THE DESIGN AND CONSTRUCTION OF POWER WORKBOATS

By ARTHUR F. JOHNSON, N. A.

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Naval architecture as applied to power work-boats lacks literature; perhaps because bigger game is more absorbing. When it is realized that the future inland waterways of this country must be developed and utilized; also that power boats will provide the means of avoiding the repetition of lamentable inefficiency in conveying the products of our interior to the principal ports or centers of distribution, proper design will be no small factor in the solution of the problem.

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Arthur F. Johnson, N. A., author of Design and Construction of Power Workboats, appears here in the uniform of Assistant Marine Superintendent of the U. S. Army Transport Service. Besides being educated as a naval architect and marine engineer, he has had wide experience in the U. S. Engineer's Department and in shipbuilding yards and as Designing Engineer for the Fabricated Ship Corporation, Milwaukee, Wis., so that he has a practical as well as a theoretical knowledge of the subject. Mr. Johnson, at the present writing is Production Manager of Nelson Purchasing Organization, Chicago, Ill.

CHAPTER I

Advantages and Classifications

THE utilization of vessels, propelled by internal combustion engines, for commercial transportation by water is no longer in the experimental stage; nor has there been a dearth of literature setting forth the general characteristics of the numerous uses to which this type of craft has been adapted. From the very first, good engineering portended success of this class of vessels, since there can be no sounder logic than that chemical energy as contained in fuel will produce maximum power when converted into mechanical energy at the nearest practicable location to the point of application of the power.

Whereas, in steam-propelled craft, the latent energy in fuel was first converted into heat of gases due to combustion, these gases then transmitting their heat to water in a boiler, generating steam; this in turn passing to the engine, losing considerable heat content en route; in a combustion engine all the energy conversion takes place in the cylinders. This not only results in saving of weight by omission of boilers and increased space for cargo storage due to lesser space occupied per horsepower, but also the abolition of heat losses and the carriage of water for boiler feed.

These advantages were at first offset by practical defects in combustion engine design, lack of skill on the part of the operators and the customary conservative frame of mind on the part of vessel owners which is inevitable to all radical innovations in industry. The tendency to let others pay for the experiments incidental to practical perfection delayed progress in development.

KUMTUX, LUMBER TOW BOAT

She is 65 feet x 16 feet and is powered with a 110-horsepower Standard-Corliss engine. She is owned by the Puget Sound Tow Boat Co. and has given her owners great service

Power Boats Have Replaced Small Steamers

Since power boats, particularly those using the lighter fuels, have practically replaced the small steamers of foregone days, and the ones requiring considerable power and cheap fuel have long since shown the desirability of diesel engines; effort should be made to co-ordinate the valuable experience of operators and record the features of design in power boats. This is particularly desirable with respect to the smaller vessels, where ordinary powerboat construction would prove fragile and the essential points should be understood by owners, operators and builders.

In general power workboats may be classified under three main headings: First, service in which engaged; second, material of which constructed; and third, type and arrangement of propelling machinery.

With respect to service, the first consideration is whether the waters navigated are to be "open" or "sheltered;" that is, whether the vessel is to go to sea or to operate in rivers and harbors.

Seagoing vessels to date have been mainly cargo carriers (wooden or steel) or auxiliary sailing craft. The construction in these being identical with that of steamers, has been thoroughly treated in other works of ship design.

Vessels traversing coastwise, harbor or inland waters are those here to be discussed and embraced:

(1) Ferries:
  (a) Fast passenger.
  (b) Passenger and freight.
  (c) Car.
(2) Tugs.
(3) Power lighters.
(4) Tank boats:
  (a) Water.
  (b) Petroleum products.
(5) Trawlers.
(6) Shop boats:
  (a) Repair boats: (Machine shops) (Welding plants)
(7) Pumping and wrecking boats.

Passenger ferries vary from fine-lined relatively fast vessels of from 50 or 60 feet, to 200 feet in length. Depending upon the length of run they may vary in speed from 10 to 20 miles (statute). Their characteristic arrangement is to afford maximum passenger accommodation: Sleeping, mess accommodations and sanitation for the large craft on long runs (seldom more than for one night); and maximum seating, sanitary and sometimes messing provisions for relatively short runs not exceeding one day (sunrise to sunset).

Jitney Boat for Commuters

A recent innovation in this connection has been the "jitney boat", making runs from points within an hour's run of a city or railroad depot, and used for transporting commuters.

Passenger and freight ferries of moderate speed (8 to 12 miles), relatively full lines and ranging in length from 50 to 200 feet are becoming increasingly popular as sources of profit. The holds and main deck are employed for freight storage and the superstructure houses the passengers. A cargo boom forward facilitates lifting heavy weights, the hoisting winch being geared from the main engine or being an independent machine. There is a single-ended type for voyages of more than one-half hour or so; the ones for short and frequent trips as well as the car ferries being double-ended. They may be propelled by screws or paddle wheels. Tugs comprise probably the most numerous class of the commercial power boats. Their lengths are from 35 to 150 feet and speeds (when not towing) from 8 to 12 miles. Many of the conventionalities in tug design could be improved or dispensed with to the ultimate betterment of the whole. This will be elaborated upon subsequently. The essential to a tug's success is great pulling power at slow speeds, requiring a heavy-duty, slow-turning engine coupled to a propeller of large diameter and low pitch ratio (0.9 to 1). Power lighters are modified types with large decks and hold space for cargo and a boom for loading. Tank boats, as their name implies, carry water or petroleum in bulk, the form being full and the engines aft (at the stern). Trawlers are of tug design, fitted with hoisting booms and fish tanks. They attained notoriety in the recent war by their utility in mine sweeping. Shop boats, carrying machine shop tools, welding plants and apparatus are becoming numerous. They are constructed with a view to bringing the repair equipment to the disabled plant, instead of requiring the cripple to visit the shipyard. Workboats used for salving and wrecking purposes carry a miscellaneous equipment, such as pumping apparatus and machines for handling divers. With the value of vessel property going up sky high these boats are becoming profitable.

Steel Too High for Small Boats

By material of construction is meant that of which the principal strength members and hull are composed. Steel is most universally employed in vessels over 100 feet long, though it has been used in pressed form for small power and life boats. In the writer's opinion powerboats as small as 50 feet long, providing they are full lined, could be built of light galvanized steel shapes and plates, riveting being replaced by spot welding. With the prevailing prices at present, and as long as steel exceeds $0.03 per pound, this would not be desirable, however.

Composite vessels are those with wooden hull planking and steel framing. For boats under 100 feet long, this is scarcely a desirable construction, though in larger ones it is being extensively employed.

Wooden construction is the most universally employed and desirable for vessels less than 100 feet long. This is due to the facility in working the material, simplicity of equipment needed in building yards and also to the fact that vessels up to this size are amply strong when built of wood. Steel, if too light, has not the requisite stiffness and corrodes through quickly. If the steel is made heavier, care must be taken that the vessel is not of greater displacement than would be the case in a wooden one of corresponding size and strength.

HALIBUT SCHOONER CONSTANCE
One of the finest boats ever built for halibut service—She measures 87 feet on deck, 18 feet beam and carries 140 horsepower Standard-Frisco engine

Power workboats of wood are much more substantially built than are pleasure craft and it is to establish standards and details in these practical vessels that this work is undertaken.

Reinforced concrete promises to become extensively used in boat construction, particularly where a considerable number of the same form and size of vessels are produced. It is no longer an experimental construction, barges and seagoing vessels now building being the result of observing, for years, those already in service.

Concrete Boats for Inland Waterways

Steel and concrete having nearly the same coefficients of expansion and the fact that painting, copper sheathing and fouling of bottoms will be troubles of the past as well as that deterioration is negligible, point to extensive utilization of this desirable material, particularly for inland waterways. A very rich mixture (1-1-½-3) of concrete, with gravel passing ¼-inch mesh, is used for the hull. This is molded or "shot" onto galvanized wire mesh supported by ordinary reinforcing rods, the total hull thickness varying from 2 to 5 inches. Internal hull structure embodies reinforcing steel skeleton work with a leaner concrete (1-2-4) or (1-3-5) again using fine gravel. The density of concrete determines its life, strength and watertightness as well as its elasticity. Ordinary concrete, as commonly used ashore, would not prove satisfactory for vessels. If the ships are molded, standard metal molds may serve for numerous hulls, but if one or two only are to be built, the "gunning" method is more desirable, particularly in view of the fact that a more nearly ship-shape form can be built in this manner. Molded hulls have resulted in crudeness of lines and while this is immaterial at low speeds, tugs or finer craft would require excessive power unless more refined in form. The type and arrangement of the propelling machinery together with the means of converting the power generated into propulsive thrust will not be elaborated upon except wherein they affect hull construction or arrangement. The power plant itself may be combustion engines of any one of the following types:

(a) Diesel or oil engines, operating on two-stroke or four-stroke cycle using heavy oil fuel (between 14 degrees and 23 degrees Baume), wherein fuel is injected as spray into the cylinders with compressed air and ignition results from high compression of the charge. Revolution 150 to 300.

(b) "Semidiesel"—or heavy distillate engines, using kerosene or distillate fuel with hot bulb ignition or spark. These engines are similar to ordinary gasoline machines, but operate at slow speed and are much more heavily constructed. Revolutions from 200 to 600.

(c) Gasoline engines (usually four-stroke cycle) using light petroleum distillate, with electrical ignition, low compression and operating (in heavy marine work) between 350 and 800 revolutions per minute.

(d) Gas producer plants using coal, wood or other gaseous fuel.

Diesel or oil engines being relatively high powered, are not much used in small commercial power boats. An interesting departure from this generality is the government tug MANTEO which has a 100-horsepower, 2-cycle, diesel engine and which is only 50 feet long.

"Semidiesel" engines, a rather vague and incorrect term, are excellent for heavy duty service providing the operator understands them. Such engines should be more extensively utilized than they now are, not only because of the saving in fuel, but their rugged construction and ability to run continuously if properly attended. There have been some sad experiences, however, when inexpertly handled.

Gasoline, or light distillate engines, of heavy duty design, are usually direct connected to the propeller and are the most generally employed. Sometimes, in order to conserve space and weight, small, high-speed engines (900 to 1200 revolutions per minute) are installed with a reduction gear to the propeller shaft. This system is comparatively recent in ships, though long used in automobiles. It promises to become popular if light fuels do not attain prohibitive prices.

Gas producer plants have never been extensively employed, though when properly designed and operated they have proved practical and economical. They consist of a producer proper, where fuel is caused to give off its combustible gases through distillation, partial combustion and sometimes chemical combination with water vapor.

The fuels used may be wood, coal of a low grade or residue combustible material. The gases generally pass through a "scrubber" where foreign matter is removed by spray or other means and thence to an internal combustion engine.

The arguments against producer plants are: Excess weight and space occupied by the plant, and skill necessary to proper operation.

The propulsive mechanism of commercial power boats may be propellers or paddle wheels.

Propellers are most commonly employed where light draft is not a factor in design. This is because of their protected location with respect to the hull, which minimizes damage by striking against docks, towed vessels or by rough seas. Another reason is that higher revolutions with efficient propulsion render them adaptable to direct coupling with engine shafts, with attendant reduction in space occupied by machinery of a given power.

Paddle wheels (at side or stern of vessels) are desirable in shoal water because of efficient propulsion under limited depth of immersion and also facility of repairing buckets damaged through striking submerged obstacles.

The practical range of revolutions in paddle wheels is between 20 and 40, rendering necessary a reduction in speed from engine to wheel. This is accomplished through belts, gears, chains, or a combination of these.

Propellers in Tunnel Boats

Propellers in tunnels, so that the water surface at rest is not more than one-third of the wheel diameter below the upper tip of blades, are frequently employed for shallow draft propulsion. Though the wheel diameter is restricted and revolutions comparatively high, excellent results have been obtained in this way, even in tow boats. In these, the out-of-the-way propellers present an advantage over the projecting paddle wheels, and the lightened and less roomy machinery afford lighter draft on a given size of vessel or permit of decrease in vessel dimensions for given draft and power.


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CHAPTER II

Analyzing Operating Conditions

THE first essential in selecting a design of power boat is a careful study of the requirements imposed by the service in which it will be engaged. This will determine the general arrangement, degree of equipment, power, amount of fuel, stores and water, material and construction, etc.

It is assumed that one undertaking the construction of a commercial vessel will familiarize himself with these requirements by careful study of the local conditions at the terminals and through the trade route which the vessel is to ply. Conditions are so varied and the combinations of these so numerous that exhaustive discussion would scarcely be warranted.

In general the factors encountered are:

(1) Character of service.
(2) Character of materials ported.
(3) Conditions of water traversed.
(4) Terminal adaptation to the trade contemplated.

The design as affected by character of service has already been considered, as have the general features called for in passenger traffic.

Freight may be roughly subdivided into:

(a) Fast package.
(b) Perishable.
(c) Miscellaneous slow.
(d) Bulk.

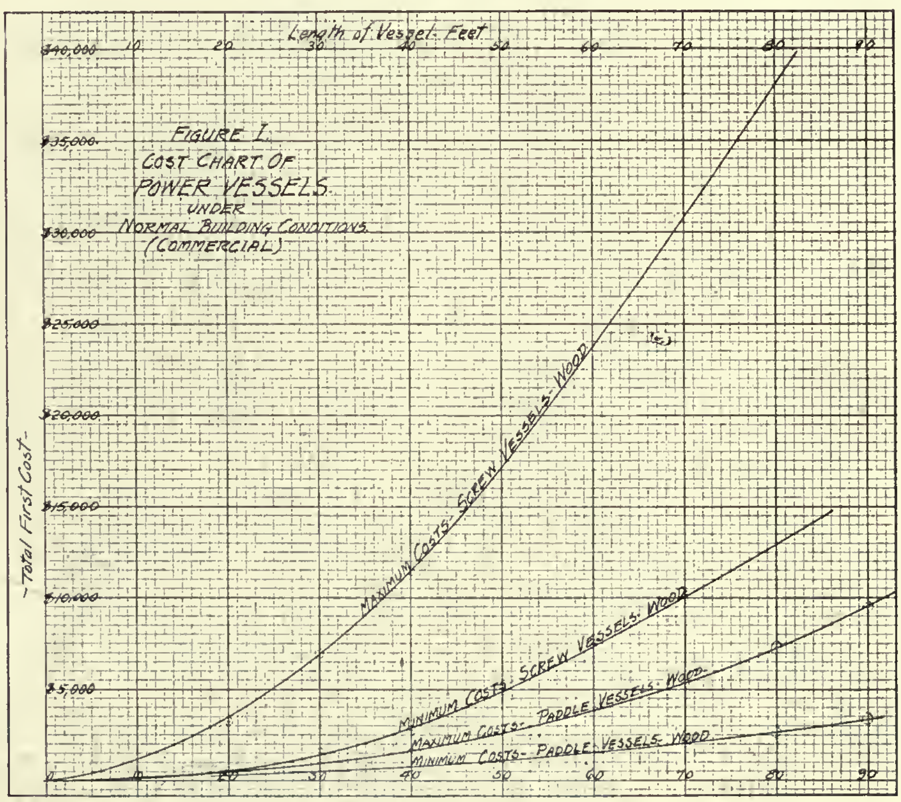
The first of these has heretofore been most extensive on ocean or large inland or sea trade routes, services in which natural conditions have prohibited land transportation. There is reason to suppose that with reliable and well administrated inland waterway runs, much of this revenue earning cargo could be diverted from the none too punctual rail routes of this country. This does not infer competition, but rather co-operation with the railroads, since many water routes are shorter between terminal points and the question of collection and delivery may affect total time in transit and portage charges. Fast water freight would work well in conjunction with passenger traffic. It is not very many years gone that travelers preferred canals to stage coach and the analogy still applies insofar as comfort and restful conditions in water travel surpass those in a sleeping car. It is merely a question of providing every convenience and shortening time in transit which are not insurmountable difficulties in many overnight runs.

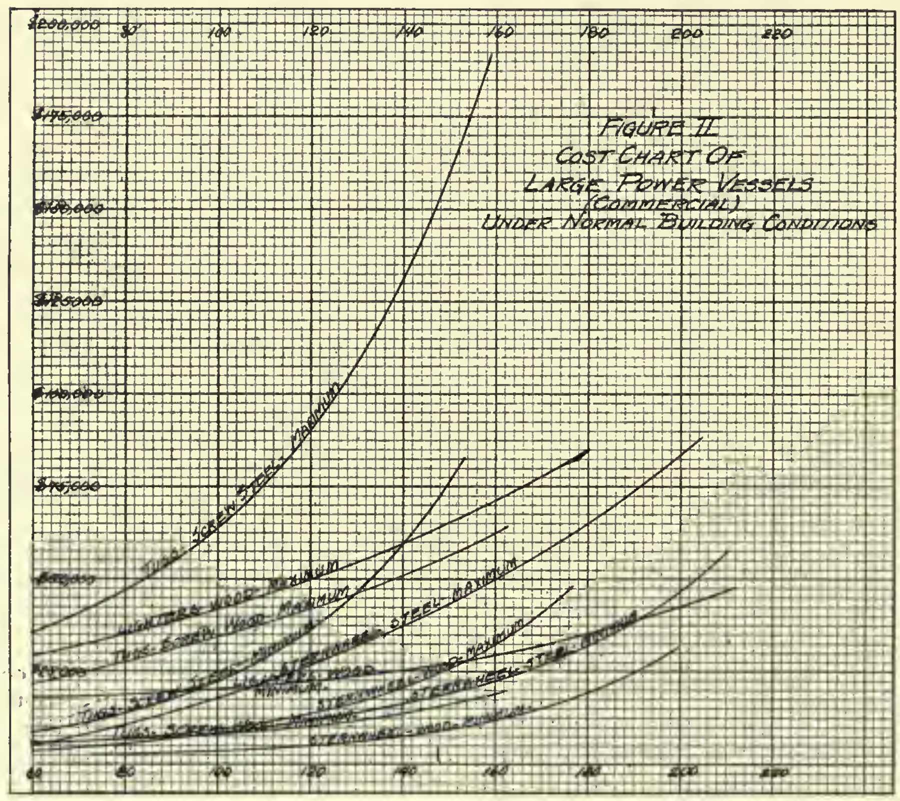
Kinds of Freight Handled

Perishable freight is of two general kinds: That which will deteriorate due to delay in shipment (mainly edibles); and that which must be protected from the weather. The first of these will require refrigeration or ventilation, and the second merely storage in holds or under cover. Both of these classes are readily adaptable to economical water conveyence, delay at terminals being the most adverse condition to be remedied.

Miscellaneous slow freight already constitutes a considerable percentage of the total transport material in some sections of this country and a greater proportion in many foreign lands than is generally supposed. It consists of many items in variegated sizes from large pieces of machinery to small boxes, cases, castings, etc.

Bulk freight lends itself most agreeably to storage and terminal loading and discharge. It consists of coal, brick, petroleum, ore, grain, etc., and renders possible the design of vessels specially fitted to carry the particular commodity. Maritime traffic in this class is also profitable and constantly increasing in volume. Freight affects hull design in conjunction with the route of travel, necessitating large closed holds or being most expeditiously stowed on deck in the open or under cover. The amount to be carried per voyage is dependent upon length of the trip (in distance as well as duration). If the distance is considerable, the decreased number of trips will necessitate a larger ship that profit may result. On a short run the assumption that gross expense of conveyance is inversely proportional to tonnage conveyed, does not necessarily hold, since the increased time for loading and discharging may be excessive when considering the loss in vessel's earning power while idle and the greater original investment. Again, the depth, width and contour of channel, dimensions of locks, wharves and maneuvering space at terminals may be considerations affecting size, proportions and even propelling mechanism of the vessel. Thus a comparatively narrow and shallow river with sharp bends, locks, and sometimes rapids, would necessitate radically different design from that permissible with a wide, deep and open stream. Paddle wheel or tunnel-sterned boats with shallow beamy hulls have arisen





from the first mentioned natural limitations, whereas the normally formed screw vessel is desirable where these obstacles are absent or negligible.

How to Determine First Cost

When the appropriate type and its lengths have been decided upon, it becomes necessary to determine the probable first cost and also the other dimensions properly applicable. The ideal condition with respect to funds would be that in which these were ample for the most desirable type of vessel. Very often this is not the case, and modifications in design must be resorted to.

If the total costs of numerous vessels in a class are plotted as ordinates upon abscissa representing vessels' lengths, it will be found that all the resulting spots lie within an area enclosed by two curves, which are the maximum and minimum amounts requisite for building this type of vessel for any length.

Figs. 1 and 2 are "cost charts" of this nature, the smaller vessels having cost ordinates to large scale in Fig. 1, while the larger vessels' prices are modified to suit the limits of Fig. 2.

It will be observed that the screw vessels in Fig. 1 are more costly than the shallow draft paddle vessels. This is because of the more complex form and rugged structure of the former, requiring more elaborate and careful workmanship to withstand the strains of rougher waters which are navigated by this class. The same reasoning applies to Fig. 2, where it will be further noted that steel vessels are most expensive in either class.

The excess first cost of this material is more than offset by the gain in strength, durability and carrying capacity, for contrary to general supposition, the total weight of a wood vessel is greater than that of a steel one having equal strength, while the interior volume of the wooden one, representing cargo capacity on given dimensions, is also less than that in the steel hull.

The costs here plotted represent results of competitive bids during normal times, contracts having been awarded not necessarily to the lowest, but rather to the most responsible bidder, as determined by capital and equipment of the boat yard.

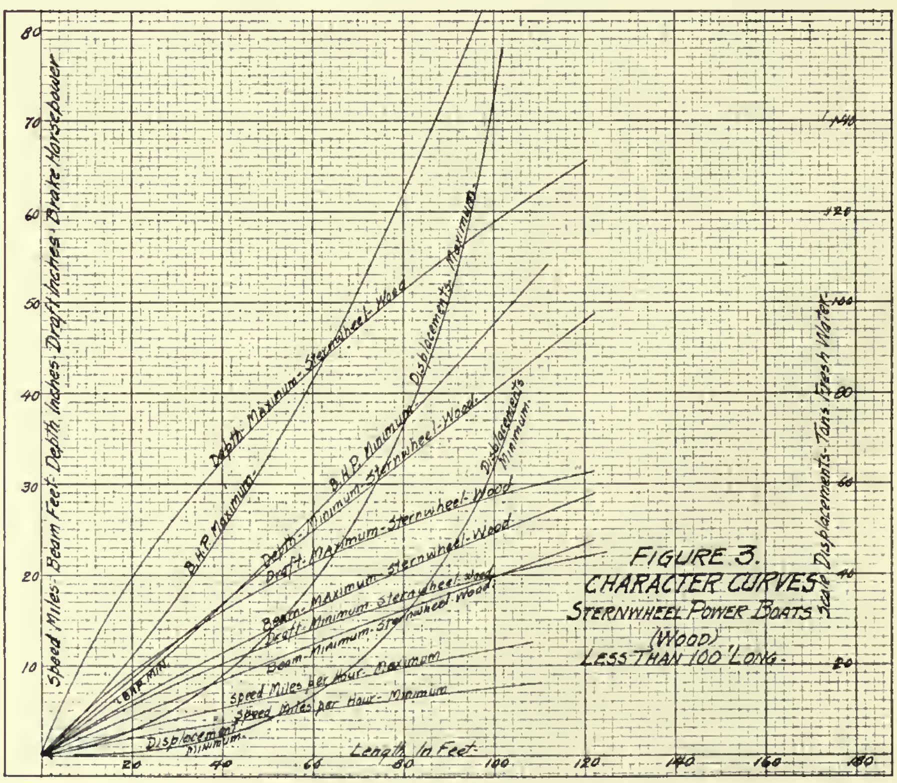
If a certain fund is available for the construction of power boats, the various sizes of a given type could be derived as follows: Assume that the amount at hand is $40,000. Then in Fig. 1, an 82-foot wooden screw tug could be built to maximum equipment standards and two 87-footers of simplest character in normal times. At present the costs would be higher—the above sum affording a vessel about 70 feet long, with all refinements and two 40-footers which would be little beyond hull, engine and steering gear.

On the other hand, if a vessel of given length is to be built, its cost range could be similarly arrived at. In Fig. 1, a 60-foot tug (wooden) would range between $7500 and $23,750. The maximum figures are most nearly in accord with present mean rates for ordinary boats.

Beam Varies on Given Length

For a given length of vessel, the beam (width) and the depth may vary considerably. This variation is limited in the case of beam, by its effect upon stability and speed for a given power. Also to complicate matters, where the increased beam heightens the tendency to resist capsizing force, it will result in greater resistance to propulsion.

The degree to which stability may be sacrificed to minimizing resistance has been determined within minimum and



maximum limits, beyond which it is rarely and with questionable gain, that proportions are assigned in design.

These proportions are graphically depicted in Figs. 3 to 7, and dimensions for any length selected from these cannot fail to produce vessels of ample strength, stability and reasonably speedy in proportion to the power installed.

The depth of hull at mid-length is an index to strength, just as the depth of a girder determines ability to resist deflection. A deeper vessel on given length is relatively stronger than a shallow one.

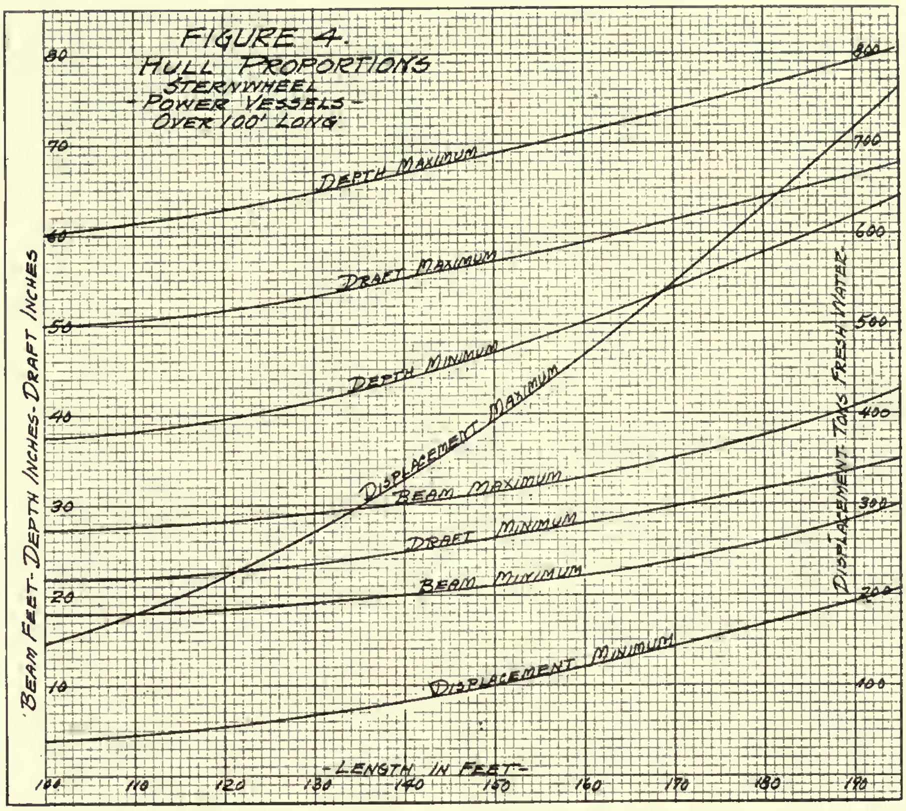
Power of the engine to drive the hull whose dimensions have been selected, is the next consideration. Too many vessels, particularly in the "small boat" class, have either too much or too little energy in the machines driving them, for a vessel may be over as well as under-powered. It is fallacious to presume corresponding increase in speed for additional horsepower.

