent closed frame ring of any form and of varying section subject to a uniform pressure, external or internal.

FIG. 1.



Referring to Fig. 1, let p be the pressure per unit length of the ring. The contour line represents the neutral axis, which has a total length, measured along the girth, L. At any point A all the molecular stress forces acting on the section can be represented by a resultant force R_A and a couple M_A, but the same result would be obtained if the force R_A were acting parallel with itself at a certain distance from P but rigidly connected with the ring so as to produce the same reaction and moment in the section. In that case we might imagine two equal and opposite forces R_A to be acting at P, of which one might be conceived as a free direct force, the other as forming a couple M_A together with the force acting away from the point P. R_A is called by Marbec "the internal resultant" (*la résultante interne*).

The frame ring is characterized by its form and flexibility. The flexibility ε at any point is such that the change in curvature produced by a bending moment M is equal to εM. Hence, according to the elementary theory of bending

$$\varepsilon = \frac{1}{EI}$$

being the change of curvature due to a bending moment of unity strength. Put

$$\varepsilon\, ds = dm$$

and conceive the flexibility as a sort of density, then dm may be considered as the mass of the elemental arc ds. We may now by integration determine the total flexibility mass of the ring:

$$m = \int_0^L dm$$

and may find its center of gravity, G, as well as its moment of inertia with respect to any axis just as in the case of actual masses.

Let GX and GY be the principal axes of inertia, then

$$\int_0^L x\,dm=0, \qquad \int_0^L y\,dm=0, \qquad \int_0^L xy\,dm=0 \tag{2}$$

The following abbreviations are adopted:

$$\left.\begin{aligned} &\int_0^L x^2\,dm=i_y^2 m, \quad \int_0^L y^2\,dm=i_x^2 m, \quad \int_0^L (x^2+y^2)\,dm=\int_0^L \rho^2\,dm=i_\rho^2 m \\ &\int_0^L (x^2+y^2)\,x\,dm=\int_0^L \rho^2\,x\,dm=i_{\rho y}^3\,m, \quad \int_0^L (x^2+y^2)\,y\,dm=\int_0^L \rho^2\,y\,dm=i_{\rho x}^3\,m \end{aligned}\right\} \tag{3}$$

All of these quantities are multiples of m, ρ is the vector from G to any point on the ring, i_y and i_x are the radii of gyration of the ring respectively about the axes GY and GX and i_ρ is the radius of gyration about an axis through G normal to the plane of the ring, $i_\rho^2 m$ being the polar moment of inertia about G. The expressions $i^3_{\rho y}m$ and $i^3_{\rho x}m$ are a sort of product-moments of inertia.

At any point A there is acting the internal reaction R_A and the bending moment M_A. R_A has the components R_{Ax} and R_{Ay}. These unknown quantities are determined as usual from the equations of conditions:

$$\int_0^L M\,dm=0, \qquad \int_0^L M\,(y_A-y)\,dm=0, \qquad \int_0^L M\,(x_A-x)\,dm=0 \tag{4}$$

where x, y are the coordinates of a running point P.

At any such point P we have:

$$M=M_A+R_{Ay}(x_A-x)+R_{Ax}(y_A-y)-\frac{p}{2}(x_A^2-2x_Ax+x^2+y_A^2-2y_Ay+y^2)$$

$$M=M_A+R_{Ay}(x_A-x)+R_{Ax}(y_A-y)-\frac{p}{2}(\rho_A^2+\rho^2-2x_Ax-2y_Ay) \tag{5}$$

Substituting in (4) and carrying out the integration, we find, after suitable transformations:

$$R_{Ax}=p\left(y_A-\frac{i_{\rho x}^3}{2i_x^2}\right) \tag{6}$$

$$R_{Ay}=p\left(x_A-\frac{i_{\rho y}^3}{2i_y^2}\right) \tag{7}$$

Put

$$\frac{i_{\rho x}^3}{2i_x^2}=b \text{ and } \frac{i_{\rho y}^3}{2i_y^2}=a \tag{8}$$

$$\therefore R_{Ax}=p\,(y_A-b) \tag{9}$$

$$R_{Ay}=p\,(x_A-a) \tag{10}$$

Further, we find from the first of equations (4):

$$M_A = \frac{p}{2}(i_\rho^2 - \rho_A^2 + 2ax_A + 2by_A) \tag{11}$$

Add to this the identity:

$$\frac{p}{2}(a^2 + b^2 - a^2 - b^2) = 0$$

$$\therefore\ M_A = \frac{p}{2}(i_\rho^2 + a^2 + b^2 - \rho_A^2 - a^2 - b^2 + 2ax_A + 2by_A)$$

But $i_\rho^2 + a^2 + b^2$ is the square of the radius of gyration i_o, of the ring relative to a point O which has the coordinates a and b in the coordinate system, GX, GY.

Hence:

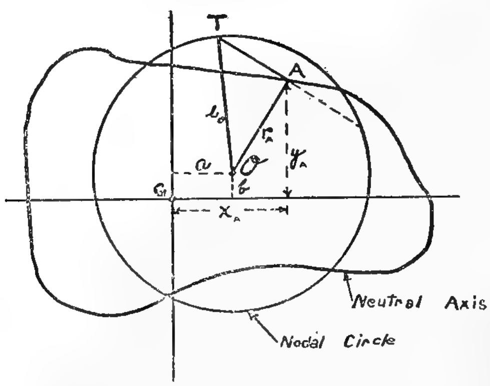
$$i_o^2 = i_\rho^2 + a^2 + b^2 \tag{12}$$

and

$$M_A = \frac{p}{2}(i_o^2 - \rho_A^2 - a^2 - b^2 + 2ax_A + 2by_A) \tag{11'}$$

Draw a circle with radius i_o and with O as center as shown in Fig. 2. This circle is

FIG. 2.



the circle of polar inertia. Join OA and draw AT normal to OA to cut the circle at T. Then $OT = i_o$ and $\overline{AT}^2 = i_o^2 - \overline{OA}^2$

and

$$\overline{OA}^2 = (x_A - a)^2 + (y_A - b)^2 = \rho_A^2 + a^2 + b^2 - 2ax_A - 2by_A \tag{13}$$

If we call the radius vector from O to any point on the neutral axis r we have:

$$\overline{OA}^2 = r_A^2$$

Hence:

$$\overline{AT}^2 = i_o^2 - r_A^2$$

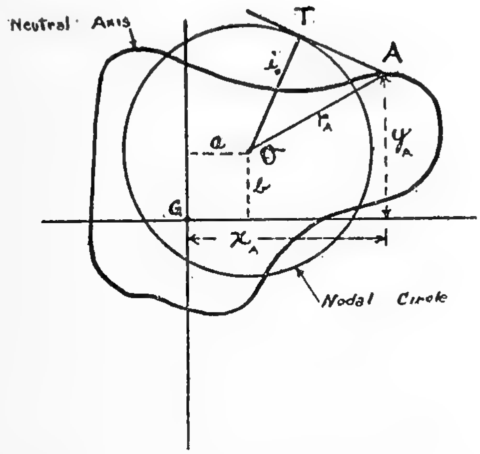
Substituting in (11′), we find that:

$$M_A = \frac{p}{2}\overline{AT}^2 = \frac{p}{2}(i_o^2 - r_A^2)$$

or, generally, at any point:

$$M = \frac{p}{2}(i_o^2 - r^2) \tag{14}$$

FIG. 3.



If A is outside the circle as in Fig. 3, draw a tangent AT to the circle and join OT. Then:

$$\overline{AT}^2 = \overline{OA}^2 - i_o^2 = r_A^2 - i_o^2,$$

but $r_A = OA$ has the same value as when A is inside the circle and as given by (13). Substituting in (11′) we find:

$$M_A = \frac{p}{2}(i_o^2 - r_A^2) = -\frac{p}{2}\overline{AT}^2$$

Hence the bending moment is again found by the formula (14), but is of a sign opposite to that when it is inside. In either case the bending moment is equal to the product of one-half the fluid pressure and the "power" of the point under consideration relative to the circle of polar inertia.

At the points of intersection between the frame and the circle the bending moment changes sign, its value is zero, and there is no change of curvature. These are points of inflection or nodes, and, since all the nodes must lie on the circle of inertia, it is also called the "nodal circle."

The resultant of R_x and R_y at any point is R.

$$R^2 = R_x^2 + R_y^2 = p^2(y-b)^2 + p^2(x-a)^2 = p^2 r^2,$$

$$R = pr \tag{15}$$

showing that the internal resultant at any point is in magnitude equal to the product of the fluid pressure multiplied by the vector at that point from the center of the nodal circle.

The direction cosines of the resultant are:

$$\frac{R_x}{R} = -\frac{y-b}{r} \text{ and } \frac{R_y}{R} = \frac{x-a}{r} \tag{16}$$

Hence the internal resultant is normal to the vector from O to the point. The distance z of the internal resultant from the point under consideration, being the leverage with which it acts in producing a bending couple, must be such that

$$z = \frac{M}{R} = \frac{\frac{p}{2}(i_o^2 - r^2)}{pr} = \frac{i_o^2 - r^2}{2r} = \frac{\overline{AT}^2}{2r} \qquad (17)$$

Thus the resultant acts along the radical axis of the point and the circle. The envelope of the internal resultants forms a funicular curve, which, when the pressure surface is of circular section, forms a circle concentric with that surface. Summing up we arrive at the following conclusions:

1. For a ring of any form and flexibility, when subject to a uniform fluid pressure, there exists an important circle called the "nodal circle."

2. Its center O has the coordinates $x = a$ and $y = b$ referred to a system of coordinates with origin at the center of gravity G of the flexibility mass of the ring and with axes coinciding with the principal axes of inertia of the ring. The coordinates of O are found from:

$$a = \frac{\int_0^L \rho^2 x dm}{2\int_0^L x^2 dm}, \qquad b = \frac{\int_0^L \rho^2 y dm}{2\int_0^L y^2 dm}$$

and the radius of the circle from:

$$i_o^2 = i_p^2 + a^2 + b^2$$

where i_p is the radius of gyration of the ring with respect to G as a pole.

3. For any point in the ring with vector r from the center of the nodal circle the internal resultant is given by $R = pr$ and R is acting normal to the vector along the radical axis of the point and the circle.

4. The bending moment at any point of the ring is equal to the product of one-half the fluid pressure and the "power" of the point relative to the nodal circle and is always found from:

$$M = \frac{p}{2}(i_o^2 - r^2)$$

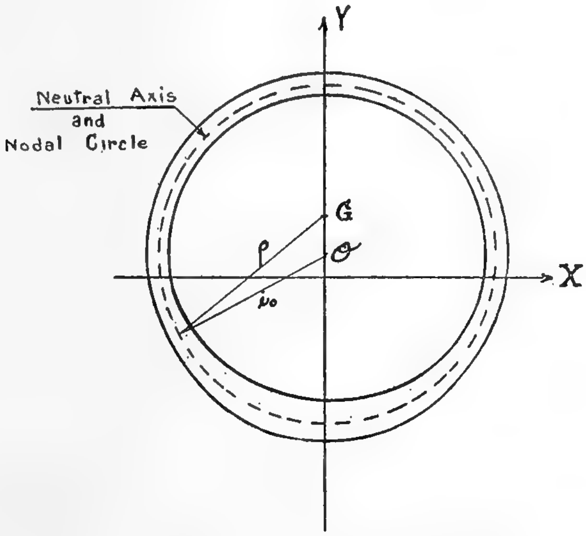
SPECIAL CASES.

We assume again the pressure to be uniform.

If a ring has two axes of symmetry both as regards form and flexibility, although the flexibilities may not be uniformly distributed, the center of the nodal circle will coincide with the center of gravity—O coincides with G—since in that case $\int_0^L \rho^2 x dm$ and $\int_0^L \rho^2 y dm$ and hence a and b are zero. If a ring has only one axis of symmetry, say the Y axis, as generally is the case in submarine vessels, O will be in this axis, a will be zero and only b needs to be calculated.

When the neutral axis is a circle, although, maybe, of varying flexibility, it can be shown that in case of relatively slender frames, whatever the position of G, the center of the nodal circle O will always be in the center of the circle formed by the neutral axis. In this case the radius of the nodal circle, which is the radius of gyration about O as a pole, must be the same as that of the circle of the neutral axis. Hence the bending moment is everywhere

FIG. 4.



zero. For instance, in Fig. 4 the center of gravity of the ring is in the vertical axis but above the center of the circle formed by the neutral axis, while O is found in that center and hence M is everywhere equal to zero. This is important, because it shows that it may be possible by proper construction to reduce the bending moments very considerably in noncircular frame rings by so designing them that the neutral axis shall be circular or nearly so. Actually the bending moments would not be exactly zero, because the pressures referred to or projected on to the neutral axis would not be uniform, but by proper adjustments it should be possible to reduce the bending moments to a minimum.

If a portion of a ring with circular neutral axis is entirely inflexible, we have $\varepsilon = 0$ for that portion, but it is still true that the center of the nodal circle coincides with the center of the circle formed by the neutral axis and the bending moments are zero. This case

FIG. 5.

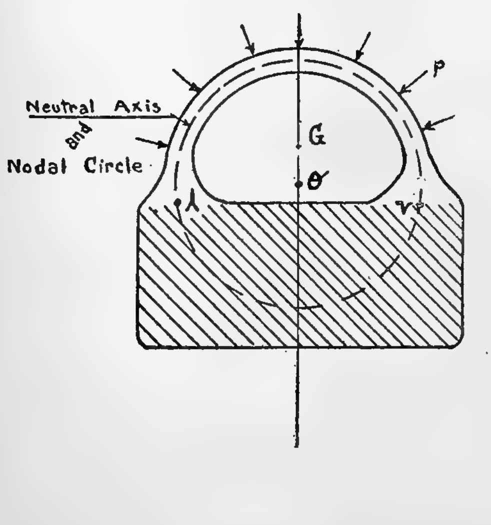
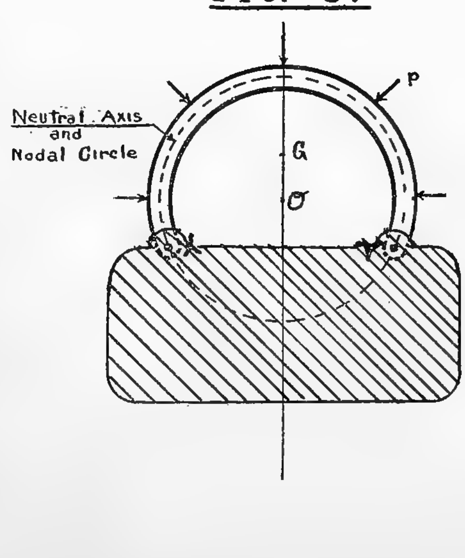


FIG. 6.



occurs, as illustrated in Figs. 5 and 6, where the ends of a circular arch are respectively fixed or connected by pin joints to an absolutely rigid structure. In such case we may imagine the circle of the neutral axis to be continued through the rigid mass of the foundation. Even if the flexibility is quite unevenly distributed in the arches, and the center of gravity does not lie in the vertical through the center of the circle of the neutral axis, the center of the nodal circle O will still coincide with the center of that circle and there will be no bending in the arch.

It is important to note that the condition for the truth of these statements is that the extensibility and compressibility of the ring all around the circle is negligible compared with the flexibility. If, for instance, the two points λ and ν in Figs. 5 and 6 approach each other under the effects of the pressure, the above theorems do not hold good.

Consider next a noncircular arch fixed at both ends to a foundation of absolute rigidity (Fig. 7). Here, again, the fundamental theorem is applicable, simply assigning to each part its flexibility. The rigid part $\lambda\nu$ does not enter into the calculations for G or for the nodal circle, since its flexibility is zero.

If a closed frame ring is hinged at one point A (Fig. 8), the flexibility is infinite at

FIG. 7.

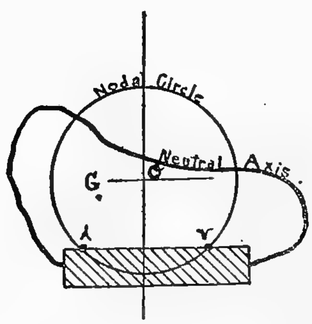
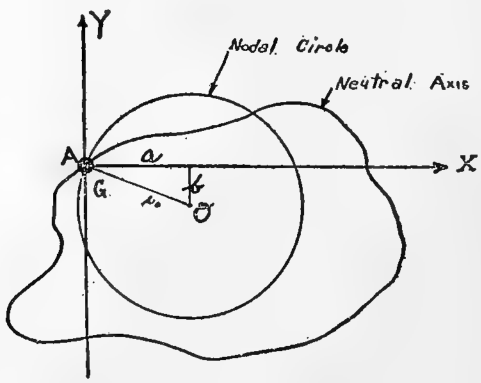


FIG. 8.



that point and the center of gravity of the flexibility, G, coincides with it. The ordinates of O are determined as usual. The nodal circle passes through A where the bending moment is zero and, since

$$i_\rho = 0, \text{ we have } i_0^2 = a^2 + b^2.$$

The method is illustrated in Plates 1 to 11. Plate 1 shows the form and structural details of the frame system of a submerged body designed for a special purpose and calculated to stand a pressure corresponding to a head of 50 feet of water. The following plates, which are believed to be self-explanatory, give the calculations. Since the frame is not quite symmetrical about a horizontal axis, the example here given is much more involved than where there are two axes of symmetry.

Professor H. H. W. Keith, of the Massachusetts Institute of Technology, has prepared Plate 1, and Mr. F. A. Magoun, of the same institute, has prepared the diagrams in the text and performed the calculations of the plates.

DISCUSSION.

The President:—The paper of Professor Hovgaard on "Calculation of the Transverse Strength of Submarines by Marbec's Method" is now before you for discussion. The Chair by no means wishes to speak irrelevantly, but he desires to refer to something which, in a measure, is connected with earlier Transactions of this Society. A paper of this kind requires a great deal of work. The incorporation of such papers in the Proceedings of our Society is exceedingly valuable for our Transactions are really encyclopedias of naval architecture and marine engineering data. I know of many who consult the earlier volumes to obtain information which is very important in their later professional work.

Therefore, while a paper of this kind may not elicit discussion, it is of very great value, and I am sure that you will desire that the thanks of the Society be tendered to Professor Hovgaard for his valuable contribution.

Professor Hovgaard (Communicated):—I wish to point out that this paper is not merely of academic interest. The problem of the strength of submarines is an actual and practical problem, as will be admitted by those who have to design such vessels, as also by those who have to operate them and whose lives depend on their strength. The calculation of transverse strength is of enhanced importance after the introduction of depth bombs, which makes it necessary to design submarines to stand the pressures at much greater depth of immersion than formerly. It is a problem which the designer of submarines cannot escape. The method here proposed differs from those previously used in its greater simplicity and in being graphical, allowing the results to be more clearly exhibited. The numerical example is purposely chosen so as to cover a very general case, *i. e.,* that of a section with only one axis of symmetry. Where two axes of symmetry are found, the calculations will be very much simplified and the elegance of the method will be more apparent. It is the first time, to my knowledge, that a complete numerical example has been given in illustration of Marbec's method, facilitating its application in practice. The paper is written primarily for this purpose, that is, for direct application in practical work. At the same time, the proof of the method is presented in what I believe is the simplest and most direct form.

If the best result is to be obtained in the construction of modern submarines, it is necessary to make scientific calculations in conjunction with experimental tests. In this way the Germans effected very considerable savings in the weight of the strength hull of their submarines during the war.

The President:—We have now come to the end of our morning program. Immediately after adjournment there will be a brief meeting of the Council. We will now stand adjourned until two o'clock.

Adjourned.

FOURTH SESSION.

FRIDAY AFTERNOON, NOVEMBER 18, 1921.

Professor William F. Durand, Professor of Mechanical Engineering, Stanford University, California, and an Honorary Vice-President of the Society, acting as chairman, called the meeting to order at two o'clock.

THE CHAIRMAN:—The first item of business this afternoon is action on applications for membership of various grades which have come in, and been considered by the Council subsequently to the action taken on a similar order of business at a preceding meeting. I will ask the Secretary to read the names of the applicants.

ACTING SECRETARY BAXTER read the names of the applicants for membership as follows:

Members (23).

Andrew J. Birch, Assistant to President, New York Harbor Dry Dock, 32 Pearl Street, New York, N. Y. P. O. address, Douglas Road, Emerson Hill, S. I., N. Y.

M. W. Buchanan, Manager, Factory Sales, Diehl Manufacturing Co., Elizabeth, N. J. P. O. address, 127 Monmouth Road, Elizabeth, N. J.

Joseph G. Callahan, Marine Engineer (Operating), Isthmian Steamship Lines, 39 Cortlandt Street, New York, N. Y. P. O. address, 90 Nonotuck Street, Holyoke, Mass.

Lawrence W. Clark, Technical Staff, Repair Department, New York & Cuba Steamship Co., New York, N. Y.

John H. Conditt, Port Superintendent Engineer, Rio de Janeiro District, U. S. S. B., E. F. C. P. O. address, 110, Avenue Rio Branco, Rio de Janeiro, Brazil.

James H. Davidson, Vice-President, Staten Island Shipbuilding Co., Staten Island, N. Y. P. O. address, West Brighton, Staten Island, N. Y.

Andre Dupont, Administrateur-Délégué des Ateliers et Chantiers de Bretagne. P. O. address, 53, rue Viviene, Paris.

H. J. W. Fay, Second Vice-President and Manager of Operations, Submarine Signal Co., 84 State Street, Boston, Mass. P. O. address, Westborough, Mass.

H. L. Foshee, Chief Engineer, S. S. Aeolus, Munson Steamship Line, New York, N.Y. P. O. address, 7110 Ridge Court, Brooklyn, N. Y.

George C. Fuller, Manager, Marine Sales Department, The Superheater Co., 17 East 42d Street, New York, N. Y.

Walter J. Harsant, Chief Engineer, Pittsburgh Steamship Co., Rockefeller Building, Cleveland, Ohio.

Charles Hibbard, Superintendent Constructor, Lieutenant (C. C.), U. S. N., Lake Torpedo Boat Co. P. O. address, Lake Torpedo Boat Co., Bridgeport, Conn.

Harvey F. Johnson, Technical Assistant to the Engineer-in-Chief, U. S. Coast Guard. P. O. address, U. S. Coast Guard, Washington, D. C.

James Foster King, Chief Surveyor, The British Corporation for the Survey and Registry of Shipping, Glasgow, Scotland. P. O. address, 27 Kingsborough Gardens, Glasgow, Scotland.

James N. Macrae, Consulting Engineer, Marine and Fuel Oil, Apartment No. 3, 105 Park Avenue, East Orange, N. J.

Samuel L. Naphtaly, Vice-President and General Manager, Los Angeles Shipbuilding and Dry Dock Co., San Pedro, Cal. P. O. address, 306 Hobart Bldg., San Francisco, Cal.

Gerald B. Newby, Chief Draughtsman, Los Angeles Shipbuilding and Dry Dock Co. P. O. address, R. F. D. No. 3, Box 455, Long Beach, Cal.

Aubrey A. Ross, Engineer in Charge of Design and Manufacture of Marine Gears, General Electric Co. P. O. address, 14 Lakewood Avenue, Schenectady, N. Y.

Hugh W. Salbador, Lubrication Engineer, The Texas Co., 17 Battery Place, New York, N. Y. P. O. address, 9 Post Avenue, New York, N. Y.

Adolph Starr, Marine Erecting Engineer, Superheater Co., 17 E. 42d Street, New York, N. Y. P. O. address, 165 Audubon Ave., New York, N. Y.

Thos. B. Stillman, Assistant to Manager, Marine Department, Babcock & Wilcox Co., 85 Liberty Street, New York, N. Y.

Lloyd Swayne, Vice-President and Consulting Engineer, Swayne & Hoyt, Inc., San Francisco, Cal. P. O. address, 430 Sansome Street, San Francisco, Cal.

William Watters, Surveyor, Lloyd's Register of Shipping, Philadelphia, Pa. P. O. address, 6545 Torresdale Avenue, Philadelphia, Pa.

Associates (9).

Paul V. Cogan, Engineering Computer, Fore River Plant, Bethlehem Shipbuilding Corporation, Bethlehem, Pa.. P. O. address, 61 Farragut Road, South Boston, Mass.

William F. Dunning, Assistant to Manager, Marine Department, Standard Oil Company of New Jersey, 26 Broadway, New York, N. Y. P. O. address, Room 504, 26 Broadway, New York, N. Y.

Herbert S. Fitz Gibbon, President, The New Jersey Asbestos Co. P. O. address, 1 Water Street, New York, N. Y.

Thomas B. Hasler, Hasler & Co., Shipowners, New York, N. Y. P. O. address, Little Silver, N. J.

Thomas J. Kain, Assistant to the Secretary-Treasurer, Society of Naval Architects and Marine Engineers. P. O. address, 354 East 28th Street, Brooklyn, N. Y.

Bror Tamm, Foreman Draughtsman, Geo. Lawley & Son Corporation, Neponsit, Mass. P. O. address, 190 Hendrick Avenue, Quincy, Mass.

Einar S. Trosdal, President, New Jersey Shipbuilding & Dredging Co., Bayonne, N. J. P. O. address, Savannah, Ga.

Edward A. Simmons, President, Simmons-Boardman Publishing Co., 233 Broadway, New York, N. Y.

William M. Wampler, President, Ellcon Co., 50 Church Street, New York, N. Y.

Juniors (2).

Roland H. Baker, President and General Manager, General Construction and Repair Co., 304 Main Street, Cambridge, Mass. P. O. address, 6 Laurel Street, Chelsea, Mass.

John W. McCabe, Assistant Superintendent Engineer, A. H. Bull & Co., 40 West Street, New York, N. Y.

TRANSFERS.

Associate to Member (2).

Evers Burtner, Instructor in Naval Architecture, M. I. T. P. O. address, 81 Laighton Street, Lynn, Mass.

Adolph A. Gathemann, Port Engineer, U. S. Shipping Board, Boston, Mass. P. O. address, Hanover, Mass.

Junior to Member (3).

Theodore G. Grier, Hull Scientific Draughtsman, Wm. Cramp & Sons Ship and Engine Building Co., Philadelphia, Pa. P. O. address, 432 Trenton Avenue, Camden, N. J.

Kenneth W. Heinrich, Sales Engineer, Auxiliary Machinery, Bethlehem Shipbuilding Corporation. P. O. address, 1215 Wood Street, Bethlehem, Pa.

J. Herbert Todd, Superintendent, Clinton Dry Dock Co. P. O. address, 46 Rutland Road, Brooklyn, N. Y.

The Chairman:—Gentlemen, you have heard these names, which have been read, together with a recommendation of the Chair for their election to the various grades as read.

Mr. Howard C. Higgins, *Member*:—I move that the recommendation of the Council be adopted.

The Chairman:—This motion, if carried, will constitute the election for membership of these applicants in the various grades, as read by the Acting Secretary.

The motion was duly seconded, put to vote and carried.

The Chairman:—The next item of business, referring to the main order, will be the presentation of Paper No. 10, "Design and Construction of Passenger Steamers," by Mr. E. H. Rigg, a Member of Council.

Mr. Rigg:—I need hardly say, when I prepared this paper, that I had not the faintest indication of the momentous proposals that the world would be considering this week. It is worthy of note that, while we have the beginnings of a passenger fleet, we are still not represented in first-class liners of the Mauretania and Aquitania type, with a single possible exception, the Leviathan, which some of us hope to visit tomorrow, but she is unfortunately not in running condition. It occurs to me that the limitation of naval armaments proposals have opened up a vista of several first-class large 30-knot liners. The question of what to do with our battle cruisers is a very interesting one, and I think there is a great deal to be said, if we are permitted to say it, in favor of considering the conversion of these vessels into real Atlantic liners of 30-knot speed all the way over. I have thought the matter over in the past day or two, and while I am well aware that there would be many technical difficulties in the way, yet I think if the American traveling public were given the opportunity of patronizing such ships as these vessels can be made to be, we will have a real place in the North Atlantic passenger-carrying trade.

Battle cruisers are obviously built on speed lines; the Mauretania, if built on such lines, would make 30 knots for the power with which she now gets 26; this, however, would be at a materially lower displacement and, by the time passenger comfort had been fully considered, would not be easy in a ship of the Mauretania's length without reducing the passenger-carrying capacity to a serious extent. The battle cruisers above referred to, being about 100 feet longer, will naturally work out to better advantage as regards speed and comfort.

Mr. Rigg then abstracted the paper and at its conclusion said: "I may add that since writing the paper, the American Legion and the Southern Cross have already made records between New York and South America. The Shipping Board and the operators, the Munson Steamship Line, are to be congratulated, and I will leave it for them to say as to whether the builders should share in the congratulations."

DESIGN AND CONSTRUCTION OF PASSENGER STEAMERS.

By E. H. Rigg, Esq., Member of Council.

[Read at the twenty-ninth general meeting of the Society of Naval Architects and Marine Engineers, held in New York, November 17 and 18, 1921.]

To one who loves his profession it is hard to imagine a title which opens up greater possibilities in the way of a chance to contribute a worth-while paper to our Transactions. The subject could well be extended to the dimensions of a large book, so many and so intricate are the avenues opened up. Without going to such lengths, it will be my endeavor to review the field as it appears today to one engaged in the design and construction of such ships.

Our new merchant marine is replete with cargo carriers of all kinds, except perhaps in refrigerator ships, of which there are only a few; it has remained for a comparatively few yards to be privileged to build the nucleus of our hoped for post-war passenger fleet in the vessels of the Old North State and American Legion classes; a fleet also contributed to by captured German ships, reconditioned after the war.

A paper by Mr. Peskett on the design of steamships from the owner's point of view (T. I. N. A., London, 1914) is well worth reading before commencing a paper such as this. His experience has been ample, and his association with a fleet of the first order lends weight to his views. His paper opens up to view an excellent summary of the conditions to be faced in determining types and sizes. It follows this up by some helpful solutions of given cases, particularly considered cases being the historic Lusitania, Mauretania, and Aquitania; in other words, the development of the Cunard fleet up to the war.

The important task of satisfactorily drawing up a typical specification and contract is ably covered by the same author before the same institution one year ahead of the above quoted paper; this also gives a clear exposition of that particular and important problem. The designer of passenger ships, especially large ones, should be familiar with the ground covered in both these noteworthy papers; the Atlantic is no barrier to their usefulness.

The main items influencing a design are about as follows: Number and type of passengers; availability and nature of cargo; economical speed; safeguards to be adopted; harbor limitations, chiefly draught, but also length; radius of action, distance between ports; type of propelling machinery and fuel; climates to be traversed; governmental regulations; mail contracts and payments.

Before any figures can be put together these features must all be assessed and their quantities determined. No serious attempt has been made to put them in their relative order of importance, but that given above is roughly correct. Governmental and classification regulations, being fairly uniform, do not, as a rule, influence designs fundamentally in the sense that an American ship would vary greatly from a British or a French one to meet similar demands otherwise; there are differences, however, which must be taken into account before actual detailed work is undertaken.

Recent international conferences on tonnage, bulkheads, freeboard, lifeboats and manning and such matters tend towards a uniform settlement of these fundamentals which is altogether desirable.

In the opening sentences of this paper, reference was made to the magnitude of the task. In order not to unduly lengthen the paper, ocean-going ships will be primarily considered, such being the field to which our attention is mainly directed; other types, however, will not be neglected.

OCEAN PASSENGER VESSELS.

The great problem of today is to design and build ships that can be made economically satisfactory; first costs of two and one-half to three times prewar figures, soaring passage rates, people taxed to the limit and otherwise hard hit by the greatest calamity of all times, unrest and strikes, fleets sunk or in bad shape due to the war, all combine to make a real problem for owner and builder.

There is no doubt that the strike habit, recently, if not now prevalent in the premier shipbuilding country of the world, is driving away repair work and holding up new construction to a point where the premiership is coming within measurable distance of transfer; the fact that the strike habit is no monopoly of any one country helps to hold matters more in a state of balance and *in statu quo.*

Whatever may be true of cargo ships—for it is true that the general falling off of trade is as much responsible for the lines of tied-up ships as the end of the war and the completion of war-building programs—is not true of passenger ships. We are still short of these vessels; the lack of new orders and holding up of old ones is solely due to economic conditions, high first costs and inability to pay the rates necessarily asked, chiefly the former.

As is shown later, ocean passenger ship design is being influenced profoundly by causes arising from the war.

The economics of general cargo ships have lately formed the subject of several able papers. Mr. Robertson recently has contributed two to our Society and four or five such papers have been recently read in England and Scotland. With these as a guide, backed up by experience—which is always invaluable—it is hard to justify a poor result in the field covered. When it comes to passenger carrying we have an extension of the same problems. Speed in cargo carrying above 11 knots is not easy of justification in normal cases; it becomes of the essence in passenger ships.

The method of solution adopted by Mr. Anderson in his 1918 and 1920 papers before the London institution can be used in association with detailed knowledge of the passenger trade on any given route. In practice, the selection of dimensions and speeds narrows down to within close limits in average cases.

The large number of our recently completed passenger ships which have gone or are about to go into Pacific Ocean trade calls for comment. Of the sixteen 535 footers and the seven 522 footers, representing a gross tonnage of some 300,000, twelve of the larger and three of the smaller have gone into service on the Pacific; of the larger, two are still to be allocated, which indicates that the fleets to which allocations have been made are temporarily satisfied. The Pacific thus gets 67 per cent of the tonnage, and there are other indications that our Pacific trade will be large—our interest in China and its development, our nearness to her markets compared with Europe. The Philippine and the Hawaiian Islands make for commerce with the Pacific coast; our Australian and Japanese trade also calls for passenger and freight services.

Then, too, South American trade presents an opportunity awaiting revived foreign trade, improvement in the exchange rate from the foreigners' point of view, improved exporting methods on our part and the working out of the recent foreign trade financial legislation.

Passenger ships were ordered in great quantity in Britain following the war; a large amount of this tonnage has been suspended or cancelled. This suspended activity gives our new ships an opening to get in on the ground floor of the revival, of which signs are now multiplying.

We are struggling with a shortage of trained personnel and with some poor engineering due to rushed war conditions; the ships in service have not been without troubles of their own. They will get over those troubles or they will lose the trade to their British and Japanese competitors. Time and tide wait for no man, and trade goes to the fellow who is there to take it.

The more one contemplates the situation the more one sees that the hour has struck for an America taking her full place in world affairs as compared with an America of splendid isolation.

PASSENGER STEAMERS FOR SHELTERED WATERS.

Perhaps nowhere in the world are there such opportunities for lake, bay, sound and river navigation as in America. Our transactions contain many full papers on this subject, and it would be hard to name one who has contributed more to their design and building than has Mr. Frank E. Kirby. The problems are not as complicated as are those of the ocean; draught is usually limited, and lines adapted for high speed in shoal water are not the same as for deep water. Ports are closer and bunkers carried are lighter; fresh water from overboard is often available for boilers, if not for drinking. Cargo is generally carried in relatively small amounts, largely on deck rather than below. Fire risks are severe in these ships and must be seriously studied and minimized. In rivers and canals, bank erosion must be guarded against, and here the experimental tank has come to our aid in studying wave making. In some recent Hudson River vessels, in particular, wave making has been notably reduced, enabling greater speed to be maintained for the same erosive action or less of such action for equal speed.

Due to the war, probably, there has been almost nothing built lately in this class which calls for comment; with renewed opportunities for such travel let us hope for some new vessels to build. The opportunities for design and decoration of extensive passenger spaces are considerable, particularly in vessels for lakes, rivers and sounds.

In the public spaces the large central wells give opportunities for architectural effect not often found in ocean liners.

Many of these vessels in the past have been built with too little beam for satisfactory stability results; top decks have been increased or added in order to crowd on more passengers, the accident point having been found in more than one instance, notably the Eastland, in recent years. Some river steamers have found it necessary to set back the rails, thus limiting the passengers who can crowd top decks; also in boats traversing water with points of interest first on one side, then on the other, water ballast chambers in the wings have been fitted so that the engineer can fill the same on the off side and empty it again after passing the particular point, such as West Point Military Academy on the Hudson.

Paddle-wheel propulsion still holds its own for this type; the experimental tank is invaluable for correctly locating the wheel center to avoid disaster due to wave profile and wheel not meshing.

Paddle wheels have been recently severely put to it to hold their own with screws working in tunnels as a means of propulsion for shallow draught vessels. We have also seen a revival in proposals made many years ago which looked to the fitting of fixed guide blades abaft the revolving blades to recover some of the energy of the propeller race. It can be said that tunnel screws have definitely established their claims.

PASSENGER-REFRIGERATOR TRADES.

The carriage of meat, fruit and dairy products in cold storage has become a very large trade during this generation.

American, Australian and Argentine fresh meats are now eaten on European tables in large quantities, and at the same time the horrors of the live cattle trade are a thing of the past, thanks to refrigeration. Tropical fruits are enjoyed in northern latitudes in increasing quantities.

Perhaps the chief feature which leads to the passenger-refrigerator ship is the speed desirable for refrigerator ships—the less time on the voyage the better. Also, these cargoes are bulk rather than deadweight cargoes, which means that larger ships are needed for a given weight. Both these considerations lead to the desirability of increasing the revenues by carrying mails and passengers. The great white fleet of the United Fruit Company, one of our strongest and best managed lines, is undoubtedly a good illustration of this.

There are also some large meat carriers fitted with accommodations for passengers, a valuable revenue being derived therefrom to pay for the speed in excess of 11 knots, about a cargo carrying economical speed limit for vessels of moderate to large dimensions.

TREND OF DESIGN; OCEAN PASSENGER SHIPS.

As an indication of this, the following classes of ships designed in part and estimated on, since January, 1918, by one large shipyard in this country, may be of interest:

Length between perpendiculars, feet.	*Speed, knots.*	*Cabin passengers.*	*Deadweight.*
400	15	100	4,350
600	18	1,460	15,000
450	23	410	3,700
500	16	250	9,000
550	15¾	1,830	8,650
475	14½	445	5,530
360	13½	50	4,100
450	16	255	6,000
400	15	200	3,900

Several of these ships had third-class and steerage passengers in varying numbers, these quarters were portable to a large extent, so only the first and second-class quarters and permanent third-class cabin accommodation have been listed above, thus giving a better guide to the characteristics of the vessel. In the 600-foot ship, accommodation for 700 third-class passengers in permanent cabins is included; also in the 550-foot ship 1,160 such third-class are included. The list thus gives the real cabin accommodation, whether first, second or third.

The 23-knot ship was primarily intended for a coastwise run, but also for transpacific, so that she is correctly rated as an ocean-going ship, though whether the full 23 knots would be maintained on a deep sea run is problematic.

The average length works out at 465 feet, a very modest figure for nine typical passenger ship designs, and, omitting the 23-knot ship, the speed averages 15½ knots. It would seem fair to regard the high speed of 23 knots in a 450-foot ship as quite exceptional. It is worth noting that 15½ knots is quite modest for a 465-foot ship and that it checks up with the tendency noted above. These ships are uniformly of the shelter or shade-deck types with ample superstructures amidships and generally with forecastles.

Fully half these inquiries were from foreign owners, an encouraging sign.

Besides the above listed vessels, other inquiries not involving detailed design work were received; they lined up well as to type with those given and do not change the indication of the trend.

As regards proportion, the old and lingering tendency to narrow beam is at last giving way; it is not going fast, but it is yielding to two influences; the old ship that capsizes when handling light in harbor, unless ballasted, evidently is a nuisance, and has plagued a good many people. The war has served to emphasize a tendency already to be seen by those on the inside, and that is to give more metacentric height and listen less to the discomfort of passenger talk that was so prevalent.

A live passenger is worth several dead ones, even if he were fractionally more seasick than the comfortably drowned ones. Personally I feel that you have to go to metacentric heights far higher than the prevalent 18 or 24 inches in order to get appreciable discomfort; in other words, get all the data you need by studying stability and rolling features in successful ships, then adopt a G. M. about twice pre-war standards and you will have a ship that is not too stiff. I cannot claim enough seagoing experience to dogmatize too strongly, though I do believe that the talk of discomfort has been overdone, having been to sea a little in almost all kinds of vessels, principally with high G. M.

The other cause leading to more beam is the finding by Admiral Taylor and other investigators working in the experimental model basins, to the effect that more beam can often be given a ship and enough coal saved by fining up (for the same deadweight) to pay for the little extra steel weight generally involved.

In other words, the bugaboo of narrow beam is under investigation and is getting to be in a bad way. It must, however, be noted that stability considerations due to the flooding of a damaged ship point to caution in increasing beam.

War experience has given us a large volume of data concerning the behavior of flooded and sinking ships, and this, intimately associated with subdivision lessons, will ultimately give us safer all-round ships.

An interesting group of papers bearing on the subject of this paragraph was read at the engineering conference in London last summer; the size of docks and ships was discussed, also cargo handling facilities. What is said elsewhere as to the future of the large liner, written by the author prior to the reading of a summary of these London papers, is borne out; after the passing of present difficulties, these authorities look for the return of the large liner, advocating dimensions for docks of 1,150 feet by 130 feet by 45 feet.

BULKHEAD SUBDIVISION.

This subject has been very much to the front since the spring of 1912, when the world was shocked by the disaster which befell the Titanic. Our own transactions, as well as those of the Institution of Naval Architects, have been favored with many able papers on the subject; lessons of the war are now at hand, so that detailed treatment of the subject is neither necessary nor does it properly belong in this paper. As the question stands today we have the results of the international convention to work on together with the British Bulkhead Committee's Report, followed up by such papers as those of Abell, Benvenuti, Chamberlain, Denny, Dickie, Donald, Finlay, Foster-King, Gatewood, Hovgaard, Lovett, Orlando, Robb, Wall, Webster, and Welch. As several of these gentlemen have contributed two or three papers, it is obvious that the above list contains much valuable data. We also have governmental and classification society instructions to guide us.

The war has taught us that a spacing of 40 feet is about the minimum desirable to cover war risks, as a closer spacing gives torpedoes a good chance of blowing out two bulkheads at one explosion.

There has also been considerable discussion concerning the merits of the one, two, or three-compartment design of ship, compared with the factorial grading of subdivision.

Before the convention is finally adopted, it appears quite safe to say that a review of the whole situation is in order. Passenger ships should, by common consent, be made safer than the "pre-Titanic" regulations required, and already much has been acomplished along these lines.

Our Pacific coastwise passenger steamers should have more attention in respect to bulkheads. A rockbound and apparently foggy coast has given us two major accidents this year, the Governor and the Alaska; these vessels were both built before 1912. These accidents have been preceded by others of a similar nature in past years.

The accounts, as we read them in the east, generally run about the same as to the speed at which the ships go down and the by no means light casualty lists which follow their going. It is not intended to cast any reflection on Pacific coast navigation. Here we have vast extents of sandy shores which eliminate the rock-hitting risk, except in the north; also the danger spots are better known, due to longer acquaintance. The casualties on a rockbound coast are bound to be more severe and sudden, which is another way of saying that we should pay more attention to efficient bulkheading.

It is proven that good bulkheading will save many a ship altogether, also that the ones it does not finally save it will often keep afloat for hours and thus give full time for rescue work to be made effective.

ONE-CLASS LINERS.

As it has developed since the war, this is a relatively new idea and one which has much to commend it; on a large, high-speed liner the *de luxe* accommodation very naturally and properly occupies the best of the available space. Second class is generally aft and quite limited as to public rooms and promenades. Third class comes in below first, and the forward deck is the airing space, this being frequently so airy that none but ablebodied seamen can navigate with safety.

What better way to solve the problem than to carry the passengers willing to pay the rates on the larger and faster mail steamers and to give the benefit of the best parts of other ships to people willing to pay cabin rates for passage in slower ships, run at lesser operating costs and carrying relatively more freight. The idea works out well in connection with the moderate sized ships built since the war; it gives greater flexibility in operating fleets, taking care of seasonal changes in business conditions.

The Cunarder Albania is a case in point, she being a postwar ship and destined for the North Atlantic service, the home waters of the *de luxe* liner.

It should be noted that vessels carrying top-rate passengers only are not here specially referred to; needless to say such ships are neither new nor rare, the old Atlantic Transport Line between New York and London being a good example.

If ocean travel is to get back to prewar peace and comfort, this experiment will be watched as one of the means of bringing back in improved form the comfort, and indeed the actual chance itself, of traveling to a great many people who cannot afford present first-class rates but who still constitute a large body that is only too anxious to travel and willing to pay fares a little nearer prewar best average rates.

It should also be noted that the White Star Line has further extended the one-class liner idea and have in service the Vedic, a ship carrying only third-class passengers and all in cabins; the best parts of the ship are theirs, and there is every facility for self-respecting humans to travel in comfort and decency. Several other examples could be quoted, but the above will serve.

The one-class ship, or rather the ship with absent class distinctions, is something that deserves to succeed, and let us hope to see it do so.

Another point which should not be lost sight of is that the one-class liner works in well with moderate first cost of ship. In these days the struggle is to keep first costs and passage rates in some relation that will stay together in at least comparative peace. With only one class of passengers per ship a smaller ship will answer our purpose; it is all available for these passengers, and we are going to have less difficulty getting promenades in the open air and deck area in the quarters.

In fact, the one-class ship looks like one shrewd answer to postwar problems.

LENGTH.

In 1912 Mr. J. Foster-King presented some very interesting diagrams to the International Congress of Navigation in Philadelphia. These prewar indications of the trend are extremely valuable at this time; the diagrams are produced to 1920 and thus enable performance and estimate to be compared. For the largest type of North Atlantic liner, the 1,000-footer was indicated; in the Aquitania and Majestic (ex-Bismarck) we find prewar justification of the forecast. Coming down to the longest types for general first-class passenger service and selecting some fourteen of the most noteworthy post-war designs actually launched, we find an average length of 585 feet, the greatest being 650 feet and the smallest 505 feet—five only being 600 feet and over. Mr. King's curves gave 775 feet for Atlantic liners, excluding the leviathans, and 650 feet for general first-class liners; it is clear that the 1912 outlook has not been realized, a point also clearly brought out in several other directions; the fact that the 585-foot average includes several Atlantic liners tends further to show the reduction, the figure with which it should be compared being intermediate between 650 and 775, in a ratio difficult to get at. It seems reasonable to say that large passenger ships have been shortened by 100 feet from considerations arising out of the war. The chief influence at work is the high cost of ships, which makes it a serious question with owners as to whether they can charge passage rates high enough to realize on their investment without killing the business of passenger carrying by reason of the inability of people in sufficient numbers to pay such rates.

THE THOUSAND-FOOT LINER.

Apart from and in extension of the references made to this length of vessel under paragraph headed "Length," some further remarks appear to be in order. As is generally known, a committee was formed under government auspices some while ago to look into this question. The subsequent long spell of idleness at her dock of the Leviathan, after invaluable troop service, is rather a damper on 1,000-foot ardor; nevertheless, it remains a fact that a vessel of this length was well in sight when the war broke out. At least one design has been seriously started and pushed to the point of a study of schedules, terminals and rail facilities, of a full set of outline plans, of extensive calculations and of detailed lay-out of proposed propelling machinery.

This design contemplated going to Panama Canal lock limiting sizes at one step; it is not necessary to say that the two ships would run between New York and London, starting and arriving at deep-water harbors at each end and with rail connections to New York and London.

It can be safely said that the engineering features, especially when high tensile steel is used, present no difficulties which cannot be met. The problem is one of economics entirely. Is the route able to support such liners without government aid in some form? If not, what justification can be advanced for claiming such aid?

We can, as shipbuilders and engineers, say that, as far as our profession is concerned, we stand ready to furnish the ship and her propelling machinery just as soon as other considerations justify such a vessel. As a matter of record and interest a few particulars of the design as it stood in its earlier stages may be of interest:

Length, over all	1,000 feet
Breadth	105 feet
Depth	76 feet
Deep load draught	38 feet
Speed at sea, knots (depending on weather)	30 to 32
S. H. P. (maximum)	150,000
First-class passengers	1,100
Second-class passengers	800
Third-class passengers	1,400

The propelling machinery at first contemplated was electric drive; with the large battle cruiser Hood at sea, the path has been opened to the full consideration of the claims of a geared turbine drive.

The oil fuel required for a round trip is in the region of 11,000 tons. This would be too much for the ship to leave this side with; the answer would be to leave here with oil for the trip over and half-way back, taking in oil for the other half of the returning voyage on the other side before leaving. At full load this vessel would have a total deadweight of about 12,000 tons. There would be no freight as is generally understood; mail, bullion and express matter, yes; also such small consignments of special freight that could be handled during the time necessary to refuel and reprovision the ship at each end.

In the early days, when this length was first proposed, the scoffers, technical and otherwise, were legion. Not so now; technical scoffers at once merely proclaim their ignorance. On the financial side there is ample room for hesitation and there the matter must rest for a while, to be taken up again as the world recovers from the effects of the war.

DEPTH AND DRAUGHT.

This subject is one calling for special mention. It can be stated at once that the draughts adopted for large liners are not those that the naval architect would choose if he had a free hand; neither are they the ones dictated by considerations of the limitations of steel as a shipbuilding material. Terminal harbors and canals are the main deciding factors, and while a discussion of harbors, existing and projected, is not within the scope of this paper, nevertheless it may be noted in passing that the improvement and deepening of harbors are again being taken up seriously, the extensions to the facilities of the port of London recently opened being a case in point. The late Sir W. H. White contributed a valuable paper bearing on this subject, among other things, to our Society in 1911; Sir J. H. Biles has shown in several papers the advantages of increased draught in large carriers, also Lord Pirrie has contributed to our knowledge on the subject. In order not to take up space with repetitions, the interested reader is referred to these papers and to the report of the Canadian Royal Commission on Oversea Communications, dated 1914, an extremely valuable document, the importance of which has evidently been masked by the war. Suffice it to say that the economics of the ship can benefit by increased draught up to the point where such increase imposes excess costs on harbor authorities, which would have to be passed back to the ship in the form of increased and excessive harbor charges.

A really first-class harbor should nowadays have a depth of at least 40 feet, and Lord Pirrie advocates 45 feet; with such depths and corresponding draughts of about 37 feet 6 inches to 42 feet 6 inches economics of transport are available. Mr. J. F. King's forecast in 1912 referred to above under "Length" is worth noting; his figures gave a 1920 draught of 36 feet 6 inches for Atlantic liners and for average passenger ships. The predicted Suez Canal depth of 30 feet came very close to being a mean draught for such ships, which showed steady increase up to a 25 to 34-foot range. Draught increases relatively and actually more slowly than length, it is hardly necessary to say.

The Panama and Suez canals are bound to exercise a profound influence on the draughts of passenger liners, the figures for which now stand as follows:

1. *Panama.*—A minimum depth of 40 feet in the canal, with 40 feet in the Atlantic and 35 feet in the Pacific approaches at mean low water, which means an available draught of about 38 feet.

2. *Suez.*—At present the available depth is 32 feet and permissible draught is 30 feet; the authorities are dredging for 34 feet 6 inches and 31 feet figures respectively.

It is to be noted that Suez has gradually been deepened by dredging from 19 feet in 1870 to 32 feet in 1920.

Liners of the future will probably not be able to avail themselves of all the draught economically desirable, for we are now approaching the region of excessive dredging costs in certain harbors.

Another big factor in restricting draught is the River Plate; many vessels now trading there on a 26 feet 6 inches limit could well have been designed for 30 feet.

SPEED AND POWER.

Looking back on the not so distant days when it was necessary to plead the advantages of experimental tank work, it is gratifying to reflect on the conditions of today. The last decade has witnessed a decided modification of attitude.

In addition to resistance and estimated horse-power curves, the experimental work now being done on model propellers, both in free water and behind ship models, calls for commendation. This is a field that has been opened up comparatively recently.

In addition to deep-water conditions, attention is given to shoal-water problems, so important in connection with inland navigation. Destroyers at high speed some time ago proved that the two forms of navigation were different. I well remember the case of one of the last of our coal-burning destroyers; a chart showing the results of some Denny shoal-water experiments was on board, but the practical people looked at it askance until they tried to get 24 knots, in water entirely too shallow, for the same power as in deep water. They knew something was wrong, and finally it began to dawn on them that there might, after all, be something to that blandly ignored chart, so they decided to haul off into deeper water, with the result that all promptly went well.

It is also known that lines suitable for deep water are not necessarily good for shoal water.

Coming to passenger liner speeds, before the war we had reached 26 knots for all the way across the Atlantic, this in the Lusitania and Mauretania. In the later Cunarder Aquitania we see a reduction to 23 knots, while the large White Star boats ran in the neighborhood of 21. About the maximum for the long routes to the Cape, India, and Australia was 18 knots.

Referring to the paragraph headed "Trend of Design," it is evident that moderate speed will be a feature of new construction for a while. Referring to the paragraph headed "Length," the average speed for the fourteen postwar designs for all trades there discussed is about 16½ knots with a range of from 14 to 18 knots; it must be noted that in three or four cases the speed was not obtainable. It is, however, obvious that speed in representative liners has been cut down from that which obtained before the war. It is seen that the evidence is all for moderate speed, even on the North Atlantic, which is another way of saying that this particular route is contenting itself at present, at least as far as new ships are concerned, with vessels that average up well with those on the general routes of world travel, instead of the accustomed 21 to 23 knots of the old days. In the attainment of better results, the competition in systems of propulsion does, and will to a greater extent, contribute to a lower consumption of fuel per horsepower. The problem is three-fold—lower resistance, better wheels, and more economical power plants. The question of inexperienced engine-room forces has troubled us lately but should become less prominent as conditions improve; men gain experience and faults of design and construction are eliminated.

The new C. P. O. S. liner, Empress of Canada, completed this year, has a speed that is decidedly in advance of the present trend. She will be the largest vessel on the Pacific, according to current reports, being about 120 feet longer than the American Legion type. She is announced to have made well over 20 knots on the mile and to be designed for 18 knots in service. One report credits her with 25 knots on the mile; if so, the owners are to be congratulated on having a vessel which lacks nothing of Atlantic liner standards except extreme size. Her entry into the service will be felt among competing lines, who will have to look to their laurels; the turn of speed she is capable of will be very useful when it becomes again economically practicable to burn the fuel.

Speed has an effect on design that is not clear at first glance. The piling up of deck houses is a noteworthy feature of many modern vessels. In the next paragraph we discuss very high speed liners of warship type as far as dimensions and proportions go. High deck houses would not go well on such vessels; they are one solution of the ventilation question that cannot be ignored, for we all like an airy room. There is no doubt that ventilation plays a big hand in the popularity of a ship; in tropical runs it is of the essence. For such vessels all modern advances in the ventilation question will have to be utilized, but there is no reason to doubt the ability of the shipbuilder to meet the need, once it is realized how great it is; American warship practice has proved that. I believe that, during the war, the British paid us the compliment of appointing a committee to study our methods in this respect.

It will mean a few less rooms and larger ducts, fans in duplicate to avoid breakdown and a margin in boilers and dynamos over the present practice.

The claims of the watertube boiler over the Scotch for high-speed ships have made good to such an extent that they will feature more largely in future ships.

THE COST OF HIGH SPEED.

Apart from the initial cost of the machinery necessary to obtain high speed, the fuel bills become very high. For example, consider a 750-foot Atlantic liner of varying speeds from 15 up to 30 knots; such a ship would have a beam of about 90 feet and a deep draught of 36 feet. Call the voyage 3,000 miles, which gives a round figure close enough for our purpose. Remember, too, that as speed goes up cargo carrying ability goes down and passengers, mails and express matter become ultimately the sole sources of revenue, outside subsidy. The figures are about as follows:

Speed at sea (knots).	*S.H.P.*	*Total deadweight.*	*Cargo deadweight.*	*Oil fuel, one way (tons).*	*Cost of fuel, one way.*
15	16,000	29,000	26,500	1,450	$26,100
20	38,000	23,000	19,400	2,550	$45,900
25	73,000	14,000	9,000	3,900	$70,200
30	113,000	5,800	.....	5,000	$90,000

Such a vessel would carry some 600 first, 450 second and 1,000 third-class passengers and would be quite big enough for speeds all the way to 30 knots. It is seen that the 30-knot ship carries nothing but passengers, mails, stores and bunkers, which is the logical outcome of this investigation.

Oil fuel is figured at six cents a gallon or $18 a ton; a figure which, of course, is subject to variation. It would be well to pursue this further, but the above table will show that, with cargo capacity falling from 26,500 tons to nothing and fuel costs rising from $26,100 per voyage to $90,000, the economics of the large ship are not easy. It is clear, however, that the greater number of voyages per year for the 30-knot ship must also be taken into account. This may be summarized somewhat as follows:

Speed of ship (knots).	*Days at sea, one way.*	*Days in port, at each end.*	*Days for single trip.*	*Single trips per year.*	*Passengers per year, at 85% full.*	*Cargo (tons) per year.*
15	8 1/3	9	17 1/3	17.3	30,270	389,700
20	6 1/4	7	13 1/4	22.6	39,550	372,650
25	5	5	10	30	52,500	229,500
30	4 1/6	3	7 1/6	42	73,500	....

The days in port are somewhat indeterminate, due to uncertainty in time necessary to load and unload. The times given are estimates only and are subject to change to suit terminal conditions; they should be fairly close. Allowance has been made for docking, overhaul, etc., also passengers and cargo are taken at only 85 per cent full, averaged over the whole year.

The compensations coming to the fast boat show up in this table; she will carry more than twice the people per year at, naturally, much higher rates per person.

It is also clear that the 15-knot ship does not deliver enough extra freight to compensate for the fewer and lower-rate passengers carried. With everything lined up properly, the 30 knotter will make twenty-one round trips in a 300-day working year, *i. e.,* a round trip every two weeks. Two such ships, laying off during the two bad months to avoid the worst weather, could command the cream of the travel.

They are not excessive in size, and even if they only make twenty round trips per year, due to miscellaneous bad weather and sometimes taking the longer southern route to clear ice and fog, such ships equipped for first and second cabin only would each average 45,000 passengers per year, which at, say, $250 per person comes out at $11,250,000 against a fuel bill of $3,800,000, which is not so hopeless. The obvious temptation is to pursue this further, but I am afraid that I shall have to refer it to the Committee on the Thousand-Foot Ship, due to lack of data on the cost of operating vessels of this size. May I commend this 750 footer to that committee as a step well worth considering in our further progress towards the solution of the problem of the modern Atlantic liner?

A recent report credits the Aquitania with transporting a total of over 90,000 persons east and west bound in her first full year on the New York run. She is rated at a capacity of 3,238 passengers and 23 knots speed, and this is believed to be a record performance. The speed stated is for coal burning; under oil she should be capable of about a knot more.

Comparison with the figures given above indicates that 90,000 passengers transported in a year is a very good performance.

Another interesting angle to the speed question is that of increasing speed in vessels of moderate dimensions. Now and then this question comes up; it is well known that speed combined with reasonable comfort is associated with size in some way not strictly definable. The Mauretania gives us one point, namely, a length of 760 feet and a speed of 26 knots; a proportional length for 30 knots would be 1,000 feet. We now want to inquire if such length is necessary for this speed. Sir W. H. White held, if I read his 1911 paper correctly, that the Mauretania represented the maximum of length necessary for her speed, also the maximum practicable speed for the North Atlantic. The Aquitania, which he did not live to see go into service, represented an increase in length and a decrease in speed. The later Paris represents a decrease in speed on the same length, the evidence thus not being conclusive.

A maximum speed-length ratio of unity has been a general guidance rule for ocean passenger ships for many years. With lighter machinery, oil fuel and other advances, the speed question again becomes one for renewed study and discussion.

The following table shows the fuel savings possible for high speed, moderate dimensioned vessels:

Length of ship (feet).	*S.H.P. at 25 knots.*	*S.H.P. at 30 knots.*
600	56,000	132,000
700	64,000	119,000
800	68,000	131,000
900	80,500	153,000
1,000	91,000	163,000

These figures represent smooth-water powers plus 10 per cent for the 25 knotters and plus 15 per cent for the 30 knotters. The dimensions dependent on length follow average merchant practice, except that the beam on the 1,000 footer has been limited to suit the Panama Canal lock dimensions to 102 feet.

It is clear from this table that a Mauretania at 30 knots would bear out Sir William White when he says that no greater length is necessary.

Destroyers attain a speed-length ratio of 2.00, but it cannot be claimed that they attain it with comfort and safety except in quite moderate weather. European cross-channel steamers obtain a ratio of 1.50 with greater safety and comfort than destroyers; where the line must be drawn for the North Atlantic is our problem. The ships listed above cover a range of from 1.225 for the 600 footer to 0.95 for the 1,000 footer at 30 knots. The Mauretania's figure is 0.95. From this it is submitted that the 750-foot ship of 30 knots as proposed is practicable, providing the fore ends of the ship and of the midship deck erections are especially designed and strengthened, with a view to avoiding deck damage in weather not otherwise severe enough to make slowing up necessary. All fittings and deck openings before the bridge would need to be of special design.

The table above for varying lengths is calculated on a somewhat different basis from that given on page 279, somewhat different proportions, coefficients, and powers. The two tables were prepared from different angles but remain substantially comparable.

The question of powers to be expected if very fast liners of warship types were to be adopted is interesting and is another angle of the question that should be investigated. The table of powers varying with length and speed given above covers merchant types developed from current liner practice; the following covers some of the ground as indicated to us by warship practice.

The proportions and speed both render large and high deck houses out of the question; the passage would be short and promenades would have to be arranged on the quarter deck aft and on one deck amidships well protected from spray.

Fast yachts have already been built on destroyer lines, so that liners on cruiser lines are only a logical step and one that has been discussed before.

The speed has been taken at a 20 per cent advance on previous general practice; the time on a 3,000-mile run in moderate weather is also given. In the powers given a 10 per cent margin for sea speed is allowed over a measured mile performance. The bunkers work out at quite large figures. It can be assumed that oil fuel is obligatory, coal handling would be well-nigh impossible both on board and alongside. These bunker capacities are high, but not impractical. Taking only first-class passengers and allowing 1½ per foot of length, we get the numbers given in the table. The longitudinal coefficient is 0.58 and the mid area 0.90 for all lengths.

It is seen that the increase from 29 to 36½ knots cuts one day off the voyage. As said elsewhere, this branch of passenger-ship design is most fascinating; full plans, however, involve an amount of work beyond the scope of this paper, and it is hoped that these few remarks will be of interest as well as of some value. It is submitted that a full design along the lines of recent experience in battle cruiser and air craft carrier practice is worth while.

As regards weights, it is clear that warship practice rather than merchant would have to be followed for machinery design; the absence of armor, torpedo protection; battery and ammunition weights being utilized on deck erections, passenger accommodations and bunkers.

Mean displacement	10,000	20,000	30,000	40,000
Full displacement	11,500	22,750	33,850	45,000
Length, feet	585	735	850	930
Breadth	58.5	73.5	85	93
Mean draught	19.5	24.5	28	31
Mean speed, knots	29	32½	35	36½
Total E. H. P.	27,500	61,000	97,250	135,000
Total S. H. P.	50,000	112,500	177,500	247,500
Oil for 3,000 miles	2,300	4,700	6,800	9,100
Days on voyage	4.31	3.85	3.57	3.42
Passengers	875	1,100	1,275	1,400

It must be remembered that some of the British battle cruisers during the war made successful passages of the Northern Atlantic at a very high rate of speed. Particulars of these voyages, made during the war, are not generally known, but it is safe to say that valuable information was obtained thereby.

THE BEGINNINGS OF OUR POSTWAR PASSENGER FLEET.

During the war our dependence on allied transports for the army troop movements was only mitigated by our few prewar troopers and liners and by enemy tonnage seized in our harbors and elsewhere. This led to the ordering of some twenty odd large and some thirty odd moderate sized transports at Newport News, Bethlehem, New York Shipbuilding Corporation and Hog Island. None of these vessels were completed prior to the armistice, and some were subsequently cancelled, mainly the smaller ones at Hog Island. These ships are now in service, some as troopers (Hog Island) and some as passenger liners, with the latter of which only are we here concerned.

A brief description of these passenger ships is in order and may well be given in tabular form. Of the larger ships, Newport News built two, Bethlehem five, and New York Shipbuilding Corporation nine, a total of sixteen ships of some 225,600 gross tons; the smaller ships number seven, all built by the New York Shipbuilding Corporation, totaling some 73,800 tons gross.

Their outline particulars are as follows:

Item.	*Old North State class.*	*American Legion class.*
Length, overall	522′ 8″	535′ 2″
Beam, molded	62′ 0″	72′ 0″
Depth, molded	42′ 0″	50′ 0″
Load draught	32′ 3″	30′ 7″
Corresponding deadweight	13,000	11,400
Sea speed, knots	14	17½
Shaft horse-power	....	12,000
Indicated horse-power	6,500	....
Boilers (oil fuel)	Scotch.	Water tube.
Motive power	Reciprocating engines.	Geared turbines.
First-class passengers	78	260
*Third-class passengers	....	300
Gross tonnage	10,540	14,100
Crew	117	134
Bulkheads	11	13

A few words on the outstanding characteristics of these ships may be in order:

1. *Passenger accommodation.*—This is unusually spacious, as may be inferred from the size of the ship and the number carried. Large rooms, beds rather than bunks, numerous private bathrooms, and ample public rooms are noticeable, especially in the larger vessels. Running hot and cold water is supplied in the rooms.

2. *Cargo handling.*—Both in the number of hatches and in the facilities at each hatch, this feature is especially well cared for, quick turn around being thus possible.

3. *Unusually close subdivision.*—Being laid down as three-compartment ships for troop service in the war zone, these vessels are all very well bulkheaded, especially the larger ones, where cargo is not so important.

4. The interior decoration has received greater care than usual, our colonial period supplying the dominating scheme of architectural effect. This has been modified in certain spaces, such as the verandas, tea rooms and smoking rooms. Furniture, decorations and draperies were from designs by W. & J. Sloane of New York. The architectural plans for the larger ships were mainly by the Bethlehem Shipbuilding Corporation and for the smaller ships entirely by the New York Shipbuilding Corporation.

5. Unusually large steaming radius to enable Pacific Ocean and South American trades to be adequately negotiated.

6. The similarity of bow and stern is unpleasantly noticeable, this being an inheritance from war days.

Since the launching of these vessels there has been a considerable general interest displayed in passenger ships; numerous designs for large vessels have been prepared which, doubtless, will bear fruit in due season. As business gets back to normal it will carry with it a demand for vessels of this character to balance our merchant marine.

It has been felt that the plans of these ships are of sufficient interest to record and they are therefore given in Plates 40 to 43. Several photographs are also given, to illustrate the general scope of the accommodations.

*Two of the smaller ships are being fitted for third-class in the top 'tween decks.

INTERIOR DECORATION.

No paper of this character can be complete without reference to such an important feature of passenger ships. The first requisite from the point of view of the passenger, after that of the general good or bad repute in which the line and ship he sails on is held, is that the general arrangement of the accommodations shall be such as to contribute to his comfort—enough promenade space and open decks for games, ample ventilation at all times and heat in winter, well-arranged staterooms and public rooms, access to all parts under cover. An essential factor in all this is the interior decoration. We have had very few papers on this subject, but one in 1915 by Mr. H. B. Etter stands out as a valuable and interesting contribution to the transactions; a careful reading of this paper will repay anyone interested in the subject.

The architectural or decorative atrocities of a hotel can frequently be recovered from by seeing nearby grand and varied scenery, or by absence for short periods. Not so with a ship; once you start, the scenery is, generally speaking, the sea and then more sea. Also, you are there to the end of the voyage, and if it is a three or four-week voyage, third-rate efforts at decoration can try men's souls.

As in Pullman cars, so in ships, we have happily gotten away far from the days of heavily applied ornamentation, just as in our houses we demand decoration and furniture which combine grace and usefulness; plaques of dead fish on dining-room walls spoil the digestion of fewer people than they did a generation ago. So in ships it has been realized more and more that good interior architecture and decoration do not necessarily involve additional expense, or rather expense beyond an immediately appreciable return in the enhanced reputation of the vessel in question in attracting passengers. Compare the beauty and general attractiveness of the United Fruit Company's steamers with the vast majority of our prewar coastwise passenger vessels. The United Fruit Company has not lost trade by the quality of its ship's arrangement and decoration; it is by no means a weak and struggling line, made so by wasting its substance on expensive interiors. Visit or travel on one of its steamers and then do the same on any of several coastwise liners; the wood and paint are there, but the decorative effects that could have been gotten from the same wood and paint are not.

Of the later periods which lend themselves to ship decorative architecture the Tudor and Flemish are found most frequently in smoking rooms; the periods of Louis XIV, XV and XVI of France in the music rooms, lounges and galleries. Read the published descriptions and visit modern liners; it is hard to realize the variety of styles which can be adapted to ship decorations. From classic and Gothic in lesser amounts we pass on to a wealth of the Renaissance of Italy and of France, to the English and Dutch evolutions and lastly to our own Colonial, the keynote to the decoration of our postwar ships of the American Legion class.

We have heard lately of ships that were overdone in the lavishness of their appointments; perhaps so. A ship designed and built for a one-week trip does not need as much in the way of accessories as one that is to be a floating home for four or five weeks at a stretch. Let ships be designed each for its own trade, with due consideration to climates passed through, to the likes and dislikes of the people carried, to the length of voyage. A rational answer to these questions will settle both the decorative and elaborateness questions.

The impression may have been given that copying the past is the only way to decorate a ship; this is not intended. Certain it is that the past, so far as it has been spared by the hand of the ignorant savagery that breaks out in humanity at intervals, furnishes us with a wealth of background to work on. The masters of all the ages have left work for us to admire and beat if we can. From Persia, Egypt, Greece, Rome, Italy, France and Europe generally do we inherit. The classic styles of Greece and Rome lead on to the Gothic and the later periods of Italian and French Renaissance, the Tudor, the Dutch, the periods of the Louis, the Regency, Empire, Adam, and Colonial; then, too, China and Japan have contributed their share. With the masterpieces of all the ages to draw from, we would be poor indeed if, while working out new ideas and adaptations, we fail to give credit to the sources of inspiration.

The latest word in large liner decoration that the public has had a chance to see is that of the Paris of the French Line; a visit to this ship leaves no doubt as to the artistic ability of the French designers and decorators. She is very much of the dimensions of the Mauretania. Large 'tween-deck heights prevail; in the upper public rooms extra height has been obtained by extending the central part up several feet. With the general scheme of decoration it is hard to find fault, though our friends of the plain and simple school had better travel on some other ship; the ornamentation is in excellent taste, the result being magnificence without gaudiness. The large windows in the public rooms give one the impression of a palace rather than a ship; they are protected by the outer windows enclosing the promenade.

EXTENT AND ARRANGEMENT OF PUBLIC ROOMS.

The arrangement which is popular in sheltered water ships of wide passages with seats, writing tables, etc., running along inside the staterooms, often with large wells at intervals, is not adapted to seagoing liners.

The arrangement which works out best in oceangoing ships gives dining rooms on the lowest passenger deck with galleys and pantries around the casings and extending full width, the other public rooms being arranged on the top deck, opening one from the other and with wide passages or galleries between, enabling the best all-round result to be obtained.

The dining rooms thus occupy decks the least desirable for staterooms, the other public rooms can be built with coach-top effect, enabling rooms of 10 and 11 feet head room to be obtained; decorative effects impossible of attainment in the ordinary 'tween deck at once become possible, comfort is increased and the ship popularized.

A dome over the dining saloon with exhaust fans is a most important contribution to comfort, coolness, lighting and decoration. Some large prewar liners have winter gardens two full decks in height, a most magnificent arrangement but also a most extravagant one.

Many have arrangements for dancing indoors as well as on deck, promenade decks with fully enclosed sides give excellent facilities for dancing, but some large liners go further and arrange the lounge so that the central part can be cleared and a ball room of the best obtained, with orchestra gallery at one end and ample seating on all sides.

Some idea of the extensive character of the public rooms of a large liner may be obtained from the following, without by any means exhausting the list: Dining rooms, restaurant or café, winter garden, smoking room, card room, library, lounge, ball room, writing room, entrances and lobbies, stairways, drawing room, children's dining room, nursery, gymnasium, Turkish bath, barber shop, information bureau, ticket, etc., office, galleries, verandas, swimming pool, candy, etc., store.

It is not to be understood that all these rooms can be found in any one ship; they are merged and grouped variously. Different names are given to the same space in different lines. The list typifies, however, the extensiveness of the public spaces on a large liner.

In the larger steamers the old-time narrow passage is giving place to the gallery between public rooms. This feature enlarges the scope of the living quarters, provides library, reading and writing facilities, besides giving ample communication under cover for use during the evening or during bad weather.

This feature is noticeable in recent Cunarders and has also been developed in Italian liners. Its appeal to Italian designers is easily understood, Rome furnishing us with many such galleries in her magnificent palaces, the galleries of the Vatican being a case in point.

Some of the gallery effect is to be noted in the design of the public spaces on the American Legion class.

PROMENADES.

Many ships sacrifice this feature to piling in the maximum possible number of state rooms, obviously to increase revenue. It is true that short-run ships do not need so much promenade space and deck room to exercise and play games that vessels going on long voyages require. Vessels on one-night runs do not need the open-air spaces that day-run ships need. High-speed ships require more sheltering arrangements, such as deflecting wind shields and sides enclosed with windows which can be either open or shut. The liner, to be popular, must have good open decks for lounge chairs, walking and games, with decks adapted for outdoor sleeping on tropical runs.

OUTSIDE ROOMS.

In smaller ships all rooms can and should be outside rooms, *i. e.,* with ports or windows opening direct to the outside air. As ships get bigger our difficulties increase; the "Bibby" room is the popular solution, the inside room having a narrow passage leading past the outside room to a port.

For vessels navigating sheltered waters the transverse berth greatly helps the designer of good passenger accommodations, but for seagoing ships, the fore and aft berth, with only occasional exceptions, is the rule.

Lately the "Bibby" idea has been extended to banks of three rooms on a side, both the inner and middle rooms having these narrow passages for air extending directly to the side; for hot weather ships this is excellent.

As we get to the largest ships this feature is not so important. These ships are generally fast and, being almost entirely on North Atlantic runs, the heat is not excessive. With eight and more rooms abreast it becomes a problem of better and still better ventilation by means of fans taking air from above. On this route we have fog and ice to contend with and consequently closed ports at night on all decks below the bulkhead line.

More and more deck houses are resorted to, with consequently narrower houses, fewer rooms abreast and more chance for windows directly opening out on deck.

The old plan of individual outside doors has given place to inside passages and doors, with outside windows, a cooler arrangement anyhow, avoiding the backing up of rooms against heated casings and enabling all available space along the center line to be utilized for toilets and baths, the best scheme for drainage and water supply, also for exhausting foul air directly from these spaces.

SINGLE-BERTH ROOMS.

No doubt this is a feature appealing to all people traveling alone; the comforts of a little place all your own for the voyage need no eulogies. On the North Atlantic such rooms are now numerous; elsewhere they are not unknown.