Further, it is impossible to calculate the exact resistance of a given sized boat by direct mathematical analysis. This is because, even with two vessels having like dimensions and diplacement, the hull forms may vary considerably.

There is at present no precise mathematical formula for that peculiarly warped surface of a hull, and until this is established (which will only be after years of investigation) the only ways to properly predetermine engines, are:

(a) By comparison of results in other similar vessels.

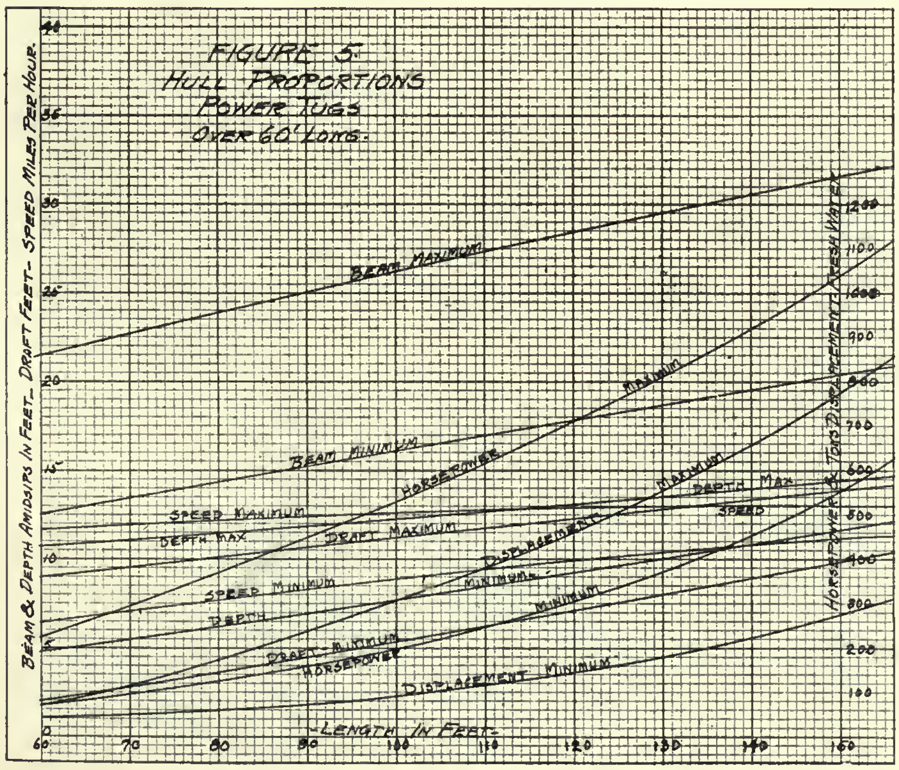
(b) By actually towing a model of the vessel, to scale, and deriving the result through the "method of comparison".



The first of these methods is that most feasible in power workboat design; the second, though in large vessels usually more reliable, is too elaborate and occasionally does not produce results anticipated, particularly in unusual forms. Since it is impossible to install machinery to scale in the model, or to fit miniature propellers, thereto, considerable experience is necessary to foretell the energy dissipated between engine and the point of expenditure of propulsive thrust. Adding to this the cost of a series of models, also the expense of conducting the tests at a properly equipped model testing basin, the method does not at present justify its adoption for small commercial boats.

In these, allaround working qualities are often superlative to minimum resistance at given speed, so that unless predecessors of like proportions have proven uneconomical, the result of observing their features (favorable or not) will ordinarily produce excellent results.

To this end, Figs. 3 to 7 have been elaborated, embracing powers, displacements, drafts and speeds of various types. These are characteristics of many boats in each class and may be considered representative.



Working Out the Details

Assume that the vessel is to be an 80-foot stern wheel towboat of wood. In Fig. 3, we would derive the following limits for particulars of the hull by reading up to the various curves as ordinate on the abscissa labeled 80:

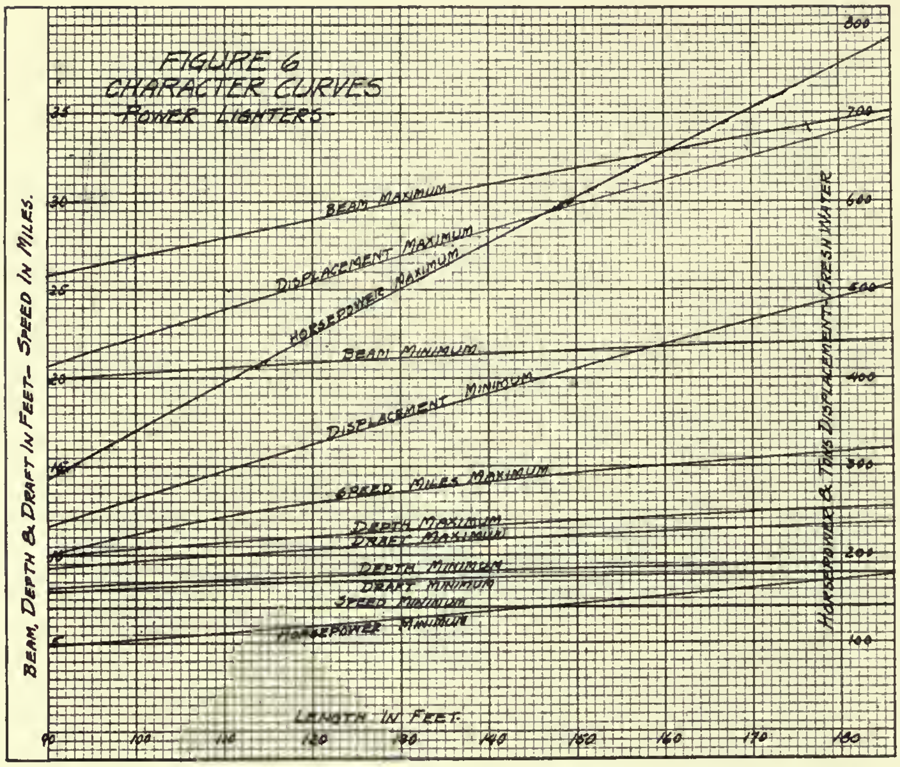
Length, 80 feet.

Beam, between 16 feet and 20 feet 6 inches.

Depth of hull, 32½ inches and 51 inches.

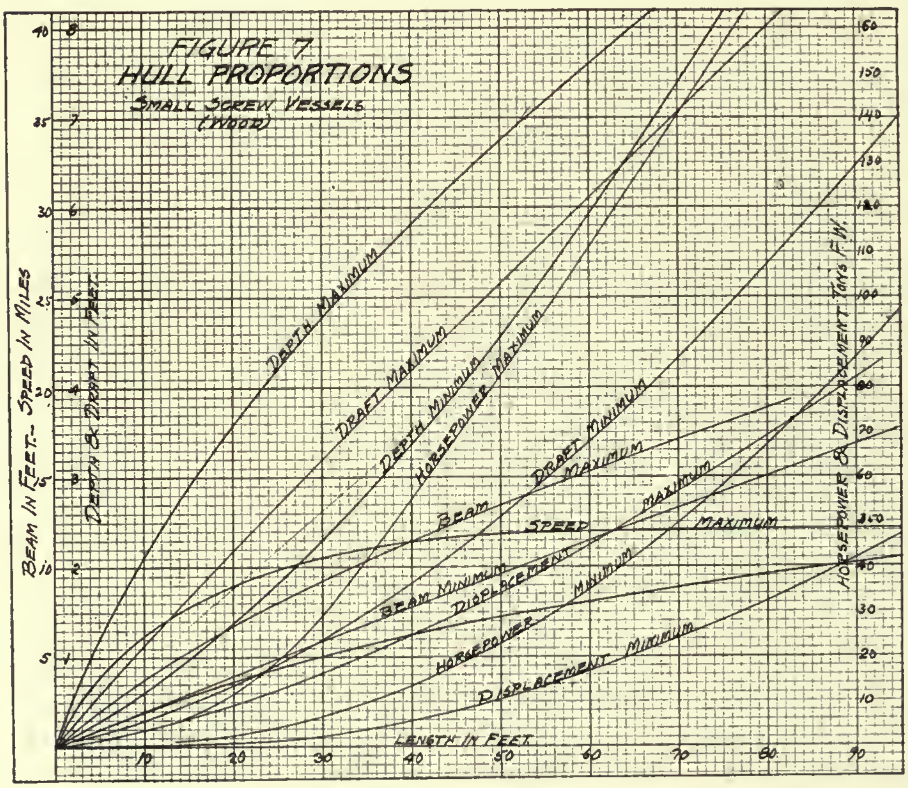
Draft in running condition, 17 inches and 25¼ inches.

Displacement (fresh water), between 31 tons and 73 tons.



Brake-horsepower of engine, 37 to 62.
Speed (per hour) 6 to 10 miles.

These preliminary figures may be derived from the remaining charts if other types of vessels are under consideration. It should be understood that



the lowest horsepower is the one which will drive the narrowest hull at the minimum speed, the higher power in the narrower boat will probably produce the maximum speed figure, while in the beamier boat this power will result in a speed intermediate between maximum and minimum.

The next consideration is that of fuel capacity, the kind having been predetermined by considerations of economy, facility of replenishing, etc., in the locality of the vessels' route. Gasoline and light distillate engines will require about a pint of fuel per horsepower per hour. This figure is high for a fuel consumption test with the engine on the blocks at the factory, but it must be understood the ordinary working conditions in the boat will prove less economical, due to wear, leakage, occasional overheating and perhaps neglect. It is therefore imperative to anticipate these difficulties by providing fuel ample under worst conditions.

Fuel oil for diesel engines will be safely estimated at 0.7 lb. per horsepower per hour.

In our chosen vessel, at 62 horsepower, burning gasoline or distillate, that many pints or 7¾ gallons would carry the wider boat eight miles and the narrower one ten. From this the tank capacity could be determined, depending upon facility of re-fueling. If the home dock were capable of re-filling tanks (a desirable feature) less fuel need be carried with increase in amount of freight. It should not be necessary to re-fuel oftener than once per working day, and, of course, if the voyage required more time than this, once per trip, if feasible.

The general arrangement will be governed by type. Accommodations for crew need only be fitted if these cannot return to their home port nightly, in which case necessary plumbing, lockers, etc., must also be installed. A study of arrangement will later be made, it being sufficient for any type to assume a somewhat similar layout to other boats in the same class, many of which have been ably described by current magazine contributions.

The preliminary study of and decisions with respect to design have now been gone over, bringing us to the stage at which details must be understood and perfected.

CHAPTER III

Buoyancy, Draft and Displacement

THE first requirement which commercial vessels must have is the ability to float. By this we mean that they should be suspended on the water's surface and that a certain portion of the hull should be above that surface. Now if the total weight of a boat be divided by its total watertight volume in cubic feet, the resulting figure is the pounds per cubic foot or the "density" of the vessel. If this weight per unit of volume is greater than that of a cubic foot of water, the vessel will sink.

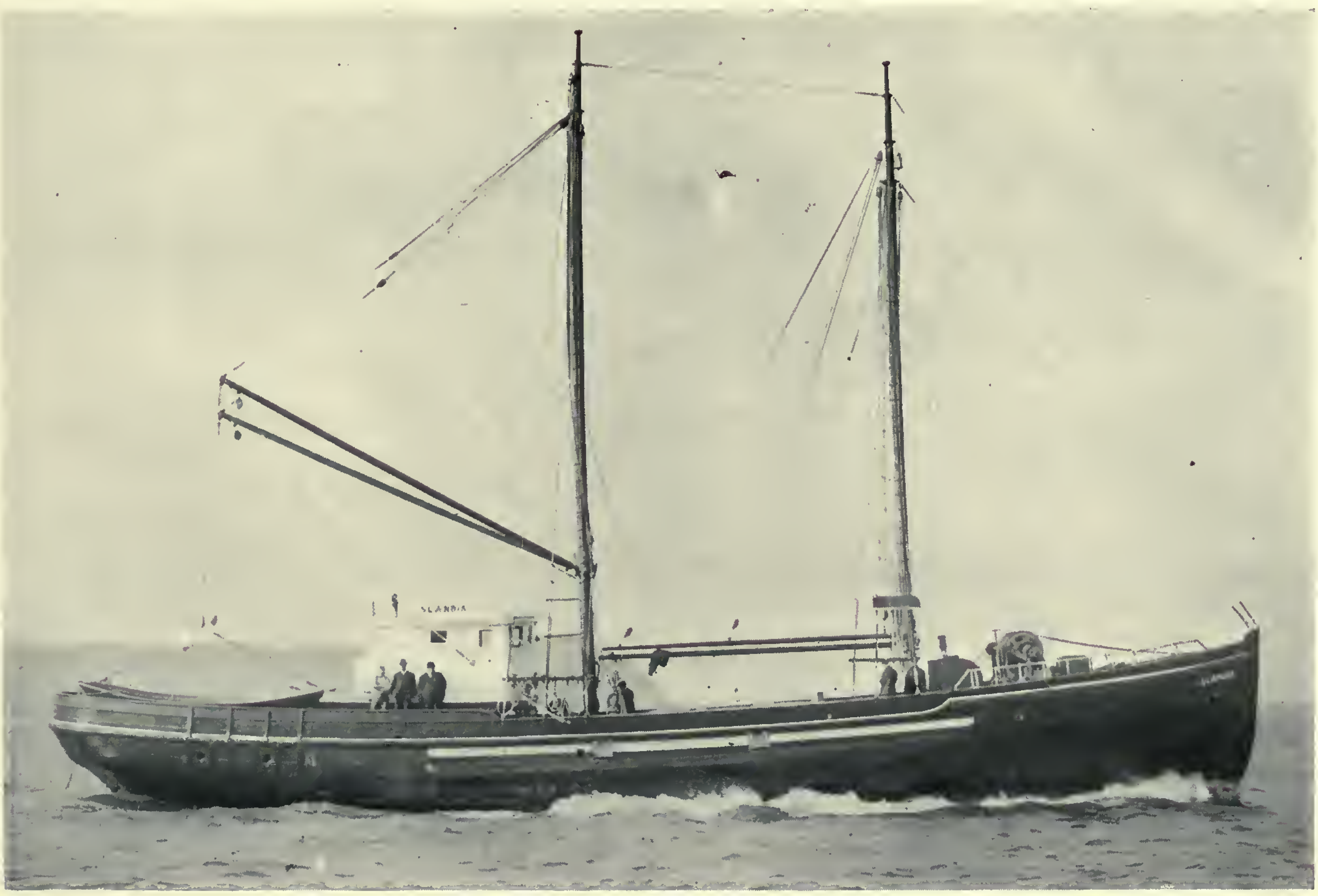
Fresh water has a weight of 62.5 pounds per cubic foot, while salt water weighs 64 pounds for an equal volume. A cubic foot of solid iron weighs 490 pounds and would sink in fresh or salt water. A cubic foot of wood which weighs from 30 to 60 pounds will float in water. If a cubical box, 1 foot on each side, were made of steel sheets ¼ inch thick the six plates forming the sides would weigh 10 pounds each, making a total weight for the box of 60 pounds. This 60 pounds is the density of the box and since it is less than the weight of a cubic foot of either salt or fresh water, the steel box will float.

In fresh water we could put a load of 2 pounds in the 60-pound steel box and it would still float. In salt water this load could be 3½ pounds.

We thus see that the difference between the total weight of a floating body and the weight of an *equal* volume of water represents the cargo carrying capacity and that the same vessel will carry more cargo in salt than in fresh water.

Experiment on Flotation

Take a shallow tray and weigh it carefully. Then place a deep bowl in the tray and fill the bowl brim full of water, taking care that it is just on the point of overflowing into the tray but that none of the water gets into the tray. Now weigh a square block of wood which is about half as wide as the bowl. Place the block carefully on the water in the bowl. The block will float in the bowl and some of the water will overflow into the tray. Take the block carefully out of the bowl and lift the bowl from the tray, being sure that no more water spills. Then weigh the tray again with the water which



SCANDIA, SEA-GOING POWER HALIBUT BOAT OF THE PACIFIC COAST was displaced from the bowl by the floating block.

Deducting the original weight of the dry tray from the final weight of the tray with displaced water will give the actual weight of the water. It will develop that the water displaced will weigh exactly what the block did.

We therefore see that the weight of a floating body is exactly equal to the weight of water it sets aside or displaces.

Now imagine that while the block floated in the bowl, we had frozen the water in the bowl. Then if the block were removed a cavity would remain in the ice and this cavity would have exactly the shape and volume of that part of the block below the water level. The shape of this cavity is called the "underwater surface" of the floating body.

If the water which overflowed into the tray were poured back into the cavity in the ice it would be filled and no water would remain in the tray.

This proves that: "The volume of water displaced by a ship is exactly equal to that part of the ship below the waterline," and that: "The weight of the water displaced by a ship equals the ship's weight."

This displaced water is the "displacement" of the ship and may be expressed in cubic feet or pounds.

Hold a body of known weight at arm's length and let go of it. The body falls to the ground. This shows that if any mass is suspended and not prevented from falling it will answer the attraction of gravity.

Now fix a spring scale to the body and again hold it out. The pull on the scale shows the body's weight. Therefore, to prevent a body from falling, the force holding it up must equal the body's weight.

A body floating is subject to the same "pull" of gravity, but is prevented from falling, or rather "sinking" by an upward force in the water called "buoyancy", whose magnitude equals the ship's weight and also that of the displaced water.

The foregoing principles are applied in determining to just what level a ship will float and the method of doing this follows:

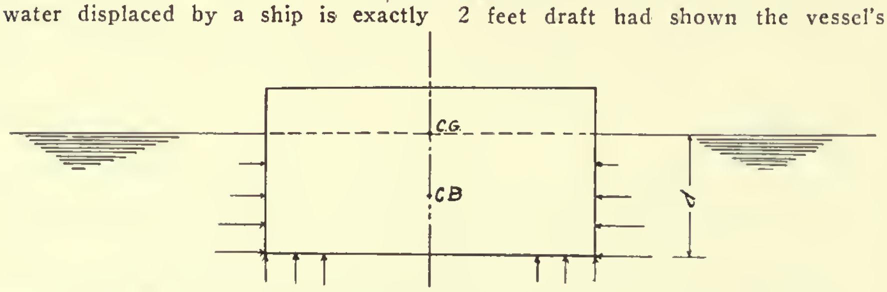


FIG. 8—SHOWS WATER PRESSURE ACTING ON A FLOATING VESSEL

First the form of hull is carefully drawn and its volume is calculated to different heights above the bottom of the keel. When the volume to each level or "water plane" has been formed, determine the weight of an equal volume of the water in which the vessel is to float by multiplying the number of cubic feet in the hull to each water level by the weight of a cubic foot of water.

In general the ton is used for displacement weights in preference to the pound, that the figures employed may not be too large. To convert cubic feet of hull volume to the number of long tons (2240 pounds) of water displaced by that volume, divide by 35 for salt or 36 for fresh water. This is based on the fact that one ton of fresh water equals 35 and of salt water equals 36 cubic feet.

Suppose that a chart is made whereon heights above a given base line represent draft to scale. On the base line we can represent displacement in tons or in cubic feet by a horizontal scale measuring from left to right. Then if our calculations at 2 feet draft had shown the vessel's underwater volume to be equal to 10 tons of displaced water we could indicate this displacement by a point on the chart 2 feet above the base and 10 tons to the right of the vertical line through zero. A similar point for the displacement corresponding to each level for which the hull volume has been calculated would show just how the weight of displaced water increased as the vessel sank to different water levels. A curve through these spots is known as the displacement curve, one of which has been drawn in Fig. 14.

Getting the Weight of the Lumber

After the complete plans showing the vessel's construction and the location of each item therein have been drawn, it is possible to calculate the weight of every item and of the structure. For example the keel may be a timber of oak 75 feet long and 8 inches wide by 10 inches deep. The volume of this timber in cubic feet is obtained by multiplying the cross sectional area by the length.

$$\frac{8 \times 10}{144} \times 75 = 41.67 \text{ cubic feet}$$

Oak weighs about 54 pounds per cubic foot when saturated with water and allowing for fastenings. Therefore the keel of the vessel would weigh:

$41.67 \times 54 = 2250.18$ pounds or slightly more than one long ton.

Performing a similar calculation for the other framing, the hull planking, the deck beams and planking, the bulkheads, deck houses, tank and engine foundations, masts, booms, deck fittings, life boats, furniture and joiner work, machinery, tanks, steering gear, etc., we obtain the complete hull weight in pounds. Dividing this sum by 2240 gives the tons for the vessel's light displacement. If the holds are calculated full of the cargo which is to be carried and the water and fuel in the tanks are added to this, the sum of these three figures is the total deadweight of cargo which may be added to the light displacement thus getting the full load weight or displacement of the vessel.

Now on the base line of the displacement curve find the figure corresponding to the light displacement in tons. Draw a vertical line from this point to the curve. Then at the point where this vertical line cuts the curve, draw a horizontal line over to the scale showing draft. The figure so found will be the light draft of the vessel and a similar procedure with the load displacement will indicate the full load draft.

After the vessel is built the displacement scale is useful in finding the weight of cargo carried per trip. This is done by taking the vessel's light displacement in tons from the load displacement as obtained from the curve by reading the tons corresponding to the draft with cargo on board. The difference gives the long tons of cargo.

An Illustration of Buoyancy

Fig. 8 shows the water pressures acting on a floating vessel. These may be divided into horizontal and vertical forces and are shown by arrows. The horizontal forces on the sides are equal and opposite at each depth below the surface and therefore balance each other so that there is no tendency to move sidewise. "d" is the draft in feet and the upward pressures on each square foot of the bottom equal "d" times the weight of a cubic foot of water. The sum of all such upward pressures equals the force "buoyancy" which keeps the vessel afloat.

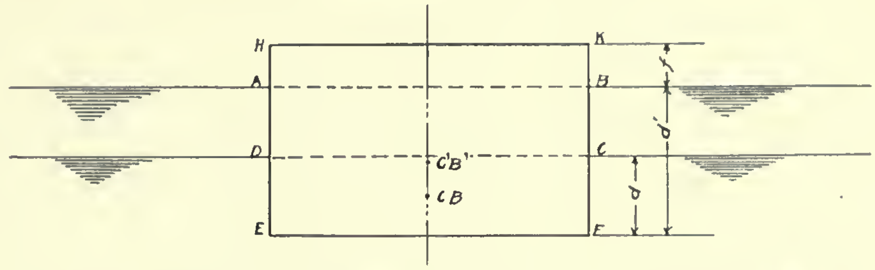


FIG. 9—ILLUSTRATES RELATION BETWEEN DRAFT AND DISPLACEMENT

Fig. 9 illustrates the relation between draft and displacement with and without cargo. When the vessel is light, "d" is the draft, "D C" the water line and the rectangle "D C E F" a cross section of the hull below water. "C B" is the center of gravity of the displaced volume and is called the "center of buoyancy". The upward force of the water is assumed to be concentrated at this point.

When cargo is placed aboard, the vessel's weight increases and the force of buoyancy acting in the light condition is not sufficient to support it. The vessel, therefore, sinks to the new water level "A B" where buoyancy as represented by the increased weight of displaced water becomes equal to the augmented weight of the vessel. "d'" is the new draft and "C' B'" the new center of buoyancy.

The height "f" of the deck above the water line is called the "freeboard". It is a measure of the weight which can be added to completely submerge the vessel by increasing the displacement by the volume "H K A B". This volume is called the "reserve buoyancy" and is necessary for stability and safety against sinkage.

What is Meant by Reserve Buoyancy

In Fig. 10 the utility of reserve buoyancy is indicated. Assume that the box-shaped vessel has two walls or "bulkheads" (G M and F N) dividing it into three compartments, and that the vessel floats at the water line W L. Suppose that a hole is made in the bottom of the central compartment so that sea water enters between the bulkheads. Before this occurred the volume of the hull (B C F G) between these bulkheads displaced a certain amount of water and thus helped to float the vessel or rather to support as much of the total vessel's weight as would equal the water displaced. When water entered the compartment the section between the bulkheads no longer afforded buoyancy since the volume of sea water originally displaced rushed back into the cavity. Meanwhile the vessel's weight has not changed and since this weight exceeds the net amount of intact buoyancy represented by the displaced volumes A B G H plus C D E F, the vessel will sink until the weight of water displaced again equals the original amount. This sinkage is assumed to the water line W' L'. During the sinkage the water rose freely inside the damaged compartment to the level M N and no buoyancy could therefore be regained in that compartment.

When sinkage has ceased, the volume L M G H plus the volume N P F E equals the original volume A D E H, and since by taking B C F G from A D E H we get the same volumes as by taking L M B A and N P D C from the sum of L M G H and N P E F, we see that the added end displacements L M B A plus N P D C must equal B C F G.

Figuring Reduced Freeboard

Notice that the original freeboard "f" has been reduced to "f'". This reduced freeboard is easy to calculate in the case of a box. For example assume that the vessel in Fig. 10 is 100 feet long, 30 feet wide and 10 feet deep. Suppose the bulkheads G M and F N to be at a distance of 40 feet from each end, or that the distance between them (B C) is 20 feet. If the draft (A H) is 5 feet before the bottom is punctured, what will be the new draft after the accident to the central compartment? First calculate the volume of the original displacement

A D E H = 100 × 30 × 5 cubic feet = 15,000.

Then $\frac{15{,}000}{35}$ = 428 4/7 tons of salt water or

$\frac{15{,}000}{35}$ = 416 2/3 tons of fresh water.

Then when G F is punctured the lost volume of displacement is B C F G = 20 × 30 × 5 = 3000 cubic feet.

Therefore the amount of original displacement remaining is

15,000 — 3000 = 12,000 cubic feet = A B G H plus C D E F.

The lost 3000 cubic feet must be replaced by volumes L M B A plus N P D C which are each 40 feet long and 30 feet wide but whose heights L A are not known.

Volume L M B A = 40 × 30 × (L A) feet; volume N P D C = 40 × 30 × (L A) feet.

Volume L M B A = 1200 × (L A) feet; volume N P D C = 1200 × (L A) feet.

L M B A + N P D C = 2 × 1200 × LA feet = 2400 × L A' = 3000 cubic feet.

L A = $\frac{3000}{2400}$ = 1¼ feet which is the amount the vessel will sink. The new draft is 5 plus 1¼ = 6¼ feet.

The Value of Transverse Bulkheads

The foregoing shows the value of transverse bulkheads and also makes it clear that the volume above the original water line W L and outside of the damaged compartment (B C G F) must be greater than the lost buoyancy (B C G F), for unless this can be regained in the undamaged ends, the sinkage (L A) will be greater than the freeboard and the vessel will not float after the accident.

When some external force inclines a boat the conditions which exist in the heeled-over position are shown in Fig. 11. The water line when upright was at W L and the displacement volume had the rectangular cross section R A S T. Point B is the center of buoyancy when upright and point G the center of gravity of the vessel and its contents. W' L' is the new water line when heeled over and it crosses the original water line at point O.

An Analysis of Stability

Observe that the cross section N D S T of the underwater body has been changed to the form of a trapezoid, whose center of gravity is at B'. This point is therefore the center

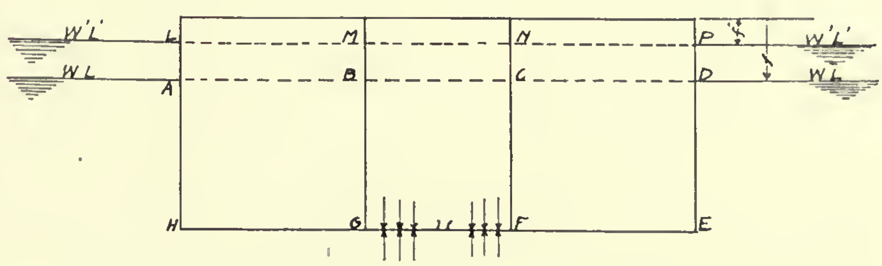


FIG. 10—INDICATES THE UTILITY OF RESERVE BUOYANCY

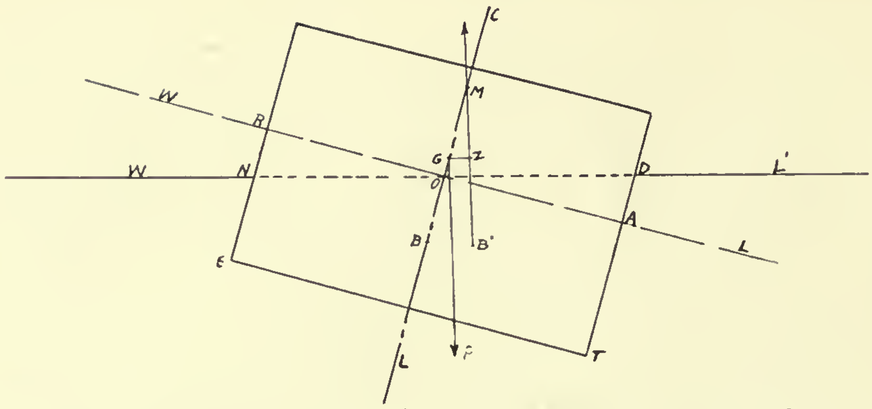


FIG. 11—HOW EXTERNAL FORCE CAUSES HEELED-OVER POSITION

of buoyancy when heeled over and we see that a change in the form of a vessel's underwater body causes a shift of the center of buoyancy.

Now the force of buoyancy acts vertically upward through B′ and is equal to the vessel's weight acting downward through G, which point is not changed in position. The two parallel forces are a distance of G Z apart and are called a "couple". They tend to rotate the vessel in a direction opposite to the motion of a clock's hands, or "counter clockwise", which in Fig. 11 tends to return the vessel to the upright. The magnitude of this couple equals one of the forces times the lever arm "G Z". Let W equal the vessel's weight (also the buoyancy or displacement in pounds or tons). G Z is in feet so when W multiplies it we have:

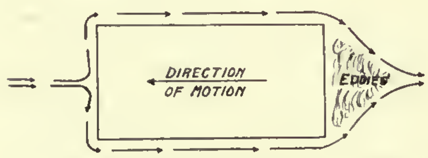


FIG. 12—PATH OF WATER AROUND A BOX-SHAPED HULL

$W \times GZ =$ the foot pounds tending to turn the vessel upright.

This product is called the moment of "statical stability".

It will be noticed that the force of buoyancy intersects the vessel's center line at the point M which is called the "metacenter". The distance G M is the "metacentric height" and is a direct measure of the distance G Z.

$$\left(\frac{GZ}{GM} = \text{sine of angle } GMZ\right)$$

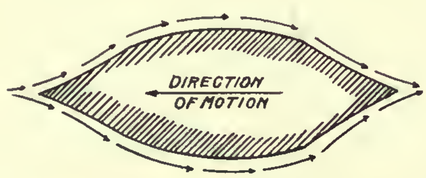


FIG. 13—GRADUAL STREAM-LINE OF A PROPERLY FORMED VESSEL

If M is above G the vessel tends to right itself and G M is called positive. When M is below G the couple is reverse in direction and would upset the vessel. G M is then called negative. This unstable condition can exist if the point G is high up such as with very heavy deck loads.

The method of calculating stability is too complicated for discussion in this article, but can be obtained by consulting Attwood's work on "Theoretical Naval Architecture".

The box-shaped vessels we have thus far considered would carry a maximum amount of cargo with given limiting dimensions of length, beam and draft. Ease of propulsion plays, however, an important part in contributing toward earning capacity.

Resistance of the Moving Hull

Figs. 12 and 13 illustrate the effect of hull form upon the resistance set up by the water when a vessel moves through it.

Looking down on a box-shaped moving boat, the arrows in Fig. 12 are the paths taken by particles of water which are deflected when the boat passes them. Notice the sharp right angle turn or sudden changes in direction of the particles' flow. These paths of flow are called "streamlines". The sharp changes in direction cause eddies at the two forward corners of the box form and also at the after portion.

Experience has shown that all changes in direction of streamlines should be gradual as in Fig. 13 and that a vessel properly formed will offset the loss in carrying capacity by the facility of propulsion.

Resistance to propulsion is made up of three distinct components:

(1) Surface friction or "frictional resistance" which depends upon the area of submerged or "wetted" surface and the smoothness and the roughness of this surface.

(2) Eddy making resistance, set up by abrupt changes of surface conformation and is most serious at the after end of vessels.

(3) Wave-making resistance which is the power expended in generating the familiar bow and stern waves. This is affected by the form of hull and speed.

Sometimes wave and eddy-making resistances are grouped under the name "residual resistance". This is because frictional resistance is the only portion which can be fairly approximated by calculations and if this is subtracted from the total resistance the result is the sum of wave and eddy resistances.

The power actually required to pull a vessel at various speeds, thus overcoming the resistances encountered, is the Effective Horsepower (E H P). Between the machinery which generates the power and the propeller or paddle wheel which converts the power into thrust driving the vessel, there is mechanical loss due to friction in the machinery parts, etc. Therefore, the power at the engines must be greater than the E H P by the amount of this loss.

Indicated Vs. Brake Horsepower

When power at the engines is derived from indicator cards which show the work done by the gases in the cylinders, it is the indicated horsepower (I H P). If the engine power is measured by the actual torsion in the crank shaft it is called the Brake Horsepower (B H P).

Clearly the less power lost between engine and propeller, the greater the efficiency and a measure of this can be expressed by the ratio of E H P to I H P or B H P. This ratio is called the "Propulsive Coefficient" and is from 50 to 70 per cent in ordinary vessels. Of course it will be higher when B H P is used than with I H P because there are losses in the engine itself between the power developed in cylinders and that delivered at the crank shaft. This engine efficiency (a ratio of $\frac{BHP}{IHP}$) should be from 80 to 92 per cent.

The surface to which a ship's hull is formed or molded is known as the "molded surface". It is parabolic in nature so that a section in any direction between a plane and the surface is a parabolic curve.

If the hull is cut by a number of planes in various directions, the resulting curves of intersection between the planes and hull surface show the character of surface and may be used as a guide in constructing the vessel. The drawing so made is called the "sheer draft" or more often the "Lines."

MATAMEK—OWNED BY COPLEY AMORY, OF CAMBRIDGE, MASS.
Used in Labradore; 36 feet long by 8 feet 9 inches beam; driven by Lawley 2-cylinder, 4-cycle engine

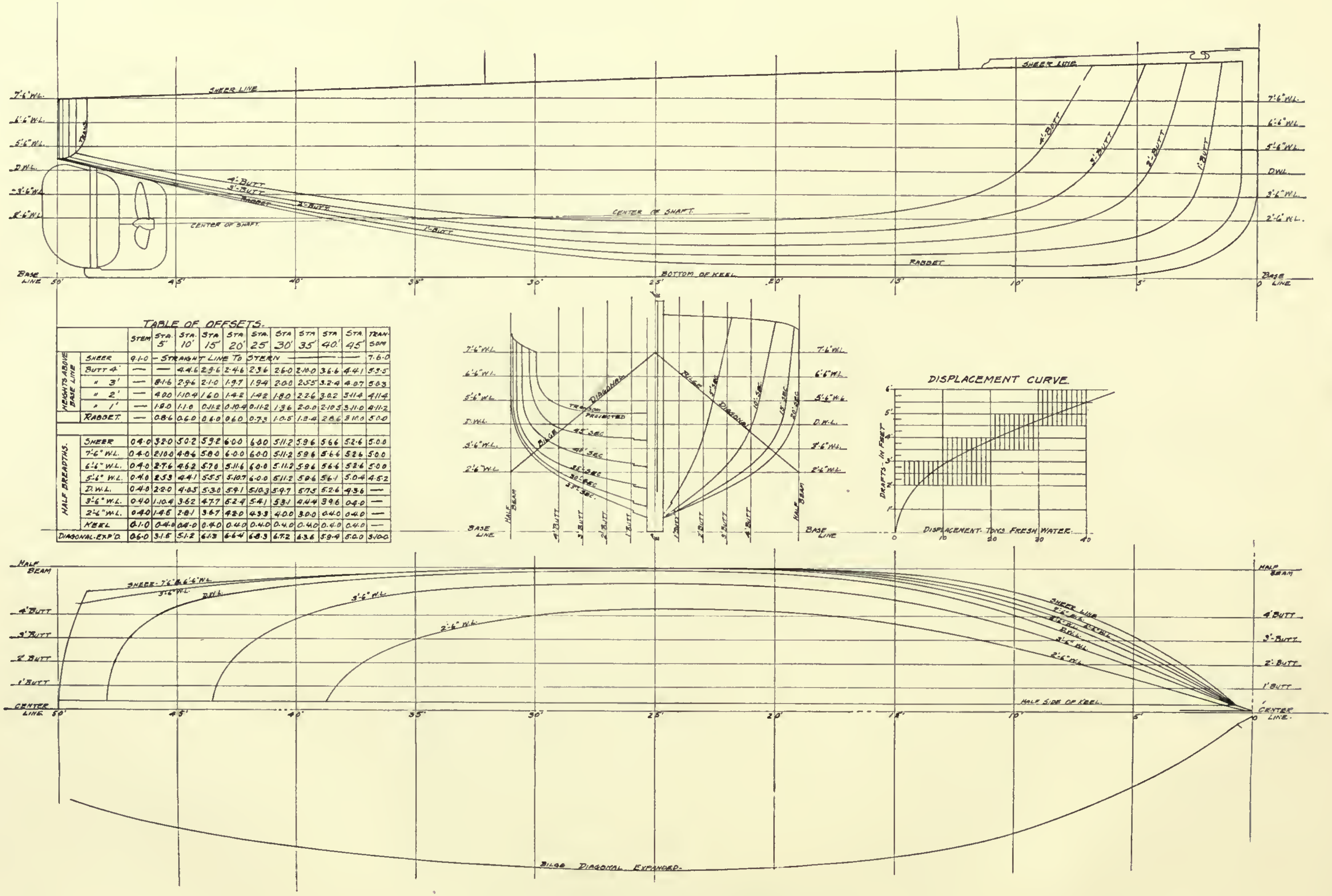


TABLE OF OFFSETS.

		STEM	STA. 5'	STA. 10'	STA 15'	STA 20'	STA. 25'	STA 30'	STA 35'	STA 40'	STA. 45'	TRANSOM
HEIGHTS ABOVE BASE LINE	SHEER	9·1·0	– STRAIGHT LINE TO STERN									7·6·0
	BUTT 4'	—	—	4·4·6	2·9·6	2·4·6	2·3·6	2·6·0	2·10·0	3·6·6	4·4·1	5·5·5
	" 3'	—	8·1·6	2·9·6	2·1·0	1·9·7	1·9·4	2·0·0	2·5·5	3·2·4	4·0·7	5·0·3
	" 2'	—	4·0·0	1·10·4	1·6·0	1·4·2	1·4·2	1·8·0	2·2·6	3·0·2	3·11·4	4·11·4
	" 1'	—	1·9·0	1·1·0	0·11·2	0·10·4	0·11·2	1·3·6	2·0·0	2·10·5	3·11·0	4·11·2
	RABBET.	—	0·8·6	0·6·0	0·6·0	0·6·0	0·7·3	1·0·5	1·3·4	2·6·6	3·10·0	5·0·0
HALF BREADTHS.	SHEER	0·4·0	3·2·0	5·0·2	5·9·2	6·0·0	6·0·0	5·11·2	5·9·6	5·6·6	5·2·6	5·0·0
	7'-6" W.L.	0·4·0	2·10·0	4·8·6	5·8·0	6·0·0	6·0·0	5·11·2	5·9·6	5·6·6	5·2·6	5·0·0
	6'-6" W.L.	0·4·0	2·7·6	4·6·2	5·7·0	5·11·6	6·0·0	5·11·2	5·9·6	5·6·6	5·2·6	5·0·0
	5'-6" W.L.	0·4·0	2·5·3	4·4·1	5·5·5	5·10·7	6·0·0	5·11·2	5·9·6	5·6·1	5·0·4	4·5·2
	D.W.L.	0·4·0	2·2·0	4·0·5	5·3·0	5·9·1	5·10·3	5·9·7	5·7·5	5·2·6	4·3·6	—
	3'-6" W.L.	0·4·0	1·10·4	3·6·2	4·7·7	5·2·4	5·4·1	5·3·1	4·4·4	3·9·6	0·4·0	—
	2'-6" W.L.	0·4·0	1·4·6	2·8·1	3·6·7	4·2·0	4·3·3	4·0·0	3·0·0	0·4·0	0·4·0	—
	KEEL	0·1·0	0·4·0	0·4·0	0·4·0	0·4·0	0·4·0	0·4·0	0·4·0	0·4·0	0·4·0	—
DIAGONAL. EXP'D.		0·6·0	3·1·5	5·1·2	6·1·3	6·6·4	6·8·3	6·7·2	6·3·6	5·9·4	5·0·0	3·10·0

FIG. 14—LINES OF A 50-FOOT POWER TUG

CHAPTER IV

Laying Down-Fairing the Lines

LAST chapter we explained as simply as an intricate question will permit, the principles involved in designing a workboat hull. There are certain fundamental features of every successful power-driven boat which must be molded into a homogeneous model, otherwise a boat may be satisfactory in some respects and entirely lacking in other requisites of performance.

Now having mastered the principles of displacement, buoyancy, stability, etc., we will endeavor to apply them to the job in hand, of creating a design from which construction of the hull may be accurately carried out. Fig. 14 is the "Lines" for a 50-foot power tug and consists of three views; a longitudinal elevation, a plan view or "half breadth" and an end view or "body plan". The relative location of these views is conventionally arranged as in the figure with the forward part of the boat or the "bow" toward the right hand.

In the elevation and body plans a horizontal base line is drawn at the lowest point and all vertical measurements or "heights" are measured from this. This base line is really the edge of a horizontal plane and numerous other horizontal planes are shown at distances above it. These latter planes are as nearly parallel to the load water line as can be estimated and are called "water planes." They are labeled "2′ 6″ W L," "3′ 6″W L," "Designed W L," etc., and appear as straight horizontal lines in the elevation and body plans. Where the hull is cut by water planes a series of longitudinal horizontal curves result. These curves can be shown only in a plan view and are "water lines." They are labeled in conformity to the water plane, which cuts them from the hull surface.

The upper hull limiting line is called the "sheer line" and may be curved or straight in elevation. It is usually higher at the bow than at the stern and if curved, its lowest point is at about one-third of the length from the stern, the line rising from this low point to the forward and after ends.

The plan view of the sheer line in the half breadth plan is widest and parallel to the longitudinal center line at about mid-length. From this it curves inward to the bow and stern respectively.

At the extreme ends in the elevation two vertical lines are drawn and are the "forward" or "after perpendicular" respectively. The distance between these is divided into ten or more equal lengths and perpendiculars are erected at the points of division. These vertical profile lines are the edges of cross sectional planes which are passed through the hull perpendicular to the base plane and the longitudinal center plane. The sectional planes intersect the molded hull surface in curves called "cross sections" which are shown in the "body plan" or end view.

The fullest of these sections is usually half-way between the end perpendiculars and is called the midship section. Its characteristics are similar to Fig. 19, where the section intersects the half siding of the keel at the "rabbet line." From this lower point and depending upon the type of vessel, a "line of bottom" extends to the "lower turn of bilge". If the line of bottom is produced to the vertical line tangent to the widest point of the section, the height of the point where the two lines intersect above the lowest point of section, is called the "deadrise". Continuing from the lower turn of bilge, the section rounds sharply upward to the point where it is tangent at the vertical line showing the maximum width. This vertical line is the "line of half breadth" and the maximum width of section to this line is the "molded beam." From the upper turn of bilge the section may be vertical to the point where it cuts the deck side, and a vessel with this type of section is called "wallsided." If the upper part of the section falls in from the upper turn of bilge to the deck at side, the amount of fall in from the line of half breadth is called the "tumble home." This feature is not essential to efficient design, being retained mainly through the dictates of custom. The height from the point where the midship section intersects the keel

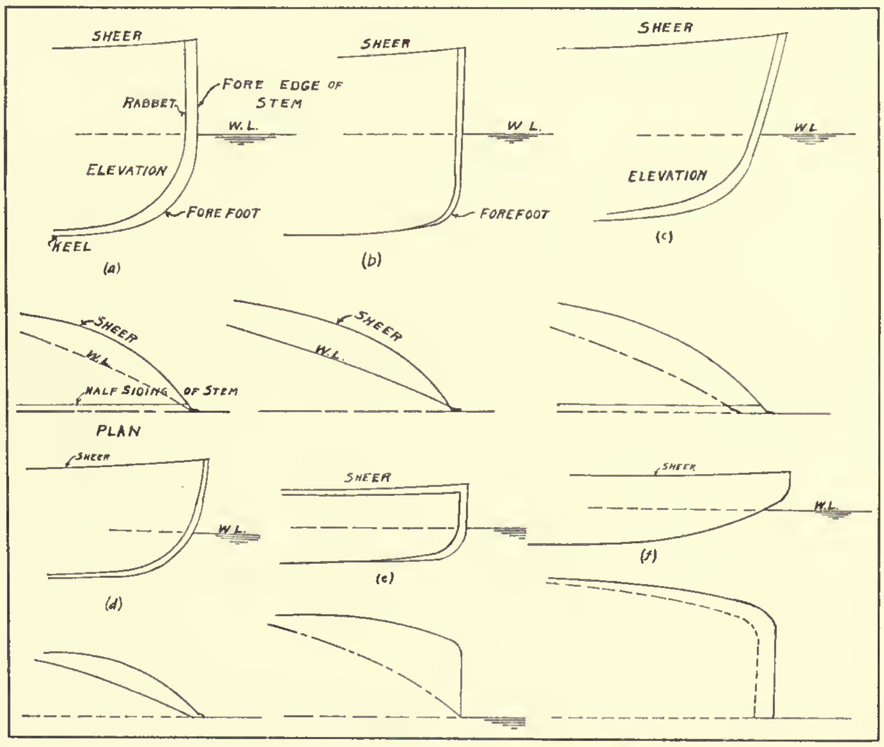


FIG. 15—VARIOUS FORMS OF STEMS

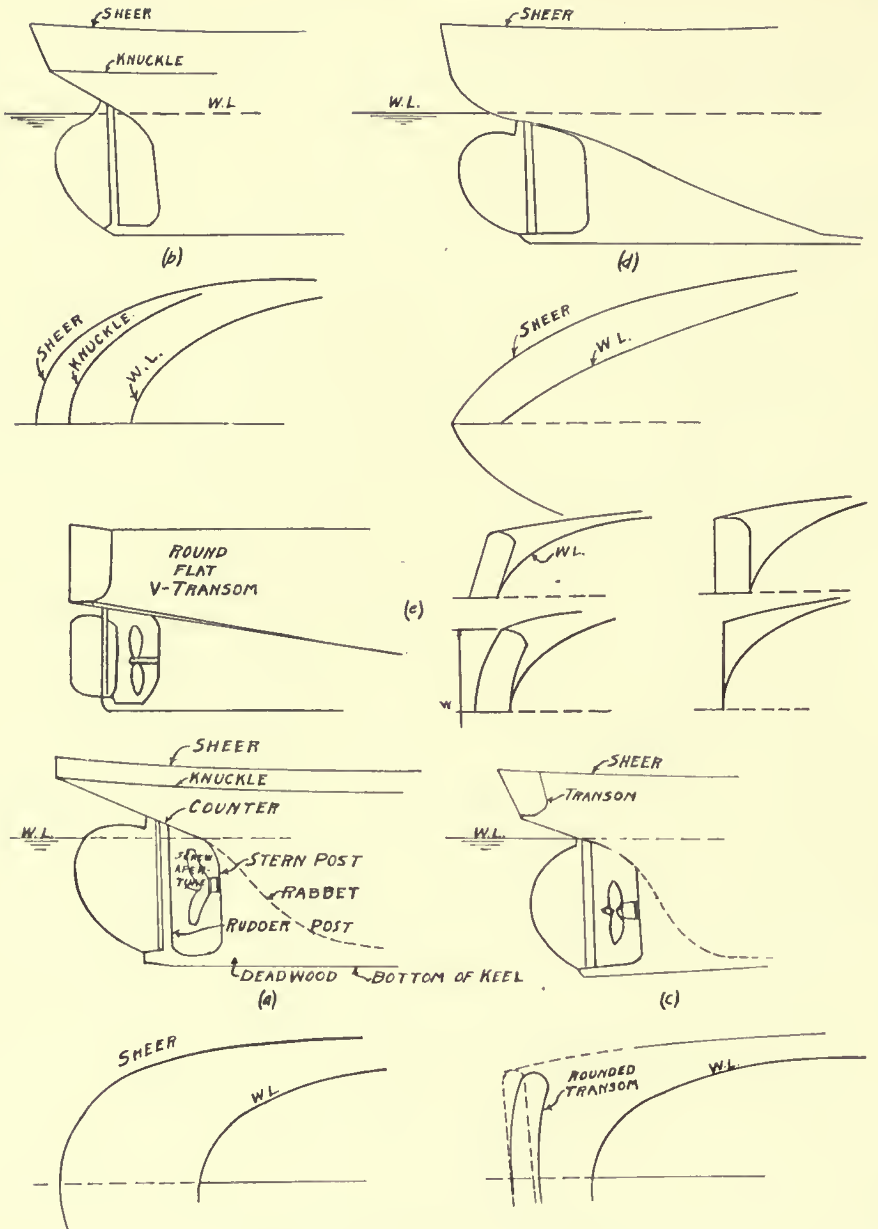


FIG. 16—VARIOUS TYPES OF STERNS

to the upper deck at side is the "molded depth."

When the deck is rounded up or "cambered" the crown of deck at center above deck at side is usually to the amount of ¼ inch per foot of deck width. This curvature may be more or less and is often entirely dispensed with. Its purpose is merely to drain the deck, but since few vessels are on an even keel very often, camber can be omitted with attendant gain in simplicity of construction.

The sections forward and aft of amidships are finer than the midship section and it is desirable to have the forward ones U-shaped at their lower endings, while the after ones are V-shaped.

When a portion of the hull amidships has the same cross section as at the midship section, it is called the "parallel middle body" and it may be as great as 60 per cent of the length. The hull forward of the parallel middle body is the "forebody", that aft of the parallel middle body the "after body".

If a series of planes is passed through the hull at varying distances from and parallel to the vertical longitudinal center line plane, the intersections of these planes with the molded surface are curves shown in the longitudinal elevation as "buttocks" and labeled "1′ Butt", "2′ Butt", etc.

Buttock planes appear as vertical straight lines in the body plan and as horizontal lines in the half breadth. The spacing of buttock planes should be the same as for water planes.

Fairing the Lines

The process of delineating a vessel's molded surface is called "fairing the lines". When "faired", the lines should be smooth, pleasing to the eye, free from sudden bumps or hollows and the volume of the underwater body should afford the proper displacement and location of the center of buoyancy under the center of gravity. Proper stability and trim are dependent on the lines. In general, the location of any point on the hull surface should be the same height above base line in elevation and body plans, the same width from the longitudinal center plane in half breadth and body plan, and the same longitudinal location in the elevation and half breadth plans.

A detailed description of the fairing process will be found in "A Manual of Laying Off", by Watson, while elaborated descriptions of displacement, stability and trim calculations are set forth in "Theoretical Naval Architecture", by E. L. Attwood.

Forms for Bow or Stem

The bow or stem may have one of the forms in Fig. 15. (a) and (b) are "plumb stems" with rounded or abrupt forefoot. The former type is extensively used on tugs, lighters and other small vessels under 150 feet long. Its name is derived from the fact that the portion above the water line is vertical.

Fig. 15-c is a "raked stem", where the part above the water line slopes forward. (e) is the stem of a shallow draft vessel, differing from the ordinary plumb stem by the wide forward deck end which is used to push barges. (d) is a rounded stem, curved from sheer line to keel and used in tugs or lighters. (f) is the spoon bow used in some shallow draft work. It has relatively high resistance and is less desirable than type (e) though simpler in construction.

Various types of after vessels' ends or sterns are shown in figures 16 and 17. Tugs and lighters have rounded sterns (Fig. 16-a) with a vertical surface between sheer and knuckle to which heavy fenders are attached. The rabbet line which was parallel to the bottom of keel amidships, rises at the after deadwood and merges into the counter. The structural appendages to which propeller and rudder are attached should be as narrow as practicable to reduce eddying.

Fig. 16-c is an overhung transom stern, the transom being a transverse plant or cylindrical surface which may slope as shown or be vertical. Employed in auxiliary sailing vessels.

Fig. 16-b is the semielliptical stern used in large vessels. Fig. 16-d is the compromise stern not common to workboats because difficult to construct. It is popular in cruisers and now often adopted in large commercial vessels.

Fig. 16-e, the full transom stern is

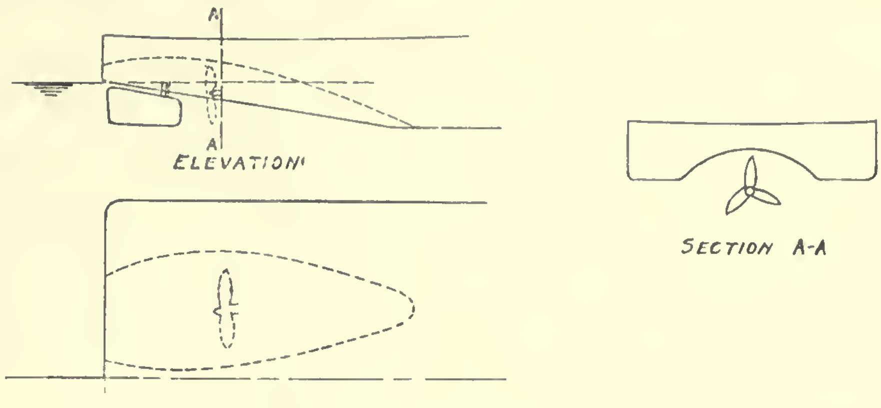


FIG. 17—STERNS FOR SHALLOW DRAFT VESSELS

used in small boats of all types. The transom may be flat, cylindrical or V-shaped.