A most ingenious plan that can be used in all vessels, particularly in those with ample 'tween-deck height, is that of placing two berths over each other, but so stepping the dividing bulkhead that one berth is in one room and the other in another room; in one room there is a lower berth only and in the other an upper berth only.

I do not recall which line gets the credit for the scheme, but it is a good one.

DETAILS OF CONSTRUCTION.

Standard transverse framing continues to be the general rule for passenger ships. Wide-spaced framing is often adopted in order to get a spacing that suits details of accommodation better. If pushed to extremes, framing too deep for good hold capacities may result, besides very heavy shell plating: in way of machinery, deep framing does not affect capacity; carefully applied, it can be made an advantage.

Longitudinal framing has not the same strong hold as in oil tankers and in long shallow vessels of all classes; vessels for rivers, etc., will always do well to consider longitudinal framing, but for deep-sea passenger vessels, with many decks, its advantages are not so clear.

Cruiser sterns for twin (and above) screw ships are here and do not need so much arguing for as a decade ago; there are still people who do not like their looks and, of course, that is their privilege. They have solid merit, however, in improving stability and speed performances. For single-screw ships they are generally a bit of a misfit.

Electric arc welding has found a definite place in shipyards; without getting too enthusiastic and hailing the all-welded ship and the exit of the rivetter, driller and caulker, it remains a fact that there is ample room for a welding department in any big yard to work on details and that not altogether, by any means, on what we may politely term "correctional" work.

Wooden decks inside quarters are well nigh a thing of the past in ocean ships; there are several satisfactory plastic deck coverings for all interior spaces other than those generally cemented and tiled. There are also several forms of cork flooring which give good results. Parquet may be desirable for inside dancing spaces. Wooden decks are still premier for open deck spaces over quarters and for promenades.

In order to shorten turn around in port, either ship or dock, and sometimes both, have to be better equipped with cargo gear than was only a short time ago considered proper. The Old North State and American Legion classes fully bear this out, their twin derrick systems and numerous hatches having been commented on in every port visited. It should be noted that their close subdivision accentuates this feature.

The recent revisions of the rules of all the classification societies have placed in the hands of the shipyards methods of designing structure and details which enable much quicker and better work to be done.

Joiner work is not so dependent on wood for panels as formerly; as with sanitary floors, so with paneling, there are now on the market several satisfactory composition boards, and panels of these, mounted directly on the tongue and groove partitions, enable the two sides of a bulkhead to be fashioned to suit the furniture to much better advantage than with ordinary panels.

Lighting, heating and ventilation have improved of late; steam heat is largely replaced by electric radiators, which are particularly adapted for individual room heating in association with a thermo-tank system raising all the air to about 60°, leaving the balance required to electric radiators.

With oil fuel, piping problems become more complex; the air escapes from the amidship tanks are sometimes difficult to handle in way of passenger spaces, an excessive possible head on the tanks being only avoided by taking them out through the shell. Oil fuel galley ranges are also a modern touch in oil-burning ships.

Communication and indicating devices get more complicated, fire-alarm systems, pneumercators, gyro-compass systems and submarine bell listening devices are among the newer modern tendencies.

Better bulkhead subdivision has helped fire protection; with alternates carried up to the top decks, modern ships have been afforded a much better chance of confining and subduing a fire.

The extra boatage now fitted on passenger ships has given trouble. Better bulkheads argue for less boats, though "boats for all" is rightly the generally recognized minimum acceptable. The writer feels that more rafts might well be allowed, especially where bulkheads are good.

Compulsory air ports on the lowest passenger deck might well be reconsidered. They can seldom be opened at sea, they are menaces when so opened, and more reliance on good lighting and ventilation from above appears to be a better solution of the question, particularly where cabins replace open steerage quarters. Warships get along very well in that respect, where men are berthed behind armor with no side ports.

The extent to which oil has been substituted for coal as a fuel calls for comment. Lloyd's returns indicate that 22½ per cent of the world's total gross tonnage uses oil for propulsion, as compared with 3 per cent in 1914, a stupendous increase and one that is mainly in vessels of American registry. Correspondingly coal has dropped from 89 per cent to 72½ per cent for the same period. This has resulted in a great increase in oil construction, both for ordinary ships' bunkers and for oil tankers. From the point of view of this paper, the recent conversion from coal to oil of several famous liners is to be noted, also the fact that our ships of the American Legion and Old North State classes are all primarily oil burners.

STANDARDIZATION.

This heading to many here will seem like the beginning of a discussion of the methods of making a series of progressive runs over the measured mile; it does not mean this form of standardization but refers to the general one of engineering standards.

It is not necessary to state that a great deal of work has been done of late years, on both sides of the Atlantic, looking to the obtaining of the benefits of standardization. When in Europe last year I was much impressed by the work done, under Sir Archibald Denny's genial and able leadership, by the British Engineering Standards Association. They have revised their rolled steel section standards, inviting us to cooperate. Some work has been done here along those lines and this society, with others, has appointed committees to act in conjunction with the American Engineering Standards Committee. As a result of the war we are in much better shape than formerly as regards the obtaining of a wider range of steel sections suitable for shipbuilding and are not without hope of being in better shape yet, once the revival of business brings the exporters to realize the benefits of standardization.

The British have gone further and are at work standardizing ship fittings as far as found practical and desirable; this is a far-seeing step in the maintenance of their shipbuilding position and one we should not lose sight of.

The work done in the standardization of marine oil engine construction has been fully covered recently in publications devoted to the internal-combustion engine.

Considerable progress has also been made abroad in standardizing steam marine reciprocating engine and Scotch boiler construction as far as moderate and low powers are concerned. This is advantageous in more ways than one. It facilitates construction and, equally important, it facilitates upkeep. With standard shafts and other parts which are most liable to need replacement available, the economy to be realized by quick repairs and consequent absence of delay should need no argument before this body.

Anything which helps standardization along rational lines should have our united support; we have the fleet now to give us the opportunity. Standardization has been pushed too far in some quarters, but after the exaggerations of the overzealous have been eliminated, there is still a large field to be covered. The claims for the prompt execution of repairs is one that should not be overlooked; it is an aspect of standardization that deserves more attention than it has received, though it is largely taken care of by standardized construction.

Referring again to the question of engineering standards, the success attending the presentation of the John Fritz medal to Sir Robert Hadfield last summer and the accompanying international engineering conferences constitute another link in the chain leading up to more effective engineering cooperation, which naturally includes standardization.

COMPETITION AND THE FUTURE.

Prior to 1914 the British and Germans divided the lion's share of the world's passenger carrying; it is not so now. Germany no longer has a passenger-carrying fleet worthy of the name.

Besides ourselves, the ancient empire of the Mikado has now come into a prominent place in passenger-carrying circles, at least as far as the Pacific is concerned. As an indication of the need that still exists for passenger ships, the following table is of interest; its meaning under normal conditions of world intercourse and trade will not necessarily be the same as under present conditions:

WORLD'S SEA-GOING TONNAGE.

	1914, gross tons.	*1920, gross tons.*
Liners and intermediate vessels........	13,345,000	12,107,000
Cargo ships	24,935,000	32,518,000
Tankers	1,479,000	2,934,000
Totals.....................	39,759,000	47,559,000

The lines of tied-up cargo ships are well explained by the above figures, which are a variation of Lloyd's regular returns, taken from a paper read by Mr. Ballard last year before the Northeast Coast Institution (England).

The shortage in ocean passenger ships is brought out, also the wisdom of the government in deciding to finish the main program of wartime transports later converted to passenger ships. In using the word shortage, care must be exercised to discriminate between present and normal times.

The strength of our position in cargo-carrying tonnage is not yet reflected in the passenger-carrying trade, but with our operators in the passenger trades encouraged by the delivery of new ships and by the reconditioning of captured vessels, the outlook for the future is brighter than it has been for at least two generations. There is also some encouragement for builders in that the void in their yards caused by the prevailing lack of cargo ship orders may be partly filled by orders for passenger ships.

Indications are not lacking that our Pacific and South American trades are soon going to become well developed. On the North Atlantic we are not as yet adequately represented. It is true that there are some ships under the flag, but these are not generally of such size and type as to command an adequate share of the trade.

The Italians and French have some excellent vessels in that run, notably the new Paris. The Leviathan remains at her dock. Her long, idle spell is bad enough, but the lack of policy which kept her not only tied up but out of condition as well is a severe blow to our place on the Atlantic. The writer feels that the lack of enterprise in this direction is only temporary; the world will not be content to go backwards in passenger liner development indefinitely.

The Pacific has given one sign of renewed progress in the Empress of Canada. She is almost as much a step in advance over Pacific Ocean average as the Mauretania was on the Atlantic, though this may be held to be somewhat of a stretching of facts. Nevertheless she is clearly a noteworthy vessel and brings cheer amid the dark clouds of the recent enforced lack of advancement in design. Our new liners will not long occupy any leading place among noteworthy ships, so that our hold on the trade will before long demand larger and faster vessels.

The laying down of a 30,000-ton passenger ship by Harland and Wolff for the Holland-America Line is reported, this being the largest vessel commenced in Britain since the war. The end of the retrogression in size appears to be in sight.

In concluding, it seems to be a safe forecast to make that passenger ship construction will figure somewhat prominently in our bigger and best equipped yards during the next few years, particularly when it is remembered that a considerable number of ships now running would, but for the war, have been out of service ere this and that they will need replacement just as soon as practicable.

The photographs illustrating this paper are available through the courtesy of the New York Shipbuilding Corporation, builders of the ships from which the views were obtained. They can be considered as representative of all the ships, remembering that there are differences in detail.

The state-room view can be taken as typical for all the ships. The rooms mostly have beds; in the larger ships some rooms have regular bunks.

DISCUSSION.

The Chairman:—This paper, No. 10, on "Design and Construction of Passenger Steamers," is now before you for discussion. Two words in the title of this paper, "design" and "construction," represent the very heart of our activities, and I am sure that you have all been very much interested in this brief abstract which Mr. Rigg has given of his paper. It is a subject which lies the very closest, possibly, to our very life and continuance as a society, and I hope it will be freely discussed. It is now before you.

Professor Herbert C. Sadler, *Member of Council:*—Mr. Rigg has, I think, presented us with a very interesting summary on the whole question of the design and construction of passenger steamers.

It is always interesting to look ahead, and perhaps a little more interesting to prophesy what is going to happen in the future. I remember some years ago—I think it was in 1902—I presented a paper before this Society on the subject of the strength of the ships, and I projected the results on to a 1,000-foot ship. At that time I was criticised in a good-natured way by my friends, who wondered what had happened to me when I was talking about 1,000-foot ships, and now, of course, the 1,000-foot ship is an actual fact, or practically so. I mention that to show that I think, as naval architects and marine engineers, the mere question of size is one that would not bother any of us, even if we have to increase the size of our shipyards. The problem from the engineering standpoint is not insuperable.

There are a few factors which will tend to limit the size of ships. The problem of speed, and the capacity of the ship, both from a passenger and a cargo standpoint, are the things that will finally determine the best size. I do not think we need to bother ourselves with projecting into the future any limitations as far as size goes. I think they will fix themselves entirely on the factors of the problem, and this is true, equally, for warships as for merchant ships. We know sufficient, or we can get the information easily, about speeds and powers, to be able to predict exactly what is going to happen before we build a ship. We know enough about construction and weight, etc., to know exactly where we are coming out in any proposed design. The thing which will finally determine the best size will be the economics of the whole thing for the particular service for which any vessel is to be designed, etc.

I think from now on the tendency will be to study the whole problem of passenger ship construction, perhaps a good deal more minutely than it has been done in the past, and it will not, perhaps, be so very necessary to go to the very large ship in order to achieve the objects we want to accomplish.

A paper like this, therefore, I think, throws out some very valuable suggestions, and it is interesting to note, as is known to all of us, of course, the enormous expense entailed in order to get a reduction of one day even in the passage across the Atlantic. I venture to throw out this suggestion: Is it worth while to save one day in five, or one day in four; that is, looking to the future? We have a competitor for high speed—the airship; and I think that the people who are going to be in a hurry in the future will probably go by air rather than by water. Those who want comfort will go, perhaps, by water, and they probably will have a little more room. But I think we should bear in mind that we have, more or less, reached our economical limits of speed on the water, and we can never hope to approach the speeds that are easily obtained in the air. In other words, I do not think we can ever hope, as naval architects, to design a ship that would go across the Atlantic in thirty-six hours.

Mr. Hugo P. Frear, *Member of Council:*—Mr. Rigg has put a lot of thought and hard work into his paper, and the Society is to be congratulated in having presented to it one so full of suggestions, facts, figures and conclusions. The subject has been probed so thoroughly and extensively that individual discussion must necessarily be restricted, and my remarks will only refer to a small portion of the paper.

This is an opportune time for the consideration of passenger steamers on account of the shortage of this particular class of tonnage, as noted by Mr. Rigg and confirmed by the large number of inquiries for plans and prices for vessels of this type during the past two years. A considerable number of contracts would, no doubt, be consummated with little delay if the purchaser were assured that present costs and rates would prevail for several years.

Not only does this apply to passenger steamers but to many vessels suitable for special trades, some of which have been referred to in this paper.

Our new merchant marine built during the war was not based on a prearranged, well-thought-out program, but on a hit-or-miss plan, resulting in an unbalanced fleet for either war or peace service, including a multitude of vessels worth less than scrap and very few suitable for special trades. On this account it seems evident that passenger steamers and vessels for special trades are the ones shipbuilders must depend upon in the immediate future for new orders.

Mr. Rigg has devoted considerable space to the trend of design, length, and cost of high speed. While it is true that the present high costs of construction—and, we might add, operation—have put a damper on the building of floating palaces of the largest and fastest pre-war types, it is not understood that even vessels such as the Mauretania, Aquitania, Imperator, Vaterland, etc., were especially profitable before the war or compared favorably in return on the investment with intermediate types of the Adriatic or Franconia class. The largest and fastest pre-war types were the result of keen competition from an advertising point of view between Great Britain and Germany and also between steamship companies. The cost of advertising is now too great to indulge in on such a scale.

It is doubtful if the trend of design for intermediate steamers or passenger steamers for special trades is towards smaller dimensions or slower speeds. The average dimensions and speeds for the Pacific trade have certainly been materially increased, and, at least in one case for that trade, still larger and faster vessels are contemplated. Designs for new steamers, larger and faster than any previously employed, have recently been completed for not less than four different trade routes. Designs were also submitted not long ago for a steamer to cross the Atlantic in less than three days. This steamer, however, was not to cross the widest part of the ocean.

In connection with the cost of high speed and fuel savings possible for high-speed, moderate dimensioned vessels, Mr. Rigg gives a table of figures on page 279 and another on page 281 which leave much to the imagination. If displacements and coefficients had been included, the data would be more complete. In working backwards I believe I have determined in close approximation the values used by Mr. Rigg and the results given appear to be sufficiently close for comparison of shaft horse-power and fuel, except possibly the shaft horse-power for the 700-foot steamer at 30 knots.

I do not quite follow Mr. Rigg so far as his conclusions from these tables are concerned, and perhaps he could make them more clear in his concluding remarks. The heading, Cost of High Speed, might preferably be termed Cost of Fuel for High Speed, as there are numerous other elements entering into the cost of high speed. It is not clear whether or not 760 feet is recommended as the limit of length up to 30 knots. The table on page 281 seems to indicate that 760 feet might not be the most desirable limit. This table also does not seem to offer convincing proof of fuel savings possible for high-speed, moderate dimensioned vessels. The 600-footer may be considered a moderate dimension vessel, but it is difficult to see from what point of view there is an economic saving in fuel as compared with the 1,000-foot vessel with a difference of only about 16 per cent in shaft horse-power and something like a difference of 200 per cent in displacement.

Mr. David Arnott, *Member*:—I wish to congratulate Mr. Rigg on the very valuable paper which he has contributed on the occasion of the annual meeting of this Society. A paper having for its subject "The Design and Construction of Passenger Steamers" is opportune, if only in view of the probability that the shipyards of this and other countries will be forced to eke out an existence for some time to come by the building of merchant vessels of a type other than the ordinary freighter or tanker.

Mr. Rigg has chosen to present a résumé of the main considerations affecting the design and economy of operation of passenger vessels rather than specialize on a particular branch of his subject, but his paper is no less useful and is certainly much more readable on that account. Plenty of opportunity is provided for discussion, as Mr. Rigg has the pronounced views which usually accompany long experience and does not hesitate to state his own ideas even on such a delicate question as that of interior decoration.

With regard to the interesting particulars given of the 1,000-foot liner, I would like to ask Mr. Rigg if the design ever got beyond the very initial stages, as it seems to me that the comparatively narrow beam of 105 feet, in association with a length of 1,000 feet and a depth of 76 feet, is a return to the proportions of the Atlantic liners of a generation ago and does not appear to accord with the trend of later practice toward increased breadth to which Mr. Rigg draws attention. If 76 feet represents the depth of the uppermost complete deck, it would be interesting to know how many tiers of deck houses were to be superimposed on this deck. I wonder if this vessel, if and when built, would meet Mr. Rigg's idea as to the proper metacentric heights for a modern oceangoing liner.

While it is true, as Mr. Rigg states, that the structural design of a 1000-foot liner would present no serious engineering difficulties, it is always a difficult problem to design a satisfactory ship structure where economy in steel weights is so vitally important as to preclude the piling on of material for the purpose of playing safe, a practice which, after all, is mighty poor design.

In a 1,000-foot ship designed for a speed of 30 knots, the panting arrangements at the ends and the anchoring of the large deck houses would require very careful and special consideration if trouble is to be avoided in these particular neighborhoods. I would like to take issue with Mr. Rigg as to the effect on the weight of increasing the breadth and fineing down the ends in a vessel of the same length and depth, and would suggest that the increase in weight over the corresponding vessel of normal proportions and block coefficient would be considerable in cases where the classification rule scantlings are required to be taken direct from tables in association with any system of numerals.

Mr. Rigg's reference to standardization is particularly appropriate at a time when economy in shipbuilding costs is of the utmost importance. The new British standard sections provide British shipbuilders with a much more economical range of bulb angles and channels than we have available for shipbuilding in America. The new shapes are, weight for weight, relatively much stronger than the old sections and are more easily rolled, while their new standard channel is more suitable for machine riveting, the taper of the flange being about midway between the old parallel shipbuilding channel and the extreme taper of the present American structural channel. It should be noted that British standard sections are common to all users of structural mild steel, including shipbuilders, bridgebuilders, etc., while here in America we have two distinct standards for channels, the structural channel and the shipbuilding channel. The bulb angle, which has distinct advantages over the channel for shipbuilding purposes from the point of view of upkeep, is used more than the channel in British shipyards, while exactly the opposite holds here, due probably to the extra cost of bulb angles as compared with channels.

The adoption of a single line of up-to-date channel sections for all structural purposes in this country would be a distinct gain to both American shipbuilders and structural engineers, and it is hoped that our steel manufacturers may be persuaded that this course will also be to their advantage, as the American shipbuilder is already sufficiently handicapped by high labor costs without being at the further disadvantage of having to use, in shipbuilding construction, shapes which are relatively less efficient than the corresponding shapes available to his foreign competitors.

Mr. Rigg draws attention to other aspects of standardization as applied to shipbuilding and engineering, such as that of Scotch boilers, marine reciprocating engines, ship fittings, etc. Lloyd's Register, the British Corporation and the Board of Trade now have common rules and regulations for the construction of ordinary Scotch boilers, which is a distinct gain to the shipbuilders and shipowners of the United Kingdom. Since 1917 Germany also has taken up the question of industrial standardization with characteristic thoroughness, and it would not only appear that the matter is worthy of the very earnest consideration of American shipbuilders and engineers, but that now is the time to go into this important matter, when business is dull, rather than wait for a revival of the shipbuilding industry.

It is refreshing to have Mr. Rigg's opinion that the recent revision of the rules of the classification societies has placed in the hands of the shipyards methods of designing structure and details which enable much quicker and better work to be done. That is entirely as it should be, as a classification society, in the modern sense as distinct from the old idea of a purely underwriter's registry, is a technical organization, whose only excuse for existence is in the authoritative and impartial service which it may render to shipping, shipbuilding and underwriting interests. All the stockholders are interested in those allied activities, and the capital is represented by the knowledge and experience of the staff.

I feel that the thanks of this Society are due Mr. Rigg for presenting a paper which must have involved considerable expenditure of time and labor.

Mr. William W. Smith, *Member:*—Referring to page 276 of the paper, the author states that electric drive was first contemplated for these vessels. No doubt this type of machinery would make a good installation and would work satisfactorily. However, it is considerably heavier and more expensive than geared-turbine machinery. In view of the performance of the Hood and many other high-powered vessels equipped with geared turbines, there is little room to doubt that this type of machinery would prove entirely satisfactory for an installation of this kind.

It would be particularly interesting if the author would give comparative data for these two types of machinery, provided it is available. From my investigation of this subject, I would estimate roughly that the weight and cost of the corresponding electric-drive machinery would be from 70 to 80 per cent more than the geared-turbine propelling units, and that the steam consumption would be from 4 to 8 per cent greater. The latter would also reduce the weight of boilers, auxiliaries and fuel to a slightly less extent.

On page 278 reference is made to tests of model propellers behind model hulls. I agree with the author that these tests are important and valuable, and it is hoped that additional data of this nature may be presented before the Society. Such experiments alone, however, are not complete unless the test results of the models are compared with the trial results of the vessel. It is suggested that, where possible, a comparison with the trial data be included. Certainly the model results of propellers will be more convincing if they are shown to agree closely with the trial data.

Also, on page 278, the author refers to the desirability of more economical power plants. In this respect, some American shipowners do not seem to appreciate fully the large economic advantages of geared turbines and high superheat. If we compare a geared-turbine installation using steam superheated to 200 degrees with a well-designed triple-expansion engine installation using saturated steam, it will show that the weight and cost of the engine installation will be about 20 per cent more than the turbine installation, and that the saving in fuel consumption of the latter will be about 30 per cent. Geared-turbine machinery has been installed on a number of important passenger vessels, both American and foreign, and its economic advantages are too important to be ignored.

In this connection it would be of especial interest if Mr. Rigg could give the machinery weight, steam and fuel consumptions for the two vessels specified on page 283. It will be noted that the Old North State class is equipped with old-type machinery reciprocating engines and Scotch boilers, whereas the American Legion has the most advanced type—watertube boilers and geared turbines.

I may add that Diesel engines are omitted from this discussion for the reason that the horse-powers under consideration are for the most part far beyond the present accomplishments in this field.

In the tables on pages 279 and 282, the fuel consumption given is approximately 1.0 pound, per shaft horse-power. While this is a fair average performance for conservative estimating, it is not as good as could be obtained with the most efficient machinery. With geared turbines and high superheat, a fuel consumption of 0.85 to 0.90 pound per shaft horse-power should be obtained for installations up to about 30,000 shaft horse-power, and above this from 0.80 to 0.85 pound should be obtained.

Referring to the last paragraph on page 281, it seems that 10 per cent margin is rather a small allowance for average sea conditions. I should think fouling alone would require more than this, and that at least 20 per cent should be allowed for a vessel in close schedule.

Mr. Rigg's views on standardization are concurred in: "I think that large economies can be effected by efficient standardization in machinery and detail parts. It would seem that shipbuilders would profit considerably by adopting common standards as far as possible. Such cooperation has proved profitable in other industries. This society might give valuable assistance by appointing a committee to cooperate with shipbuilders in adopting such standards."

In closing, I may add that the Society is fortunate in hearing such a thorough presentation of this subject which is of especial interest at this time.

Mr. W. M. McFarland, *Honorary Vice-President:*—I was specially impressed, from the nature of my own work, with some of the very encouraging remarks of Mr. Rigg with regard to watertube boilers. On page 279 he says: "The claims of the watertube boiler over the Scotch for high-speed ships have made good to such an extent that they will feature more largely in future ships." And, on page 282, he says: "As regards weights, it is clear that warship practice rather than merchant would have to be followed for machinery design" on high-powered vessels. That is, of course, something that the makers of watertube boilers have been preaching for a great many years, and it is interesting to reflect on the fact that some of the large passenger vessels today are using watertube boilers. As Mr. Rigg says in the paper, the vessels built at his yard, the New York Shipbuilding Corporation, and the ones built at Newport News, have watertube boilers, Babcock and Wilcox type, and those built for Bethlehem at Sparrow's Point have the Yarrow boilers. It is also probably known that the three big former German vessels, the Berengaria (Imperator), Leviathan (Vaterland) and Majestic (Bismarck), all have watertube boilers, which, I understand, are of the Thornycroft-Schulz type.

The new Holland-American ship to which Mr. Rigg refers will be supplied with Babcock and Wilcox boilers, built in England; and I may add that the International Mercantile Marine is also building two 20,000-ton vessels at Harland and Wolff's, which will also have Babcock and Wilcox boilers in them. I am not sure that Mr. Rigg has this information, but it must give him some satisfaction to have his predictions verified so completely and so soon.

The question of weight is one which is very striking indeed. I remember that almost ten years ago, one of the last papers written by my dear old chief, Admiral Melville, discussed this question of the watertube boiler and the saving of weight by its use. I will put the figures in my remarks when revised, but my recollection is he made a comparison about the saving of weight, that would have occurred on the Mauretania and Lusitania, if watertube boilers had been used, instead of having Scotch boilers, and my recollection is that the saving was somewhere between 1,500 and 2,000 tons. (Melville's paper gives the figures as 1,950 tons for watertube boilers against 4,000 tons for Scotch boilers.) They are vessels of large power, 70,000 horse-power. When we run into such large horse-powers as Mr. Rigg has given in the paper, where there is a possibility of 163,000 horse-power, we can see that in such vessels it will be necessary to use the very lightest type of boiler.

You all know that our battle cruisers which are building, even if they are going to be scrapped, would have 180,000 horse-power, and obviously in that case it was necessary to use watertube boilers as has for years been the practice with all naval vessels.

I want to express my appreciation of Mr. Rigg's paper, which is an admirable one and which I have greatly enjoyed.

I would be remiss in giving these data about watertube boilers in passenger vessels if I failed to remind you of the fine record of the Great Northern and Northern Pacific, whose boilers were built by my company for Cramps, who built the vessels. Their service as transports during the war was very arduous. The Great Northern holds the record for long-distance, high-speed steaming, and naturally all concerned in her building are very proud of it.

It may interest you to know that when Sir Wm. White read his paper on "Size of Transatlantic Steamers" at our 1911 meeting, and referred to a new one then under consideration, he had planned a slightly smaller Mauretania, made possible by the use of Babcock and Wilcox boilers.

Commander T. Kawahigashi, C. C., I. J. N. (Communicated):—Mr. Chairman and gentlemen, it is indeed, a very great privilege to be permitted to say a few words about the most interesting paper which has just been read by Mr. Rigg. In it he describes his experience in designing passenger ships. While this is outside my specialty, I could not help being impressed recently, during the trial trip of the American Legion, with the admirable design of this ship. In every particular, it was well constructed, and its trial trip was more successful even than had been expected by its designers. I learned with no little satisfaction that a large number of these ships are destined for Pacific service, where they will undoubtedly play an important part in increasing the trade and consequently the friendship between the United States and Japan and in bringing these two countries closer together by an ever-decreasing distance.

Mr. Rigg gives us an interesting table of shaft-horse-power required to get the speed of 25 knots and 30 knots for ships of various lengths, to show fuel saving high speed. I am impressed by the fact that the shaft horse-power at 30 knots is remarkably small for a ship of 700 feet. I should like to ask whether there is some difference in the shape of these ships and also whether these figures have been obtained from actual experiments.

The experiments with the model propeller which are being carried on in this country are very interesting to me, because we, in Japan, have done nothing along this line. It was my privilege to see the experiments with model propeller carried on at the Naval Experimental Tank in Washington for the tanker being built by the New York Shipbuilding Corporation for our navy. In this connection, I cannot help pointing out how fortunate you are, in this country, to be given the benefit of the experiments carried on by your navy. The equipment of the experimental tank is so expensive and the expert knowledge necessary to carry on the experiments is so hard to obtain that, in a country where the navy is willing to share the results of what is done experimentally with private shipbuilders, the art of naval construction is bound to make rapid progress.

The recent tendency to decrease the length of passenger ships seems to me only a temporary phenomenon of this post-war reduction. It will soon return to the pre-war condition. Mr. Rigg's opinion regarding the avisability of increasing the breadth of a ship is another indication of how we are profiting by the lessons learned in the great war. By increasing the breadth beyond the proportion usually accepted, greater stability is secured and the life of the ship is safer. The passengers may find it less comfortable, but this is far outweighed by the fact that a number of accidents can be avoided. Mr. Riggs is using this idea in a very different kind of ship, and I am sure that its advantages will be as great as in a passenger ship. I refer to the tanker designed by Mr. Rigg for our navy and which is being built by the New York Shipbuilding Corporation. There is no type of ship to which stability is of greater importance than to a fleet oil carrier, and I am convinced that this design will give a decided advantage to the oil carrier in question.

Will you permit me here to take the liberty of saying a word about this same tanker? Twenty-five years ago, two cruisers were built in this country for the Japanese Navy, but since then most of our foreign construction has been done in England. We have consequently been influenced almost entirely by British ideas. Recently, however, you in this country have made such strides in naval architecture that we have been eager to learn from you. Science and art should know no nationality and should be used only for the advancement of mankind. Hence we have come to learn from you one of the most important discoveries of recent times, namely, that of electric propulsion.

Last spring we contracted with the New York Shipbuilding Corporation for a tanker of the following dimensions: Length, W. L., 496 feet; breadth, 67 feet; depth, 38 feet; displacement, 19,550 tons; cargo oil, 10,000 tons; shaft horse-power, about 8,000; speed, about 15 knots.

The electric propulsion apparatus is being constructed at the works of the General Electric Company.

Electric propulsion is only an experiment in our navy, and its success depends largely upon this ship, which requires therefore the greatest care in its construction. As one of the inspectors of this work, I must express my appreciation for the splendid spirit with which everyone is cooperating to make it a success. Undoubtedly electrically propelled ships are going to play an important part in future naval construction, and it is gratifying to know that our Japanese Navy is getting its first lesson in this development from the United States.

Mr. Ernest H. B. Anderson, *Member:*—I think the Society is greatly indebted to Mr. Rigg for this paper, but it seems to me that its value would be greatly enhanced if a second paper could be written describing the machinery in the various ships that Mr. Rigg has referred to. As Mr. Rigg points out, one class has reciprocating engines, while the other class has geared turbines. We all know there are many types of geared turbines; there are also various types of gears, and it would certainly improve matters in finally arriving at the economy and overall performance of these ships if some particulars of the machinery could be published. We have had a certain amount of discussion regarding the different types of boilers, and this is just another phase of the question.

Mr. McFarland referred to the types of boilers in the large German ships. My impression is that the Thornycroft-Schulz has three lower water drums connected by tubes to one large steam drum; in other words, this gives a formation of two fireboxes or combustion chambers, whereas the German ships really have a modified Yarrow boiler with one large steam drum and two lower water drums. A complete description, with illustrations, of the boilers in the Imperator was published in *Engineering* of June 12, 1914.

Mr. Elmer A. Sperry, *Member:*—I think the Society is to be congratulated upon the paper just presented. This paper gives a forward look and I think it is good for the Society also to have such a view. Our friend Mr. Smith says that the Diesels were not considered in his remarks, because they have not yet risen to the occasion. Neither has this ship. So, inasmuch as they are both futures, is it not perfectly proper to stop for half a minute and consider the Diesel? We have to face the facts, and as surely as we are here, Diesels will do our work—the direct combustion of the fuel in the cylinder, where it has absolutely direct application to the delivery of power to the crank shaft, is just as sure to supersede other power as anything in the world.

Now there is nothing insuperable about the size of the gear, because sizes are in sight now of over 12,000 horse-power per engine, with only six combustion cylinders in line, and these are limited to our present knowledge as to the sizes and thickness of the walls of combustion cylinders. Within our present knowledge of the limitations of these vital points, it is possible to make a 12,000 horse-power direct consumption oil engine now. Compounding makes all this easy and simple. Suppose we take this 115,000 horse-power which the author suggests on page 279, and suppose we take the same cruiser, four shafts, and use geared Diesels. These Diesels only require about 7,200 horse-power each, and just think of what we are accomplishing in the point of weight. I venture to say that these Diesels will not weigh as much as the water in the system with steam. We need the weight thus saved to put into fuel capacity, cruising radius, cargo and passengers. Now see what this means from the point of fuel economy. With the steam we would require 6,250 tons of oil for the passage of four days, and with the Diesels we could do with 1,600 tons. That saving alone is worth the entire equipment, and, I repeat, these are things we must not neglect. We are sure to be faced with a large Diesel, direct-connected to the tail shaft or through gears. That is the coming power, and the Diesel is here to do it. Think of running 27,000 miles without grinding a single valve. Oil engines have achieved a wonderful success in the last five years, and we have to face the situation. It is not a theory but an actual condition.

THE CHAIRMAN:—If there is no further oral discussion on this paper on the Secretary's desk there are two contributed discussions, one by Mr. Petersen, and one by Mr. Norton. I am afraid we must read these discussions by title, with the assurance, of course, that they will appear in full in the Transactions. I assume that neither of these gentlemen is present.

MR. CARL E. PETERSEN, *Associate* (Communicated):—Mr. Rigg's paper is a valuable contribution to the Society's Transactions and is of particularly timely interest in view of the existing world shortage of ocean passenger ships. Altogether too little has been written about this subject, which could be extended to the dimensions of a large book as stated.

I should like to add, to the listed items influencing a design, a factor that is of the utmost importance commercially, and that is the necessity of offering accommodations and service superior or at least equal to that of competitive vessels. As regards proportion, the author is quite right in stating that the tendency is to increase beam. Several of the ex-German fleet of vessels with narrow beams and relatively small metacentric heights have been particularly tender and require extreme care in handling. Reasonable increase in beam is highly desirable.

The "one-class" liner has not met with the success it deserves for several reasons; principally the curtailment of third-class passenger traffic, due to the Immigration Act, and the fact that people prefer to travel third class on vessels having first and second-class accommodations. In other words, the pride of the passenger must be considered. Under present conditions there are few trades where a "one-class" ship may be operated with success.

On the subject of length, the pre-war trend of increasing the length has been checked by the economic factors arising from the war. Generally, the length of post-war passenger liners has been considerably less than one would expect. The advent of oil for fuel in the large liners and leviathans, with the consequent operating economy, has had the effect of justification of lengthier vessels. Mr. Rigg, in stating that the problem of the 1,000-foot liner is one of economics, entirely prompts the question: Under present conditions, how long a vessel, other dimensions and particulars being proportionate, could be built and profitably operated in the North Atlantic passenger service? My own opinion is that a length of 700 feet would be justified, but I should like to hear what Mr. Rigg has to say concerning this.

With reference to large liners in the North Atlantic service, the arrangement which works out best is that giving over the greater portion of the main superstructure decks for first-class accommodation, the after portion of the vessel to second class and the forward to third class. The various public rooms for the first class are usually located on the upper decks, with the exception of the dining saloon, which is on the lowest passenger deck, immediately forward of the main galleys and pantries. The second-class public rooms are usually located aft on the main superstructure decks with the exception of the dining saloon, which is placed on the same deck as the main dining saloon but immediately aft of the galleys and pantries. The galleys and pantries should extend for the full width of vessel, always be adjacent to the dining saloons, and arranged only after considerable study to meet service requirements.

A noticeable influence of competition and the Immigration Act can be seen in the third-class accommodations. Quality and comfort are the watchwords today rather than quantity in accommodations, and steerage in the North Atlantic service is fast becoming a thing of the past. Vessels with large steerage capacity can only be filled at the height of the season, and only on the west-bound voyage, and suffer greatly between seasons due to their poor accommodations. Hence the best practice today is to provide comfortable cabins for third-class traffic.

In the intermediate type of vessel it is essential that a large portion of the third-class cabins be of the portable type to permit the spaces being used for cargo if desired. Another important essential in liners which Mr. Rigg has made no mention of is to have certain blocks of interchangeable rooms which may be used for either first or second, or either second or third classes, depending on the variations of the trade. In this case the rooms must meet the requirements of the higher class. The crew, particularly the stewards, should in general be quartered in close proximity to their work, or else a fore and aft working passage provided on one of the lower decks. Where third-class accommodations are located forward, it is desirable to have a forecastle and plated bulwarks and so avoid the condition Mr. Rigg refers to of the forward deck being "so airy that none but able-bodied seamen can navigate with safety."

Single-berth rooms should invariably be inside ones and the larger rooms located as outside ones, this in a large measure minimizing the ventilation difficulties.

With reference to "Details of Construction," may I call attention to the fact that plywood has recently been used in joiner bulkheads and panelled as required, proving very satisfactory and also a time saver. Electric galley ranges are to be preferred to oil fuel ones.

It is agreed with Mr. Rigg that we are not as yet adequately represented on the North Atlantic, but this year has seen the beginning with the placing in service of several ex-German vessels recently reconditioned, the George Washington in particular; this vessel, being the largest and finest in the American service, is as good a combination of the practical and artistic as any. Bids are now being asked for the reconditioning of the Leviathan, and it is to be hoped that the reconditioning of the Mount Vernon, Agamemnon, President Grant and others will soon follow. Our place on the North Atlantic could be realized earliest by the immediate reconditioning of the better ex-German liners augmented by several of the 535-foot class vessels after extensive arrangements and additions have been made to meet the requirements of this trade.

Mr. Harold F. Norton, *Member* (Communicated) :—I have not been able to give the paper sufficient time to really properly digest its contents, but it is certainly quite interesting.

Of course their best friends would hardly cite the Shipping Board passenger vessels as ideal in arrangement, especially for general access. The reason is not far to seek—their design as troop ships and conversion into passenger vessels. However, the point is that the American shipbuilder has not yet had a really good opportunity to show what he might do with a large passenger ship. Also, in our experience, it has appeared that the matter of arrangement depends largely upon the intelligence and progressiveness of the owner or operator. His ways of doing things must be provided for and his ideas deferred to. These ideas are built up from experience, and unless he is already changing long previous practice, or has the vision to see how it may be changed to advantage, one ship cannot be very much of an advance over another.

It is doubtful whether in this country or any other the possibilities of comfort, service, convenience and entertainment of passengers on shipboard have been developed to anything approaching a maximum. Quite possibly some genius of an operator will some day appear who will develop a dining-room service, a room service and a deck service, and will provide for the comfort, convenience and pleasure of his passengers in a way that will quite astonish all of us. He will cause, or permit, an arrangement of the ship and its service features which it will be delightful to contemplate. However, it will only be through the cooperation of an operator and designer, each with sense and imagination, that any such happy culmination is likely to be made possible.

The Society should feel indebted to the author for a paper which furnishes considerable information for future reference and suggests many lines of interesting thought.

The Chairman:—If there are no further remarks, I will ask Mr. Rigg to close the discussion.

Mr. Rigg:—I thank you, gentlemen, for the reception you have accorded my paper, and in reply I will endeavor to be as brief as possible without being so brief that I do not make myself clear. Dr. Sadler's point as to giving deeper study to passenger ship design is well taken. Undoubtedly airship development must be taken into account in the long run; at present it is not in any way a rival for transatlantic passenger carrying, but it is now a rival to cross-channel ship service in Europe. Regular lines from London to Paris and London to Brussels are running. To what extent these lines are commercially successful is not known to me—but, judging by recent experience, the cross-channel steamers still have plenty to do. Recent large airship experience is not encouraging to transatlantic flight enthusiasts.

Saving one day in five is evidently worthy of consideration, and that is what a 30-knot ship does as compared with the present maxima. For a surface ship to cross the Atlantic in thirty-six hours is not yet in the realms of practicability, involving, as it does, about three times present top speeds.

Mr. Frear raises the question of the power given for the 700-footer on page 281 at 30 knots. On checking over the table I find that I was a little unfair to the 600-footer at 30 knots in the matter of displacement-length ratio, which had the effect of running the power up unduly. The figure of 137,000 originally given has been modified to 132,000. This balances the curve better, one object of which was to show the undesirability of trying to push the 600-footer at 30 knots on account of the high residuary resistance. The term "fuel saving at high speed" does need qualification; it would be better to have said "comparison of powers necessary for varying lengths at high speeds." Commander Kawahigashi also refers to this table; the low power at 30 knots for the 700-footer is that the residuary resistance is coming down to a practical amount at this length. These figures were based on experiments carried out in the Washington tank, but not on experiments for these particular vessels.

Mr. Arnott asks if the design for the 1,000-footer ever got beyond the initial stages. It did not, but the initial stages were carried well along, though by no means up to the point of commencing to order material; the general arrangement plans were completed and some work done on weights and stability. I believe also that some experimental tank work was started.

With regard to deck houses, they would not be as extensive as is common on modern liners. With regard to the effect of increasing beam on the steel weight, there is, as stated in the paper, an increase in this item; it becomes a question of economy how much fuel is saved and what is the capital cost of that operating economy. I believe the operating economy is frequently more than enough to justify the cost.

Referring to Mr. Smith's comment, detailed reference to the machinery of the new ships and its performance was avoided as not coming within the legitimate scope of this paper. The various methods of ship propulsion now available are most interesting, and adequate discussion of them is in process of formation, as is evidenced by other papers presented at these and similar meetings.

Mr. McFarland's remarks on watertube boilers are to the point; he has added information on new work of which I was not aware.

Mr. Anderson's suggestion of a later paper on the machinery of these new liners is a good one. Perhaps the Society will be able to secure such a paper next year; it is something that would be valuable, because not any too often do you get a chance to compare different types of machinery in identical ships.

Mr. Sperry's optimism in the matter of high-power Diesel engines opens up a vision of economy in ship operation that will go further than appears at first sight; it will lower the size of ship needed to do the work as well as actual fuel per mile.

Mr. Petersen speaks from an owner's point of view, and that is very welcome at these meetings and something we could well have more of. I am glad he backs me up in the matter of more beam and in the question of arrangement of saloons and galleys. The question of interchangeable rooms is an important one in several trades. As to the justifiable length for transatlantic liners, I have no set views, but have tried to urge the claims of the 750-footer as giving a ship large enough for comfort and good driving qualities. The 500-footer is out of it as a modern proposition; the 600-footer is small if you want speed in the present sense of the word. The 1,000-footer is out of joint with the present condition of world finances.

Mr. Norton strikes a note that needs emphasizing—the comfort, service and convenience of the passenger. How familiar we are with the old game of crowding in as many rooms, miscalled state rooms, as possible. We cannot expect a ship to be a favorite that does not come out well along the lines Mr. Norton indicates. In a pinch, people will submit to a term on ships of the opposite character, but such ships do not develop passenger service in the real sense; they merely give a lift to a fellow who has to take the road.

In conclusion I want to thank the gentlemen who have contributed so much of value to this discussion and to thank you all for your kindly reception of the paper.

The Chairman:—I as sure that we thank Mr. Rigg for this very stimulating paper.

We will now take up Paper No. 11, entitled "The Influence of Shape of Transverse Sections upon Resistance," by Professor Herbert C. Sadler, Member of Council, and Professor E. M. Bragg, Member. The paper will be presented by Professor Sadler.

Professor Sadler presented the paper.

THE INFLUENCE OF SHAPE OF TRANSVERSE SECTIONS UPON RESISTANCE.

By Professor Herbert C. Sadler, Member of Council, and
Professor E. M. Bragg, Member.

[Read at the twenty-ninth general meeting of the Society of Naval Architects and Marine Engineers, held in New York, November 17 and 18, 1921.]

From time to time results of experiments on the influence of shape of bow and stern sections upon the resistance of ships' forms have been recorded, but usually these have referred to special cases, sometimes accompanied by other changes of form and generally for vessels of somewhat high speed.

Froude's original dictum of U-shaped sections forward and V-shaped aft still lingers in the minds of most designers as applicable to all forms at all speeds. Some years ago some experiments on models of full form were conducted in the experimental tank at the University of Michigan (see Vol. 17, Society of Naval Architects and Marine Engineers), in which it appeared that the V-shaped sections, both forward and aft, gave the better results.

The following investigation was therefore undertaken with the object of covering the field more fully, especially for the slower and moderate speed types.

The parent body plans and curve of sectional areas are shown in Fig. 1, Plate 53, and indicate the changes in type of sections used. They are based upon a vessel 425 feet B. P. by 56 feet, with a normal load draught of 24 feet 9 inches and a deep load of 27 feet 9 inches. The vessel has a cruiser stern and a length on the deep load line of 435 feet, this length forming the basis for the spacing of sections.

The shape of the cruiser stern had to be modified slightly with different lengths of run for fairing purposes, but at the 24-foot 9 inch draught the change in length was negligible.

The various percentages of ends and middle bodies are given in terms of the length between perpendiculars. All the results have been reduced to a temperature of 65° F.

In general, two parent forms were taken as follows:

1. A model with a fixed length of run and with "medium" type of stern sections.
2. A model with a fixed length of entrance and "medium" type of bow sections.

Each model was further modified in the following manner:

Fixed run 40.5 per cent L. B. P.	Five lengths of entrance from 23.7 per cent to 48.5 per cent L. B. P.	Each type with U, Medium, and V-shaped sections forward.
Fixed entrance 27 per cent L. B. P.	Four lengths of run from 24.3 per cent to 48.6 per cent L. B. P.	Each type with U, Medium, and V-shaped sections aft.

The parent forms, with the above lengths of entrance and run, were selected from a former series of experiments covering some hundred types and appeared to be those that gave the best results from a resistance standpoint, for the range of speeds suitable for the present series of models. Each model was tested at four different draughts and consequently represents four types of vessels with varying ratios of beam to draught, and varying prismatic coefficients.

The particulars of the parent form are given in the following table, the prismatic coefficients being for the whole vessel, and a parallel middle body of 32.5 per cent.

	Bow sections varying		*Stern sections varying*	*B/d*
15-foot draught	U,	.734	.737	
	M,	.730	.728	3.73
	V,	.727	.721	
20-foot draught	U,	.756	.757	
	M,	.754	.753	2.8
	V,	.753	.750	
24-foot 9 inch draught	U,	.772	.772	
	M,	.772	.772	2.26
	V,	.772	.772	
27-foot 9 inch draught	U,	.785	.783	
	M,	.786	.784	2.02
	V,	.787	.785	

For other variations of percentage of middle body and ends the change in prismatic coefficient is shown in Fig. 2, Plate 54.

METHODS OF PLOTTING RESULTS.

There has been some discussion in this and other countries as to the various methods used for recording the results of tank experiments. Here it has been customary to give the residuary resistance in pounds per ton of displacement on a speed-length ratio base. Abroad, the Froude constant system or $\boxed{C}$ values, or a modification by Baker, or $\boxed{P}$ values have been used. Arguments pro and con for each system can be made, but the deciding factor rests in the use to which the results are to be put. If for general comparative purposes in tank work, then the $\boxed{C}$ values on a speed-length ratio base, or even $\boxed{P}$ values possess certain advantages. In other words, the "ideally best" vessel may be readily determined. If, however, the results are to be used by the practicing naval architects, it would seem that a somewhat more simple form would be preferable, especially as limiting conditions of design and the necessity of arriving at the results of minor modifications quickly are the governing factors.

The following results have therefore been plotted in the form of effective horse-power per ton of displacement or $\frac{\text{EHP}}{\text{Tons}}$ upon a speed-length ratio or $\frac{V}{\sqrt{L}}$ base, and apply directly to a 425-foot ship.

They can be readily modified for any other length by multiplying by the square root of the length ratio up to a difference of 10 per cent either way, and within the limits of, say, 2 or 3 per cent either way may be taken as practically constant for a given speed-length ratio.

Another reason why there appears to be no particular necessity for having a system which will apply to all lengths of ships from the model up is that in practice the ratio of length to beam and beam to draught will vary considerably in passing from a small to a large vessel, and therefore the results of any set of experiments must necessarily have a somewhat limited application.

The ratio of horse-power to displacement is also one of the factors entering into the economy of vessels and hence in preliminary design work may have to be taken into account.

A discussion of the proposed method is given in the appendix.

In order to exaggerate certain features in the present paper so that the diagrams will show more clearly the effect of the varying the shape of section of the vessel and to bring them into the limited dimensions of the volumes of our Transactions, some of the figures have been modified by a factor representing the cube of the speed-length ratio.

RESULTS OF EXPERIMENTS.

As a general comparison of U and V-shaped sections, Fig. 3, Plate 55, shows the effect upon the resistance for a full and a fine vessel with (*a*) stern sections and (*b*) with bow sections varied. With regard to the influence of bow sections it is apparent that, within the range of speed suitable for the vessel concerned, the V-shaped sections are best for the full form and the U-shaped sections for the fine form.

When the stern sections only are varied, the influence upon resistance is not so marked, but in general the U shape appears to give the better results. It should be remarked, however, that the so-called U sections aft are of the moderate type and not so pronounced as the corresponding bow sections.

The diagrams shown in Fig. 4, Plate 56, and Fig. 5, Plate 57, illustrate, for a selected model, the variation of resistance in terms of speed due to modification of bow sections with a constant medium type of stern, and modification of stern sections with constant medium type of bow; and also the influence of change of draught from the light to the deep load.

Figs. 5, 6, 7, 8 and 9, Plates 57 to 61, show the percentage of parallel middle body at which the resistance is minimum for any given speed, and the value of the effective horse-power per ton at that speed. They have been obtained from curves similar to that shown in Fig. 10, Plate 62, which illustrates the effect of the various changes for a selected speed-length ratio of .581. Each of the above figures refers to a given draught or, for the models concerned, a variation of breadth to draught of from 3.73 to 2.02.

CONCLUSIONS

A study of the diagrams will reveal certain facts which are of interest. In the first place, it is evident that no hard and fast rule can be laid down as to the best type of bow and stern sections for all ships at all speeds; and, in the second, that the best type of section for a given ship at the load draught is not necessarily the best for the same ship at lighter draughts. The selection of the best type of section will depend upon:

1. The speed-length ratio.
2. The fullness of the vessel.
3. The distribution of displacement longitudinally.
4. The ratio of breadth to draught.

Certain rather broad conclusions may, however, be drawn. In the finer types of vessels of the merchant ship type and at speed-length ratios over .75 and not exceeding, say, 1.0, the U-shaped bow sections accompanied with moderately V-shaped sections aft, *i. e.*, sections not too full on the waterline, will in general give good results.

In the fuller types and at speed-length ratios in the neighborhood of about .6 or under, the V-shaped bow sections, accompanied with moderate stern sections as above, will, in the majority of cases, give a satisfactory form.

If it is anticipated that the vessel is to run at reduced draught for any appreciable percentage of her time, then the U-shaped bow sections lose their advantage, and a compromise section will prove more satisfactory. Oil-carrying vessels and Lake ore carriers are an illustration of the case where the vessel runs for 50 per cent of its time at a considerably reduced draught.

The underlying cause of the variation of resistance due to shape of section is probably to be found in the general conditions of stream-line flow at the ends, so that the prismatic coefficient of the ends, combined with the speed-length ratio of ends and also what might be called "diagonal fineness," will influence the results. Admiral Taylor's experiments on stream-line flow around vessels show conclusively that a good deal of the general flow is in a downward direction and, consequently, anything that can be done to make the path as easy as possible; *i. e.*, by paying some attention to the lower parts of the sections, particularly where these fair into the midship part, will probably reduce resistance.

APPENDIX.

The effective horse-power of any ship taken as a model will be

$$E.H.P._1 = (f_1 S_1 V_1^{2.83} + R_w V_1) \times .00307.$$

f_1 = Coefficient of friction for model ship.

S_1 = Wetted surface of model ship.

V_1 = Speed of model ship in knots.

R_w = Wave resistance of model ship in pounds.

At the same speed-length ratio the effective horse-power of a similar ship whose dimensions have the linear ratio λ to the model will be

$$E.H.P._2 = (f_2 S_1 \lambda^2 (V_1 \lambda^{.5})^{2.83} + R_w \lambda^3 V_1 \lambda^{.5}) \times .00307$$

$$= (f_2 S_1 \lambda^{3.415} V_1^{2.83} + R_w V_1 \lambda^{3.5}) \times .00307$$

$$\therefore E.H.P._2 = (E.H.P._1 \lambda^{3.5} - (f_1 \lambda^{3.5} - f_2 \lambda^{3.415}) S_1 V_1^{2.83} \times .00307.$$

In terms of effective horse-power per ton of displacement, since displacement varies as λ^3:

$$\frac{E.H.P._2}{Dispt._2} = \frac{E.H.P._1}{Dispt._1} \lambda^{.5} - \left(f_1 \lambda^{.5} - f_2 \lambda^{.415}\right) \frac{S_1}{Dispt._1} V_1^{2.83} \times .00307.$$

Where the similar ship is only 10 to 12 per cent longer or shorter than the model ship, the second term can be neglected without introducing any serious error, and the effective horse-power per ton obtained by multiplying the similar quantity for the model ship by $\lambda^{.5}$. The power so obtained is for the same speed-length ratio as in the model ship.

As an illustration, the following table has been prepared for a model ship of 425 feet:

Similar ship	λ	Beam	Beam = $\frac{L}{10}$ +	$\lambda^{.5}$	f_1	$f_1 \lambda^{.5}$	f_2	$\lambda^{.415}$	$f_2 \lambda^{.415}$	$f_1 \lambda^{.5} - f_2 \lambda^{.415}$
375	.882	49.5	12.0	.94	....	.00853	.00913	.949	.00867	—.00014
425	1.00	56.0	13.5	1.00	.00908	....	....	....	....	....
475	1.118	62.5	15.0	1.057	....	.00960	.00905	1.047	.00947	+.00013

At the deepest draught the ratio of wetted surface in square feet to displacement in tons does not exceed 2.9 for the model ship, and for the lightest draught rarely exceeds 4.0.

At the high speed-length ratio for this type of .68, the value of $V^{2.83}$ is about 2,000. Using these values for a similar ship where $\lambda = .882$ the value of the corrections becomes:

$$+ .00014 (4 \times 2000 \times .00307) = .0034.$$

At the lowest draught the effective horse-power per ton of displacement of the model ship is about .30. If the simplified expression is used, the effective horse-power per ton for a similar ship will be .3 × .94 = .282; and if the complete expression be used it will be .3 × .94 + .0034 = .2854 at the same speed-length ratio.

In this extreme case the correction amounts to a trifle more than one per cent.

DISCUSSION.

THE CHAIRMAN:—This paper, No. 11, entitled "The Influence of Shape of Transverse Sections upon Resistance," is now open for discussion.

PROFESSOR L. B. CHAPMAN, *Member*:—The Society is very fortunate to have this very valuable paper presented by Professor Sadler and Professor Bragg. An entirely new field has been covered, and the results will be very useful in merchant ship design. The profession is certainly indebted to them for this piece of work which, we all know, must have taken a long time to perform.

I should like to speak briefly about the method of presenting the results. Last year we had considerable discussion along this line in connection with Mr. Robertson's paper. The method used by Admiral Taylor and, until this year, by Dr. Sadler is to divide the resistance up into frictional and residuary. The residuary is plotted in pounds per ton of displacement on a base of $V \sqrt{L}$. This is a very convenient method, for the frictional resistance can be carefully and accurately determined and the residuary estimated from published data. The frictional resistance is generally about two-thirds of the total, and this can be definitely computed if the wetted surface is known. For ships without parallel body we have Taylor's Standard Series as a basis for comparison of residuary resistance, these curves being very useful as a standard for comparing the residuary of a new ship. Also, for this type of ship the wetted coefficient C in the formula W. S. $= C \sqrt{\text{D.L.}}$ is well known.

Now when we come to ships with parallel bodies practically all of the published data is given in terms of $\boxed{C}$, where E. H. P. $= \dfrac{\boxed{C}\, V^3\, D^{2/3}}{427.1}$ the standard ship being 400 feet long.

The experimenters in this field—namely, Baker, Semple and Robertson, all use a different base, either $V \sqrt{L}$ or some variation of this ratio. McEntee gives all his data as E.H.P. for a 400-foot ship; so $\boxed{C}$ can be easily obtained. For ships of this type there are little published data on the value of the wetted surface coefficient C; and as all the data have been given in the form mentioned, it is a very useful and convenient method.

Now Doctor Sadler comes forward with a new method of presenting results—namely, E.H.P. per ton, on a basis of $V \sqrt{L}$. As the curves of pounds of resistance per ton are known to cross each other when changes are made in the draught he probably used this method in place of the $\boxed{C}$ method. In order to keep his curves within reasonable limits he has divided the values of $\dfrac{\text{E.H.P.}}{\text{Disp.}}$ by $(V \sqrt{L})^3$. This is perfectly clear on the curves and can be easily corrected for. However, I believe that the correction necessary to apply before using these results—namely, that $\dfrac{\text{E.H.P.}}{\text{Disp.}}$ has to be multiplied by the square root of the length ratio ($\sqrt{\lambda}$)—is going to be overlooked bu the practicing naval architect. Thus, if the ship in question has some other length than 425 feet, is not the man picking up the paper going to overlook the necessary correction factor. It seems to me that if Doctor Sadler had presented his results as E.H.P. $\div D^{7/6}$ the possibility of this error would have been avoided.

For changes of length within the limits that this data would be used, the second part of his correction factor can be neglected, as clearly shown in the appendix.

Mr. A. J. C. Robertson, *Member:*—In this very briefly worded paper, the authors have presented this Society with a mass of most valuable tank-test data which it would take many weeks to thoroughly assimilate. They have thrown a great deal of new light on the resistance of the fuller types of ships, suitable for slow to moderate speed, and the more we are able to go into these curves the more thoroughly do we appreciate the enormous work and the great value of this contribution.

A good model freight ship has been used as a starting point, and that model has been varied radically in the shape of the transverse sections in the fore and after bodies, and in addition the lengths of these bodies are variously proportioned to the whole ship length; and all the models have been tested at four different draughts and the results furnished (except in case of Plate 55).

Plate 55 gives the first set of results, a full form of long run, and a fine form with equal entrance and run, and shows each with two kinds of stern and one bow, and also with two kinds of bow and one stern. The variation of the stern lines shows very small change in the resistance values, but in general the U-shaped stern with the consequent narrower water lines shows up somewhat better. This permits shipbuilders to indulge in a reasonable amount of club foot of the stern lines, permitting more rigid support to the propeller shaft and somewhat easier lines above water, preventing the slamming which occurs with a full counter when the vessel is making its way against a head sea.

The variation in form is much more interesting where the bow is changed, and in general the results also help the naval architect because with the fuller model the V-shaped bow shows up considerably better than the U-shaped bow for the useful range of speeds, whereas in the fine model the U-shaped bow is the best. This apparently indicates that a certain amount of fullness is permissible near the base line irrespective of the fullness of the water line, but that excessive fullness, which is fatal to the ship's structure in head seas, is also bad for the ship's propulsion.

In Plates 56 and 57, a single model is shown at four different draughts, and this throws a great deal of light upon the problem of U and V-shaped lines. In plates 56 and 57 the M-bow and M-stern resistance curves are indentical, Plate 56 being devoted to the effect of varying the bow sections and Plate 57 the varying of the stern sections.

Quite apparently the variation in the bow sections is the more important one, and considerable savings in power can be gained by the adoption of the correct transverse form. You will notice that, at the very large draughts shown at the bottom of the diagram, the difference between the V-bow and the M-bow is very much less than for the lesser draughts; this curious feature is in accordance with the observation I have made in analyzing other models. A fullness of transverse section in the underbody affects the resistance in proportion to its nearness to the load-water line. It is customary to think of the residuary resistance of ships as wave-and-eddy-making, and though we have no means of measuring the relative amounts of these resistances this practice is a good one. That part of the ship which is sufficiently far under the surface has relatively little to do with the development of the diverging waves which are always lost, and the transverse waves which may be lost or may be, in a large measure, recovered according to the length of the parallel bodies adopted. If the lines low down are shaped for eddy-making only, the result will be good providing the draught of the ship is sufficient, but at the lighter draughts wave-making is set up and interferes with the normal resistance of the ship. Before leaving Plate 56 it should be pointed out that for the different curves there is a different prismatic coefficient except at $\frac{B}{d} = 2.26d = .435$.

Passing to Plates 58, 59, 60 and 61, these will probably be considered the most valuable part of this very valuable contribution. They represent an enormous amount of work and provide the greatest assistance to the designers of full-form ships, as they enable the designer at once to select the fullness of model satisfactory for any given speed at any given draught and provide him with resistance figures corresponding to that model. As for Plates 56 and 57, the prismatic coefficient varies throughout this series, and therefore the resistance curves are composite ones representing an optimum model with constantly varying fullness to suit its particular speed.

The speaker is fairly familiar with the various tank tests made public in this country and elsewhere, but I must confess that I feel very much at sea in regard to these new methods of presenting tank tests. Doctor Sadler and Professor Bragg have used two methods in these sets, Plate 55 being in the form of $\frac{\text{E.H.P.}}{\text{Displ.}}$ curves, and the other diagrams use a similar form divided by the cube of the speed ratio, a new form which is supposed to assist in the ready application of the results to ordinary ship work.

The authors must be aware, however, that anyone who makes a serious study of the correct form for a ship must take into consideration not only this particular paper but all preceding contributions to this subject to form a proper judgment of the value of these curves, and must have a good basis of comparison with other work. Unfortunately the conversion of the results of this paper to any other standard method of presentation is going to be quite a serious matter. For C curves at 425 feet the ordinates would be multiplied by

$$\frac{\Delta^{\frac{1}{3}} \times L^{1.5}}{427.1} \left(= \frac{\Delta^{\frac{1}{3}}}{20.5} \text{ for these models} \right).$$

You will notice that the resistances have been presented for a vessel 425 feet long, whereas generally in other papers these had been presented for a standard ship 400 feet long. The model resistances have been reduced to a constant temperature of 65° (the first time which Doctor Sadler has used a temperature correction), and this temperature must therefore be corrected to a temperature of 70° to make the results comparable with Washington, or a temperature of 55° to compare with the Teddington tank. I think it is a great pity that the authors did not adhere to the 70° which is used in Washington. This temperature was also used in the paper last year by myself, and as the Ann Arbor tank temperature frequently runs as high or even above it, no serious error could possibly have been involved in adhering to this figure until such time as the important authorities on ship resistance decide upon a standard method of presentation.

The standard model used by Doctor Sadler evidently lies between model E.W. and the model F.W. in the paper of last year presented by the speaker, showing an excellent ε/ρ ratio of 0.65, and the results of varying parallel middle bodies have been presented on a percentage of parallel body.

The authors must surely be aware that such a form is very misleading if any changes are made in the curves of areas forward or aft. For that reason the speaker last year suggested the use of a standardized method of measuring entrance and run designated ε/ρ. The most serious criticism of the whole paper in my mind has to do with the actual quantitative results themselves. These are expressed as already indicated, as E.H.P. upon displacement, divided by the cube of the speed ratio. Now I submit that this system, which is quite novel, and therefore useless for comparison purposes with any previous results, is also without the one advantage claimed for it—that it is suitable for ready application by the busy naval architect who does not specialize on ship resistances. This form of expression, which does not follow the law of comparison, gives serious differences for very limited changes in draught, and is impossible of application for any important changes in length, and therefore the data presented are very limited in their application; even a 12 per cent variation in length above or below that at which the results are given shows 1 per cent variation in resistance; and other draughts than those presented could only be obtained by the use of cross curves.

Doctor Sadler and Professor Bragg must be aware that the advantage of experimental tank results is largely that it enables a designer to choose the minimum dimensions of a vessel for a given duty, and that the economies so effected are usually greater than the economies gained by a slight variation in the resistance of a vessel of fixed size. Any investigation along the lines of variation of ship dimensions must be carried out on a different basis than that on which these results are presented. Anyone who has had any experience with the Froude "C" Constant System will realize how very much superior it is to the one here used.

I hope the authors of the paper will understand that in spite of this rather stringent criticism the paper appears to me as being one of the greatest value, and I join heartily in congratulating the Society in obtaining this admirable contribution.

Mr. E. H. Rigg, *Member of Council:*—It is in order to once more call attention to the very valuable work which Professor Sadler and his colleague, Professor Bragg, have done in the cargo-boat field. We heard this morning of the importance of economy of operation, and as a practicing naval architect I want to bear witness to the fact that these gentlemen have contributed to this in a very material, even if highly mathematical, way; they are steadily publishing the results of experiments which are valuable to our profession, assembled here and in other places, all tending to bring about economy of actual ship operation. It is just as important to have a low E.H.P. per ton of displacement as it is to have a low fuel consumption per horse-power developed.

With regard to the methods of presentation, I am not going to enter particularly into that discussion, which is in able hands, but I feel strongly that anything that this Society could do to help standardize these methods would be welcomed by the profession at large. I have talked with Admiral Taylor, Sir Archibald Denny, and Mr. Robertson; and on one occasion, some years ago, was rash enough to venture some remarks of my own on desirable methods of presentation of results. The proper solution seems to be that the tanks should each retain their own working methods but adopt a common standard for publishing results; that appears to be the general opinion which I gathered in talking the matter over with gentlemen intimately connected with experimental tank work.

Mr. Hugo P. Frear, *Member of Council:*—Doctor Sadler, as I understand it, has taken models on which exhaustive tests had previously been made to determine the best longitudinal distribution of displacement and found that by modifying the distribution of displacement up and down a considerable saving could be made. It is not my intention to discuss at length the body of the paper, because I have not given it sufficient study and there are others here who have and are carrying out that part of the program very well.

In regard to the system of notation I think naval architects, who are working on the job all the time, have methods of their own and reduce data given in various papers under different notations to some form they are accustomed to and thus are able to make more ready use of it.

In the appendix I notice a formula Professor Bragg gives to develop from a given test the effective horse-powers for the same speeds of vessels of greater or less displacements due to an increase or decrease of from 10 to 12 per cent in length. It is seldom that, within a range of 10 or 12 per cent, one could not almost guess at the power for the same speed. In most cases it is necessary to jump over a much greater range to handle the miscellaneous problems confronting us almost every day.

If model tests could be presented on four different draughts, by drawing cross curves, an almost unlimited number of modifications of length to draught and breadth to draught ratios would be available. Any formula or method by which this data could be extended over a greater range than 10 or 12 per cent in length would greatly enhance its value. I have used a method for over twenty-five years with satisfactory results, as far as my experience has gone, without going astray very badly. We all know that skin resistance does not follow the same law of similitude that the residuary resistance does. If it did, corresponding powers and speeds of similar models could be readily found by using the ratio of displacements as a function of the power and the 6th root of this ratio as a function of the speed. For a range of only 10 or 12 per cent, this would probably produce results sufficiently close for practical purposes and involve no greater error than is often made in determining the propulsive coefficient. I have found that, by using a slight variation of the 6th root of the ratio of displacements as a function for corresponding speeds, very accurate results can be expected over a much greater range. The modification of the 6th root will vary a little with different types but will not fluctuate much above or below. With data now available it is not difficult to determine these values, after which corresponding powers and speeds close enough for all practical purposes can be derived—at least this has been my experience.

Mr. H. C. Towle, *Member:*—It is some five or six years since I departed from a naval architect's office, where I spent ten years applying these principles, and I probably look at some of these things a little differently from the naval architect who is actually practicing. These papers are like education—they form a valuable background for the practicing naval architect to work from; they give him, you might say, his limits, but enough emphasis is seldom placed on two points referring to the construction of vessels. One is that the naval architect tries to design a theoretical vessel as far as resistance goes, and tries to maintain the maximum efficiency in resistance, without adequate knowledge from the owners of the route over which the vessel is to trade. We have had recently, if I may criticise a little, some $60,000,000 worth of ships designed with U-shaped forward sections, very fine in the region of the propellers, but with very full waterline aft due to the cruiser stern, the natural result being that in a seaway these vessels dive unmercifully into the water forward. This probably would have been foreseen and guarded against if they had been designed for the particular trade they are in. The architect, I think, if possible, should make a voyage or two on the owner's vessels before he is given the job of designing a boat for that owner's trade. I think that more attention should be paid to that matter.

Mr. H. H. Schulze, *Member:*—Without attempting to criticise Doctor Sadler's experiments, which are a very welcome addition to Constructor McEntee's previous paper, I would like to enter the discussion on the method of presenting it. Having to make resistance calculation very frequently, I find that Taylor's method is very satisfactory, giving comparative results, and is a yard stick by which we measure the resistance of vessels, taking into account length, breadth, draught, longitudinal coefficient and the displacement-length coefficient. These are the factors which enter into his calculations, but not the refinements which are the results of Doctor Sadler's present investigations.

In most of the vessels built and designed nowadays—that is, slow-speed vessels—the skin resistance is probably two-thirds of the total resistance, and, therefore, we have attempted to devise methods of calculating the wetted surface very accurately; in other words, we attempted to determine two-thirds of the resistance very accurately, which allows great latitude for the one-third remaining.

By calculating by Taylor's method, resistance of models for which we have actual resistance curves, we obtain coefficients showing the relation of our own models to Taylor's series, and, applying Taylor's method and these coefficients, we can predict results with accuracy.

The Chairman:—If there is no further discussion, I will call on Professor Bragg to close the discussion.

Professor Bragg:—As there seems to be some misunderstanding regarding the use of the formulae given in the appendix I will dispose of that question first.

The effective horse-power necessary to drive a ship at a certain speed can be divided into friction horse-power and residuary, or wave, horse-power. Given the data in this divided form, it is possible to find the horse-power necessary to drive a larger or smaller, similar ship at a corresponding speed by simply multiplying the wave horse-power by a quantity equal to the length-ratio raised to the 3.5 power, and the friction horse-power by a quantity equal to the length-ratio raised to the 3.415 power. This friction horse-power should also be multiplied by a factor involving the frictional coefficients of the two lengths.

If one does not have the effective horse-power divided into these two parts, but merely has the total of the two parts, the formulea given in the appendix can be used if the wetted surface of the model ship is known.

If one does not have the wetted surface of the model ship given, then a close approximation to the true E.H.P. can be obtained by using the simplified expressions successively. This is illustrated by the following example where we start with a ship 425 feet in length and work up by increasing the length 10 per cent in successive steps to a ship 624 feet long. The speed-length ratio is 0.727, or equal to 15 knots for the 425-foot ship. The wetted surface of the 425-foot ship is 36,350 square feet. The total E.H.P. in the table can be obtained by either of the first two methods mentioned.

Length of ship, feet	425	468	515	567	624
Ratio of length to preceding length	....	1.1	1.1	1.1	1.1
Friction coefficient	.00908	.00905	.00904	.00903	.00902
Wave horse-power	1,140	1,592	2,222	3,100	4,328
Friction horse-power	2,160	2,990	4,148	5,755	7,990
Total E.H.P.	3,300	4,582	6,360	8,855	12,318
E.H.P. obtained by using $1.1^{3.5} = 1.395$	....	4,605	6,427	8,970	12,510
When factor 1.39 is used	....	4,590	6,385	8,880	12,340

The wave horse-power goes up as $1.1^{3.5} = 1.395$, while the friction horse-power goes up as $1.1^{3.415} = 1.388$, with a slight modification for difference in frictional coefficient. If the form is good and the speed not excessive, the friction horse-power will constitute from 70 to 75 per cent of the total. If a multiplier nearer to 1.388, say 1.39, should be used, the approximation is very close.

The use of the approximate formula is well illustrated by the table in Mr. Rigg's paper, on page 282. He starts out with a vessel of 585 feet length and goes up to one of 930 feet length. I do not know how he obtained those powers, but you can see how simple a matter it is if you make use of the approximate expression.

Length (feet)	585	735	850	930
Length ratio to preceding	....	1.255	1.155	1.092
Length ratio raised to 3.5 power	....	2.21	1.63	1.36
Power given by approximate formula	27,500	60,775	99,110	134,750
Power given by Mr. Rigg	27,500	61,000	97,250	135,000

Occasionally it is desirable to be able to determine approximately the horse-power necessary to drive a ship at a certain fixed speed as the length is increased or decreased. If we have the horse-power for a ship at a certain speed, the horse-power at the same speed for a longer or shorter similar ship can be obtained from this by multiplying by the length ratio raised to the 1.7 power. This approximate formula should be used only when the speed of the derived ship is not in excess of a speed-length ratio of 0.6. When working from a model ship to a derived ship of greater length the power curve will be slightly under the true curve, crossing it at a speed-length ratio of about 0.6 and at high speeds will lie above the true curve. The reverse will be true when working from the model ship to a shorter derived ship.

The data here given can be carried to any length of vessel desired by the formulae given in the appendix. If the displacements of various 425-foot ships are desired, they can be obtained from the prismatic coefficients given in Plate 54 and the midship-section coefficients of .979, .981, .983 and .985 for the four draughts tested. The wetted surface can be found with all the accuracy needed for these formulae by means of the expression:

$$\text{Wetted surface} = 16\sqrt{\text{length} \times \text{displacement}}.$$

Mr. Robertson is quite right in calling attention to the fact that the parallel middle body percentage is of minor importance and the ratio of ends is the important factor. Plate 2 gives the ratio of ends in terms of parallel middle body for the various models tested.

The reduction of results to a standard temperature of 65° has been criticised. The temperature correction is uncertain at best, and it seemed wise to use 65° since the water varies from about 60° to 70° in our tank. The data were corrected at the rate of 1 per cent for every 3° of temperature variation.

Various criticisms have been made regarding the form in which the results are given. Some would like to have the [C] values used, some would like to have the residuary horse-power given in term of $(\text{displacement})^{7/6}$, some would like to have all results reduced to a length of 400 feet.

The authors would like to call attention to the fact that the paper was written primarily to call attention to the influence of shape of transverse sections upon resistance. No one has said that the form of presentation did not bring out that effect clearly, and it was the qualitative effect that the authors had in mind quite as much as the quantitative effect.

The data from the Michigan tank have always been issued in the form of E.H.P. or W.H.P. per ton of displacement, and this paper does not depart from that custom except where necessary in order to show more clearly the effect of shape of section. The cube of the speed-length ratio was used for the purpose of bringing out more clearly the effect of section shape, and it was realized that the results in this form would not be as convenient to the naval architect as if given in the form of E.H.P. per ton of displacement.

Mr. Robertson states that in the form in which the data are given its application is limited when draught and length are changed. This is true of any system, even of the one which Mr. Robertson advocates. In his paper of last year he gave the results for only one draught ratio, and the application of those results is very limited. In this paper we have given the results for four draught ratios with a corresponding increase in the scope of application.

The authors wish to thank all those who have spoken so kindly of the paper and hope that the results may be of some value, even if each one does not find the data given in his favorite form.

The Chairman:—Do you wish to comment further, Professor Sadler?

Professor Sadler:—I do not think I have anything to add to Professor Bragg's remarks—he covered most of the points. I think if you will read this method of plotting carefully—you probably have not had an opportunity to do so—you will see that the E.H.P. per ton has certain advantages, and very evidently there has been some misconception as to the appendix in this paper. As Professor Bragg pointed out, the illustration in the appendix is simply to show the amount of error if you omitted the last part of the expression; and I think his illustration of the figures obtained by this method as applied to Mr. Rigg's paper, which was all done here in a few minutes on the floor, ought to be an indication that there is something in the method of using the E.H.P. per ton.