Sterns for shallow-draft vessels are of the tunnel or paddle wheel type. Fig. 17-a shows the elevation plan and half section of a tunnel stern. It was originated by the necessity for a larger propeller than could be fitted under the hull with the limited draft. Consequently, a depression was made in the way of the propeller, as shown by the dotted lines in elevation and plan views. A cross section of the tunnel at any point in its length is the arc of a circle.

Fig. 18 is the outline in elevation, plan and section of a paddle wheel stern. The hull terminates at the transom, as shown, while the paddle wheel is overhung on two or more girders.

When the proper stem, stern, midship section and sheer line have been decided upon, they are drawn in on the rectangular layout of water planes, buttock and cross sectional planes in the line drawing.

Drawing in the Rabbet Line

The rabbet line joining the lower end of stem with the stern is now drawn in the elevation. Its height above the bottom of keel amidships equals the depth of keel timber minus the thickness of garboard plank. The forward and after endings of the rabbet line depend upon the cross sections, but may be roughed in for final fairing later on.

A line showing the half width of keel, stem and deadwood is drawn parallel to the longitudinal center line in the half breadth and body plans. Then the width of forward stem edge is indicated by a line at half this width parallel to the center line at the forward end of the half breadth plan. This surface on fore edge of stem varies from one-half to three inches and serves as a backing for the half round iron bar which is screwed to it and protects the stem timber. All water lines end at this line forward and on the half siding of deadwood and keel aft.

A trial load water line is now drawn in the half breadth of proper width at the midship section and with forward and after ends fixed from the points where fore edge of stem and rabbet line are cut by the load water plane in the elevation.

Then two sections located midway between amidships and the ends can be derived from the half breadth by taking their widths on the trial water line and the sheer line. These widths are placed at the proper levels in the body plan, care being taken that the forward section is on the right and the after section on the left of the vertical center line. The height of sheer and of rabbet on these sections is measured from the elevation.

Intermediate water lines are then drawn in the half breadth plan by taking widths from the three sections already shown in body plan, and by finding the forward and after endings in the elevation.

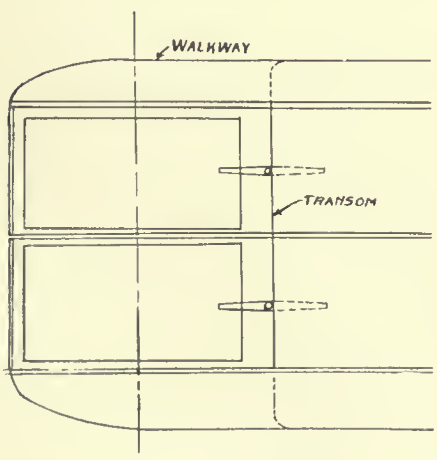
These water lines should always spring to a fair curve when using a slender wooden "spline" or "batten" which is bent through the points through which the line should pass. If this cannot be done, the batten should pass through a majority of the points and spring fair between them. The corrected line may then be drawn in and the width of section through whose spot the batten would not spring, should be made that of the fair line on that section and transferred to the proper water plane in the body plan. The section curve should then be corrected to pass through this new point and the other fixed points.

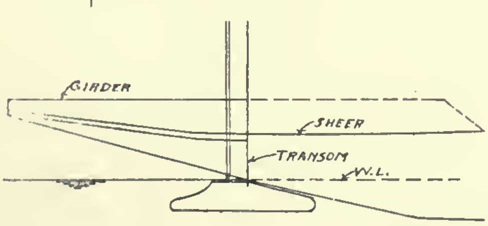
A buttock line half way between center line and molded beam line can now be drawn in the elevation, taking the heights from intersection of the chosen plane with the sections of the body plan and transferring these heights to their proper sections in the elevation. By squaring up from the half breadth to the elevation, the longitudinal locations of points where the water lines and sheer line cut the chosen buttock plane, it is possible to obtain the abrupt curvature of the ends of the buttock line.

Continuing this fairing process for the remaining water lines, buttocks and sections, correcting all unfair points as the work proceeds, the lines will finally be "faired".

Next the volume of displacement should be calculated as heretofore described and if the ship's weight is such as to result in proper draft and trim, the lines are complete. If this is not the case, the proper volumetric correction must be made before making the "offset table" which gives the molded surface dimensions of all the lines.

A final check on the fairness is obtained by passing diagonal planes, shown in the body plan of Fig. 14. The slope of these planes is such as to be at nearly right angles to most of the sections and to cut the bilge of the midship section. Such a plane cuts a curve called a "diagonal" from





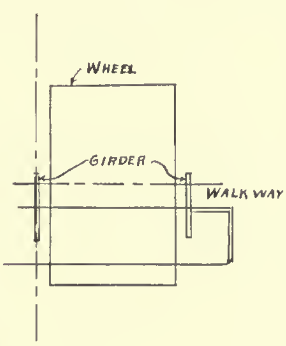


FIG. 18—PADDLE WHEEL STERN

the hull surface. Sometimes more than one diagonal is employed. The true shape of a "diagonal" is obtained by "expanding" the inclined plane into the horizontal. To do this, the plane is assumed to revolve about its intersection with the longitudinal center line plane, so that the curve is shown as it really appears on the diagonal plane. The exact distances from the center line are measured along the diagonal plane to each section in the body plan and are then laid off below the center line in the corresponding sections on the half breadth plan.

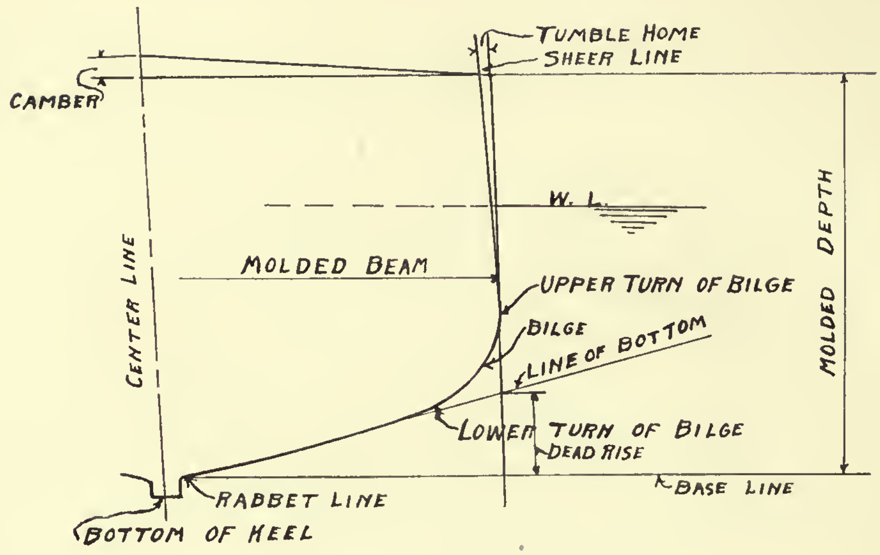


FIG. 19—ILLUSTRATING A TYPICAL BODY SECTION

The heights at which the inclined plane cuts the transom and the half siding of stem are transferred to the elevation and squared down to the half breadth plan. This gives the longitudinal location of the diagonal endings at the transom and the rabbet lines, and the distances along the diagonal to these two can be expanded at the points so found in the half breadth.

The offset table is used as a guide for drawing the lines in the boatyard to the full size of the vessel. This is done on a smooth floor called the mold loft and ensures elimination of the inaccuracies which would result if molds were made from the original small scale line drawing.

Dimensions of the different lines at the various sections are recorded in three groups: those showing heights of sheer, buttock and rabbet lines above the base in the elevation; those giving widths of sheer, water line and keel from the center line in the half breadth and those giving true distances along the diagonal plane from the center line to each section in the body plan. All offsets are recorded in three figures representing feet, inches and eighths of inches. For example, in the table on Fig. 14, the figure to the right of the word "sheer" and directly below "stem", is 9-1-0. This indicates that the stem is 9 feet 1 inch above the base line at the stem.

The profile and plan of stem and stern should be dimensioned in the elevation and half breadths, to establish their true outline.

CHAPTER V

Stem, Keel and Stern Design

THE fore end of a vessel is a ridge formed by the intersection of the side surfaces, the structure consisting of a bar called the stem. This bar may be of wood or of steel in conformation to the material composing the hull. Attached to the stem are the side planking or plating, the longitudinal framing of the hull, the forward end of the keel and keelsons, and some of the extreme forward frames.

Stem construction for wooden vessels is shown in Figs. 20, 21 and 22.

Fig. 20 is the stem of a wooden tug between 90 and 150 feet long. The stem log is backed by an "apron", both timbers being fastened together with through bolts having countersunk heads riveted over ring washers. Where the longitudinals end and at the deck, these bolts extend through heavy knees called "breasthooks". The lower ends of stem and apron are scarphed to the stem knee and its backing timbers (called the forward deadwood) as shown. In Fig. 22 the stem of a larger vessel, the deadwood is heavier; while in Fig. 23, the stem of a large vessel (250 to 325 feet long), the forefoot is formed by two knees scarphed to the stem, apron, keel, keelsons and filling piece, the whole being backed by deadwood timbers.

Fig. 21 is the stem of a small vessel or shallow draft one with model bow. The stem and keel are connected by a natural crook knee, meaning one in which the grain follows a curve. These knees (formerly of hackmatack but now frequently of locust, oak or fir), are cut from tree stumps, one arm of the knee being in the lower extremity of the trunk and the other in one of the large main roots diverging therefrom. The single knee forefoot is applicable to small vessels only, being limited in use by the maximum size of knees available. It is unusual to obtain these with arms longer than 6 feet.

(A-A), (B-B) and (C-C) in Fig. 20 are cross sections at various points in the stem structure. The hull planking joins the stem and keel at a recess or "rabbet", the intersection between outside of plank and side of keel or stem being the "rabbet line".

In large wooden vessels with "model" or ship-shaped forms, the stem is arranged somewhat as in Fig. 23. Apron and stem terminate at their lower ends in scarphs bolted to knees and deadwood. The keelsons and keel scarph into the after knee, while the space between end portions of these and the knee is fitted with a filling piece. The extreme forward frames are notched into the deadwood as in section at frame (1), Fig. 23.

The construction of a "spoon bow" for shallow draft vessels is as indicated in Fig. 24. One or more heavy "bow timbers" extend across the forward hull end, being scarphed to receive the deck, bottom and side planking. The trusses ordinarily built into the shallow hull for longitudinal strength, terminate against the bow timbers; while the space between these timbers and the first beam and floor, are fitted with filler pieces. A filler is also fitted at the intersection between upper and lower chords (if the dimension "d" is small enough to bring this about).

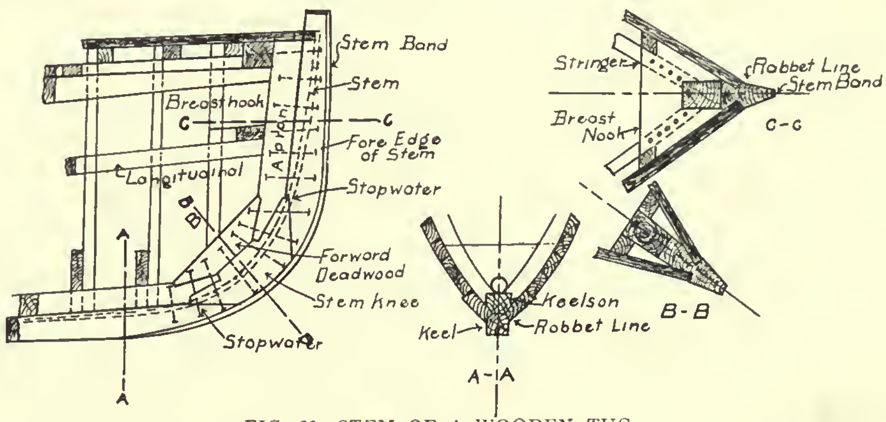


FIG. 20—STEM OF A WOODEN TUG

Auxiliary sailing vessels are fitted with "clipper stems" affording a maximum outreach for the forestays with increased jib areas. Fig. 25 indicates construction of the upper part in wooden clipper (or overhang) stems.

Keels form the strong center line girder connecting lower extremities of stem and stern post. Since their function is contribution of longitudinal strength, it is essential that their structure be continuous. In wooden vessels this feature is particularly necessary but is prohibited by limited lengths in which timber is obtainable. This in turn varies with kind of timber.

Oak formerly was almost altogether used in keels. Oregon fir now has become popular, principally because of its large sizes, long lengths, strength and durability.

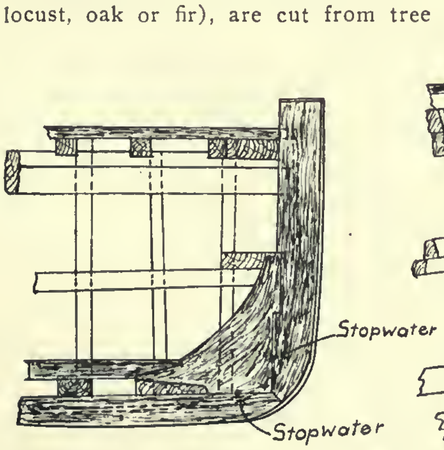


FIG. 21—STEM OF A SMALL POWER WORKBOAT

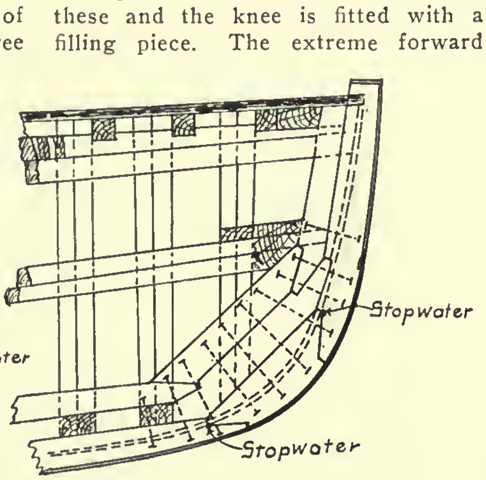


FIG. 22—STEM OF A LARGE VESSEL 250 FEET LONG

When the vessel is of such size that a continuous keel timber is unobtainable, two or more lengths are "scarphed" together as shown in the longitudinal section of Fig. 26. The "hook scarph" here shown is securely

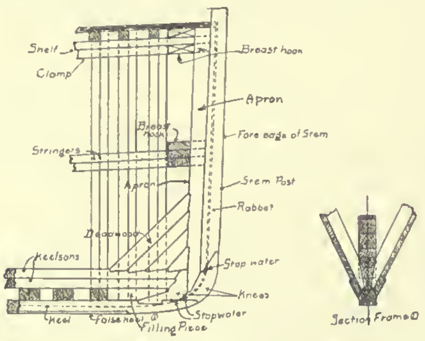


FIG. 23—STEM OF A LARGE WOODEN VESSEL

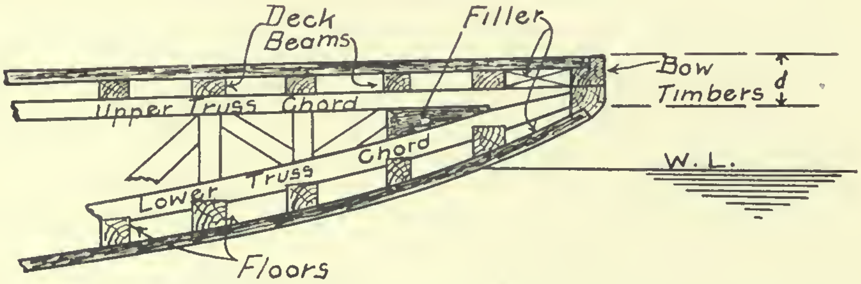


FIG. 24—CONSTRUCTION OF SPOON BOW FOR SHALLOW DRAFT BOATS

fastened with countersunk head bolts with ends riveted over ring washers, the recesses at bolt ends being plugged in white lead. (Fig. 26-a.)

Fig. 25 shows a cross section and a longitudinal section of the center line hull bottom girder formed by conjugation of the keel and center line "keelsons". The five keelsons (as large as 18 x 18 inches each) are bolted together horizontally and vertically, their scarphs being spaced well apart to avoid excessive weakening. Long vertical bolts (b) pass from keelson through the double frames to the keel. Shorter through bolts connect keelsons to frames outboard of the keel. The false keel is spiked to the keel proper over the metal hull sheathing and is readily detachable when worn.

The extra heavy planks adjacent to the keel and called the "garboards" are sometimes rabbeted into the keel (Figs. 27, 28 and 29) or they may be fitted closely against the keel as in Fig. 26. Where garboards are of considerable thickness, they may be edge bolted to the keel.

At points where scarph joints cross the rabbet throughout the stem, keel and stern, wooden plugs called "stopwaters" are fitted across the joint (Figs. 17 to 23 and Fig. 26). These prevent entrance of seawater through the joint into the hull.

The keel of a wooden schooner, 110 to 160 feet long, is shown in Fig. 27. An intercostal filler is fitted between keel and keelsons while the frames have no joint in the center line. The lower keelson is shown notched over the frames.

Fig. 28 is the keel and keelson of a wooden tug with continuous transverse frames; while Fig. 29 is a similar detail of boats 50 to 80 feet long. The keelson in the latter is directly on the keel, forming therewith a rabbet and having the frames butted on the center line. Additional longitudinal strength is contributed by the engine keelsons which are notched over the deep transverse floor timbers and extend as far fore and aft as practicable.

Shallow draft vessels may be as in Fig. 30 or the keel may be of same thickness as remainder of bottom planking. The reduction in strength is justified by considerations of draft and is reimbursed by corresponding increase of interior hull strengthening.

Drainage of bilge water in all these types is effected through "limber holes" cut in the frames as shown. Galvanized "limber chains" pass con-

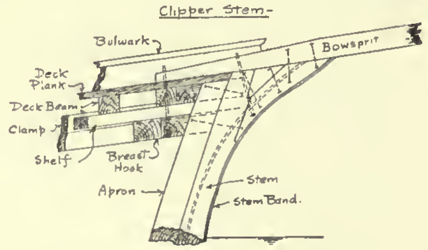


FIG. 25—CLIPPER STEM OF AUXILIARY SAILING VESSEL

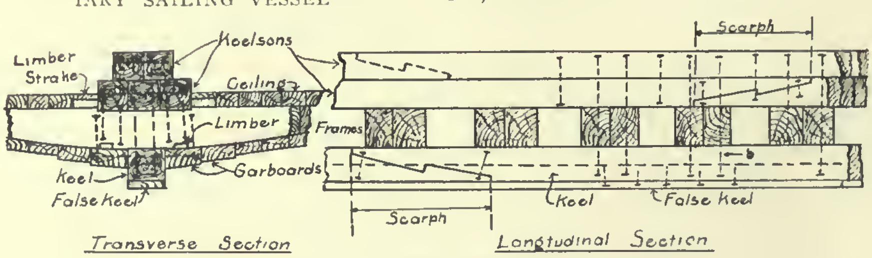


FIG. 26—CONSTRUCTION OF BOTTOM GIRDER OF LARGE WOODEN SHIP

tinuously through these holes so that when drawn back and forth the holes will be cleared of clogging matter. The "limber strakes" fitted in the ceiling of large vessels afford access to the limber holes.

Figs. 31 to 36 inclusive are various types of sterns in wooden vessels. An auxiliary schooner or large cargo carrier (150 to 300 feet long) may have an overhung transom stern (Fig. 31). The keel extends beyond the rudder post, forming a lower step-bearing for the rudder. Both stern and rudder posts mortice into the keel, the "shoe" between their lower ends being reinforced by natural crook knees which form the lower arch of the propeller aperture.

The line of counter is formed by a heavy "horn timber", morticed to take the upper end of the stern post and to permit passage of rudder post and stock. The forward end of horn timber extends into the hull and is securely bolted to the deadwood and shaft log, against which it terminates. Notice the way the beveled ends of all timbers are cut to prevent feather edges. At its upper and after end the horn timber is let into the knuckle timber (Fig. 31), or the rim logs (Fig. 32).

The propeller shaft passes through a hole cut in a "shaft log" which has a stuffing box at its inboard end and is morticed to the sternpost at its outer terminus. Great care must be observed in boring out the shaft log, particularly if it is long, so that alignment with machinery may result. Sometimes it is made in halves (section "A-A" Fig. 32), facilitating this. All such joints must be well coated with thick white or red lead and securely bolted. Shaft logs may be lined with a lead sleeve bedded in white lead and flanged at the extremities under flanges of stuffing box and stern bearings. Ordinary pipe may be used here and threaded into the fittings at its end, sufficient clearance about the shaft being provided to insure against binding.

The frames whose lower ends converge at acute angles at the stern are let into deadwood timbers and securely through bolted. Abaft the sternpost they butt against the horn timber, which is rabbeted to take the hull plank ends as indicated in Fig. 31.

The upper end of rudder post is securely bolted to the deck beams and forms the forward side of a watertight box or "rudder trunk" through which the rudder stock passes to the quadrant or tiller. A stuffing box embraces the stock at top of trunk under the "rudder support bearing" which carries the weight of the rudder The trunk is large enough to permit unshipping the rudder.

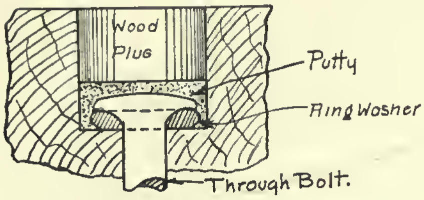


FIG. 26a—HOW KEEL BOLTS ARE COUNTERSUNK

The rudder blade is formed by heavy timbers fitted as shown and edge bolted together. Metal straps assist in tying them together and are formed into sockets at their forward ends. Hinge bolts or "pintles" fit into these sockets or "gudgeons" and corresponding ones on the rudder post, the gudgeons sometimes having metallic bushings. Notice that the rudder stock extends in one piece to the keel. Where this is impracticable the two lengths should be securely scarphed. Lugs called "stops" on the rudder post should bear against similar ones on the rudder stock, preventing a rotation of more than 45 degrees on each side of center line. Rudder chains, shackled to an eye on the rudder blade are led to pad eyes on each side of the stern and serve as emergency stops in event of breakdown.

Between the knuckle and upper deck, transom frames are fitted as in Fig. 31, the transom planks extending athwartships being fastened there to. The outline of transom forms a knuckle and a heavy timber conforms with it, being scarphed to take the ends of the hull and transom planks. The knuckle timber and rim logs (Fig. 31) form parts of this transom margin log.

Tugs and power lighters have usually but one deck and a semi-elliptical

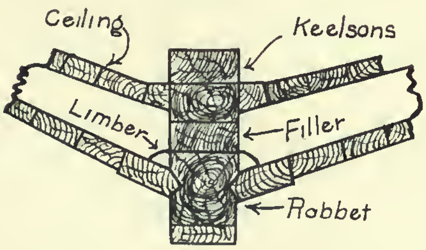


FIG. 27—KEEL OF A WOODEN SCHOONER

stern whose general construction is as heretofore described. In Fig. 32 the main point of difference is at the deck where heavy rim logs are shown and a guard timber is securely bolted to these. The rudder stock passes through the deck and is covered by a grating upon which hawsers are stowed. Sometimes the quadrant is below decks. Sterns of this type are common to tugs and lighters between 50 and 150 feet long .

Full transom sterns (Fig. 33) are common to small craft of all descriptions up to 80 or 90 feet long. The transoms may be variously formed as previously described but the same general construction applies for all of them. Keel, deadwood, shaft log and horn timber have already been considered, except that where a metal rudder is fitted the shoe is formed by a casting as shown.

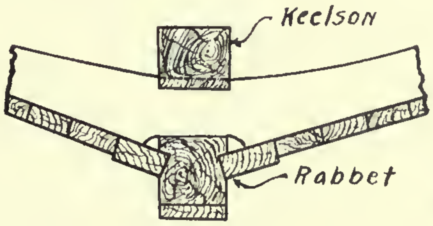


FIG. 28—KEEL OF A WOODEN TUG

The rudder stock passes through a lead-lined opening in horn timber and bearing log. A natural crook knee connects horn timber keelson or stringer ends to transom framing. Cheek plates are sometimes fitted over the junction of shaft log and deadwood with sternpost.

The proper rudder areas for various small boats will be considered under steering gear. In event of breakdown to this gear a spare tiller may be inserted through the deck plate shown in Fig. 33 and fitted over the square rudder head.

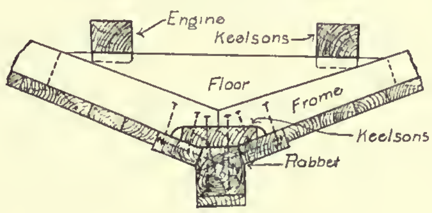


FIG. 29—KEEL OF A 50-FOOT WORKBOAT

Transom sterns properly formed are desirable for the additional hold storage space, the wider deck, the tendency to prevent squatting when under way and the facility of construction. They do not render a vessel difficult to steer nor make her uncomfortable in quartering seas unless they are extremely broad and flat underneath.

Compromise sterns (Fig. 34) are seldom fitted to commercial power boats. They are similar in structure to the stem, having a central ridge formed by the horn timber, a knee and the stern log. The planking scarphs to these timbers and care must be observed that the plank ends fit properly and are not too narrow. The flat iron shoe shown in Fig. 34 is not recommended but is indicated merely as common in pleasure boats. Such a shoe affords little protection to the propeller since it is liable to distortion on contact with submerged obstacles, in which case the rudder may be thrown out of alignment or twisted and jammed.

Shallow draft sterns with sternwheels are as indicated in Fig. 35. The flat bottom planking rises to a transom whose lower edge is at or near the water line. The hull is not pierced as in vessels formerly considered but rudder stocks extend up to the house deck as shown. Bearings at the transom and house decks support these stocks and the tiller arms are linked together over the house or "texas".

Multiple rudders are necessary because of the limited draft and unwieldiness of the boxlike hull. The forward upper edges of these rudders are very close to the bottom planks so that obstructions cannot wedge

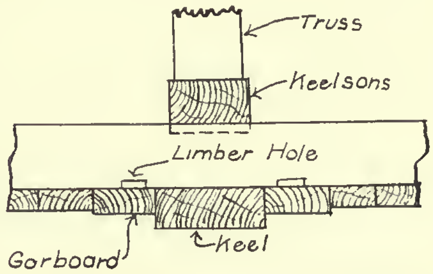


FIG. 30—KEEL OF SHALLOW DRAFT VESSEL

themselves between rudder and hull. Details of construction will be considered under steering gear.

The stern wheels, whose details of construction will be later taken up, are supported upon two or more overhung girders whose inboard ends securely bolted through the main deck to the longitudinal trusses in the hold. If the continuous trusses do not end under these girders it is necessary to provide auxiliary trusses or other reinforcing. The extreme outboard ends of wheel girders are connected by a heavy transverse timber and walkways are provided outside of the outer girders to facilitate inspection and repairs to the wheels.

Vibration is minimized by hog posts and tie rods as shown which form part of the longitudinal strengthening truss above the hull necessary in these shallow hulled boats.

The paddle wheels revolve in a clockwise direction, dip of the buckets being fixed by vessel's draft, but seldom exceeding 27 inches. The after deckhouse bulkhead is termed the "splash bulkhead" and is watertight.

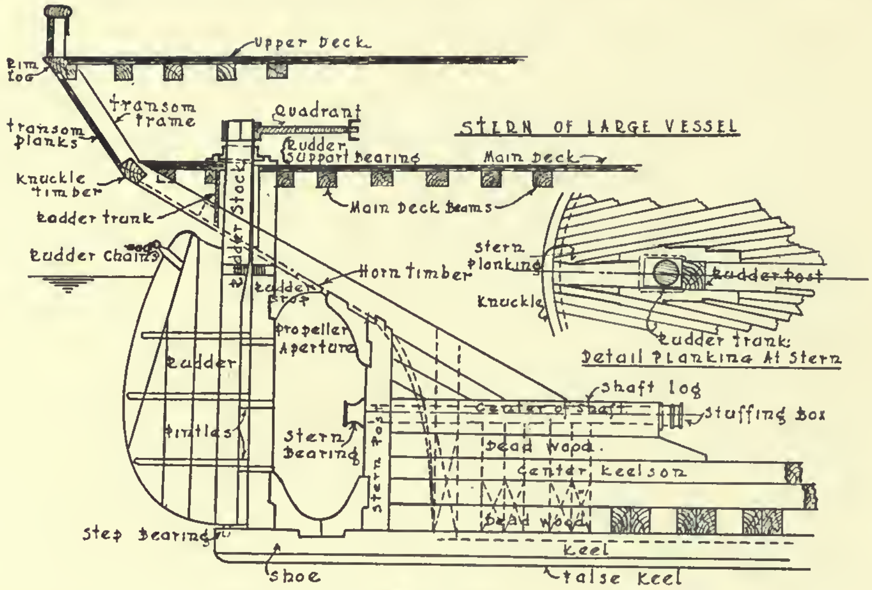


FIG. 31—OVERHUNG TRANSOM STERN OF AUXILIARY SCHOONER

The wheel shaft bearings fitted on each girder are bolted to timber pads. Wheel girders are designed as cantilevers to take the wheel weight but a high factor of safety must be employed to allow for the vibrational stresses. At the same time these overhung weights are not directly supported by buoyancy so that care must be taken not to trim the vessel by the stern. In most cases it is necessary to locate the engine and fuel tanks well forward to offset the stern weights.

Propeller-driven, shallow-draft boats are very successful if properly designed. Their advantages over sternwheel vessels are reduced machinery weights, less difficulty in obtaining proper trim, improved maneuvering qualities, greater free deck space and compactness of hull appendages. Higher speed of the propeller permits of lighter and better balanced machinery for the same power.

Fig. 36 is a longitudinal section through a wooden tunnel-stern vessel;

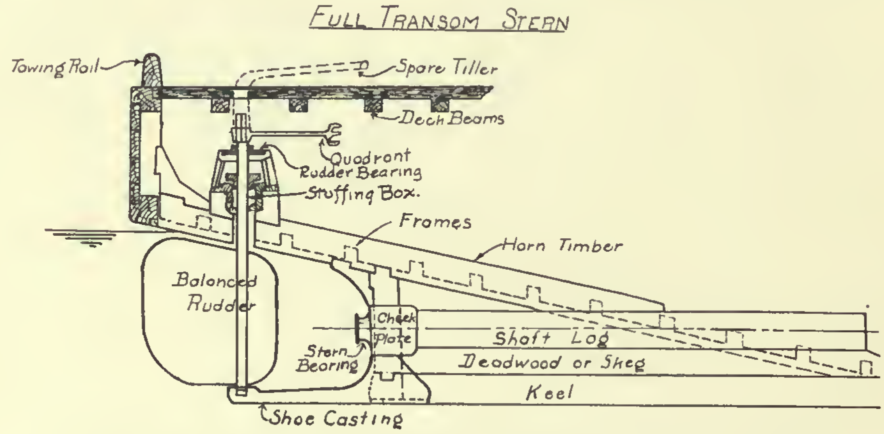


FIG. 33—TRANSOM STERN FOR SMALL BOAT WITH METAL RUDDER

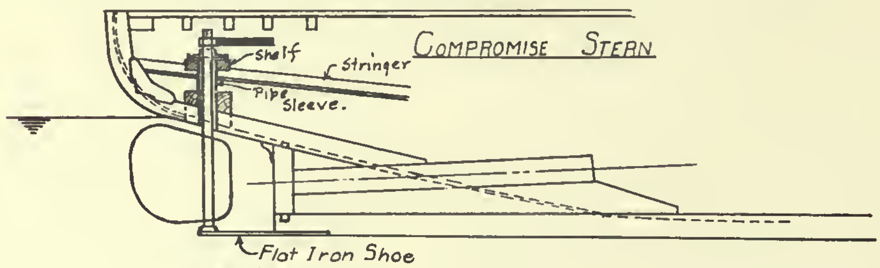


FIG. 34—COMPROMISE STERNS SELDOM USED ON WORKBOATS

Fig. 37 ("a" and "b") are two cross sections at "A-A" of Fig. 36 for different tunnel constructions. Two or more propellers are necessary since the limited draft cuts down permissible diameter and the total thrust area must therefore be distributed.

The tunnel should be a smoothly scooped out recess in the vessel's bottom and the propeller tips should fit into this with minimum practicable clearance (½-inch if possible). The highest point of tunnel should not be more than one-third the propeller diameter above the water line and the after end should just touch the water line at the stern. If this is not practicable, a vertically hinged flap should cover the after tunnel end, opening with the stream flow when going ahead. This is to insure good backing qualities, the water filling the tunnel when flap is forced closed by astern motion.

Cross sections along the tunnel should be circles with varying diameters and their upper points in the longitudinal profile curve of tunnel.

Workmanship in wooden tunnel sterns must be of highest class, since smooth water flow is essential and leakage is likely due to complex structure.

In Fig. 37-a the tunnel is merely a watertight box with arch beams to which is fastened a metal fairwater top; 37-b has the tunnel formed by bottom planks which are cut and bent into place, calked and fastened to arch beams inside the hull.

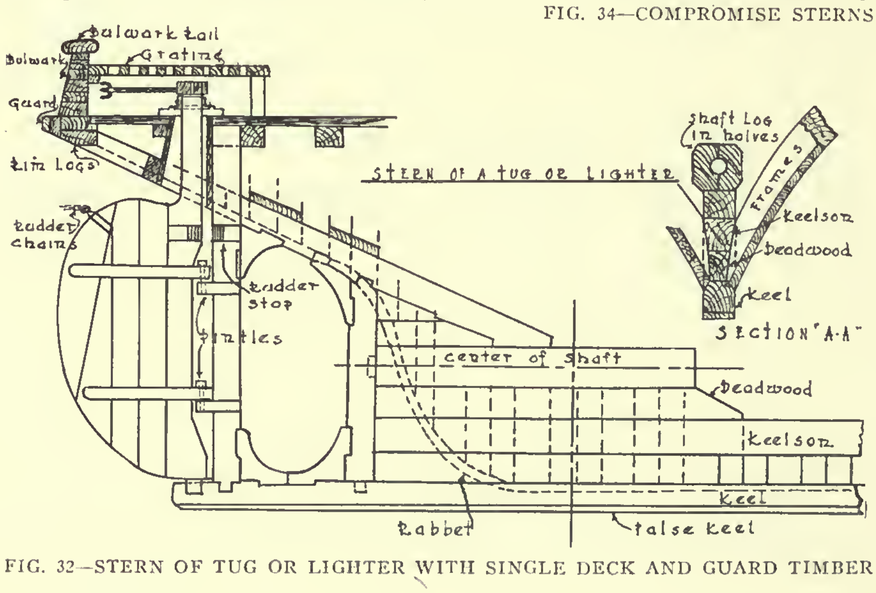


FIG. 32—STERN OF TUG OR LIGHTER WITH SINGLE DECK AND GUARD TIMBER

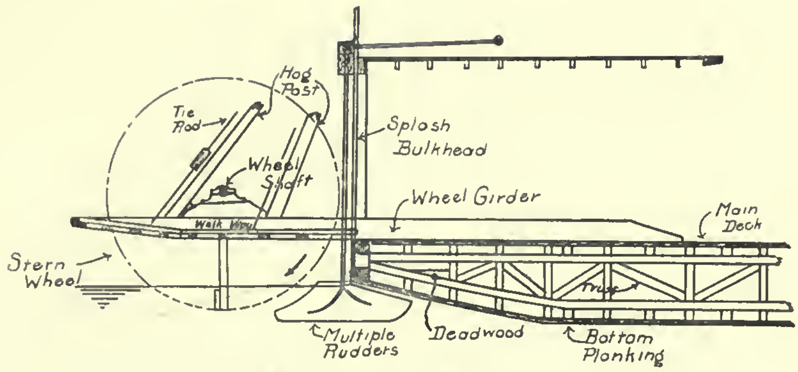


FIG. 35—SHALLOW DRAFT STERN WITH STERN WHEEL

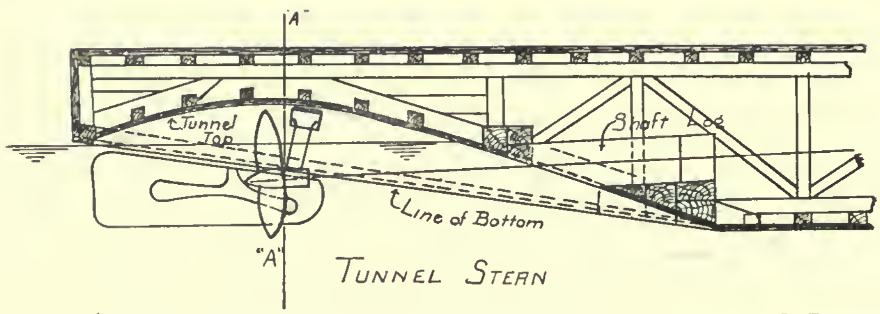


FIG. 36—LONGITUDINAL SECTION OF WOODEN TUNNEL STERN BOAT

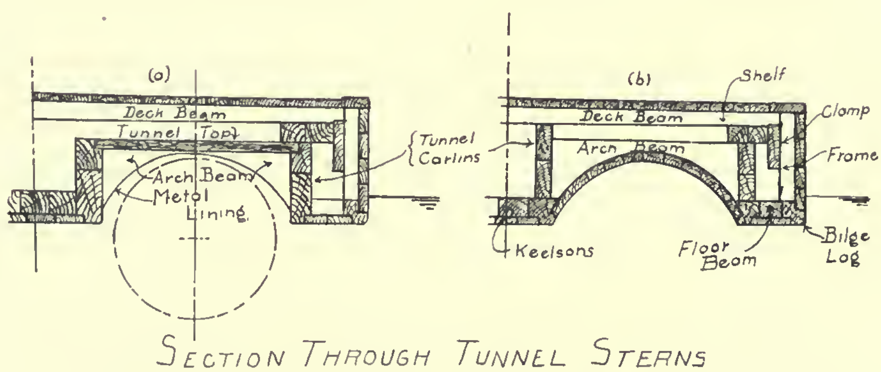


FIG. 37—CROSS SECTIONS SHOWING DIFFERENT TUNNEL CONSTRUCTION

KAMCHATKA—A SAILING VESSEL RECENTLY CONVERTED INTO AN AUXILIARY FOR USE AS A WHALER IN THE ARCTIC OCEAN AND BERING SEA

144 feet long by 31 feet beam by 16-foot depth. Fitted with a 300-horsepower MacIntosh & Seymour diesel engine, which drives her at 7½ knots loaded. Two auxiliary engines, one 25 horsepower Burn-Oil, and a 20 horsepower gasoline engine installed.

CHAPTER VI

Application of Steel Construction

STEEL construction as here considered will be limited to practice in commercial vessels between 50 and 250 feet long. Bar stems are ordinarily fitted in these and are scarphed to the plate keel or bar keel as in Fig. 38-*a* and *b*. The length of these scarphs is nine times the thickness of bar stem and keel and the scarph faces are machined to fit closely together (Fig. 38-*b*). The shell plating is flanged to the stem and is connected thereto by through rivets with countersunk heads. In small vessels a single row of rivets is used but in vessels more than 75 feet long two rows of zig-zag rivets are employed. When bar stems join a plate keel (Fig 38-*a*) their lower ends are flattened out and riveted thereto (Section Frame 2).

At one-twentieth of the vessel's length from the stem a transverse watertight bulkhead extends from side to side and from keel to upper deck. This is the "forepeak" or "collision" bulkhead and the space between it and the stem is the "forepeak".

Deep transverse floor plates whose upper edges are stiffened by the reverse frames, connect the lower ends of frames and are cut to permit passage of the center keelson plate and angles (Section Frame 2). Where longitudinal girder angles (called keelsons or stringers, according as they are on the vessel's bottom or sides), join at the stem, they are connected by horizontal bracket plates or "breasthooks" which are connected to the hull plating between frames by short "shell clips" and have their after edges stiffened by an angle. Large breasthook and floor plates are pierced with "lightening holes" cut from the least affected part to reduce the weight. Limber holes drain the spaces between floors (Section Frame 2).

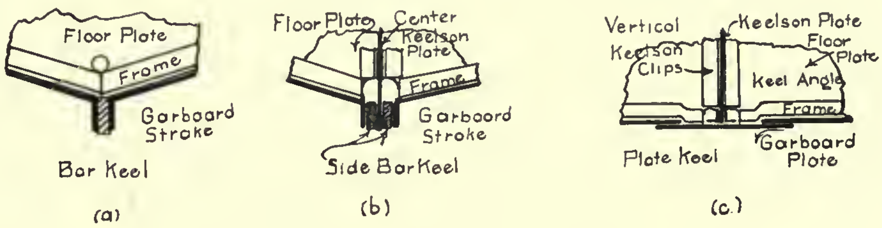


FIG. 39—THREE TYPES OF KEELS OF STEEL VESSELS

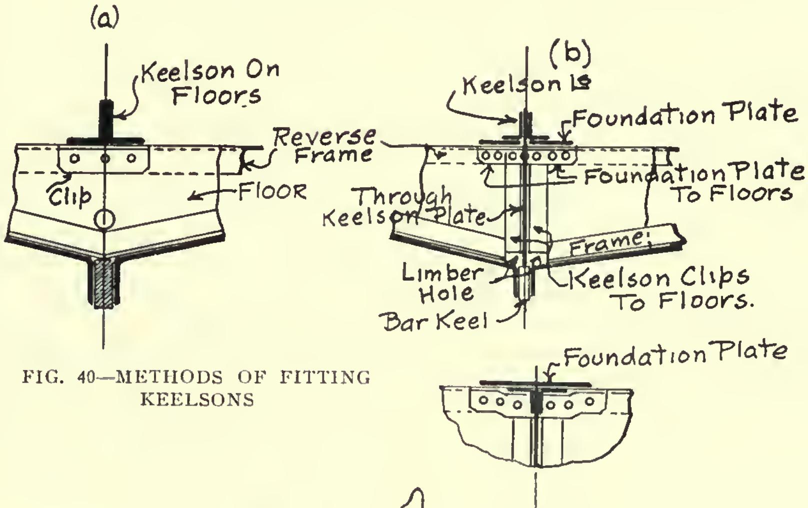


FIG. 40—METHODS OF FITTING KEELSONS

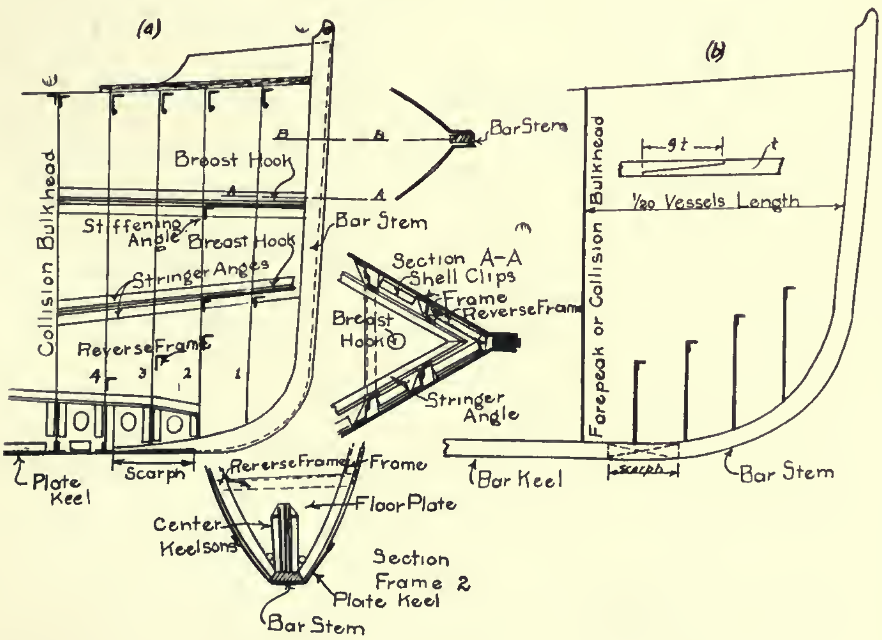


FIG. 38—BAR STEMS AND METHOD OF SCARPHING

Keels of steel vessels are of three types: plate, bar and side bar (Fig. 39-*a-b-c*). Plate keels are common to large steel vessels and to those of shallow draft.

Bar keels are used in tugs, power lighters and in general for vessels up to 150 feet long.

Side bar keels are not extensively employed due chiefly to the difficulty of obtaining good rivet connections through the five thicknesses of metal (two garboard plates, two keel bars and the center keelson plate).

The Center Keelsons

Center keelsons form a girder with the keel and their construction is affected by the size of vessel together with the method of making connection with transverse "floor plates" which are a part of the framing and will be later discussed. With respect to these

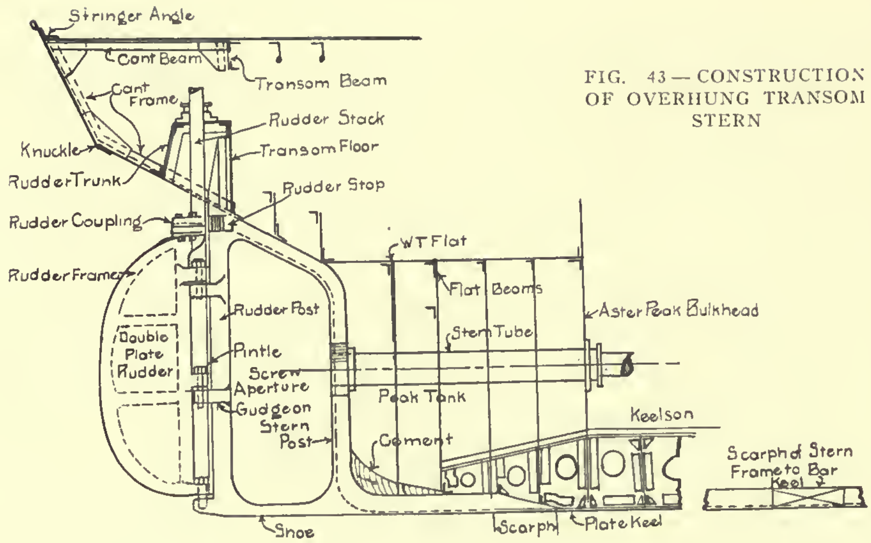
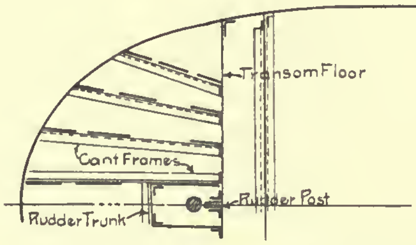


FIG. 43 — CONSTRUCTION OF OVERHUNG TRANSOM STERN



"floors", keelsons may be built above them and extend continuously fore and aft; the floors may be cut at the center line to admit a continuous plate keelson extending down to the keel; or the keelson plate may be intercostal between floors, with continuous keelson angles on top of floors.

Fig 40-*a* is a continuous keelson on floors, attachment to upper edge of floor plates being by rivets through the reverse frames on one side and a clip on the other side of plates.

The keelson may consist of two angles, as shown; of two bulb angles, four angles with a rider plate over the upper ones, whose long flange is horizontal, or four angles with a "foundation plate" under the lower angles and on top of floors, a rider plate being fitted over the upper angles.

When through keelson plates of floor depth are fitted (Fig. 40-*b*), the upper keelson angles may be above the floor tops, or (in small vessels) below this level. The upper part of keelson girder may vary in structure as did the type entirely above floors. Double clips are always fitted connecting the keelson and foundation plates to the floors. When a bar keel is employed the lower edge of keelson plate butts against it without angle connections. In the case of a plate keel this is connected to the keelson plate by continuous double keel angles (Fig. 39-*c*).

Fig. 41 shows a center keelson with intercostal plate and continuous upper

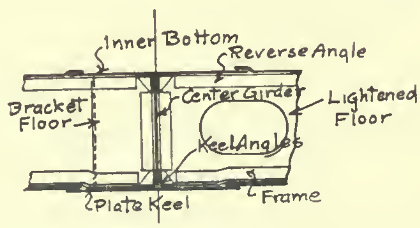


FIG. 42—TRANSVERSE SECTION OF DOUBLE BOTTOM

angles. The intercostal plate is in sections of frame space length which are cut to pass the frames and heel pieces at keel and the reverse frames and reverse frame clips at floor top. With bar keels there is no lower keelson plate connection, but double intercostal keel angles are fitted with plate keels.

Tanks built in the ordinarily wasted space below floor tops are used for fresh water, fuel oil or ballast water. The floor tops are plated over by an "innerbottom" or "tank top". Center keelsons in these "double bottom" compartments are composed of continuous girder or keelson plates with double keelson angles and top angles to the inner bottom plating. Fig. 42 is a transverse section through a keelson in double bottoms. Generally double bottom tanks extend the full vessel's length between peak bulkheads, but often they are limited to spaces under machinery compartments. When this is so the keelsons outside of tank are of the constructions in Figs. 39 to 41.

Steel sterns applied to commercial power craft are ordinarily limited to those in Figs. 43 to 48 inclusive.

Passenger and cargo or auxiliary sailing vessels may be fitted with semi-elliptical or overhung transom sterns (Fig. 43), where the transverse framing extends aft to the "transom floor", which is a deep vertical transverse plate against which the upper end of rudder

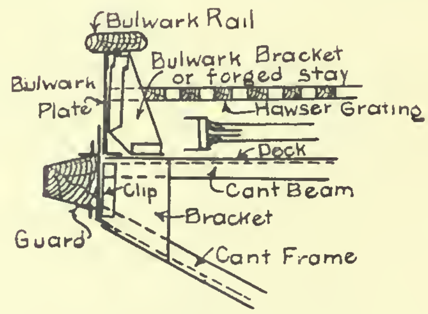


FIG. 44—ATTACHING GUARDS AND RAILS

post is clipped with double angles. The rudder and stern posts, connected at their tops as shown and at their lower ends by a "shoe", form the "stern frame" forging. This is scarphed at its forward end to the plate or bar keel, tapering down to the horizontal plate connection in the former case and being connected as for stems in the latter instance. This keel scarph should begin at least two and one-half frame spaces forward of the stern post which is "bossed" to permit passage of the center line propeller shaft, which passes through a cast steel stern tube to the after peak bulkhead, where a stuffing box is fitted.

When twin screws are fitted no screw aperture is necessary unless the propeller tips overlap at or come close to the center line. Fig. 45 is a twin screw frame and indicates the forged strut which supports each wing shaft.

The shoe under the propeller aperture is of flattened elliptical section and ex-

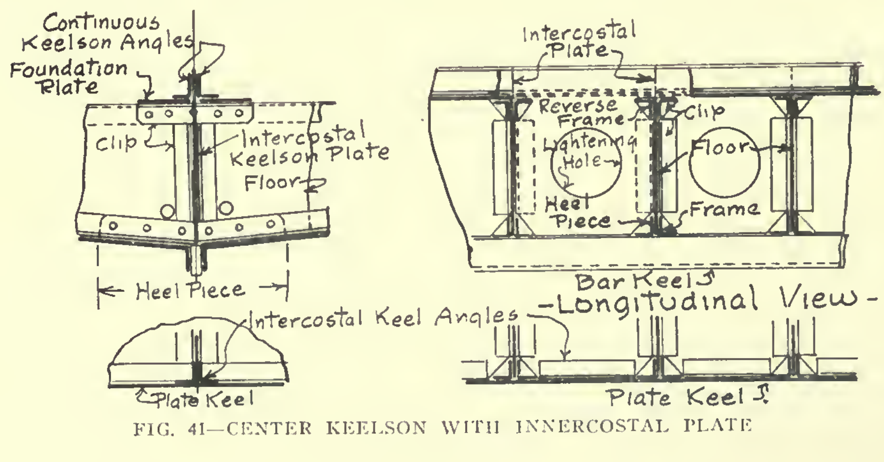


FIG. 41—CENTER KEELSON WITH INNERCOSTAL PLATE

tends beyond the rudder post to form a step bearing for the rudder.

Forged to the sternpost are eyes or "gudgeons" which receive the pintles about which the rudder hinges and which may be bushed with metal or lignum vitæ wood. At the upper end of the rudder post, heavy lugs are forged to form "rudder stops" which prevent greater angular swing than 45 degrees.

Large vessels have their rudder stock coupled to the blade, as in Fig. 43, this connection being a horizontally or vertically transverse flanged or a scarphed joint.

Rudder Construction

Double plate rudders (Fig. 43) consist of a forged or cast frame with plates riveted on each side and the intervening space filled with pine well coated with pitch or other preservative. Single plate rudders (Fig. 45) are composed of one plate riveted to forged arms on the rudder stock.