The Chairman:—This paper comes in that category of papers which so greatly enrich our Transactions and are viewed as a great repository of facts, as the result of research and study. I think that the Society is to be congratulated on having this very important contribution presented at this session, and I am sure that you will wish to convey the thanks of the Society to the authors for their contribution.

COMPLIMENTARY REMARKS TO RETIRING PRESIDENT, REAR ADMIRAL CAPPS.

Mr. W. M. McFarland, *Honorary Vice-President:*—I desire to bring up another matter, and do so now rather than to wait until the close of the proceedings, because some of the members may desire to leave before that time. You will see that we should have as many of the members present as possible when we do what I shall submit for your action in a few moments.

I think it is always a very fitting thing, when a member of an organization has played a very prominent part in its work for many years, and in fact, has been a guiding spirit, and one of the most active and efficient workers that has ever been honored by the highest gift which the Society can make, and has filled out his term as president in an admirable way and to the entire satisfaction of every member of the Society, that the Society should place on record its appreciation of what he has done, and its appreciation of him as a man.

Our retiring president is a man whom many of us have the great privilege and pleasure of counting as a personal friend. I have known him for a great many years. If I told you just how many, it would tell you something about how old we both are, and I will omit that. He was one of the charter members of the Society, was secretary of the Society for many years, and has been one of the most active and earnest workers towards promoting the efficiency of the Society that we have ever had. It has been an honor to the Society to have such a man as president.

He has filled a great many eminent positions in public life. He has been the Chief Constructor of our Navy. He has been the president of the Emergency Fleet Corporation, and he has filled with great efficiency a most honorable and exceedingly difficult position as chairman of the Compensation Board for the Navy during and since the war, during which time contracts amounting to more than a billion dollars were passed on by him.

I feel I am only voicing the sentiment of every one of you when I propose a vote of thanks to Admiral Capps for the admirable way in which he has conducted the affairs of the Society during his term as president, and for all the work he has done during the entire life of the Society; added to which is our wish that he may live for many years to see the Society grow in usefulness, efficiency and reputation in the way his own efforts have been exerted. (Applause.)

Mr. Hugo P. Frear, *Member of Council:*—It is a great pleasure for me to second the motion of Captain McFarland.

The Chairman:—By way of putting the motion, I am going to suggest that we give a rousing approval of the motion by applause instead of the usual method. Those in favor of the motion will manifest it in this manner.

The members joined in great resounding applause of the motion.

The Chairman:—Admiral Capps, it gives me very great pleasure to convey to you the appreciation and thanks of the Society in terms that you have already heard.

President Capps:—Gentlemen, this appears to be something that was not on the calendar—it certainly was not on my calendar—and I was quietly doing a little work which I hope will bear fruit in a few hours, so that I almost missed the major part of the performance until there sounded that appreciative note which brought to mind the image one might see if one were reading his own obituary—expressions of appreciation that do not always come to one's ears when he is able to appreciate them. The remarks of the President-elect were particularly appreciated, not only as coming from my successor as your president, but from one who has been a life-long friend—we were not at the Naval Academy together, but the period between was not very great—and, throughout the career of this Society, has been what we can most properly and complimentarily call a veritable wheel horse of efficiency.

I wish to thank him and all my colleagues most fervently for their expression of appreciation. My work for the Society has been one of the real labors of love during my official life, and, no matter what the future may hold, I believe that this Society has a very great field of usefulness before it. It is more prosperous now than it has been at any other time in its history. The interest in it is very keen. Moreover, the interest in the Society is not confined to the younger members, but goes right through the list, including those of mature experience and years, and this interest will, I trust, continue forever. We have just arranged this morning at our Council meeting to have "memberships in perpetuity." Those who fill the requirements laid down by the Council will have their names appear in the list of members continuously, even after they have passed from their field of activity.

Again, gentlemen, let me thank you fervently for your very beautiful tribute. It is unnecessary for me to repeat that what has been said in appreciation of my services appeals strongly to one's deeper feelings. I thank you again, most sincerely. (Great applause.)

The Chairman:—Passing to the other papers, Paper No. 12 was read at the morning session. We will therefore pass to paper No. 13, entitled "Power and Speed Trials of Ten-Thousand Deadweight-Ton Tanker," by Mr. H. A. Everett, a member of the Society.

Mr. Everett presented the paper.

POWER AND SPEED TRIALS OF TEN THOUSAND DEADWEIGHT-TON TANKER.

By H. A. Everett, Esq., Member.

[Read at the twenty-ninth general meeting of the Society of Naval Architects and Marine Engineers, held in New York, November 17 and 18, 1921.]

The following description of the trials of a modern oil-carrying steamer of good size are presented, not with the idea of showing an exceptional performance but with the thought that extensive progressive speed trials of a merchant vessel at full load draught in conjunction with the predicted performance, based on model experiments, will prove useful information to members of this Society. Incidentally there are several points in the working up of the data which differ from the methods commonly used for merchant vessels.

GENERAL DESCRIPTION.

The ship on which the trials were made was built by the Union Shipbuilding Company of Baltimore and was a new, steel, longitudinally framed, bulk oil carrying steamer, and with the characteristics tabulated as follows. The trials were run April 19, 1921:

Length (O. A.)	436′ 1″
Length (B. P.)	419′ 3″
Breadth (Mld.)	56′ 3″
Depth (Mld.)	33′ 4″
Class—Lloyd's, *100 A-1; American Bureau, *A-1.	
Draught on trial, forward	25′ 6½″
aft	25′ 7″
mean	25′ 6¾″
Trial displacement (fresh water)	13,390 tons.
Wetted surface	39,160 square feet.
Block coefficient	.801

Propeller—4 bronze blades, steel hub, 18″ 0′ diameter, 15′ 6″ pitch.

Engine—One triple expansion, $\frac{27'' \times 45'' \times 75''}{51''}$

Boilers—Three S. E. Scotch, 15′ 10″ diameter by 11′ 4″ length.

Furnaces—Nine 46″ diameter.

Total heating surface	8,952 square feet.
Total grate surface	189 square feet.
Working pressure	195 lbs.

S. & K. oil burners.

The model was towed at the U. S. Experimental Model Basin in Washington, D. C., and the results of these tests are given on Plate 63.

THE TRIAL COURSE.

The trials were run over a measured mile in Chesapeake Bay, off Kent Island and nearly opposite Annapolis. The course is an excellent one, with a depth of about 120 feet, but is affected by appreciable tidal currents, which, however, usually run in a direction parallel to the course. The water is brackish with a density slightly greater than fresh water. The ranges are well defined, and, in addition, the terminals are marked by buoys.

METHOD OF RUNNING TRIALS.

The trials were run continuously and consecutively, beginning with the slow speeds and working up, except for runs 2 and 4, which are transposed on account of a misunderstanding of signals. The power was obtained with Crosby outside spring indicators, and at least three diagrams were worked up for each cylinder on each run. The reducing motion was of the quadrant type. The time over the course was taken by two observers with stop watches. Long turns were made at each end and conditions well stabilized on the straightaway before crossing the starting lines.

PRELIMINARY CURVES.

From the observed data two curves were plotted (Plate 64), one for the northerly runs and one for the southerly runs. These curves were then corrected in two steps, first for the wind effect, and second for the tidal or current effect.

The observations made were time over course, revolutions per minutes and indicator cards. From the time over course, speed by shore can be derived; from the indicator cards, the mean effective pressure for each cylinder was figured and the mean effective pressure referred to low-pressure cylinder calculated. (Denote revolutions by R. P. M., speeds by *V* and mean effective pressures referred to low-pressure cylinder by M. E. P.) As *V* and M. E. P. both vary with R. P. M., it is convenient to use R. P. M. as the primary variable.

When plotted on R. P. M., speeds and M. E. Ps. fall into two groups—northbound and southbound. Northbound, the ship was running against both wind and tide; southbound, with both. Except for a few erratic points, fair curves can be drawn through these two groups of *V*s. and M. E. Ps. and used in place of the original observations.

Plate 64 shows the original observations plotted and the northerly and southerly curves, uncorrected for wind or tide, faired through them.

DERIVATION OF FINAL CURVES.

To these original observation curves were applied corrections for wind effect and tidal or current effect, as follows:

The effect of the wind on the speed of the ship is proportional to the square of the relative velocity of the wind by the ship. For example, at about the time of runs 2 and 3 the wind was estimated at 15 knots. Run 2 speed was 7.5 knots against wind and tide; run 3 speed was 9.5 knots with wind and tide. Relative wind speed "against wind" was 22.5 knots; relative wind speed "with wind" was negative, or helping the ship, and of an intensity of 5.5 knots. The normal air resistance should be against the ship and equal to the speed of the ship through still water, or about 8.5 knots.

Against; proportional to $\overline{22.5}^2 = 507$
With; proportional to $\overline{5.5}^2 = 30$
Normal; proportional to $\overline{8.5}^2 = 72$
Change from normal—Against 435
With 102
Ratio 4¼

The wind thus had approximately four times as much retarding effect as aiding effect.

The M.E.P. curves feel only the wind effect, as the tidal currents move the whole body of water in which the ship is floating. From the above, therefore, we may approximate the location of the corrected M. E. P. curves at runs 2 and 3 as about one-fifth the distance between the curves drawn with and against the wind. At higher speeds the wind dropped and the ratio of wind effects was less; at lower speeds the wind was stronger and the ratio was larger. In this manner the curve of still air M. E. Ps. was drawn.

The next step was to make corresponding corrections on the two speed curves. The simplest explanation of the method is an example: The M. E. P. at 60 R. P. M. against the wind is 18.5 pounds; in still air this value would occur at slightly over 62 R. P. M. Therefore, from the "against" curve, the speed at 62 + R. P. M. can be read and plotted as corrected for wind on 60 R. P. M. The corrections for the "with" curve were made in a similar manner but are decreases instead of increases. The two speed curves corrected for wind can now be drawn.

As the runs were made at fairly uniform intervals, the most accurate way of correcting for the tide is by halving the differences in speed between the "with" and "against" curves corrected for wind.

The curves were then replotted, using speeds as the abscissae. From the corrected curves of speed on R. P. M. and M. E. P. on R. P. M. we can read for any speed, R. P. M. and M. E. P.: thus the I. H. P. at *V* knots can be computed.

FINAL CURVES.

The final power and standardization curves are given on Plate 65, together with curves of apparent slip and Admiralty coefficient derived therefrom. Table I, page 322, gives the observed and resultant data.

Plate 63, already referred to, shows the curve of effective horse-power derived by towing the model at the U. S. Experimental Model Basin at Washington. The curve is for a slightly larger displacement (salt water) than the trial (fresh water) and was corrected to trial displacement. The difference was small, and the reduction was made directly proportional to the displacements. The ratio $\frac{\text{E. H. P.}}{\text{I. H. P.}}$ gives the curve of propulsive coefficients also shown on Plate 65.

CHECK ON WIND CORRECTION.

The curve of M. E. P. on R. P. M. is independent of tidal or current effects and is affected only by the force of the wind. This being so, it should be possible to obtain from the curves the actual magnitude of the wind force on the ship. The no-wind curve is (subject only to variations in slip and propulsive efficiency) a direct measure of resistance of the ship, so that at the same speed the difference between the curves for "still air" and "against the wind" will be the M. E. P. used to overcome the force of the wind. As the M. E. P. curves are plotted on R. P. Ms., however, it is necesary to obtain the effect first from the speed curves in terms of R. P. Ms. (for constant speed), then for these R. P. Ms. to read the corresponding M. E. Ps. For example, we already know the corrections to the speed curves to allow for wind effect, and by adding and subtracting these to the final or no-wind curve, we can derive curves of speed on R. P. M. "with" and "against" the wind but without tidal effect.

TABLE I.—*Data and Results of Standardization Trial.*

OBSERVED DATA.

Time of day	Run No.	Direction	Time over course		Revolutions per minute	Indicated horse-power	Speed
			Mins.	*Secs.*			
6:59	1	S	7	51 1/5	46	531	7.640
7:18	2	N	8	18 4/5	60.5	1,307	7.217
7:42	3	S	6	15 1/5	62.2	1,302	9.595
8:15	4	N	12	03	44	530	4.979
8:45	5	S	5	33 1/5	70.8	1,883	10.804
9:12	6	N	6	29 2/5	69.8	1,868	9.245
9:35	7	S	4	54	79	2,615	12.245
9:58	8	N	5	38 4/5	76.9	2,448	10.626
10:41	10	N	4	59 4/5	84	3,131	12.008
11:05	11	S	5	02 3/5	82.1	2,994	11.905

RESULTS.

Speed, knots	Revolutions per minute	Indicated horse-power	Apparent slip	Admiralty coefficient	Propulsive coefficient
5	35.6	278	.083	254	.42
6	42.6	443	.079	275	.46
7	49.4	665	.074	291	.50
8	56.3	975	.071	296	.52
9	63	1,355	.067	303	.53
10	69.9	1,835	.065	308	.53
10½	73	2,090	.059	312	.54
11	76.3	2,392	.058	314	.55
11½	79.7	2,724	.057	315	.56
12	83	3,090	.055	315	.58

These curves are not actually drawn in again on Plate 64 in order to avoid confusion, but the result of a computation is given below.

In still water at 8 knots speed the R. P. M. for the no-wind conditions are 56.3, while the R. P. M. for this same speed, when the wind was blowing against the ship, were 2.5 more, or 58.8.

Corresponding to these the M. E. P. for the still-water and no-wind condition is 15.3 pounds (read at 56.3 R. P. M.), and the M. E. P. in still water but against the wind is 17.8 pounds (read at 58.8 R. P. M.). To visualize this, if the ship were going over a current-less course at 8 knots in still air, the engine would operate at 56.3 R. P. M. and 15.3 pounds M. E. P. If a wind sprang up, in order to maintain the same speed the R. P. Ms. would have to be increased to 58.8 and also the M. E. P. to 17.8 pounds in order to produce the R. P. M. of 58.8.

The difference between the I. H. Ps. for these conditions is (engine constant is 1.1316):

I. H. P. (against wind) $= 1.1316 \times 17.8 \times 58.8 = 1{,}184.4$
I. H. P. (still air) $= 1.1316 \times 15.3 \times 56.3 = 974.8$
Increase in I. H. P. $= 209.6$
Increase in E. H. P. = I. H. P. $\times$ propulsive coefficient $= 209.6 \times .52 = 109.0$.

$$\text{Wind force} = \frac{\text{E. H. P.} \times 33{,}000}{8 \times 101.3} = 4{,}440 \text{ pounds.}$$

This wind force is that part of the total air resistance due to the moving wind. The assumed wind at this time was about 15 knots; relative wind 23 knots.

Froude's formula for the air resistance of a ship is given by Taylor ("Speed and Power of Ships") as:

$$R_w = .0043\, AV^2$$

Where

R_w = Air resistance in pounds.
V = Speed through air in knots.
A = Area of upper works projected on an 'thwartship plane.

For the case in hand .0043 A works out to 8.95, so that:

$$R_w = 8.95\, V^2$$

The force of wind by this expression is then:

$$\text{Wind force} = 8.95\ (23^2 - 8^2) = 4{,}160 \text{ pounds.}$$

which is approximately 6 per cent less than the experimental value derived above (4,440 pounds).

Proceeding in a similar manner, going with the wind,

R. P. M. = 55.7 at 8 knots; M. E. P. = 14.7 pounds.
Difference of M. E. P. $= 15.3 - 14.7 = 0.6$ pound.
Wind force = 1,023 pounds aiding.

Wind as before 15 knots, then relative wind = 7 knots pushing ship:

$$8.95\ (49 + 64) = 1{,}010 \text{ pounds.}$$

or practically one per cent less than experimental value.

Since these two percentages are not the same, it means that the no-wind M. E. P. line is not quite correctly located, but the difference is trivial.

Either the area for use in Froude's formula was estimated too small or the velocity of wind was assumed too little.

It should be borne in mind that the experimental values of the wind force are arrived at by a process which is equivalent to the subtracting of one quantity of large magnitude from another, only slightly larger—always a treacherous proceeding; also that Froude's expression for air resistance of ships is considered to be only approximate. However, large variations in a small corrective term, such as wind resistance usually is, do not have serious effects on the accuracy of the final results.

For completeness there are included reproductions of typical indicator diagrams for each run (Plates 66 and 67), the engine-room log (Plate 68), and a drawing of the propeller wheel used on the trials (Plate 69).

DISCUSSION.

The Chairman:—This paper, No. 13, entitled "Power and Speed Trials of Ten-Thousand Deadweight-Ton Tanker," is now open for discussion.

Professor E. M. Bragg, *Member:*—I think the Society is very fortunate in having this kind of information laid before it. There is information here which is very valuable to those who are trying to get data on propellers. A careful trial of a ship at various speeds is rather hard to find. In order to use this data for propeller design, there is only one thing missing, I think, and that is the wake of the vessel. It so happens that at the tank, while we have been testing models with various lengths of run, we have been running current meters behind the models to get the wake, and one of the current meters used is very close to the diameter which the propeller of this boat would have if reduced to the size of the model. The wake shown by these tests was about 29 per cent, and we are glad to contribute that information so that this data can be used for propeller design.

This wake may seem to be rather low in comparison with the block coefficient, but the tests we have made so far show that the block coefficient is a very poor criterion of the wake and that there are other factors which affect it much more.

Having contributed this much, I will ask Mr. Everett to contribute a little more. This paper can be used also for engine data. I know some years ago when I was trying to work up engine data, I found it very difficult to get good data on merchant-ship engines—I could get plenty of data on naval engines, but data on merchant-ship engines were very scarce. In order to use these data for that purpose, it will be desirable to have the diameter of the piston rods, and also for the author to give the clearances, top and bottom, and the cut-offs of the different cylinders. To be sure, one can get the apparent cut-off from the cards, but these cards are small, and the apparent cut-offs seldom agree with the design cut-offs, and we have to work with design cut-offs.

Again, model experiments such as have just been described in the last paper are run on models with a certain ratio of length to breadth. As soon as you get away from that ratio of length to breadth, you are a little uncertain as to the application of these results. The ratio of length to breadth in the previous paper was about 7.6, and the ratio of length to breadth in this model is 7.46. If we could have a little more data in regard to the lines of this vessel, it could be used in extending the data obtained in the case of a ship of one length-breadth ratio to a ship of another length-breadth ratio. If we could have the percentage of length, divided by entrance, parallel middle body, and run, I think it would help out; and also the general shape of the sections, whether V-shape, U-shape, or medium shape.

Mr. E. H. Rigg, *Member of Council:*—I have taken up too much of your time this afternoon and will not take up any more than a few minutes now. I think we are to be congratulated on having made available from time to time the standardization results of typical merchant vessels at full load draught. As Mr. Everett says, they are generally not readily obtained; in this particular case, an oil tanker, the loading is easier, and it is gratifying that the builders and owners have seen fit to contribute the results of the model tank tests compared with the actual runs. I would make one suggestion in connection with the question of standardization, and that is, instead of making runs in pairs, which I think was done ——

Professor Everett:—They step up ——

Mr. Rigg:—I have evidently not as yet read the paper carefully enough to catch that point. What I was going to say was that the runs should be made in sets of three, as the Navy does, rather than in pairs, in order to eliminate tidal variation. The stepping-up method has a decided advantage in that R. P. M. have to be held with accuracy only during single runs. Could you decide definitely as to whether a ship had actually made her contract speed without a regular set of three or five high runs?

We ran an oil tanker standardization recently on the Delaware breakwater course and had some trouble with the wind.

Our analysis of the results showed that a loss of about 0.3 knot at full power was caused by the 20-mile breeze blowing down the course; however, I do not consider the data accurate enough for recording in detail, though it is clear that for trustworthy results the trials should be run over again on a day of less wind.

Mr. Hugo P. Frear, *Member of Council:*—I would like to ask where the vessel was tried and the depth of water on the course, and whether or not any correction is necessary on account of depth of water.

Professor Everett:—There was about 120 feet mean depth of water.

Mr. Frear:—Was that on the Annapolis course?

Professor Everett:—Yes, right off Annapolis.

The Chairman:—Is there any further oral discussion? If not, I will ask the Secretary to read a communicated discussion by Chief Constructor D. W. Taylor.

Rear Admiral D. W. Taylor, C. C., U. S. Navy, *Vice-President* (Communicated):—This paper, giving actual results of careful trials, is of the type which is always welcome to our Transactions; its value is permanent, for those of the profession interested in such matters refer to such papers for years.

I was particularly interested in the method adopted for running trials, as it follows to some extent one of two methods proposed by me some years ago as desirable. The corrections for wind effect constitute a new departure, and I think few of us have realized how great this effect is in many cases. By the author's method of dealing in the first place with curves of mean effective pressure plotted on revolutions, the wind effect can be reasonably well eliminated if fairly close observations are taken of it.

The further step to correct the speed curves for wind effect is not so obvious, but I gather that, if we assume the slip to be constant, the method is exact in theory which makes it quite close enough for the actual conditions of practice.

The efficiency of propulsion deduced would be a shade higher if the actual E. H. P. for the trial displacement had been used. The assumption that in the neighborhood of the trial displacement the E. H. P. varies with displacement is near enough for practical purposes, but brings the E. H. P. slightly lower than if model trials had been made corresponding to the actual trial displacement.

I hope that in the future we may have more such papers in our Transactions, and further investigations of the wind effect on trials.

There is another effect, very real but hitherto not subjected to analysis, namely, the effect of the rudder. We know that the rudder when put over constitutes a very powerful brake, and there is a material difference between the speed and power curve with a good helmsman and a poor helmsman. Possibly some of our scientific members may reduce this matter to rule in time.

The Chairman:—I will ask Professor Everett to close the discussion.

Professor Everett:—With regard to Professor Bragg's request for additional data, I will be glad to furnish it. The reason why I put a drawing of the propeller in the back of paper is that I thought someone might wish to work up something in that connection.

The cut-offs are given on Plate 68. The other data I will furnish. I will not be able to furnish exact clearances, but they will be nearly exact, and I will also send in the data requested with reference to the lines. The information in regard to wake is extremely interesting.

With reference to Mr. Rigg's remarks, may I take a moment to ask him to look at Plate 64 again, because the object of the paper was partly to get away from the method that he mentions, namely, the averaging of groups of runs.

As Admiral Taylor mentions in his discussion, some years ago he proposed two methods of making trials, one by running groups of runs under as nearly the same condition as possible and taking the average, and the other, by starting at low speed and going up progressively, but keeping the runs in sequence, down and back over the course. It is the latter method that these trials are based on; that is, the trials were run consecutively, gradually increasing speed and paying no attention to the averaging of runs. If anyone should prefer to work up the runs, using the other method, the original data are given in Table I. I did it in a casual way, and the result came very little different from the final curve shown on the last page. I think the method used here has merit as being the logical procedure for getting rid of both the wind effect and tidal effect.

I did not mention, in the brief abstract just read, one point I should like to bring out. On Plate 65, the lower right-hand curve is the E. H. P. taken from the model tank runs. The trial of the ship was made at a displacement which was slightly different from that (370 tons less), due to the fact that the trials were run in fresh water but at the salt water load draught. To correct for the trial displacement, we derived the lower E. H. P. curve by comparison directly on the displacement basis, and the work which Professor Sadler and Professor Bragg have just given us in the appendix to their paper is very interesting, because it shows how little that assumption was open to question.

Admiral Taylor's remarks are to the effect that the propulsive efficiency curve would be slightly higher if the model were towed again at the tank at a displacement corresponding to that of the trial. We were unable to have that done, but I believe, as he says, that the error involved in that slight correction is not material.

Agreeable to my promise I am supplying the information requested by Professor Bragg in his discussion at the meeting:

Diameter piston rods		6½ inches
Clearances,	Top	⅜ inch
	Bottom	⅝ inch

	H. P.		M. P.		L. P.	
	Top.	Bot.	Top.	Bot.	Top.	Bot.
Cut-off in inches	38.9	37.5	38.8	37.6	37.4	35.8
Cut-off per cent of stroke	76.4	73.6	76.2	73.8	73.4	70.2
Cut-off per cent of stroke (mean)	75		75		71.8	

Lines—Length fore body, 108.5 feet = 25.9 per cent.
Length mid. body, 164.1 feet = 39.1 per cent.
Length after body, 146.7 feet = 35.0 per cent.

In further reply to Professor Bragg's inquiry as to the character of the sections, the sections forward would probably be called of the "U" type, although they are by no means full U's. The sections aft are V's and the form has easy buttocks, and also easy waterlines. It should be noted from the proportion of form of the middle and after bodies given above that the vessel had a long and easy run for a vessel with a block coefficient as large as this one.

Mr. James Kennedy, Superintendent of the Marine Department of the Gulf Refining Company, which is operating the ship, has very kindly contributed copies of the deck and engine-room logs for one of the normal voyages of this ship whose route lies between Port Arthur and Bayonne, N. J. These are interesting in that they show normal operating conditions. In this connection, however, it should be borne in mind that the vessel is operated so as to take full advantage of the Gulf Stream on the northerly run, and this effect is noticeable on the logged distances which are higher than would be obtained if operating on a route with no current. (Plates 70, 71, 72 and 73.)

The Chairman:—This is another of the papers which greatly enrich our Transactions, and such facts represent the results of carefully conducted trials, something we can tie to whenever our work may lead us into this particular field.

I am sure you will desire me, on your behalf, to convey the thanks of the Society to Professor Everett for his most interesting paper.

The next paper to be presented is entitled "American Shipyard Apprenticeships, Evening Schools and Scholarships," by Mr. Charles F. Bailey, Member of Council.

Mr. Bailey presented the paper.

AMERICAN SHIPYARD APPRENTICESHIPS, EVENING SCHOOLS AND SCHOLARSHIPS.

By Charles F. Bailey, Esq., Member of Council.

[Read at the twenty-ninth general meeting of the Society of Naval Architects and Marine Engineers, held in New York, November 17 and 18, 1921.]

The object of this paper is to review the present situation and to call out suggestions for improvement.

Apprenticeship in shipbuilding is generally in vogue in the older, established shipyards of this country. Some yards have had apprentice courses for many years, but only within the later years has there been any considerable interest in the matter, and even at this time there is an opportunity for advances which would be of benefit to both the apprentices and the yards.

At present the various yard apprenticeship regulations are quite similar and include a considerable course of study, in most cases as a part of the system; in some yards independent evening schools are maintained for the benefit of the apprentices and other employees, both male and female.

A movement is now under way to offer, as an incentive to apprentices, short scholarships in higher institutions of learning, which may be won by competition.

The various apprentice regulations in the shipyards of this country embody the following features, but no one yard includes them all.

The purpose of the course is usually to secure home trained men familiar with the work and methods peculiar to the individual yard.

Trades in which apprenticeships are offered are as follows: Anglesmith, Blacksmith, Boiler Maker, Coppersmith, Draughtsman (Construction), Draughtsman (Engineering), Draughtsman (Hull), Electrician, Joiner, Machinist, Machinist (Steam Engineering), Molder, Pattern Maker, Plumber, Sailmaker, Sheet Metal Worker, Ship Carpenter (including shipwright work, boat building and spar making), Ship Fitter (including Mold Loft work), Ship Rigger, Welder (Electric and Acetylene worker).

Length of Course.—This is usually designated as four years, sometimes of a certain number of hours per year. A number of companies have provisions for credits by which the length of the course may be reduced to a minimum of three years by reason of special proficiency and all-round excellence. In one yard the credits on merit ratings are stated as follows:

"At the end of each year the apprentice's merit records in shop and in school are averaged to get a total average merit rating for the year. In striking this average the shop record carries twice the weight of the school record.

"On the basis of this yearly merit rating the next succeeding year (2,240 hours) is subject to reduction on a sliding scale as follows:

By securing in school and in shop a yearly average rating of (per cent):	Apprentices shall have deducted, from the next succeeding year, time as follows (hours):	Equivalent to (per cent):
95 to 100	560	25
90 to 95	396	17.9
85 to 90	268	12.1
80 to 85	136	6.1
Below 80	0	0

In other yards apprentices are credited with class work, two hours on their apprenticeship for each hour of classroom work. This is for class work held on the apprentice's time, from four o'clock to six p. m. On completion of the course an additional bonus of one hour per week is allowed for good attendance and faithful application.

Another company allows credit for evening school and study courses, for time equivalent to the time spent in school. This company defrays the tuition of the boys at the school attended.

All of these credits are given as an incentive to better work and greater efforts on the part of the apprentices.

Requirements for Apprenticeship.—The applicant must be between the ages of sixteen and twenty years, although application may be filed twelve months prior to reaching his entrance age. A written statement from two competent persons certifying to the good moral character and habits of the candidate must be presented at the time of filing application. The applicant is not finally accepted as an apprentice until after a six-month probation period. At the end of the probation time a written report and recommendation by the foreman and leading man is made, and the boy's suitability and qualifications for apprenticeship are acted upon by the supervisor of apprentices or by an official or committee in charge of the matter.

Preference is given to applicants from families of the company's employees and to those who have made the best progress in the public schools.

Qualifications necessary are stated by various yards thus: average alertness, a good grammar school education, ability to read and write, familiarity with arithmetical processes, satisfactory personal presence, of such stature as to fit them for the trade selected, each candidate required to pass a physical examination by the company's surgeon before entering the apprenticeship and a similar examination annually thereafter during the apprenticeship. To apprentices who have graduated from manual training schools, high schools or similar institutions or who have special qualifications, the company may allow a reasonable time credit. Apprentices entering the drawing rooms shall have had at least two years of high school work.

Number of Apprentices in the Trades.—No definite rule has been generally adopted as to the number of apprentices in the various shipyard trades. This is largely accounted for by the uncertainty of the work whereby the number of employees has varied greatly due to trade conditions and requirements for naval and merchant work. In slack times it is best to retain as many apprentices as possible, only weeding out those least desirable.

One or two companies designate the number of apprentices in each department, as, for instance, in the pattern shop the ratio of number of apprentices to number of workmen is 25 per cent; foundry, 20 per cent; core shop, 20 per cent, etc.

We have found from statistics that at the end of a five-year period only about 20 per cent of the men on the rolls at the beginning of the period remain, and at the end of ten years about 5 per cent remain in the employ of the company. These data are not available for the different trades but are for the entire force. On the basis that these data apply to the various trades (which they probably do not, strictly), it would appear well to employ apprentices approximately in the ratio of 20 to 25 per cent of the number of journeymen in each trade.

Supervision.—This is handled by various methods. In one yard a supervisor of apprentices has general oversight of all the apprentices throughout the yard and is the principal of the school work; under him are several instructors. The ratings for all of the boys, both in the shops and for school work, are reported by the supervisor. Courses of study are outlined, competitive examinations for assignment to the drawing offices are held, examinations for promotion are made and intelligence tests of Otis or Terman systems are conducted.

In the shops apprentices are instructed by mechanics who especially look after a number of boys, assign them work and instruct them in the correct method of performing the work, operating the tools, etc. This instructor arranges for a diversity of work in consultation with the foreman and the supervisor and makes monthly reports showing attendance, proficiency, character of work, etc. These reports are made in some cases on specially prepared forms by which each apprentice is rated. Following is such a form:

SHOP REPORT ON APPRENTICE.

....

For month of..

How many days absent this month?.............. Reason:..

....

How many times tardy this month?..

What shop rules has he violated?..

....

....

Character of work engaged in:..

....

Date transferred to this work:..

Remarks: ....

....

....

....

FOREMAN INSTRUCTOR

Apprentice..

TRADE ABILITY	CHARACTER
WORKMANSHIP	INTEREST
O Excellent	O Enthusiastic
O Good	O Interested
O Fair	O Willing
O Poor	O Indifferent
ACCURACY	INITIATIVE
O Accurate	O Excellent
O Careful	O Good
O Fair	O Fair
O Careless	O Poor
APPLICATION	JUDGMENT
O Very Industrious	O Excellent
O Good Worker	O Good
O Fair	O Fair
O Lazy	O Poor
APTITUDE	CONDUCT
O Quick to learn	O Excellent
O Medium	O Good
O Slow	O Fair
O Dense	O Unsatisfactory
SKILL	MORAL SENSE
O Adept	O High
O Skilful	O Good
O Fair	O Medium
O Awkward	O Low

Check Your Opinion Under Each Heading

Promotion.—Promotion is based on the rating from the monthly reports from the various shops and for school work. In some cases the shop work counts double that in the school.

School Work.—There is no uniform practice in regard to school work for apprentice boys in the various yards, although certain requirements in schooling are made by many of the yards.

One yard states that apprentices may be required to take courses of instruction recommended or provided by the company and their rating in such studies and progress in work will be used as a guide for promotion.

Another company expects apprentices to attend evening school unless their previous education renders this unnecessary. Here the apprentice committee cooperates with the city educational authorities in outlining the course of study to assist the apprentice to understand the fundamentals of the trade to which he is apprenticed. Some of the yards make use of the night schools entirely, sometimes with indifferent success.

In one yard a school is established having six daily sessions per week, during the regular working hours beginning the second Monday in September and ending the last Saturday in

May. Each apprentice is required to attend the school two half-days each week during the school session for three yearly sessions, unless excused by the supervisor or on account of taking equivalent subjects in which instruction is given. Teachers are appointed under the supervisor of apprentices to give instruction and to prepare reports. For attendance on the school sessions the apprentices are paid at the regular rates.

At one yard the classroom work is conducted through government aid under the Smith-Hughes Act. Under this act several teachers are obtained from the city high school, and classes are conducted in the plant during Saturday mornings. The salaries of the teachers are paid out of the fund provided by the act. It is reported that this arrangement has worked satisfactorily and that all of the teachers and apprentices take a great interest in the work. An objection to this procedure has been raised on the ground that the control passes from the yard.

At another yard the classroom work is conducted by the Division of University Extension, State Department of Education. Apprentice classes are held, on the apprentices' time, from four o'clock to six p.m. No expense for instructors is borne by the company, which, however, provides the building, light, heat, etc. Apprentices under this course are credited with two hours on their apprenticeship for each hour of classroom work. On completion of the course an additional bonus of one hour per week is allowed for good attendance and application. A similar arrangement is also in vogue in another yard of this corporation in a vocational night school with corresponding credits.

The one constant problem confronting the yards in connection with apprenticeship work is that of maintaining the interest and devotion of the boys. It is more difficult to hold the enthusiasm of the boys where studies are taken outside of the working hours than where the school work is a part of the daily or weekly shop schedule. Some of the more ambitious boys will, in addition to their apprenticeship work, voluntarily join, at their own expense, night school classes, but the number of such boys is small.

Drawing-room apprentices are selected from shop apprentices after having had at least two years' practical experience. Competitive examinations are held in selecting these candidates, who must have had two years of high school work.

Pay of Apprentices.—This varies in the different yards, ranging, as compared with first-class journeyman wages, from about 30 per cent for the first six months to 80 or 90 per cent for the last six months. It is usual to increase the pay on the completion of each six-month period so that for a four-year course there are eight grades. At some yards the pay ratio is higher at the beginning and less at completion than given above.

It is advisable, and most companies so provide, that the pay is subject to change as the rates of journeymen in the trades are varied. Several companies provide that no boy under nineteen years of age, or some other specified age, shall receive, in any department, a rate higher than he would receive as an apprentice in that department. This requirement was important during the war period in order to prevent dissatisfaction among the apprentices.

Pay for lost time is not usually allowed, except in special cases recommended by the foreman and the head of the department. Overtime is usually paid at the same proportional rate as is paid other workmen, but only the straight time worked is allowed to apply on the apprentice term. Some companies reserve the right to pay an apprentice on piece work, contract or on a premium scale of wages, and the hours worked, so paid for, are counted in the number of hours constituting a year or half year.

Bonus.—At the end of the apprenticeship course it is usual to provide a bonus, varying from $50 to $100, for satisfactory completion. In some cases where the apprentice is obliged to leave before the completion of this time, otherwise than due to the neglect of duty, disobedience of rules or other improper conduct, the apprentice is paid such portion of this sum as the time served bears to the total term of apprenticeship.

The yards reserve the right, in their discretion, to terminate an apprenticeship and discharge the apprentice for cause or improper conduct, and some of the yards reserve the right to suspend or change the hours of labor as commercial conditions render advisable, or, when necessary to reduce the working forces, to dispense with the services of the apprentices by suspension or dismissal.

It is becoming a practice to provide for a regular and frequent change of occupation for each apprentice in order to give a varied experience.

With a further view to increasing the apprentice's general knowledge of shipbuilding and marine engineering it has been suggested that small divisions of the apprentices, accompanied by an instructor, spend a portion of one school session weekly in visiting the various shops, divisions and departments of the yard to observe the important operations of work.

At the completion of the term it is usual to present the apprentice with a diploma, which should be attractively and suitably engraved and signed by an official and the superintendent, certifying that the apprentice has completed his course as an apprentice in such and such a trade. (See Plate 74.)

Owing to the large increase in interest in the American merchant marine during the last few years, it has seemed advisable to make the apprenticeship courses more attractive and more valuable as a means of training men for shipbuilding and engineering work. There has therefore been an increase in the opportunities given to the apprentices in the yards as a means of providing better satisfied, more skillful workmen. It is usual and well to take apprentices largely from the families of the employees, which tends to reduce the turn-over.

The courses are therefore becoming more inviting to the boys, both from an educational and social standpoint. The apprentices are encouraged to organize themselves into associations with duly elected officers, which of itself adds considerably to the education of the apprentice and to his general knowledge of affairs. A large number of questions are settled by these associations, as they are self-governing to a considerable extent. The apprentices thereby, if properly supervised, learn many of the essentials of good citizenship. They promote sports and athletics and the spirit of rivalry throughout the organization and with other employees of the yard in games, such as football, basket-ball, baseball, etc. The value of such work is seen in the splendid physique, bearing and manliness observed in many of the boys.

As will be noted, there is a growing endeavor to stimulate interest and good work by means of competition and prizes or credits for meritorious work.

Evening Schools.—In addition to the apprenticeship schools some yards in conjunction with the industrial Y. M. C. A. of the community or with other organized bodies or vocational schools, conduct evening classes to which the apprentice boys may or may not be eligible. These classes are not usually self-supporting. They should have the highest grade of talent in the director and in the teachers; and frequently this is easily obtained in large yards by drawing on the trained, technical college graduates, who are willing to give their time for a reasonable remuneration. Such schools are largely attended by workmen and young women, and some of the apprentices also take advantage of them for advanced work and for fitting for college. Their success depends upon the character of the director or supervisor.

With the right man to inspire and lead and with cooperation and interest evinced by the officials of the company, great encouragement is given employees for such work. The studies include the ordinary grammar-school subjects and others such as electrical work, bookkeeping, French and Spanish, public speaking, hull construction, machine work, forge work, pipe installation, engine installation, steam engineering, joiner work, electrical work and sheet metal work.

In speaking of the regular apprentice course, one of the large electrical companies expresses it thus: "One of the problems facing most boys of sixteen who are trying to choose a profession is, 'If I start work now, I cannot get a good education. If I get a good education, I cannot start work now.' As a matter of fact they can do *both.* Many boys feel discouraged because they cannot go to college for four years. It is a mistake for them to think that such an education is absolutely necessary in order for them to get along in the world.

"These apprentice courses enable a boy to obtain a four-year job, and at the end of the term, in addition to having received a good practical education, he will have earned approximately $3,000. What is perhaps more important still, he will have learned three important things which are not taught in college, viz., the value of a dollar, the independence which comes from earning one's own living, and the strength of character developed by working with men.

"In addition to these things apprentices come out possessed of a trade, and they are in line for promotion to higher positions. As someone has remarked, 'Four years is a long while for a boy to look forward to, but it is a mere trifle for a man to look back upon.' "

Scholarships.—Some employees welcome an opportunity for advancement dependent upon their individual efforts and competition. In line with this it is suggested that large shipbuilding companies give consideration to the establishment of a small number of scholarships as follows:

(*a*) A four-year course covering work in language, mathematics, physics, chemistry, metallurgy, electricity, marine engineering, naval architecture or allied subjects in an approved university, technical school or institute, granting the degree of Bachelor of Science.

(*b*) A two-year course covering similar work in several of the above subjects in an approved university, technical school or institute.

(*c*) A one-year course covering similar work in several of the above subjects in an approved university, technical school or institute.

(*d*) A home correspondence school course in an approved correspondence school or a course of thirty-six weeks in the Industrial Y. M. C. A. Evening Preparatory School of the city.

Examinations for these scholarships to be held at suitable intervals.

Provided candidates pass the requirements appointments to scholarships should be made yearly. It is suggested that the number of appointees be small during the first year that the scholarships are offered and gradually increased for the next three years, after which the appointments would follow the maximum number allowed for the fourth year. This number of appointees is on the basis of a shipyard employing approximately 10,000 men with about 200 to 225 regular apprentices in the various trades.

NUMBER OF APPOINTEES.

Scholarships	(*a*) and/or (*b*) and/or (*c*)	(*d*)
First Year	2	4
Second Year	3	8
Third Year	5	8
Fourth Year	6	8

If in any year no candidates meet the requirements for a scholarship no appointment should be made for that year. Candidates for appointment to scholarships (*a*), (*b*) or (*c*) to have had the equivalent of a thorough high school course, which may be acquired by attendance at evening preparatory schools or otherwise.

No apprentice should be eligible to more than four years of scholarship work or more than two successive scholarships, (*a*), (*b*) or (*c*) or more than three successive scholarships (*d*).

The company should reserve the right to revoke a scholarship at any time on evidence that the recipient is not making a satisfactory record, and to change the number of appointees or to discontinue the plan at its option.

In connection with scholarships (*a*), (*b*) and (*c*) the company should pay the necessary fees and tuition and provide a reasonable sum annually to cover subsistence for each school term and to defray the cost of technical books, instruments, etc., which should become the property of the apprentice. It is suggested that an allowance for traveling expenses, equivalent to one round trip annually, be made. An expense account in detail on proper form to be submitted monthly for approval.

In connection with scholarship (*d*) the company should pay the necessary fees or tuition in the school selected and provide a reasonable sum to defray the cost of books, instruments, etc., which should become the property of the apprentice.

On the above basis the cost to the company for the first year would amount to about $1,900; second year to about $3,400; third year from $4,500 to $5,000 and for the fourth year, and each subsequent year thereafter, from $4,400 to $5,950.

Fifty per cent of the time spent away from the yard engaged on scholarships (*a*), (*b*) or (*c*) to count as part of the student's apprenticeship. No time from the term of apprenticeship to be deducted for scholarship (*d*).

During attendance on scholarships (*a*), (*b*) or (*c*) the apprentice should not receive the regular apprenticeship pay. He should serve in the works of the company during vacations, for which service he should be given the regular apprentice rate of pay.

Some people object to the establishment of scholarships for apprentices on the ground that the apprentice course is established primarily for the purpose of supplying skilled mechanics and that the offering of scholarships will tend to cause dissatisfaction among the apprentices. It should be remembered, however, that in any large yard with, say, 200 apprentices, there are found yearly some of marked ability and that such boys, while they may serve out their apprentice course, will not continue as mechanics. Often these boys with brilliant minds are without means and sometimes in our own experience we have known them, after having served their apprenticeship, to enter college or technical schools under handicapped conditions and still make good. It is believed that, if wisely conducted, the granting of a few scholarships to the apprentices will attract a better class of boys to the apprentice courses and will lead to the discovery, by the company, of a much larger number of young men who will develop into valuable quartermen, foremen and officials, of even greater responsibility.

With companies employing several thousand men it should be the aim to recruit both their technical staffs and managerial staffs as largely as possible from their own employees. The shipbuilding companies under the present business conditions and outlook for marine construction cannot offer a large number of extensive practical testing courses to technical graduate students as is done with such marked success by the large electrical manufacturing companies, and hence the technical graduate sometimes becomes discouraged and leaves the employ of the shipbuilder after only a short term.

It is believed that a trial of the scholarship plan will greatly assist the shipbuilder in keeping up the quality of his construction and technical staff.

The common cause of failure of home correspondence school courses is the lack of encouragement and assistance to the student and his desire to begin advanced courses without suitable preparation. Where such a course is won as a scholarship the boy has the constant incentive to maintain his apprenticeship record and he also has the guidance of the supervisor or instructor to assist and encourage him.

The establishment of scholarships (*b*), (*c*) and (*d*), as outlined above, has been authorized by one large American shipbuilding company, and the details of this work are being developed with the intention of announcing these scholarships so that a few of them may be competed for and granted within the next year.

In solving this problem of supplying our shipyards with men possessing manual skill, as well as technical and theoretical ability and knowledge, it is well not to overlook home talent familiar with the work of the home yards and whose ties are largely there. Such young men are in line for more valuable service to the company than those who are only highly technically educated or manually skilled or without the community ties. The combination of these qualifications is a step in the direction of efficiency and progress.

In making general promotions in the yard consideration must be given to the effects on the general morale. It is sometimes evident that men who have worked for most of their lives at their trades do not take kindly to working under foremen who are theoretical and technical men without practical experience. This, therefore, is a call for trained workmen brought up through the apprenticeship system, well educated, skilled in the trades of their choice. Such graduates from the apprentices may work up to foremen and even superintendents.

The large electrical companies have given the apprentice question more consideration than have the shipbuilders. They employ large numbers of technical graduates and immediately place them in positions where they gain a good degree of practical experience in what might be termed "technical apprenticeship courses" open to graduates from engineering colleges.

A novelty in apprentice training has been introduced by the General Electric Company at Lynn, known as the cooperative course at the Massachusetts Institute of Technology. By the cooperative plan the apprentice alternates three months with the Institute of Technology and three months in the apprentice shops. This course has been arranged to cover a period of two years. A similar arrangement is in vogue with the Westinghouse Company and a leading university, and I understand some of the locomotive companies have also followed such a procedure with success. It is quite feasible for some shipyards, advantageously located, to take the initiative and work out something on the principle of the cooperative course with an engineering college, by which the apprentices may alternate with the institution selected. This would not be easily adaptable for isolated yards, far distant from the vicinity of technical schools, but for yards situated near such institutions the problem is not difficult.

This matter of apprentice training and education is one of great human interest and, if properly accepted by the shipbuilding companies, it is certain to strengthen the morale, reduce the turn-over and benefit both employers and employees. It should not be looked upon as social work but as a business proposition. Many large organizations now see that business with service is most desirable; here will be found a field for both.

In the preparation of this paper I wish to acknowledge valuable information and suggestions from Messrs. H. A. Magoun, C. P. Wetherbee, Harry Brown, J. F. Metten, W. W. Smith, A. A. Howitz, G. Guy Via, C. P. Turner, and from the General Electric publication, "Life in a Large Manufacturing Plant."

DISCUSSION.

The Chairman:—Mr. Bailey's paper, entitled "American Shipyard Apprenticeships, Evening Schools and Scholarships," is now before you for discussion.

Mr. Ernest H. Peabody, *Member:*—I think I express the unanimous feeling of this Society when I say that any paper presented by Mr. Bailey must not only receive the consideration and approval of the members of the Society but will also prove a valuable contribution to our Transactions. But I think that in this paper he has given us a very unusual essay and a much needed impetus to stop a moment and think about a subject which is at the very foundation of our lives. Most men are too busy chasing the ten-dollar bill (we used to go after the dollar but that is not enough now) to give any thought to the fundamental basis of education of the young men who must follow us in our work when our job in life is finished.

If we are going to leave the world any better off than when we found it, we have got to see that the young men who follow us have opportunities to learn their jobs so that they can carry on the work better than we have carried it on ourselves. And I do not think this is altogether an altruistic matter either. Every employer must take young men, inexperienced men, into his business, and invariably for a good many years he pays these men more money than they are worth.

Now it seems to me that it is likely to be a money-saving proposition if the education of the young man is begun in a systematic way and is properly directed. I am a great believer in technical education, and I see not only no objection, but every advantage, in coupling technical training with practical work in the shop.

I feel, however, that there is one very important matter which should not be overlooked. I do not intend to discuss the curriculum offered by Mr. Bailey. I am not a trained educator and I am not a shipbuilder. I have just stopped a moment in the whirl of life to think about this subject, and I find it of very great interest. But there is just one thought I would like to bring out and that is, as I see it, teaching is a "fine art." It has to be studied, and if the teacher is going to achieve results with the young men he has under him he must not think that he can merely stop a moment in his everyday work—in his work, for example, of directing pattern-makers in the shop—to say a few haphazard words to the student. It will be necessary for him to give considerable thought and study to the subject of just how he is going to talk to the young men in a way which will instruct and encourage them, because encouragement is, I think, a most important factor.

I feel, too, that fair and honest treatment and avoidance of even apparent discrimination against a boy is of paramount importance. Youth is very susceptible to impressions, and if you discourage a boy with injustice, or what he thinks is injustice, you will not get much work out of him and the memory will last a lifetime.

My point therefore is that the curriculum must be supplemented by careful study as to how it shall be presented.

Mr. Spencer Miller, *Member:*—The paper by Mr. Bailey indicates that he has a true understanding of the wider educational facilities of our great industrial establishments. If it be true that we learn by doing, our factories must be adding not alone to the knowledge of the worker but to the science of education itself.

Mr. Bailey suggests by bold relief the need of a closer cooperation between our technical schools and our industrial establishments. This closer contact cannot fail to be of distinct value to both institutions. It would seem to be logical that a plan devised to meet the needs of apprentice boys could not fail to bring into the ranks of the American workers an intelligence and perspective on their own work, and the relation of their job in life to the community as a whole which would be most salutary.

What is true of the shipbuilding industry is no less true of the other great American industries. In the light of our modern understanding of our responsibilities, our concern about the men who work in our factories does not begin at the factory gate in the morning nor end with the factory whistle in the evening. The growth of personnel, managers, and the extension of service has gone wide of the mere working hours. And it is proper that this should be so.

Lord Haldane, one of England's most distinguished public servants, recently said in the October *Forum* that "education, if it be made adequate, may be looked on with hope as a palliative of industrial unrest." Again he said, "It is the development of the soul of democracy in this fashion that the movement for the education of the adult worker aims."

It is for this reason that I say that Mr. Bailey conceives of this plan with a true vision. The details of his classification (*a*), (*b*), (*c*), (*d*) provide a systematic way in which the varying demands of the apprentice group may be wisely met. It might add to the general honor conferred upon the different apprentices if the democratic machinery of self-government as outlined on page 334 were utilized and the candidates for these scholarships nominated by the apprentice group and selected by the educational adviser in the shipyard or industrial establishment.

To the leadership of men like Mr. Bailey in the shipbuilding industry, we as engineers are indebted for showing the way to a better and more harmonious industrial relation. Industrial unrest is not inevitable unless we think it is. The application of intelligence, of understanding and good will, will do much to foster the real spirit of cooperation which is needed in our democratic commonwealth as well as in our industrial establishments.

Professor Harold A. Everett, *Member:*—It is very refreshing to have a paper on education given before this Society, because such papers are not so very frequent in our proceedings, and I thoroughly agree with what Mr. Peabody said—that the life of the industry rests with the young men you are training. It is not a question of altruism, it is purely a question of self-preservation of the industry, and any industry is by no means any stronger than the young men it has in training for taking positions in the industry later in life.

The outline which Mr. Bailey has made here for apprentices presupposes, to a certain extent, that it is for the trades, and I believe that is the main object of the paper. As such, it seems to me admirable, and there is only one suggestion I have to offer, and that is with reference to his scholarship, Grade A. For this he is suggesting that the apprentices be sent to an engineering school for a four-year course. If this is meant as a reward of industry, I think it is admirable. If it is meant as a method of supplying applicants for second-line positions in the industry, it seems to me as if it would be better to get at it in another way, namely, to enter into cooperation with the technical colleges and get the men from the technical colleges on some sort of contract basis. These men can be put through any course in practical training desired and then put into the positions they are heading for. We have worked out a scheme something like this, and it has been tried out with fair success. Our scheme was this—we took young men fresh from college on a two-year contract basis. We offered them $25 a week and started them with the full knowledge we would lose money on the men at first. They were to be stationed in various departments of the plant, and we were to keep tabs on them as they went from place to place, the stationing was to rest in our hands and not to be decided by their preference. The question of increase of compensation was arranged on the basis of an increase of $1 per week for every two months' service they rendered, and that was an increase amounting to $6 a week during the course of a year, and at the end of the contract—the two years—the man either remained with us or did not at our option. As it happened, the cessation of activity put a crimp in our work, and we were compelled to part with many of the men we would like to have retained.

We made compensation for experience in this way—we started a fresh graduate at $25 a week. The man who had been out of college for a year received $30 a week, and if he had been out of college two years he received $35 a week. The man who had been out more than two years was not eligible for the corps.

I believe the industrial companies agree with the educational institutions that this is the best way of supplying the second line of offense and are willing to cooperate with them, and it has been my experience that the technical colleges are not the ones who hang back on such an agreement as that. They are always willing to regulate the courses in any way they can to meet individual needs, without positively rearranging them, as some organizations seem to wish. You hear complaints from some of the short-sighted industrial organizations that these men are "no good," and you analyze the matter carefully and find they are "no good" because some man, when the superintendent has asked him, has failed to know how to carefully adjust a lathe or how to install certain piping, or some other bit of detailed knowledge. It is not that the colleges have failed, for they are not supposed to teach details but to give a sound, fundamental training. The industrial organizations should realize this.

Mr. Benjamin G. Fernald, *Member:*—Mr. Bailey's paper discloses a recognition of the absolute necessity of thoroughly training, in the crafts, sufficient men to furnish a nucleus for the continuation of a high standard of workmanship, and he has met the difficulties squarely by offering sufficient incentive to attract and hold boys of the right sort.

The technical college has brought about a condition with which I am not in sympathy. I do not believe that it works for the ultimate good of any business or industry to separate its man power into two groups, namely, one group which does all of the actual work with little, if any, hope of promotion to an executive position, and another group consisting of the graduates of technical schools to whom the first group impart a smattering of practical knowledge in order that the second group may then do all the superintending and executive work.

As I see Mr. Bailey's plan, it would eventually render any company following it able to man its executive staff with trained men and educated from the start to finish in and by the company. It might be argued that some of the men would leave the company and carry their knowledge to a competitive company. I do not consider this important as compared with the advantage of having executives who have a thorough comprehension of and sympathy with the duties and life of the workmen in the shop and yards.

I know of a recent instance where a man who served an apprenticeship in a plant and went elsewhere, was brought back to it in an executive capacity and accomplished a decided improvement in production over the best efforts of many highly trained and specially educated executives. Undoubtedly the results accomplished can be attributed primarily to the bond between the workmen and the executive because he had been and was still one of them. At the time this man served his apprenticeship no collateral educational advantages were offered by his company, and he had to acquire them in his own time and independently.

The average success in after life of the graduates of technical schools would be very much increased if a larger percentage of them were recruited from such apprenticeship courses as outlined by Mr. Bailey.

The only suggestion that I have to offer is that all concerned in putting such a plan into effect must guard against losing sight of the fact that its fundamental purpose is to make competent workmen, and that the educational features are in the nature of a reward for effort on the part of the apprentice beyond that merely necessary to secure his journeyman's certificate. Where such a system is in vogue, little, if any, preference should be shown to technical graduates. If the education acquired by the latter before entering practical work is of any merit to them or their employer, that merit should be demonstrated and not conceded.

Professor Lawrence B. Chapman, *Member:*—I am greatly delighted to hear this paper by Mr. Bailey this afternoon, and as a college professor I can assure you all that the universities will be very glad, indeed, to cooperate to the fullest extent in such a plan as he proposes.

Most of our students in college come to us without a clear vision of the field they purpose to enter, and many of them depend upon the advice of students or others in choosing their course at college. They generally are certain that they wish to study engineering, but their mind is not made up whether they should take the course in civil, mechanical, electrical engineering or naval architecture, etc. If we could have a class of men coming from the shipyards who have had practical experience and a clear idea of what kind of work they would be called upon to do, we could turn out a much better type of graduate.

Careful attention should be given to the man's high school training and preparation, however, so that he will have the proper preparation to enter college.

I want to endorse the idea of practical training paralleling the theoretical training. The course in naval architecture that we have recently started at Lehigh University has for one of the requirements for the degree that the men must spend eight weeks in a shipyard on actual construction work, and eight weeks at sea, during the summer months. We now have our first senior class of eleven men who have completed the requirement of practical experience of eight weeks in a shipyard and who have come back this fall after eight weeks at sea in the engine room. The shipowners have cooperated to the fullest extent in placing these men, some going to the west coast, others to Europe, and others to Mexico and Cuba. This present senior class is the best I have ever had the pleasure of teaching, as they have had enough practical experience to take great interest in their theoretical studies; and they take hold of their work in ship design with some first-hand knowledge of the sea and ships.

Mr. Hugo P. Frear, *Member of Council:*—There is probably more information in Mr. Bailey's paper on American shipyard apprenticeships than available from any other one source. It seems to cover the field both concisely and comprehensively. Those who have not given the subject special attention will note that as much progress has been made in the methods of training and encouraging apprentices as in the methods of teaching in our public schools and universities.

As the world progresses, the demands on the profession, the educator, the artisan and apprentice are more exacting. Opportunities for the deserving must be afforded for the attainment of greater proficiency in a shorter time than formerly. It is, however, difficult to say how far the education of the average apprentice should be carried in addition to making a good workman. Increased opportunities are to be recommended to the extent that they do not effect a decrease in personal effort. Fundamentally any system of apprenticeship is to afford a boy an opportunity to learn a trade to make his living. The majority must work at productive labor or we would all lose our jobs.

It seems to me that a grammar school education is sufficient for one who always expects to follow his trade, and that he certainly should have acquired this before arriving at the age of sixteen. The educational features of an apprenticeship should, of course, be open to all and not compulsory, but rather planned for the brighter boys who have the ambition to become something more than tradesmen. While this may not be precisely the idea expressed in the paper, it is perhaps not so dissimilar. The system of credits, reports and marks as outlined by Mr. Bailey is well calculated to segregate the boys into their respective classes.

While there seems to be some difference of opinion on scholarships, it seems to me an excellent idea. They should be awarded to only those who deserve them on account of their ambition, ability and personal effort. This, also, is in line with the thought expressed by Mr. Bailey.

Local conditions would, in some measure, influence apprenticeship activities. Where there are good night schools they seem to fill the requirements and may be more permanent. They, at least, require effort and sacrifice on the part of the boy. The boys who will be most benefited will make the effort to go to a night school. I have known of about one hundred boys from one yard going to night school at their own expense. The same thing applies to correspondence home courses, but not to the same extent.

The apprentice should learn the value of money and thoroughly understand that his pay and the privilege of learning a trade are compensation for work performed. No other money should be paid him except in the nature of a prize for completing his apprenticeship. Scholarships, correspondence courses, night schools, and other advantages, if paid for in part or in full by the company, should be regarded as prizes subject to more or less competition.

Mr. Bailey has the right idea about keeping up the interest of the boys. Individual attention has a great influence in keeping up interest. This individual interest should be dominated by the foreman who is always on the job, rather than by the professor, who may be able to render great assistance but, on account of other duties, cannot be everywhere at the same time.

Mr. William W. Smith, *Member:*—Mr. Bailey has covered this subject so well that there is but little to say except to express my agreement with the author's views.

The proper training of men, and especially the younger ones, is vital to the efficiency of an organization, and especially so to a complicated one such as a shipyard.

As we all know, the training of men costs in time and money. Consequently, after a man has been trained in a certain line in a certain organization, reasonable effort should be made to keep him a permanent part of the organization. This applies especially to the more skilled trades and professions.

It seems to me that more attention should be given to the training of technical graduates. Suitable courses which will give these men the varied practical experience required will, I think, amply repay shipyards. Some of our most successful industries depend on technical schools for their most important supply of men.

In general, I think that the training of personnel should be an official responsibility and function of a company. If it is not regarded as such, it cannot meet with success.

Mr. H. C. Towle, *Member:*—I have a few remarks to make on the principal features of the apprenticeship system, but I cannot resist the opportunity to say first a few words to my college professor friends. I am a college graduate myself, and for the last few years I have endeavored faithfully to put college graduates to work. I would urge you to make all the students understand that their college education is mainly useful to them as a background for their activities. Of all the college graduates who have been under me, I only know of three who were conspicuously successful. They became successful because they forgot the theory taught in the college, and became (to use the vernacular) "roughnecks" with the gang.

Many schemes for training employees have been discussed in the technical press and many books published on the subject in the last few years. With this mass of ideas available it seems essential to me that each shipyard management shall:

First, select the object that they wish to obtain by training.

Second, select the students capable of accomplishing the desired object.

Third, select material which, when taught to the employee, will accomplish the desired object.

Fourth, select a method of teaching.

It is further necessary in our judgment to "sell" the idea of training to the executives and staff of the plant; and sell the idea to the employee himself. In the case of an apprentice it is also necessary to sell the idea to the parent of the apprentice.

Under the first heading we wish to point out that, broadly stated, there are only two objects in view:

(*a*) Training in the "art and technique" of the shipyard trade chosen.

(*b*) Furnishing the opportunity for the highest possible development of each individual.

Second, we think that more attention needs to be paid to the selection of boys or men for training. Undesirable or unsuitable material which, in spite of careful selection, may be enrolled should be dropped promptly. The probationary period of six months usually accomplishes this.

By the end of the first year apprentices should be classed as to trade, the boys with designing or technical ability separated, and the "natural-born" leader identified. As soon as these qualities are determined the boy should probably be placed under training especially adapted to his individual ability.

Third, we think that much training suffers from lack of definite, detailed objective. Whenever the training is successful someone must have, first, analyzed each trade into its constituent parts; second, determined how to present each elementary part to the apprentice; third, made sure that the boy comprehends the information presented.

Fourth, whatever methods of teaching are adopted, we would call attention to the fact that the utmost flexibility in training courses is required, so that the apprentices may always have a task that requires their utmost ability and application. The habit of mental and physical activity is by far the most valuable asset a young boy can acquire.

We find that the selling of the idea is most difficult and is an element that requires a broad-gauged, sympathetic understanding of the problems of the boys or men who may be under training. Particularly for boys the opportunity for advancement must be clear-cut and definite in order to arouse the boy's ambition and clearly show the steps that must be taken in the future. Ten or fifteen years in a subordinate position when one is fifty years old appear as but one step on the ladder of promotion, but to a sixteen-year-old boy it is a lifetime, overwhelming and discouraging.

One or two detailed experiences in the administration of a training department may be of interest:

Some years ago apprentices for one or two years usually did the work of helpers, cleaning shops and machines and other work of like character. While we believe this is permissible for a few weeks, if long continued it results in disgust with the job and loss of interest. In one shop the evil was effectively corrected by fitting out a section of the shop with a complete line of the smaller sizes of machine tools—15-inch and 18-inch lathes, 24-inch planer, 8-inch slotter, 48-inch boring mill, universal milling machine, and radial and post drills and other tools. Practical instructors were assigned in charge of this division, and machinist apprentice courses were laid out so that they would spend their first two years in this shop, after which they were transferred to the larger tools of the main shop. The special instruction this furnished resulted in a more rapid development of whatever latent mechanical ability the apprentices possessed.

Shortly after the above method was inaugurated the instructors reported that they were having trouble in keeping the boys interested because the work assigned to this division was usually of a repetitive character, very limited in variety. Remembering certain crude boilers and engines built in youthful days with small skill and great enthusiasm, the shop was directed to turn over the construction of all small machinery such as turning engines, circulating pumps and engines, and the like, to the apprentices. At present such small machines are completely assembled, adjusted, run by air, and delivered complete and ready for operation. This method not only furnished a large variety of machine work, but it was found that if there was any mechanical aptitude at all in the boy, working toward a definite completed object aroused enthusiasm and sustained his interest.

Several years ago courses in mathematics, drawing, strength of materials and similar studies were introduced. One incidental result is particularly worthy of mention. The six months' probationary period is supposed to result in weeding out incompetent and otherwise undesirable boys, but we found that sons of men holding supervisory positions were seldom dropped during this period, due, no doubt, to the disinclination of the shop foreman to possibly offend his immediate assistants. As soon, however, as the independent educational division began making reports of progress of the boys, we discovered the true conditions and corrected them. Today to be continued as an apprentice a boy must show ability both in his practical work and in his studies.

Mr. C. S. Coler (Communicated) :—Mr. Bailey in his excellent paper has pointed out many of the modern phases of industrial training.

We are not awakening to the need for industrial education too soon. If America would build ships, we must have skilled artisans. If America would operate a merchant marine, we must have trained seamen. If America would have cargo to export, we must have economical production and distribution.

Broadly speaking, the main costs which enter into all these enterprises in which we are so vitally interested are labor costs. Trained men, if properly trained and directed, reduce the unit costs of production to a point where higher wages can economically be paid.

In the past we have depended on Europe for much of our skilled labor. In order to meet the rigorous competition there it was necessary for the men to be carefully trained. We now enter a competition here which will reward the well-trained individual and the well-trained organization. If we are to compete in the markets of the world, we shall have to train our own men to a greater and greater extent.

The following observations are made from experience in trades training with the Westinghouse Electric and Manufacturing Company.

Work should be the backbone of industrial training. It must be dignified to a greater extent in our homes, schools, and also in our industries.

Incentives should be established in order to attract, hold and encourage the proper young men. Apprentice rates should advance faster during the latter part of their course than in the earlier periods. The best apprentices should be enabled to materially reduce their length of training. The compensation after completing the course should be based on merit, as exhibited during the training period. Trades courses should be looked upon as one of the best means to prepare men for supervisory and planning positions. Opportunities for promotion to work of this kind should be offered those exhibiting executive characteristics, within a reasonable time after completing their course.

As pointed out by Mr. Bailey, scholarships should be awarded those men who should, in justice to themselves and society, be given an opportunity for more advanced college training.

The interest and assistance of parents should be solicited in connection with the training of their sons.

The boys should be given increasing responsibility during their training period and the opportunity to meet and know some of the capable men of their trade.

The future progress in industrial training, as in industry, lies in a quality rather than a quantity standard—fewer men, better trained.

Mr. Maxwell W. Day, *Associate:*—The General Electric Company is not a shipyard, but it was mentioned in Mr. Bailey's paper, and I would like to present a few comments on the part of our educational committee.

We do not attempt, in any of the plants of the General Electric Company, to maintain a definite ratio of apprentices to journeymen in any trade, but the figures given in the report, suggesting 20 to 25 per cent, seem high. This may be due to the difference in classification, as we have comparatively few trades reported in the apprentice course compared to those outlined in the report. We believe that special efforts should be made to retain graduate apprentices in the employ of the company and, if that is done consistently, it will cut down the percentage an appreciable amount.

We believe that a well-equipped training room gives an apprentice a better start in his trade than he could obtain in the open shop under the supervision of a mechanic. At all of the large plants of our company where apprentice courses are maintained we have training rooms which are fully equipped with all types of modern machinery. All apprentices begin their work in these training divisions under competent supervision and are given thorough instruction on machine operation in addition to their classroom work. The length of time spent in the training room varies at the different plants but in general covers from nine to twelve months. After the boy has demonstrated his ability he is placed in the shops, where his training is completed.

We heartily approve of the scholarship features and hope, eventually, to have something similar in our own industry. There is a growing demand for technically trained men in the shop, and we believe that a young man who has been trained in the shop and then sent to college for advanced training will prove a good investment. We have endeavored to employ students during their vacation periods, especially between their junior and senior years, with the idea of familiarizing them with our organization and the opportunities available in the various lines of work. This, however, is in no way comparable with the full-time scholarship arrangement.

In addition to the apprentice course for the shop we have a student engineering course for graduates of technical schools, selected by a representative of the company who visits the various technical schools.

Mr. L. C. Brooks, *Member:*—In connection with Mr. Bailey's very excellent paper regarding the training of apprentices, I wish to emphasize the idea of cooperation between the school and shop.

In the year 1917 the A. S. M. E. devoted considerable time to the discussion of this subject, especially as applying to machine shops. As large machine shops and shipyards are somewhat parallel in their activities, no doubt the results of one would be helpful to the other.

I believe that the University of Cincinnati and the machine tool builders of that city have carried out a scheme similar to that mentioned by Mr. Bailey as applying at Lynn, and with very good results.

The best workmen of a generation ago, both in this country and Europe, were apprentice graduates. The basic principle of those days was *work*. But today, as Mr. Peabody stated, too many are looking for the dollar, and possibly trying to escape work. It is a question whether this tendency can be overcome with the present generation. The offering of rewards, etc., no doubt, will help a great deal.

But I firmly believe that we must go farther back if we wish to have the boy in the proper state of mind when we begin with him as an apprentice. We must begin with the primary school.

As we read our local papers and note the tax rates, and comment on the increase or decrease, do we stop to think how much better prepared our boys would be to meet the problems of life if our taxes were increased a few more cents so that we could pay the primary school teacher a sufficient salary to attract an efficient person as teacher?

Mr. W. M. McFarland, *Honorary Vice-President:*—My good friend Bailey asked me to say a few words on this paper. I think he was under the impression that there would not be much discussion concerning it—on the contrary, the paper has had more discussion than any other paper presented, and almost every point that occurred to me has been made by other speakers.

I have read the paper several times, and I want to compliment Mr. Bailey on the care with which it has been prepared. I agree heartily with practically everything he says in it. I think that one point he has looked out for was not stressed in the discussion, namely, that the main object of the apprenticeship course is to train skilled workmen and not designing engineers. He makes the point that in the course of the training of these boys to be skilled workmen, some very brilliant ones may come along, and an opportunity should be given to let these boys develop to the very best of their ability, and with that I am in hearty accord.

I remember some years ago when Professor Goldwin Smith, the famous historian, who was in Cornell in the early days, made an address before a Cornell alumni banquet in Washington. Mr. Cornell's idea in starting the college was to make it easy for everybody to get a college education. They had a machine shop where boys were supposed to earn a living, and also a farm and a printing shop. It was found, in the working out of the plan, that the two things did not go together, and they had to go to straight education. I am telling you this to show what Professor Smith had been through. He said he had been a believer in higher education, but that he had come to the conclusion that it was a mistake to make higher education too easy, or, in other words, offer a bonus to encourage large numbers of people to go to college. He thought, on the contrary, it was better to make it a little difficult to get the higher education, so that the ones who did get it would be persons of real stamina and real value.

In another part of the world, in an entirely different way, I had my attention called to this same thing, and that was in connection with Greece. I became acquainted with a Scotch engineer in Smyrna who had a works of his own, and he told me that the Greek people were so impressed with the value of education that the shepherds in the farming part of the country would deny themselves food in order that their boys might go to the college in Athens and get a college education and become lawyers. He said: "What was the result? After so many of them became lawyers there was not enough work for them, so they got into politics, and the 'outs' are always trying to turn out the 'ins' so that they could get in, and that is the reason why they have so much trouble there."

Dr. Smith said: "I am afraid in making the higher education too easy we have spoiled a good many good clerks and good mechanics and people of that kind to make a lot of people who seek higher grades of activity with indifferent success." I think Mr. Bailey's plan is well laid out with regard to this matter of training boys to be skilled mechanics, with the chance that the brilliant ones, when they are discovered, will be encouraged to go on and qualify themselves for the higher work.

I am connected with a little school myself, and this is the proper place to speak of it, as Mr. Webb, the founder, was a charter member of our Society and one of our early vice-presidents. As most of you, I hope, know, Webb Institute of Naval Architecture provides an education free of expense. The only expense upon the boys is to provide their own clothing—the institute provides the teaching, board and lodging, medical attendance if they are sick, books, instruments, and everything of that sort. The entrance is by competitive examination, and I speak of it in this connection, because while many of the large and wealthy corporations (if there are any now, in view of present circumstances) might be able themselves to pay for the education of boys whose families could not afford it, I will say that we admit some twelve or fifteen every year at Webb, and it is a wonderful opportunity for a bright boy whose people are not able to send him to one of the larger institutions where he would have to pay.

I hope that all the people connected with our shipyard and engine building concerns will bear Webb Institute in mind, and, when any of their men have bright boys who have a high school education, will tell them that we will be happy to have them make application to Webb, and will give full information about where to take the examination.

The Chairman:—It is unfortunate that clocks go on, and if there were more time available I am sure we would all like to discuss these subjects further. There are two communicated discussions which we will not have the time to have read here, but they will be incorporated in the Proceedings. They are by Mr. Macalpine and Mr. Cathcart.

Mr. John H. Macalpine (Communicated):—I have read Mr. Bailey's paper with the deepest interest and cannot commend too highly the enlightened and altruistic service which will be rendered by the institution of the proposed scholarships.

In the eighty's on the Clyde, and possibly other shipbuilding centers in Britain, the plan of selecting by written examination the apprentices to enter the drawing office was initiated. But there was no thought of a school in the works to train all the apprentices. The more ambitious of those, who had no opportunity of university training, flocked in large numbers to excellent technical schools which had both day and evening classes. But long hours in the works and then evening classes made a very exhausting day and left little time for adequate study. Nevertheless, this system gave great results.

The opening of schools in the works, as is now common in this country, was a great advance in several directions. While the equipment and teaching force of such schools must always be far below that of a good technical school, it can take in all the apprentices, reduce the working day to a proper length, and give opportunity, to those who are earnest and ambitious, for study and preparation in the evening. This, with the daily practical shopwork, will not only give us again the excellent mechanics which were the product of the old apprenticeship system, now fallen into desuetude, but new men of broader training and intelligence.

Those works' schools are not intended to replace institutions of higher learning, and could not possibly do so. Thus there was a step missing. But, as Mr. Bailey points out, they make it possible to discover the brilliant minds and, by scholarships, supply the opportunity which, frequently, want of means has withheld. In many cases the desire for learning will be aroused for the first time. It is perhaps becoming too common for parents in good circumstances to believe that their sons should go to college whether ardent students or not. But the plan proposed has none of this danger. Every day shipbuilding and engineering are leaning more and more on science, and it is necessary for the advancement of these professions, and, through them, of the country, that those who are capable of attaining a mastery of chemistry, physics, mathematics or allied subjects should be given the opportunity to do so. I intentionally write "a mastery," for we frequently hear the expressions "engineering-mathematics" or "engineering-physics" which are as objectionable as other hyphenates. A man's power in engineering will grow with his knowledge of such subjects, and he cannot advance too far—his studies should be limited only by his capability and his required attention to other necessary duties. But with the growth of his theoretical knowledge he should earnestly strive to acquire what is much more elusive—engineering judgment and common sense. For instance, if a physical problem in connection with engineering has to be solved, the proper assumption and data for his equations can only be determined by a sound knowledge of practical conditions such as the practical part of his apprenticeship course can supply; not, as has so often been the case, by some imaginary conditions, only remotely resembling fact, which perhaps allow the equations to be solved more easily.

There is one condition which is proper and probably laid down, but which Mr. Bailey does not mention. It would only be fair that, in return for receiving a scholarship, the apprentice should bind himself to give the company his services for a term of years after the apprenticeship is completed or to pay back the money received. The remuneration would have to depend on the position he could hold and his ability. (Since writing the above I was interested to learn that the Westinghouse Electric and Manufacturing Company has instituted War Memorial Scholarships, four each year for not more than four years. The value is $500 per annum. The first four were awarded in 1919. There is no condition, such as I suggest, attached.)

The arrangement between the General Electric Company at Lynn and the Massachusetts Institute of Technology is probably the same as that now adopted by several universities and originated as the Cincinnati plan fully fifteen years ago. For instance, "every student of the School of Engineering of the University of Pittsburgh during his course is required to work four terms of three months each, in some of the engineering industries of the Pittsburgh district." The quotation is from a pamphlet entitled "The Cooperative Plan of Engineering Education," giving details, which can be obtained from this university. While in the works the students are kept under the observation of their professors.

PROFESSOR W. L. CATHCART, *Member* (Communicated) :—This paper has marked interest and value, both in its comprehensive review of the present training of apprentices in American shipyards and in its suggestion of changes in the methods of their education which would attract a better class of boys to these positions and act also to strengthen the morale and increase the loyalty and permanence of the whole force of shipyard workers.

The author states: "We have found from statistics that, at the end of a five-year period, only about 20 per cent of the men on the rolls at the beginning of the period remain, and at the end of ten years about 5 per cent remain in the employ of the company. * * * On the basis that these data apply to the various trades (which they probably do not strictly), it would appear well to employ apprentices approximately in the ratio of 20 to 25 per cent of the number of journeymen in each trade." From these statements it is clear that, to maintain the full efficiency of a shipyard force, the adequate training of a relatively large force of apprentices is essential.

With regard to present systems of training, the author states that apprentices are usually given a four-year course which includes, in addition to shop and yard work, a considerable course of study in sessions during working hours or at evening school. He adds: "The one constant problem confronting the yards in connection with apprentice work is that of maintaining the interest and devotion of the boys."

To stimulate that interest, the author suggests that large shipbuilding companies establish—to be won by competitive examination—a limited number of scholarships for marine engineering, naval architecture, and their allied subjects, in technical schools or universities, and leading, in the case of a four-year course, to the degree of Bachelor of Science.

The establishment of such scholarships would, in my view, go far toward stopping a waste of brain power and money which seems inherent in the present system of training apprentices. In every class of them there will be found a few boys abler mentally than the rest, and stirred by a desire for a higher education than the yard schools can give. The money spent on their training in the usual apprentice course is lost to the company, since these boys will not remain in the yard as mechanics but will inevitably seek other fields giving them better educational facilities. On the other hand, these scholarships would, in most cases, bring these boys, after graduation, back to their home yards and make them available there for service in responsible positions.

As training for mechanics only, the four-year apprentice systems now in operation in our shipyards would seem to be adequate, especially since, as the author notes, "it is becoming a practice to provide for a regular and frequent change of occupation for each apprentice, in order to give a varied experience," and, further, if "small divisions of the apprentices, accompanied by an instructor, spend a portion of one school session weekly in visiting the shops, divisions and departments of the yard to observe important operations."

This training would serve admirably also for boys who win scholarships, since they would have a general acquaintance with the main operations in marine engineering and shipbuilding. If, at the expiration of a two-year practical course in this line, these ambitious lads had also acquired, at evening preparatory schools or otherwise, the equivalent of a thorough high school course, they would be better fitted than the average student for a course in marine engineering or naval architecture at a technical school or university.

Since the object of this expenditure by shipbuilding companies for educational purposes would be purely to train men for their work, a special two-year course devoted wholly to marine engineering or naval architecture and their allied subjects should, in most case, be preferable to the full four-year science course leading to a degree, since in this special course and the preliminary practical course at the yard the student apprentice would spend but four years in obtaining a good technical education.

In his admirable exposition of present conditions in this matter, and the suggestion of methods of improvement, the author has made marine engineering and shipbuilding his debtors.

Professor H. C. Sadler, *Member of Council* (Communicated) :—The subject of training for all classes and types of men who intend to follow the business of shipbuilding, or, to use a somewhat comprehensive term, marine engineering, is one which should occupy the attention, not only of the professional educator but also of those actively engaged in the practical end. Mr. Bailey's paper is therefore a timely one, and the author is to be congratulated in presenting to the Society, not only a general outline of the methods adopted by his company but also in giving actual data in the way of what might be called quantitative results.

With modern developments there is a great danger of the disappearance of real "craftsmanship" and a strong tendency towards scanty and inadequate training in the different trades. The methods adopted by Mr. Bailey's firm, therefore, aim to counteract this deficiency and are well worthy of application by everyone interested in the same line of work. The author has, however, dealt mainly with the training given for the actual operations of shipbuilding, and I venture to suggest that, with a few modifications, his method might be easily applied to those who are aiming to fit themselves for the higher positions either in the executive, financial or design departments.

I would refer especially to the young men who have decided to take a regular four-year course at some recognized university or technical school. It would seem most desirable that there should be the closest possible cooperation between the two institutions in these cases. I think that it is probably well understood that engineering curricula in colleges cannot possibly cover "practical" work, and that the aim of such institutions is to give the student a thorough groundwork in the theory of his profession, together with a certain amount of the application of the same. In the past there has been somewhat of a tendency to expect too much from the college graduate, mainly because of the misunderstanding relative to the "type" of work and experience which he has gained. Perhaps in some cases the young man has been somewhat to blame.

I would suggest, therefore, that a regular course of practical work, comprising experience in the important branches or divisions of the shipyard, and covering a period of from one to two years, would be a good thing to establish. The men could be watched and graded during this time and at the end of the course placed in the department to which they seemed best fitted, or in such positions as are deemed advisable. A student could start such work during the summers, even while he was attending the university, and in many ways this is the most desirable method and is commonly known as the "Sandwich" system.

One important point that is often overlooked, and which has been the cause of the loss of a number of men to the shipbuilding business in this country, is that the young man should be made to feel that there is a *future* for him if he makes good. With the establishment of some regular system of training, and taking care of the men as far as possible at the end of the same, this question is largely answered; but with a lack of the same there is a strong tendency for the college man to look around to other branches of engineering where advancement may appear to be more assured.

The cooperative plan between the technical school and the industry has already been established by certain institutions and firms in other branches of engineering, and I feel it is time that such a scheme should be introduced in marine work generally; perhaps not only with the shipyards but with shipowners and others associated under this category.

So far as the University of Michigan is concerned, I can promise the heartiest cooperation, and I feel that in this way the best results may be secured for obtaining a nucleus from which the future personnel for important positions may be drawn.

Mr. H. T. Herr, *Member* (Communicated) :—In the main I think Mr. Bailey has covered the situation very well indeed. We have one practice which is not touched on in the paper and which I think is quite important: We have the heads of our different departments lecture to the regular apprentices, and especially to the fourth-year men, on the functioning of our different departments to make up a comprehensive organization and to pass the work through the shop to completion in the most efficient manner from the standpoint of engineering, production, accounting, etc. For instance, the head of our Production Department will lecture to the boys on the functioning of his department, the head of our Turbine

Department will tell them something of the engineering methods in preparing designs for the shop; our Pattern Shop man will talk on the construction of patterns, the relation of the Pattern Shop to the Engineering Department and Foundry, and so on down to the Foundry, Forge Shop, Machine Shop, Erecting Shop, Scheduling Department, Rate Setting Department, etc., the object being to give the apprentice a comprehensive idea of what it means to actually bring through a piece of machinery in a large organization such as we have and to do it in such a way as to keep the records straight and the operations coordinated to the finish of the job and its final shipment from the works. All these men who lecture to the apprentices are thoroughly acquainted with their departments and their relation to the whole organization and are practical men in every way; consequently the boy gets what we want most to give him: the practical end of the manufacturing business.

Our apprentice work is divided into two general classes, the regular or trade apprentices and the special or technical apprentices, the distinction being that the latter class must come to us with a technical training. Their courses are naturally very different from the trade apprentices, but I understand Mr. Bailey's paper deals only with the latter class.

Our company has instituted in recent years, as a memorial to the boys who left our service during the war, five scholarships open to trade apprentices and shop men, which scholarships call for training in any university or technical school properly selected, on the order suggested in Mr. Bailey's paper. We pay a very great deal of attention to the training of young men, both trade and technical apprentices, and thoroughly believe in the expenditure made in doing so; in fact, it seems absolutely necessary to do so in order to replenish the supply of men from year to year.

THE CHAIRMAN:—I will ask Mr. Bailey to close the discussion.

MR. C. F. BAILEY:—Mr. Chairman and gentlemen, time and space do not permit of replying to all of the many interesting points raised in this discussion.

Mr. Peabody's point relative to the encouragement of the apprentices is very important.

Mr. Spencer Miller's suggestion that consideration be given to the selection of candidates for scholarships from nominations made by the apprentices is a very worthy one.

The purpose of the scholarships, referred to by Professor Everett, might be summarized as follows:

To attract the more intelligent class of boys as apprentices;

To develop the best efforts of each boy and to fix in his mind the fact that the company believes in him and thus appeals to his sense of loyalty;

To enable the boys to see the fine possibilities and the interesting opportunities in the trades in which they are apprentices;

To recruit continually a force of skilled and satisfied mechanics and from this force to draw for quartermen, foremen and others.

It is not contemplated that all of the technical staff be brought in through the apprenticeship system. All large shipyards must rely to a great extent upon the technical schools for such men, but at the same time an opportunity should be given the leaders in the apprentice classes to also attain to such positions.

Mr. Fernald's comment as to the bond between the workmen and the executives is one of vital importance.

We must all appreciate the point made by Professor Chapman as to the training of the apprentice to prepare him thoroughly before entering college and the importance to the college student of the experience in practical work gained in the shipyards and at sea.

Mr. Frear's statement that individual interest should be inspired by the foremen directly over the boys is excellent. The encouragement of the apprentices by the foremen, the superintendents and the executives is much to be desired.

The subject of training engineering graduates in shipyards, as referred to by Dr. Sadler, Professor Everett, Mr. W. W. Smith and others, is admirable in principle and is practiced to a limited extent in most yards. The uncertainty attaching to marine construction is delaying the establishment of systematic courses of training such as are in vogue in the large electrical manufacturing companies, but if an aggressive merchant marine policy is inaugurated this subject should be given renewed consideration, and, as Dr. Sadler suggests, such men should be made to feel that there is a future for them in this work.

The discussion submitted by Mr. H. T. Herr, vice-president of the Westinghouse Electric and Manufacturing Company, is of great interest, especially his reference to their practice of having the heads of the various departments lecture to the apprentices, explaining and describing the work of the different departments in order to give the boys a general idea of the activities of the company, and also his statement as to the establishment of scholarships for trade apprentices and shop men.

Mr. Towle's reference to the increase in interest brought about among the apprentices by employing the boys upon miscellaneous work and tools in the shops is suggestive and valuable; it is only natural that boys should be interested and encouraged by such opportunities for training. Our experience with technical graduates, I am glad to say, has been more fortunate than that referred to by Mr. Towle. We have a large number of such young men, trained since leaving college, who are now occupying very responsible positions and with the greatest credit.

The comments of Mr. Coler are very helpful. His suggestion that an opportunity be given for the boys to meet and know some of the capable men of their trades is excellent.

Mr. Day's point that the number of apprentices suggested seems high would be well taken if the shipyards were able to continue their employees in steady work. The large labor turnover in shipyards is, to a considerable extent, the result of the lack of any national policy for the upbuilding of our merchant marine. Mr. Day's statements relative to the training of the General Electric Company's apprentices are very valuable. It is encouraging to hear his comment as to his company's belief in the scholarship feature and their hope of incorporating something of this idea into their own industry. The student engineering courses, to which Mr. Day refers, should also develop in shipyards when marine work takes its proper place among the industries of this country.

Mr. Brooks' reference to the qualifications of the boy who enters the apprenticeship courses is important. Many boys fail through lack of this preparation and their appreciation that hard work is necessary for great success. At this point I wish to call especial attention to the mental tests, as referred to in the paper, employed in selecting apprentice applicants for the trades. Comparison between these tests and the shop and school records has demonstrated in this work the great value of such tests in selecting and classifying the boys. These tests also when properly given will frequently save the company from admitting boys to apprenticeship courses who later will be found incapable of carrying on the work.

I am glad to hear Captain McFarland's remarks as to the main object of the apprenticeship course: to train skilled workmen and not designing engineers; and further that in the course of training these boys some very brilliant ones may come along and that an opportunity should be given such boys to develop. The object is distinctly not to furnish a liberal education but to stimulate the worthy, deserving, promising boys. For this reason we considered the establishment of scholarships of such a range as to furnish an incentive to the brightest boys and also to the average boys, hence the different scholarships suggested as follows:

(*a*) Four years of college work.
(*b*) Two years of college work.
(*c*) One year of college work.
(*d*) Thirty-six weeks of correspondence school work or night school work.

We feel that scholarship (*d*), in correspondence school work and night school work, of which there are the larger number, will be of great advantage when taken under the guidance of the supervisor of apprentices. It is well known that the correspondence schools furnish courses of great value in many trades and boys who follow these courses are so brightened and stimulated that they see many things in their trade to interest and encourage them which would otherwise go unnoticed; for instance, we have had during the past year a night school course of instruction in foundry work, taught by one of our college graduate engineering draughtsmen, Mr. F. R. Benson. This class proved a most remarkable success, and I wish the members might have seen the splendid work and development which took place among the men and quartermen who followed this work.

The communication from Dr. Macalpine is full of important suggestions.

We have intentionally made no claim on the future service of any apprentice who may be appointed to a scholarship, as we believe that the young man's feeling of loyalty and appreciation will naturally lead him to desire employment with the company who may have granted him the scholarship, and further, the scholarships are intended as incentives and rewards for ability and excellence of service while in the employ of the company and, therefore, we think the company can afford to make the contribution without attempting to control the recipient after his term has been completed. This point of the boys returning to the yard is brought out by the communication of Professor Cathcart. We have felt that the two-year course in marine engineering and naval architecture, suggested by Professor Cathcart, could not be taken without first having the foundation gained by the science studies, and therefore naval architecture and marine engineering are included as only part of Scholarship (*a*).

Since the preparation of this paper the owners of the Newport News Shipbuilding and Dry Dock Company, Mr. and Mrs. Henry E. Huntington, have approved of the granting of scholarships corresponding to (*b*), (*c*) and (*d*), providing for an annual total number of appointees as given in the paper for the four scholarships there mentioned. The president, Mr. H. L. Ferguson, the directors and the other officials are interested in making this the means of encouraging and helping the young men serving apprenticeships. We believe that here is a field for development, and we should be glad to cooperate with shipbuilding companies or other large business concerns in outlining practicable working plans.

It is most encouraging to note the interest shown by the Society in this subject.

Referring again to Captain McFarland's comments, I believe there is a general desire to find and help the boy who may be our apprentice today and who has the mind and heart to become what another apprentice boy became, an Admiral Melville, or what still another apprentice boy became, a Stevenson Taylor, the Society's beloved former President.

THE CHAIRMAN:—If there is any subject which is more important in the upbuilding of our great American industries than that dealt with by the present paper, I am sure I do not know what it is. We are to be congratulated on having this very stimulating paper, with its attendant discussion, brought before us on this occasion. I am sure that you will wish me to present our thanks and appreciation to the author on this occasion.

Tomorrow is the day for visiting the Victorious and Leviathan, should your engagements permit, and tickets may be obtained in the rear of the room which are self-explanatory as to the ways and means of making these visits.

I am asked to announce that an insufficient number of visitors from out of town took the necessary form of railroad certificate to permit taking advantage of the possible reduction in railroad rates on the return trip, so that no reduction will be possible, so far as railroad rates are concerned.

I am sorry that the Acting Secretary has found it necessary to leave before the close of the session, and I hope that the reporter will make a minute on the record of the appreciation of the Society for his services as Acting Secretary on this occasion, Captain W. J. Baxter.

Also, I am requested, on behalf of the President, to say that the exigencies of preparing for the program this evening made it necessary for him to leave before the closing of the session, much to his regret, and unless there is further business to come before us on this occasion, I shall declare the professional session adjourned without day.

MR. ERNEST H. PEABODY, *Member:*—Gentlemen, I have just learned that Chairman Durand has not been here at a meeting of the Society for seventeen years. I move a vote of thanks to him for the efficient way in which he has presided at our session this afternoon.

The motion was seconded and carried unanimously with loud and prolonged applause. The meeting then adjourned.

TWENTY-NINTH ANNUAL BANQUET

OF

THE SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS

HELD AT THE

WALDORF-ASTORIA HOTEL, NEW YORK, N. Y.

FRIDAY EVENING, NOVEMBER 18, 1921

REPORT OF SPEECHES AT THE TWENTY-NINTH ANNUAL DINNER OF THE SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS HELD AT THE WALDORF-ASTORIA, NEW YORK, N. Y., NOVEMBER 18, 1921.

After the service of the dinner, the President, Admiral W. L. Capps, acting as Toastmaster, called the company to order, and said:

"Gentlemen, on the program the President is usually put down for some remarks. This evening he thinks it is advisable to reduce them to a minimum. We are now passing through a very serious stage in the history of shipbuilding and ship designing. There are a great many clouds on the horizon, but I feel perfectly sure that your attendance here this evening shows that you are not cast down, and that whatever the future has in store for us, engineers, shipbuilders and naval architects will do their duty, even though it may not be in shipbuilding always.

"As all of you doubtless know, our program has been rather seriously interfered with by the exigencies of public affairs in the city of Washington. The last day or two have been signalized by the receipt of several telegrams of regret and withdrawals of previous acceptances for this evening. Incidentally, in this same city at this same hour, is being held a banquet of a sister society. This, undoubtedly, has attracted a great many. But as this room is already as full as possible, I think we are starting off very well.

"Now, gentlemen, you have some interesting addresses in store for you so I will immediately proceed to the business of the evening. At all of our gatherings it is our very high privilege and honor to begin our proceedings with a toast to 'The Health of the President of the United States.' "

THE TOASTMASTER:—"The President."

The company rose and drank the toast, the orchestra playing the Star Spangled Banner.

THE TOASTMASTER:—Gentlemen, it is also invariably our custom to follow with a toast to the senior arm of the National Defense—"The Army." We had an acceptance of our invitation to this banquet from one of the most distinguished officers of the United States Army, who would have responded to that toast. A few days after receiving his acceptance, however, it developed that, on the same evening, in New York, was to be given a banquet to a most distinguished foreign military officer, thus necessitating General Bullard's withdrawal of his previous acceptance. This particular foreigner is the most illustrious military figure which has emerged from the great world war. His name and fame are known to all of you. It also so happens that he has had under his command the largest number of American soldiers ever commanded by any one commander. It, therefore, would seem unusually appropriate that, in giving this toast to the "Army," we couple with it the name of that distinguished general, who commanded all of the allied forces in France, including two million officers and men of the United States Army. I give you, gentlemen—"The Health of Ferdinand Foch, Marshal of France." (Great applause and "hear, hear," all guests standing and the orchestra playing the Marseillaise.)

The Toastmaster:—It is with the greatest regret that I have to announce that the Secretary of the Navy, who was to have been one of our most honored guests this evening, has found it impossible to be with us. A few minutes before entering this hall, I received the following telegram from him:

"Up to the last moment I had hoped to be with you tonight, but urgent public business has prevented me. I regret my inability to be present. May I add that the Society of Naval Architects and Marine Engineers has an opportunity to exert a beneficent influence over the maritime affairs of this country, and in so doing will do more to preserve a sound policy than almost any other agent. You have my best wishes.—Edwin Denby."

(Great applause.)

Just before leaving Washington on Tuesday, I made a last visit to the Assistant Secretary of the Navy, who bears a name which is revered throughout this land, and who, in his own right, is fully entitled to the high office which has been intrusted to him. (Applause.) Colonel Roosevelt assured me he would do everything humanly possible to get here tonight. I would not have been surprised had he turned up at the last moment by airplane. His not having come makes it very evident that the very important duty committed to him in connection with the International Conference now sitting in Washington made it quite impossible for him to leave.

Colonel Roosevelt was to have responded to the next toast—"The Navy." The Navy, however, is never without a successor in command. A short time ago I warned the Commandant of the Navy Yard that in these days we never knew who would be the next in succession. He is here with us tonight. The Navy, as you well know, is always ready for emergencies. Therefore, it gives me the greatest pleasure to give you the toast "The Navy," and to couple with it the name of one of our most distinguished officers, who is now in command of this naval district, Captain Carl T. Vogelgesang, United States Navy. (Applause.)

Captain Carl T. Vogelgesang, U. S. Navy:—Mr. Toastmaster, distinguished guests and gentlemen, I feel quite sure that the Society of Naval Architects and Marine Engineers will not expect very much from a last-moment substitute for a real orator. We know, as was intimated by our presiding officer a few moments ago, that matters of great concern are now being deliberated in Washington. It therefore behooves us of the Navy, and of the sister branch of the service perhaps, not to be overindulgent in things that we give to our tongue. I wish to say, however, that while it is not given to us poor mortals to climb the skies and pierce the councils of the Almighty One, and while we are unable to penetrate the screen which obscures the future, I know that I voice the sentiment, the spirit, and the morale of the Navy, as exemplified in its entire history, when I say that whatever is disclosed when the veil is rent aside, whatever the future may have in store for us, your Navy will be as it has always been, undaunted and undismayed. (Applause.)

The Toastmaster:—Gentlemen, there are in this country at this time, in connection with the Washington Conference, many distinguished foreigners, and among them many officers of great distinction representing several foreign armies and navies. There are two, however, who stand out with special preeminence. One, now in this city, you have just had an opportunity of honoring. The other is detained in Washington on most important duty as a member of the Committee on Reduction of Naval Armaments, of which Colonel Roosevelt is chairman. This officer represents the highest naval ideals. In the grinding test of war he showed that he exemplified, in his own personality, the highest traditions of the service which he adorns. We had hoped that he would be our guest of honor this evening. He was first constrained to decline our invitation, because he was scheduled to leave this country on November 15. Subsequently his reservations were cancelled, as he was detained in connection with the work of the Conference now in session in Washington. The invitation was renewed by your President in person, and I was told that nothing would have given this officer greater pleasure than to attend our annual banquet, but that he feared his duties in Washington would absolutely prevent his coming to New York at this time.

Today I received the following letter:

"It is a great regret to me that my duties in Washington have prevented me from attending the dinner of the Society of Naval Architects and Marine Engineers. The wonderful results achieved by the United States in the building of both naval and mercantile vessels in large quantities and in an incredibly short time, during the war, did so much to assist the cause of humanity. I am glad to have this opportunity of paying my small tribute to them for their skill as naval architects and marine engineers.

"BEATTY,
"Admiral of the Fleet."

(Great applause.)

THE TOASTMASTER:—I now ask you to drink the health of Admiral of the Fleet, Lord Beatty.

The company rose and drank to the health of Lord Beatty, the orchestra playing the British National Anthem.

THE TOASTMASTER:—In these days of great tasks there is no one agency under this government which has a greater task, a greater responsibility, than that committed to the U. S. Shipping Board. We all know the tremendous efforts made during the war to increase our merchant tonnage. We are prone, I fear, to place too much stress upon the money spent, and too apt not to give full weight to the very great things which are accomplished—psychologically, at least, if not always physically.

The opportunities and the duties of the Shipping Board are as important now as they were, even during the war. The very life of the American merchant marine hangs largely upon the wisdom and success of its undertakings.

It is, therefore, a very great privilege to have with us tonight the man who has been recently selected by our President to head this organization. I have, therefore, the very greatest pleasure in proposing the toast—"Overseas Commerce and Its Relation to American Shipping," and to couple with that sentiment the name of the Hon. A. D. Lasker, chairman of the United States Shipping Board. (Great applause.)

ADDRESS BY HON. A. D. LASKER, CHAIRMAN OF THE UNITED STATES SHIPPING BOARD.

In the thirty odd years since the birth of the Society of Naval Architects and Marine Engineers, I am told, no single year has passed when speakers at this annual dinner have failed, in well-rounded phrases, to clamor for an American merchant marine and to hold forth the hope of the dawn of a new day in American over-sea shipping. When the war, as one of its vital problems, thrust on this nation the necessity for the creation of an over-night merchant marine, it seemed as if the vision of shipbuilder and shipowner was nearly an accomplished fact. When month after month showed mounting records of tonnage launched and vessels completed, until peak production was reached in 1919, at nearly double Great Britain's maximum yearly production, to many the American merchant marine appeared an accomplished fact. When demand for ships continued, so that every vessel could find a cargo in every trade, when America's 10,000,000 tons flew the flag on every sea, to many of those nearest the business the dream of a merchant marine seemed close to achievement. Then came the anti-climax.

In the spring of 1920 began the softening of freight rates, the falling off of demand for tonnage, which, on an ever-increasing scale, continued well into the present year. Today this country finds between one-third and one-fourth the privately owned vessels of its fleet and two-thirds of its government-owned fleet are swinging idly at anchor or moored with smokeless funnels at their docks. Falling freight rates have again stressed all of the disadvantages under which American ships must operate in competition with their rivals. Greater carrying charges due to higher first cost, higher bills for wages and for living expenses, greater upkeep cost, higher insurance, and more stringent government laws have all made the lot of the American shipowner a conspicuously unhappy one in a market where the shipowners of the entire world are crying out for better times.

Confronted by this situation, a new Shipping Board took office some five months ago, and at the end of this short but busy period is just now ready to settle down as an organization, and for the first time to begin functioning as contemplated by the Merchant Marine Act of eighteen months ago.

It is idle to explain to this audience the magnitude of the problem that confronts the board. It is useless to paint to you who have spent your lives in shipping and shipbuilding the picture of the difficulties that surround the problem and that must be overcome if sound principles are to be enunciated and a foundation laid upon which can be erected a permanent structure of American-built, owned, manned, and operated merchant marine sufficient to carry the greater part of this country's foreign commerce. Nor can the board today report that it has made more than a first beginning in the study of these mighty problems or that it has seen more than the first blush of the coming dawn, before the daylight that we hope will soon flood out the darkness that now surrounds this situation.

It has seemed good to me tonight to present to this body some of the first facts that have been gathered in the study of our foreign commerce, an understanding of which must form the beginning of our knowledge of the lines along which to proceed; indeed, in the study of these facts many things have already become clear that have changed our preconceived picture and that I believe form food for the serious thought of you who are here tonight.

A great difficulty surrounding any study of our merchant marine lies in the fact that no reliable basis of comparison can be found in the past.

Because of the war, no single year of the past ten can be here marked as normal, while conditions more than ten years ago are too dissimilar to those existing today to form as accurate a comparison as could be wished.

The study of the water-borne export and import trade of the United States must, therefore, be made from basic facts. Opinions as to the future will, of necessity, be largely matters of judgment and belief. Minor fluctuations must be ignored or assigned to their true causes, while general trends of broad and basic conditions must be picked out clearly from the confusing background of less vital facts.

In attacking this broad problem, we have not considered whether or no certain industries can be fostered in the United States, but only whether or no the sea-borne commerce of the United States, measured in terms of tons, as used by the shipowner, is growing; in what direction this commerce chiefly moves; how it is likely to change in the future; what ratio, from the standpoint of quantity, is carried by American ships and what under foreign flags; and more than all, how an increase in the number of American-flag ships can be made to go hand in hand with an increase in American trade and, therefore, increase the wealth and prosperity of the American people. (Applause.)

Man's first requirement is the air he breathes, then food, then clothing and shelter and then luxuries. These have resulted in a natural cycle of progress for civilized countries which have passed in order from the grazing to the agricultural and then to the manufacturing stage of their development. Progress has naturally been more rapid where the necessary raw materials to permit a country to become a manufacturing nation have been most easily available. Sparsely populated countries must raise the food supply for the densely populated manufacturing territories, and this broad principle, to a very wide extent, underlies the general commerce of the world.

In these United States, with thirty-six persons to each square mile of our continental territory, we are generally considered a food-producing nation. Our output of grains and meats is enormous, but so is the population which it must sustain. We still export large amounts of food and necessarily did so during the war, and will continue to do so until the deficiency caused by the Russian cataclysm has been made good from other sources. Now, here we come to the first, to me, startling fact in our study. The peak of the United States development as an exporter of raw foodstuffs was passed as far back as 1880. By this, I mean that in 1880 the percentage by value of foodstuffs to the total value of exports reached its maximum. In 1880, foodstuffs constituted close to 60 per cent of exports. In 1920, this had fallen to 25 per cent of exports. The United States of seventy-five years ago may be compared to the Brazil, the Argentine, the Australia and the Canada of today.

It is of vital interest to compare the percentage by value of exports of raw materials and manufactured articles over the last seventy years. In 1850, manufactured articles were less than 20 per cent by value of our exports; raw materials other than foodstuffs, about 60 per cent; and foodstuffs, crude and manufactured, about 20 per cent. In 1920, after many years of quite uniform growth, the per cent by value of raw materials has dropped to 20; the export of manufactured and crude foodstuffs constitutes about 25 per cent by value; and the export of manufactured articles has risen to 55 per cent, so that today, without giving any credit for manufactured foodstuffs, our manufactured exports comprise the major portion of this branch of our trade.

Turning now to imports, in 1850, 70 per cent by value was manufactured material; less than 10 per cent was raw material; partly manufactured material about 15 per cent; and the balance manufactured foodstuffs. The partly manufactured materials and foodstuffs have maintained a curiously constant percentage, while raw materials have steadily risen, and totally manufactured material has nearly steadily decreased, until in 1920 the percentage by value of importations of raw material has risen to 40, while totally manufactured material has decreased to 30 per cent. This represents an increase of nearly 500 per cent in the percentage of importation of raw material and a decrease in the percentage of totally manufactured material of over 100 per cent; as startling a change in three and one-half generations as can be found in the history of the world.

America today, with unparalleled resources, is dependent for its growth and progress on importation of raw materials necessary to supplement its own vast stores.

Of our raw-material exports in 1920, bituminous coal ranks first; then grain, crude oil, cotton, phosphate rock, and lumber. Of the nineteen million tons of coal exported, ten million went to Europe, a market largely closed to us today. Of the balance of these raw commodities, some twelve million tons of exports, a large part was grain produced in this country because of the failure of the Russian supply. On the other hand, our greatest single import is crude petroleum from Mexican fields, which in 1920 amounted to no less than sixteen million tons. Next to oil comes sugar, of which nearly four million tons, mostly from Cuba, was imported in 1920. Then come iron ore, nitrates, potash, and potassium salts; then bananas, of which no less than eight hundred thousand tons were imported in 1920; then coffee, copper ores, sissal, jute, and kapok.

Our exports of manufactured articles are nearly as varied as our industries, with refined petroleum at the head of the list by tonnage, then manufactured steel, dairy products, flour, machinery of all kinds from automobiles to phonographs.

Our export of cotton for twenty years has remained practically stationary, the actual increase of output being absorbed in American mills. In 1920, no less than eight hundred and fifty million yards of cloth were exported. Today we consume more cotton than we export, and import 10 per cent of our consumption from Egypt to make good our own immediate insufficient supply of long staple cotton.

The shoemaking industry affords an interesting example of the changes going on around us. In 1920, nineteen million pairs of shoes were exported. This business was founded on our supply of cheap and excellent hides. Today the bulk of our hides comes from Argentine; while the exhaustion of our local supply of oak bark necessitates the importation of quebracho also from Argentine, so that much of the foot-gear of Argentine travels in the form of raw materials some seven thousand miles to our tanneries and factories and back again to the feet of the ultimate consumer.

Our imports of manufactured material cover a wide variety, principally of specialties; German and Japanese toys, coal-tar dyes, optical glasses, special silks, Irish linens and English worsteds. These rank high in value because of their character, but low in tonnage.

Geographically, the United States may be divided into the raw material and foodstuff exporting localities covered by the Central, the Gulf and the Pacific sections, and the manufactured-article exporting district, the North Atlantic district, which may be roughly considered as including the territory east of the Mississippi and north of the Ohio River; together with the New England and North Atlantic states. Since water hauls are cheaper than rail hauls, shipping will attempt to get as close as possible to the source of manufacture in the case of exports and to the center of consumption in the case of imports. Trade of the central region seeks its outlet by the line of least resistance; western grain through Portland, Seattle, Vancouver, Kansas and Nebraska, wheat by way of Galveston, northern grains by Canadian railways, by the lakes, the St. Lawrence, or the canals and railways to the Atlantic. Other raw materials have fairly definite points of export, generally so located as to give the shortest rail haul. Our Atlantic, Gulf and Pacific coasts have offered unequaled opportunities for coastwise shipping, with the result that before the war our sea-going merchant marine was largely limited to vessels in this trade. With the outlying possessions assumed to be included under coastwise laws, the ship that runs from Hawaii to New York, or from the Philippines to San Francisco, is not the kind of ship that in other countries is known as a coasting vessel. Should the President include the Philippines under our coastwise laws, as contemplated by section 21 of the Merchant Marine Act of 1920, there will be developed under our flag a truly ocean-going traffic of no mean proportions.

Of the traffic of our great fresh-water lakes, and of the bulk oil carriers between Mexico and the United States, little need here be said. The bulk of both of these traffics is in special ships which form almost as much a part of the business of the manufacturer as do the hammer and chisel of the mason. They can be more nearly considered as tools of the trade than the ordinary floating carrier. Tankers are almost exclusively limited to the bulk oil trade.

Leaving these specialized businesses, we come to that trade which is of most vital importance to the United States. The islands of the Caribbean offer what is today almost the only voyage permitting full cargoes in both directions, although even here trade is to a large extent seasonal. Our exports to these countries are made up approximately of 50 per cent coal; 10 per cent foods; 10 per cent lumber; 7 per cent steel; 5 per cent cement; and the balance general merchandise. Our import tonnage, which over the year practically balances our exports, includes sugar, 55 per cent; bananas, 14 per cent; oil, 15 per cent; and the balance general importation. American capital is heavily interested in the West Indies and, therefore, controls products exported from the islands, together with the ships which carry them, as in the case of the United Fruit Company, the primary purpose of whose vessels is to transport bananas to the United States, and the ore-carrying vessels of the Bethlehem Steel Corporation, whose business is to transport the Cuban ores to Sparrows Point.

There is little or no excuse today for our letting any third party share with us any part of the West Indian trade. To the South, the entire continent of South America requires coal, and this market should largely belong to us. This coal, added to the balance of our exports for the first eight months of the present year, has closely approximated by tonnage the importation from South America, comprising such materials as tannery products, linseed and nitrates.

Our trade with the South Pacific, Australasia, Dutch East Indies and India is varied to a considerable extent, in the transition period; practically 70 per cent of our exports were petroleum products, a trade that has been well maintained since the war. In return for these products, one-half of our inbound cargoes is jute, but all of our business with these Pacific countries is negligible in comparison with the Central American and South American business previously mentioned. South Africa has been little developed as a trade possibility for the United States, but to the Orient we have exported large quantities of oil products, manufactured articles, cotton cloth, automobiles, and steel. In return for these, silks, grasses, rice and sage; and before the opening of the Panama Canal, coal and manganese ore have made up the bulk of our imports.

This leaves, then, for consideration the great Mediterranean and European countries, to which the vast bulk of our exports goes, and from whom, in return, we receive relatively insignificant tonnage of imports. The exports cover practically the entire range of our production. Here we are met by one of the most remarkable results of these studies. From the United Kingdom, North Europe, and the Mediterranean, we import, in tons, less than one-quarter of our exports, a situation that clearly illustrates one of our difficulties, in that full cargoes for the return voyage are very difficult in this trade as it exists today.

A study of the total tonnage imported and exported from the United States, omitting tonnage on the Great Lakes, and tonnage of oil carriers, is interesting in the extreme. Over the last year, the average monthly tons of imports are about one million, while the average tons of exports are a little over three million.

If we take out from these totals the commerce of middle America, that is, the West Indies and Central America, this discrepancy is even more astonishing. With these figures excluded, imports have reached little more than half a million tons per month, while exports have averaged slightly under three million tons, or six to one, a readily understandable reason for the large number of ballast homeward voyages.

It is interesting to study the change that has taken place over the last year in the percentages of cargoes carried in American vessels. To find out exactly what is going on this study has been made to exclude the Great Lakes, the Mexican oil and the West Indian trades, so that the comparison would only show those routes in which our ships might move in competition for market. On those routes, comprising all the rest of those world-trade routes in which the United States shares, one-quarter of the exports in January last was carried in American ships. These rose to a peak of 40 per cent in June, when many cargoes of coal were moving because of the British strike, and fell back in September to 25 per cent, showing a practically constant percentage, at the beginning and end of this period, of largely diminishing traffic. In the case of imports, however, the story is quite different. In January, nearly 75 per cent of the imports were carried in American vessels. This percentage fell by April to about 35 per cent, and had fallen by June to a minimum of little more than 30 per cent, from which date it has ascended to about 40 per cent for the month of September. For a nation with ten million tons of idle shipping, this is not a record to be proud of, nor one that will satisfy any red-blooded American. (Applause.)

Such is the inventory of current tonnage operations on export and import with which the present Shipping Board finds itself confronted at the inception of its term. With a fleet in magnitude beyond any dreamed of by Americans a decade ago; with a fleet, if total tonnage alone were to be considered, far beyond the world's immediate absorbing power, the new Shipping Board finds the use of its other American tonnage currently decreasing. In measure this can be attributed to Great Britain's releasal of its government control over its own shipping which has given flexibility to British tonnage that it did not possess during the period when the government set the routes which its ships must follow.

In measure, the decrease in American tonnage carried in American ships is due to the difficult economic times the world throughout, which make for keen competition by other nations which America, with its standards of living, cannot meet. In measure, but very small measure, this condition is due to the government's retirement, under the present Shipping Board, of many trips so unprofitable as to find no warrant, even with a view to building up for the future.

But the present Shipping Board, confronted by this condition, far from being discouraged, feels encouraged, because it realizes that we are now dragging bottom. It feels that now we are going through the lowest period that American shipping will go through. The present Shipping Board feels that, with the physical assets we have, with the inspiration that will undoubtedly be given to American shipping by President Harding in his administration, American ship operators, bankers and manufacturers will work at one with the Shipping Board in a constructive policy to make solidly for our carrying our full share of our world's trade. Rather than being dismayed by the picture, we feel that we know the worst and are experiencing the worst; we feel that courage and vision must and will solve our problem, since what we are going through is the worst.

Modern nations must pass through certain well-defined stages in their development: first, the grazing or live-stock stage; second, the agricultural stage; and third, the manufacturing stage. In our vast country, certain parts are today represented in each of these stages of development. We have expanded industry to a geometric ratio; our manufacturing industry has been increased to meet the demand of an increasing population, not alone by continuous output, but by the additions to manufacturing plants.

The lack of adequate export markets was beginning to rest heavy on us at the outbreak of the war. With this same war, however, came the truly abnormal demand on our facilities, which resulted in a badly ordered, but enormous, expansion of our already top-heavy manufacturing structure; still further augmented by the period of inflation that followed the short period of depression of the early months of 1919.

Then the bubble burst, and today we are left with enormous manufacturing capacity in many lines far beyond any possible domestic need, and with such a surplus of food products that the Secretary of Agriculture talks of the possibility of burning corn in place of coal in certain parts of the country as an economically defensive proceeding.

Through the war period cost played little part in foreign trade. Goods could be marketed as manufactured; foreign markets became available because of the fortunes of war far more than through individual effort and energy. Too little attempt was made to hold them by good-will, with the natural consequence that in many directions we have lost ground, until today, except for the export of foodstuffs, we are nearly back on a 1913 basis.

Now these same exports of foodstuffs are, for us, a temporary stage. Canada, Australia, Argentine will, in the not distant future, absorb this business, while the nations that fought shoulder to shoulder with us in the war owe us some ten billions of dollars, interest upon which can only be paid in goods or through the extension to them of further credit; and practically all of these debtor countries are in the manufacturing stage of their development. It follows that their very attempts to pay their debt to us must make them the keenest of competitors, both in our home and in our foreign markets. In order to pay for our imports of raw materials and of foodstuffs and for the increasing number of valuable articles, many mere luxuries, and to reduce the overhead of our enormous manufacturing establishments, it will be of the utmost importance that we produce industrially to capacity.

This means strenuous work to develop new and permanent foreign markets for our own surplus of these exports must go to a very considerable extent to undeveloped countries with whom, heretofore, we have not enjoyed a large export trade.

Even to balance our imports of raw materials, a bulk low-grade outbound commodity cargo must be available. This is our export coal. Its normal market is South and Central America, which not only has no adequate supply of coal, but which must furnish us with the raw materials, nitrates, or linseed and hides necessary for our manufacturers.

South America must also be a great field for our domestic and foreign export of manufactured articles. With the increase of exports to South America and to the Orient, the development of our commerce may lie in the so-called triangular voyage. Our ship, with cargo of coal to Buenos Aires, may find it necessary to return to Hampton Roads via Europe, transporting a grain cargo to that continent and returning in ballast across the North Atlantic.

Today, transportation is available at nearly pre-war rates. In quantity, far more is waiting to the exporter's hand than existed before the war. Cheap and plentiful ocean carriage is assured. The development of markets waits on the united effort of shipowner, manufacturer, banker, exporter; all under the eye of a government that has adopted the model of more business in government and less government in business. (Applause.)

Under the mandate of the Jones Act, and because it is the spirit of the Harding administration, the Government as quickly as possible wants to retire from government operation and ownership, that private inspiration and private initiative may conquer the almost insuperable obstacles that seem to face us in all forms of world trade. (Great applause.)

With this in view, aside from the development of American shipping, if American prosperity as a whole is to be insured through the development of American foreign trade, an inspired interest for group action must be born among bankers and manufacturers as well as shipowners. The Edge law, in constructive statesmanship, provides for such combinations among manufacturers in the foreign trade. In time, such groups should be a bulwark for our merchant marine.

But, recognizing the need of strong groups of united manufacturers and bankers in our country to meet the competition of strong groups of united bankers and manufacturers in other countries is not enough.

We must come to the realization that the great North Atlantic and Pacific trade routes, so far as passenger service is concerned, are in the hands of a few strong foreign groups. Germany, with all its great effort between the wars of 1870 and 1914, was able to build up in the North Atlantic only two strong companies. Great Britain, with hundreds of years on the seas, has but two major passenger carrying lines in the North Atlantic.

It is this competition that we must meet—not domestic, but foreign—and we must meet it in kind. This in nowise means that the small operator and the new operator of many types of ships shall not be encouraged. Indeed, he will be fostered to the utmost by the Government. But it does mean that we must interest all the strength of our people, not only government but private concerns and individuals, in a united effort to win our place on the seas in competition with the united power of individual nations of the world. (Great applause.)

I would like to address to this body, which has, possibly, as large a direct interest in shipping as any group in America, a few words as to the interest of President Harding in a merchant marine, that interest being to many of you a matter of great concern at this particular time. I remember in the course of the campaign, in the early days, last July, when I was trying to secure his attention to another subject, he turned to me, who was then in nowise interested in shipping, and said: "One of my major ambitions is to be the President who aids in putting back the American flag on the seas." (Great applause.) At present, President Harding's attention and that of most of the members of the Cabinet is centered in the Limitations Conference in Washington, and I know the hopes of all of us are for its success. In the declaration to other countries at the conference our government has stated that, in the event of Naval Disarmament, the Merchant Marine becomes of increased importance in an inverse ratio, and this must be so, if we are to keep our flag on the seas. To the American merchant marine must the American shipyard look for future business, and without an established merchant marine the art of shipbuilding in America will be lost.

The total tonnage owned by the Government includes five million tons of as fine a tonnage as exists in the world which was created as a war condition, and its production is a record of which our country will ever be proud. The purpose back of it was to build, as expeditiously as possible, a bridge over the ocean to the battlefields of Europe. The pontoon bridges which were put on the Marne have been destroyed and lost, but we glory in the part played by every man and every tool they handled. The pontoon bridge which we built to cross the Atlantic, our great steel fleet, is still with us, and instead of that fleet disappearing, as did the other tools of war, it should be our purpose and our inspiration, if we are to assure America's prosperity in peace, and ensure her balanced strength in times of national prosperity, that it be the nucleus of a merchant marine, enduring and lasting. (Applause.)

This fleet is an unbalanced one, it is necessarily such because of the manner in which it was built, and our government, and our people, if they are to ensure domestic prosperity, must augment that fleet with the types that are needed. This cannot come merely through the genius of America, as so many would have us believe—genius is not alone in America, proud as we are of our country—it must come by the recognition of the inland dweller as well as the coastal dweller that America must own its vehicles of transportation on the seas. Being new and young, if we are to compete with the nations of the world, it must come through a governmental policy, which must soon be arrived at or originated, for by such aid only will shipbuilding and ship operation, an industry which is comparatively new and reborn with us, be enabled to exist. (Applause.) This must mean education and recognition on the part of our people in all parts of the country. With such aids and with our needs, none of us need look but hopefully to the future, and it is within the coming year that America will undoubtedly be called on to decide whether or not in our generation we shall be restored to our proper place on the sea, or whether once more the American flag shall retire practically to coastal service.

My hope and belief is that, and I can, in a measure, speak for the President, but I have no right to speak for Congress—my hope and belief is that with the recognition of Congress, our people will do that which is necessary to attract American capital, American genius, American interest, to a merchant marine. Such is my hope and my prayer. Another year we may know. (Great applause.)

The Toastmaster:—Gentlemen, our cloud has a decidedly silver lining when the Chairman of the Shipping Board gives voice to such sentiments as we have just heard. We are under great obligation to him for having come to us tonight, and for having expressed his views in so terse and lucid and compelling a manner. I think we can begin to be optimistic again. I thank you, Mr. Chairman, for your address. (Applause.)

In these days we must not forget that America, during the last century, occupied a most prominent place in the shipping world. At one time, in fact, she led the world in shipbuilding and ship operation. We are fortunate in having present tonight a gentleman who has been very closely identified with the development of the American merchant marine, practically throughout his life. He was closely associated with that prince of men, the first president of this Society, the late Mr. Clement A. Griscom. He is now a colleague of the gentleman who has just spoken with such convincing prophecy.

I have great pleasure in proposing the sentiment, "The Shipping Spirit of America," and even greater pleasure in coupling with that sentiment the name of the Hon. E. C. Plummer, a Commissioner of the U. S. Shipping Board.

ADDRESS BY HON. E. C. PLUMMER.

Mr. Toastmaster and gentlemen, it is with feelings that some of you gentlemen readily will appreciate that I address you tonight, for it was here thirty years ago that I first was granted the privilege of becoming associated with those strong men who then were undertaking a real work for the establishment of an American merchant marine; and the little part I, a young man, was permitted to play in making possible the American Line, with its then magnificent Atlantic greyhounds, is to me a cherished memory that the swiftly passing years have left undimmed.

Few of the men who were associated in that original undertaking are with us now; and through the failure of essential legislation then attempted, their more elaborate plans, which contemplated such a development of our shipping as would have meant much to this country, became as they are now.

But the passing of a generation has brought back to us the maritime opportunities which those men then so clearly saw; a greater merchant fleet than that of which those men even dared to dream has been flung to us by the tempest of war—a fleet belonging to the people whose sacrifices made it possible and which must, and shall be, preserved, and therefore tonight I can speak with a confidence born of an assurance that the American flag is again on the seas and that it is there to stay. The fact that, including American shipping under foreign flags, our people now own more tonnage than any other nation should not be overlooked; neither should the fact based on normal growth that it is not a case of too much world tonnage that is causing the fleet tie-up of today, but a falling off in cargoes of which Germany's change from 130,000,000 tons in 1913 to 30,000,000 tons in 1921 is but one illustration.

Therefore it is not inappropriate that one whose home is by the river where, thirteen years before the Pilgrims landed, there was built the first ocean-going vessel the New World had produced, the historic Virginia, should speak of this country's shipping spirit—a spirit which sometimes has slumbered, but which did achieve so much that was glorious in the past and which now is in position to renew its triumphs wherever ships may go.

The measureless losses from which our people suffered during those awful years of the World War have impressed upon this generation that unchanging truth so clearly understood by our fathers, that merchant shipping is one of the four cornerstones upon which the permanent prosperity of this nation rests—a stone that cannot be removed without imperiling the whole structure. In this our education is not unique. These established facts have not only been taught to, and recognized by, other countries, but they were emphasized by the experience of our own people long ago. The cruel trials and losses of the Pilgrims, sustained while their helplessness compelled them to trust their humble, but to them vital, cargoes to the vessels of others who should have been their friends, so pitifully pictured in Bradford's simply worded narrative, is one which no American who reads the record can forget; and the fact that the first commercial act of the Massachusetts Bay Colonists was to construct a then great ship, the Blessing of the Bay, that they might have tonnage which should enable them to handle their own products and not leave them at the mercy of men across the sea, has the same significance now as it had in those early days.

Fresh in the minds of those men was the knowledge that the ablest statesmen ever gathered around the throne of Britain, those advisers of Elizabeth who made the name of England immortal, had established the policy of paying liberal bounties from the national treasury to British merchants that England might have a commercial fleet to dominate the seas—and they followed that example. They exempted from military service shipwrights in those days when prowling savages made the musket an inseparable companion of the settler.

They knew what such exemption from military service really meant—that this aid to merchant shipping was a concession that might call for payment in their life blood; but they paid it. The result was that shipping in the colonies developed so rapidly that politicians of Europe soon saw in it a peril to England's maritime supremacy, and Sir Joshua Child in his discourse on trade presented in 1668 made this comment, the truth of which was to be so many times re-emphasized: "Of all the American plantations His Majesty has none so apt for the building of ships as New England." Every student of maritime history knows how the colonists developed the shipping industry; how they broke away from old established types and gave the world such merchant craft as had been before unknown. When the Revolutionary War came on the colonists were without a navy; but they had shipping men, men accustomed to challenge all the dangers of the ocean; men to whom the tumbling breakers had been playmates in their childhood days; and when Paul Jones made his historic advent to the British Channel he found there had been before him many a little colonial privateer, bravely assailing Britain's proud shipping in its home waters. When the United States had won its independence, but before the government had been formed, there was a period when American shipping was an outcast upon the sea. Those vessels had no national protection; each had to depend upon its own powers to preserve its existence.

Yet in those days between 1873 and 1789 the fearless ships of the colonists ventured into every sea in increasing numbers, and in 1789 there were more than forty ships of this feeble country trading beyond the Cape of Good Hope; venturing half-way around the world to China, defying the Barbary pirates and those merciless Malays of the eastern waters. During this period there went out from the port of New York the little ship Experiment, built on the Hudson, measuring but 80 tons. Every man in her crew knew not only the sailor's art but he had learned to handle the cannon, the musket and the cutlass; and with her crew of fifteen men she made the voyage to Canton and return. During that same period, still unprotected, the Columbia of but 200 tons, and her consort, the Lady Washington of but 90 tons, ventured around deadly Cape Horn, into the Pacific and circled the globe; finally discovering the majestic river which took the Columbia's name, and helped to give this country that marvelous country of the great northwest.

Such was the spirit of the American shipping men of those days. You know their subsequent triumphs. How those pioneers in ocean traffic achieved their success is clearly set forth by the British historian of shipping, Lindsey, when he states that the masters of American ships were greatly superior to the British masters. The Americans had the training of merchants; they had the inspiration of ownership and initiative; they had the boldness that knew no fear; they demanded of the ocean its treasure as if it was rightfully theirs—and the ocean responded to their dauntless demands. Some of you will remember that way back in the old clipper days, many a time the crew of a foreign vessel, lumbering along under lower topsails, would see a cloud of snow-white canvas come over the horizon, and soon a "Baltimore" clipper would go booming by, royals flying, rigging singing in the wind, and the lee rail resting in the waters. (Applause.) The men of New York were among the maritime leaders of those days.

It was in New York that the great steamers of the then unmatched Collins Line were built; and the business men of New York and the engineering skill of New York made those marine marvels possible. The wealth of the Morgans, the Ogdens and their associates produced the unmatched Dreadnought, that theme of song and story whose memory will be cherished so long as men go down to the sea in ships; and it was from New York that there went out the tiny vessel greeted by British shipwrights with such careless scorn, but which, when the trial came and America's marine skill was pitted against the best that England could produce, carried the Stars and Stripes to triumph on that day when to Her Majesty's inquiry "What yacht is second?" for she knew then that America was first, the answer came—"There is no second."

Some political somnambulists have argued, and a few still argue, as if it were an open question, the proposition of whether or not our government should aid its merchant shipping. (Applause.) This chatter should have been ended long ago. Every maritime nation that has achieved success upon the ocean has achieved it by giving direct and powerful assistance to its shipping. (Applause.) The record is completely unbroken and unchallengeable on this point.

Perhaps it is because those people have come to realize the hopelessness of any attempt to destroy our shipping by direct assault that some of them now seek to accomplish the same end by distracting attention from the real issue through citing changes in laws and rules which unquestionably have a material effect upon our merchant marine, and by proclaiming the wonders which American genius sometimes performs. But this is no time to lose sight of the main and absolutely essential fact that by government aid alone can American shipping remain in the foreign trade. So to those people I say: "First, make the position of our shipping secure upon the sea. Experience will show what minor matters must receive attention. First make sure that you have a baby; the little stranger itself will then aid you in determining whether you should name it George Washington or Dolly Madison. It is poor judgment to stand considering whether you should employ cedar or spruce shingles for patching the roof of your house when the house itself is on fire."

Another method employed to shake the confidence of our citizens in the possible success of an American merchant marine is seen in the phrase so brazenly coined and given such wide circulation by many innocent parties, that the people of the United States are not ship-minded. Not ship-minded! When we still have with us the old frigate Constitution which in her day was the unmatched flyer of the seas. Not ship-minded! When in the glorious days of the sailing craft our vessels took and held and hold every record upon all of the great race courses of the oceans. Not ship-minded! When in the fifties, before foreign influences had secured their strangling hold upon this great industry, this country produced the largest, fastest, finest and most efficient ocean-going steamships in the world. Not ship-minded! When the first transatlantic greyhounds built in this country took, held and still hold the record for number of round trips across the ocean made in any one year. (Great applause.) And they still hold the record, so significant to every shipping man, of never having been sea-swept.

Not ship-minded! When, during that closing year of the World War, in response to the despairing cry of Europe for help, the chosen ships of all the world were racing across the ocean to put our boys upon the battlefields of France, before the fateful hour should strike, it was the Great Northern, designed by Americans, built by Americans, and manned by Americans that, challenging the best that England, France and Germany could produce, set and held and still holds that wonderful time record for a round trip across the Atlantic. Not ship-minded! "Where do they get that stuff?" They get it from the enemies of an American merchant marine. (Great applause.)

But the descendants of those whose humble homes were on the seacoast, and who, in the Pilgrim days, depended so much upon the water for sustenance of life, the children of those strong men and noble women, who subsequently crossed the sea to cast their lots among those who were so triumphantly performing the great miracle of changing a savage wilderness into the richest and most blessed land the world has ever known, feel the ocean heritage is a part of every true American life—that rush to the ships at duty's call in the epochal years just passed has proven this again; and now we may with confidence look forward to that day, already dawning, when the many-faced opponents of an American merchant marine shall find their subtle efforts unavailing, and the ships that bear the Stars and Stripes shall brighten again the waters of the world, even as in those days when every sunrise upon every ocean revealed the shimmering sails of an American ship, the silver ripple beneath her bow, moving in fearless pride along the liquid highways of commerce, a queen upon the sea. (Great applause.)

The Toastmaster:—I am sure, gentlemen, you wish the Toastmaster formally to express your thanks to Mr. Plummer for his words of cheer and hope, even though you have, by your applause, already voiced them much more effectively than he can.

Now we have finished the formal numbers on our program of speeches. There are two gentlemen, however, that I wish to present to you—I will not detain you long and you should meet them or renew your acquaintance with them. The first is an officer of the Navy, who has just been assigned to one of the highest technical posts in the gift of the Government—a very great and responsible post.

I take great pleasure in presenting to you the engineer-in-chief of the Navy, Rear Admiral John K. Robison.

Admiral J. K. Robison:—We have the same job ahead of us. It is new to me, but you are more or less used to it. I have forty cents next year to do—per horse-power, that is—what they had a dollar to do with ten years ago. I do not know how to do it yet. I need your help. We in the Navy have been taught from the beginning that when you get in trouble we take you out. We are up against exactly the reverse side of that proposition now. I have to get the help of some A No. 1 he men, because I do not know how to make forty cents go as far as a dollar did ten years ago. Prices have not gone down that much. That is what I am up against. I have not the most remote doubt in the world that we are going to do it. I do not know all the details. I do know some of them, but I have not the most remote doubt in the world that you are going to have the Navy, what there is of it, fit and ready when you need it. (Applause.)

The Toastmaster:—Now, gentlemen, one more introduction and a most important one. Yesterday the Society elected a new president. He is here tonight. He needs no introduction whatever from me to an audience of this kind, but it is my privilege to say that, after long, faithful, devoted service, having always the best interests of this Society at heart, sparing no time or trouble, there has come to him the highest honor in the gift of the Society, and he richly deserves it.

I take great pleasure in presenting to you the president-elect of this Society, Mr. Walter M. McFarland. (Great applause.)

ADDRESS BY PRESIDENT-ELECT WALTER M. McFARLAND.

Mr. President, honored guests and fellow-members of the Society, such an introduction as Admiral Capps has just given me, and such a reception of it as you have tendered, is enough to make any man very proud. As the Admiral has truly said, I have worked faithfully and devotedly in the interest of the Society. It has always been very near my heart. I do not think that I can hope to make such a record as he has made, because he was one of the charter members and one of the organizers of the Society. I was one of the early members, and I have worked faithfully ever since. It has always been a great delight to me.

Many of my best friends are members of this Society, and at one time, when I had gone beyond the Allegheny Mountains and supposed I was cut off, in large measure, from marine affairs, it was always the greatest pleasure of the year for me to come back here and attend our annual banquets, so as to be able to see all these dear, familiar faces and to have the old ties of association renewed.

Now, as has been pointed out, and as is in everybody's mind, this is a time when things look somewhat blue for the marine interests, but, while sitting here, I was thinking about what our boys said on the other side when things looked blue—they said "Are we discouraged?" The answer came—"No," and I believe in my heart that is the way all of us feel. Americans are not the kind of people to be thrown down. We will face the situation, and we will do our very best to go forward. I only ask all of you, who have the interests of the Society at heart, just as much as Admiral Capps and Mr. Taylor and all the rest of us who have been working for it all these years, to give me the same hearty support in carrying out my duties as your president that you have given to those very distinguished gentlemen who have preceded me. With such support I know that we can continue to make the Society, as has already been remarked tonight by a distinguished foreigner, one of the greatest instruments for the advancement of the maritime interests of the United States. (Prolonged applause.)

At this point Commander Stevenson Taylor arose amid great applause.

Commander Taylor:—Gentlemen, I arose not to make a speech, but to say that tonight practically ends the term of a president than whom no man has given, since the organization of this Society, more careful thought for its advancement and for the cultivation of its interests. The past three years' service has only added to our obligations of all of the previous years, and I ask you to rise and with our best wishes drink the health, the perfect health, if such is possible, of President W. L. Capps. (Long and loud applause.)

President Capps:—Gentlemen, I greatly value the words of appreciation uttered by our former president, and the way in which you have received them. You well know how I cherish such sentiments, but at this hour I shall surely not detain you by saying anything further.

We are now at the end of a very successful annual meeting and, in spite of the many unexpected obstacles, I believe we have had also a most enjoyable and a most successful banquet, thanks to those who took the trouble to prepare the addresses which you have heard, and who came long distances to deliver them.

I think we really can be optimistic of the future, in view of the very positive statements made by those gentlemen who have spoken this evening and who are in a position to translate words into deeds. And I feel assured that, so far as the power lies with them, they will make these words deeds in fact.

Now, gentlemen, it only remains to thank those who made possible the success of this evening, especially our Entertainment Committee, and to thank the Secretary and his staff for all their work, which we may not see, but of which we experience the benefits. Let me wish you all a very, very happy fulfillment of your hopes during the next year, with many pleasant rays of sunshine to illumine the clouds that have hovered over our professional affairs in recent times.

I now declare our meeting adjourned *sine die.*

Obituary

ELLSWORTH PRICE BERTHOLF

MEMBER

Commodore Bertholf was born in New York City, April 7, 1866. He was educated at the Naval Academy and the Revenue Cutter School. He was appointed a 3rd Lieutenant, and was advanced through all grades of the Revenue Cutter Service, during which time he saw service on nearly all of its stations. His most conspicuous services were in Alaska and the Arctic. In December, 1897, he volunteered as a member of the overland expedition to go to the rescue of 300 whalers, whose vessels had become icebound and wrecked in the vicinity of Point Barrow, the northernmost land on this continent. Without sufficient food it was almost certain that the entire number would be doomed to starvation during the long winter. President McKinley accordingly directed the Revenue Cutter Service to rescue the unfortunate men. Such an expedition into the Arctic in mid-winter had never before been undertaken, and it was successful only because of the indomitable courage of Bertholf and his two associates, who, with the aid of natives, drove a large herd of reindeer across the barren and frozen wastes of Alaska and arrived in time to furnish food and save the lives of the famishing sailors. For this heroic duty Congress awarded each of the three officers a gold medal.

In 1911 the then Captain Bertholf was selected as the Commodore Commandant of the Revenue Cutter Service, a position which he filled with marked ability for eight years. During his incumbency of the office, and largely due to his efforts, the Coast Guard was created by the merging of the Revenue Cutter and Life Saving Services.

Retiring from government service on June 30, 1919, he was at once appointed as a vice-president of the American Bureau of Shipping, a position which he filled with distinction until his untimely death.

He was elected a member of this society at the annual meeting in 1914. He died suddenly in New York on November 11, 1921.

MARTIN CORYELL ERISMANN

MEMBER

Mr. Erismann was born in Lambertville, N. J., in 1877, his mother being one of the Coryell family, of Coryell Ferry on the Delaware, and his father a native of Switzerland who came to this country as a young man. An inborn love for everything which floats led to a course in naval architecture at Glasgow University as the finish of an education, after which followed some twenty years of professional work in both commercial and yacht designing.

His first work as a draughtsman was with Stearns & McKay, the yacht builders of Marblehead, followed by a term at the Fore River Shipbuilding Co., with Maryland Steel Co., Sparrow's Point, and Marine Construction and Dry Dock Co., Shooter's Island, N. Y. About ten years ago Mr. Erismann settled in Seattle and engaged in commercial work. During the war he had charge of the designing for the Craig Shipbuilding Company at Long Beach, Calif., and more recently he was associated with Eads Johnson, Inc., in New York. His experience covered every line of work from small racing yachts and power cruisers to the largest sea-going vessels, dredges, fishing craft and dry-docks.

Visits to Europe in early youth afforded an opportunity for the study of foreign types and of access to the works of the early writers on naval architecture, and above everything else Mr. Erismann reverenced the traditions and conventions of the craft; he knew Chapman by heart, and though progressive and even radical in his everyday practice, he would turn for inspiration and suggestion to this and other of the ancient authorities.

With an intimate knowledge of marine artists and writers, he devoted much time to the collection of their works, and in addition he always found time for the study of local types of all kinds. When engaged in yacht work about Boston he unearthed one of the last of the now extinct Block Island boats and refitted her for a study of the type; he took off her lines and built a replica for further experiment. For many years he had collected the lines of similar local craft such as the Friendship sloops and the Hampton boats of the Maine coast, and at the time of his death he was at work on a book in which, under the comprehensive title of "Boats," he proposed to cover the whole subject of American small craft, following the comprehensive work of Admiral Paris on the boats of the world. While always an indefatigable worker, the recent death of his father left him in a position to withdraw largely from commercial practice and to devote himself to the study of books and boats for the benefit of others, and his love for the subject, his thorough familiarity with it, his skill as a draughtsman and his supply of material afforded ample guarantee of what the result would have been. Apparently in the best of health and in the prime of life, a sudden attack of pneumonia ended a career of achievement in the past and promise for the future.

Mr. Erismann had been a member of the Society since 1903. He died in New York City in November, 1921.

FRANK LYSANDER FERNALD

HONORARY VICE-PRESIDENT

Frank Lysander Fernald was born at Kittery, Me., November 11, 1835, the son of William Salisbury and Sarah A. (Hanscom) Fernald. He was educated in the public schools until 1853, being engaged during a portion of that time and until 1854 in shipbuilding work.

In 1854 he entered the service of the Government as a draughtsman, and by reason of his aptitude and efficiency was promoted through successive grades until he reached that of chief draughtsman at the Navy Yard, Boston, in 1868. On May 4, 1871, he was appointed an Assistant Naval Constructor in the Navy, with the rank of Lieutenant. On March 12, 1875, he received his promotion to Naval Constructor, his rank in this grade being increased in due course to Lieutenant Commander, Commander and Captain, the last named rank being attained in June, 1896.

From 1871 to 1882 he was on special duty at Chester, Pa., and at the Navy Yard, Philadelphia, in connection with the rebuilding and completion of double-turreted monitors, including the U. S. S. Miantonomoh. During this period he was also ordered to duty abroad in connection with the manufacture of armor for naval vessels, and made an extensive professional tour in England, France and Germany.

In October, 1882, he was assigned to duty as a member of the Naval Advisory Board. This board was organized under the presidency of Commodore R. W. Shufeldt, under the provisions of the Act of August 5, 1882, his other associates on the board being officers who had gained distinction as experts in ordnance and engineering. The work of this board was an important element in the early development of our modern steel navy. In fact, it determined the technical features of the designs of the Chicago, Boston, Atlanta and Dolphin, the first vessels of our so-called new navy, and until its dissolution about five years later it exercised important functions in connection with the designs of U. S. naval vessels.

In January, 1887, Captain Fernald was relieved from duty with the Advisory Board and ordered as superintending constructor of naval vessels building at the Union Iron Works, San Francisco, Calif. While so serving he superintended the construction of the cruisers Charleston (first steel vessel of this name) and San Francisco; also the double-turreted monitor Monterey, a vessel whose design called for the heaviest battery installed up to that time on a U. S. naval vessel. The unusual professional ability and experience of Captain Fernald while on this duty were of special value not only to the Navy Department but also to the shipbuilding yard, since few naval architects in this country, either in civil life or the naval service, had had his opportunity for such extensive practical experience in work of this kind. The high quality of workmanship on the vessels built under his supervision at this time amply attested the efficiency of his performance of duty.

In 1891 he was detached from duty as superintending constructor at the Union Iron Works and ordered to the Navy Yard, New York, in charge of the Department of Construction and Repair. While serving as head of this department he supervised the building of the armored cruiser Maine (subsequently destroyed at Havana, Cuba, in 1898) and the cruiser Cincinnati, the last named having only recently been stricken from the navy list. Aside from interruptions of additional duty as a member of various boards, he continued on duty at New York until 1895.

One of the most important boards on which Captain Fernald served during this period was the so-called Stability Board, of which Rear Admiral John G. Walker, U. S. N., was president. This board was charged with the general investigation of the stability of vessels of the U. S. Navy, and had in its membership some of the most experienced officers of the naval service. Captain Fernald was the senior of those representing the Construction Corps. Extensive alterations subsequently made in the gunboats Machias and Castine, with a view to increasing their efficiency and seaworthiness, were directly due to recommendations submitted by Captain Fernald while a member of this board; and these alterations were carried out subsequently under his personal supervision at the Navy Yard, New York.

In 1895, in connection with his duties as a member of the Board of Inspection and Survey, he was ordered to proceed to Southampton, England, for the inspection of the mail steamer New York and other vessels of her class, with a view to reporting upon their seagoing and structural qualities in connection with their possible use for naval purposes in time of war. His reports were of great value to the Navy Department, and it is a matter of history that these vessels performed efficient service a few years later as armed cruisers in the naval service.

During the period from 1895 until his retirement in November, 1897, Captain Fernald served on various important naval boards, and also as superintending constructor at the Bath Iron Works, Bath, Me. At the time of his statutory retirement for age he had had a total service of twenty-six years and seven months on the active list of the Navy, being unemployed less than three months of this period.

In March, 1901, Captain Fernald was again placed on active duty and ordered to proceed to the Asiatic Station and to report to the Commander-in-Chief for special duty. In January, 1902, upon the completion of this duty, he was detached and ordered to proceed to Washington via Rangoon, Burmah.

After a short period of service in Washington, he was assigned to duty as superintending constructor at the works of the Gas Engine and Power Company, Morris Heights, New York; the Crescent Shipyard, Elizabethport, N. J.; and the Columbian Iron Works, Baltimore, Md. Also, during the period from June, 1902, until May, 1906, he was a member of various departmental boards, one of the most important of which was that under the presidency of Rear Admiral Thomas O. Selfridge, U. S. N., this board being charged with the very important duty of appraising the value of work performed on various naval vessels, contracts for which had been forfeited. In May, 1906, he was detached from all duty, ordered home, and returned to an inactive status on the retired list.

The connection of Captain Fernald with the Society of Naval Architects and Marine Engineers was especially notable. He was a Charter Member, an Incorporator and one of the original Members of Council. In due course he became one of its Vice-Presidents and was also one of the first to be accorded the distinction of being elected an Honorary Vice-President. Up to the very end he manifested great interest in the development of his profession and was constant in his attendance at the annual meetings of the Society, where his presence was always warmly greeted, not only by his former professional associates but also by the rising generation of shipbuilders and engineers, all of whom held him in high and affectionate esteem.

The foregoing summary recital of the principal duties performed by Captain Fernald while an officer of the Construction Corps of the Navy, with brief allusion to his connection with this Society, gives only a meager outline of the character and extent of the professional activities of that very able officer during his long and distinguished service.

He was an officer of unusually sound professional judgment, broad experience and high ideals, and he has left to his former colleagues, and especially the younger generation, an example of efficient and loyal performance of duty worthy of highest admiration and all possible emulation.

Captain Fernald died on May 29, 1921, while on a visit to California. He is survived by a son, Chester Bailey Fernald, an author of note, now living in London, England.

WILLIAM DUNDERDALE FORBES

MEMBER

Mr. Forbes was born in Perth Amboy, N. J., on July 10, 1854. He was educated abroad and while a student in France served in the Franco-Prussion War as a franc-tireur in the French Army. Before returning to this country he worked with the famous gunsmiths of Switzerland and for a time was on the editorial staff of *Engineering* of London.

Upon returning from Europe in 1872, Mr. Forbes began his professional career with the Delamater Iron Works, at that time located on West 11th Street, New York City. Following this, he became engineer of the Gould Sprinkler Company, 237 Broadway, New York. He then spent two years in Kingston, Jamaica, as operating engineer for the Watson Sugar Plantation Company, and in 1878 was appointed by Governor Palmer of Colorado as chief engineer of the Gunnison Division of the Denver and Rio Grande Railroad Company with headquarters at Gunnison, Colo.

Returning east after two years, he became superintendent of the Eaton, Cole & Burnham Manufacturing Company, Bridgeport, Conn. At this time he invented the Forbes patent die stock and, forming a partnership with Roderick P. Curtis of Bridgeport, took up the manufacture of this specialty, selling his interest to the Curtis family in 1888.

As Mr. Forbes was chiefly interested in the development and manufacture of high-speed marine engines and other marine machinery, he came to New York and, entering into partnership with the late Col. E. A. Stevens, established the W. D. Forbes Company in Hoboken, N. J., for the manufacture of marine engines and ice machines for the Government and for owners of private yachts. For sixteen years this plant, known to many as the "gun shop" on account of Mr. Forbes' interest in the development of rapid-fire machine guns, was in active operation in Hoboken, after which it was moved to New London, Conn., where later, owing to unfavorable business conditions, the business was discontinued.

In 1914 Mr. Forbes was stricken with brain fever, resulting in total blindness. During the last years of his life, although deprived of sight, Mr. Forbes continued his professional activities in the design and development of mechanical devices, including a successful automatic rifle, and in contributing to the engineering press.

Mr. Forbes was an active member of the Society of Naval Architects and Marine Engineers since 1898, serving several terms as a member of the Council. He was also a member of the Engineers' Club of New York, an associate member of the American Society of Naval Engineers, and a life member of the American Society of Mechanical Engineers. Apart from his professional career, his interests were many and varied. For nine years he was a member of the Board of Education of New Jersey, and for several years was in charge of the colored school at Bordentown, N. J. He is survived by a wife, a daughter, widow of Lieutenant Murray E. Cramer, of the 107th Infantry, and a son, Reginald D., who is State Forester of Louisiana.

To those who were privileged to know and work with Mr. Forbes, his life will always be an inspiration, not only because of his ability and achievements, but also because of the brave and generous spirit which marked his cheerful and helpful association with his fellow-men.

Mr. Forbes died on February 17, 1921, at his son's home in New Orleans, La.

WILLIAM EDMOND FRANCIS

MEMBER

Mr. Francis was born in Wales, July, 1875. He served an apprenticeship at Millbrook Engineering Co., Swansea, South Wales. He then entered the sea service of the B. C. S. N. Co. and China Mutual S. N. Co. He obtained an extra first class engineer's certificate and was later assistant manager of the Mercantile Pontoon Dry Dock, Cardiff, South Wales, and engineer and assistant superintendent of Williams & Robin Sons Water-Tube Boiler Works, Queens Ferry, South Wales. Mr. Francis came to this country in 1912. He first took a position with the General Electric Company and later assumed charge of the engineering department of the Barnet Leather Works in Little Falls, but returned to the General Electric Co., and during the war he had charge of installation of marine geared turbines for that company. Mr. Francis died December 21, 1920, leaving a wife and four children. He had been a member of the Society since 1918.

EMILIO SEVERO GODOY

MEMBER

Emilio S. Godoy was born in Santiago October 15, 1872. He graduated from the Institute of Havana in 1889 and two years later entered the street railway field as manager of the city system of Lima, Peru. He projected the first electric railway in Peru, a 20-mile interurban line from Lima to Chorrillos, and managed its construction in 1904. He undertook, soon after, the electrification of the Lima system, comprising about 20 miles of track. and completed the work in 1906. He was one of the organizers of the Empresas Electricas Asociadas of Lima, which was founded in 1906, and served on the Board of Managers till 1913, when he accepted the appointment of general manager of the Santiago system. While in Santiago de Cuba, Mr. Godoy was also a manager and director of the Compania de Urbanizacion y Ensanche de Santiago y Caney, a land development company, fully developing and building what is the most modern part of the city. He held both positions until the latter part of 1916, when he was appointed general manager and vice-president of the Standard Shipbuilding Corporation, of Shooter's Island, Staten Island, N. Y., which he reorganized, increasing its personnel during the war to approximately 7,000 men, and launching 27 ships. He was elected a member of this Society in 1918 and died January 12, 1921.

MAURY POLK GREGG

MEMBER

Mr. Gregg was born April 20, 1892. He was a graduate of the Blight School and the course in naval architecture in the Franklin Institute of Philadelphia. He served an apprenticeship in the Cramp's Shipyard, 1910-1914, and was later employed as draughtsman by J. Murray Watts, New York Navy Yard, and Chester Shipyard, 1914-1917. He served as surveyor in the American Bureau of Shipping from 1917 until his death in San Juan, P. R., January 27, 1921. Mr. Gregg had been a member of Company B, Philadelphia Engineering Corps, National Guard of Pennsylvania, and left surviving him a mother and a sister. He had been a member of this Society since 1917.