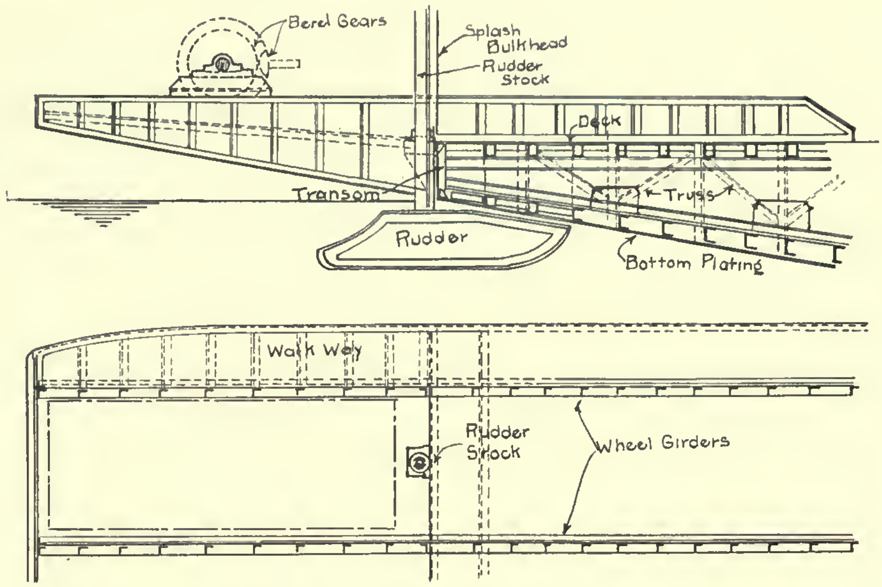


FIG. 46—ELEVATION AND PLAN OF STERN WHEEL VESSEL

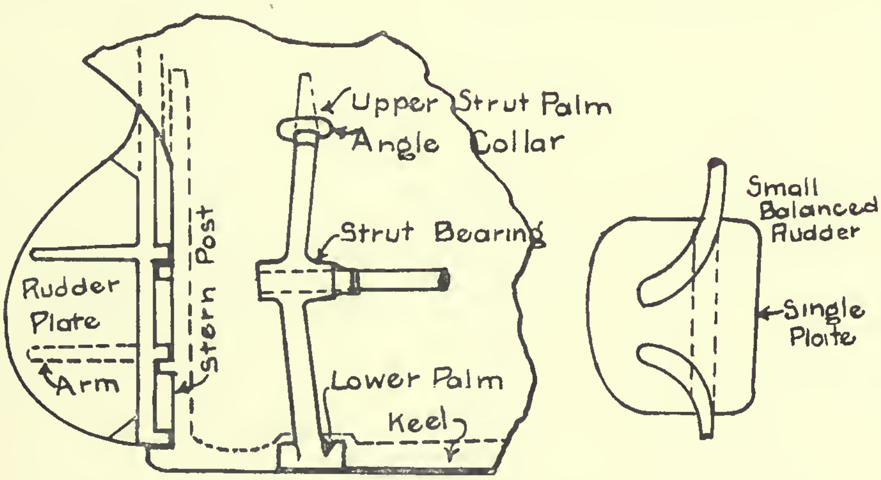


FIG. 45—CONSTRUCTION OF RUDDERS AND STRUT BEARINGS

All rudder heads must pierce the hull through some form of watertight box or "trunk", at the top of which is a stuffing box and the rudder support bearing, surmounted by the steering arm or quadrant. This trunk is connected to the afterside of transom floor and shaped to permit unshipping the rudder. The side and top trunk plates are connected by forged angles caulked watertight.

Aft of the transom floor ordinary transverse framing is supplanted by radiating "cant frames" and beams, strongly bracketed together and at their forward ends to the transom beam and floor. Cant frames are spaced around the knuckle at intervals equaling the ordinary frame spacing amidships.

A watertight "flat" or short deck usually extends from after the peak bulkhead to sternpost, the space beneath which is too fine and congested for cargo stowage and is termed the "after peak tank." It may store fresh water or serve as a trimming tank when filled with or emptied of sea water.

Fantail sterns are similar in construction to the overhung type but differ at the deck marginal connection, where the vertical distance between deck and knuckle is just sufficient to attach the heavy guard shown in Fig. 44. Being common to tugs and lighters and consequently constructed for towing, a bulwark rail strongly supported by forged stanchions or brackets is fitted. The tiller or quadrant cannot usually be installed below deck due to lack of space, and is therefore covered by an ash grating upon which hawsers may be coiled when not in use.

Shallow draft sternwheel vessels have the same characteristic construction as was pointed out under wooden hulls, and Fig. 46 is an elevation and plan of this type.

A tunnel stern (Fig. 47) has the bottom plating dished to the tunnel contour and the bottom angles forged in conformity. It is much more readily and simply fitted in steel than in wooden vessels. The stern casting shown flanges to the outside of tunnel and has a bearing at the after end with the

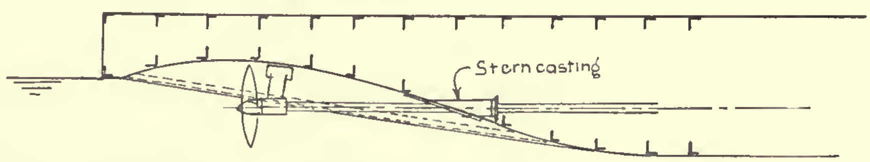


FIG. 47—HOW THE BOTTOM PLATING IS DISHED FOR TUNNEL STERN

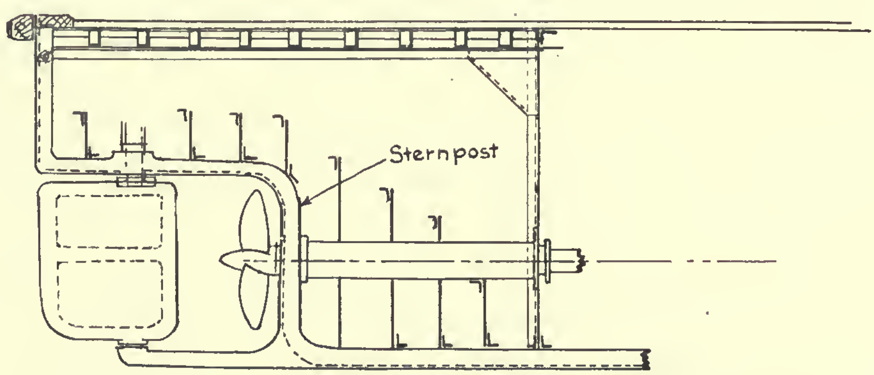


FIG. 48—STERN (OR BOW) OF DOUBLE ENDED STEEL FERRY BOAT

usual stuffing box inboard.

The stern (or bow) of a double-ended screw steel vessel, such as ferry boats, is shown by Fig. 48, the peculiar contour of stern frame being the only radical departure from ordinary stern construction. Because of the relatively wide ending of deck in this type, cant frames need not be fitted though they sometimes are, particularly in wooden vessels. Heavy longitudinals should, however, be introduced to absorb the end thrust in docking. When side paddle wheels are employed the screw aperture is dispensed with and the sternpost is located close to inboard edge of rudder. In such a case the rudder may be formed to fair into the normal hull surface, but this is an unnecessary elaboration. The forward rudder is always locked on the center line either by a through pin from the deck or by locking the rudder stock.

CHAPTER VII

Wood and Steel Transverse Framing

THE watertight hull cannot be made sufficiently thick to withstand longitudinal, transverse or local stresses, for the light displacement would be thereby increased to an uneconomical degree; even assuming that the required strength could be brought about by such cumbersome construction. An inner system of framing accordingly has been introduced to suitably reinforce the skin and is called the framing.

It can be readily seen that this framework must run both longitudinally and transversely, and that one system must be predominant because of structural limitations. Now the most severe strains are ordinarily longitudinal in character, which would make it desirable to run the principal framing in fore and aft directions. This is practicable in steel and small wooden ships, though the construction is complicated by the warped and refined hull surface at the vessel's extremities.

(a) Wood Framing

Large wooden vessels (100 feet long and above) cannot be rigidly constructed with longitudinal frames because the framing timbers are relatively short, the end connections between timber lengths weak, the timbers cannot be suitably bent and beveled without serious loss of strength by cutting across grain, and finally the planking which is in narrow strips could not be properly fastened. To run this hull planking transversely would seriously increase the resistance and result in loss of strength by the already comparatively weak structure.

Framing of Wooden Vessels

The transverse framing of large wooden vessels is similar to Fig. 50. Here the frames, relatively heavy timbers, are sawn to shape and fitted in two thicknesses (doubler), with butts of sections in each thickness staggered with those of the adjacent member of that frame. Butt joints at the center line are avoided and the molded dimensions of timbers (that measured in the vessel's transverse planes) may be constant or gradually decreasing from keel to frame head at upper deck. The two sections of each frame

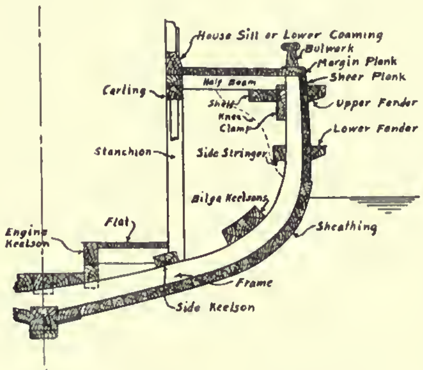


FIG. 49 — CONSTRUCTION FOR TUGS AND POWER LIGHTERS

are bolted together. Sided dimensions of frames (measured in fore and aft direction) are usually the same from keel to head.

Except at the vessel's extreme end, all frames are perpendicular to the keel. At the ends where the inward curvature of water line would entail extreme bevel with accompanying loss of frame thickness, the frames are placed nearly at right angles to most of the water lines. These radiating frames, called "futtocks", are shown in Fig. 50 (a), which is a plan view of the vessel's end framing with the ceiling and longitudinals omitted.

When wooden bulwarks are fitted, one of the double frame heads passes through the deck margin planks to form a bulwark stanchion. Every alternate or third frame is thus extended.

Frame heads are connected to the deck beams by continuous longitudinal clamp and shelf timbers, as shown.

In wooden construction the deck beam ends do not always butt against nor lap on the frame heads, though this should be so if practicable. At least every third or fourth beam should be directly connected to frame heads by heavy natural crook timber knees the intermediate beams landing on the clamp and shelf which are through bolted to these and the frame heads.

Limber holes must be cut at the lowest point of frame heels providing longitudinal drainage for bilge water to the pump suctions. In wooden ships limber chains are fitted in these holes.

Tugs and Power Lighters

Tugs and power lighters have midship sections similar to Fig. 49. The frames cross or are butted at the center line, tapering to reduced molded dimensions at the deck. Except in extremely light construction, frames are sawn in sections with double timbers and staggered butts, through bolted longitudinally. Light frames may sometimes be bent to shape but this is not practicable with large timbers which tend to split and are stiff. Bending is preceded by steaming the timber in a box and then forming it to the proper crook.

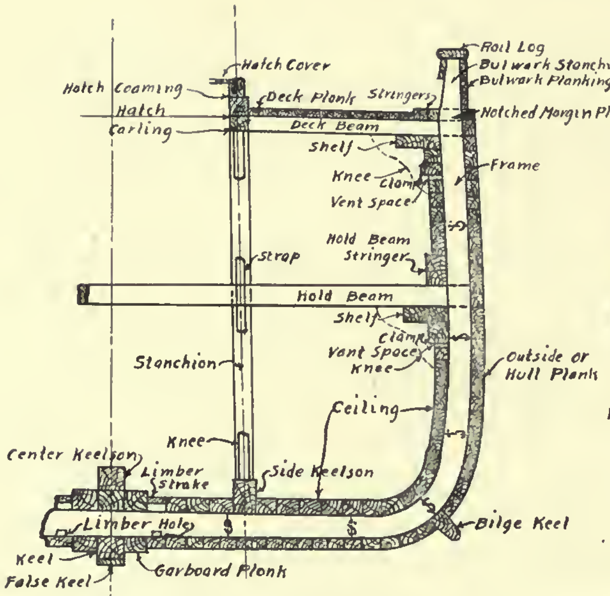
Frames in shallow draft vessels are straight on the bottoms and sides, butting against a timber called the "bilge log" at each bilge. (See Fig. 51.)

Where considerable deadrise exists and always in the machinery space, heavy transverse floor timbers should be fitted at the lower point of frames on center line. These floors are sometimes introduced all fore and aft.

Wooden deck beams extend in one length from side to side except where hatches or other deck openings necessitate cutting them (Figs. 49 and 50). In this case the resultant "half beams" are butted against or mortised into heavy longitudinal "carlins" which bound the opening.

The weather deck beams are sometimes sawn to a camber on their upper edges, the lower edge being flat and the ends reduced in depth. When beams are light enough to permit, they may be steamed and bent to camber. The outer ends of beams should be notched over clamp timbers and kneed to frames, as previously described. Inner ends of half beams where the stanchions are fitted should have a natural knee.

Hold beams consisting of heavy double timbers widely spaced, are introduced in larger vessels. The beam ends bear on hold stringers or shelf



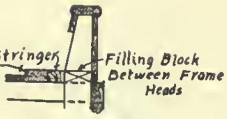


FIGURE 49-(b)

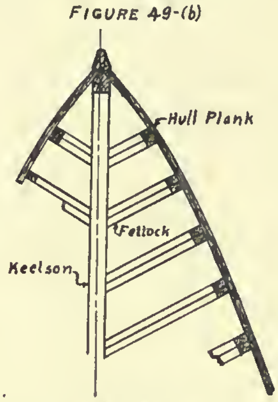


FIGURE 49-(a)

FIG. 50—TRANSVERSE FRAMING OF LARGE WOODEN VESSELS

and clamp, to which they may be kneed in vertical and horizontal directions. Where stanchions mortise through double hold beams, metal cheek straps should be fitted (Fig. 50).

Stanchions supporting the decks are fitted in wide vessels and deep holds. They should always be on a frame and their lower end or "heel" should bear on a keelson and have wooden knees. Sometimes a forged metal strap is employed at heads and heel connections or the heel may notch over a keelson and be through bolted. (Fig. 49.)

Stanchions should always be fitted at each corner of large deck openings and to every third intermediate frame at hatch cabins. The upper ends or "heads" should be strongly kneed to carlins and deck beams.

When fitted in holds, stanchions should support adjacent beams through a longitudinal girder fitted at heads. (Fig. 51.)

In shallow draft hulls the hold depth in proportion to beam and length renders it imperative to introduce strengthening "trusses" running longitudinally and athwartships. In these trusses the girders at stanchion heads and keelson at heels are termed the upper and lower "chords". Diagonal tie timbers serve as compression members against racking. (Fig. 51.)

The longitudinals are from one to four in number depending on the beam. Transverse trusses or simply "transverses" are at every tenth or twelfth frame.

(b) Steel Framing

Fig. 52 is the midship section of a steel tug or lighter. The transverse framing is composed of frames extending from keel to deck, floor plates at keel, knees or beam brackets connecting upper end of frames to deck beams, deck beams and stanchions supporting these.

Frames may be one of the various structural shapes shown by "Sections at A-A" Fig. 52. Angles and channel

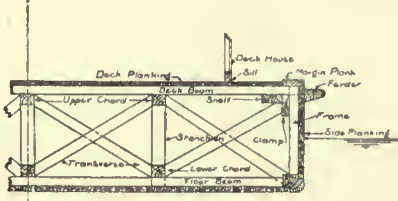


FIG. 51—FRAMES FOR SHALLOW DRAFT VESSELS

bars are most frequently used. They are spaced from 15 to 27 inches apart and are in one length from keel to deck. Frame ends at keel are dependent upon the type of keel and center keelson, and were shown in diagram of the latter. When floors are not cut at center lines the frame heels butt at this point and a heel bar 3 feet long is fitted on the opposite side of floor.

Good Riveting is Essential

Reverse frames which stiffen the inner edge of frame angles and extend along the floor tops on side opposite to frames, form an inner flange to which keelsons, stringers and other members may be conveniently attached. The overlap of frames and reverse frames should be sufficient to ensure good riveting. When frames are of bulb, channel or zee section, reverse frames are fitted on upper edge of floor plates only, but ordinary angles and reverse bars are used at the ends of the vessel where the channels and "Z" bars would be difficult to bend and bevel.

Reverse frames at floor tops are single except under machinery foundations where they are doubled. At the vessel's ends it is necessary to keep the athwartship frame flange in a transverse plane and to bevel the shell flange in conformation to the hull form. (Fig. 52.) This bevel should always be "open", that is, the angle between flanges should never be less than 90 degrees. This is essential to good riveting. The lower ends of frames at the vessel's bow and stern are lapped at the keel and riveted together.

The bending of steel frames to proper contour and bevel is performed by means of templates as guides which are secured to a heavy cast metal slab. The frame bar is heated, placed on the slab and bent against this template, the standing

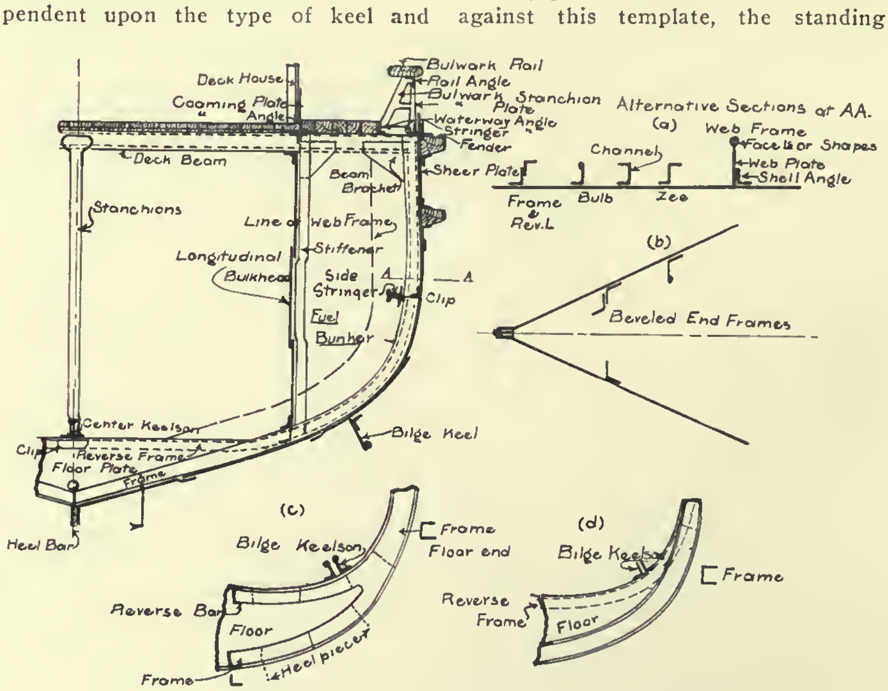


FIG. 52—MIDSHIP SECTION OF STEEL TUG OR LIGHTER

flange being properly beveled at the same time. Spring "dogs" of round bar iron clamp the horizontal frame flange to the "bending slab" being driven into square holes closely spaced in the slab. Bevel templates of light wood or metal, cut to the proper slope which has been obtained from the lines, are used as guides in properly beveling the standing flange.

Machines for bending and beveling structural shapes have been employed successfully in many shipyards.

The shell flange of frames must bear directly against the hull plating and since the longitudinal strakes of this are usually lap jointed, it is clear that either the frames or plates must be joggled (Figs. 52 and 53).

The practice of bending frames to a fair curve and fitting liner pieces between shell flange and outside hull plates is still used but should be avoided because of the excess weight of structure and generally unsatisfactory structural fitting resulting therefrom.

Where the Main Deck Overhangs

Passenger and ferry boats for inland waters usually have the main deck overhang the hull. This overhang may be supported on brackets or be formed by a sudden hull protuberance above the waterline (Fig. 53a). In the first construction the transverse framing resembles that for tugs or lighters, while in the second the frames are knuckled to conform with the deformed hull surface. This overhang is to afford a maximum of deck space with minimum permissible beam of actual hull, so that the speed may not be seriously reduced.

Shallow draft vessels (Fig. 54) have straight frames on their bottoms and sides. The bilges are usually rounded and a bracket may be introduced to join side and bottom lengths. This avoids furnacing the frames and is as satisfactory a construction as when the side frames are bent to the bilge radius and overlapped on the bottom frames (Fig. 54a). In small vessels it may be possible to obtain the frame shapes in sufficient lengths to extend in one piece from gunwale to gunwale, but this is not ordinarily feasible.

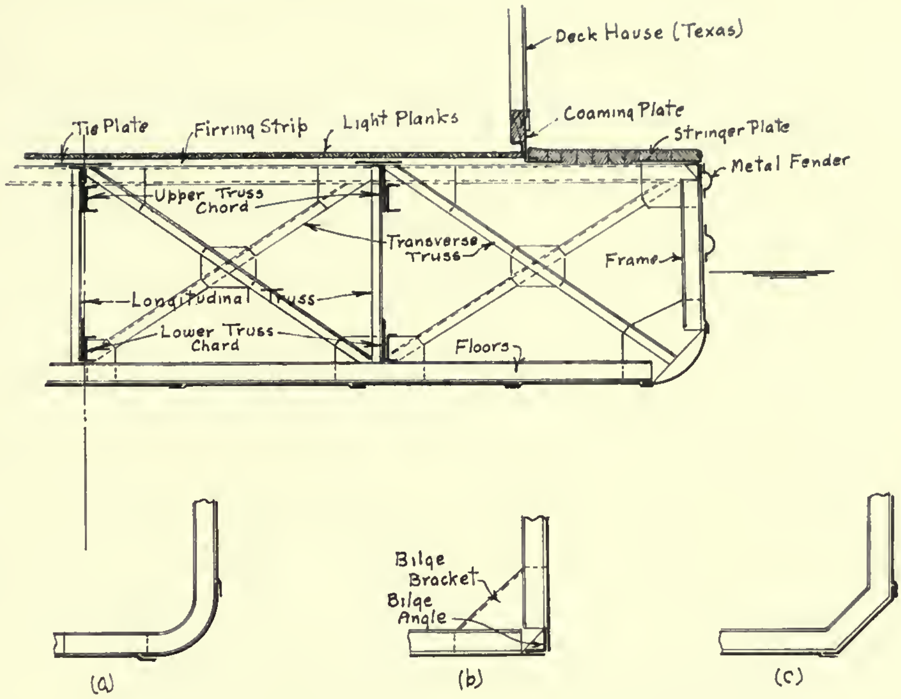


FIG. 54—SHALLOW DRAFT VESSELS HAVE STRAIGHT FRAMES

Square bilges with heavy bilge angles connecting the side and bottom plating may be employed and if the hull ends are properly modeled this will not prove a serious detriment to efficient propulsion. Bilge brackets are in this case also employed. (Fig. 54b.)

Of late the bilges have occasionally been cut at an angle and a flanged bilge plate fitted to forged frames. (Fig. 54c.)

Web frames (Fig. 52) are fitted on every sixth to tenth frame and at the ends of the large hatches or forecastles, bridges and poop erections. They consist of a web plate from 14 to 42 inches wide connected to the hull by single or double angles and faced with half round or angle "face bars". The outline of a web frame is indicated by the broken line in the midship section (Fig. 52). The lower ends of web frames fair into floors and are connected thereto by lapped joints. The face angles continue along upper edge of floor plates in similar manner to reverse frames. Web plates may have lightening holes cut in them.

Floor plates from 8½ to 36 inches deep at the center line form transverse brackets at the lower ends of side framing. The depth at a distance from center line of ¾ the half beam must be at least half what it is on the center line for large vessels. With a flat bottom this sometimes permits of sloping the upper edge of floor plates downward and outward to save structural weight and gain hold space.

It is usually preferable to have the upper floor edge horizontal and in small boats this is usually done regardless of the consequent reduction in overall width of floors.

Where the side frames join the floor plates the reverse angles diverge from the frames crossing the bottom of vessel at the upper edge of floors. If frames are of channels, zee bars, or bulb angles, these may be run along the lower edge of the floors to the keel and a reverse angle bar be fitted to upper edge of floors on the opposite side to the frames. Such reverse bars overlap the frames at the outboard floor ends. (Fig. 52d.)

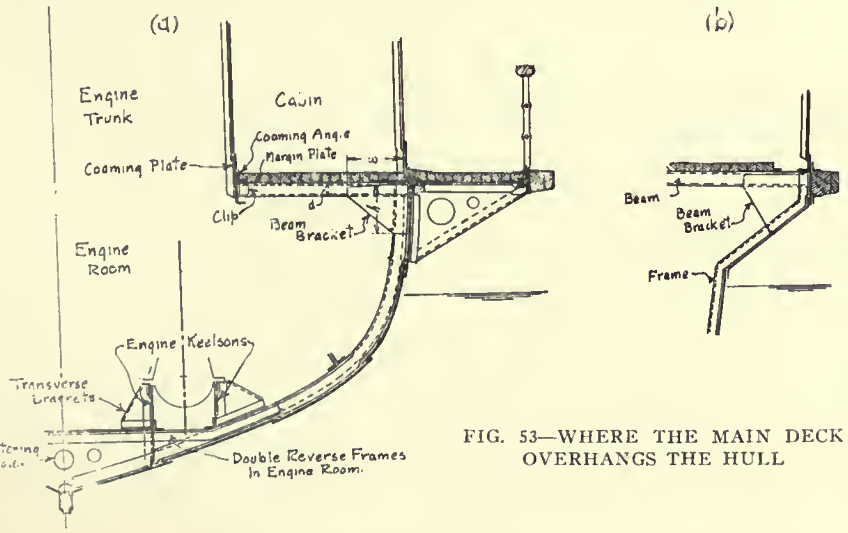


FIG. 53—WHERE THE MAIN DECK OVERHANGS THE HULL

Sometimes the channels, bulbs or zee bars are split at their junction with the floor ends and the upper portion forged to join the reverse bar on floor tops, while the lower half joins a frame angle at lower edge of floors (Fig. 52c).

In the Machinery Space

Floor plates in machinery space should be thickened by 0.04 inches and the reverse bars be doubled at their tops. In the peak tanks at the forward and after ends of vessel, floors are deepened to form strong brackets at the acute lower intersection of the hull sides. The reverse angles are also fitted at their tops, and floors in after peak tanks sometimes support the shaft tube which pierces them.

All floors may be lightened by circular or elliptical holes cut at their neutral axes. Care should be taken that depth of lightening holes does not exceed one-half the depth of the plate. Deck beams are of angles, bulb angles, channels or bulb Tees, fitted in one length across the deck and bracketed at the deck sides to the frame heads. Angles, bulb angles or channels face in opposite direction to the frames so that they may be connected back to back at the beam brackets. When the deck is of steel plating, beams are fitted on each frame while with a wooden deck the steel beams are on alternate frames.

It is common to bend or "crown" deck beams upward in a circular arc so that the height at center above sides is ¼-inch per foot of deck width at the particular beam considered. This camber was formerly claimed to contribute transverse deck strength due to the arching effect. The fallacy of this theory is that all arch thrusts are taken at the ends which in this case are the relatively flexible ship's sides. Camber is now employed for drainage purposes only, but since a ship is very seldom on an even keel, even this is scarcely warranted, since the water often accumulates on the high side of deck houses and coamings amidships.

Flat deck beams or those with straight ridged sides rounded at the center line, are becoming widely used.

The saving in furnace work and fitting expense of the attached members of the ships' structure is considerable.

Where hatches or trunks necessitate cutting deck beams the severed beam ends are connected by angle clips to a strong longitudinal coaming plate which forms a girder supporting the deck sides between the hatch ends. Heavy girder beams at the ends of these deck openings take the abutments of longitudinal coamings and are built up of a plate with upper and lower angles. These heavy beams are usually bracketed to web frames.

In forming beam brackets to frames it was formerly common to split the beam section, bend the lower portion downward and weld a piece of plate into the forked opening at beam ends thus formed. This expensive method has been replaced by riveting beam and frame ends to a bracket plate (Fig. 52) whose inner edge may be flanged (Fig. 53), and into which lightening holes may be cut.

The depth ("d" Fig. 53) at the inner bracket end on deck beam should not be less than six times the diameter of rivets connecting the bracket to the beam; while the depth "h" and length "w" of bracket sides on frame and beam respectively, should be three times the beam depth.

In holds of considerable depth it becomes necessary to introduce widely spaced "hold beams" which tie the ship's sides together and end on "stringers" or heavy longitudinal side girders. Strong vertical and horizontal brackets are fitted at hold beam ends to these stringers and to web frames which should coincide in spacing with the hold beams. Hold beams are usually built up of a plate with double upper and lower angles or of two channels back to back.

The long length of beams in proportion to their sectional depth renders it necessary to support them at intervals by stanchions extending to the vessel's bottom. The unsupported beam length should not exceed 15 feet for ordinary construction and must be less than this if heavy deck loads are carried.

Stanchions may be disposed longitudinally on alternate frames or they may be widely spaced with girders under deck beams connecting their heads. Closely spaced stanchions, as the former are termed, may be of solid round bars or of extra heavy wrought iron pipe welded to forged heads and heels. This type should be fitted at the corners of all hatches and large deck openings.

Fig. 55a shows a closely spaced pipe stanchion with head having a vertical palm connected to a bulb angle beam. The heel is forged to a flat palm in this case, but if the stanchion steps on a steel flat the heel is connected to an angle clip by a vertical palm similar to the head here shown. If the deck beam is of channel section the stanchion head may have a horizontal palm as in the heel here shown. The objection to closely spaced stanchions is the degree of obstruction to cargo stowage which they introduce. Widely spaced stanchions of tubular or other sections (Fig. 55-b-c-d-e) are now fitted to most vessels carrying hold cargoes. Longitudinal and transverse bracket plates connect the heads to the beam girders and deck beams (Fig. 55b); while the heels are bracketed to foundations on the inner bottom plating or the floor tops (Fig. 55). In the latter case, brackets clipped to the reverse frames afford double angle connection to the floors and the foundation channels extend at least three frame spaces. It is desirable to fit all stanchions above the longitudinal girders in a ship's bottom known as "keelsons".

Shallow draft hulls have the stanchions on frames in the longitudinal trusses. Bracket plates connect the stanchions to the upper and lower chord shapes and to the diagonal angle braces.

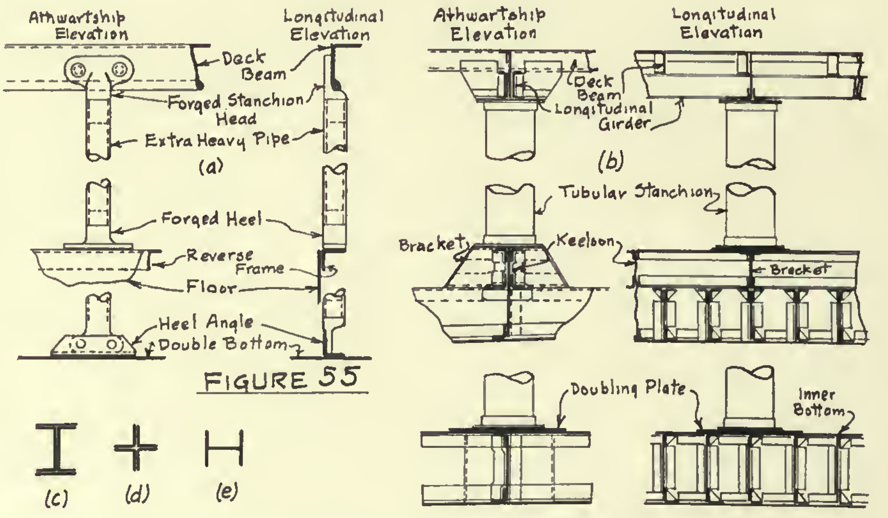


FIG. 55—STEEL STANCHIONS AND STANCHION HEADS

CHAPTER VIII

Design of Longitudinal Framing

THE principal strains set up in ordinary vessels are longitudinal in character and can be best understood if it is assumed that a wave of the vessel's length has its crests at the bow and stern; or this same wave has a crest amidships and a trough at the bow and stern.

The length of a wave is measured between the highest points of two successive crests or the low points of two successive troughs. The height of a wave is the vertical distance between the lowest point of a trough and the highest point of a crest. This height is taken as one-twentieth of the wave length, so that a 100-foot wave would be 5 feet high. The profile of a wave is a curve called a "trochoid," generated by a point on the circumference of a rolling circle.

Wave Action Causes Strain

When the vessel's water line has a wavy contour, the maximum longitudinal strains are set up in the vessel by a wave of its length. Where the crests are at the bow and stern and the trough is amidships it will be seen that displacement is concentrated at the ends and lacking amidships. Since the vessel's weight is greater at midlength due to the machinery and cargo, the tendency would be for the unsupported middle body to sag. The hull in this case resembles a beam supported at the ends and with a downward load midway between the supports. This sets up compressive strains tending to crumple the deck and tensile strains tending to stretch the keel. The cross section of the vessel is that of an equivalent girder and the longitudinal bending strains can be taken only by the hull planking or plating and such longitudinal framing as may be fitted.

When the wave crest is amidships, the deck tends to hog and the bow and stern to sag. Tension is here set up in the deck and compression at the keel. In either case the midship section is that most greatly strained and the change from tension at the top to compression at the bottom, or vice versa, is gradually reduced from maximum intensity at the extreme top and bottom to zero at a point about halfway between the keel and the deck. The plane of zero stress is called the neutral axis.

If the moment of inertia of the midship section were calculated about the neutral axis and the greatest bending moment for hogging and for sagging were derived from curves showing the longitudinal distribution of hull weight and buoyancy, the stress in the extreme deck and keel structure could be calculated from the well known formula:

$$M \text{ equals } \frac{SI}{c}$$

where M is the bending moment in foot pounds or tons.

S is the stress in pounds or tons per square inch.

I is the rectangular moment of inertia of the midship section.

c is the vertical distance from neutral axis to upper edge of deck or lower edge of keel.

Strength of Framing Defined

Ordinarily it is not necessary to perform this complicated and extensive calculation for strength, since the experiences of years have established the proper sizes and disposition of the hull structure. For steel vessels this has been particularly well accomplished by the large marine insurance societies such as the American Bureau of Shipping, Lloyd's Register of Shipping, The Bureau Veritas, etc. Here the various structural members are tabulated according to the dimensions of the vessel and if these are known it is a simple process to select the proper scantlings. Large wooden vessels have been similarly tabulated but not so thoroughly, since wood as a ship material has been so broadly replaced by steel. In smaller vessels the reverse is true and wood will doubtless continue the material composing hulls less than 100 feet long. At the conclusion of these chapters a tabular scantling

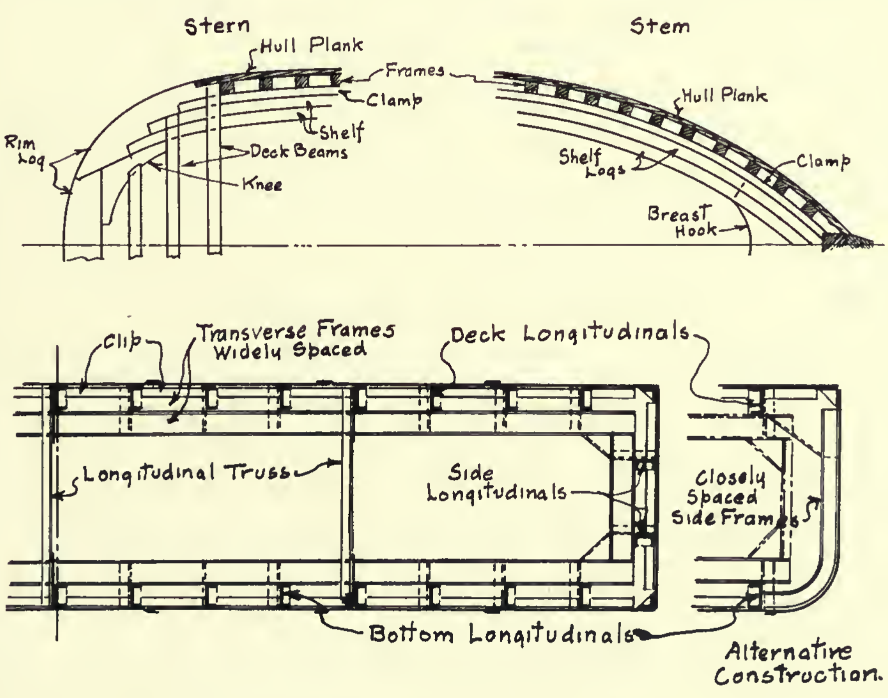


FIG. 56—LONGITUDINAL STRINGERS AND SHELVES FOR WOODEN TUGS AND FRAMES FOR SHALLOW STEEL VESSELS

table for commercial power boats will be appended and duly explained, with a view to facilitating the construction of commercial power boats.

If the above theory held in practice, the longitudinal framing would be strongest on the vessel's bottom and at the deck and little or none would be needed at the sides. This is not quite true in practice because the vessel may be subjected to hogging and sagging stresses whole it is rolled over at an angle. The sides would here contribute toward resisting the longitudinal strains and even disregarding this condition it is necessary to reinforce the ordinary transverse frames by side longitudinals to withstand the local bending introduced when striking or rubbing against docks or other vessels.

Keelsons

Longitudinal girders on the vessel's bottom are termed keelsons and should extend as far for and aft as possible. They are ordinarily not more than 8 feet apart at the midship section. There is usually a center keelson fitted in conjunction with and directly above the keel. Side or "sister" keelsons are between the center keelson and the lower turn of bilge. "Bilge keelsons" are at the turn of bilge. "Engine keelsons" are fitted under the main engines and should carry the machinery vibrational strains to the other framing.

Fig. 49 indicates the disposition of keelsons in a large wooden vessel (from 100 to 300 feet long). The center keelson is composed of two or more timbers side by side and superposed in pyramidal fashion. Long vertical bolts pass through each keelson timber and each transverse frame, the bolt ends being riveted over countersunk ring washers. Those timbers directly above the keel are vertically bolted to it at each frame and the countersunk lower bolt heads are covered by the false keel. The keelson timbers are also bolted together by vertical bolts between the frames and by horizontal bolts uniformly spaced to clear the vertical fastenings.

Notched Keelsons Not Necessary

Sometimes the keelson timbers are notched over the inner frame edges with a view to reducing the tendency to trip in the latter. The added labor in constructing notched keelsons and the weakened cross section caused by cutting away material at the notches together with the difficulty of obtaining accurate joints, render it doubtful whether this elaborated construction is justifiable.

In all cases where wooden longitudinals are composed of more than a single timber and it is impracticable to extend these in one length from stem to stern, the butt scarphs in the various timbers should be carefully disposed so that no two joints are at or near the same point. By this means the loss in longitudinal strength at the butt joints is not such as to materially weaken the girder.

Other forms of wooden and steel center keelsons in vessels with transverse framing were discussed in conjunction with keels in Chapter V.

Side or sister keelsons are fitted in large wooden vessels as in Fig. 49. Where there is but one on each side of the center line the hold stanchions should step on it and be connected thereto with natural crook timber knees or forged metal brackets. Where practicable the side keelsons should form part of the engine foundation framing, particularly in small vessels. If the alignment of the engine bed casting does not conform with the top of the continuous side keelsons, auxiliary timbers of proper shape and dimensions should be bolted on top of the keelsons to receive the engine, or should rest on the tops of transverse framing immediately alongside the side keelsons, being side bolted thereto.

Engine Keelsons Should be Long

When it is not practicable to incorporate the side keelsons with the engine keelsons, the latter should be of considerable length. The timbers to which the engine is bolted are usually too close together to pass the large flywheel of most internal combustion engines. For this reason these local timbers are bolted to and inboard of a keelson on each side and the difficulty of passing the flywheel is obviated by the thickness of the foundation timbers.

If it is not feasible to extend the engine keelsons all fore and aft they may butt against forged angle collars on the forward and after engine room bulkheads, particularly if these are of steel.

It is not customary to fit more than than one side keelson in large wooden vessels, since the ceiling timbers on the inside of transverse frames from the center line to the bilge are made extra heavy. Care should be taken to stagger the end joints of adjacent and neighboring ceiling timbers in the same way as for center and side keelsons, in order that no serious local weakening may result.

Steel side keelsons, one or more in number, are fitted in transversely framed vessels as in Fig. 58 (a) to (c). They consist of continuous longitudinal steel shapes on the floor tops, with or without intercostal plates extending between the floors to the sheel plating. Types (a), (b) and (c) are fitted in large vessels. They consist of continuous angles, bulb angles or a built up girder connected to the floor tops by a reverse bar clip having at least three rivets. The intercostal plates have their upper edges riveted between the continuous keelson angles and are notched to permit passage of the frame, reverse frame and reverse slip. A vertical clip joins the intercostal plates to each floor while lightening holes may be cut to save weight.

Bilge keelsons are usually part of the heavy bottom ceiling timbers in large wooden vessels (Fig. 50). Small wooden vessels usually have two or more square bilge keelsons sprung into place and through bolted to the frames (Fig. 49).

Steel bilge keelsons consist of two angles or bulb angles fitted back to back on the inner edges of transverse framing at the bilges. (Fig. 52 (c) and (d).

Steel engine keelsons (Fig. 53) are longitudinal plate girders on tops of the floor plates, with angles at the lower edges riveted to the reverse

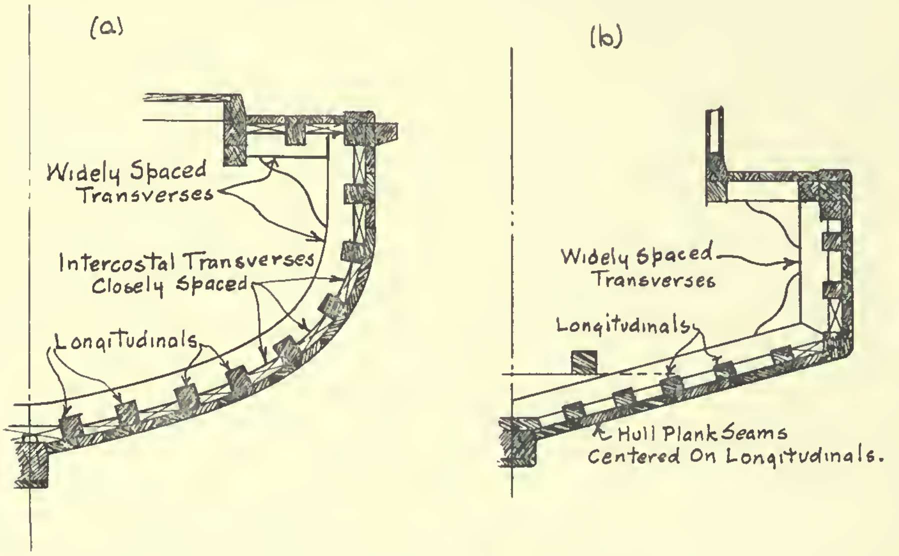


FIG. 57—CROSS SECTIONS LONGITUDINAL SHOWING FRAME CONSTRUCTION

frames. The engine base is bolted to continuous angles on the upper edges of the engine keelsons.

Where possible, as in the case of wooden vessels, one of the engine keelsons should merge into a side keelson, the keelson plate being deepened locally to the proper height for receiving the engine base. Transverse brackets clipped to the keelson plates and the reverse frames should support the engine girders at each frame.

Keelsons in shallow draft vessels consist of the lower truss chords previously described (Fig. 51 and 54) and the bilge log or the bilge angle.

Stringers

All longitudinal girders on the vessel's side above the bilge are covered by the term "stringers". The location determines the nomenclature of each stringer, so that:

(a) Hold stringers are those between the bilge and the lowest deck.

(b) Stringers at sides of decks or on tiers of beams in the hold are called "uper deck stringers", "lower deck stringers", "hold beam stringers", etc.

(c) Stringers located midway between two decks are "between deck stringers".

(d) Short stringers at the vessel's ends are called "panting stringers".

Large wooden vessels usually have heavy ceiling on the inner edges of the side framing, rendering it necessary only to fit stringers on top of the deck beams at their endings on the frames.

Upper deck stringers are sometimes called "margin planks" and are fitted to wooden vessels. If the frames extend through the stringer to form bulwark stanchions, a continuous stringer timber is fitted inboard of a notched margin plank fitting closely around and between the frame heads. This notched plank may be dispensed with by fitting filling blocks between the frame heads and the continuous stringers inboard of these. When the frames do not pierce the weather deck, the rail is on top of the continuous margin plank.

Lower deck stringers in wooden construction consist of one or more continuous timbers, side by side or one above the other such as the hold beam stringer.

Side stringers may be fitted in line with the lower fender with through bolts thereto.

All wooden stringers should be securely through bolted to every frame and to the beams on which they lie. The vertical bolts should pass through shelf timbers if these are fitted under the beams. Timbers should be in long lengths with scarphs in adjacent timbers widely separated.

Clamps

Clamps are heavy timbers on the inner edges of frames under the endings of beams. They may be of a single plank with its long side vertical and notched under the beam. Or several timbers may be used. Through bolts should be used transversely through clamps and frames or vertically through clamps and beams.

One or more timbers under beam ends may be fitted inboard of clamps and are called the "shelf". These assist in tying the beams to the frames and are through bolted to both.

The forward and after endings of stringers, clamps and shelves should be as in Fig. 56, with overlapped terminations to breast hooks or to filling blocks between the deck beams and to the stem logs.

Steel deck stringers are heavy horizontal plates at the sides and securely riveted to ends of deck beams. A continuous outer angle connects these stringer plates to the shell plating. In lower decks the frames usually pass up through slots in the outer edge of the stringer plate and the continuous stringer angle is fitted along the inner frame edges, being riveted to the stringer plate and to the reverse frame edges, to which they are securely joined, with short angle clips in addition to the reverse frame angles. An intercostal plate may fit between the stringer angles and between the frames to the shell plating where an intercostal clip secures its outer edge.

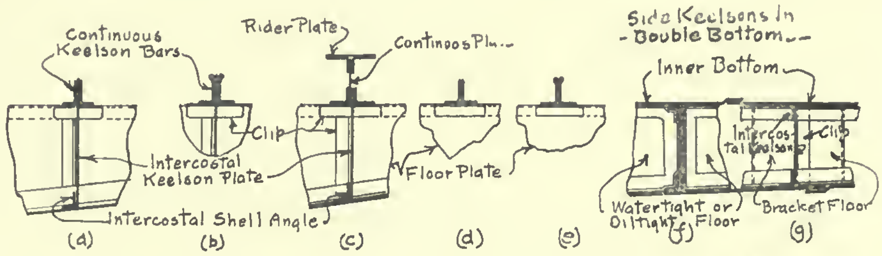


FIG. 58—STEEL SIDE KEELSONS WITH TRANSVERSE FRAMING

Good practice calls for side stringers at least every 8 feet and this may require additional short stringers in overhung sterns, where the extreme slope of the ship's sides creates excessive length of unsupported side framing between decks.

Panting stringers are fitted at the bow between the endings of continuous side stringers. Heavy breast hooks or bracket plates connect the ends of these at the stem. These panting stringers serve to reinforce the fine forward hull against the heavy local strains set up by encountering waves.

Carlings

Wherever it is necessary to cut hatches or other large openings in the decks so that the beams must be cut, a serious loss of deck strength results. It is necessary to compensate for the weakness so caused by butting the short cut beams on longitudinal girders which span between the intact beams at the ends of the hatch or opening. In wooden vessels these longitudinal girders are called "carlings".

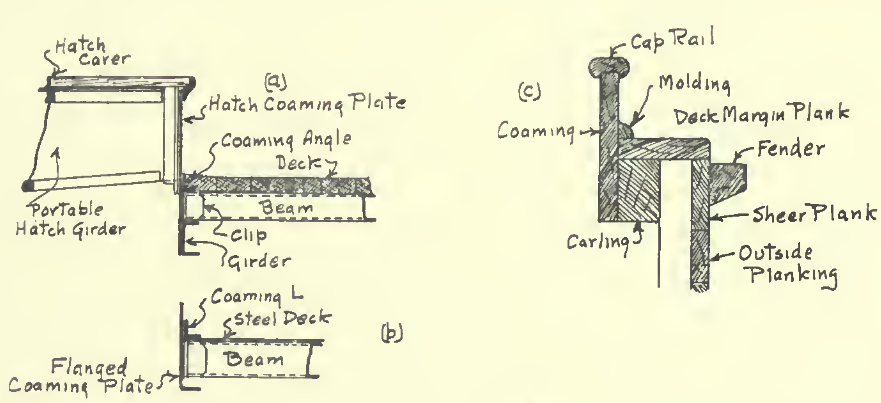


FIG. 59—HATCH AND COCKPIT COAMING CONSTRUCTION

The space between frames, stringer angle and shell plating, should be filled with cement or by a tightly fitted wooden block.

Between deck or hold, stringers of steel may be of two angles or bulb angles fitted back to back on the inner

Carlings are heavy strong timbers, always in one length and should always be supported by stanchions at their ends. When more than 10 feet long, an extra stanchion should support each carling midway between the ends. These stanchions should have heavy timber knees to the carling and the beam at their heads. The short deck beams should be morticed to the carlings at their inboard ends. Heavy horizontal timber knees should connect the ends of carlings to the beam at ends of the opening against which they butt. Naturally these knees should not ordinarily obstruct the hatch opening but should be fitted on the outboard side of carlings under the deck planking. All connections where possible, should be through bolted.

Coamings and Sills—Wood

The edges of all deck openings should have heavy coaming timbers fitted above the carlings and deck beams at ends. These coamings reinforce the carlings and prevent wash of considerable moisture into the hatches. They are rabbeted at their upper inner edges to receive hatch covers and are fitted with lugs to support the ends of portable hatch girders under these covers. Coamings should be through bolted to the carlings.

When carlings are fitted below the lower edges of deck beams, heavy filling pieces should be fitted between the ends of deck beams which extend over the carling. This provides solid timber between the carling and the coaming or lower deck house sill which rests on top of the inboard beam ends.

All through bolts in wood construction should pass through solid timber, for if there were a space between the timbers in which the bolt heads are embedded, the two timbers would spring when the bolt was tightened.

Cockpits in Small Boats

With wide open cockpits such as are employed in smaller fishing boats, the coaming may be a continuous heavy oak plank extending above the deck as in Fig. 59c. This is securely bolted to a carling which fits between the coaming and the inner edges of the frames. A heavy cap rail may be let over the upper edge of the coaming plank and a ¼ round molding is fitted at the junction of coaming with deck planking.

Steel hatch coamings are shown in cross section by Fig. 59 (a and b). The upper edges are fitted with angles or a special steel molding in which the wooden hatch covers rest. Steel hatch covers will be later taken up. The ends of cut deck beams are clipped to the coaming plate, as shown, and a margin plate is fitted on deck all around the hatch opening. This margin plate is connected to the coaming plate by the riveted coaming angle.

The lower edge of coaming plates should be fitted with angles or channels to form a stiff girder at the sides of the hatch. Sometimes this lower edge of coaming plate is flanged over, as in Fig. 59b.

Deck girders over the heads of stanchions and supporting the deck beams are fitted of wood or steel if the stanchions are widely spaced. Shallow draft hulls which are not deep enough to be rigid have longitudinal trusses in the holds. These consist of a continuous lower girder or chord on the bottom, and upper chord under the deckbeams and stanchions between these chords at intervals of from 3 to 6 feet. Diagonal braces extend from the foot of one stanchion to the head of the next in zig-zag manner. These hold trusses may be wooden or of steel angles and bracket plates.

Longitudinal Frames—Wood

The fitting of most of the internal hull framing in a fore and aft direction is becoming very popular and properly so. In light pleasure boats these longitudinals are peculiarly desirable with "V" bottom hulls. This is because the relatively slight curvature of any cross section permits the use of wide planks and light longitudinals are fitted over each longitudinal plank seam.

In power workboats with shipshaped hulls it is impracticable to fit planks wide enough to allow for sufficiently heavy longitudinal frames at each seam. To lighten the frames in keeping with the plank width should not be attempted without study. Fig. 57 (a) and (b) shows the application of heavy longitudinal framing to workboats. Transverse frames at intervals of from 4 to 8 feet are fitted inside the longitudinal frames which are spaced from 12 to 18 inches apart. It is necessary to fit filling pieces between the hull plank and the widely spaced transverses, so that the plank seams between longitudinals are properly supported.

It would be simpler to run the hull planking transversely or diagonally across the longitudinal frames as is done in some barge construction. This is not recommended for vessels which are self-propelled unless the bottom is sheathed with metal, because the roughness of the surface is increased with respect to the direction of travel and more power is lost in skin frictional resistance.

Longitudinal steel framing is not used in vessels of smaller sizes, but has been considerably employed in barges and box-shaped hulls. In steel shipbuilding this is known as the "Isherwood" system, having been patented under that name.

Fig. 60 is the cross section of a tug built on the longitudinal system of framing. Continuous bulb angles spaced from 20 to 27 inches apart extend fore and aft on the inside of the shell plating and under the deck. At the vessel's ends where the girth of section is less than amidships, it is necessary to stop some of the longitudinals at the peak bulkheads to which they should be bracketed. It is common to stop all longitudinals at these peak bulkheads and to substitute ordinary transverse framing from these points to the stem and stern, respectively.

Heavy transverses which are merely web frames spaced from 10 to 12 feet apart, are fitted as in Fig. 60 to resist transverse and local stresses.

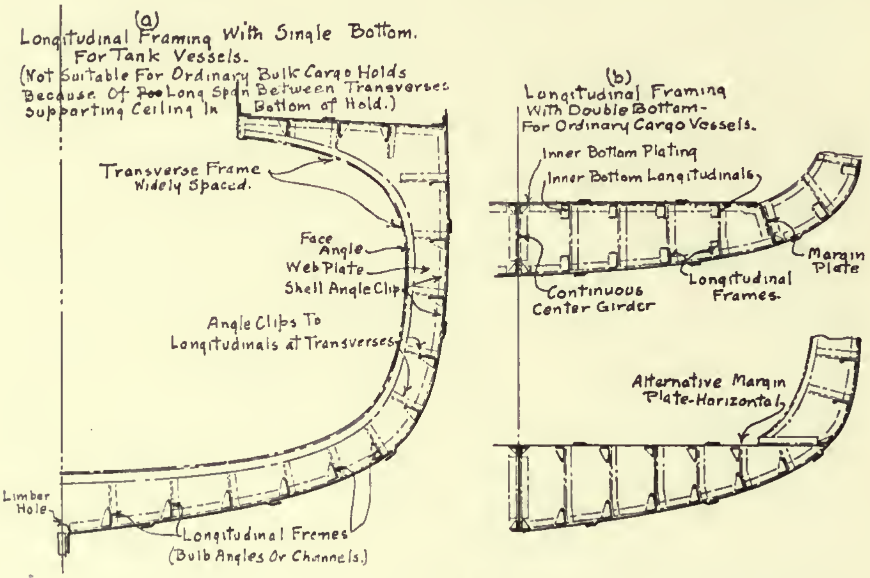


FIG. 60—CROSS SECTION OF A TUG WITH LONGITUDINAL FRAMING

CHAPTER IX

Bulkheads Demand Careful Planning

ALL vertical partitions in a vessel are called "bulkheads." They are what correspond to the interior walls in an ordinary house. They are classified according to their strength and purpose as:

(a) Structural: Non watertight, watertight, oil tight.

(b) Divisional, partitions, etc.

Bulkheads running across the ship are called "transverse" and those extending fore and aft are "longitudinal bulkheads."