PETER COOPER HEWITT

MEMBER

Mr. Hewitt was born in New York City, March 5, 1861; son of Abram Stevens and Sarah Amelia (Cooper) Hewitt. His father was a prominent iron manufacturer and merchant of New York, member of Congress from New York and mayor of that city, and his mother was a daughter of Peter Cooper, founder of The Cooper Union for the Advancement of Science and Art, manufacturer and philanthropist of New York.

Mr. Hewitt was educated in Stevens Institute of Technology, Hoboken, N. J., and Columbia University, New York City, making a specialty of economics, physics, electricity and chemistry. Inheriting a taste for mechanics, he devoted his attention to the improvement of mechanical processes and to scientific and mechanical investigations of a miscellaneous order. He obtained patents on improvements in glue-making machinery, invented and patented new forms of centrifugal machines and evaporators,and applied his inventive ingenuity to the development of automobiles, flying machines and electrical devices. During the war against Germany and Austria he invented and built a helicopter which would fly straight up without a "take off" and come straight down. He is best known to the public through his work in electricity, to which he began to devote his serious attention in 1898. On April 12, 1901, he announced the laws governing the electrical conductivity of gases at Columbia University, and demonstrated the requirements necessary to obtain a gas or vapor as a conductor having definite resistance characteristics and called attention to many associated phenomena. He invented the Cooper Hewitt lamp which creates light by causing a gas or vapor to conduct the electric current. The invention is utilized, by means of a specially constructed lamp made of blown quartz, to provide a powerful source of ultra violet rays for therapeutical use, sterilization and for promoting chemical reaction.

Mr. Hewitt invented a light transformer. The light transformer receives light waves of one length or color, transforms the energy so received and radiates it as light waves of another color. It is used as a reflector in connection with the Cooper Hewitt lamp, to generate the red rays in which the light of the Cooper Hewitt lamp is deficient.

Another important invention is a device called by Lord Kelvin "Static Converter," but more popularly known among engineers as the "Cooper Hewitt Converter." It is used to transform alternating currents into direct currents. He invented an electrical interrupter for rapidly turning off powerful high tension currents, and a vacuum, gas or vapor device for automatically making and breaking an electric circuit, and used it for producing alternating currents from a direct source, and for producing high frequency impulses and alternating currents such as are used in wireless telephony and telegraphy.

Mr. Hewitt invented a vacuum, gas or vapor amplifier for relaying of telephone messages and amplifying them and for amplifying other electric variations.

These six fundamental inventions in the electrical field, the Cooper Hewitt lamp, the Cooper Hewitt converter, the interrupter, the Cooper Hewitt pulsator, the electric wave amplifier, the telephone relay and the wireless receiver, were all developed by Mr. Hewitt as the result of years of experimental study of the phenomena attendant upon the flow of an electric current through a vacuum, gas or vapor.

In 1907 Mr. Hewitt constructed one of the first hydroplane motor boats. It weighed 2,000 pounds and had four sets of gliding planes, each set consisting of several planes in tiers. He also devoted considerable time to the subject of aeroplanes and dirigible balloons and obtained patents thereon. He received the honorary degree of Science Doctor from Columbia University in 1903 and from Rutgers College in 1916. Mr. Hewitt was first vice-chairman of the Naval Consulting Board of the United States upon the organization of that board during the great war.

The Elliott Cresson Gold Medal was awarded to Mr. Hewitt in 1913 by The Franklin Institute of the State of Pennsylvania for the Promotion of Mechanic Arts.

Peter Cooper Hewitt was a member of numerous societies, clubs, etc., and became a member of this Society in 1907. He died in Paris, France, August 25, 1921.

WILLIAM NEILL HOWELL

MEMBER

Mr. Howell was born in Minersville, Schuylkill County, Pa., on May 8, 1860. He was educated in private and public schools and at the University of Pennsylvania, taking private instruction under his father who was then Professor of Mineralogy and Chemistry.

Mr. Howell entered the shipyard of Messrs. Wm. Cramp & Sons on the Delaware in 1878, as an apprentice machinist, and after three years in the shop entered the drawing room and worked his way up to the position of chief draughtsman in the engine drawing room.

At the outbreak of the Spanish War in 1898 he left Cramp's and entered the U. S. Navy as chief engineer of the monitor Montauk with the rank of senior lieutenant.

Shortly before the war was over he went to the Sandy Hook Proving Ground and finished up the design and testing construction of the 10-inch Howell depressing gun carriage for Admiral John E. Howell and Mr. C. E. Creasy of Washington. This was an experimental carriage the work on which he had undertaken while with Messrs. Wm. Cramp & Sons.

In the early part of 1899 he went to Cleveland, Ohio, as chief engineer of the Globe Iron Works, but left in the fall of 1900 and was for a few weeks at Sparrows Point, Md., in the Marine Department of the Maryland Steel Co.

On January 1, 1901, Mr. Howell commenced his duties as superintendent of the Phoenix Iron Works Co., of which Mr. Samuel Dick was president, and remained with them until the spring of 1903, when he resigned to accept the position of superintendent engineer of the Eastern Shipbuilding Company, of Groton, Conn., who were building the two large steamers Minnesota and Dakota of the Northern Pacific R. R. Co. These two ships were finished in the summer of 1904 and he stayed in New London until January 1, 1905, and then went to Philadelphia and entered into a partnership with Robert Snyder as consulting engineers, under the name of Howell and Snyder, until May 9, 1905, when he sailed for Germany to take charge of the Berlin office of the Lake Torpedo Boat Co., which was building a number of submarines for the Russian Government.

After about two years in Berlin the company moved the office to London where he spent two years. During this time he went to St. Petersburg, Russia, for four months. Finally, when the Russian and Austrian work was finished in the latter part of March, 1909, he left London and came back to America and continued with the Lake Torpedo Boat Co., in charge principally of experimental work on heavy oil engines of the Diesel type until October, 1913, when the Lake Company shut down.

On July 15, 1914, he accepted a position with the Patterson, Allen Engineering Co., of

2 Rector Street, New York, as superintendent of their Jersey City plant and lived in Jersey City until September 25, 1915, when he was appointed superintending engineer for the New London Ship and Engine Co., of Groton, Conn. He went to Quebec, Canada, for this company to supervise the construction of 400 80-foot motor boats for the British Admiralty, and on completion of the order returned to New London.

On July 1, 1919, he accepted a position as senior naval architect with the Emergency Fleet Corporation, 140 North Broad Street, Philadelphia, in the Cost Review Department, with whom he remained until March 3, 1920.

On April 28, 1920, he was transferred to New Orleans, to finish up work for the Emergency Fleet Corporation in connection with the Gulf Shipbuilding plants, remaining until November 3, 1920, when he accepted the post of surveyor for the American Marine Insurance Syndicate for the Gulf District, with offices at 203 Orme Building, New Orleans, where he was employed at the time of his death, June 26, 1921. He had been a member of the Society since November, 1904.

SAMUEL SPRING JORDAN

MEMBER

Mr. Jordan was born in Cape Elizabeth, Me., on June 26, 1862. He was graduate in mechanical engineering of Worcester Polytechnic Institute. He spent about a year as a machinist with the Star Match Company and the Portland Company, Portland, Me., and another year setting up marine engines in the works of the latter company. He returned to the Star Match Company, where for two and a half years he designed, built and ran special machinery. During part of that time he had supervision of the machine shop and automatic machinery.

In March, 1886, Mr. Jordan entered the employ of John Roach of Philadelphia in charge of the engine work and draughting in his shipyard. The following year he accepted a position as first-class draughtsman to work on designs of triple-expansion engines for cruisers 4 and 5. These engines were built at the Union Iron Works in San Francisco, Calif. Later Mr. Jordan was employed at Cramp's shipyard, and during his stay there the cruisers New York and Brooklyn were built. He resigned from this position to become superintendent of the Quintard Iron Works, New York, N. Y., where he was located until 1903, when he opened offices as a consulting engineer and naval architect. For the past fifteen years Mr. Jordan was managing the family estate in Scarboro, Me.

Mr. Jordan was a member of this Society since 1896. He died January 5, 1921.

HENRY LYSHOLM

MEMBER

Mr. Lysholm was born November 30, 1865, in Trondhjem, Norway. During a number of years of his youth he lived at the Navy Yard at Horten, Norway, of which his father, David Lysholm, was at that time the commandant. Thus at an early age his thoughts became associated with the work which he later followed.

After completing his studies in civil and mechanical engineering at the Trondhjem Technical Institute, he served an apprenticeship in practical shipbuilding in the Horten Navy Yard.

In 1888 Mr. Lysholm came to America. His first employment was in New York with Cooper, the prominent bridge designer of that time. Later he engaged in general civil and mechanical engineering, engine and boiler building, and wooden ship construction.

In the later nineties he became associated with the Harlan and Hollingsworth shipyard at Wilmington, Del., where he began the templating system based on that employed in bridge construction.

When in the latter part of 1899 Mr. Henry G. Morse, an official of that company and himself a bridge builder, left to organize the New York Shipbuilding Co., Camden, N. J., he, recognizing Mr. Lysholm's ability, asked the latter to come with him as his technical assistant. Mr. Lysholm worked on the preliminary plans of the lay-out of the New York Shipbuilding Co., and, when the construction of the first vesel was started, took charge of the fabrication, including the development of the loft template system which was to be one of the main features of the work at that plant. How well he succeeded is shown by the fact that this system, considered impossible and almost foolish by so many shipbuilders of twenty years ago, has been adopted by all the leading yards of this country and by many abroad. It was this successful development under his direction at the New York Shipbuilding Co. that blazed the way for the possibility of the fabricated ship during the war. Mr. Lysholm remained at this plant for sixteen years as superintendent in charge of the structural drawing room, mold loft, plate and angle shops, etc.

In 1916, Mr. Lysholm was one of the organizers of the Pennsylvania Shipbuilding Co., at Gloucester, N. J., and became its general manager. The original intention was to build the hulls only of small vessels, the propelling machinery and much of the equipment to be contracted for outside, as done in many European countries.

In 1918 the Pusey & Jones Co., of Wilmington, Del., took over the Pennsylvania and New Jersey shipyards at Gloucester, and Mr. Lysholm became the vice-president of the combined plants.

Contracts were undertaken for larger vessels than originally planned for, and, owing to the conditions existing then, it became necessary to manufacture more and more of the parts other than hull structure. The constant strain of attempting to meet new and rapidly changing conditions, together with that imposed by this country entering the war, caused Mr. Lysholm to suffer a severe physical break-down from which he never recovered. It became necessary for him to give up active shipyard management in the summer of 1918.

In November, 1918, he opened an office in Philadelphia as consulting engineer and naval architect, in which work he was engaged up to the time of his death. In this capacity his services were retained from time to time by a number of the larger shipbuilding firms of this country. A notable case was that of advisory engineer for the torpedo boat construction at the New York Shipbuilding Corporation.

Numerous valuable inventions relating to ship construction were made by him, the most important being the Lysholm plate punching table, whereby the complete control not only of the punch but also of the movements of the plate itself was brought under the hands of one operator. This invention, eliminating the labor of several men per punch, and at the same time greatly increasing the output of a machine, contributed much in the speed-up program during the war.

Mr. Lysholm was of a very retiring nature, very generous, loyal to his friends and adopted country, and, above all, exceptionally devoted to his family, consisting of his wife and four daughters. He was greatly respected and admired by the thousands of men who have worked under him.

Mr. Lysholm died September 20, 1921, and had been a member of the Society since November, 1904.

JOHN McINNES

MEMBER

Mr. McInnes was born in Port Glasgow, Scotland, December 29, 1867.

After attending the public schools in Port Glasgow he became a ship draughtsman apprentice with the firm of Blackwood & Gordon of that city in 1882 and completed this apprenticeship in 1887. From 1887 to 1888 he was a shipfitter with Russel & Co., Greenock, Scotland. From 1884 to 1888 he attended classes in mathematics and naval architecture in Port Glasgow and Greenock. From 1888 to 1891 he was a ship draughtsman at Palmer's Shipbuilding & Iron Co., Ltd., Jarrow-on-Tyne, England.

In 1891 Mr. McInnes came to the United States, which country he made his home for the rest of his life. He began as chief hull draughtsman at the Columbian Iron Works and Drydock Co., Baltimore, Md., in 1891. In 1893 he went to the Wm. Cramp & Sons Ship & Engine Co., Philadelphia, and remained there until 1895 when he returned to the Columbian Iron Works and Drydock Co. in Baltimore as naval architect. He remained there until he took the position of superintendent of construction at the Bath Iron Works, Ltd., Bath, Maine, in 1900. He held this position until his death. He was also a director of the above company from 1905 until his death. During his connection with the Bath Iron Works, Ltd., he was in full charge of the design and construction of the hulls built at that plant.

John McInnes was a man of high character and of a personality that made and held many friends. He became a naturalized citizen of the United States, and his efforts for his adopted country during the war were a constant stimulus to many born American citizens. His widow and three sons survive him.

Mr. McInnes had been a member of this Society since 1916. He died in Glasgow, January 22, 1921, while on a visit to the land of his birth.

JOHAN HUGO NORMAN

MEMBER

Mr. Norman was born in Sweden on October 22, 1868. He was a graduate in naval architecture of Chalmer's Technical College, Gottenburgh, Sweden, class 1892. Coming to this country the same year, he secured employment as a draughtsman with the Steel Motor Company, Cleveland, Ohio. In 1897 he obtained a position with the Newport News Shipbuilding and Dry Dock Company, with whom he remained one year, and in 1898 he entered the employ of Wm. Cramp & Sons Ship and Engine Building Company, continuing with this firm until his death April 21, 1921. Mr. Norman had been a member of the Society since 1900.

FLORAINE JOSEPH RENZ

MEMBER

Mr. Renz was born January 22, 1874, in New Haven, Conn. After finishing a course in the public and high schools of that city, he entered the marine field, being connected with J. Rosenfeld & Sons for several years. He later became sales manager to Briggs Bituminous Composition Company and sales agent for the Federal Composition Company. He was a member of Whitehall and Traffic Clubs and an Associate Member of the Society since 1917. He died December 23, 1921, leaving a wife and one daughter.

HUGO BERNARD ROELKER

MEMBER

Mr. Roelker was born in Osnabruck, Germany, September 19, 1843. After obtaining his early education in a technical school, he served an apprenticeship in a machine shop and later worked in the employ of an instrument maker. He later was engaged as mechanical draughtsman in an engineer's and architect's office. At the age of eighteen he came to this country and after a year's experience in getting acquainted with the language and methods of working, in 1861 he secured a position as draughtsman in the DeLamater Iron Works at 13th Street and North River, New York City. He rose rapidly to become respectively, chief draughtsman, assistant superintendent, and in 1883 became superintendent.

The DeLamater works were the largest general machine and repair shops in the country. The technical genius of the works was Captain John Ericsson and practically all the leading engineers of the country had their work done there, and Mr. Roelker enjoyed their acquaintance and confidence in developing and supervising their work. He saw several vessels of the Monitor type built there, including the largest of them, the Dictator. In 1869 thirty gunboats were equipped there complete for the Spanish government to suppress the insurrection in Cuba. Marine engines for many coastwise and river vessels were built there and stationary engines for large industrial plants.

These works fathered the screw propeller which Captain Ericsson brought to this country and for years turned out more propeller wheels than all other marine shops in the country together. The method of sweeping these wheels in loam moulds was originated there. Many of the large industries of the day started there in Mr. Roelker's office—notably sugar mills, air compressors, ice machines, hot air pumping engines. The preliminary experimentation for the elevated roads was carried on there.

The first self-propelled torpedoes, torpedo boats, destroyers, submarine boats, etc., were all developed under Mr. Roelker's supervision.

When the works closed down on the death of Mr. DeLamater and Captain Ericsson in 1889, Mr. Roelker opened an office in Maiden Lane, doing a general mechanical and marine engineering practice, and making in later years a specialty of the Allen Dense Air Ice Machine, principally for the U. S. Navy.

Mr. Roelker was most helpful in extending the facilities of the works to the students of Columbia College, School of Mines, Yale College, Sheffield Scientific School, Stevens Institute of Technology, etc., who came there with their professors and spent several days and reporting their observations in their classes later.

He was most genial and helpful as head of his department, and many young engineers who served under him succeeded in after life as the result largely of his encouragement.

He belonged to the Arion, Liedercranz, Columbia Yacht, and Engineers Clubs, and the American Society of Mechanical Engineers, was also the first vice-president of the American Society of Refrigerating Engineers, and was a Trustee of Die Deutsche Gesellschaft and incorporator and director of the Maiden Lane Savings Bank. His wife survives him.

Mr. Roelker died on April 18, 1921, and had been a member of this Society since its organization.

JAMES PRENTICE SNEDDON

MEMBER

The untimely death of Mr. James Prentice Sneddon while at the height of his mental and physical vigor removed a strong personality which was widely known throughout marine circles, and, indeed, in all engineering circles where there is appreciation of the highest-class work fabricated under supervisory ability of the highest grade.

For more than a score of years Mr. Sneddon had been identified with the manufacture of high-class steam boilers, at first with the Stirling Company, and for the last fifteen years with the Babcock & Wilcox Company, of which he was general superintendent in charge of manufacturing. His career is a testimony to what can be accomplished by native ability of a high order when backed by untiring energy and devotion to work in spite of the lack of early opportunities.

He was born in Newmains, Scotland, July 7, 1863, came to the United States when fourteen years old, and attended school at St. Louis and Carbondale, Illinois. After some preliminary work on leaving school, be became satisfied that his abilities were along mechanical lines and learned the machinist's trade with the Rankine & Fritsch Company of St. Louis. A few years later he was master mechanic of the Crystal Plate Glass Company at Crystal, Mo., but soon returned to the Rankine & Fritsch Company as its manager.

The panic of 1893 changed his plans and he was employed with various companies until he joined the Stirling Company in 1899, at its plant at Barberton, Ohio. Shortly after his arrival he was made superintendent in general charge of manufacturing, and greatly improved the ship methods and the product of the company. In 1906, when the Stirling Company was taken over by the Babcock & Wilcox Company, he became the general superintendent in charge of all the manufacturing plants. This position he held during the remainder of his life.

Mr. Sneddon was a thorough mechanic and a born executive, keenly alive to all improvements and adopting them in his own plants where appropriate. It has been well recognized throughout the profession that the high reputation of his company for the excellence of its product is due in large measure to his technical and executive ability.

Although marine boilers are the smaller part of the output of his company, the large number turned out under his supervision in the last fifteen years, particularly for naval vessels, made him a very important factor in the marine work of this country, and he was well known to all of the leading shipbuilders, who thoroughly appreciated his ability.

Probably the greatest opportunity for his efficiency as an executive and technician came with the enormous demand for marine boilers on account of the Great War. His company was called upon to build about 400 destroyer boilers, more than a hundred other naval boilers, and about 1,200 boilers for the Emergency Fleet Corporation. For the first time in the history of marine boilers this gave an opportunity to manufacture them and to apply the principles governing quantity production. All of these Mr. Sneddon was quick to utilize, with the result that the works were soon turning out three boilers per day for the Emergency Fleet, one large-tube boiler per day for the Navy, and one large express-type boiler for destroyers per day. This involved, of course, a great extension of the works and equipment and a double turn. Even more was involved, because it was necessary to duplicate some of the large, special tools which had been built by the company itself, both for increased production and to guard against any possible stoppage of work. To do this it became necessary to make some large machine tools ancillary to the fabrication of the special boiler-manufacturing tools, because the machine-tool builders of the country were absolutely swamped and could not possibly make delivery in time. A machine of the required type which was in the works was dismantled, working drawings made from it by the Draughting Department, the necessary castings made in the company's foundry, and finished in its own machine shop. With such indomitable energy as a driving force no obstacle was allowed to interfere.

There had been some concern in the Navy Department, and in the Emergency Fleet, that the company might not be able to deliver in time the enormous program which had been assigned to it, but it is gratifying to record that under this untiring executive all the various classes of boilers were delivered before the dates stipulated, and, in some cases, a considerable period before the shipbuilders could utilize them. It is a stroke of good fortune to have an opportunity to make such a record, but the successful fulfillment of the opportunity is not good fortune but is due to ripe experience, executive ability of the highest order, and the further ability to inspire zeal and loyalty in the subordinates who are to carry out the great program.

Mr. Sneddon died on June 11, 1921, at Johns Hopkins Hospital in Baltimore, after undergoing two operations, and thus lacked only a month of being 58 years old. There was every reason to anticipate many remaining years of usefulness, but he could certainly feel that he had made an enviable record and had thoroughly fulfilled every duty which came upon him.

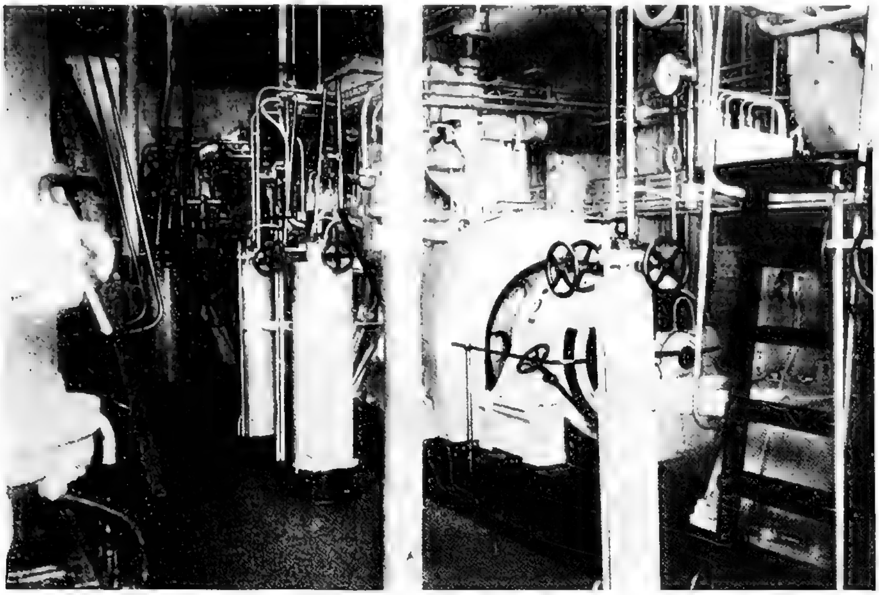
He was a handsome man of striking appearance, due to his prematurely white hair, and his personality had a charm which will long be remembered by the wide circle of those who were privileged to count themselves as his friends.

He had been a member of this Society since November, 1905, and was also a member of the American Society of Mechanical Engineers and of the Engineers' Club of New York.

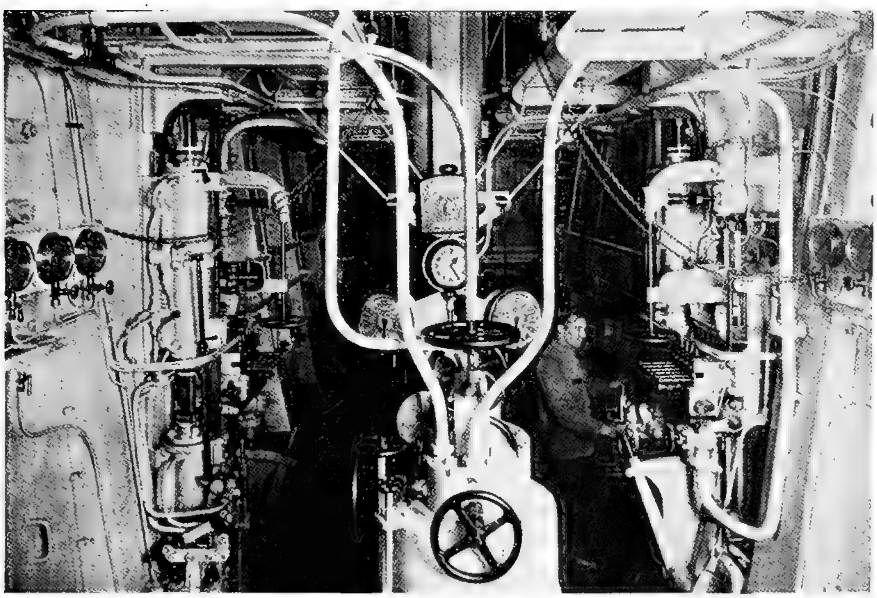
He is survived by his widow, a son and a daughter.

Transactions Society Naval Architects and Marine Engineers, Vol. 29, 1921. *Plate I*

To illustrate paper on "The Internal-Combustion Engine as Applied to Marine Propulsion," by John F. Metten, Esq., Member, and J. C. Shaw, Esq., Member.

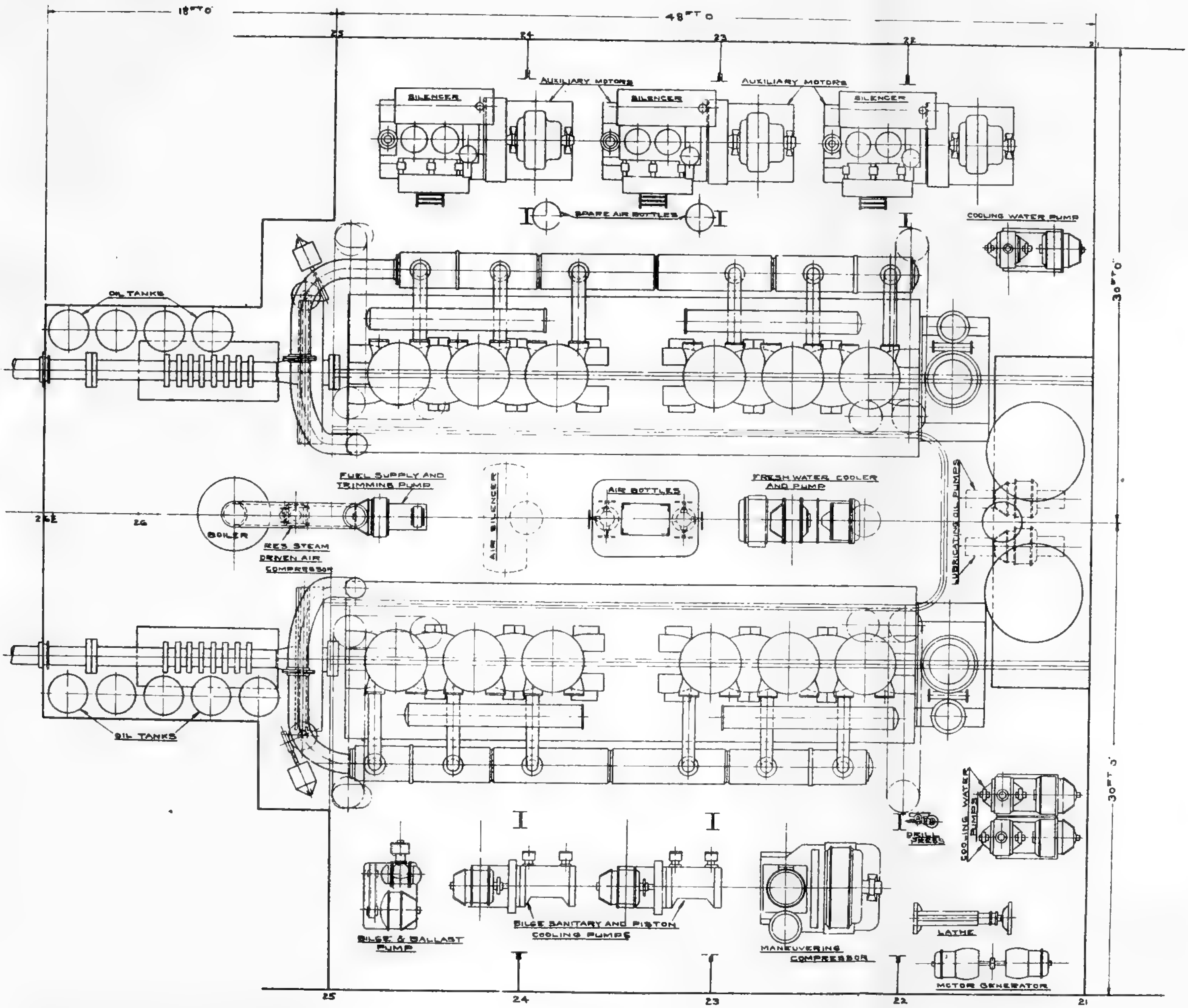


Auxiliary Diesel Engines and Dynamos for Working All the Auxiliary Machinery of 10,000 Tons Deadweight Diesel Engined Ship.



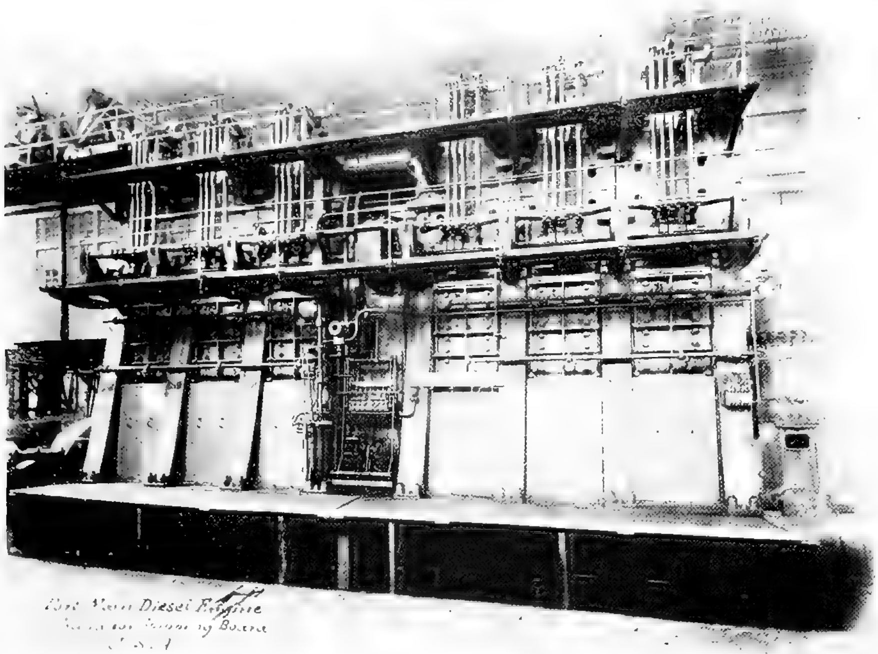
Maneuvering Platform of the Motor Ship Fionia.

To illustrate paper on "The Internal-Combustion Engine as Applied to Marine Propulsion," by John F. Metten, Esq., Member, and J. C. Shaw, Esq., Member.



ARRANGEMENT OF MACHINERY
MOTORSHIP "WILLIAM PENN."

To illustrate paper on "The Internal-Combustion Engine as Applied to Marine Propulsion," by John F. Metten, Esq., Member, and J. C. Shaw, Esq., Member.



Port Engine for Motor Ship William Penn.

To illustrate paper on "Reduction Gears for Ship Propulsion," by Robert Warriner, Esq., Member.

MARINE REDUCTION GEAR DATA
DOUBLE REDUCTION

Reduction Gear Number	1				2				3				4			
Horse Power of Ship & No of Screws	1500 - Single Screw				2300 Single Screw				3100 Single Screw				4500 Twin Screw			
Horse Power Transmitted by Each Gear	1500				2800				3100				2250			
Horse Power Transmitted by H.P. Pinion	1500				1400				1550				2250			
R.P.M.	3600 - 90				3566-90				3196 - 90				3300-105			
Type of Gear	One Plane				Three Plane				Three Plane				One Plane			
Element	High Speed		Low Speed		High Speed		Low Speed		High Speed		Low Speed		High Speed		Low Speed	
Part	Pinion	Gear	Pinion	Gear	Pinion	Gear	Pinion	Gear	Pinion	Gear	Pinion	Gear	Pinion	Gear	Pinion	Gear
Number	1	1	1	1	2	2	2	1	2	2	2	1	1	2	2	1
R.P.M.	3600	578	578	90	3566	539	539	90	3196	538	538	90	3300	444	444	105
Pitch Diameter (D)	8500"	53000"	12400"	79600"	775"	51.250"	15.613	93.387"	8.500"	50.500"	15.629"	93.371"	7.00"	52.00"	11.274"	47.726"
No of Teeth	34	22	31	199	31	205	31	187	34	202	39	233	40	297	30	127
Diametral Pitch	40		2.5		4		1.99		4		2.50		5.71		2.66	
Normal Diametral Pitch	5.65		3.53		5.65		2.16		5.65		2.71		8.02		3.00	
Helix Angle	44°-53'-30"		44°-53'-30"		44°53'-30"		22°-58'-8"		44°53'-30"		22°58'-30"		44°26'		27°30'	
Pressure Angle	26°-56'-30"		26°-56'-30"		26°-56'-30"		20°		26°56'-30"		25°		20°		20°	
Effective Width of Face	15"		36"		14"		26"		16"		27.5"		20"		40"	
Velocity of Pitch Line '/sec	133.5		31.2		121		36.7		118.5		36.6		100.9		21.9	
Tangential Tooth Pr # of Face (P)	42		733		455		808		450		845		307		706	
K (P÷K√D)	141		208		163		204		154		214		116		210	
Length of Helix/Dia of Pinion	1.76		1.45		1.81		.832		1.88		.880		1.43		1.77	
Stress at Base of Teeth #/□"	3260	2775	3780	2525	3680	2500	3840	2860	3565	2472	4220	3160	5100	4220	4400	3520
Weight per Gear in Pounds													100000			
Bearings																
Type													C I Shell - Babbitted			
Number & Size													2-6"x8"	2-9"x14"	[illegible]	[illegible]
Surface Speed '/min (V)													5190	1047	1047	358
Pressure #/□" (P)													48	840	880	33
P x V.													24900	88000	92000	11800
Turbine	Single				Compound				Compound				Single			
Gear Maker	Falk Co				Falk Co				Falk Co				Bethlehem Corp			

Reduction Gear Number	5				6				7				8			
Horse Power of Ship & No of Screws	2500 Single Screw				2400 - Single Screw				4000 - Single Screw				3000 - Single Screw			
Horse Power Transmitted by Each Gear	2500				2400				4000				3000			
Horse Power Transmitted by H.P. Pinion	2500				2400				4000				1500			
R.P.M.	3180-90				3302-75				3480-90				3360 - 90			
Type of Gear	One Plane				Two Plane				One Plane							
Element	High Speed		Low Speed		High Speed		Low Speed		High Speed		Low Speed		High Speed		Low Speed	
Part	Pinion	Gear	Pinion	Gear	Pinion	Gear	Pinion	Gear	Pinion	Gear	Pinion	Gear	Pinion	Gear	Pinion	Gear
Number	1	2	2	1	1	2	2	1	1	2	2	1	2	2	2	1
R.P.M.	3480	463	463	90	3302	657	657	75	3430	458	458	90	3360	595	585	90
Pitch Diameter (D)	7.4"	55.6"	10.25"	52.75	6.5"	32.667"	11.000"	96.333"	7.62"	57.833"	0.75"	51.75"	5.196"	29.830"	9.238"	60.045"
No of Teeth	37	278	41	211	39	196	33	289	38	289	43	219	27	155	28	182
Diametral Pitch	5		4		6		3		5		4		6.2		3.03	
Normal Diametral Pitch	7.07		4.33		6.73		3.26		6.11		4.35		6		3.5	
Helix Angle	45°		23°		27°		22°58'		35°		23°		30°		30°	
Pressure Angle	15°		15°		22°-13'		21°-32'		23°-57'		16°-14'		16°-38'		16°38'	
Effective Width of Face	18"		45"		18.4"		32"		19.6"		48"		20"		36"	
Velocity of Pitch Line '/sec	112		207		937		316		115.7		215		76.2		23.6	
Tangential Tooth Pr # of Face (P)	340		740		332		652		486		1065		541		972	
K (P÷K√D)	125		231		150		196.5		176		325.5		237		320	
Length of Helix/Dia of Pinion	2.44		2.20		1.415		1.455		1.29		2.23		1.93		1.95	
Stress at Base of Teeth #/□"					4370		3500		4000		6750		10500	8300	11000	8500
Weight per Gear in Pounds	75000				77000				124000				63800			
Bearings																
Type	C I Shell - Babbitted												Babbitted			
Number & Size	2-6"x12"	2-9"x12"	[illegible]	[illegible]	2-6"x10"	4-6"x10"	4-9"x16"	[illegible]	2-7"x10"	2-10"x15"	[illegible]	[illegible]	[illegible]		[illegible]	2-13"x15"
Surface Speed '/min (V)	5050	1090	1090	342	5190	1035	1550	275	6400	1200	1200	400	4180		[illegible]	312
Pressure #/□" (P)	415	62	99	10	58	94	77	925	58	70	97	134	103		157	43
P x V.	20950	67600	107800	13680	30050	97500	119200	25400	37100	81000	116400	53600	430000		[illegible]	13400
Turbine	Single				Single				Single				Compound			
Gear Maker	De Laval Co				General Electric Co				General Electric Co				Westinghouse Co			

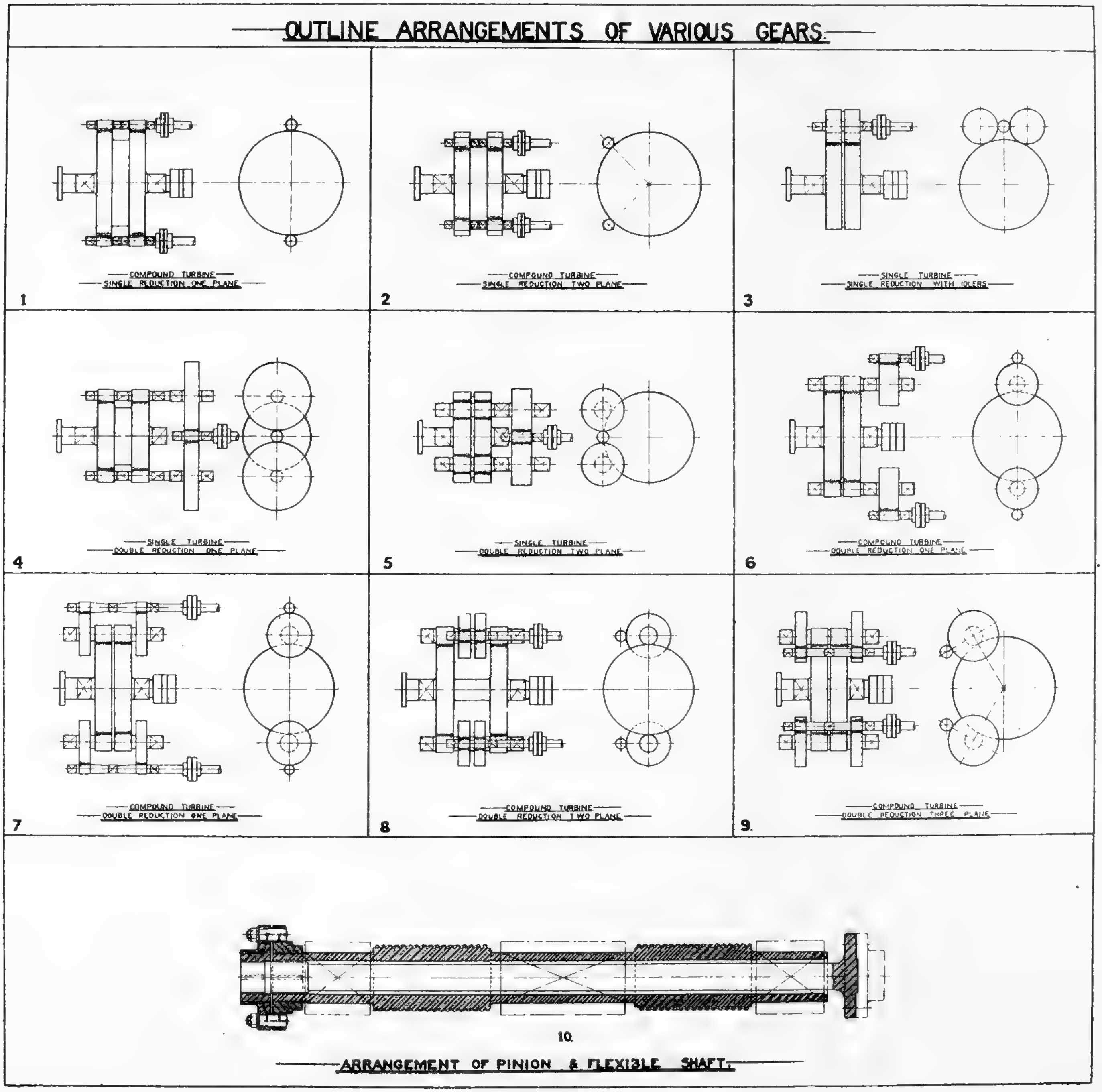
FIGURE 1

MARINE REDUCTION GEAR DATA
SINGLE REDUCTION

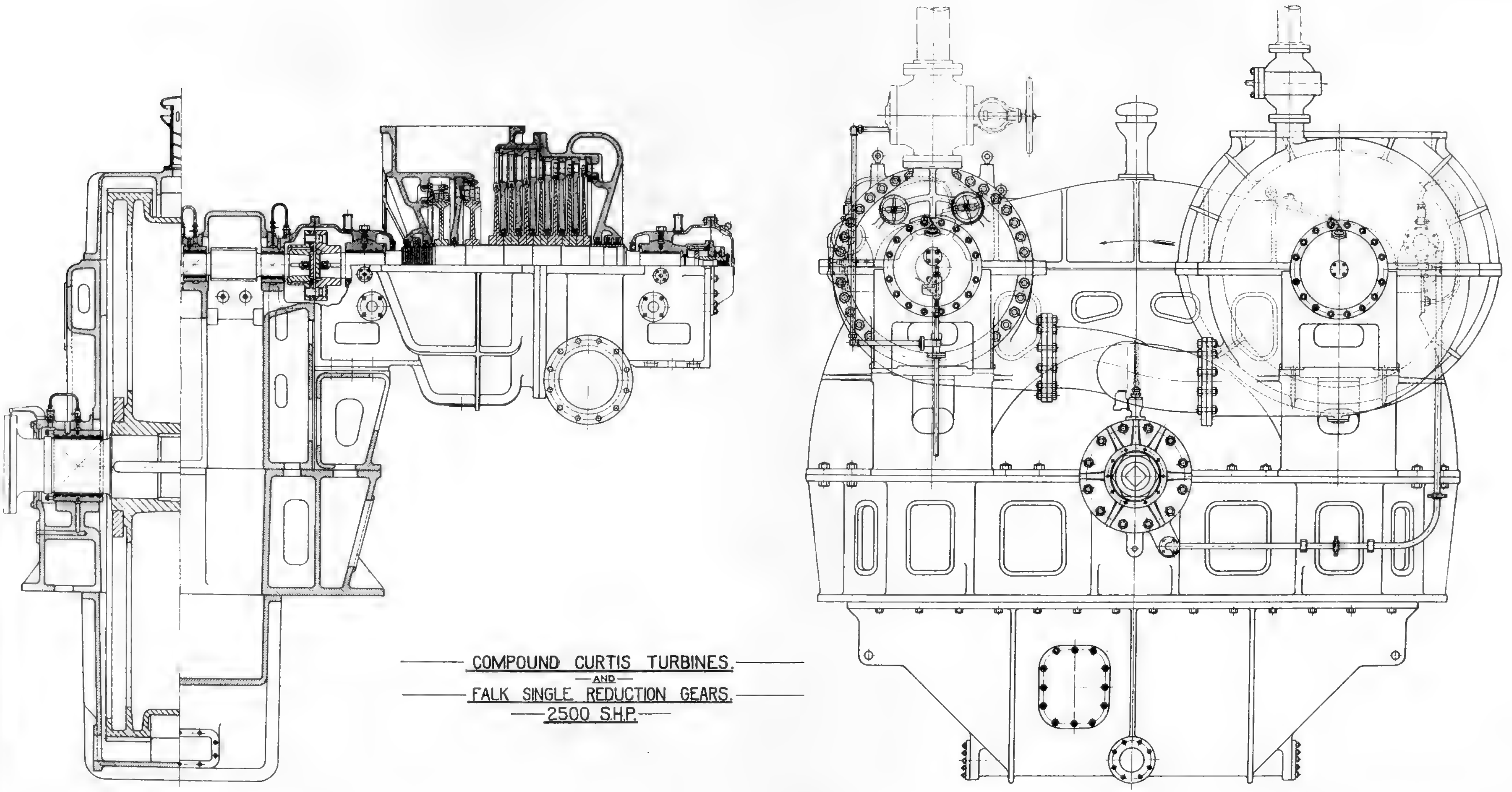
Reduction Gear Number	9		10		11		12		13		14			15		16	
Horse Power of Ship & No of Screws	9000 - Twin Screw		5000 Twin Screw		4500 Twin Screw		10000 - Twin Screw		12000 - Twin Screw		28000 - Twin Screw			90000 Quadruple Screw		27000 - Twin Screw	
Horse Power Transmitted By Each Gear	4500		2500		2250		5000		6000		14000			22500		13500	
Horse Power Transmitted By H.P. Pinion	2250		1250		1125		2500		3000		7000			11250		6750	
RPM	1500-120		2204-110		1924-105		1793-125		1789-125		3217 & 2994-450			2513-400		2950-455	
Type of Gear	One Plane		One Plane		Two Plane		One Plane		One Plane		One Plane			One Plane			
Part	Pinion	Gear	Pinion	Gear	Pinion	Gear	Pinion	Gear	Pinion	Gear	H.S. Pinion	L.S. Pinion	Gear	Pinion	Gear	Pinion	Gear
Number	2	1	2	1	2	1	2	1	2	1	1	1	1	2	1	2	1
Pitch Diameter (D)	8.50"	106.75"	6.000"	120.240"	7.143	130.857	9.143"	131.143"	10.0"	143.143"	10.800"	11.600"	77.200"	13.429	84.286	10.227	66.314
No of Teeth	34	427	25	501	25	458	32	459	35	501	27	29	193	47	295	31	201
Diametral Pitch	4		4.167		3.5		3.5		3.5		2.5			3.5		3.03	
Normal Diametral Pitch	565		500		404		495		495		3.54			404		3.5	
Helix Angle	45°		33°-33'-26"		30°-2'-54"		44°-53'-30"		44°-53'-30"		44°-53'-30"			30°-2'-54"		30°	
Pressure Angle	15°		20°		25°		26°-56'-30"		26°-56'-30"		25°			25°		16°-38'	
Effective Width of Face	48"		24"		22"		36"		38"		39"			48"		26"	
Velocity of Pitch Line '/sec	55.5		57.8		60.0		71.7		78.2		151.5			147.2		131.5	
Tangential Tooth Pr #/in of Face (P)	463		496		469		532		555		770			877		1080	
K (P÷K√D)	159		202		175		176		175		234	226		239		328	
Length of Helix/Dia of Pinion	2.83		2.00		1.54		1.97		1.90		1.53	1.42		1.79		1.27	
Stress at Base of Teeth #/□"			5630	3960	3960	2770	3610	2555	3780	2660	6010	5920	4125	4300	3855	11750	9100
Weight per Gear in Pounds	76000		60000								38400					21200	
Bearings																	
Type	C.I. Shell-Babbitted		C.I. Shell-Babbitted		C.I. Shell-Babbitted		C.I. Shell-Babbitted		C.I. Shell-Babbitted		C.I. Shell-Babbitted			C.I. Shell-Babbitted		Babbitted	
Number & Size	[illegible]	2-14¾"x13"	4-5½"x9"	2-14¾"x13"	4-5½"x5½"	2-13"x12"	[illegible]	2-15"x12"	[illegible]	2-15"x12"	[illegible]	[illegible]	2-13"x14"	[illegible]	2-15"x12"	[illegible]	[illegible]
Surface Speed '/min (V)	2550	455	3170	403	2650	358	3760	491	3750	491	6750	6280	1530	6090	1570	6180	1360
Pressure #/□" (P)	107	99	62.2	92	108.2	121.2			106.5	106	73.3	73.3	45.0	136.5	70.8	153	42
P x V	273000	45000	197000	37000	287000	43500			400000	52100	495000	460000	69000	831000	111200	948000	57000
Turbine	Compound		Compound		Compound		Compound		Compound		Compound			Compound		Compound	
Gear Maker	De Laval Co		Bethlehem Corp.		Falk Co		Falk Co		Falk Co		Falk Co.			Falk Co.		Westinghouse Co	

FIGURE-2

To illustrate paper on "Reduction Gears for Ship Propulsion," by Robert Warriner, Esq., Member.

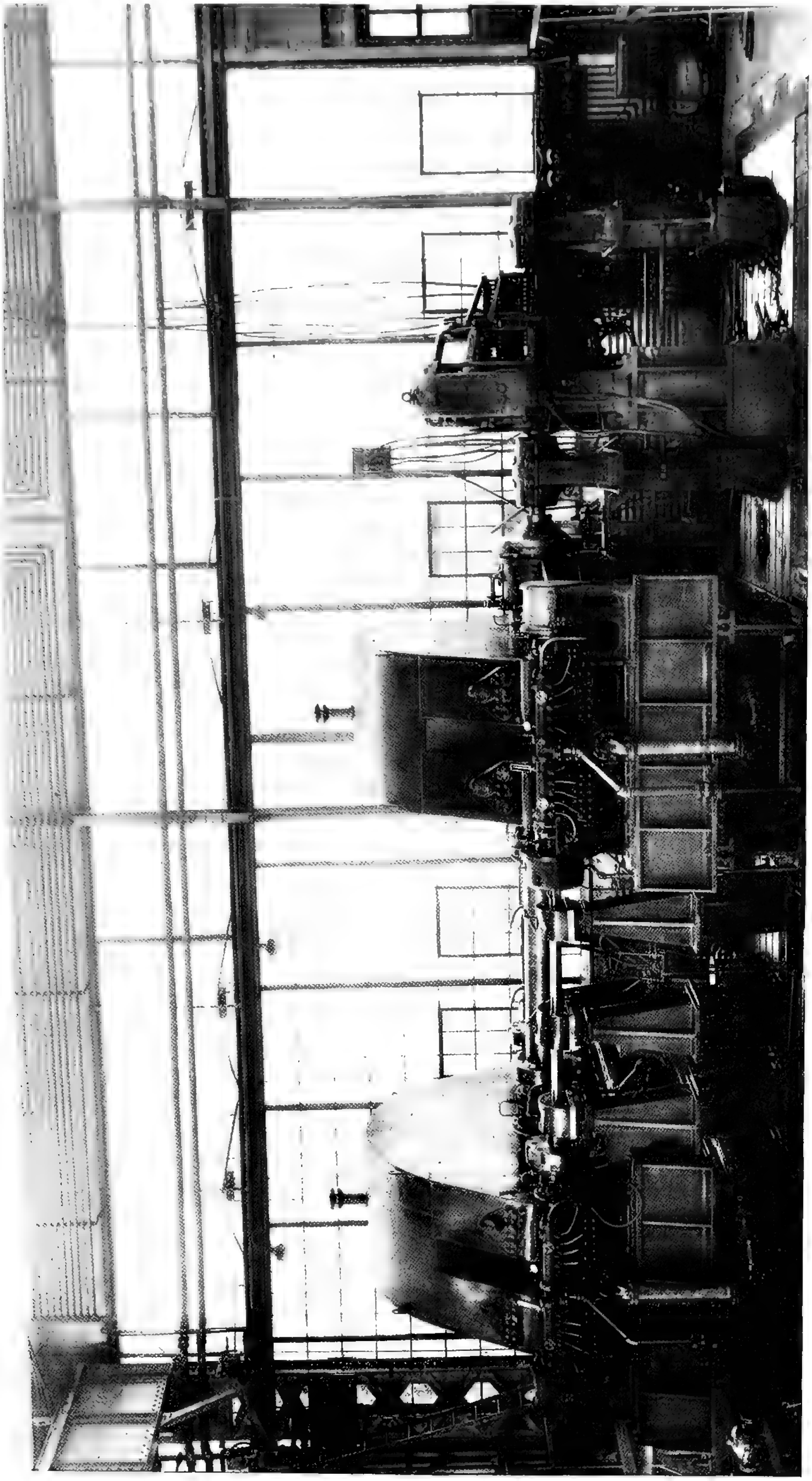


To illustrate paper on "Reduction Gears for Ship Propulsion," by Robert Warriner, Esq., Member.



COMPOUND CURTIS TURBINES
AND
FALK SINGLE REDUCTION GEARS.
2500 S.H.P.

To illustrate paper on "Reduction Gears for Ship Propulsion,"
by Robert Warriner, Esq., Member.



Testing Two 6,000 Horse-Power Units at Full Load and Speed. Keystone State Class.

To illustrate paper on "Reduction Gears for Ship Propulsion," by Robert Warriner, Esq., Member.

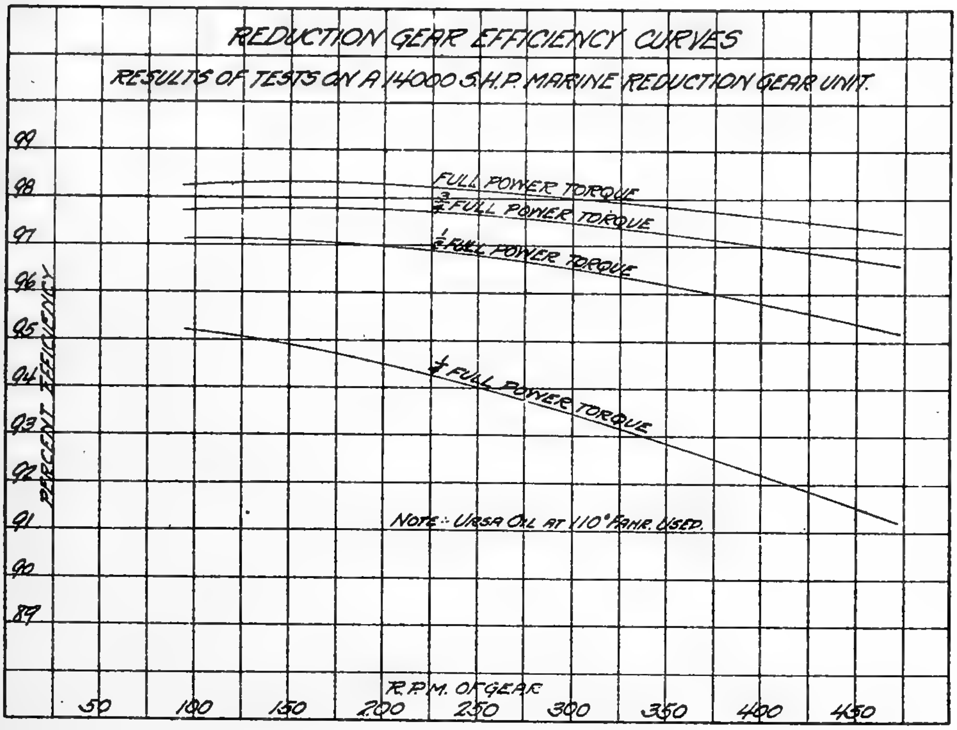


FIGURE-4

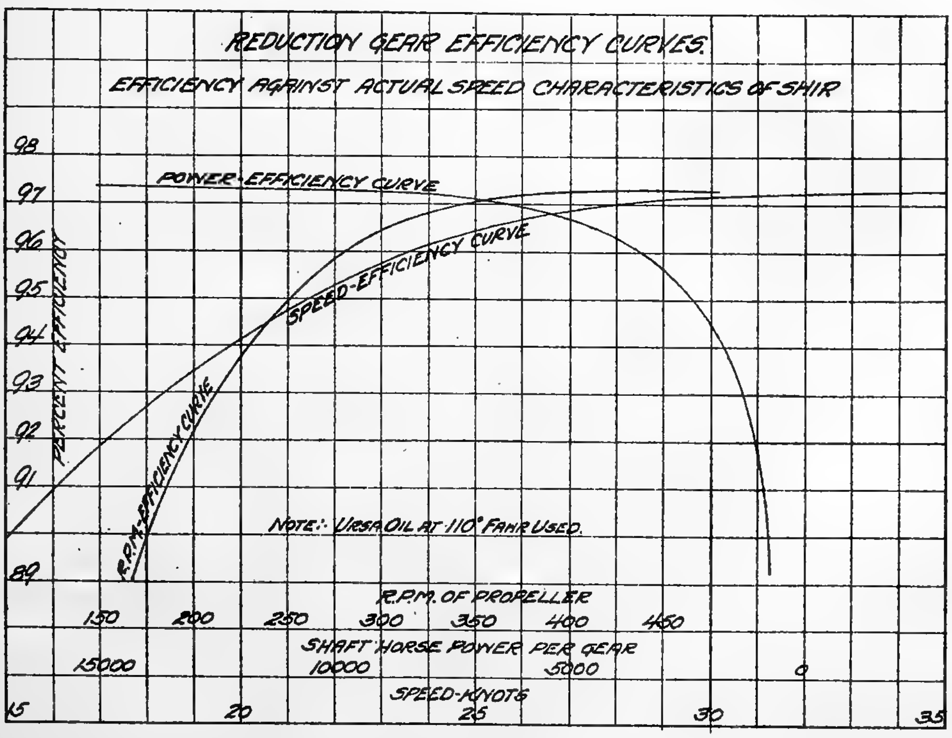


FIGURE-5

To illustrate paper on "Reduction Gears for Ship Propulsion," by Robert Warriner, Esq., Member.

RESULTS OF REDUCTION GEAR TESTS.

TEST NO.	2	3	4	5
DURATION OF TEST	21 HOURS	14 HOURS	11 DAYS	8 HOURS
TOTAL H.P. OUTPUT OF TWO GEAR UNITS	12000	12000	6000	6200
HORSE POWER DELIVERED BY EACH PINION	3000	3000	1500	1550
TOOTH PRESS. #/IN. OF FACE - H.S.	630	553	482	448
TOOTH PRESS. #/IN OF FACE - L.S.	—	—	862	842
INLET TEMPERATURE OF WATER TO OIL COOLER, °FAHR.	67.0	59.5	51.7	54.0
OUTLET TEMPERATURE OF WATER FROM OIL COOLER, °FAHR.	82.2	75.1	72.4	67.9
POUNDS OF WATER PER MIN. TO COOLER	424	442	312	386
H.P. ABSORBED BY COOLING WATER	152	168	151	126
TEMP. OF OIL TO UNIT °FAHR.	125	110.5	103	118.5
TEMP. OF OIL FROM UNIT °FAHR.	131	120.5	—	124
PRESSURE OF OIL TO GEARS	18.4	8.9	12.0	11.7
R.P.M. OF PROPELLER SHAFT	125	125	90	90
H.P. LOSS IN UNITS	229	209	203	186
OUTPUT + LOSSES OF GEAR UNITS	12229	12209	6203	6386
GEAR UNIT EFFICIENCY	.981	.983	.968	.973

To illustrate discussion by Benjamin G. Fernald, Esq., Member, on paper entitled "The Internal Combustion Engine as Applied to Marine Propulsion," by John F. Metten, Esq., Member, and J. C. Shaw, Esq., Visitor, and on paper entitled "Reduction Gears for Ship Propulsion," by Robert Warriner, Esq., Member.

COMPARATIVE OPERATING ANALYSIS

TYPE "B" CARGO SHIP (8600 TONS D.W.)

8600 TONS D. W. Length 400' - 0". Beam 53' - 0". Loaded draft 25' - 0". 11 knots, sea speed loaded.

OPERATING ASSUMPTIONS:-

	Distance.	Days at sea.	Waiting cargo days per trip.	Loading days per trip.	Single trips per year.
Freight Rate:- $20.00 per ton. Route:- Tokyo - San Francisco.	4800 knots	11 knots 264 knots per day 18	6	6	11

DATA ON PROPELLING EQUIPMENT:-	1:- RECIPROCATING ENGINE.	2:- GEARED COMPOUND TURBINE.	3:- TWIN DIESEL ENGINES
DESCRIPTION:-	Engine:- 1-3000 IHP - 2800 BHP - 80 RPM 27" x 47" x 78" x 48" stroke. Boilers:- 3 Scotch #190, 8,000 sq. ft. total heating surface, oil fired forced draft.	Turbine:- 1-2800 SHP - 90 RPM Parsons-Compound Turbine with Falk Double Reduction Gear, (as per proposal U.S. Shipping Board.) Boilers:- 3 Scotch #210, 50 deg. superheat, 7,000 sq. ft. heating surface, oil fired forced draft.	Engine:- 2-1400 BHP - 1850 IHP - 115 RPM 4 cycle, 6 cylinder, B. & W.
MACHINERY WEIGHT:-	455 Tons complete with all auxiliaries and 100 tons additional for water in boilers and condenser, total 555.	355 Tons complete with all auxiliaries and 100 tons additional for water in boilers and condenser. Total 455 tons.	795 Tons complete with all auxiliaries. Fresh cooling water included in water and stores. Total 795 tons.
COST - INSTALLED:-	$394,500 installed complete and ready for sea	$321,000. installed complete and ready for sea. (Turbine, as per quotation U. S. S. B.)	$687,500. installed complete and ready for sea (Based quotation to U. S. S. B.)
FUEL OIL CONSUMPTION:-	#1.25 per SHP hr. including auxiliaries. Water rate #16½ per SHP hr. 37.5 tons per 24 hrs.	#1.00 per SHP hr. including auxiliaries. Water rate #12 per SHP hr. 30 tons per 24 hrs.	#0.45 per BHP hr. including auxiliaries. 13.5 tons per 24 hrs.
FUEL OIL TANK CAPACITY:-	Round trip 675 tons x 2 plus 10%:- 1435 tons. 1500 tons assumed.	Round trip 540 tons x 2 plus 10%:- 1188 tons. 1200 tons assumed.	Round trip 243 tons x 2 plus 10%:- 535 tons. 550 tons assumed.
WATER & STORES WEIGHT:-	200 tons assumed.	200 tons assumed.	150 tons assumed (Based operating date M. S. "Falstria" East Asiatic Co.)
CREW:-	Deck:- 4 officers 21 men. Engine Room:- 4 officers 12 men.	Deck:- 4 officers 21 men. Engine Room:- 4 officers 12 men.	Deck:- 4 officers 21 men. Engine Room:- 4 officers 8 men.
CARGO CAPACITY:- D.W.LLOYD'S SUMMER LOAD LINE:-	8600 tons.	8600+ 100 = 8700 tons.	8600-240=8360 tons.
FUEL WATER & STORES:-	1700 tons.	1400 tons.	700 tons.
TOTAL D.W. CARGO CAPACITY:-	8600-1700=6900 tons.	8700-1400=7300 tons	8360-700=7660 tons.
NET D. W. CARGO CAPACITY:- (at 80%)	5520 tons.	5840 tons.	6128 tons.

ANNUAL OPERATING BALANCE SHEET

-RECIPROCATING ENGINES-

Cost:- $175.00. per D.W. ton (8600 D.W.)
Investment:- $1,505,000.

		Dr.	Cr.
Revenue from freight:-			
11 trips @ 5520 tons:-	60720		
+5 trips @ 675 additional:-	3375		
	64095 @ $20:-		$1,281,900.
Capital Charges:- Interest @ 7%:- Depreciation @ 5%:- 17.5% Insurance @ 4½% Taxes @ 1%:-		$263,550.	
Operating Cost:- Fuel Oil:- 11x675 tons 10% port consumption 8168 tons 54,500 Bbls. @ $1.60		87,200.	
Oil & Supplies:-		3,000.	
Crew:- Deck:- 4 officers @ $150.	600.		
21 men @ $30.	630.		
Engine Room:- 4 officers @ $150	600.		
12 men @ $30.	360.		
Per month:-	2200.		
Per year:-		26,400.	
Food:- 41 x 365 days @ $.75 per day:-		11,200.	
Maintenance:- Engine Dept. @ 1½%:-		5,900.	
ANNUAL OPERATING COST:-			397,250.
OPERATING SURPLUS:-			884,650.

+Utilization of 1/2 bunker space on return trips.
Fuel Oil @ $1.60 per Bbl.San Francisco
(Quotation Oct. 29, 1919)

- GEARED COMPOUND TURBINES -

Cost:- $164.50 per D.W. ton (8700 D.W.)
Investment:- $1,431,500.

		Dr.	Cr.
Revenue:- 11 trips @ 5840 tons:-	64240		
+5 trips @ 540 additional:-	2700		
66,940 @ $20.			$1,338,800.
Capital Charges:- Interest @ 7%:- Depreciation @ 5%:- 17.5% Insurance @ 4½%:- Taxes @ 1%:-		$250,510.	
Operating Cost:- Fuel Oil:- 11x540 tons 10% port consumption 6534 tons, 44,000 Bbls. @ $1.60		70,400.	
Oil & Supplies:-		2,000.	
Crew:- Deck:- 4 officers @ $150.	$600.		
21 men @ $30.	630.		
Engine Room:- 4 officers @ $150.	600.		
12 men @ $30.	360.		
Per month:-	2200.		
Per year:-		26,400.	
Food:- 41 x 365 days @ $.75 per day:-		11,200.	
Maintenance:- Engine Dept. @ 1½%		4,800.	
ANNUAL OPERATING COST:-			365,310.
OPERATING SURPLUS:-			973,490.

Increase over Reciprocating Engine:- $88,840.

+Utilization of 1/2 bunker space on return trips. Fuel Oil @ $1.60 per Bbl. San Francisco (Quotation Oct. 29, 1919.)

- TWIN DIESEL ENGINES -

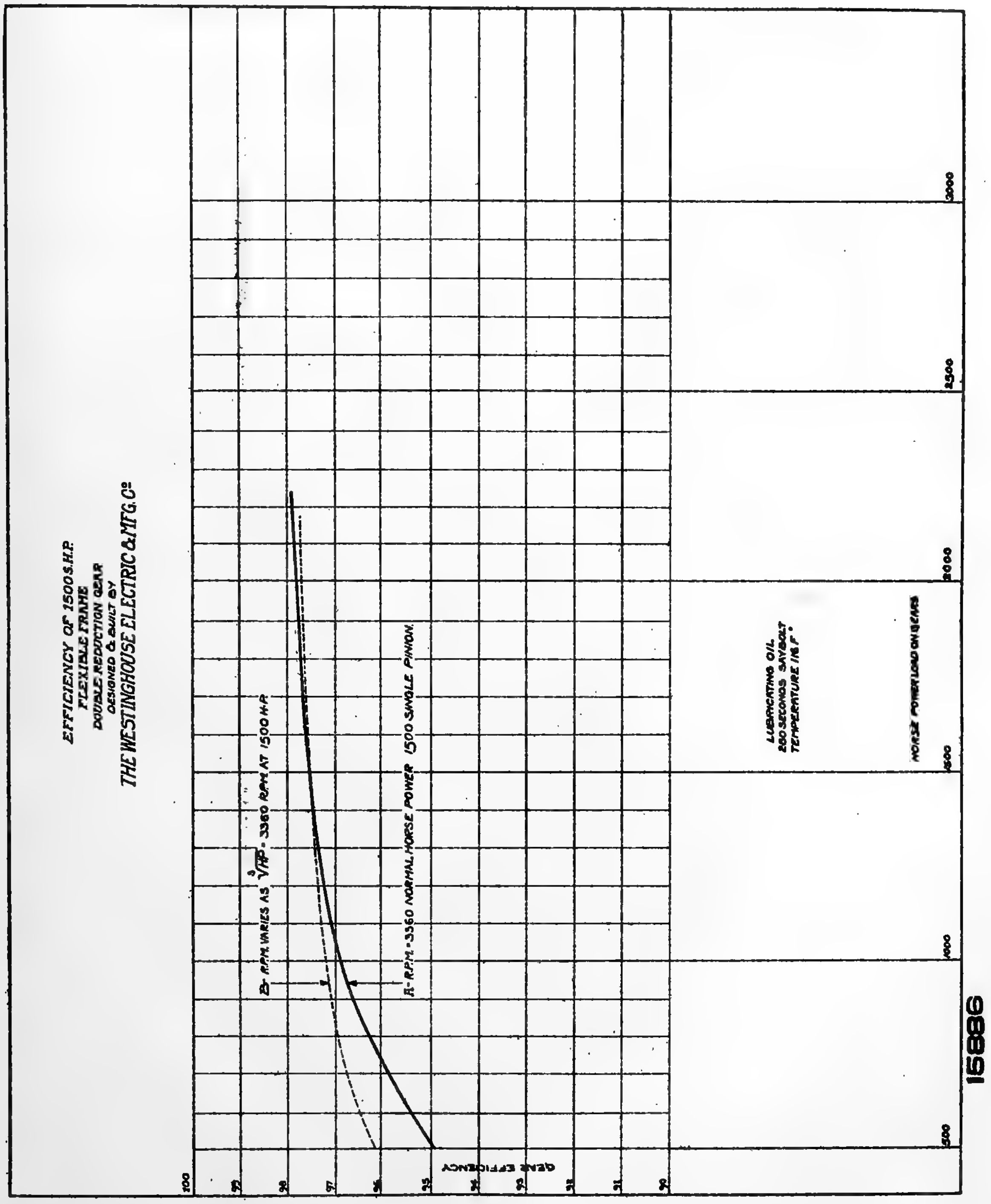
Cost:- $215.00 per D.W. ton (8360 D.W.)
Investment:- $1,798,000.

		Dr.	Cr.
Revenue:- 11 trips @ 6128 tons:-	67,400		
+5 trips @ 240 tons additional:-	1,200		
68,600 @ $20.			$ 1,372,000
Capital Charges:- Interest @ 7%:- Depreciation @ 7%:- 19.5% Insurance @ 4½%:- Taxes @ 1%:-		$ 350,600.	
Operating Cost:- Fuel Oil:- 11x243 2% port consumption. 2726 tons. 18,250 Bbls. @ $3.50 Bbl.		64,000.	
Oil & Supplies:-		5,000.	
Crew:- Deck:- 4 officers @ $150.	$600.		
21 men @ $30.	630.		
Engine Room:- 4 officers @ $150.	600.		
8 men @ $50.	400.		
Per month:-	2230.		
Per year:-		26,700.	
Food:- 37 x 365 days @ $.75 per day:-		10,200.	
Maintenance:- Engine Dept. @ 3%		20,600.	
ANNUAL OPERATING COST:-			477,100.
OPERATING SURPLUS:-			894,900.

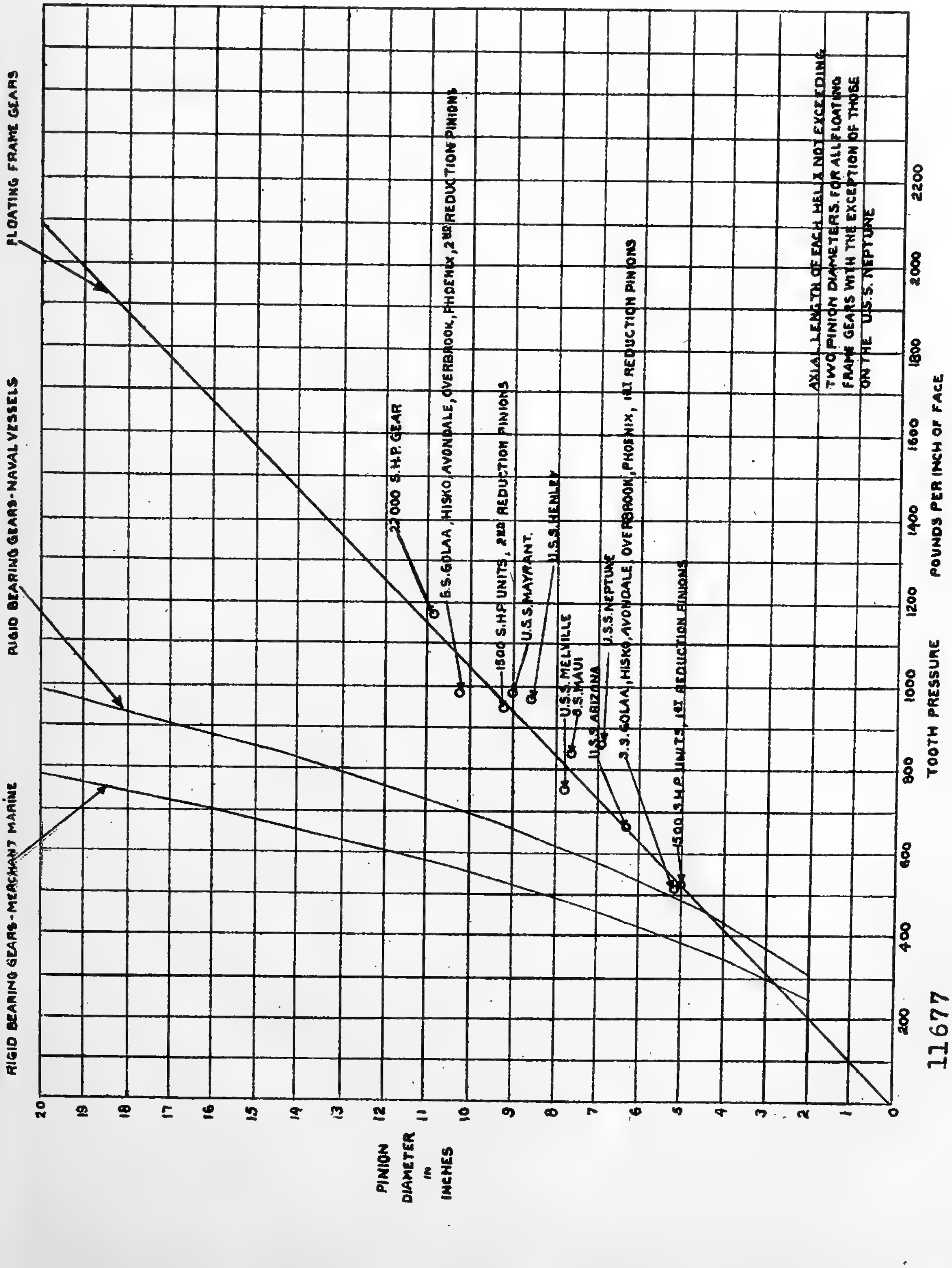
Increase over Reciprocating Engine:- $10,250.
Decrease from Geared Turbine:- $78,590.

+Utilization of 1/2 bunker space on return trips.
Fuel Oil:- "Polar Diesel" as used M.S. "California" and M.S. "George Washington." If California crude could be used the Annual Operating Cost would be reduced $34,875.

To illustrate discussion by W. B. Flanders, Esq., Visitor, and E. F. Clark, Esq., Visitor, on paper entitled "The Internal Combustion Engine as Applied to Marine Propulsion," by John F. Metten, Esq., Member, and J. C. Shaw, Esq., Visitor, and on paper entitled "Reduction Gears for Ship Propulsion," by Robert Warriner, Esq., Member.



To illustrate discussion by W. B. Flanders, Esq., Visitor, and E. F. Clark, Esq., Visitor, on paper entitled "The Internal Combustion Engine as Applied to Marine Propulsion," by John F. Metten, Esq., Member, and J. C. Shaw, Esq., Visitor, and on paper entitled "Reduction Gears for Ship Propulsion," by Robert Warriner, Esq., Member.



11677

To illustrate paper on "Electric Propulsion of Ships," by W. E. Thau, Esq., Member.

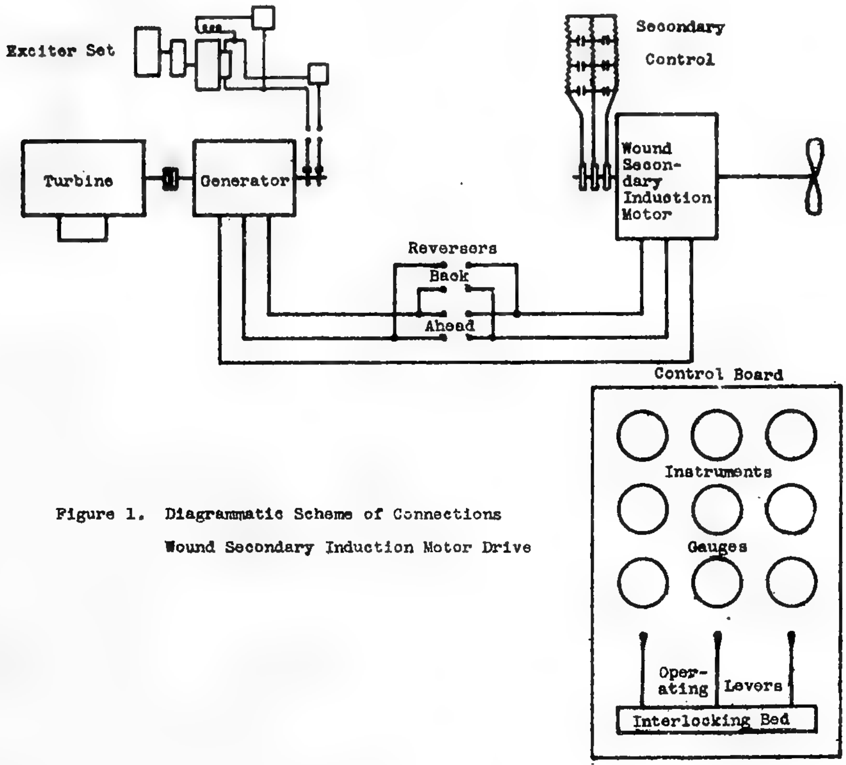


Figure 1. Diagrammatic Scheme of Connections
Wound Secondary Induction Motor Drive

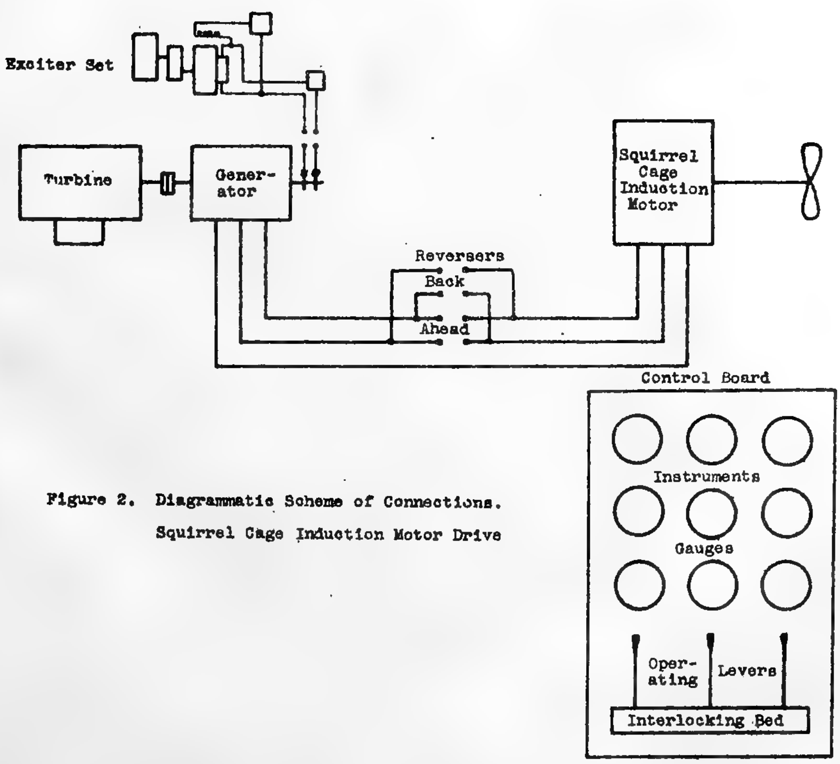


Figure 2. Diagrammatic Scheme of Connections.
Squirrel Cage Induction Motor Drive

To illustrate paper on "Electric Propulsion of Ships," by W. E. Thau, Esq., Member.

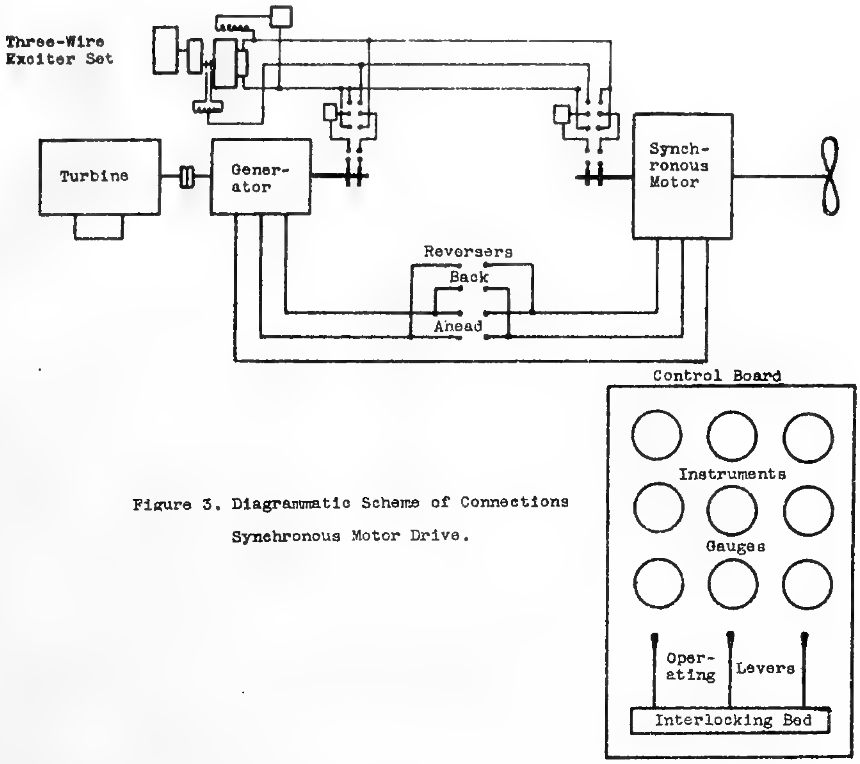


Figure 3. Diagrammatic Scheme of Connections Synchronous Motor Drive.

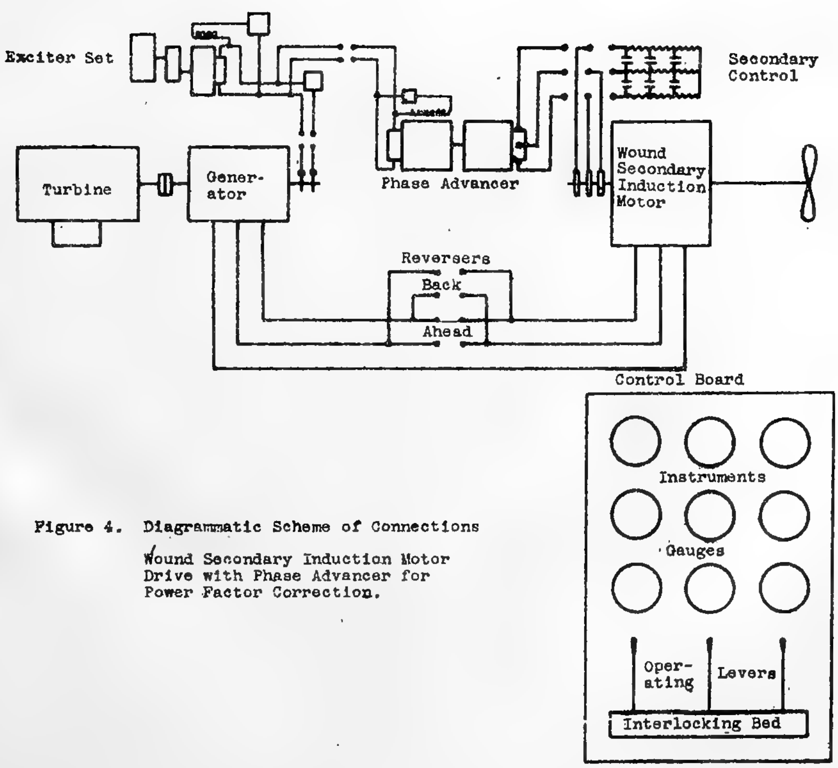


Figure 4. Diagrammatic Scheme of Connections Wound Secondary Induction Motor Drive with Phase Advancer for Power Factor Correction.

To illustrate paper on "Electric Propulsion of Ships," by W. E. Thau, Esq., Member.

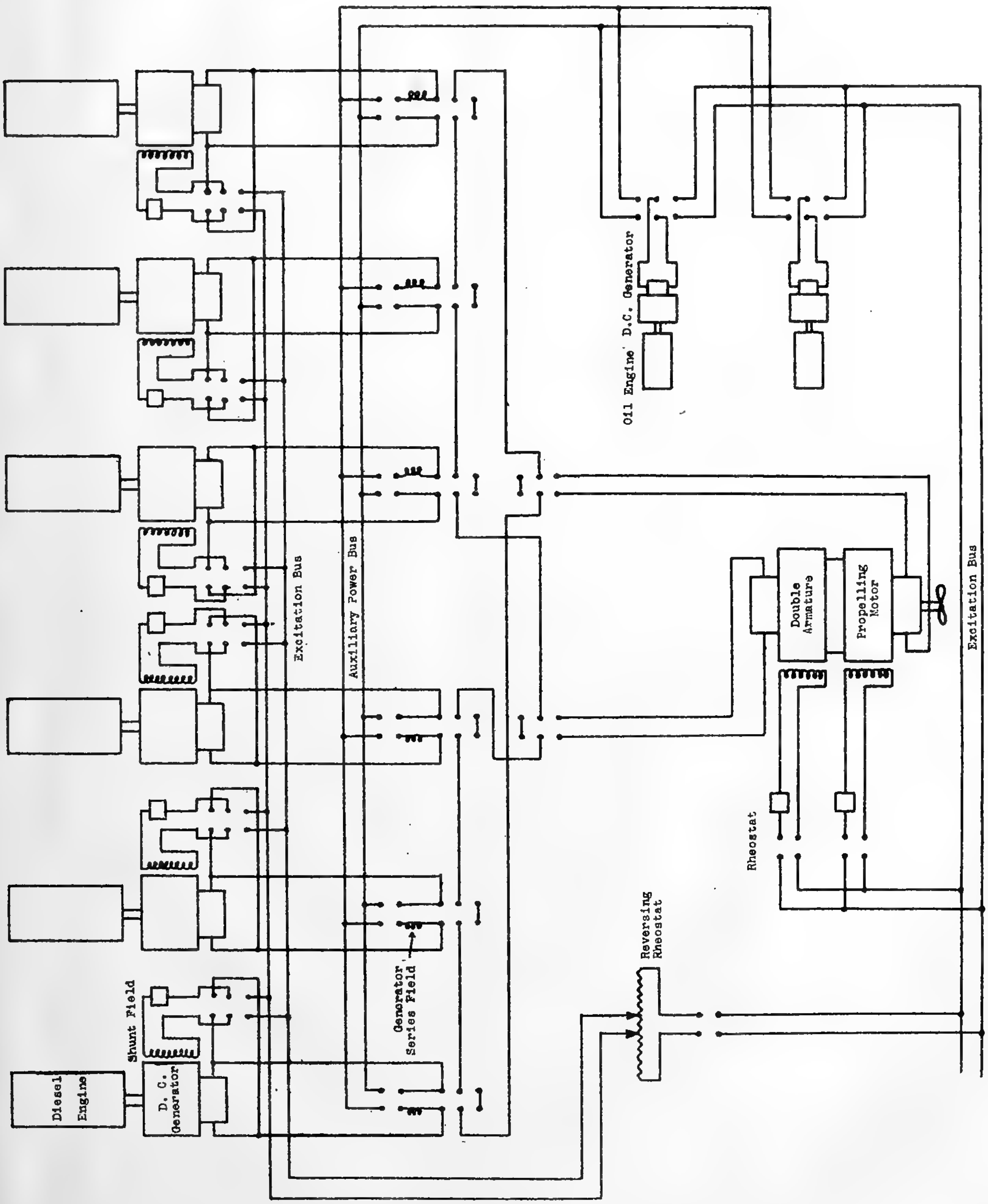


Fig. 5. Diagrammatic Scheme of Connections Diesel - Electric Drive.

To illustrate discussion by Charles F. Bailey, Esq., Member of Council, on paper entitled "Electric Propulsion of Ships," by W. E. Thau, Esq., Member.

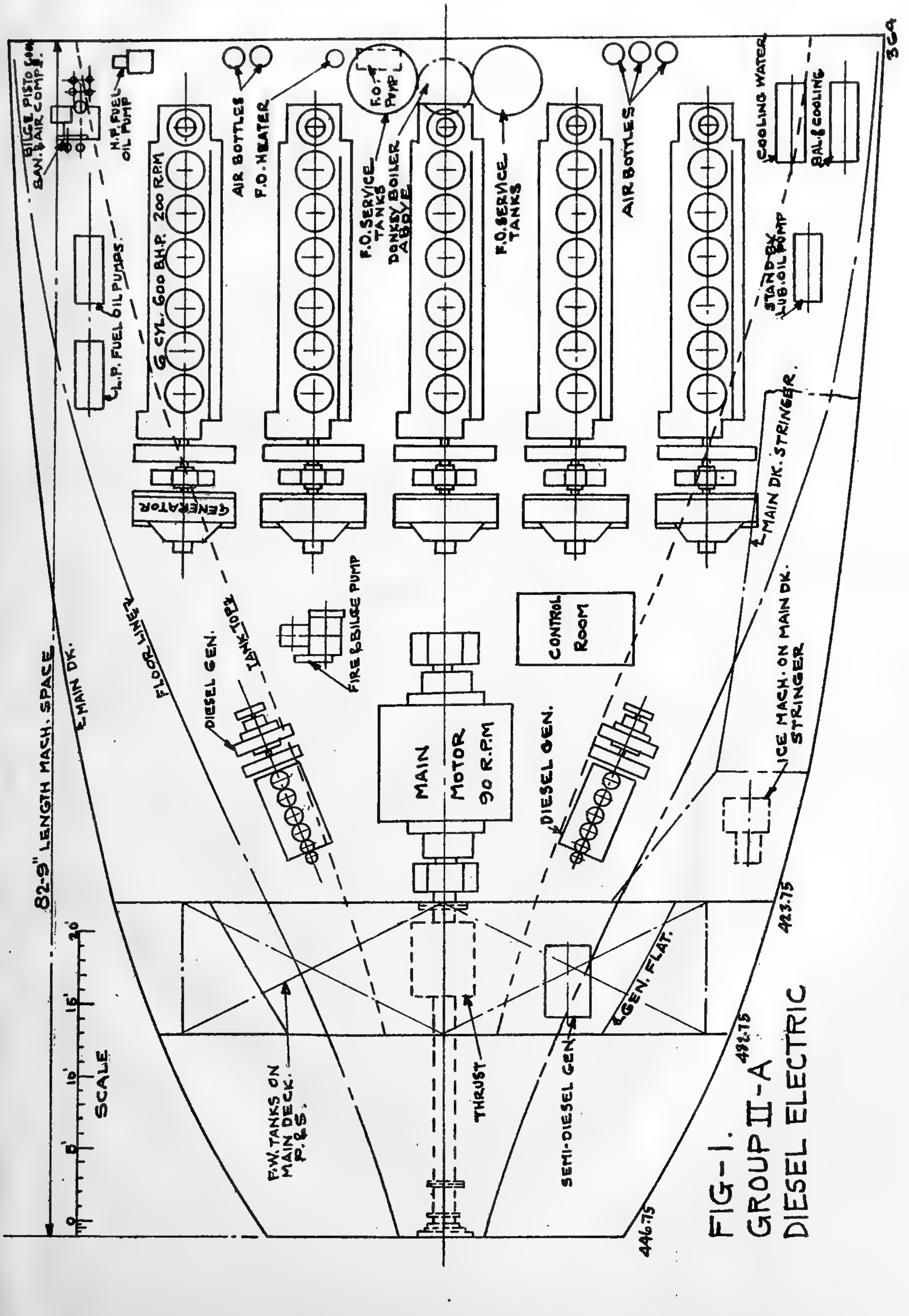


FIG-1.
GROUP II-A
DIESEL ELECTRIC

To illustrate discussion by Charles F. Bailey, Esq., Member of Council, on paper entitled "Electric Propulsion of Ships," by W. E. Thau, Esq., Member.

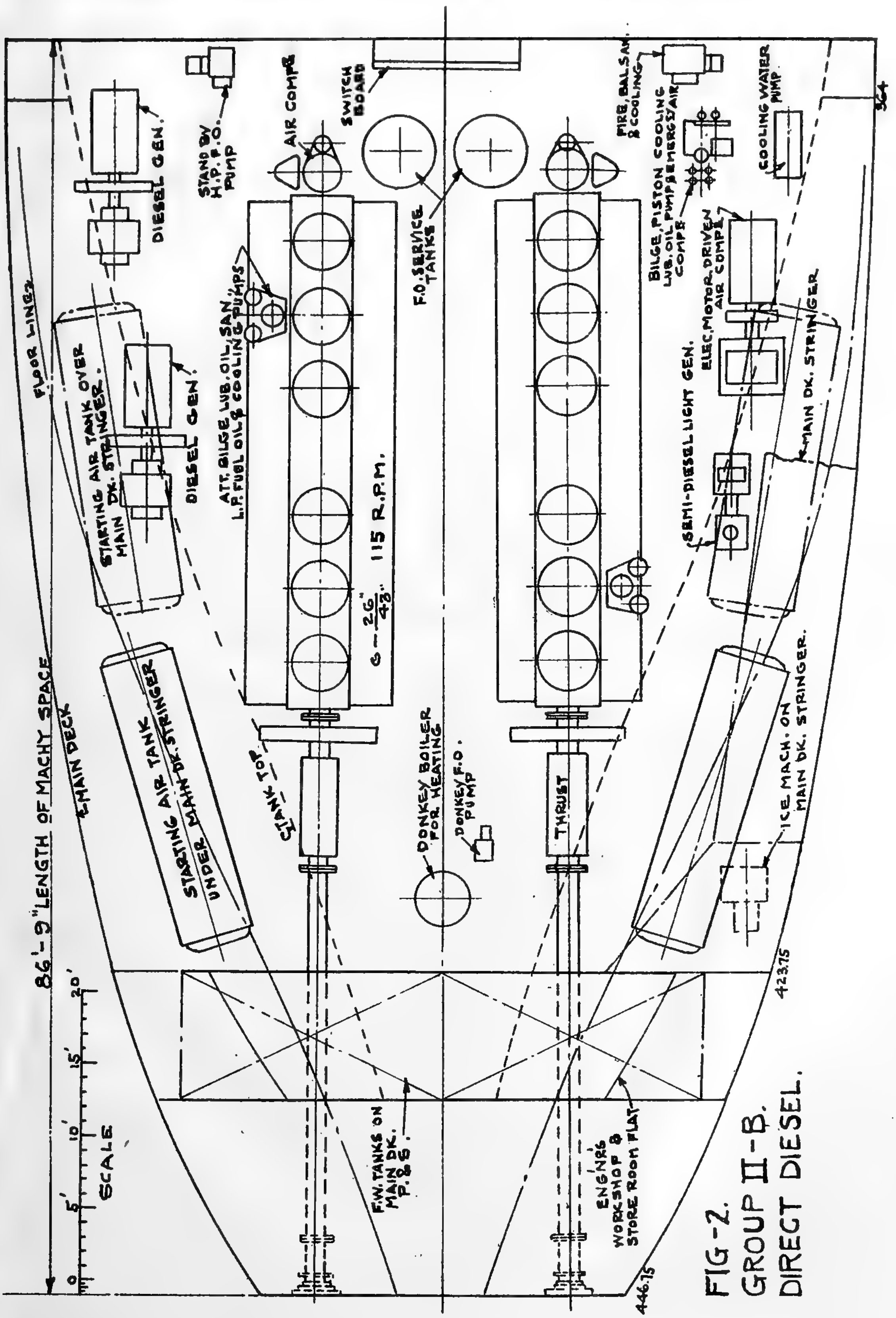


FIG-2.
GROUP II-B.
DIRECT DIESEL.

To illustrate discussion by Charles F. Bailey, Esq., Member of Council, on paper entitled "Electric Propulsion of Ships," by W. E. Thau, Esq., Member.

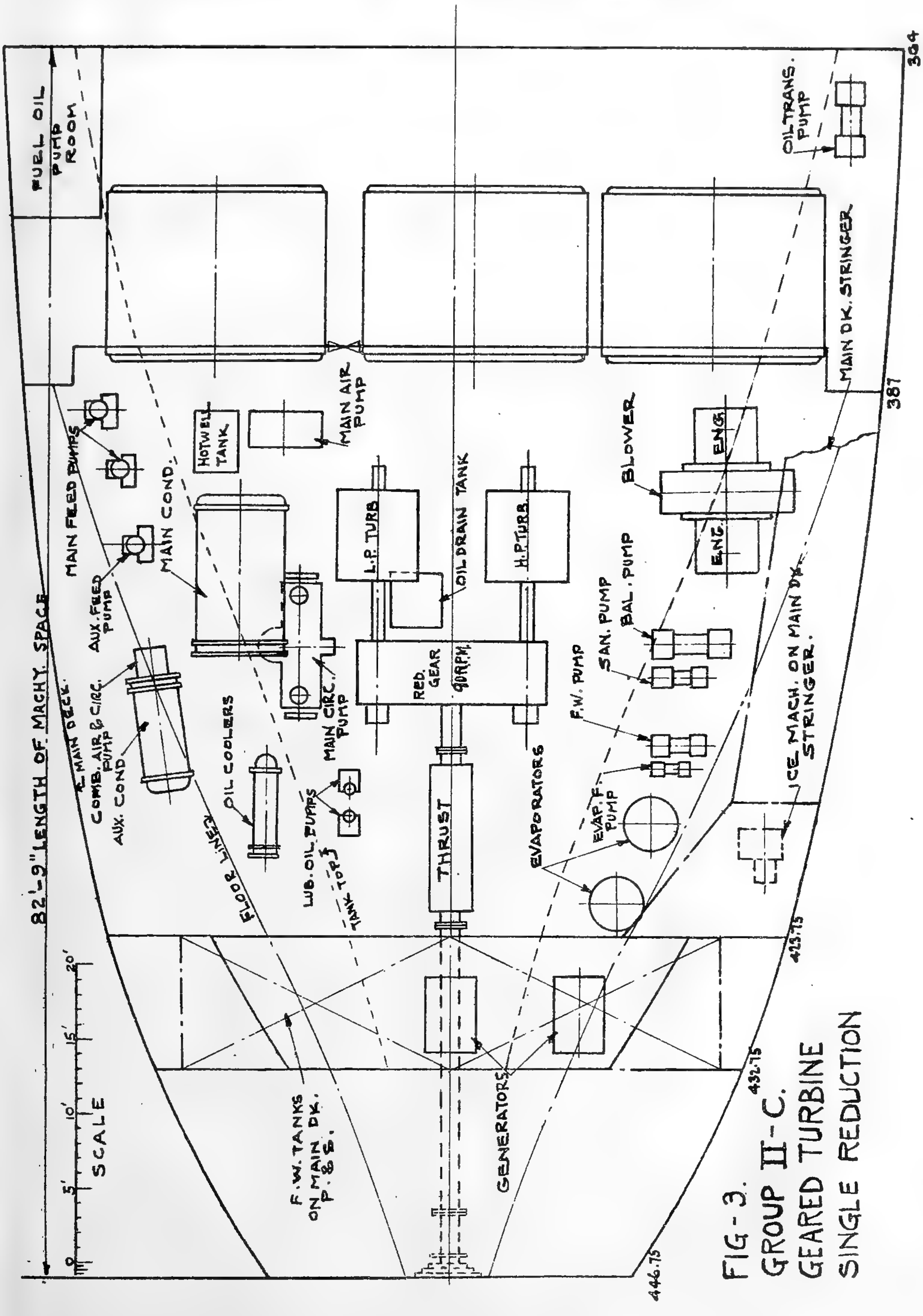


FIG - 3.
GROUP II - C.
GEARED TURBINE
SINGLE REDUCTION

To illustrate discussion by Charles F. Bailey, Esq., Member of Council, on paper entitled "Electric Propulsion of Ships," by W. E. Thau, Esq., Member.

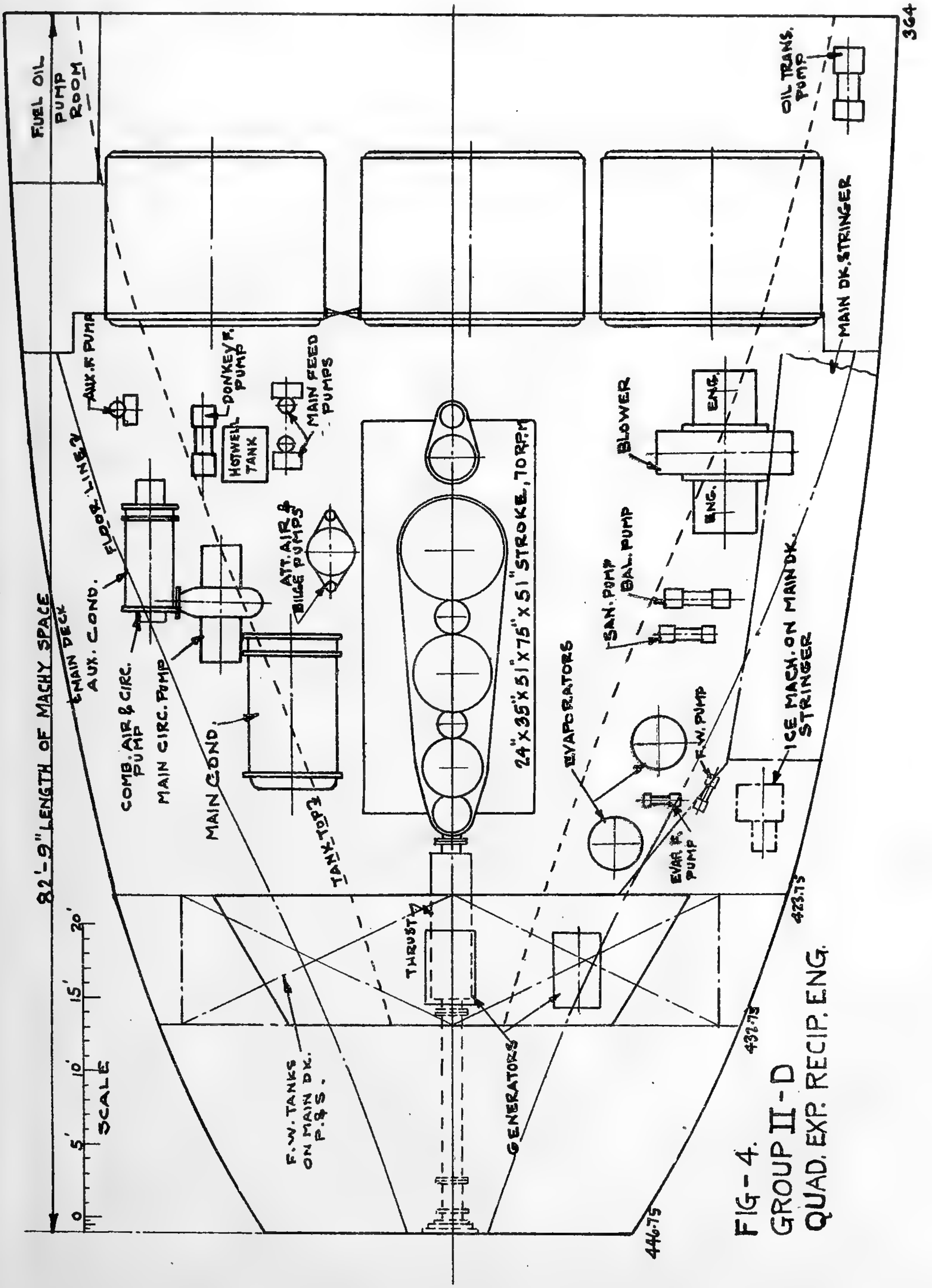


FIG - 4.
GROUP II - D
QUAD. EXP. RECIP. ENG.

To illustrate discussion by Charles F. Bailey, Esq., Member of Council, on paper entitled "Electric Propulsion of Ships," by W. E. Thau, Esq., Member.

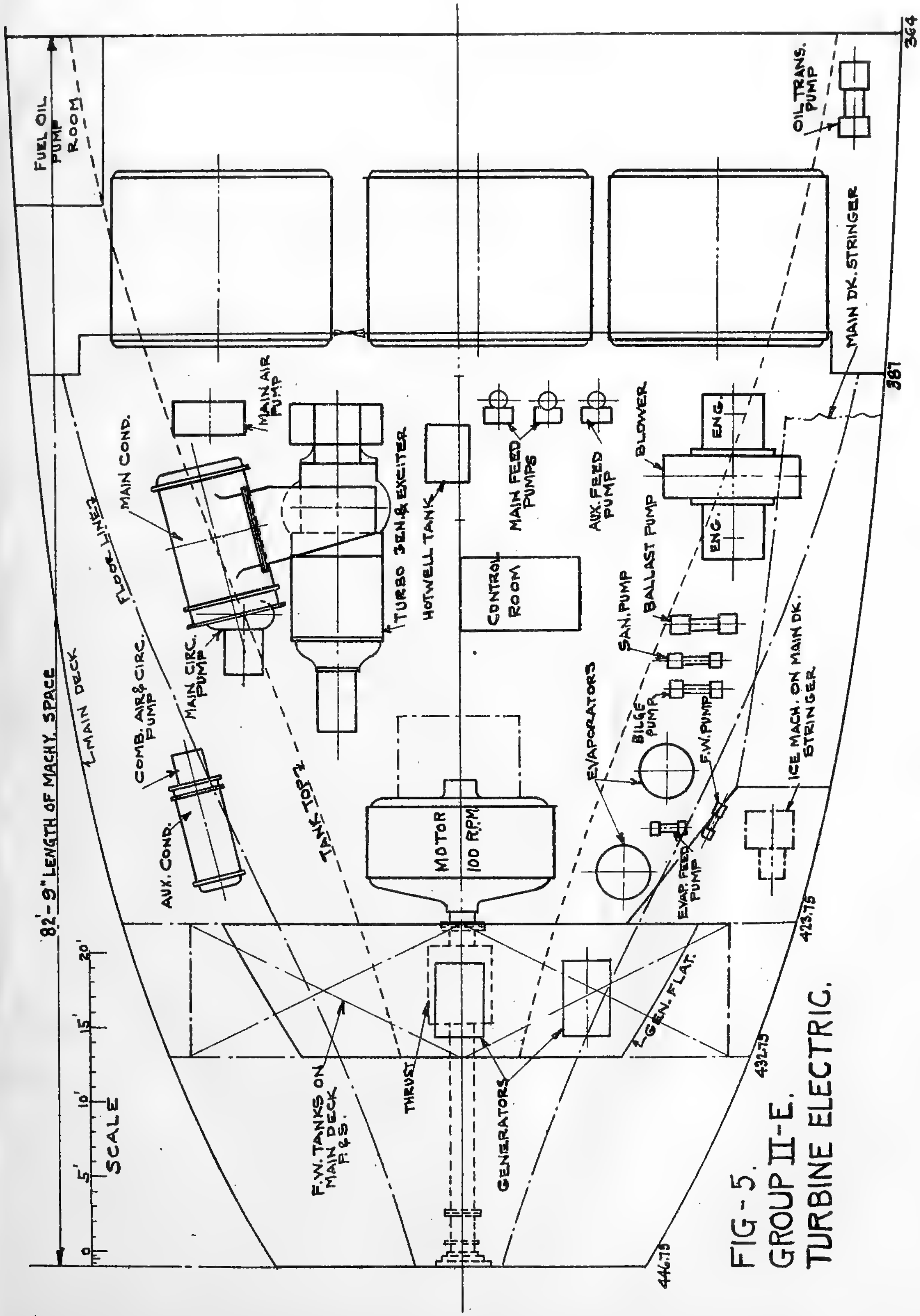


FIG-5.
GROUP II-E.
TURBINE ELECTRIC.

To illustrate discussion by Charles F. Bailey, Esq., Member of Council, on paper entitled "Electric Propulsion of Ships," by W. E. Thau, Esq., Member.

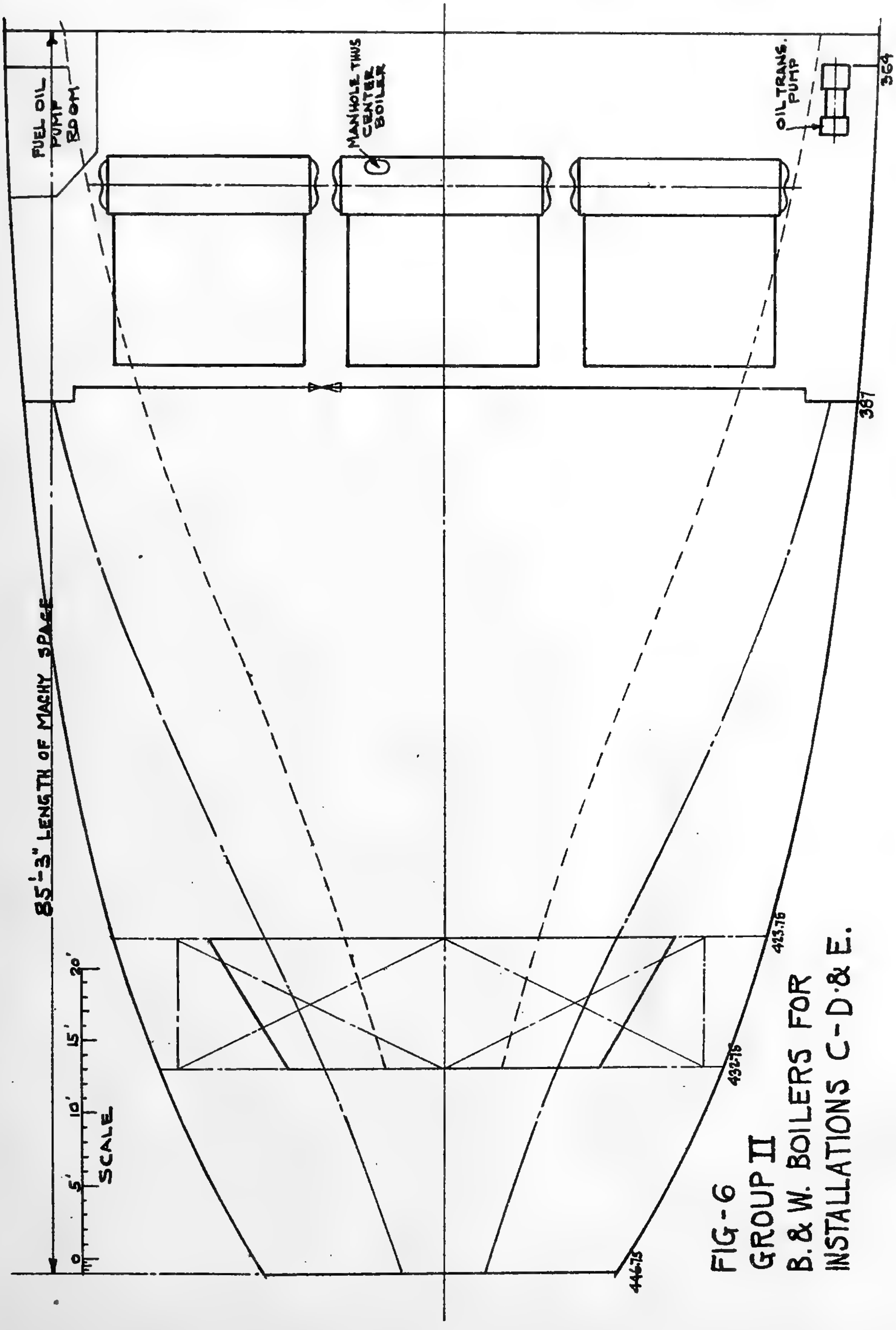
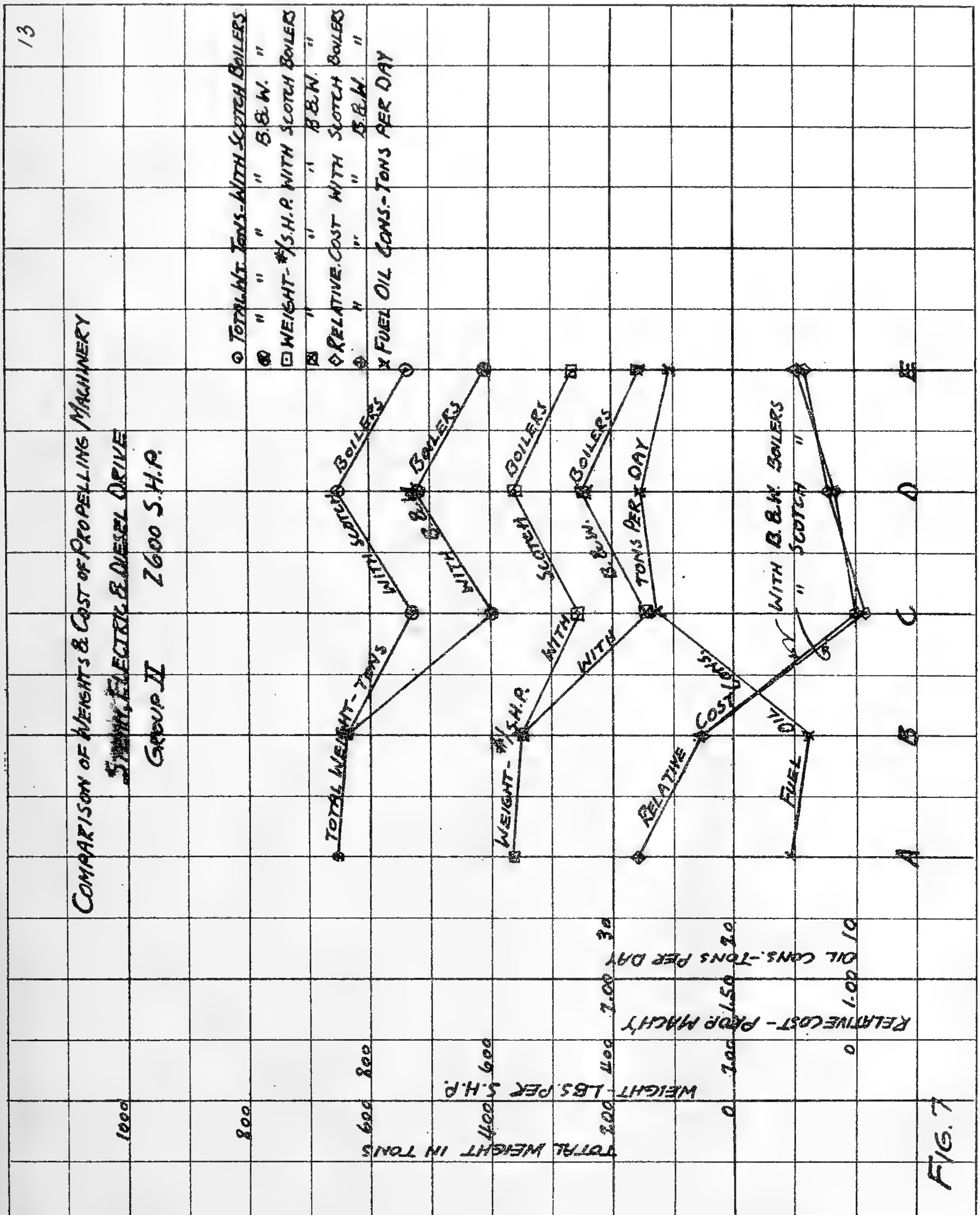
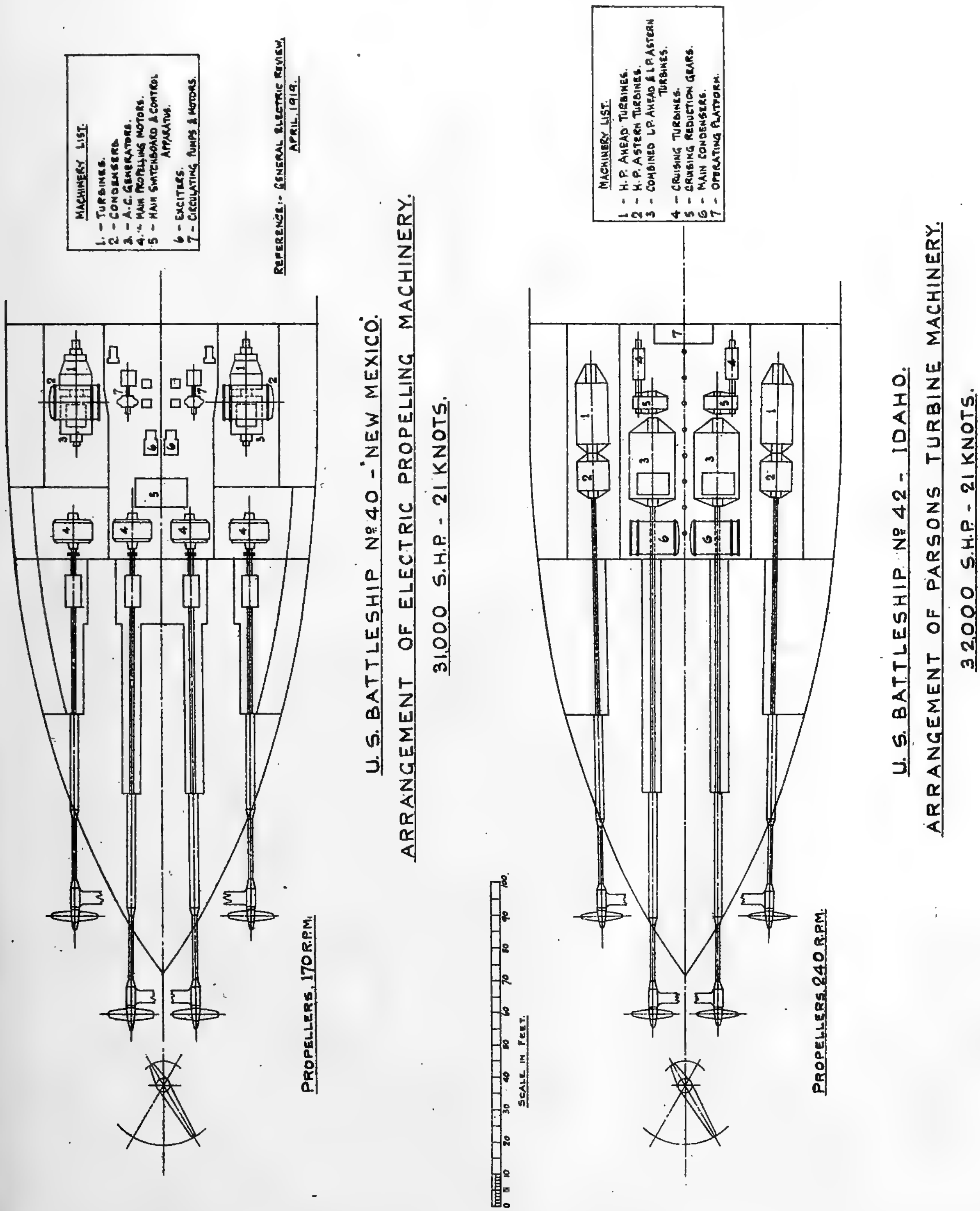


FIG-6
GROUP II
B. & W. BOILERS FOR
INSTALLATIONS C-D-& E.

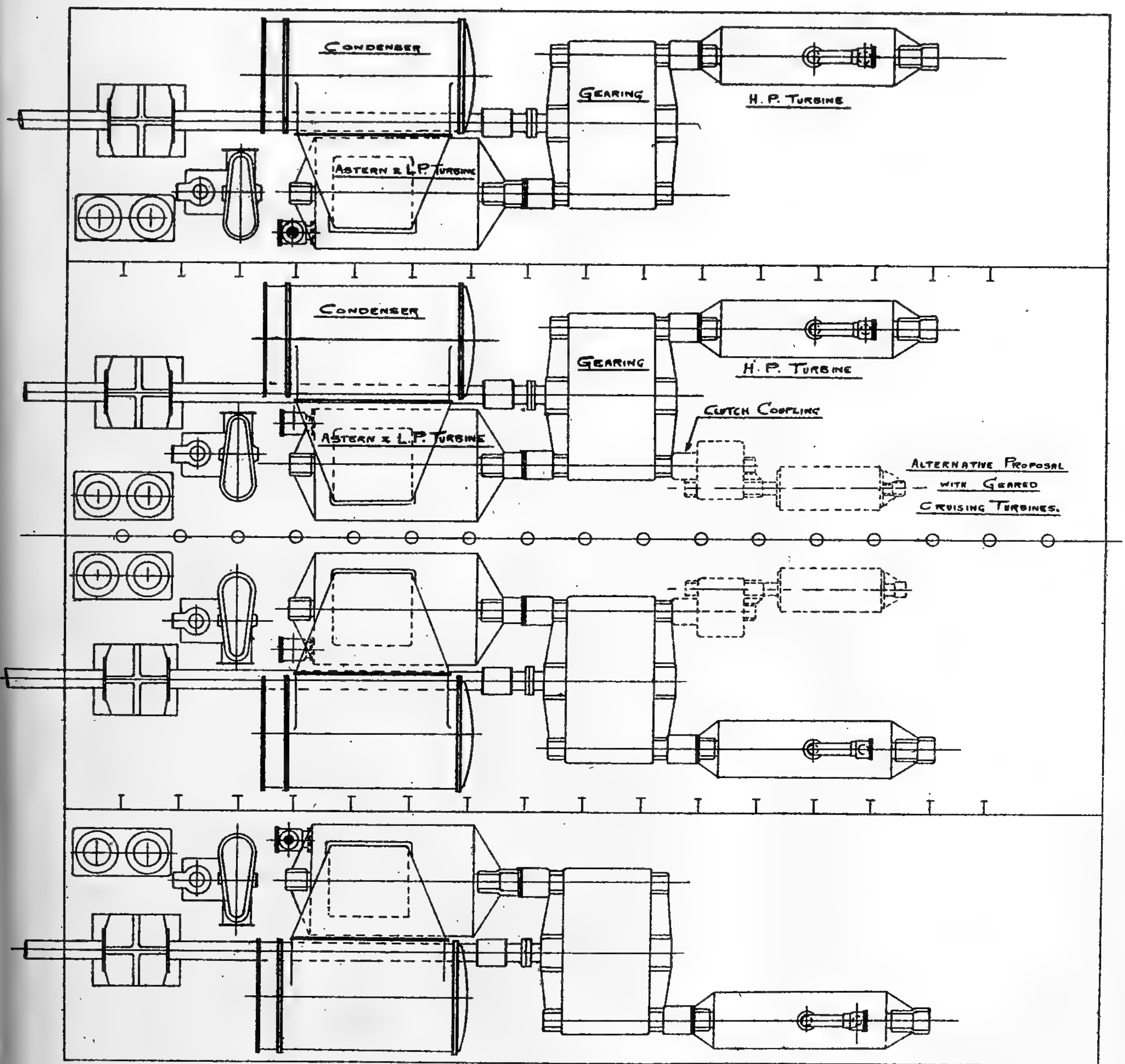
To illustrate discussion by Charles F. Bailey, Esq., Member of Council, on paper entitled "Electric Propulsion of Ships," by W. E. Thau, Esq., Member.



To illustrate discussion by E. H. B. Anderson, Esq., Member, on paper entitled "Electric Propulsion of Ships," by W. E. Thau, Esq., Member.



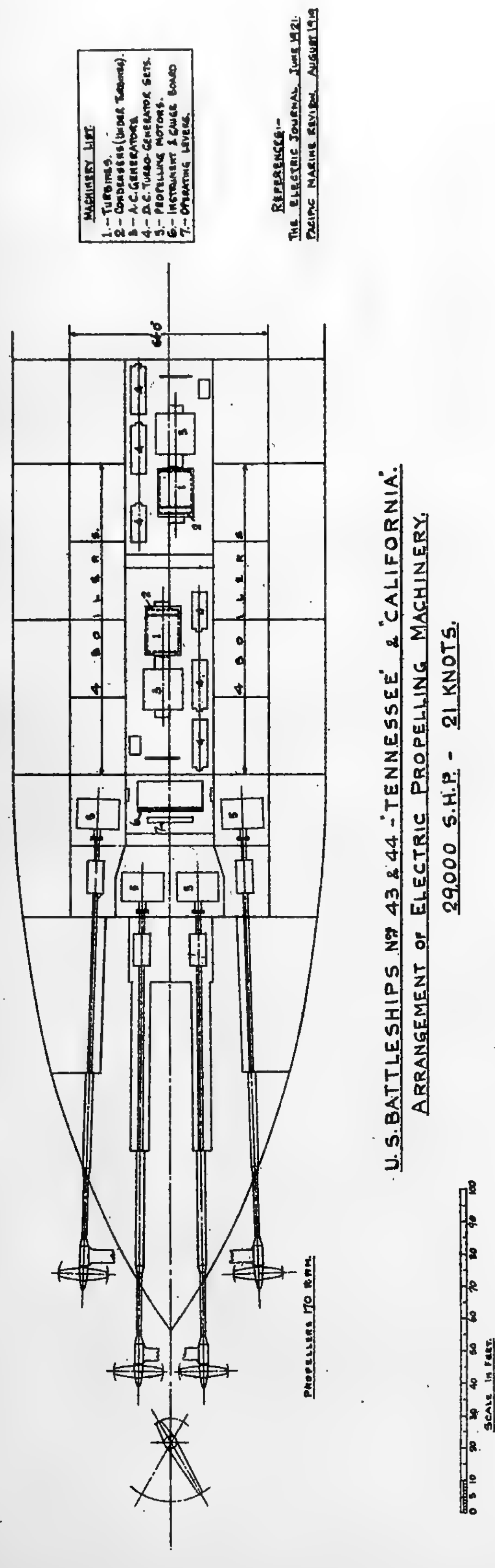
To illustrate discussion by E. H. B. Anderson, Esq., Member, on paper entitled "Electric Propulsion of Ships," by W. E. Thau, Esq., Member.

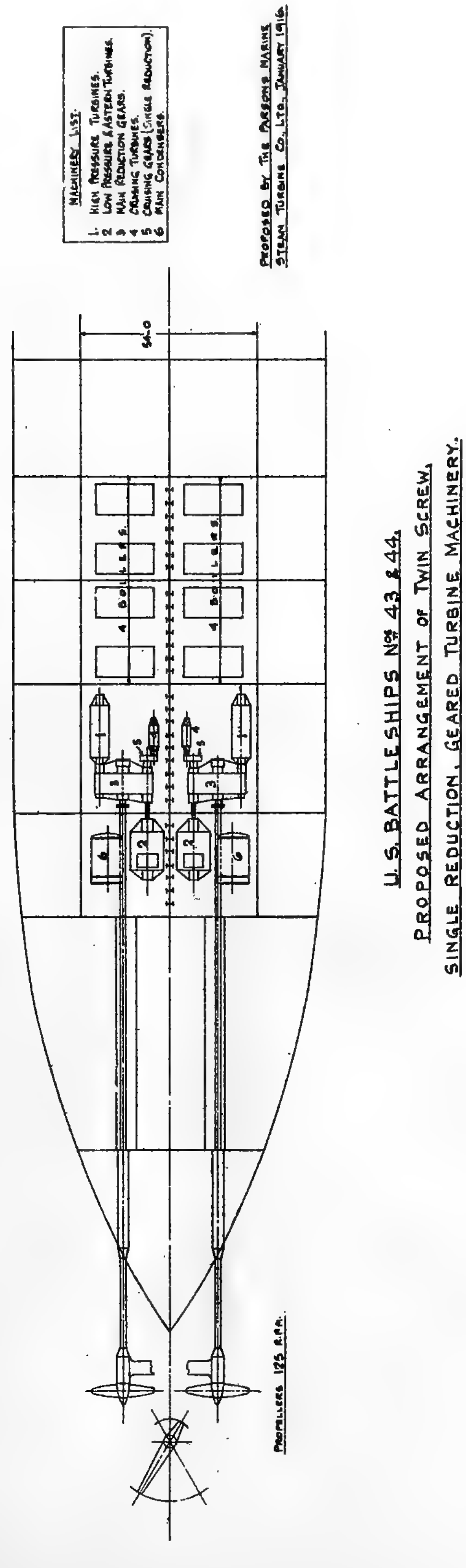


U. S. BATTLESHIPS.

PROPOSED ARRANGEMENT OF GEARED TURBINE MACHINERY.

To illustrate discussion by E. H. B. Anderson, Esq., Member, on paper entitled "Electric Propulsion of Ships," by W. E. Thau, Esq., Member.





To illustrate discussion by Elmer A. Sperry, Esq., Member, on paper entitled "Electric Propulsion of Ships," by W. E. Thau, Esq., Member.

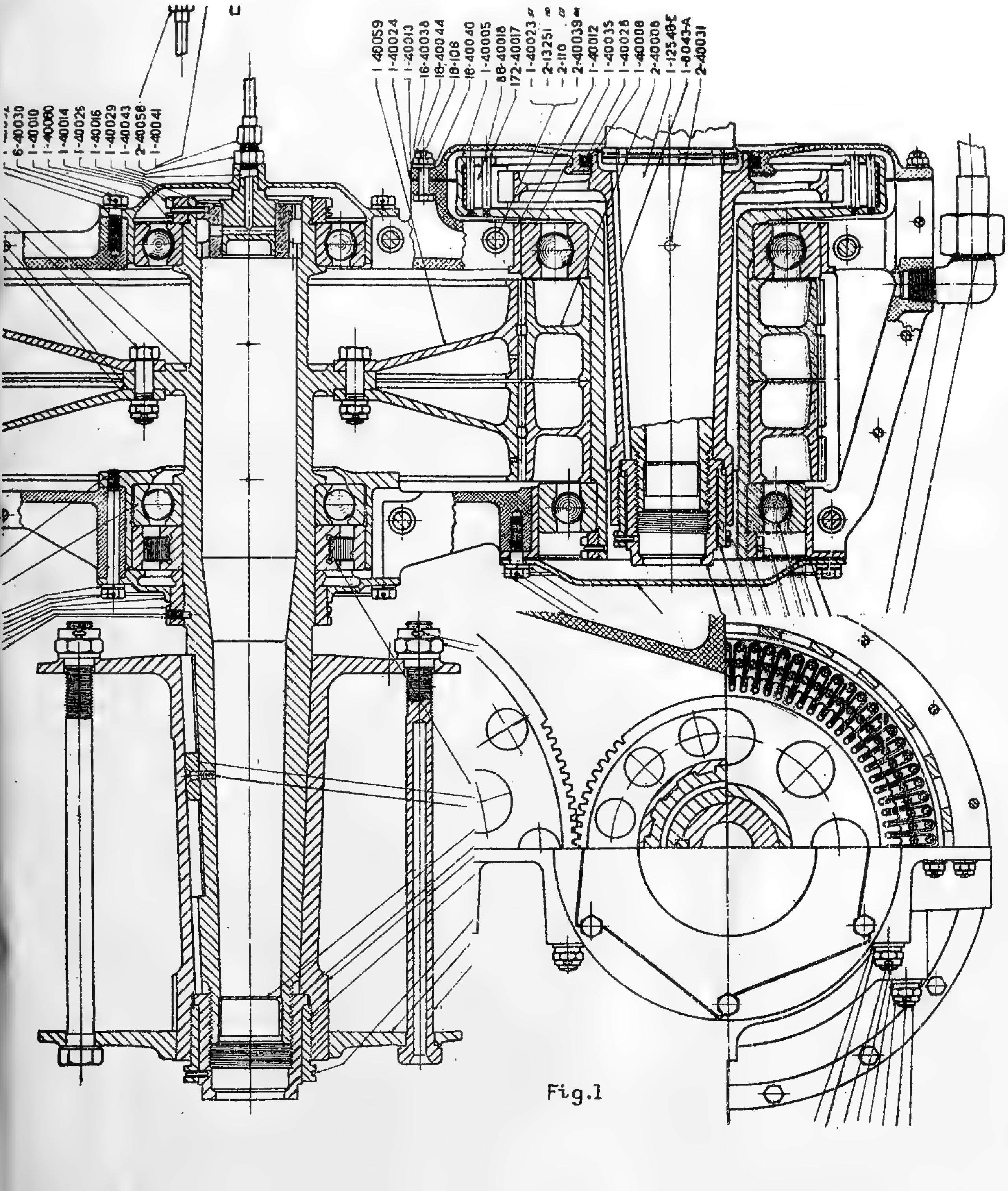
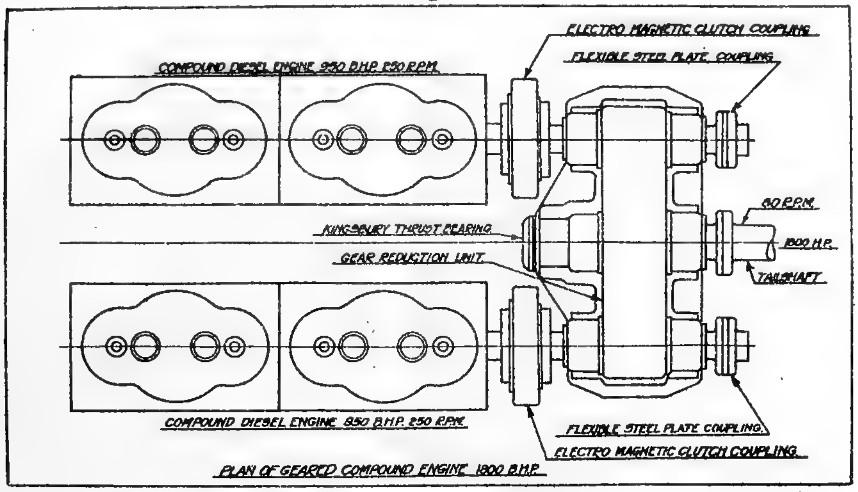


Fig.1

To illustrate discussion by Elmer A. Sperry, Esq., Member, on paper entitled "Electric Propulsion of Ships," by W. E. Thau, Esq., Member.

Fig. 5



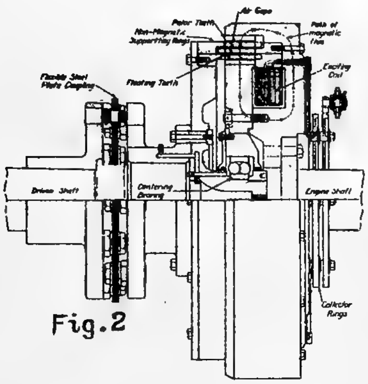


Fig. 2

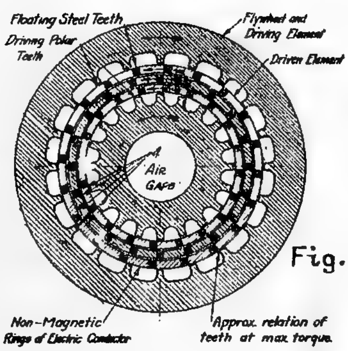


Fig. 3

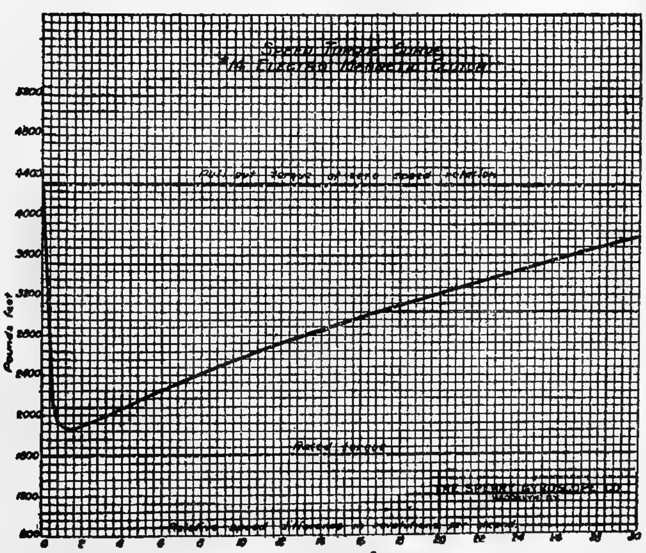


Fig. 4

To illustrate paper on "Electric Auxiliaries on Merchant Ships," by E. D. Dickinson, Esq., Member.

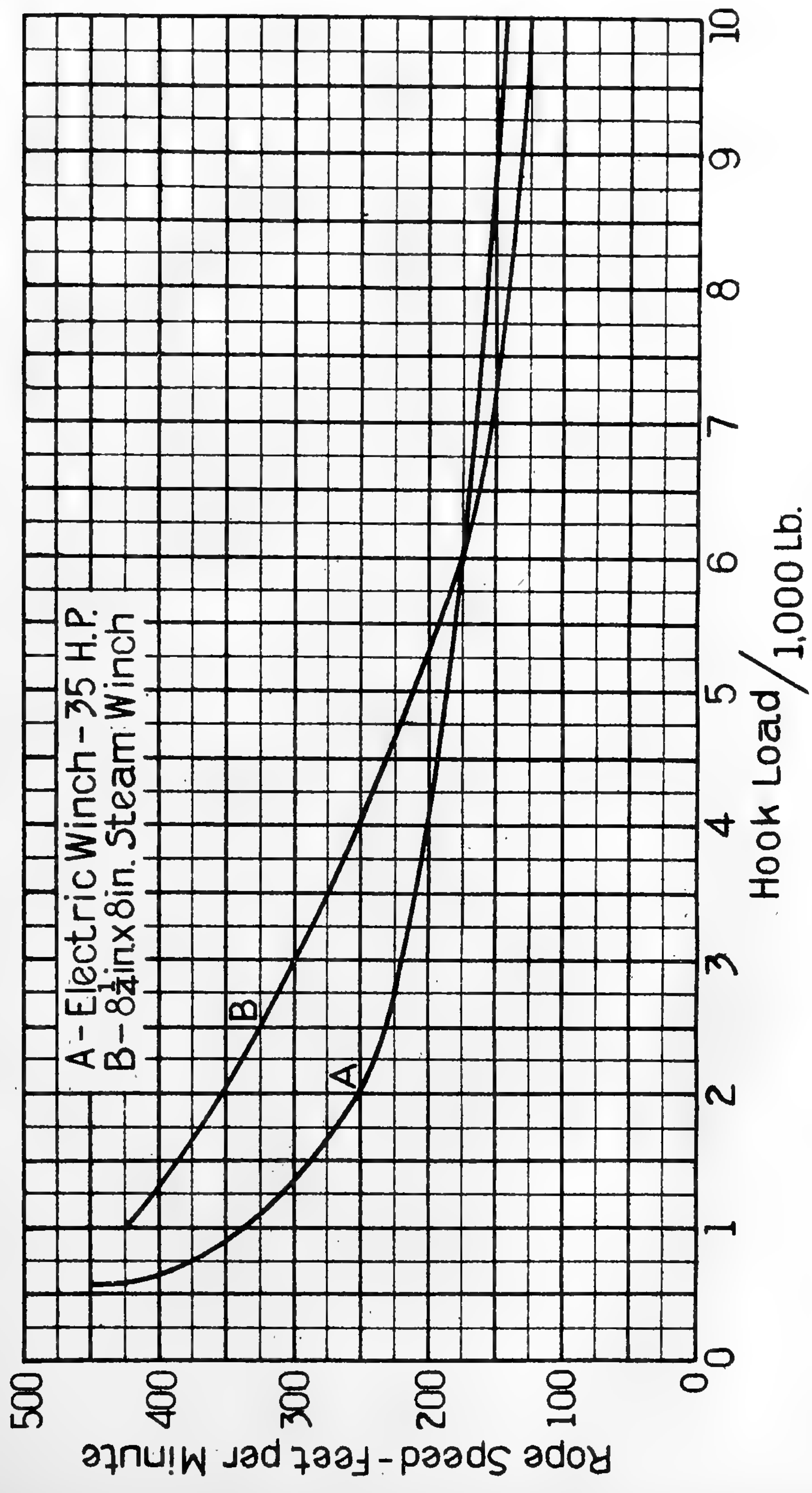
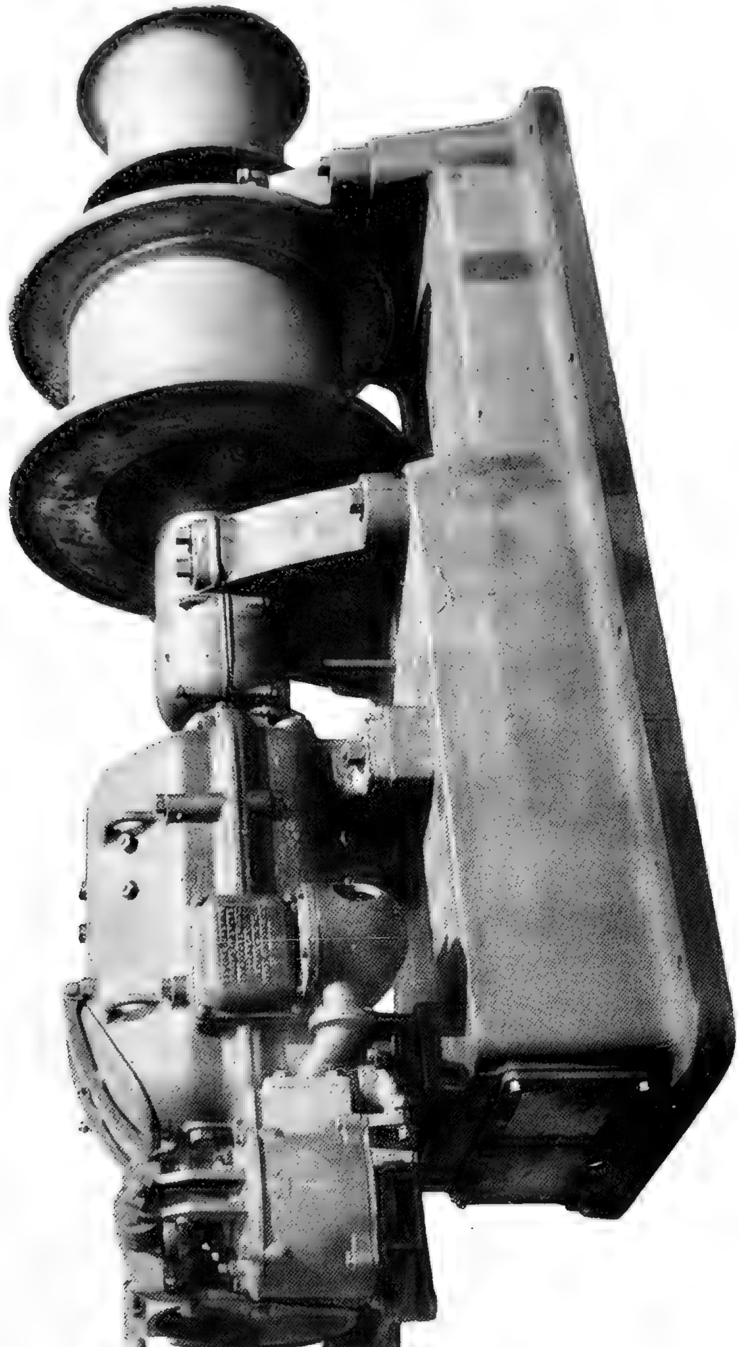


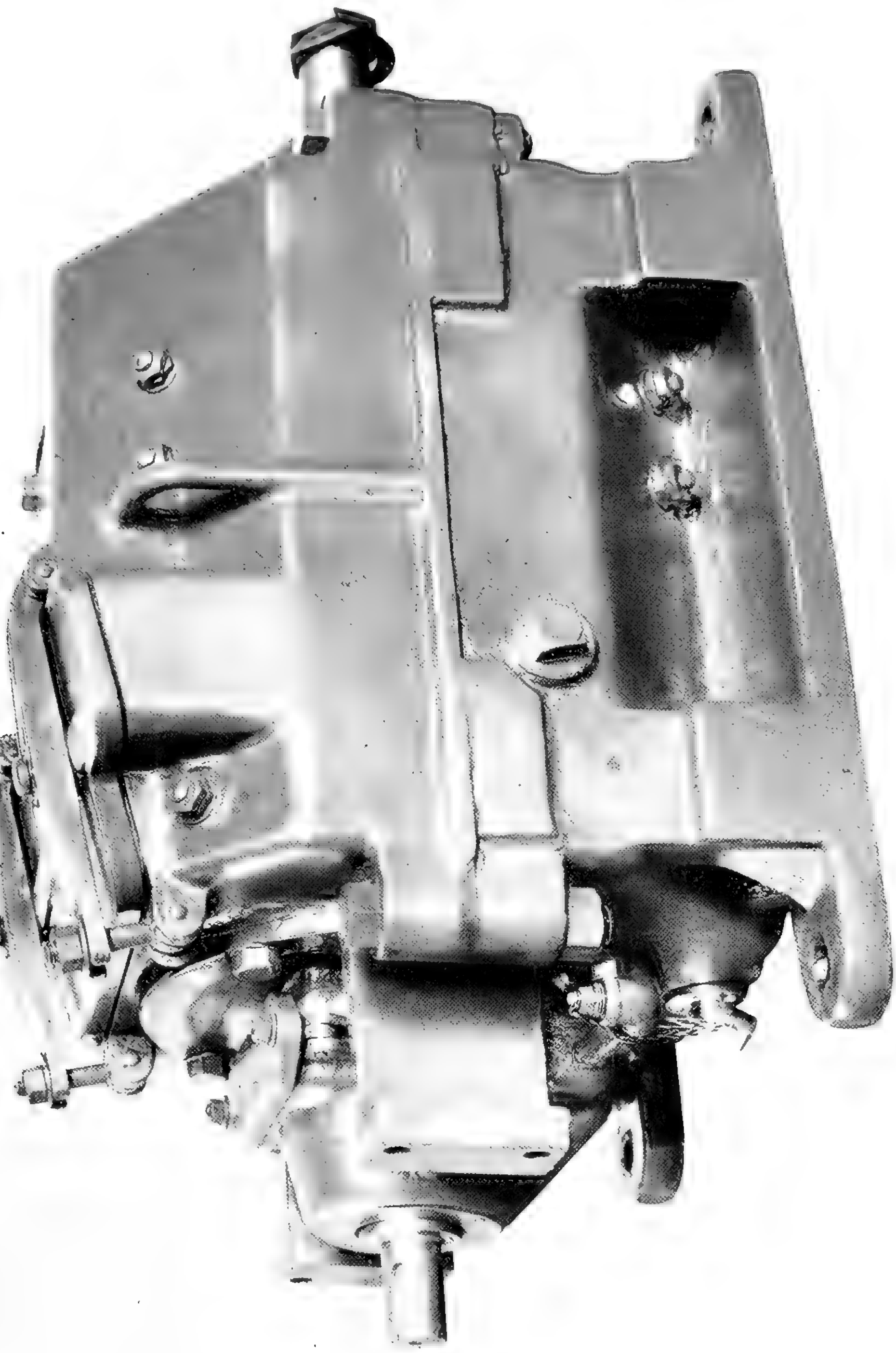
Fig. 1 CHARACTERISTIC CURVES OF ELECTRIC AND STEAM WINCHES

To illustrate paper on "Electric Auxiliaries on Merchant Ships,"
by E. D. Dickinson, Esq., Member.



New Type of Electric Cargo Winch Having the Reduction Gear Inside the Drum.

To illustrate paper on "Electric Auxiliaries on Merchant Ships," by E. D. Dickinson, Esq., Member.

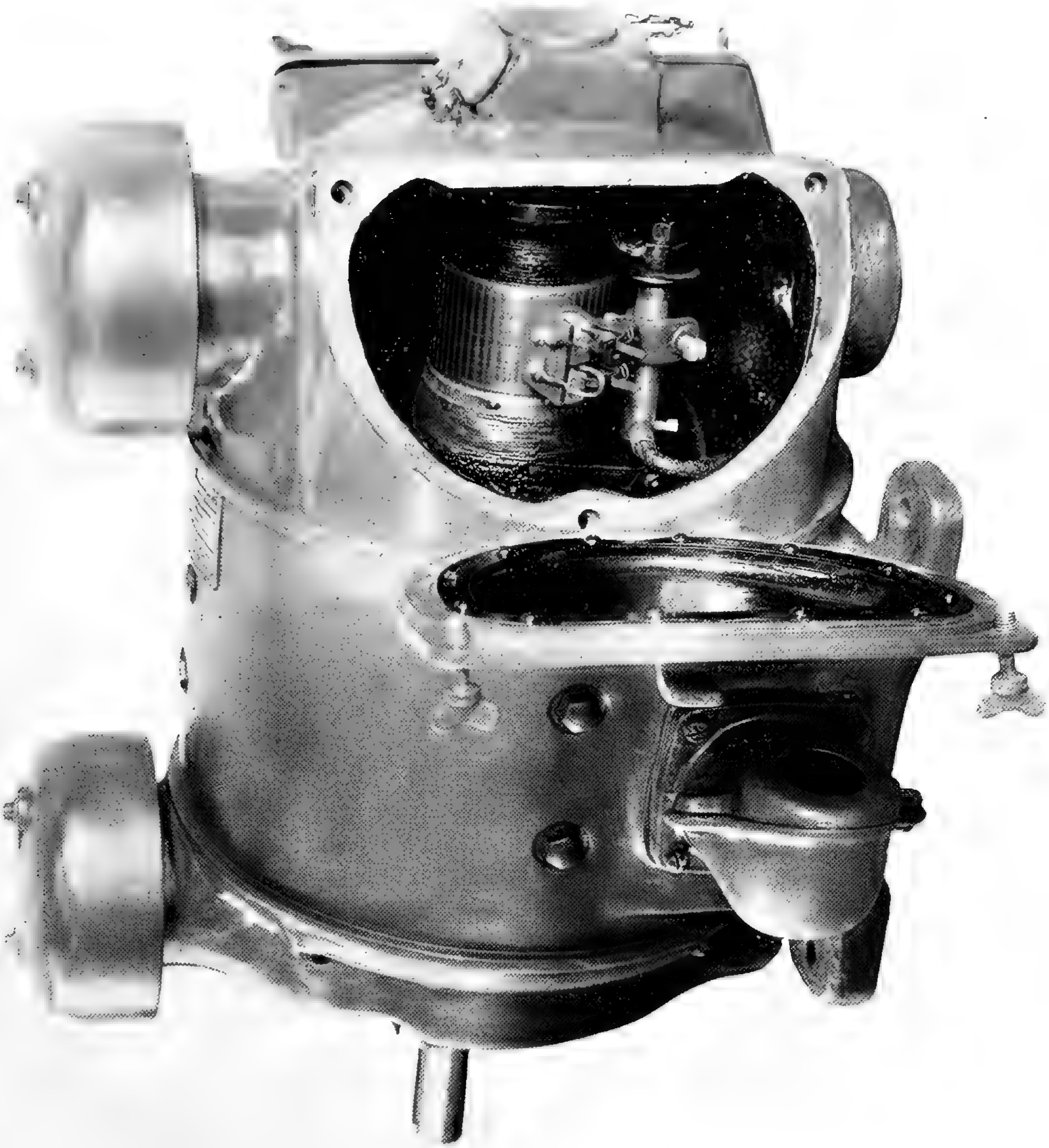


Marine Direct-Current Motor, Enclosed, for Operating Deck Machinery.

To illustrate paper on "Electric Auxiliaries on Merchant Ships," by E. D. Dickinson, Esq., Member.

MARINE CONTROLLER FOR DECK MACHINERY MOTORS.

To illustrate paper on "Electric Auxiliaries on Merchant Ships," by E. D. Dickinson, Esq., Member.



Marine Direct-Current Motor, Enclosed, Ventilated for Operating Below Deck Machinery.

To illustrate paper on "Calculation of the Transverse Strength of Submarines by Marbec's Method," by Professor William Hovgaard, Member.

TABLE I.

CHARACTERISTICS OF FRAME.

(SEE MIDSHIP SECTION — PLATE 35)

SECTION	AREA SQ. INS.	DIST. OF NEUTRAL AXIS FROM OUTER SURFACE OF HULL,—INCHES	DIST. OF NEUTRAL AXIS FROM INNER FLANGE INCHES	INERTIA ABOUT NEUTRAL AXIS (INCHES)[4]
A	3.147	1.73	2.42	7.36
B	3.147	1.73	2.42	7.36
C	3.147	1.73	2.42	7.36
D	4.159	1.76	2.69	11.61
E	4.833	3.28	10.22	80.98
F	4.802	4.34	11.91	191.64
H	4.179	3.22	13.78	98.73
I*	—	—	—	VERY LARGE
J	4.351	2.61	10.22	60.04
K	4.159	1.76	2.69	11.61
L	3.147	1.73	2.42	7.36
M	3.147	1.73	2.42	7.36

*IN WAY OF ENGINE.

TABLE II.

CENTER OF GRAVITY OF FLEXIBILITY MASS.

(SEE CURVES — PLATE 37.)

SECTION	I INCHES[4]	FACTOR FOR AVERAGE SECTION	I AVERAGE INCHES[4]	$\frac{1}{I}$	ORDINATE FROM BASE INCHES	MOMENT ABOUT BASE INCHES[3]	ABSCISSAE FROM CENTER LINE—INCHES	MOMENT ABOUT CENTER LINE — INS.[3]
A	7.36		7.36	.1359	77.2	10.48	0.0	.00
B	7.36		7.36	.1359	70.6	9.58	−25.0	−3.40
C	7.36		7.36	.1359	38.8	5.27	−45.7	−6.21
D	11.61	$\frac{I_D+2I_A}{3}$	8.78	.1139	15.3	1.74	−37.3	−4.25
E	80.98	$\frac{I_E+2I_A}{3}$	31.90	.0313	7.0	.22	−23.5	−.74
F	191.64	$\frac{I_F+2I_A}{3}$	68.12	.0147	5.4	.08	−13.7	−.22
H	98.73		98.73	.0101	3.3	.03	0.0	.00
I	VERY LARGE		VERY LARGE	.0000	3.8	.00	+13.7	.00
J	60.04		60.04	.0166	7.0	.12	+26.5	+.44
K	11.61		11.61	.0861	15.2	1.31	+37.3	+3.21
L	7.36		7.36	.1359	38.7	5.26	+45.7	+6.21
M	7.36		7.36	.1359	70.6	9.58	+25.0	+3.40

AREA UNDER FLEXIBILITY CURVE 223.56 SQ. INS. SCALE FACTOR = .01
AREA UNDER VERTICAL MOMENT CURVE 111.12 " " " " = 1
AREA UNDER HORIZONTAL MOMENT CURVE −1.30 " " " " = 1

POSITION OF C. of G. FLEXIBILITY MASS

ABOVE BASE $\frac{111.12 \times 1.}{223.56 \times .01} = 49.7$

FROM CENTER LINE $\frac{-1.30 \times 1}{223.56 \times .01} = -0.58$

TABLE III

PRINCIPAL AXES OF INERTIA, FLEXIBILITY MASS
(SEE CURVES — PLATE 38.)

$I_{x_o} = \int y_o^2\,dm$ $I_{y_o} = \int x_o^2\,dm$ $Z_o = \int x_o y_o\,dm$

$$\tan 2\theta = -\frac{2Z_o}{I_{x_o} - I_{y_o}}$$

SECTION	dm	x_o	x_o^2	$x_o^2 dm$	y_o	y_o^2	$y_o^2 dm$	$x_o y_o$	$x_o y_o dm$
A	.1359	+.10	.01	.001	+4.62	21.34	2.90	+.46	+.06
B	.1359	−4.06	16.40	2.230	+3.53	12.46	1.70	−14.34	−1.95
C	.1359	−7.40	54.76	7.441	−1.80	3.24	.44	+12.88	+1.75
D	.1139	−6.12	37.45	4.265	−5.63	31.70	3.61	+34.46	+3.92
E	.0313	−3.81	14.52	.455	−7.07	49.98	1.56	+26.94	+.84
F	.0147	−2.18	4.75	.070	−7.32	53.84	.79	+15.96	+.23
H	.0101	+.10	.01	.000	−7.67	58.83	.59	−.77	−.01
I	.0000	+2.30	5.29	.000	−7.60	57.76	.00	−17.48	.00
J	.0166	+4.50	20.25	.336	−7.08	50.13	.83	−31.86	−.53
K	.0861	+6.31	39.82	3.430	−5.70	32.49	2.80	−35.97	−3.10
L	.1359	+7.63	58.22	7.912	−1.80	3.24	.44	−13.81	−1.88
M	.1359	+4.30	18.49	2.513	+3.53	12.46	1.68	+15.14	+2.06

AREA UNDER I_{x_o} CURVE 30.42 SQ. INS. SCALE FACTOR = 1
AREA UNDER I_{y_o} CURVE 70.36 " " " " = 1
AREA UNDER Z_o CURVE +2.30 " " " " = 1

$$\tan 2\theta = -\frac{2 \times 2.30}{30.42 - 70.36} = +.1152$$

$$\theta = 3^\circ\ 17'$$

TABLE IV

COORDINATES OF CENTER AND RADIUS OF NODAL CIRCLE
(SEE CURVES — PLATE 39.)
(FOR NODAL CIRCLE SEE PLATE 36.)

$a = \frac{\int \rho^2 x\,dm}{2\int x^2 dm}$ $b = \frac{\int \rho^2 y\,dm}{2\int y^2 dm}$ $i_\rho^2 = \frac{\int \rho^2\,dm}{\int dm}$

$$i_o^2 = a^2 + b^2 + i_\rho^2$$

SECTION	dm	ρ*	ρ^2	$\rho^2 dm$	x*	x^2	$x^2 dm$	y*	y^2	$y^2 dm$	$\rho^2 x dm$	$\rho^2 y dm$
A	.1359	4.63	21.44	2.91	+.37	.11	.01	+4.62	21.34	2.90	+1.08	+13.40
B	.1359	5.40	29.16	3.96	−3.87	14.98	2.04	+3.77	14.21	1.93	−15.33	+14.93
C	.1359	7.62	58.06	7.89	−7.48	55.95	7.60	−1.38	1.90	.26	−59.02	−10.90
D	.1139	8.35	69.72	7.94	−6.47	41.86	4.77	−5.32	28.30	3.22	−51.38	−42.25
E	.0313	8.06	64.96	2.03	−4.23	17.89	.56	−6.89	47.47	1.49	−8.59	−13.98
F	.0147	7.68	58.98	.87	−2.61	6.81	.10	−7.23	52.27	.77	−2.27	−6.29
H	.0101	7.70	59.29	.59	−.33	.11	.00	−7.70	59.29	.59	−.19	−4.54
I	.0000	7.97	63.52	.00	+1.90	3.61	.00	−7.75	60.06	.00	.00	.00
J	.0166	8.42	70.90	1.18	+4.10	16.81	.28	−7.32	53.58	.89	+4.84	−8.64
K	.0861	8.55	73.10	6.29	+6.00	36.00	3.10	−6.04	36.48	3.14	+37.70	−38.00
L	.1359	7.88	62.09	8.44	+7.54	56.85	7.73	−2.21	4.84	.66	+63.64	−18.65
M	.1359	5.60	31.36	4.26	+4.50	20.25	2.75	+3.31	10.96	1.49	+19.17	+14.10

AREA UNDER $\rho^2 dm$ CURVE 102.76 SQ. INS. SCALE FACTOR = 1
" " $\rho^2 x\,dm$ " +1.75 " " " " = 6
" " $\rho^2 y\,dm$ " −19.82 " " " " = 6
" " $x^2 dm$ " 70.75 " " " " = 1
" " $y^2 dm$ " 29.43 " " " " = 1
" " dm " 223.56 " " " " = .01

$a = \frac{1.75 \times 6}{2 \times 70.75} = .07$ INS. $b = \frac{-19.82 \times 6}{2 \times 29.43} = -2.02$ INS.

$$i_\rho^2 = \frac{102.76}{223.56 \times .01} = 45.97$$

$$i_o^2 = .00 + 4.09 + 45.97 = 50.06$$

$i_o = 7.07$ INS. ON DRAWING — FULL SIZE = 42.42 INS.

*VALUES OF ρ, x, AND y ARE MEASURED IN INCHES ON PLATE 36.

To illustrate paper on "Calculation of the Transverse Strength of Submarines by Marbec's Method," by Professor William Hovgaard, Member.

TABLE V

INTERNAL RESULTANT AND BENDING MOMENT

(SEE CURVES – PLATE 36)

p = LBS. PER INCH RUN OF FRAMES SPACED 15 IN. APART FOR A PRESSURE HEAD OF 50 FT. OF SEA WATER = $\frac{50 \times 64 \times 15}{144}$ = 333.4 LBS. SQ. IN.

i_o^2 = 1799 INCHES^2

SECTON	r INCHES	INTERNAL RESULTANT $r \times p$ LBS.	r^2	$i_o^2 - r^2$	MOMENT $\frac{p}{2}(i_o^2 - r^2)$ IN. LBS.
A	39.76	13,260	1,581	+218	+36,340
B	41.90	13,970	1,756	+43	+7,168
C	45.50	15,170	2,070	−271	−45,180
D	43.75	14,590	1,914	−115	−19,170
E	38.75	12,920	1,502	+297	+49,510
F	35.00	11,670	1,225	+574	+95,680
H	34.10	11,370	1,163	+636	+106,020
I	36.00	12,000	1,296	+503	+83,860
J	40.12	13,380	1,610	+189	+31,510
K	43.08	14,360	1,856	−57	−9,500
L	44.83	14,950	2,010	−211	−35,170
M	41.38	13,800	1,712	+87	+14,500

TABLE VI
CALCULATION OF STRESSES

$$\sigma = \frac{R}{A} + \frac{My}{I}$$

SECTION A

$\frac{R}{A} = \frac{13,260}{3.15}$ = 4,210 LBS. SQ. IN.

$\frac{My}{I}$ = TENSION – INNER FLG. $\frac{36,340 \times 2.42}{7.36}$ = 11,950 LBS. SQ. IN.

$\frac{My}{I}$ = COMPRESSION – SHELL $\frac{36,340 \times 1.73}{7.36}$ = 8,540 LBS. SQ. IN.

TENSION = 11,950 − 4,210 = 7,740 LBS. SQ. IN. COMPRESSION = 8,540 + 4,210 = 12,750 LBS. SQ. IN.

SECTION C

$\frac{R}{A} = \frac{15,170}{3.15}$ = 4,820 LBS. SQ. IN.

$\frac{My}{I}$ = TENSION – SHELL $\frac{45,180 \times 1.73}{7.36}$ = 10,620 LBS. SQ. IN.

$\frac{My}{I}$ = COMPRESSION – INNER FLG. $\frac{45,180 \times 2.42}{7.36}$ = 14,860 LBS. SQ. IN.

TENSION = 10,620 − 4,820 = 5,800 LBS. SQ. IN. COMPRESSION = 14,860 + 4,820 = 19680 LBS. SQ. IN.

SECTION H

$\frac{R}{A} = \frac{11,370}{4.18}$ = 2,720 LBS. SQ. IN.

$\frac{My}{I}$ = TENSION – INNER FLG. $\frac{106,020 \times 13.78}{98.73}$ = 14,800 LBS. SQ. IN.

$\frac{My}{I}$ = COMPRESSION – SHELL $\frac{106,020 \times 3.22}{98.73}$ = 3,458 LBS. SQ. IN.

TENSION = 14,800 − 2,720 = 12,080 LBS. SQ. IN. COMPRESSION = 3,458 + 2,720 = 6,178 LBS. SQ. IN.

SECTION L

$\frac{R}{A} = \frac{14,950}{3.15}$ = 4,745 LBS. SQ. IN.

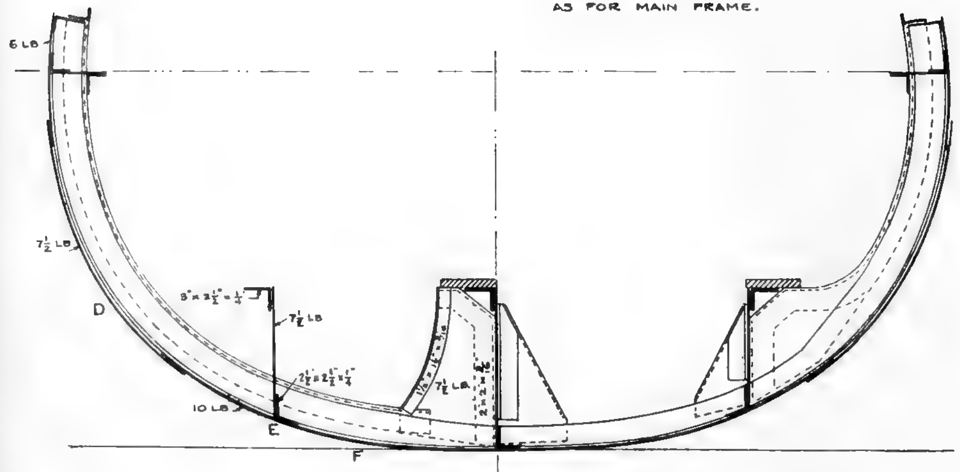
$\frac{My}{I}$ = TENSION – SHELL $\frac{35,170 \times 1.73}{7.36}$ = 8,270 LBS. SQ. IN.

$\frac{My}{I}$ = COMPRESSION – INNER FLG. $\frac{35,170 \times 2.42}{7.36}$ = 11,560 LBS. SQ. IN.

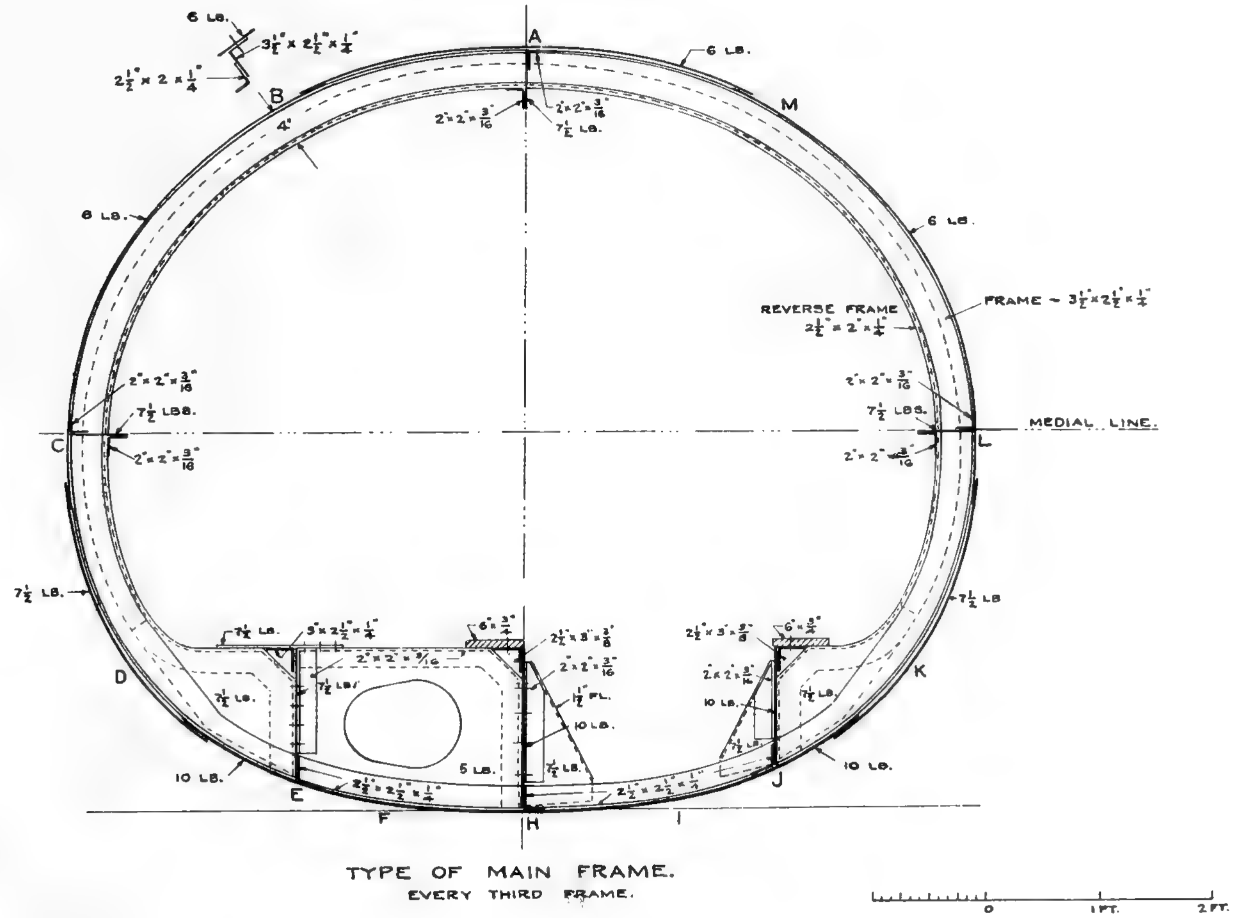
TENSION = 8,270 − 4,745 = 3,525 LBS. SQ. IN. COMPRESSION = 11,560 + 4,745 = 16,305 LBS. SQ. IN.

To illustrate paper on "Calculation of the Transverse Strength of Submarines by Marbec's Method," by Professor William Hovgaard, Member.

MIDSHIP SECTION.

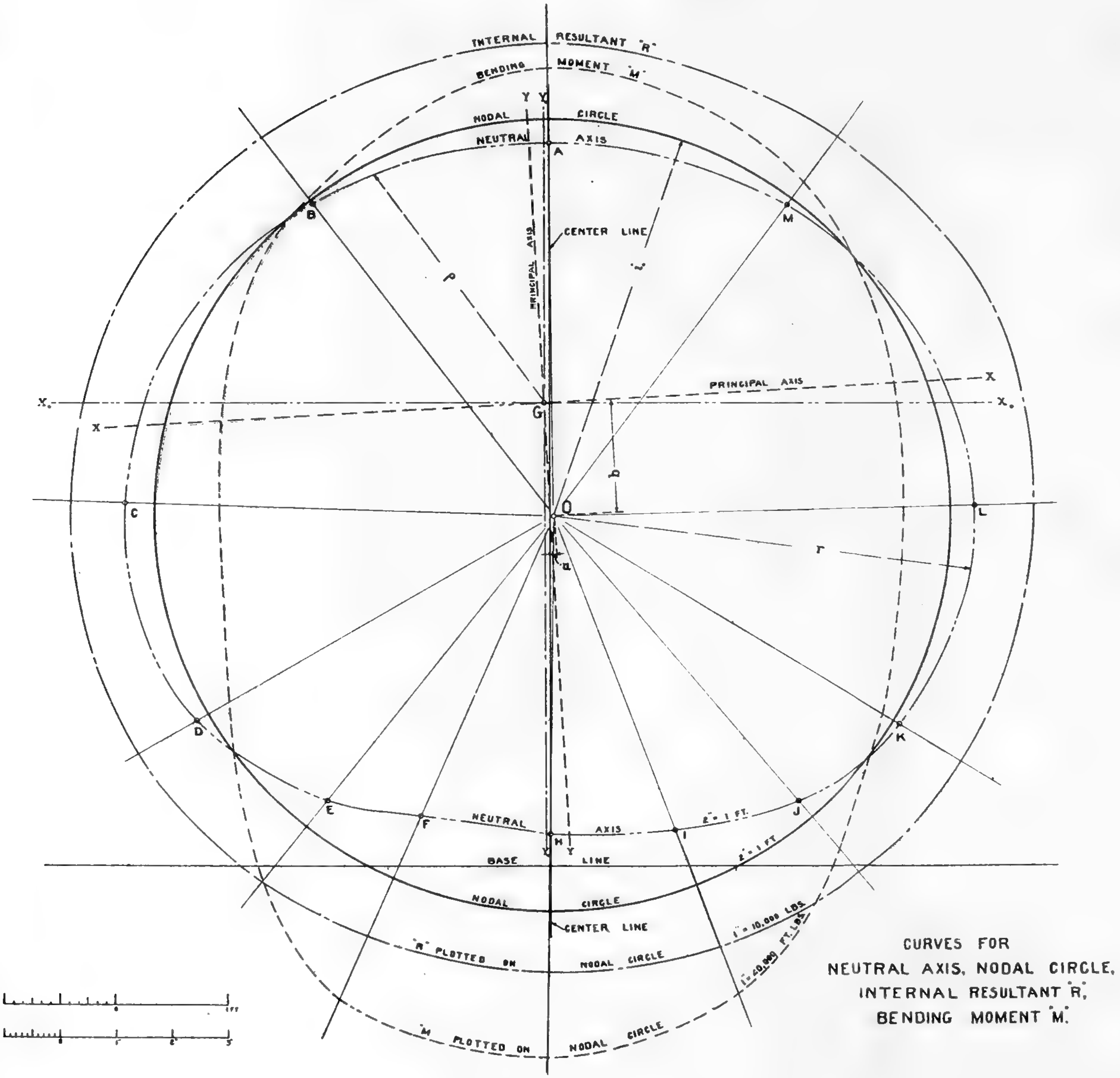


TYPE OF INTERMEDIATE FRAME.

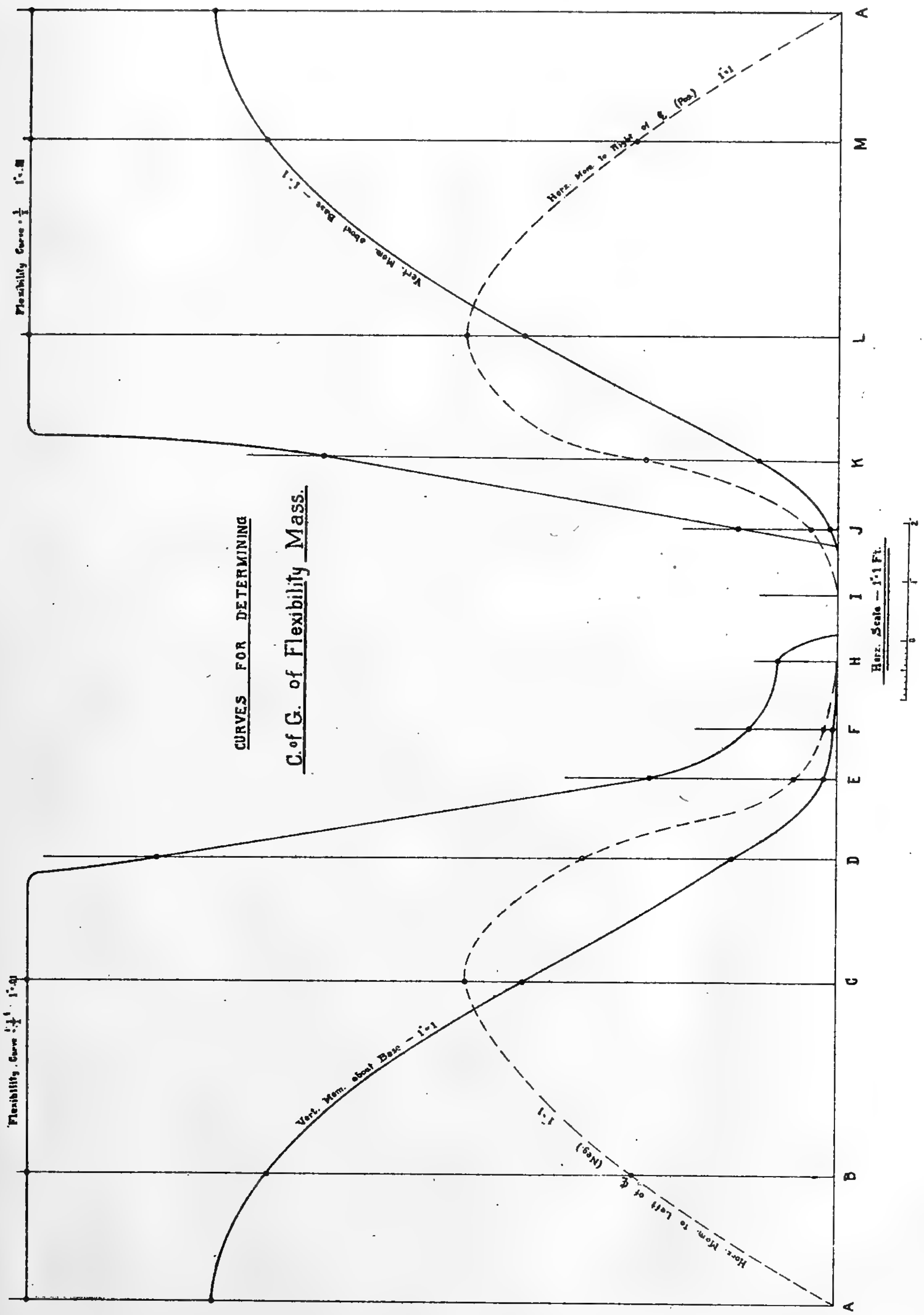


TYPE OF MAIN FRAME.
EVERY THIRD FRAME.

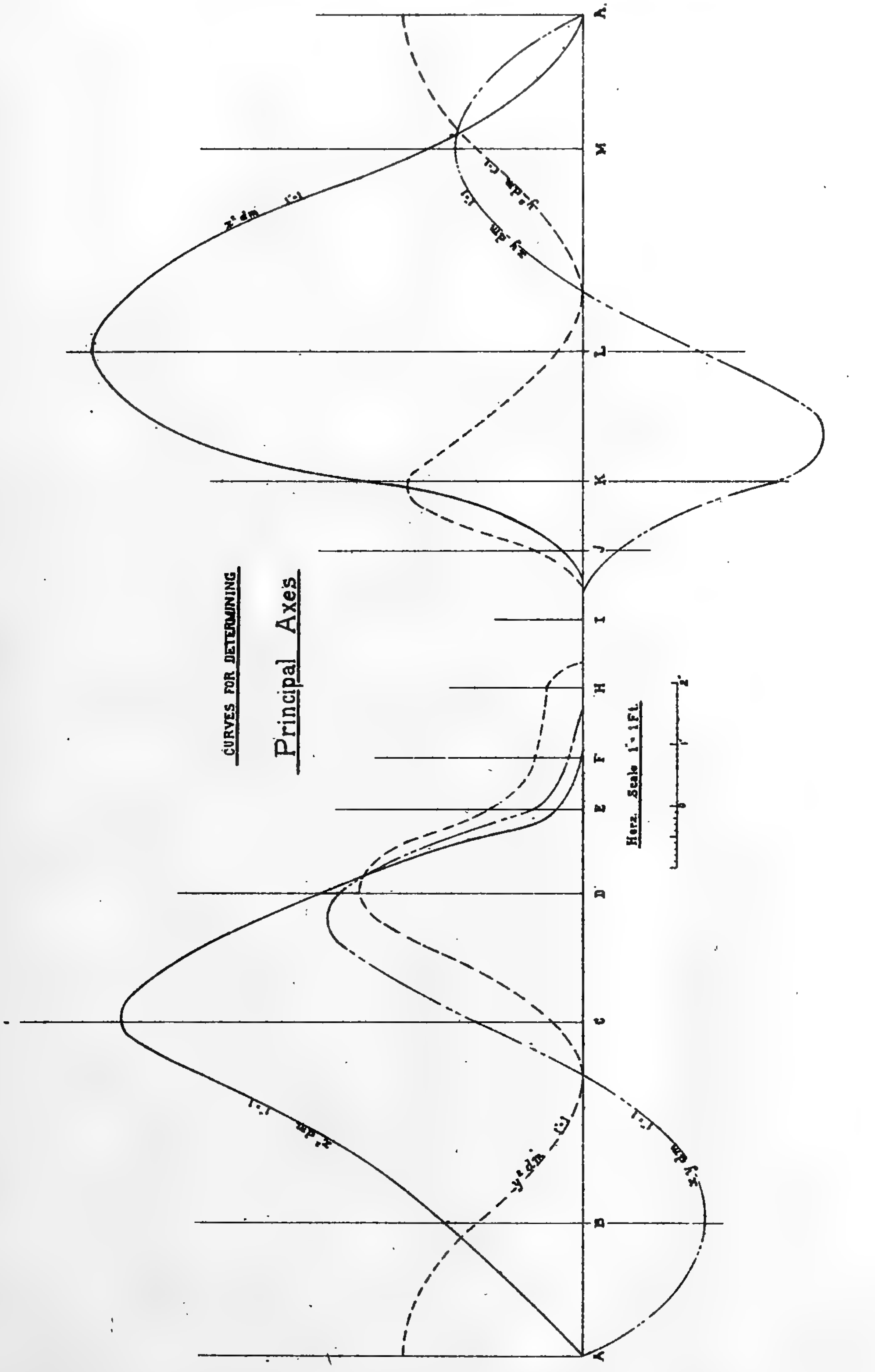
To illustrate paper on "Calculation of the Transverse Strength of Submarines by Marbec's Method," by Professor William Hovgaard, Member.



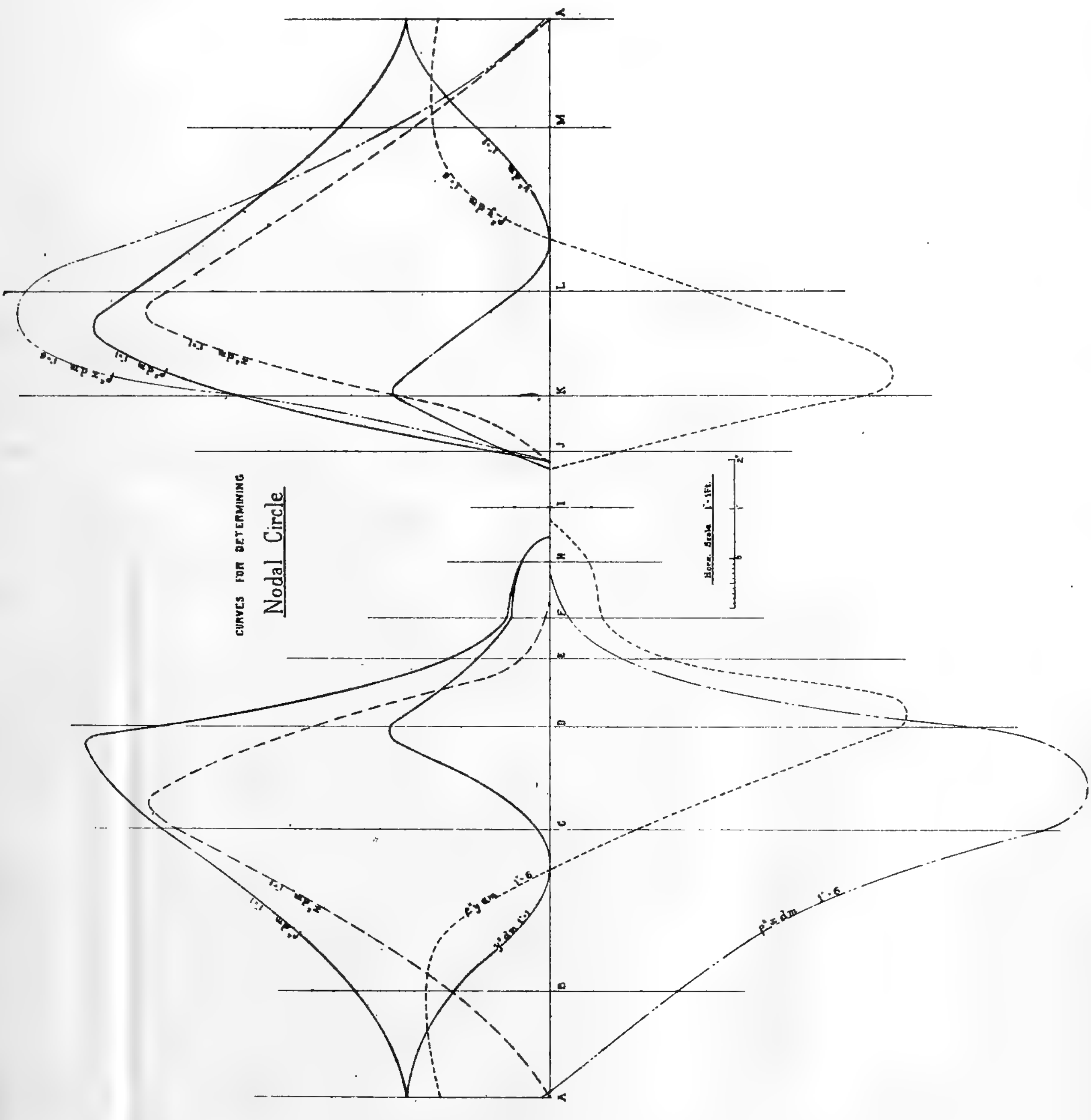
To illustrate paper on "Calculation of the Transverse Strength of Submarines by Marbec's Method," by Professor William Hovgaard, Member.



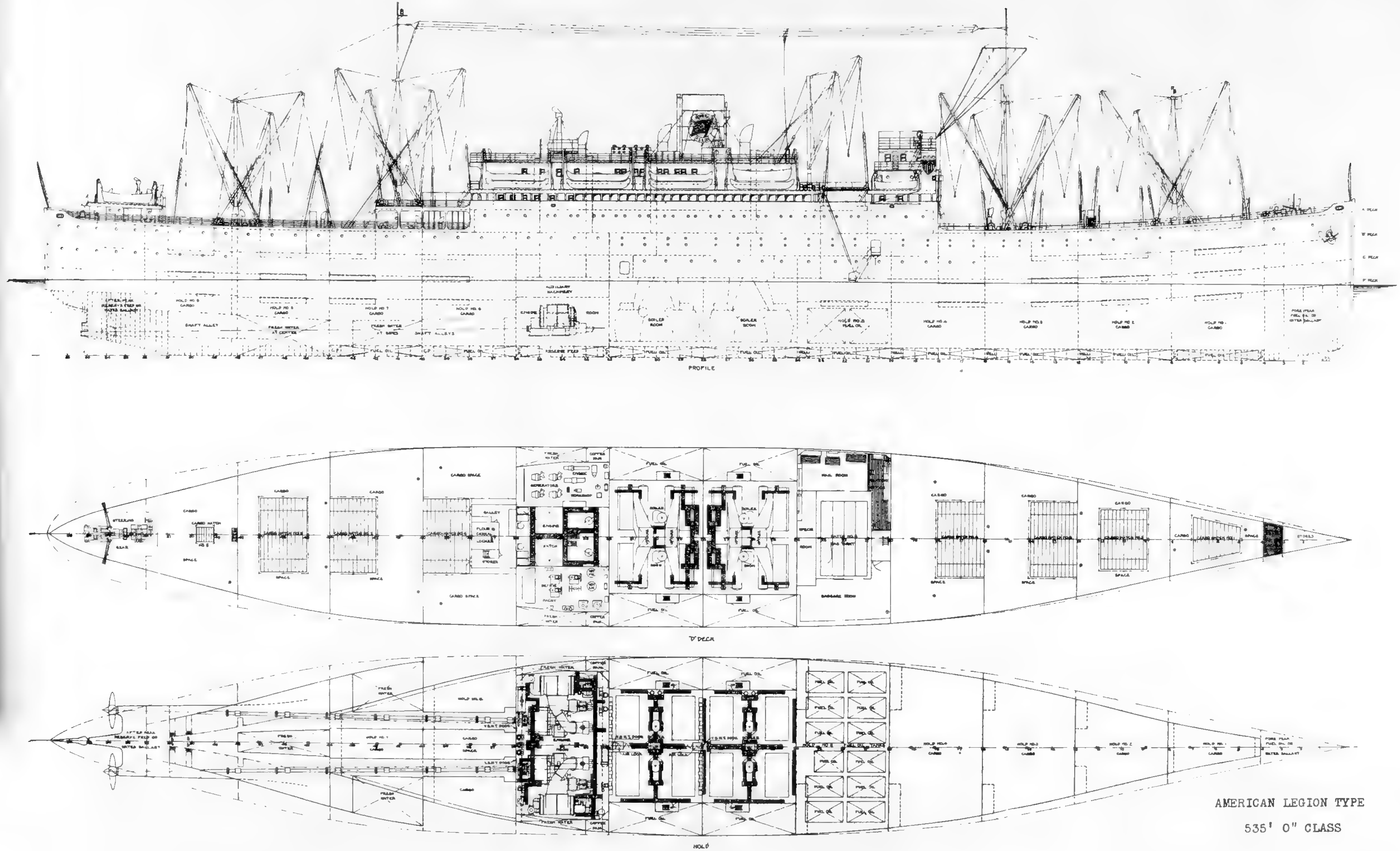
To illustrate paper on "Calculation of the Transverse Strength of Submarines by Marbec's Method," by Professor William Hovgaard, Member.



To illustrate paper on "Calculation of the Transverse Strength of Submarines by Marbec's Method," by Professor William Hovgaard, Member.

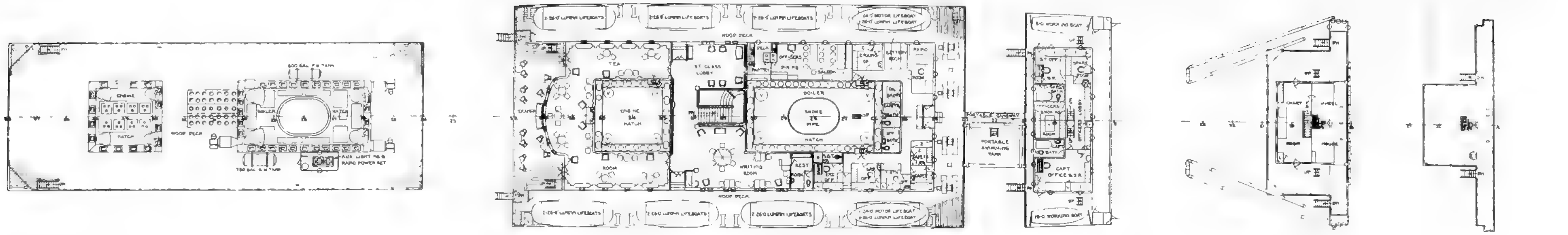


To illustrate paper on "Design and Construction of Passenger Steamers,"
by E. H. Rigg, Esq., Member of Council.

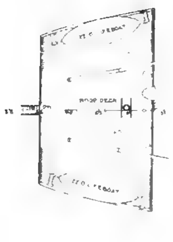


AMERICAN LEGION TYPE

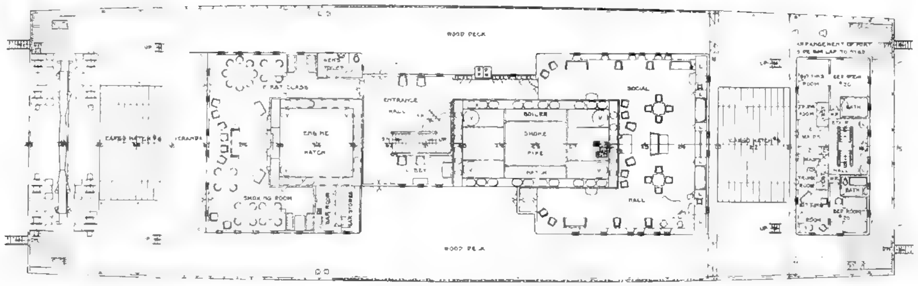
535' 0" CLASS



HOUSE TOP BOAT DECK NAVIGATING BRIDGE FLYING BRIDGE



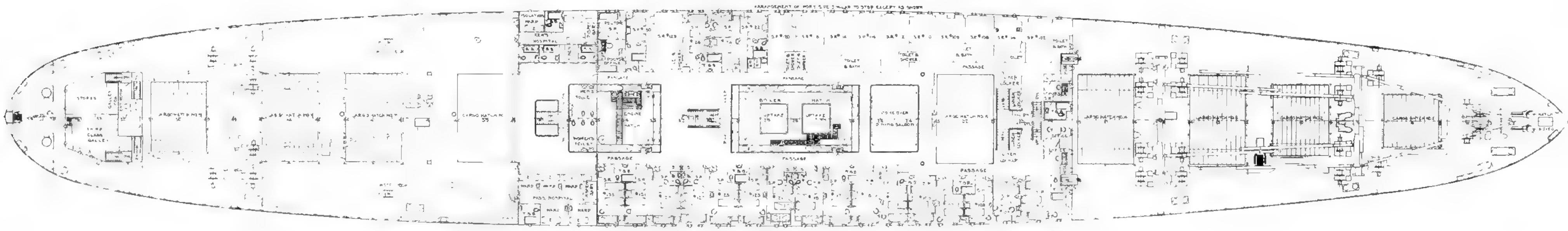
HOUSE TOP



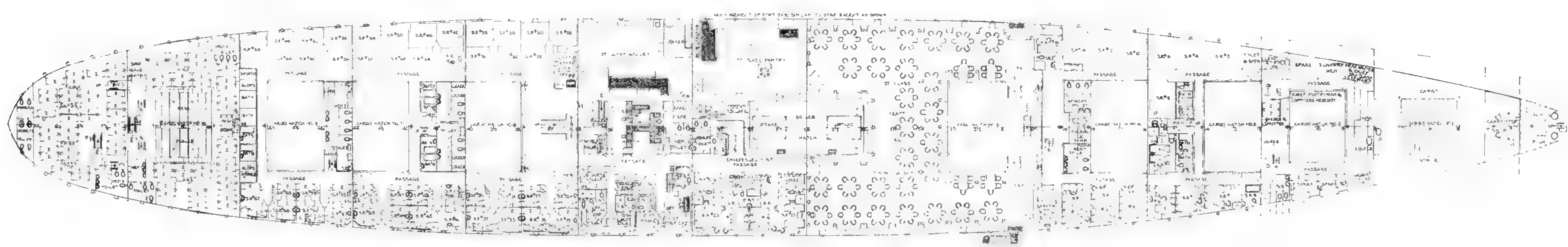
BRIDGE DECK

TABLE OF PASSENGERS & CREW

DECK	PASSENGERS				OFFICERS & CREW					
	FIRST CLASS		THIRD CLASS	TOTAL PASS	DEPARTMENT			SPARE ROOMS		TOTAL CREW
	ROOMS	BERTHS			DECK	ENG'RS	STEW'D'S	ROOMS	BERTHS	
BOAT	—	—	—	—	10	—	—	1	1	11
BRIDGE	4	8	—	8	—	—	—	—	—	—
"A"	31	85	—	85	—	—	2	—	—	2
"B"	65	161	144	305	2	1	15	3	9	37
"C"	—	—	154	154	33	35	92	—	—	161
TOTALS	100	284	298	552	45	46	109	4	10	210



"A" DECK



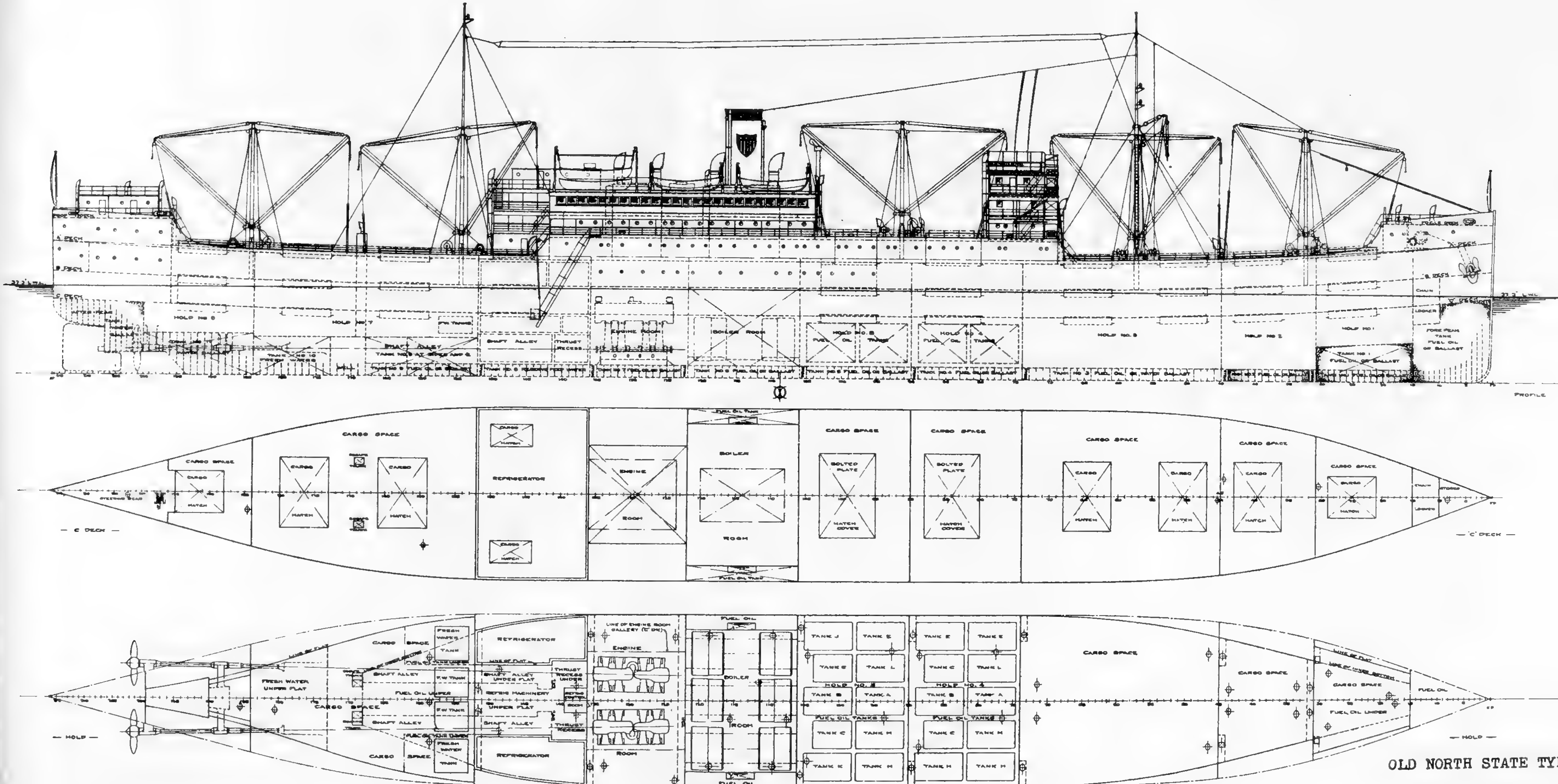
"B" DECK

"C" DECK

AMERICAN LEGION TYPE

535' 0" CLASS

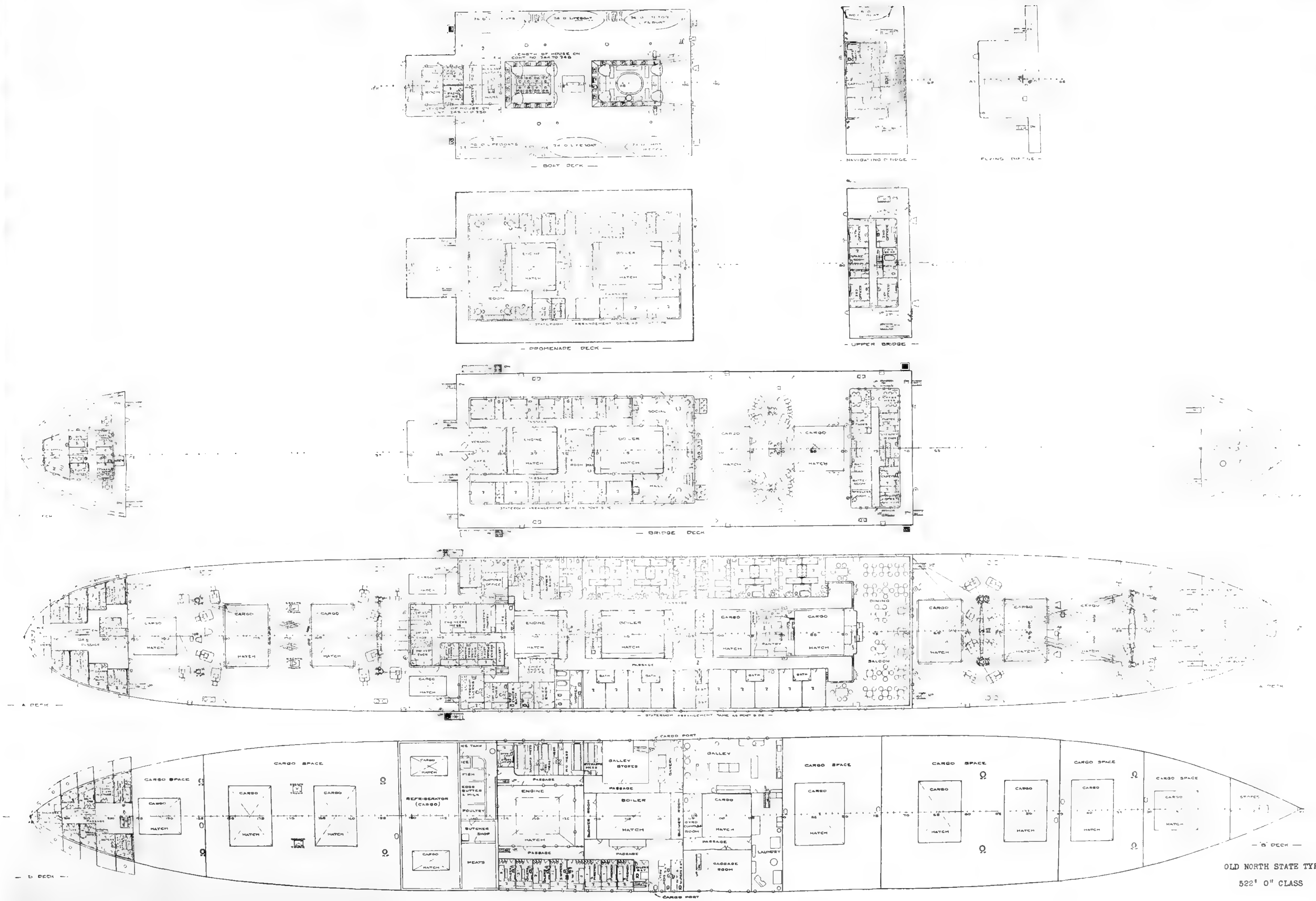
To illustrate paper on "Design and Construction of Passenger Steamers,"
by E. H. Rigg, Esq., Member of Council.



OLD NORTH STATE TYPE

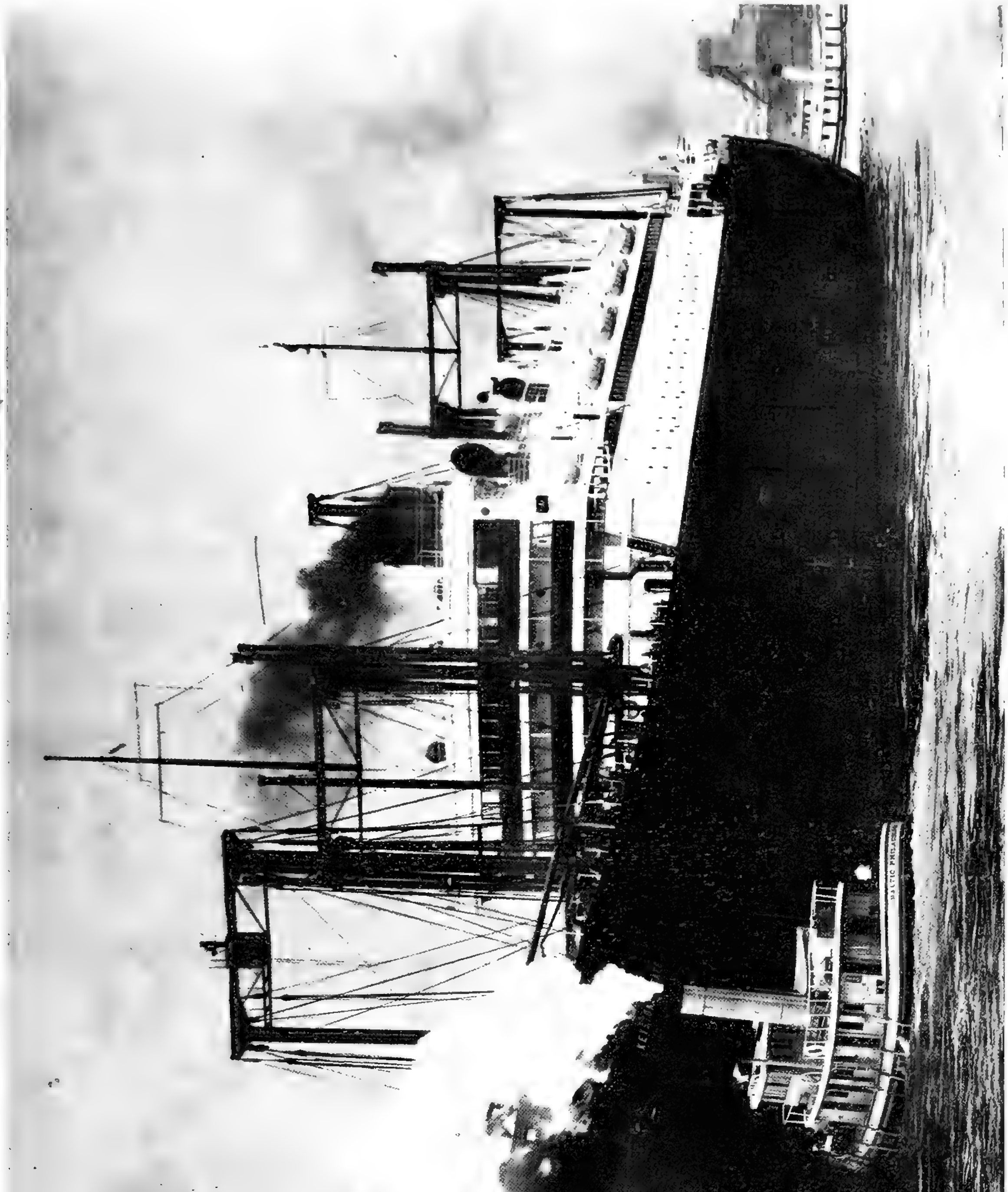
522' 0" CLASS

To illustrate paper on "Design and Construction of Passenger Steamers,"
by E. H. Rigg, Esq., Member of Council.



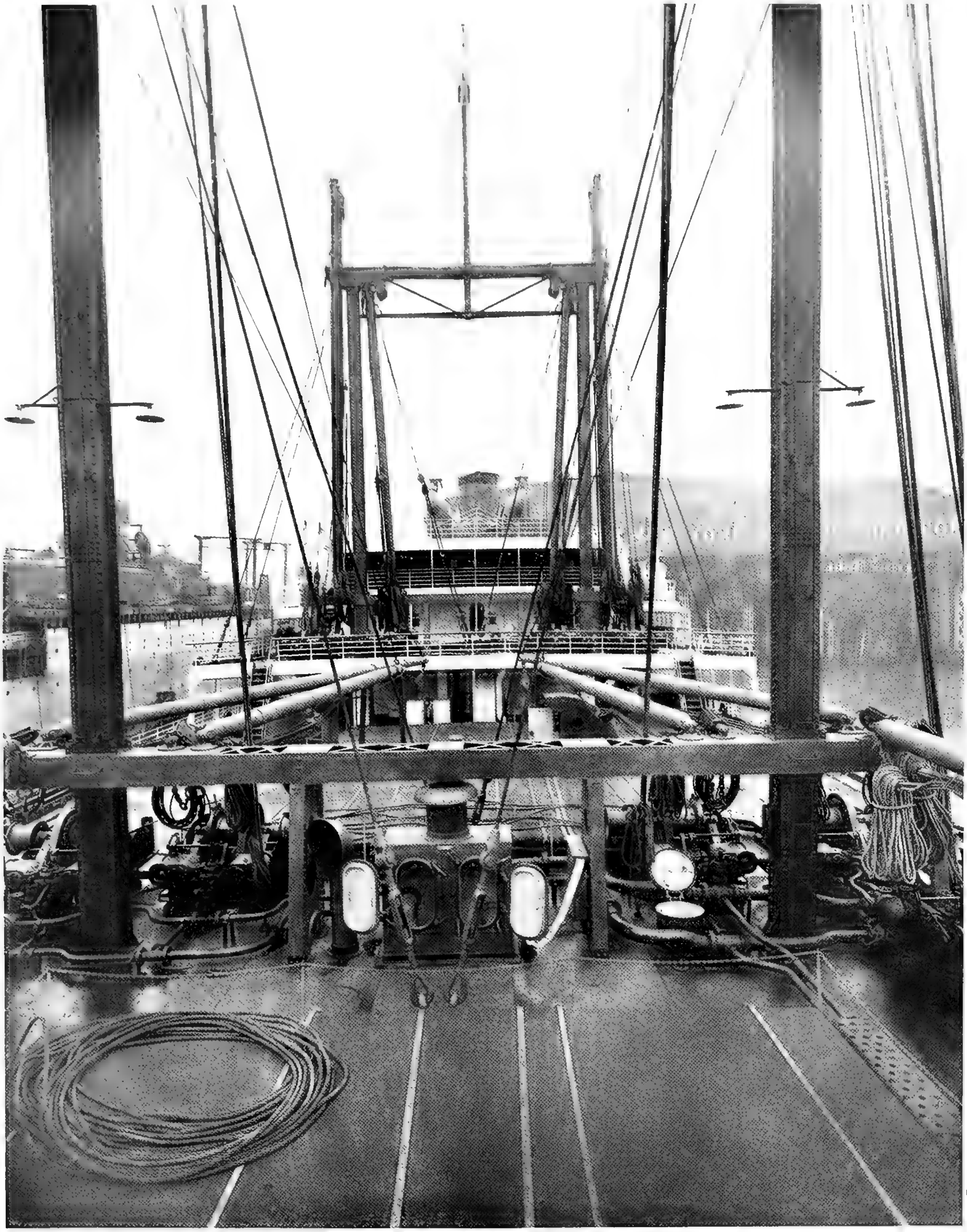
OLD NORTH STATE TYPE
522' 0" CLASS

To illustrate paper on "Design and Construction of Passenger Steamers," by E. H. Rigg, Esq., Member of Council.



American Legion Class:—Keystone State Being Warped Away from Pier Preparatory to Leaving on Maiden Voyage.

To illustrate paper on "Design and Construction of Passenger Steamers," by E. H. Rigg, Esq., Member of Council.



American Legion Class:—Wenatchee. View from After Deck House, Looking Forward.

To illustrate paper on "Design and Construction of Passenger Steamers," by E. H. Rigg, Esq., Member of Council.

American Legion Class:—American Legion, Social Hall.

To illustrate paper on "Design and Construction of Passenger Steamers," by E. H. Rigg, Esq., Member of Council.

American Legion Class:—Wenatchee. View of Social Hall, Showing Fireplace.

To illustrate paper on "Design and Construction of Passenger Steamers," by E. H. Rigg, Esq., Member of Council.

American Legion Class:—American Legion, Dining Room.

To illustrate paper on "Design and Construction of Passenger Steamers," by E. H. Rigg, Esq., Member of Council.

American Legion Class:—Wenatchee, Smoking Room.

To illustrate paper on "Design and Construction of Passenger Steamers," by E. H. Rigg, Esq., Member of Council.

American Legion Class:—American Legion, Tea Room.

To illustrate paper on "Design and Construction of Passenger Steamers," by E. H. Rigg, Esq., Member of Council.

Old North State Class:—Pan Handle State. Trial Trip.

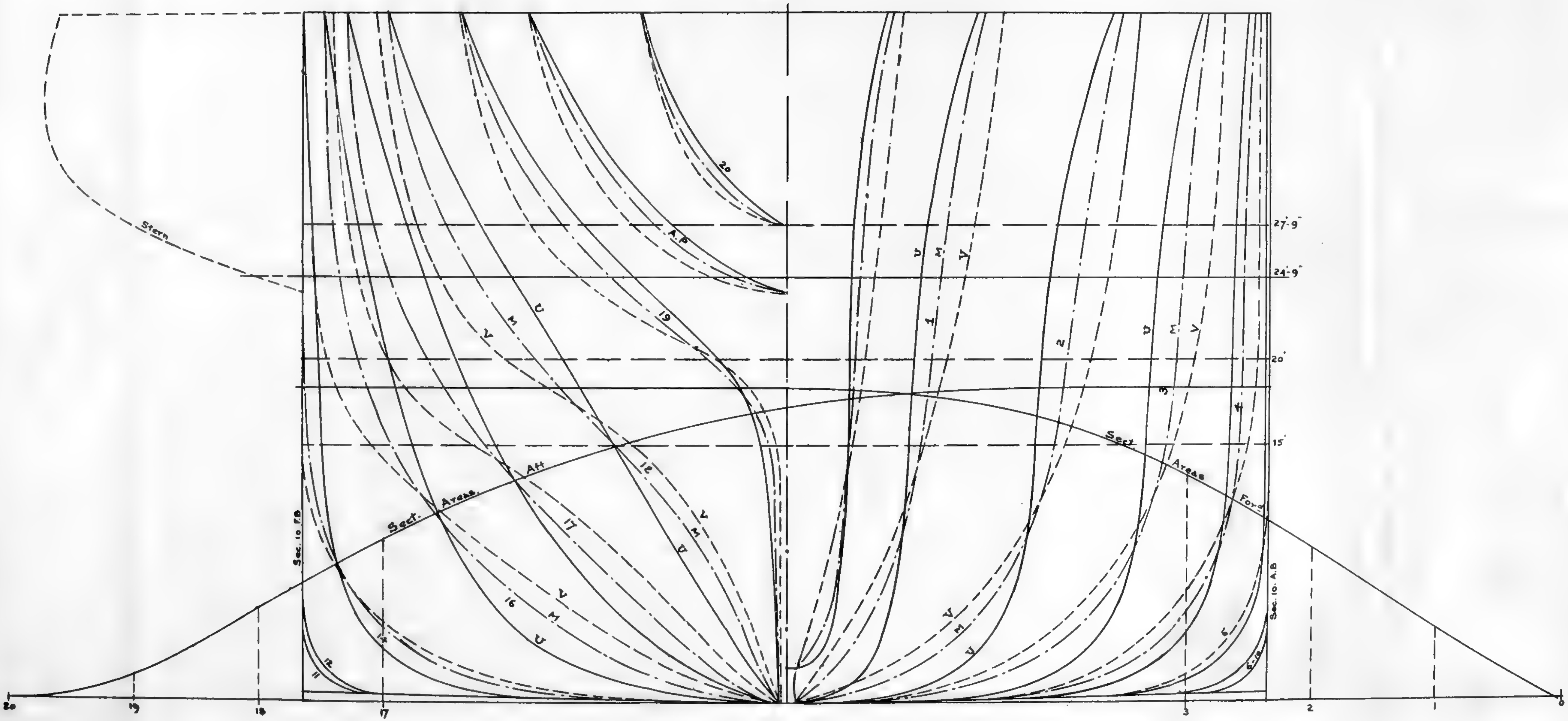
To illustrate paper on "Design and Construction of Passenger Steamers," by E. H. Rigg, Esq., Member of Council.

Old North State Class:—Pan Handle State. First-Class State Room.

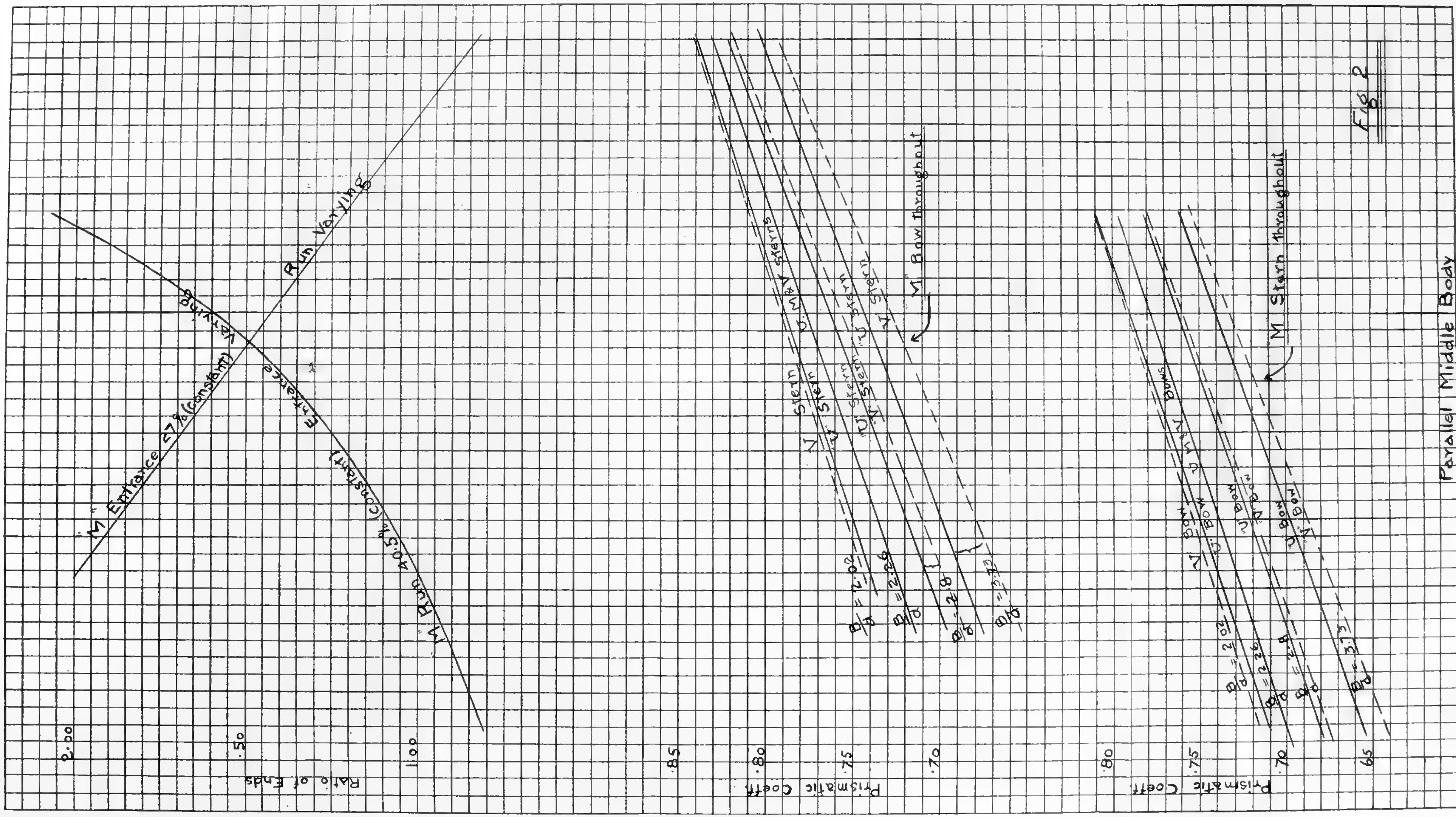
To illustrate paper on "The Influence of Shape of Transverse Sections Upon Resistance," by Professor Herbert C. Sadler, Member of Council, and Professor E. M. Bragg, Member.

Body Plans

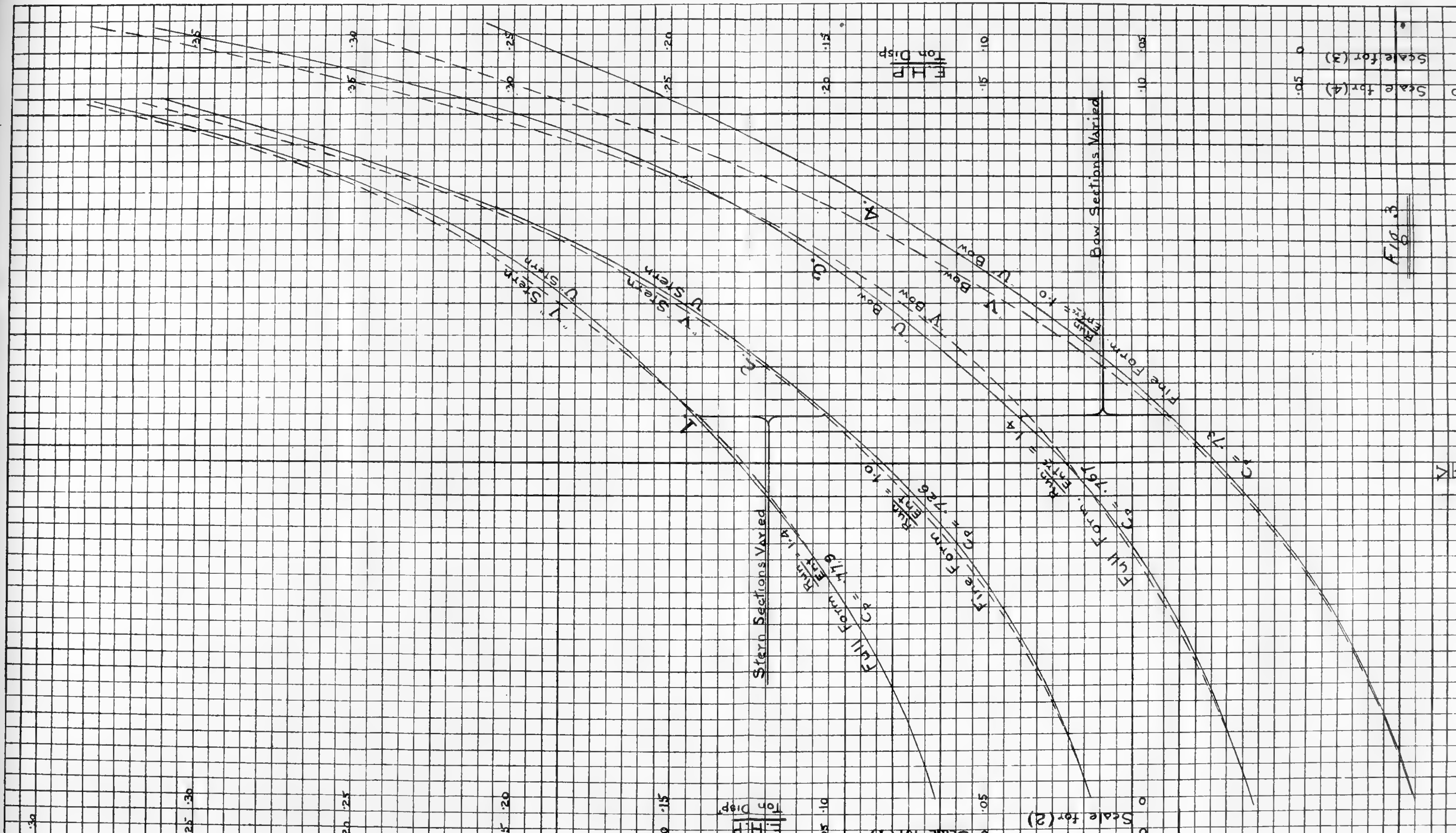
Fig. 1.



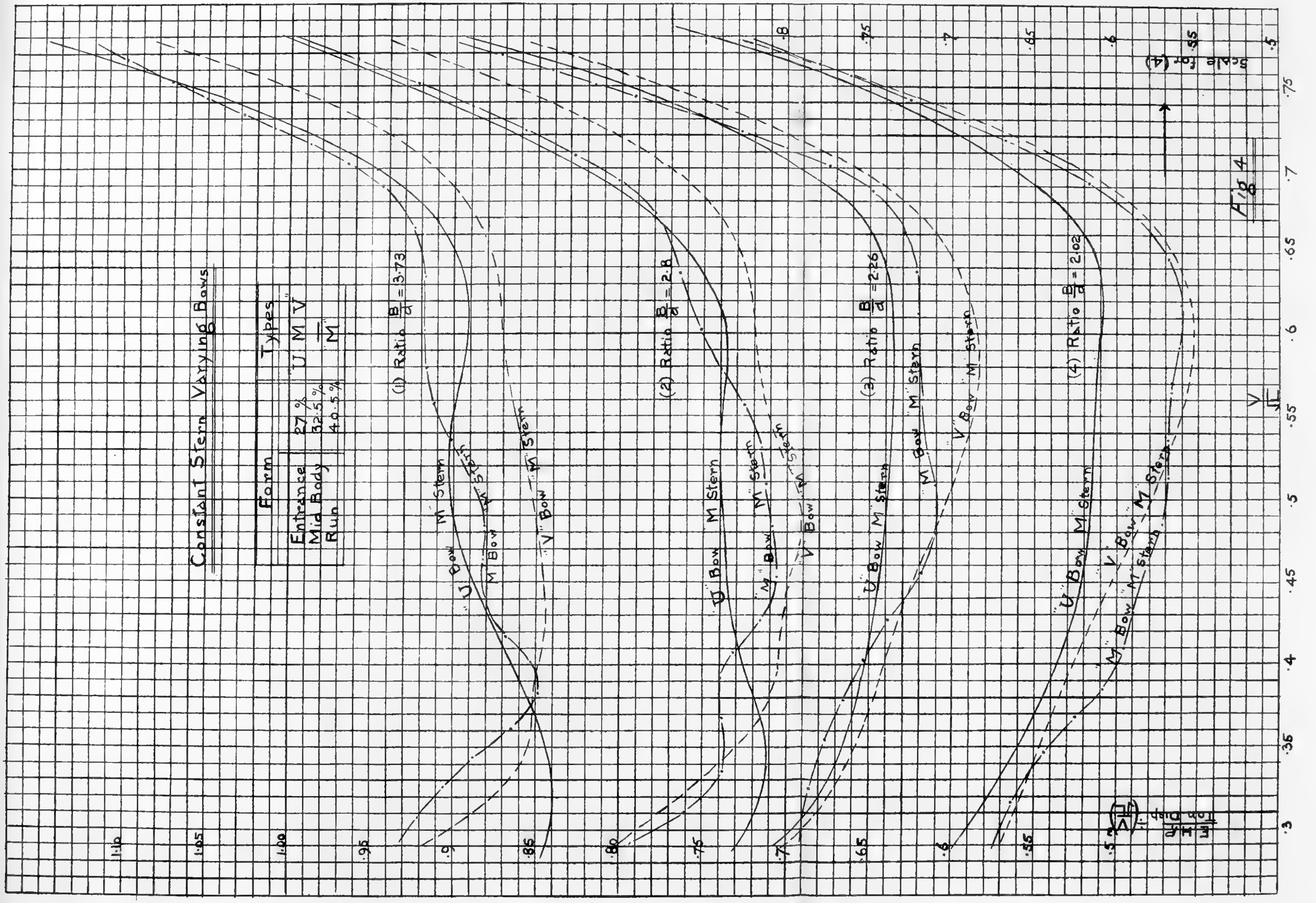
To illustrate paper on "The Influence of Shape of Transverse Sections Upon Resistance," by Professor Herbert C. Sadler, Member of Council, and Professor E. M. Bragg, Member.



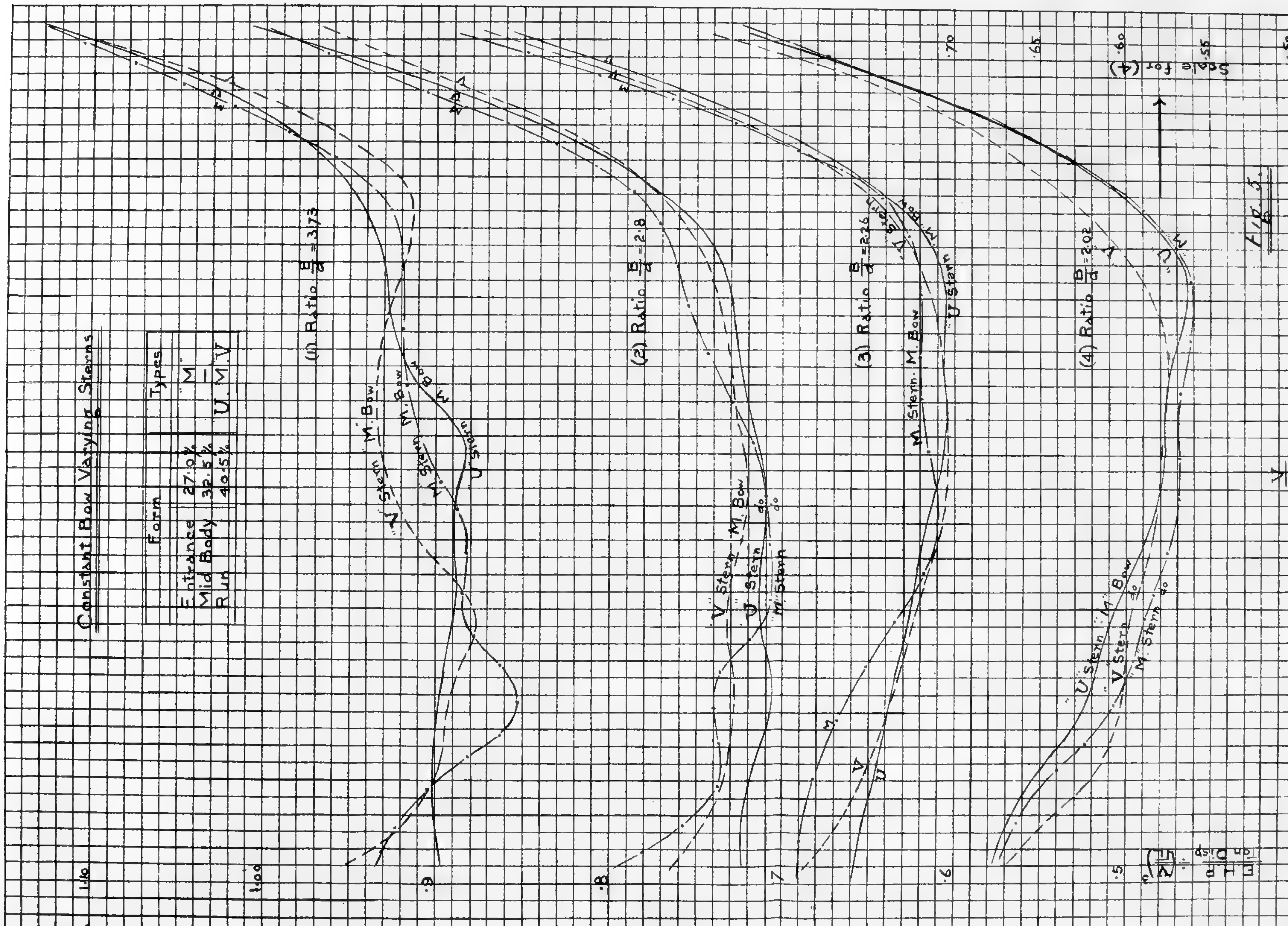
To illustrate paper on "The Influence of Shape of Transverse Sections Upon Resistance," by Professor Herbert C. Sadler, Member of Council, and Professor E. M. Bragg, Member.



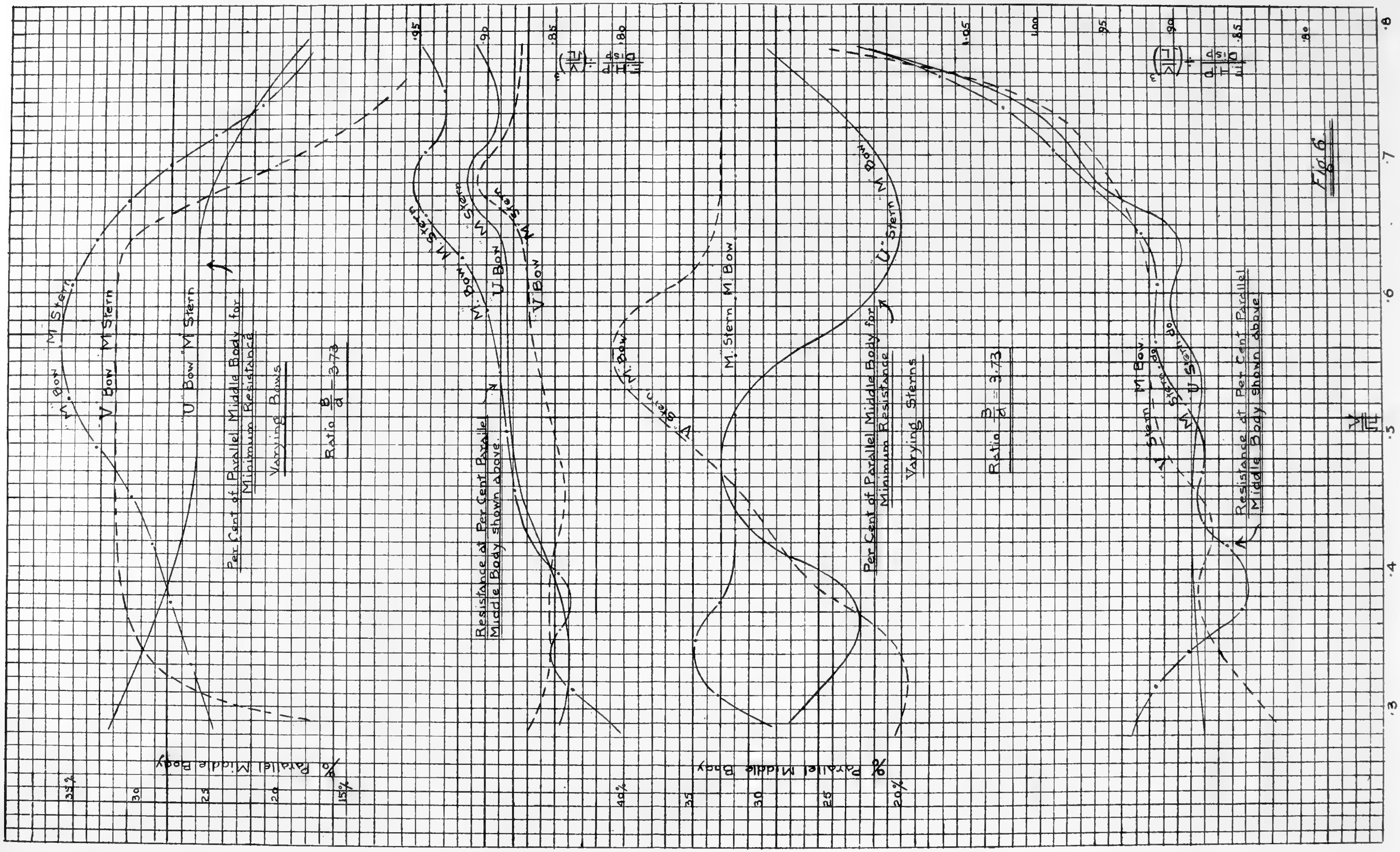
To illustrate paper on "The Influence of Shape of Transverse Sections Upon Resistance," by Professor Herbert C. Sadler, Member of Council, and Professor E. M. Bragg, Member.



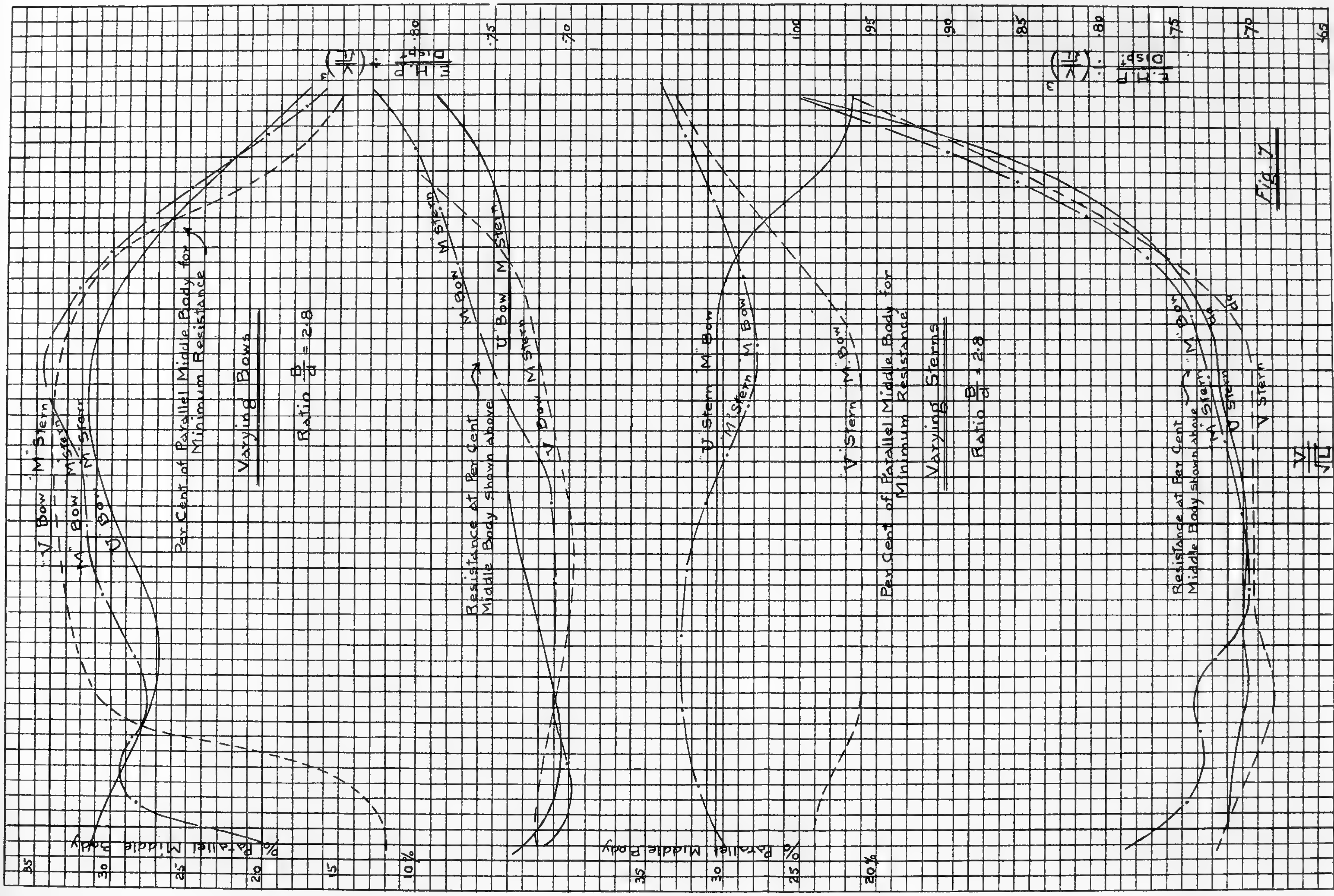
To illustrate paper on "The Influence of Shape of Transverse Sections Upon Resistance," by Professor Herbert C. Sadler, Member of Council, and Professor E. M. Bragg, Member.



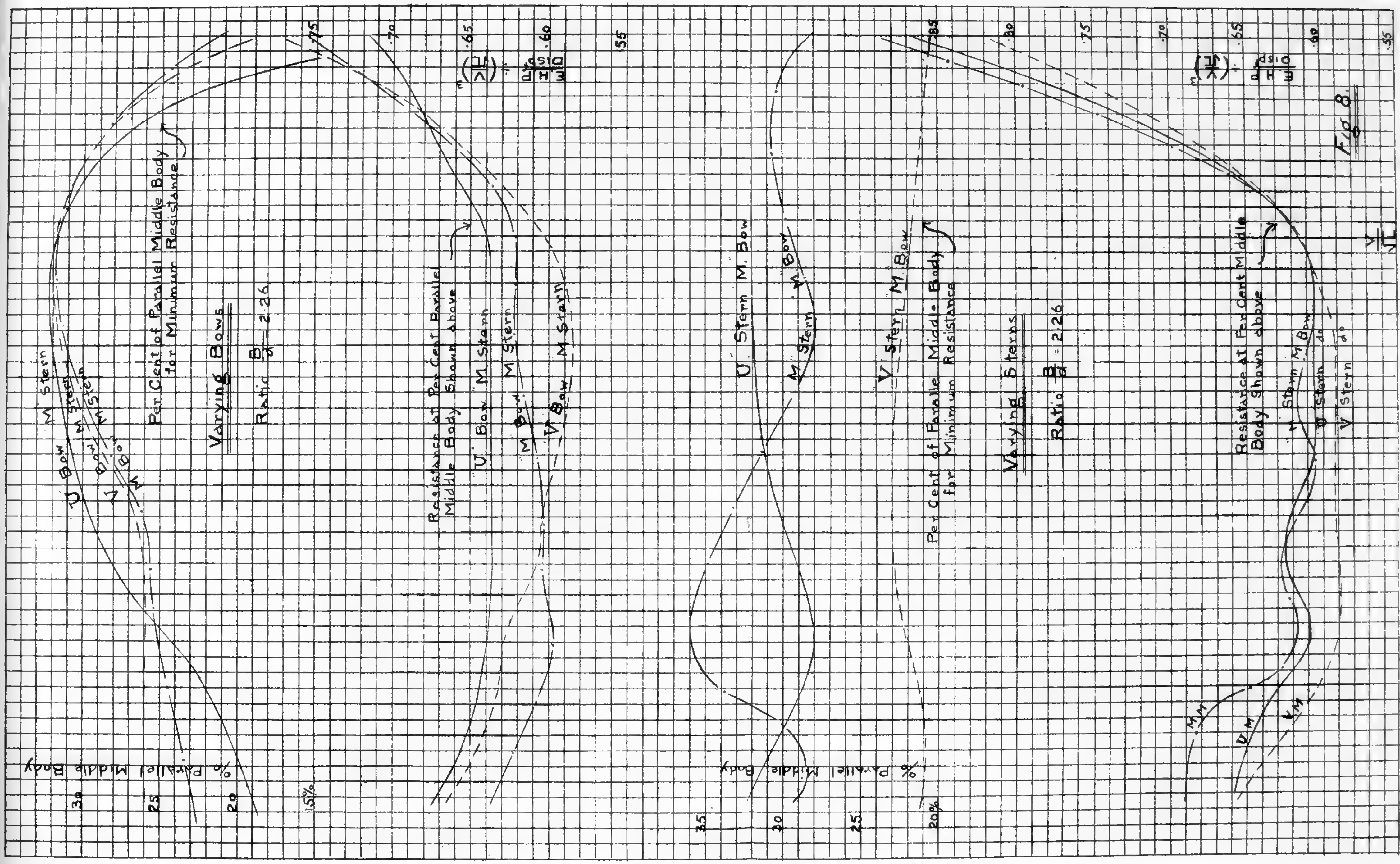
To illustrate paper on "The Influence of Shape of Transverse Sections Upon Resistance," by Professor Herbert C. Sadler, Member of Council, and Professor E. M. Bragg, Member.



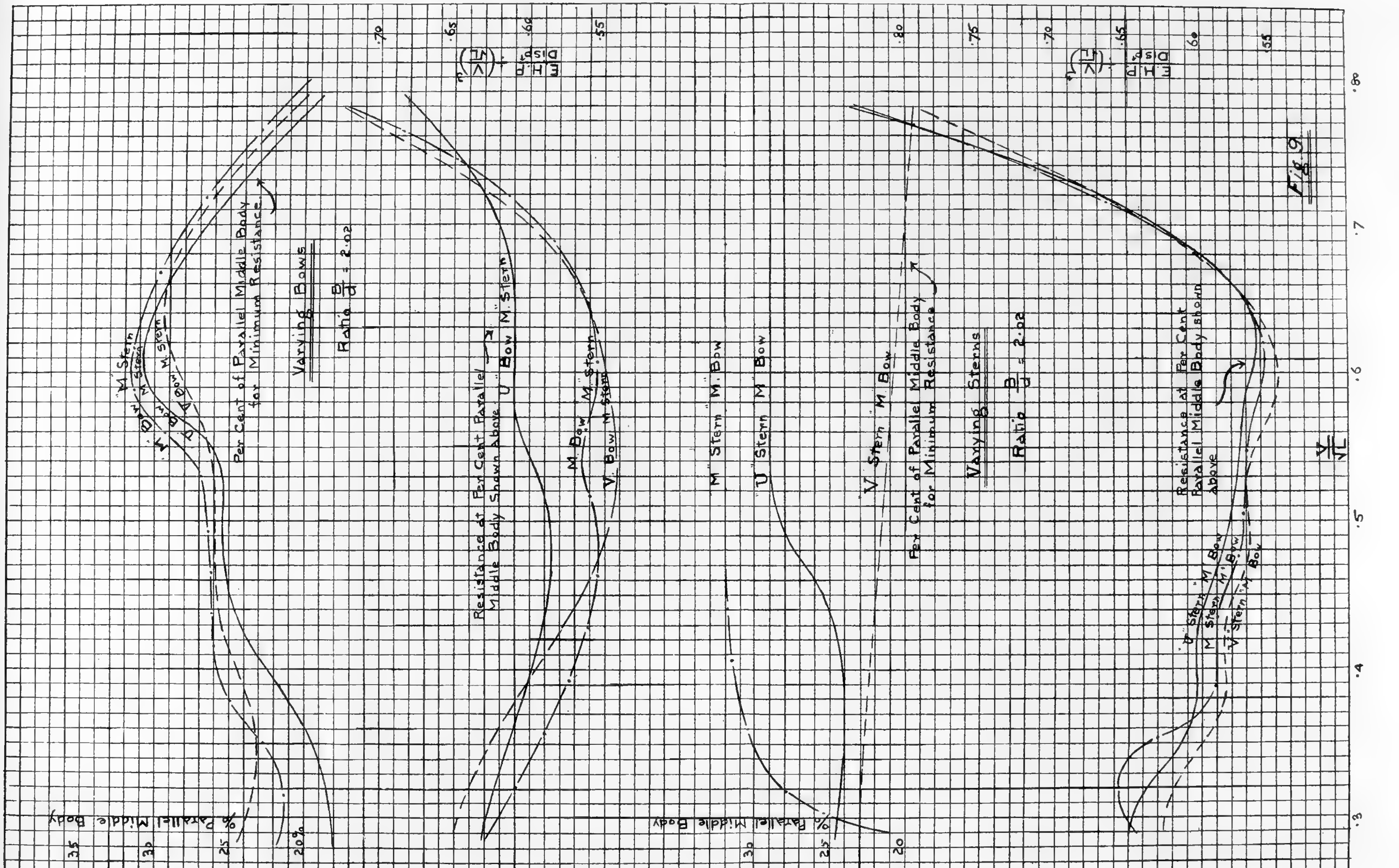
To illustrate paper on "The Influence of Shape of Transverse Sections Upon Resistance," by Professor Herbert C. Sadler, Member of Council, and Professor E. M. Bragg, Member.



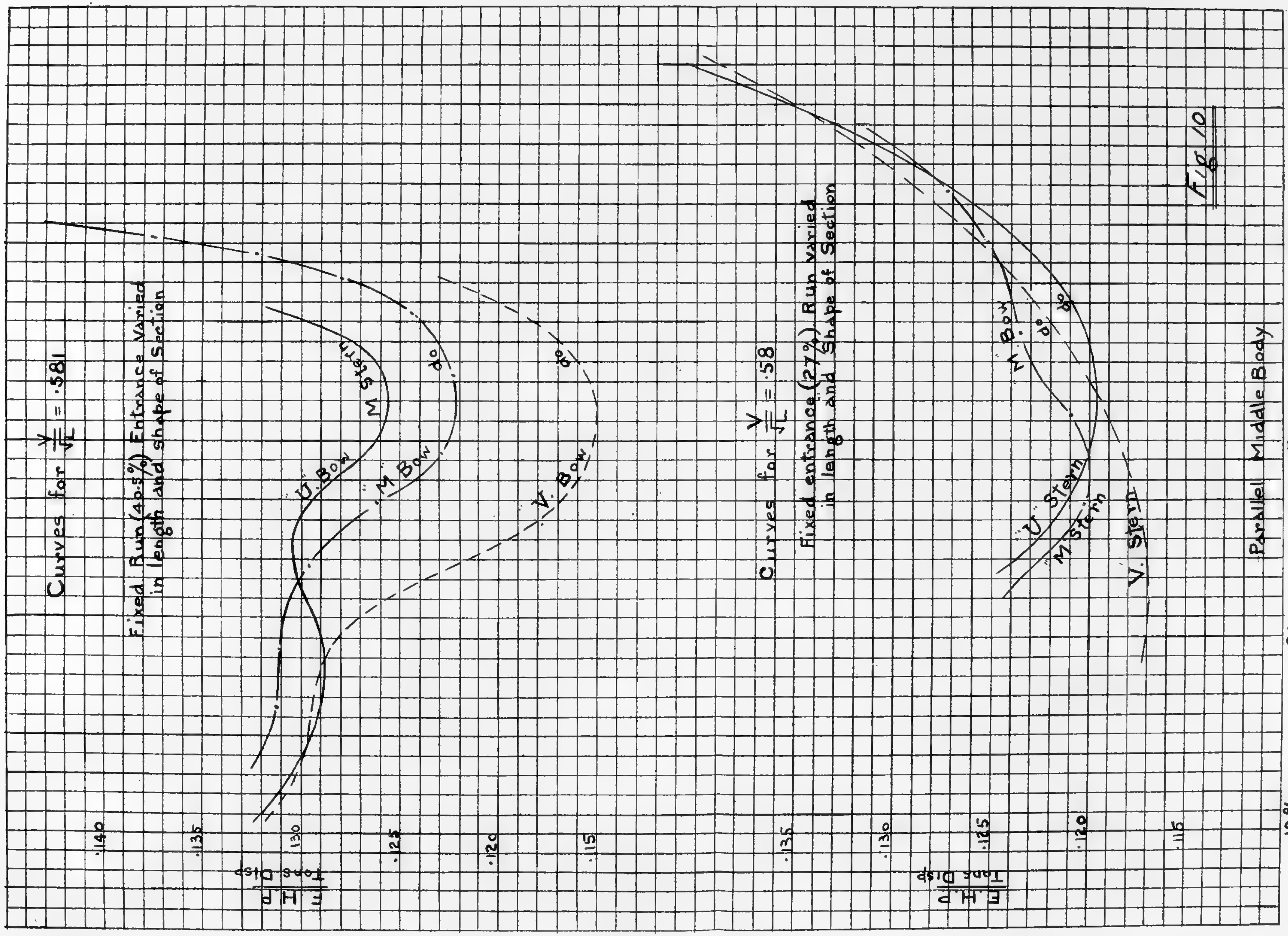
To illustrate paper on "The Influence of Shape of Transverse Sections Upon Resistance," by Professor Herbert C. Sadler, Member of Council, and Professor E. M. Bragg, Member.



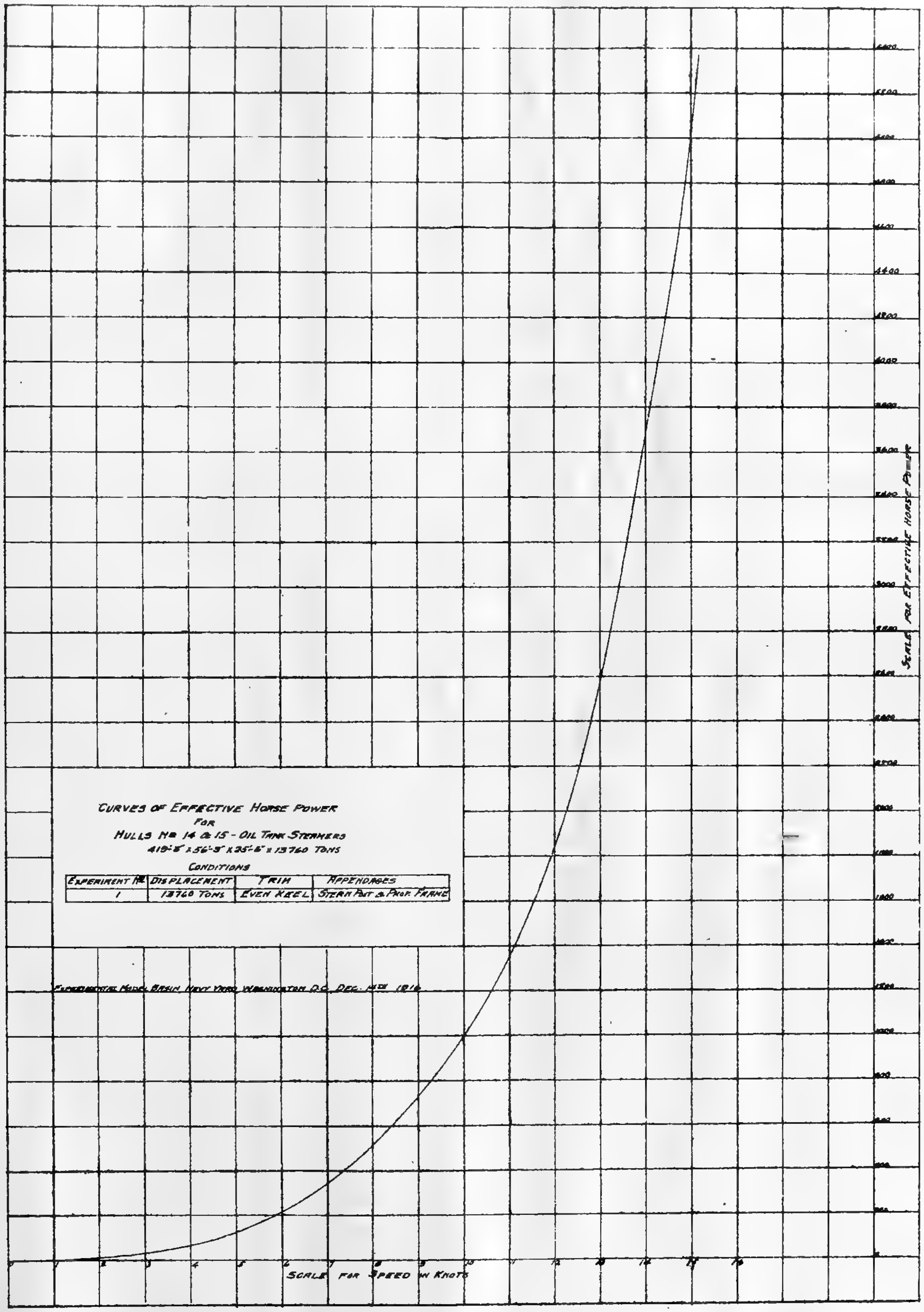
To illustrate paper on "The Influence of Shape of Transverse Sections Upon Resistance," by Professor Herbert C. Sadler, Member of Council, and Professor E. M. Bragg, Member.



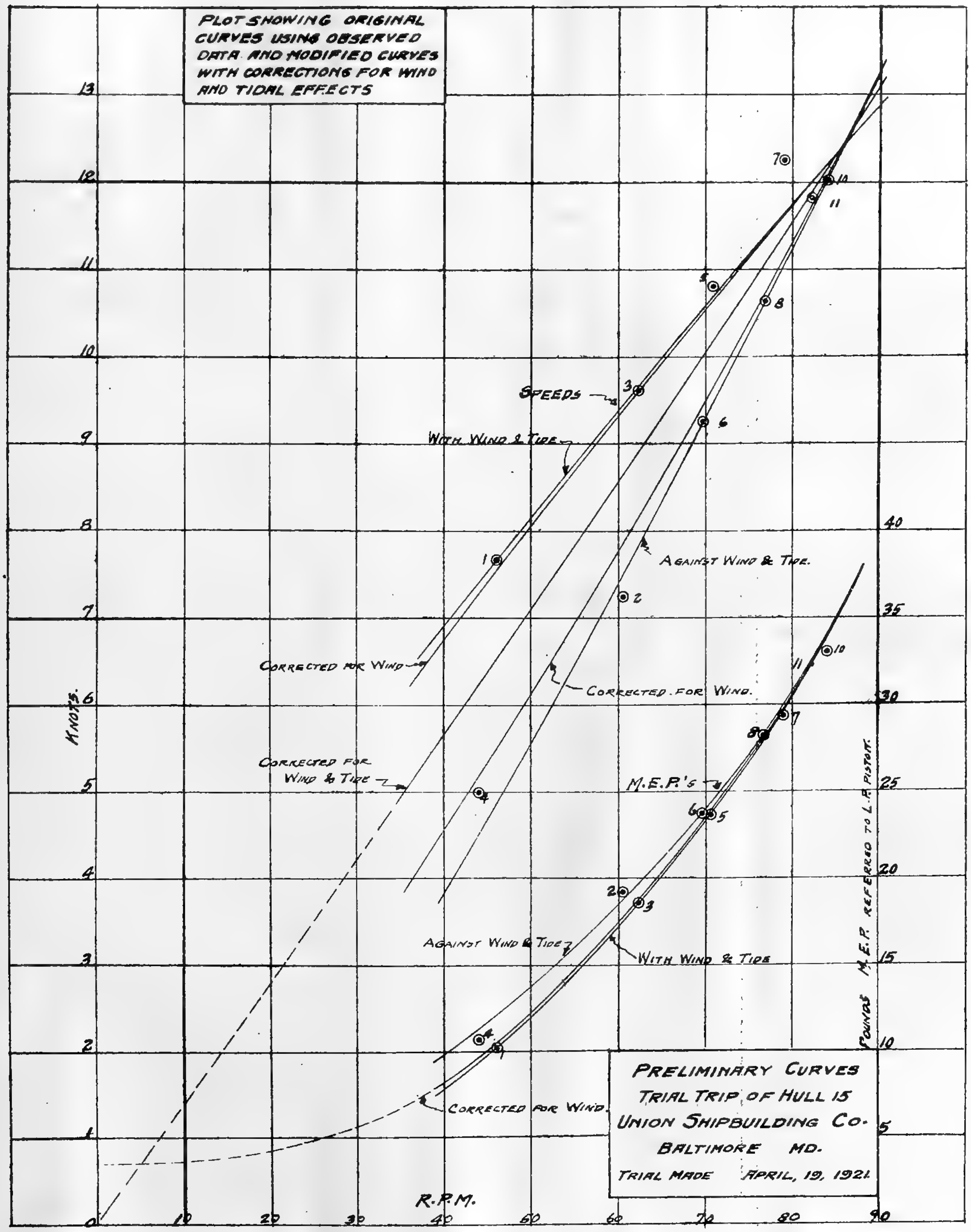
To illustrate paper on "The Influence of Shape of Transverse Sections Upon Resistance," by Professor Herbert C. Sadler, Member of Council, and Professor E. M. Bragg, Member.



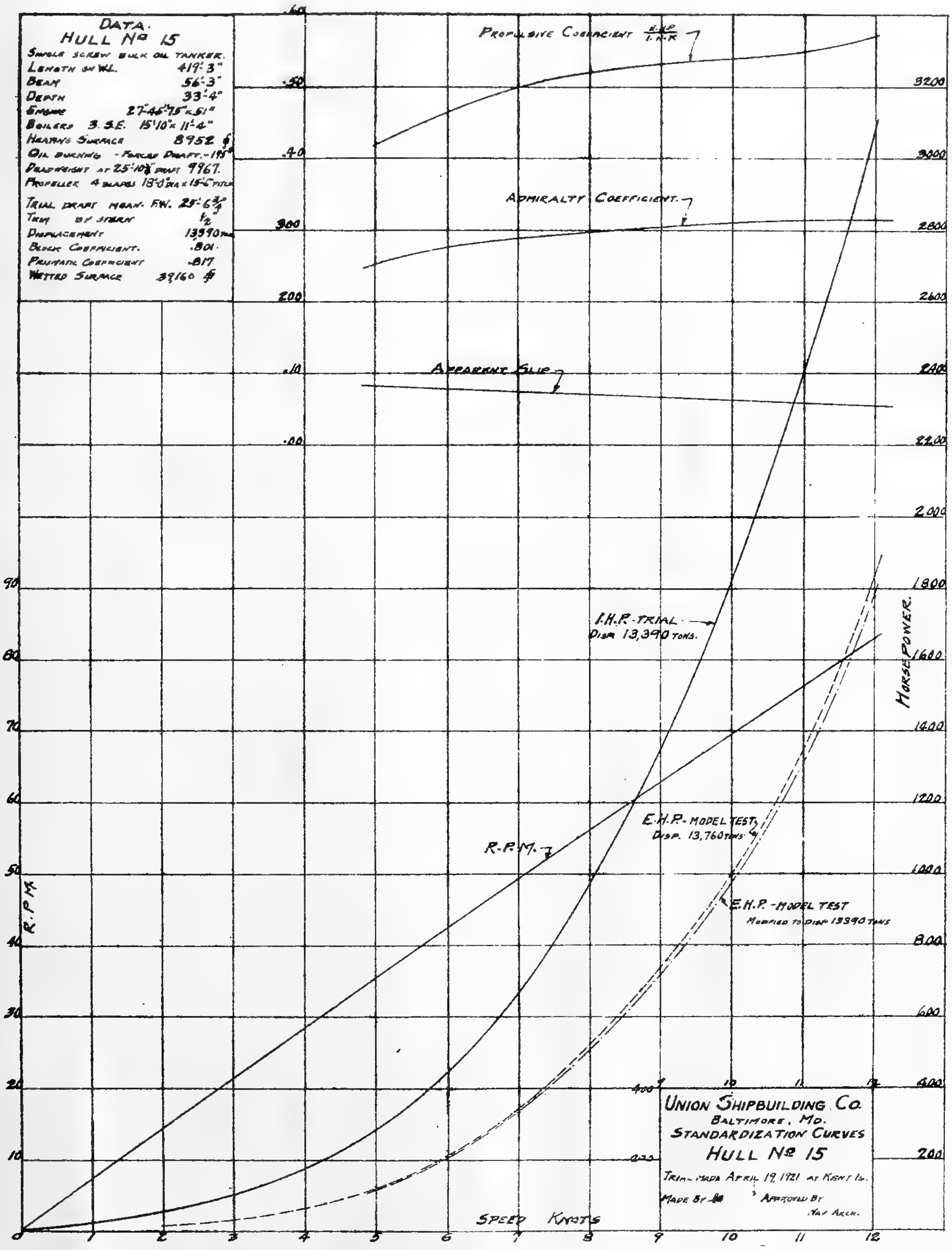
To illustrate paper on "Power and Speed Trials of Ten Thousand Deadweight-Ton Tanker,"
by H. A. Everett, Esq., Member.



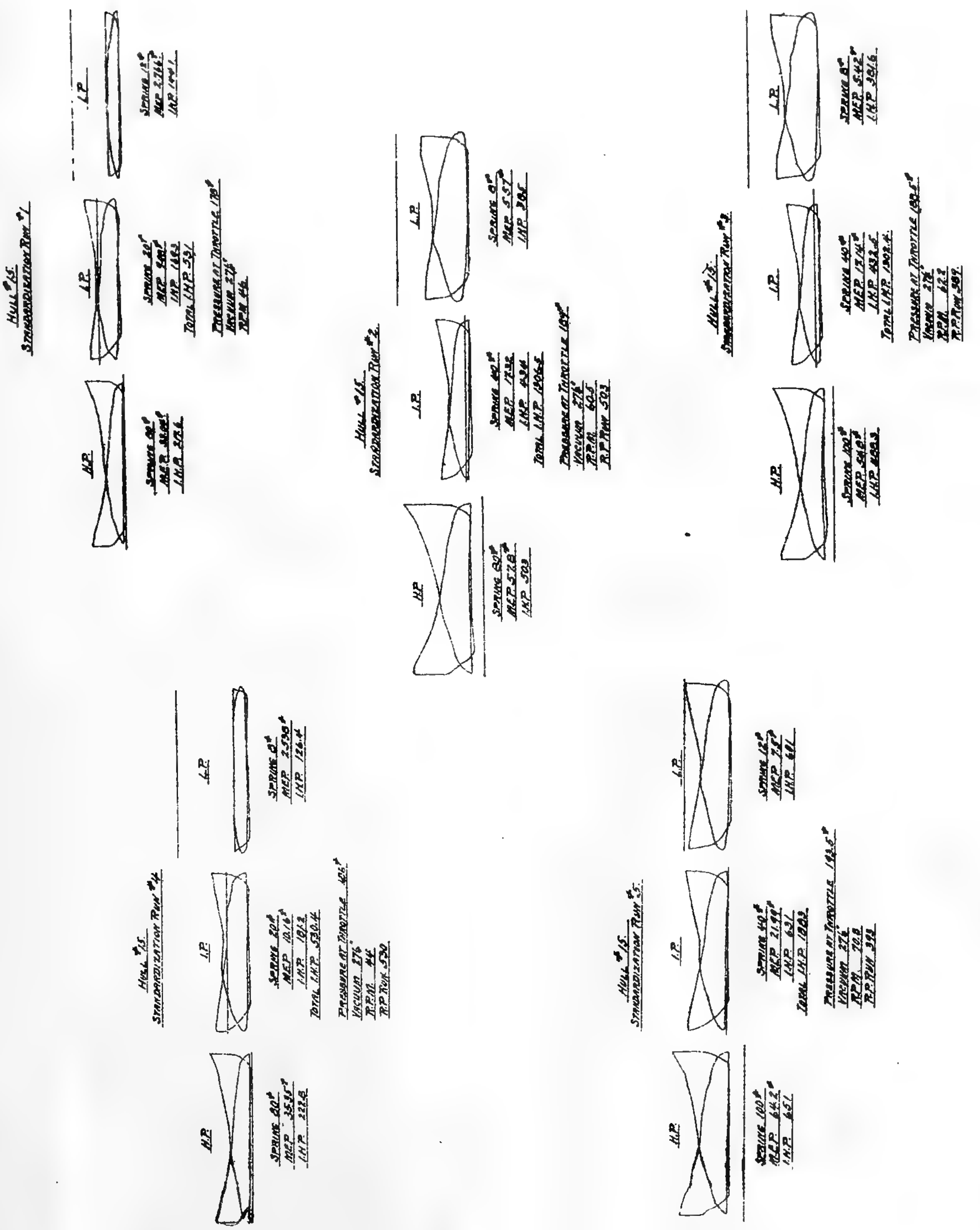
To illustrate paper on "Power and Speed Trials of Ten Thousand Deadweight-Ton Tanker," by H. A. Everett, Esq., Member.



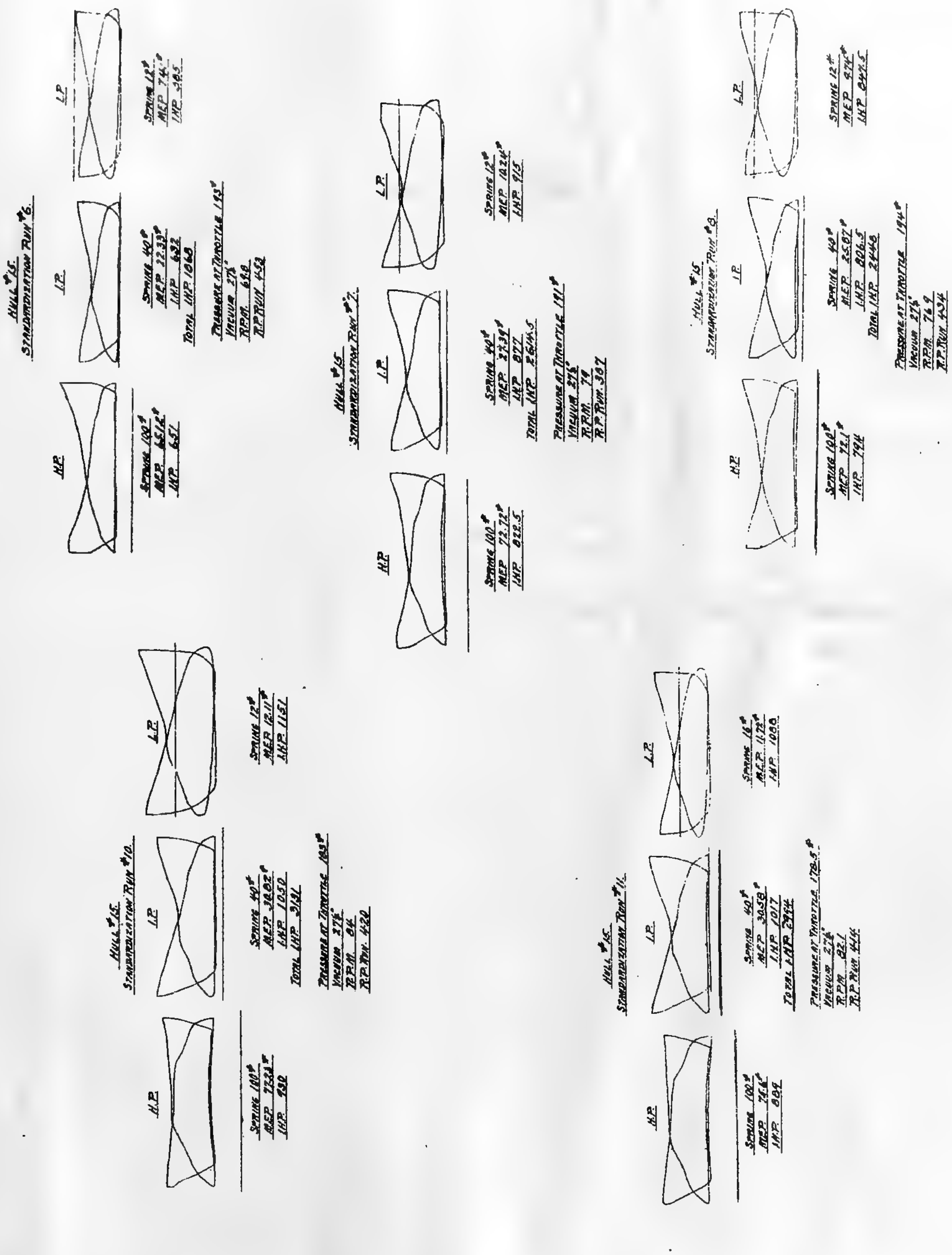
To illustrate paper on "Power and Speed Trials of Ten Thousand Deadweight-Ton Tanker," by H. A. Everett, Esq., Member.



To illustrate paper on "Power and Speed Trials of Ten Thousand Deadweight-Ton Tanker," by H. A. Everett, Esq., Member.



To illustrate paper on "Power and Speed Trials of Ten Thousand Deadweight-Ton Tanker," by H. A. Everett, Esq., Member.



To illustrate paper on "Power and Speed Trials of Ten Thousand Deadweight-Ton Tanker," by H. A. Everett, Esq., Member.

STANDARDIZATION RUNS.

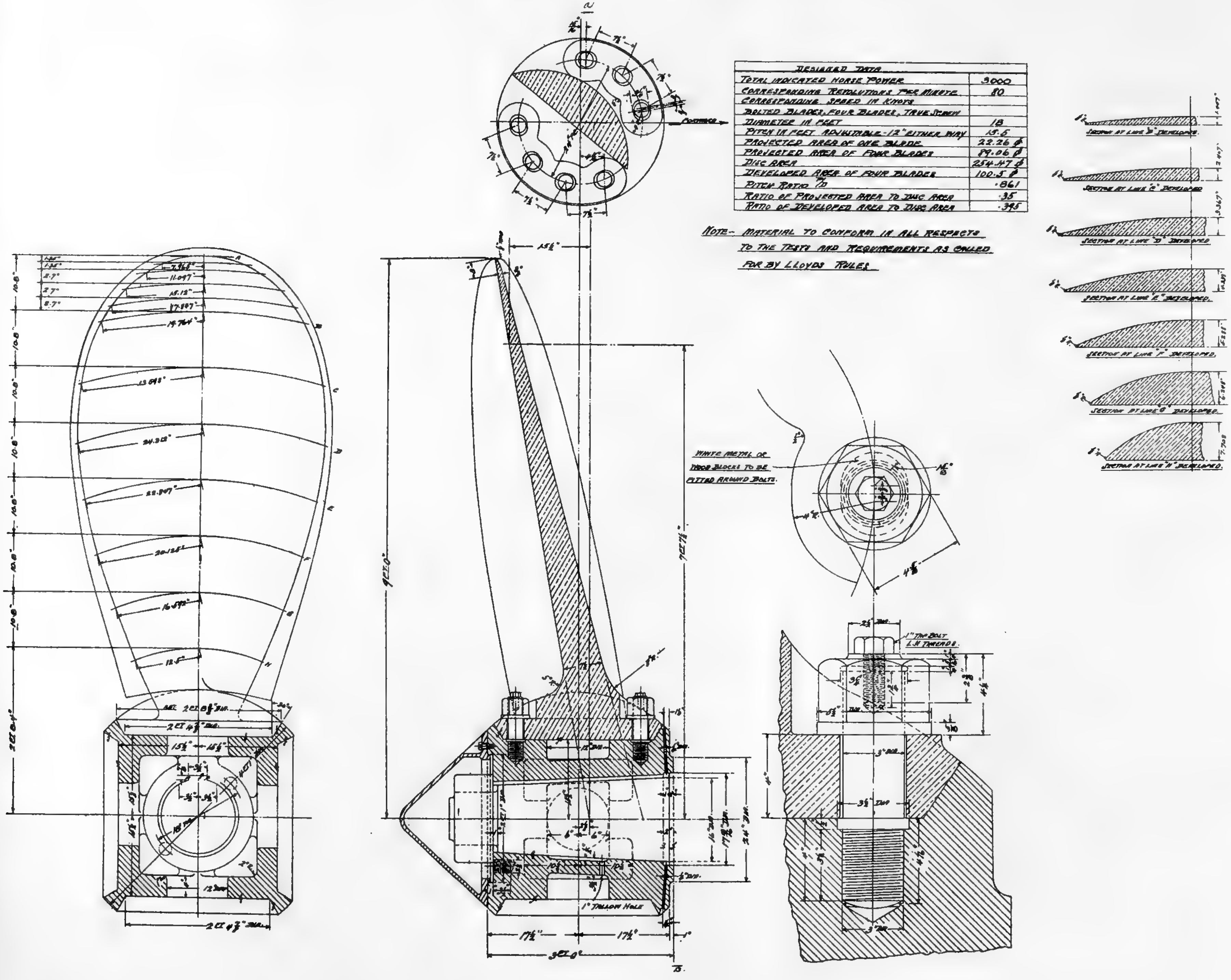
ENGINE ROOM LOG

NAME OF SHIP HULL No 15

DATE APRIL 19-1921

No. of Run	Time A.M.	Card Number	Counter Reading	R.P.M. for Card	Time on Course in Minutes	Linked Up: H.P. Full Gear = % In % In %	Linked Up: I.P. Full Gear = % In % In %	Linked Up: L.P. Full Gear = % In % In %	M E P (Average of 3 Sets of Cards): H.P. Card	M E P: I.P. Card	M E P: L.P. Card	M E P: M.E.P. Referred to L.P. Cyl.	I.H.P.: H.P. Cyl.	I.H.P.: I.P. Cyl	I.H.P.: L.P. Cyl.	I.H.P.: Total Engine	Pressure: At Throttle	Pressure: I.P. Receiver	Pressure: L.P. Receiver	Vacuum-Main Condenser	Direction of Run
1	6 59			46		74.35	74.75	70.31	33.04	9.08	2.766	10.19	217.6	169.3	144.1	531	178	4	-10 ins	27 1/4"	S
2	7 18		36761			"	"	"									193	27	-1 1/2	"	
	7 26		37264	60.5	8.313	"	"	"	57.8	17.32	5.57	19.08	500.5	424.6	381.4	1306.5	185	25	-2	"	N
3	7 42		38243			"	"	"									190	27	-1 1/2	"	
	7 48		38632	62.2	6.253	"	"	"	54.8	17.14	5.42	18.51	488.3	432.5	381.6	1302.4	187	25	-2	"	S
4	8 15		39911			"	"	"									190	12	-10	"	
	8 27		40441	44	12.05	"	"	"	35.35	10.16	2.538	10.65	222.8	181.2	126.4	530.4	182	11	-10 1/2	"	N
5	8 45		41522			"	"	"									194	38	2 3/4 lbs.	"	
	8 51		41915	70.8	5.553	"	"	"	64.2	21.99	7.5	23.51	651	631	601	1883	193	38	2 3/4	"	S
6	9 12		43335			"	"	"									190	38	2 5/8	"	
	9 18		43788	69.8	6.49	"	"	"	65.12	22.33	7.41	23.67	651	632	585	1868	196	39	3	"	N
7	9 35		45026			"	"	"									192	52.5	7 1/4	"	
	9 40		45413	79	4.9	"	"	"	72.72	27.39	10.24	29.25	822.5	877	915	2614.5	190	48	6	"	S
8	9 58		46797			"	"	"									193	50	6	"	
	10 04		47231	76.9	5.647	"	"	"	72.1	25.87	9.74	28.14	794	806.5	847.5	2448	195	50	6 3/8	"	N
10	10 44		50430			"	"	"									184	66	11 1/2	"	
	10 49		50850	84	4.997	"	"	"	77.23	30.82	12.11	32.95	930	1050	1151	3131	182	65	11 1/2	"	N
11	11 05		52134			"	"	"									178	63	11	"	
	11 10		52548	82.1	5.04	"	"	"	75.6	30.58	11.72	32.24	889	1017	1088	2994	179	64	11 1/4	"	S

To illustrate paper on "Power and Speed Trials of Ten Thousand Deadweight-Ton Tanker,"
by H. A. Everett, Esq., Member.



DESIGNED DATA	
TOTAL INDICATED HORSE POWER	3000
CORRESPONDING REVOLUTIONS PER MINUTE	80
CORRESPONDING SPEED IN KNOTS	
BOLTED BLADES, FOUR BLADES, TRUE SCREW	
DIAMETER IN FEET	18
PITCH IN FEET ADJUSTABLE-12" EITHER WAY	15.5
PROJECTED AREA OF ONE BLADE	22.26 ⌀
PROJECTED AREA OF FOUR BLADES	89.06 ⌀
DISC AREA	254.47 ⌀
DEVELOPED AREA OF FOUR BLADES	100.5 ⌀
PITCH RATIO P/D	.861
RATIO OF PROJECTED AREA TO DISC AREA	.35
RATIO OF DEVELOPED AREA TO DISC AREA	.395

NOTE— MATERIAL TO CONFORM IN ALL RESPECTS TO THE TESTS AND REQUIREMENTS AS CALLED FOR BY LLOYDS RULES

Transactions Society Naval Architects and Marine Engineers, Vol. 29, 1921.

To illustrate paper on "Power and Speed Trials of Ten Thousand Deadweight-Ton Tanker,"
by H. A. Everett, Esq., Member.

Form No. 14

Sailed from Dock Aug. 23, 1921

Arrived at Dock Aug. 30, 1921

GULF REFINING COMPANY

MARINE DEPARTMENT

Towed by ______

Towed Barge ______ { From ______ To ______

Voyage No. 4

ABSTRACT OF LOG OF THE { S. S. ~~BARGE~~ Gulfprince **CAPTAIN** O. Kleiman **FROM** Port Arthur **TO** Bayonne **VIA**

Date		Position at Noon: Latitude	Position at Noon: Longitude	Distance Run Knots	Length of Day: H.	Length of Day: M.	Average Speed Per Hour	Steam Pressure	Revolutions Per Day	Average Conditions During Last 24 Hours: Wind & Force	Average Conditions During Last 24 Hours: Sea	Remarks
Aug	23	Dock to	Sabine Bar	13								Aug. 23, 9^{40} AM Left Dock 12^{45} P.M. passed Sabine Bar Buoy
"	24	27° 48'	89° 44'	244	23	15	10.5	185	98050	Var. 3	Smooth	Aug. 26, 10^{00} A.M. Passed Sand Key
"	25	25° 46'	85° 35'	252	24	-	10.5	"	103930	NE 3	"	Aug. 29, 3^{00} A.M. Passed Diamond Shoals L.V.
"	26	24° 26'	81° 25'	252	24	-	10.5	"	103540	Var. 4	"	Aug. 30, 10^{50} A.M. Passed Scotland L.V.
"	27	28° 36'	79° 45'	300	24	-	12.5	"	103110	NE 5	Mod.	12^{30} P.M. Anchored off Stapleton
"	28	32° 40'	77° 24'	288	24	-	12.0	"	102170	E 4	Rough	2^{40} P.M. Left anchorage
"	29	36° 33'	74° 50'	276	24	-	11.5	"	104070	Var. 4	Mod.	4^{10} P.M. Docked at Bayonne
"	30	Dist. to Scotland L.V.		240	22	50	10.5	"	100200	Var. 3	"	
"	"	Scotland L.V.	to	Dock	30	Knots						
Average For Trip				268	24		11.15	185	103320			

TIME AND DISTANCE

Arrived at Dock	P.A. Aug. 20.		10:00 A.M.
Sailed from Dock	" " 23,		9:40 "
Time at Dock	2 d.	23 h.	40 m.
Total Time from Dock to Dock	7 d.	6 h.	30 m.
Total Stoppages, if any	- d.	2 h.	10 m.
Net Steaming Time	7 d.	4 h.	20 m.
Distance from Dock to Dock		1890	Knots
Total Time from Light to Light	6 d.	22 h.	5 m.
Distance " " " "		1852	Knots
Average Speed from Light to Light	11.15		Knots per hour
Duration of Stay in Port	2 d.	23 h.	40 m.

CARGO AND DRAUGHT

Cargo on Board	72,236.72		Bulk Barrels
" " "	30,893 lbs.		Packages
Total			Barrels
Draught Leaving	25 ft. 6 ins.	Forward	Mean
	26 " "	Aft	25'-9"
Draught Arriving	25 " 6 "	Forward	Mean
	24 " 10 "	Aft	25'-2"
Loading Bulk Cargo	Began	Aug. 21, 6:30 A.M.	
	Finished	Aug. 23, 6:45 "	
Discharging "	Began	Aug. 30, 5:00 P.M.	
	Finished	Aug. 31, 6.50 P.M.	

FUEL, ETC.

Fuel in bunkers leaving	193640	Gallons
Fuel consumed on voyage	59845	"
Fuel remaining on arrival	133795	"
Fuel delivered ashore		"
Oil Hose on Board { ______ 6 in. Lengths	6	
available for use { ______ 4 in. "	2	
Number of wire towing Hawsers on Hand,	One	
Number and size manila Hawsers on Hand,	None	

(Sgd.) O. Kleiman
MASTER.

To illustrate paper on "Power and Speed Trials of Ten Thousand Deadweight-Ton Tanker," by H. A. Everett, Esq., Member.

Form 75

GULF REFINING COMPANY —— MARINE DEPARTMENT

Engineer's Log Abstract. Steamer, *Gulfprince* Voyage No. *4* Sailing from *Port Arthur* to *Bayonne* Left *August 23* 19*21* Arrived *August 30,* 19*21.*

19*21* Date		Pressures				Vacuum	Cut Off	Revolutions		Average I. H. P. Main Eng.	Length of Day		Distance		Slip %	Average Speed Per Hr. Knots	Stoppages		Gallons Fuel Oil Consumed (to Noon) Oil in Gals.						Maximum Density in Boilers	Pres. at Blower	Evaporator Working Hrs.	Temperature—Fahr.						
		Boilers	H. P.	I. P.	L. P.			Per Min.	Per Day		Hrs.	Min.	Obs.	Wheel			H.	M.	Per Day	Per Knot	Per I H P Per H.	Remaining	Eng.	Cyl.				Feed	Sea	Discharge	Hot Well	Eng Room	Fuel Oil	Stack
Aug.	23	185									3	05	20																					
	24	185	180	65	85	25	65	70.3	98050	2370	23	15	244	250	04	10.5			7934	31.52	.144		14	½		.5		230	85	122	132	102	220	
	25	"	"	"	"	"	"	72.2	103,930	2420	24	-	252	265	04.9	10.5			8363	33.18			"	"		"			85	"	"	99	"	
	26	"	"	"	"	"	"	71.9	103,540	2400	24	-	252	264	04.5	10.5			8294	32.89			"	"		"			83	"	"	100	"	
	27	"	"	"	"	"	"	71.6	103,110	"	24	-	300	263	neg 14	12.5			8294	27.65			"	"		"			83	"	"	97	"	
	28	"	"	"	"	"	"	70.9	102,170	"	24	-	288	261	neg 08	12.			8294	28.80			"	"		"			82	"		96	"	
	29	"	"	"	"	"	"	72.2	104,070	2470	24	-	276	265	04.1	11.5			8536	30.92			"	"		"			77	"	"	96	"	
	30	"	"	"	"	"	"	73.1	100,200	"	22	50	240	255	05.8	10.5			8120	33.83			"	"		"			70	"		96	"	
Average per trip		185	180	65	85	25	65	71.7	103,250	2410	24		268	264	01.6	11.15			8352	31.23	.144		14	½		.5		230	81	122	132	98	220	

TIME AND DISTANCES

- Total Time from Dock to Dock *7* d. *6* h. *30* m.
- Total Stoppage if any *–* d. *2* h. *10* m.
- Net Steaming Time *7* d. *4* h. *20* m.
- Distance from Dock to Dock *1890* Knots
- Total Time from Light to Light *6* d. *22* h. *05* m.
- Distance from " " *1852* Knots
- Average Speed from " " *11.15* Knots Per Hr.

MISCELLANEOUS

- Grade of Fuel Received *Fuel Oil*
- Specific Gravity *.9015*
- Beaume " *25.5*
- Weight per Gal. *7.510* Lbs.
- Pitch of Propeller *15* Ft. *06* Ins.
- Diameter " *13* Ft. *–* Ins.
- Average I. H. P. Auxiliaries *100* I. H. P.

REMARKS

Date	Remarks
Aug. 23	9[40] A.M. Left Refining Dock, Port Arthur
	12[45] P.M. Sabine Bar
	Fuel Oil in Aft Tank Mexican Reduced
	Fuel Oil in For'd Tank 30 Gas Oil
30	10[50] AM Scotland L.V.
"	12[30] PM Anchored
"	4[10] PM Made fast to dock, Bayonne, N.J.

FUEL STATEMENT — Gallons

- On hand Completion of Last Voyage *23,549*
- Consumed in Port *4970*
- Balance on hand *18,579*
- Received at *Port Arthur* *175,061*
- { Delivered as Cargo / Taken from Cargo
- Total from all Sources *193,640*
- Consumed on Trip *59,845*
- Remaining on Arrival *133,735*

FUEL CONSUMPTION — Gallons

- Average per 24 hours between Lights *8352*
- Average per Knot between Lights *31.23*
- Average per I. H. P. per hour main engines *.144*
- Average per I. H. P. per hour all machinery *.138*
- In and Out of Port (Inside of Lights) *890 + 1,120*

(Sgd.) A. Nelson Chief Engineer

To illustrate paper on "Power and Speed Trials of Ten Thousand Deadweight-Ton Tanker," by H. A. Everett, Esq., Member.

Form No 74

Sailed from Dock Aug. 31, 1921

Arrived at Dock Sept. 7, 1921

GULF REFINING COMPANY

MARINE DEPARTMENT

Towed by

Towed Barge { From / To

Voyage No. 4

ABSTRACT OF LOG OF THE { S. S. ~~BARGE~~ Gulfprince **CAPTAIN** O. Kleiman **FROM** Bayonne **TO** Port Arthur **VIA**

Date		Position at Noon: Latitude	Position at Noon: Longitude	Distance Run Knots	Length of Day: H.	Length of Day: M.	Average Speed Per Hour	Steam Pressure	Revolutions Per Day	Average Conditions During Last 24 Hours: Wind & Force	Sea	Remarks
Aug	31	Dock to Scotland L.V.		20								Aug. 31, 7[15] P.M. Left Dock. 8[55] P.M. Passed Scotland L.V.
Sept.	1	37° 42'	74° 37'	166	15	05	11.0	185	65920	SE 3	Smooth	Sept 2, 2[22] A.M. Passed Diamond Shoals L.V.
"	2	33° 51'	77° 01'	276	24	-	11.5	"	105360	SE 3	"	Sept 4, 8[15] A.M. Passed Jupiter
"	3	30° 39'	80° 20'	264	24	-	11.0	"	105960	Var 3	"	Sept 5 4[30] A.M. Passed Sand Key.
"	4	26° 18'	80° 02'	264	24	-	11.0	"	106900	SE 3	"	Sept. 7. 5[50] P.M. Passed Sabine Bar Buoy
"	5	24° 40'	83° 14'	252	24	-	10.5	"	107380	SE 3	"	7[30] P.M. Arrived at Port Arthur
"	6	26° 54'	87° 44'	276	24	-	11.5	"	107640	S 3	"	
"	7	29° 11'	92° 31'	288	24	-	12.0	"	106640	S 3	"	
"	"	Dist. to Sabine Bar		72	5	50	12.5	"	26020	S 3	"	
"	"	Sabine Bar to Dock		18								
Average For Trip				261	24	-	11.3	185	106639			

TIME AND DISTANCE

Arrived at Dock	Bayonne, Aug. 30, 4[10] PM.					
Sailed from Dock	" Aug. 31, 7[15] PM					
Time at Dock	1	d.	3	h.	5	m.
Total Time from Dock to Dock	7	d.	-	h.	15	m.
Total Stoppages, if any	-	d.	-	h.	-	m.
Net Steaming Time	7	d.	-	h.	15	m
Distance from Dock to Dock			1896			Knots
Total Time from Light to Light	6	d.	20	h.	55	m.
Distance " " " "			1858			Knots
Average Speed from Light to Light			11.3			Knots per hour
Duration of Stay in Port	1	d.	3	h.	5	m.

CARGO AND DRAUGHT

Cargo on Board	—		Bulk Barrels
" " "	55727 lbs.		Packages
Total	——		Barrels
Draught Leaving	2 ft. ins	Forward	Mean
	18 " "	Aft	10'-0"
Draught Arriving	2 " - "	Forward	Mean
	18 " - "	Aft	10'-0"
Loading Bulk Cargo	Began / Finished	——	
Discharging "	Began	Aug. 30, 5.00 PM	
	Finished	" 31, 6.50 PM	

FUEL, ETC.

Fuel in bunkers leaving	74873	Gallons
Fuel consumed on voyage	58173	"
Fuel remaining on arrival	16700	"
Fuel delivered ashore	Bayonne, Voy. #4 55427	"
Oil Hose on Board, 6 in. Lengths	6	
available for use, 4 in. "	2	
Number of wire towing Hawsers on Hand,	One	
Number and size manila Hawsers on Hand,	None	

(Sgd) O. Kleiman
Master.

To illustrate paper on "Power and Speed Trials of Ten Thousand Deadweight-Ton Tanker," by H. A. Everett, Esq., Member.

Form 75

GULF REFINING COMPANY —— MARINE DEPARTMENT

Engineer's Log Abstract. Steamer, *Gulfprince* Voyage No. *4* Sailing from *Bayonne, N.J.* to *Port Arthur* Left *Aug. 31* 1921 Arrived *Sept. 7th* 1921

1921 Date		Pressures: Boilers	H. P.	I. P.	L. P.	Vacuum	Cut Off	Revolutions: Per Min	Per Day	Average I. H. P. Main Eng	Length of Day: Hrs.	Min.	Distance: Obs.	Wheel	Slip %	Average Speed Per Hr. Knots	Stoppages: H	M.
Sept.	1st	185	180	65	8.5	25	63	72.4	65920	2300	15	05	166	168	1.1	11.00		
"	2nd	185	180	65	8.5	25	63	73.0	105,360	2400	24	00	276	268	negative 2.8	11.50		
"	3rd	185	180	65	8.5	25	63	73.5	105,960	2400	24	00	264	270	positive 2.2	11.00		
"	4th	185	180	65	8.5	25	63	74.2	106,900	2430	24	00	264	272	2.9	11.00		
"	5th	185	180	65	8.5	25	63	74.5	107300	2450	24	00	252	273	7.6	10.50		
"	6th	185	180	65	8.5	25	63	74.7	107640	2450	24	00	276	274	negative .07	11.50		
"	7th	185	180	65	8.5	25	63	74.4	106640	2440	24	00	288	272	negative 5.5	12.00		
"	7th	185	180	65	8.5	25	63	76.2	26020	2450	5	50	72	66	neg. 8.3	12.50		
Average per trip		185	180	65	8.5	25	63	741	106646	2422	24	00	271	271	.03	11.30		

1921 Date		Gallons Fuel Oil Consumed (to Noon): Per Day	Per Knot	Per I. H. P. Per Hr.	Remaining	Oil in Gals.: Eng.	Cyl.	Maximum Density in Boilers	Pres. at Blower	Evaporator Working Hrs	Temperature—Fahr.: Feed	Sea	Discharge	Hot Well	Eng Room	Fuel Oil	Stack
Sept.	1st	5160	31.9	.141	69100	8	1/2	Fresh	.6"	0	230	72	120	130	34	215	Unknown
"	2nd	8280	30.0	.143	60820	13	1/2	"	"	"	230	77	120	130	98	215	"
"	3rd	8270	31.3	.143	52550	12	1/4	"	"	"	230	83	120	130	100	200	"
"	4th	8260	31.2	.143	44290	12	1/4	"	"	"	230	83	120	130	100	200	"
"	5th	8390	33.2	.142	38360	13	1/4	"	"	"	230	83	120	130	100	200	"
"	6th	8300	30.0	.142	27600	12	1/4	"	"	"	230	83	120	130	100	200	"
"	7th	8260	28.6	.142	19340	12	1/2	"	"	"	230	83	120	130	100	200	"
"	7th	2040	28.6	.142	17300	3	1/4	"	"	"	230	81	120	130	98	200	"
Average per trip		8280	30.6	.142		12	3/8	Fresh	6"	0	230	82	120	130	98	210	"

TIME AND DISTANCES

- Total Time from Dock to Dock *7* d. *0* h. *15* m.
- Total Stoppage if any d. *0* h. *0* m.
- Net Steaming Time *7* d. *0* h. *15* m.
- Distance from Dock to Dock *1896* Knots
- Total Time from Light to Light *6* d. *20* h. *55* m.
- Distance from " " *1858* Knots
- Average Speed from " " *11.30* Knots Per Hr.

MISCELLANEOUS

- Grade of Fuel Received *Mixed Reduced Crude and Gas Oil*
- Specific Gravity *9015*
- Beaume " *25.5*
- Weight per Gal. *7.510* Lbs.
- Pitch of Propeller *15* Ft. *6* Ins.
- Diameter " *18* Ft. *0* Ins.
- Average I. H. P. Auxiliaries *100* I. H. P.

REMARKS

Date	Remarks
Aug 31st, 1921	Left Bayonne Oil Dock 7⁴⁵ P.M.
"	Passed out by Scotland Light Ship 8⁴⁵ P.M.
Sept 1st	Fair Weather
" 2nd	" "
" 3rd	" "
" 4th	" "
" 5th	" "
" 6th	" "
" 7th	Fresh Southerly wind with Rain Squalls
" "	Sabine Bar buoy abeam 5⁵⁰ P.M.
" "	7:30 PM Made fast to Canal Bank in Turning Basin Port Arthur

FUEL STATEMENT (Gallons)

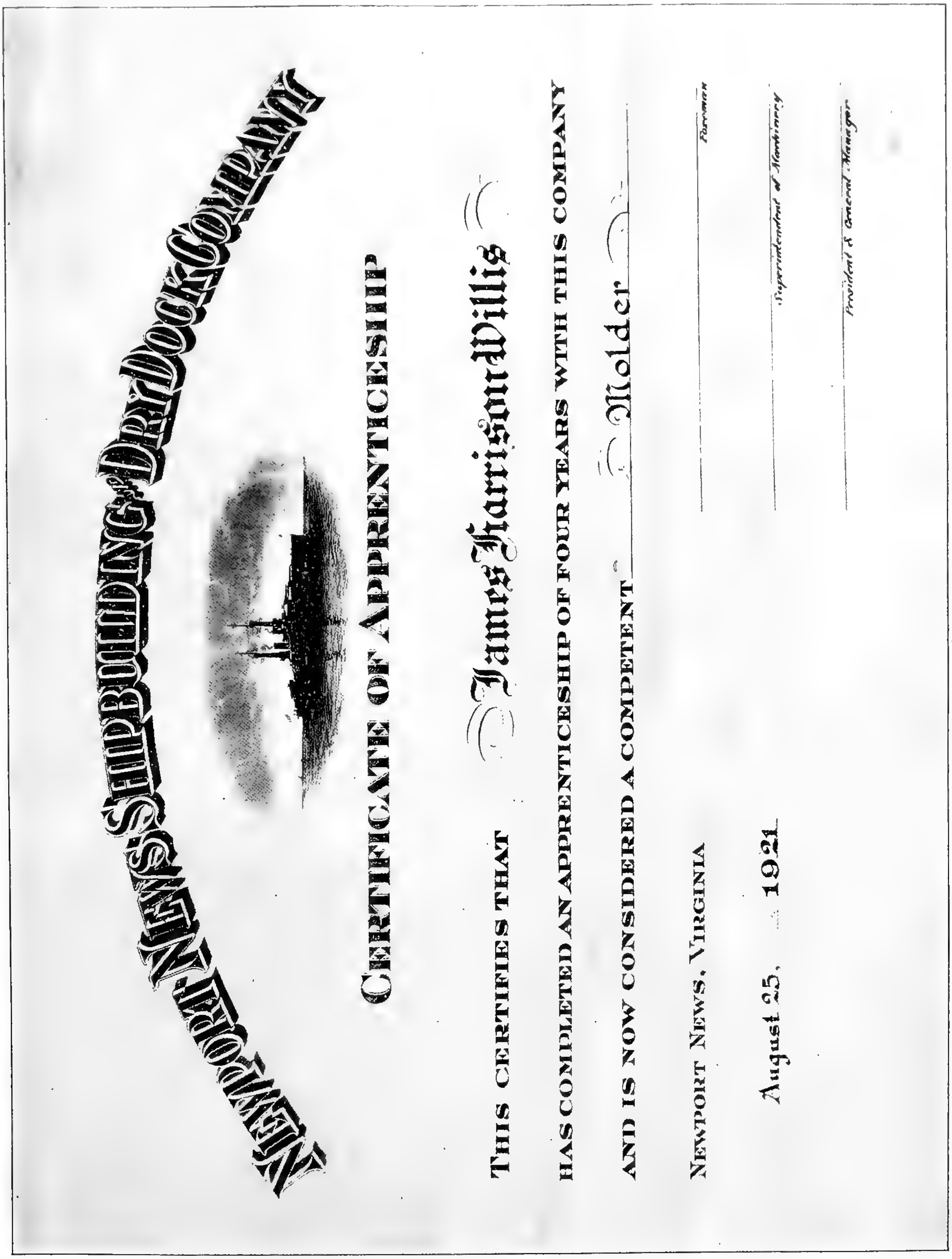
- On hand Completion of Last Voyage *133795* "
- Consumed in Port *3495* "
- Balance on hand *130300* "
- Received at
  - Delivered as Cargo *at Bayonne 55427* "
  - Taken from Cargo
- Total from all Sources *74873* "
- Consumed on Trip *58173* "
- Remaining on Arrival *16700* "

FUEL CONSUMPTION (Gallons)

- Average per 24 hours between Lights *8280 gals.*
- Average per Knot between Lights *30.6*
- Average per I. H. P. per hour main engines *.142*
- Average per I. H. P. per hour all machinery *.133*
- In and Out of Port (Inside of Lights) *613 + 600*

(Sgd) J. T. Cruise Chief Engineer

To illustrate paper on "American Shipyard Apprenticeships, Evening Schools and Scholarships," by Charles F. Bailey, Esq., Member of Council.



NEWPORT NEWS SHIPBUILDING AND DRY DOCK COMPANY

CERTIFICATE OF APPRENTICESHIP

THIS CERTIFIES THAT James Harrison Willis

HAS COMPLETED AN APPRENTICESHIP OF FOUR YEARS WITH THIS COMPANY

AND IS NOW CONSIDERED A COMPETENT Molder

NEWPORT NEWS, VIRGINIA

August 25, 1921

Foreman

Superintendent of Machinery

President & General Manager