Steel or wood may be used in bulkhead construction. Watertight bulkheads are fitted in the holds of most vessels, their object being to minimize the danger of sinkage by confining the seawater to any compartment in which the hull may be damaged by collision, grounding or other accident. Transverse bulkheads are most effective for this purpose. Tanks containing fresh water, water ballast or for fish preservation in trawlers are also fitted with watertight bulkheads. The number of watertight bulkheads installed varies with the size and type of vessel.

The Collision Bulkhead

Nearly all vessels have one transverse watertight bulkhead called the "collision" or "forepeak" bulkhead. This is fitted near the bow and should be on a transverse frame. In large vessels the distance abaft the stem is one-twentieth of the vessel's length, but in vessels less than 125 feet long this distance is greater (from one-eighth to one-sixteenth of the length).

There is also a watertight bulkhead at each end of the machinery space and usually enclosing compartments in which fuel is carried in separate tanks. When (in the case of steel vessels) the fuel tanks are part of the hull, the bounding bulkheads must be of especially tight construction to prevent leakage.

In a previous article the need of reserve buoyancy and the purpose of bulkheads was demonstrated by assuming that a central compartment of a box shaped hull was punctured and that the bulkheads in this compartment prevented the inrushing water from flooding the entire hold. The vessel then sank until the volume of water which the damaged compartment had originally displaced, was regained by the intact parts of the hull on each side of the damaged compartment. The symmetry of the regained buoyant volumes caused the vessel to settle parallel to her original water plane.

Fig. 61 shows what occurs to a vessel when damaged in the more usual and less favorable manner of having a compartment near the bow or stern torn open to the sea.

Suppose that the water plane (W-L) is that at which the vessel floated before the compartment (RSTV) was damaged. The point (B) will represent the center of buoyancy of the original underwater volume (DEFV) and the point (G) is the center of gravity of the vessel's structure and contents. These two points are located on the axis (X-X) which is perpendicular to the original water line (W-L). Now when the sea water enters compartment (RSTV), the displaced volume is decreased by the portion (HFTV), and the vessel may be assumed to settle to the water line (w-l), which is parallel to (WL). The volume (OEPH) between these water planes must equal the lost displacement (HFTV) and the new intact underwater volume is (ODRT). The point (B') halfway between the bulkhead RT and the end OD is the center of buoyancy of this new underwater volume and it is to the left of the original center (B). If the vessel floated at (w l) after damage as assumed, the force of buoyancy would act through the point B' and upward on the line (y-y) which is perpendicular to the line (w-l). The vessel's weight would act downward through the center of gravity (G) and along the line (x-x). This line is also perpendicular to the line (w l) so that we would have two equal forces acting in opposite directions as shown and separated from each other by the distance (h) between (x-x) and (y-y). These two forces form what is called a couple and would tend to rotate the vessel in the direction taken by the hands of a clock (called clockwise). It will also be seen that when these two forces act in the same straight line there will no longer be a tendency to rotate the vessel and since the forces are equal but opposite, the vessel will then come to rest.

Accordingly let W'L' be the inclined water plane to which the vessel will incline or "trim" when the forces of buoyancy and the vessel's weight are again vertically in the same straight line (z-z). The final underwater volume (ARTD) will equal the original displaced volume (EFVD) and (B") is the final center of buoyancy.

It is possible to calculate the position of the inclined water plane (W'L') and consequently the effect upon the vessel of flooding any compartment. This calculation is involved and of too great length to be considered here. For a complete discourse on this subject refer to Attwood's text book on "The Theoretical Naval Architecture" or to Biles' "Design and Construction of Ships."

Notice that the freeboard is less at the damaged than at the intact end of the vessel and that the draft S V is greater at the damaged end than the draft A D at the other end.

The quality which a vessel has of inclining in the above manner is known as "changing trim." The difference in feet and inches between the draft S V at the low end and A D at the high end is called the "change of trim" and is equal to the sum of F S and A E. But F S and A E are the changes in draft from the original water line W L to the new water line W' L'. Therefore, the "change of trim" is equal to the sum of the changes in draft at the forward and after ends of the vessel. Change of trim may be produced by moving a weight from its position on the vessel, to a point nearer the bow or stern. The weight which must move one foot to cause a change of one inch in trim, is called the moment to change trim one inch.

Large ships are so designed that if two adjacent hold compartments should be flooded, the change of trim will not be excessive and the vessel

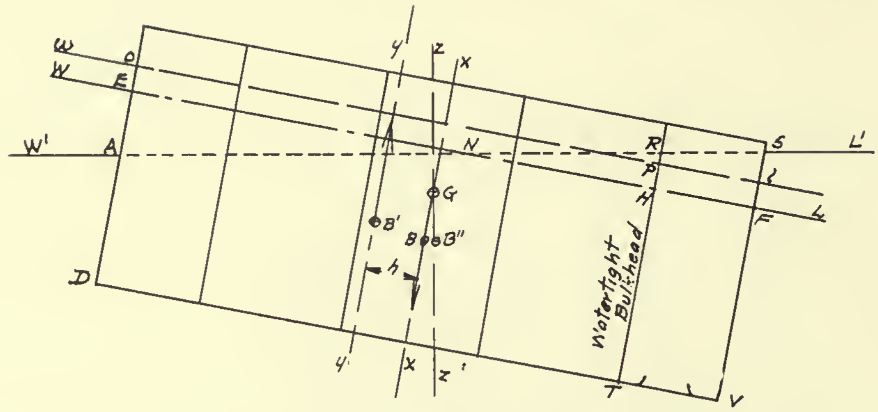


FIG. 61—WHAT HAPPENS WHEN THE BOW OR STERN COMPARTMENT IS FLOODED

will float, or if three remote compartments are flooded the vessel will not sink.

Small vessels can with difficulty be made to conform to such requirements, since the increased number of bulkheads necessary would make the hold compartments too small to carry cargo economically.

Again, wooden bulkheads or steel bulkheads in wooden hulls cannot be made absolutely watertight in case of hull damage. This is because the seams of the hull planks would ordinarily "start" for some distance on each side of the point of impact, permitting the water to leak around the margin of the bulkheads to the other compartments.

Bulkheads serve to retard the leakage and to save the vessel if action is quickly taken and the pumps have sufficient capacity to discharge the water as it leaks in. Steel bulkheads in steel vessels can be made watertight, but do not necessarily make the vessel "nonsinkable." This term is a fond dream concocted in the fertile imagination of laymen.

In very small vessels such as lifeboats where the holds are not used to carry cargo, watertight metal tanks are sometimes built into the hold compartments and they afford sufficient buoyancy to float the boat if the exterior hull is damaged. If these tanks are also punctured, their utility ceases and the boat will sink.

Wooden Bulkheads

Fig. 62 is a transverse watertight bulkhead in the hold of a wooden vessel longer than 125 feet. The ceiling which contributes to the longitudinal strength of the vessel, should not be cut at the bulkhead which fits closely inside of the internal longitudinal hull timbers. Two thicknesses of tongue and groove planks with a layer of canvas in thick white lead, tar or paint between them, form the bulkhead proper. The seams of these two thicknesses of planking are at right angles to each other, one set running vertically and the other horizontally; or both sets being at complementary angles of 45 degrees to the vertical ship's center line.

The bulkhead planks are through bolted between two deck beams at their tops and between heavy bulkhead margin timbers all around their edges. Canvas strips thickly coated with thick lead and called stop waters, are fitted between the bulkhead planking and the margin timbers. In very heavy construction all the bulkhead planking and margin seams should be calked, particularly if one of the compartments is to form a permanent water tank.

A steel angle iron properly forged to fit closely around the bulkhead edges may be substituted for the margin timbers and canvas stop waters or calking should also be used in the seams where the bounding angle fits against the bulkhead planking and the longitudinal ceiling.

Heavy stiffening timbers should reenforce the bulkhead plank on each side. They should be spaced about four feet apart and should be logs whose square section is at least four times the bulkhead thickness. The stiffeners extend vertically on one side and horizontally on the other side of the bulkhead. Heavy natural crook timber knees or forged metal brackets connect the ends of bulkhead stiffeners to the deck and ceiling. Where practicable, stiffeners should terminate on keelsons and stringers.

The thickness of bulkhead planking for the above construction varies from one-half inch for each layer (one inch total thickness) in small boats (30 to 50 feet long); to four inches for each layer (eight inches total thickness) in vessels 325 feet long.

These larger bulkheads may be constructed of one thickness of six to eight-inch planking, calked on both sides, but the strength and tightness are not equal to those obtained with the double layers at right angles to each other.

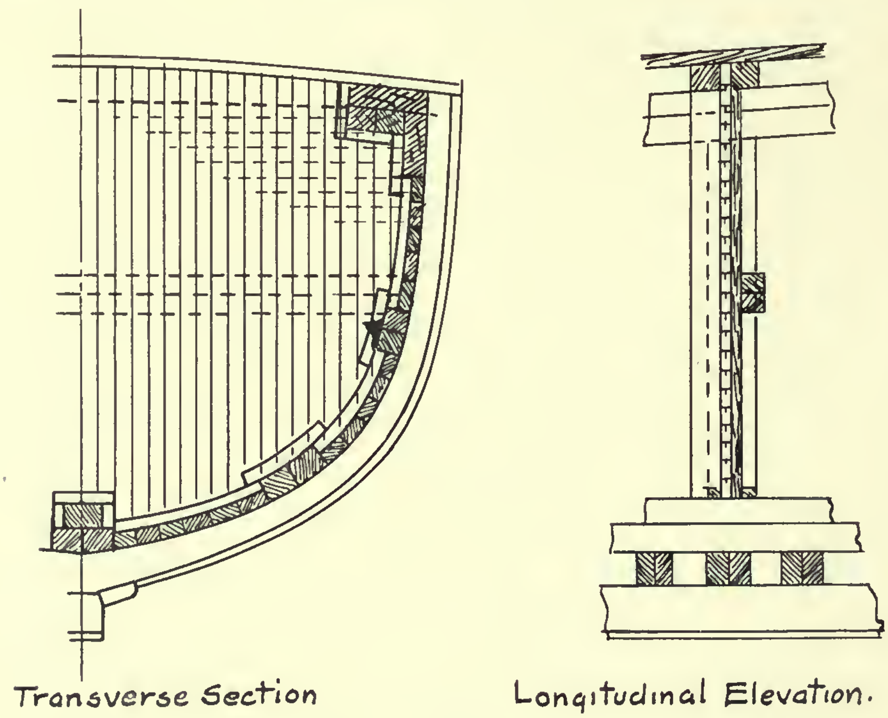


FIG. 62—TRANSVERSE WATERTIGHT BULKHEAD OF WOODEN VESSEL LONGER THAN 125 FEET

Transverse Watertight Bulkheads

The transverse watertight bulkheads of small vessels in which the ceiling planks are not fitted for strength, may be constructed as in Fig. 63. In this case the only longitudinal framing which passes through the bulkhead consists of keelsons, stringers,

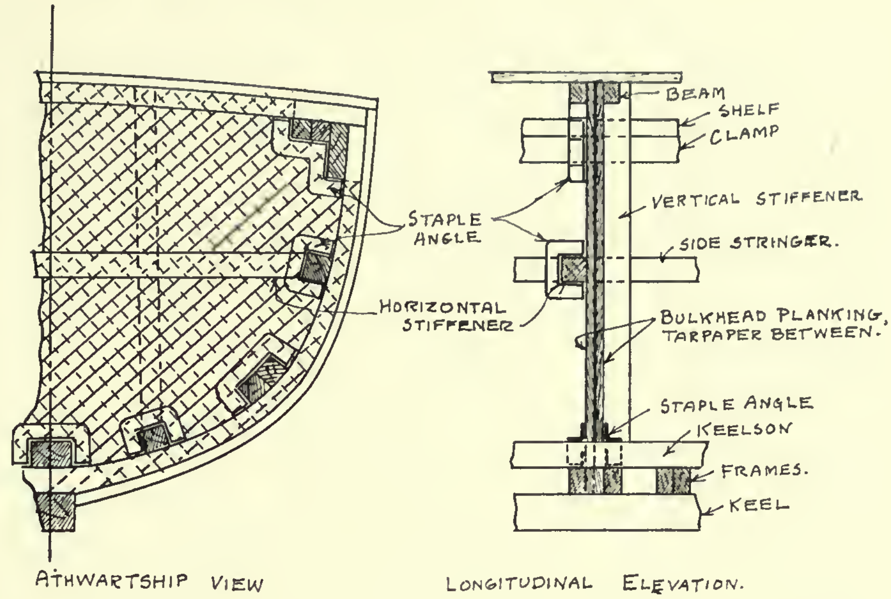


FIG. 63—TRANSVERSE WATERTIGHT BULKHEAD FOR SMALL WOODEN VESSEL

clamps and shelf logs. The bulkhead planks extend out to the hull planking with double frames and beams forming the margin logs. Canvas stop waters are bolted between the bulkhead planking and the marginal framing. Steel angle bar staples are forged to fit around the longitudinals which pass through the bulkheads.

In this connection it may be remarked that watertight bulkheads were not fitted in holds during the period when wooden ships were predominent.

Longitudinal watertight bulkheads of wood are not often fitted. The construction is identical with that for transverse bulkheads when they are used.

Engine Bulkheads Fireproof

It is desirable to render bulkheads in the engine room fire resisting and this is accomplished by covering the side toward the engine room with a layer of asbestos mill board or other insulator. Galvanized sheet iron is tacked over this insulation. Yellow pine or fir planks are used for watertight bulkheads.

Divisional or minor wooden bulkheads serve to divide the interior of vessels into the various compartments for berthing, messing, storage, etc. They may be longitudinal or transverse and built of vertically staved tongue and grooved planks, panels or composition wallboard tacked over wooden staves.

When extending athwartships it is desirable that they fit against a transverse deck beam (Fig. 64-a). The lower ends of bulkhead stavings are set into a grooved sill as shown and the planks driven home then blind nailed at top and bottom. If the height is more than seven feet (unsupported planks) and the thickness is less than one inch, an intermediate horizontal studding should be fitted between vertical stiffeners of 2 x 4-inch timber spaced not more than four feet apart.

This same reasoning applies to panels (Fig. 64-f), but the studding should be lighter and the paneling be fitted on both sides thereof (Fig. 64-k).

Bulkheads In the Cabins

Divisional longitudinal bulkheads in living spaces extend to a scantling which is grooved to receive the bulkhead sheathing and is fitted *under* the transverse deck beams (Fig. 64-b). This leaves an open space for ventilation between the top of the bulkhead and the deck above. This space may be left open or fitted with a grill of wood or metal.

Galleys, pantries, baths and toilet spaces should be completely shut off from the other compartments by extending the longitudinal bulkhead sheathing between the beams to the deck or cabin top overhead as in Fig. 64-c. A quarter round or other molding is neatly fitted around each beam.

Galvanized sheet iron, zinc or lead should line the bulkheads in shower or bath compartments to protect the wood from the splash. Tongue and groove bulkheads may be of V chamfered or of beaded planks (Figures 64-d and e respectively) and vary in thickness from ⅝-inch to 1¼-inch.

Bulkheads of composition wallboard in combination with staving are shown in Fig. 64-g and h. The wallboard varies from 3/16-inch to 5/16-inch in thickness and the sheets are securely tacked to the staving. A molding strip is nailed over the wallboard seams and may be of stained wood, thus affording a paneled affect. When the staving is solid as in Fig. 64-g, the thinner wallboard is employed, but heavy board should be used with widely spaced staving (Fig. 64-h). These staves are from ¾-inch to 1¼-inch thick and from 3 to 4 inches wide. A clear space of from two to four inches may be allowed between staves.

Divisional bulkheads may be fitted in the deck houses and superstructure of steel vessels. The construction is the same as in the case of wooden boats and the object of using wood is to lighten the minor bulkheads, thus reducing the total structural weight and gaining carrying capacity on a fixed load displacement.

Steel Bulkheads

These may really be made watertight or oil tight in steel vessels and they are more nearly so than wooden ones in wooden vessels. The common practice is to make the bulkheads enclosing the machinery space of steel, for fire resisting and to build the bulkheads in holds outside the engine room of wood in wooden vessels.

Where continuous inner wooden

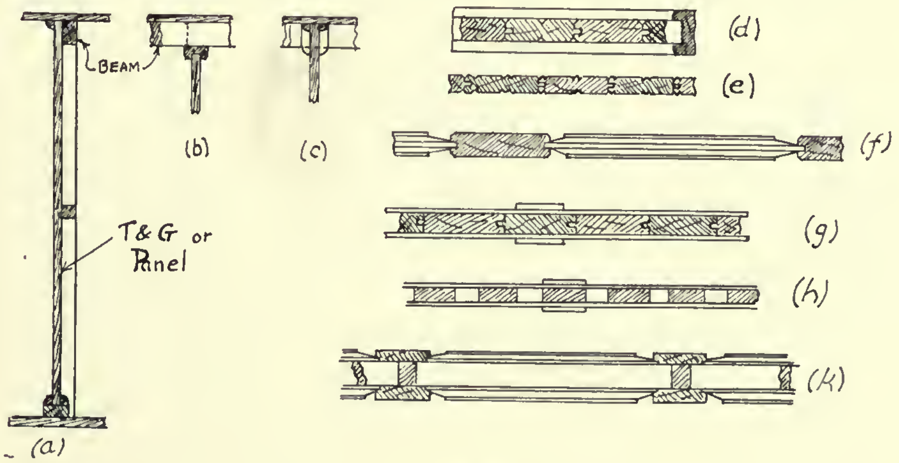


FIG. 64—CROSS SECTIONS OF VARIOUS MINOR BULKHEADS FOR CABINS, ETC.

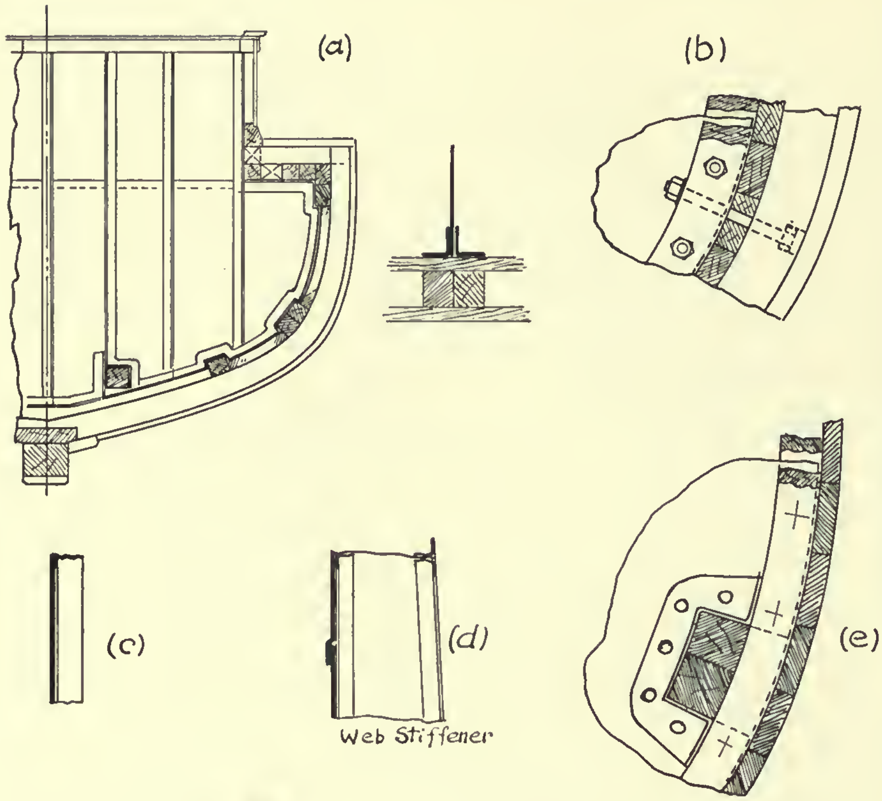


FIG. 65—STEEL BULKHEADS AND FASTENINGS FOR WOODEN VESSELS

ceiling is fitted for strength of wooden vessels, the steel bulkheads fit inside the ceiling (Fig. 65-a) and have double steel margin angles. Sometimes wooden margin timbers are fitted on both sides of the steel bulkhead plating which is bolted to them. (Fig. 65-b).

Canvas stopwaters in white lead are inserted between the margin angles or timbers and the ceiling. Through bolts spaced between the ones joining the margins to the bulkheads, extend to the outside of the transverse frames, where the bolt heads are countersunk over washers and the recesses filled with cement or wooden plugs. These radiating bolts on opposite sides of the bulkhead should be staggered as shown in (Fig. 65-a and b), to prevent local weakening of the frames due to material cut away. They should also clear the bolts or spikes which fasten the hull planking to the transverse frames.

Bulkhead plating in holds varies in thickness from 5 pounds per square foot (⅛-inch thick), to 15 pounds per square foot (⅜-inch thick), the width and depth of bulkhead regulating the thickness.

The number of plates in a bulkhead is governed by the maximum width to which the steel mills can roll and varies according to the thickness, width and length of the plate. This is governed by the size of steel billet from which the plate is rolled and the width of the plate rolls.

Use Standard Plates

The steel companies publish tables stating the standard widths of plates for each thickness and the layout of bulkhead plating should be such that standard plates may be used where possible. This will reduce wasted material and extra expense involved by sheering and planing the plates.

The seams of bulkhead plating are lapped and single or double riveted. The plate edges of seams in watertight bulkheads should be planed to a slight bevel and should be calked after riveting. Calking of steel plates will be taken up in connection with shell plating, as will also riveting. The scantling tables appended to this series of articles, sets forth the proper thickness of steel bulkheads, the size and spacing of rivets and stiffeners. Rivet holes in seams should always be punched from the "faying" surfaces which are those bearing together at the seam.

Bulkhead plating is so thin relative to its depth and width that structural stiffeners consisting of angle bars, bulb angles, channels or deep web plates in conjunction with angles must be fitted. (Fig. 65-c and d). These are usually fitted vertically at intervals of from 18 to 27 inches.

Deep bulkheads have horizontal stiffeners on the opposite side of plating to which vertical ones are fitted. Horizontal stiffeners are spaced about four feet apart.

Bulkheads In Steel Vessels

Transverse watertight bulkheads in steel vessels are similar to those in wooden ones except that the marginal angles are riveted to the shell plating and the stiffeners are bracketed at their ends. No stop waters are fitted and all the angles and rivets are calked. Fig. 66 is a transverse and longitudinal elevation of this type of bulkhead.

Keelsons and stringers may be cut at the bulkhead and secured thereto with bracket plates and angle clips or may pass through openings in the bulkhead plating and then be made watertight with forged staple angles or "shoes" as in Fig. 66. These alternatives also apply to longitudinal frames where the vessel is so constructed.

Observe that the vertical stiffening angles are on the side of bulkhead plating away from that on which the

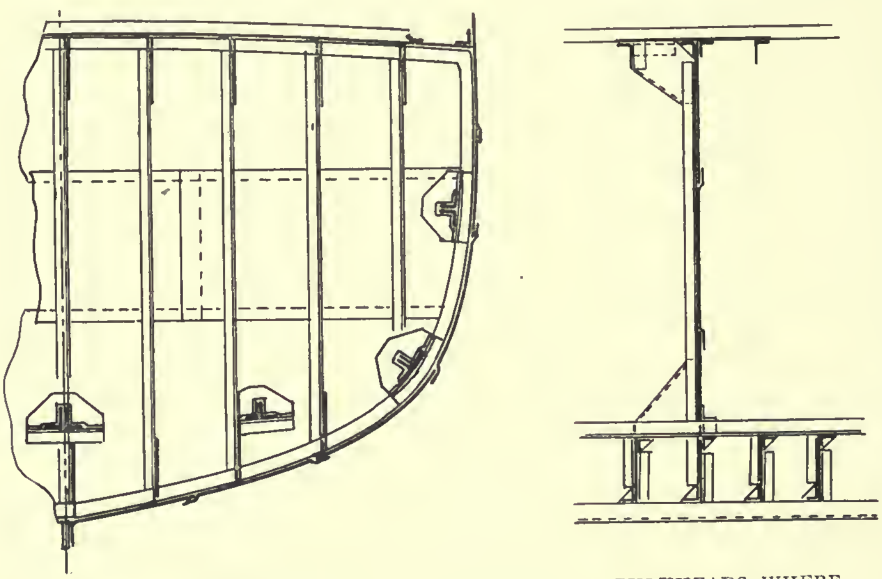


FIG. 66—SHOWS METHOD OF FITTING "SHOES" AT BULKHEADS WHERE KEELSONS AND STRINGERS ARE CUT

plating is joggled for seam laps; that the vertical seams of bulkhead plates are located between stiffeners and that in the case of a vessel with wooden decks (Fig. 66) a steel deck plate is fitted under the deck planks for one beam space on each side of the bulkhead so that the upper stiffener brackets may be riveted to it.

Where it is necessary for piping to pierce watertight bulkheads, a flanged joint is fitted at the bulkhead plating.

Tank Bulkheads—Steel

Compartments designed to carry water, oil or other fuels in bulk, require heavier bulkhead construction than was the case in those where safety against sinkage was the main object of installation. The severe stresses due to washing of the contents from side to side calls for closer subdivision so that longitudinal bulkheads are usually fitted on the vessel's center line and "swash bulkheads" are fitted to cut down the surge of the fluid.

These swash bulkheads are merely flanged plates, stiffened vertically and extending between the ends and sides of the compartment (Fig. 67-a) or may be continuous light plates with large holes cut in them (Fig. 67-b). Vertical angles about 24 inches apart stiffen the light swash plates and connect them to the watertight bulkheads at the tank ends and sides. Swash bulkheads are spaced from 8 to 12 feet apart.

Longitudinal watertight or oil tight bulkheads should have their lower plating formed by deepening the center or side keelson plates and these plates should always be continuous. All transverse framing on the vessel's bottom should be cut at the longitudinal bulkhead and connected to it by bracket plates. Sometimes deck beams extend through the top of longitudinal bulkheads and forged angle stapling is fitted around the beams to prevent leakage. More often the beams are cut and bracketed to the bulkhead, resulting in lessened expense of construction and ample strength.

Longitudinal centerline bulkheads have double angle bars all around their margins, affording connection to the keel plate, deck plating and transverse bulkheads against which the longitudinal bulkhead terminates.

Longitudinal bulkheads forming wing tanks are located on side keelsons and usually have a single large margin angle.

The lower plating of watertight and oiltight bulkheads is usually heavier than the upper strakes because of the greater pressure imposed on the lower portion of the bulkhead by the "hydrostatic head." In any fluid the pressure increases with the depth and is equal to the weight of a cubic unit of the liquid multiplied by the depth of the surface acted upon below the surface. Thus the weight of fresh water is 62.5 pounds per cubic foot and the pressure on an area one foot square at a depth of 10 feet below the water surface would be 10 x 62.5 or 625 pounds.

Center of Pressure

It is usual to assume that all the pressure load on a submerged surface is concentrated at a point called the center of pressure. This is located on the surface at the level corresponding to the center of gravity of an area formed by a curve showing the variation of the pressure load with the depth. If the surface is rectangular, the pressure load will be equal to the pressure per square foot times the area of a strip one foot wide whose center is at the depth considered. By computing the pressure at successive depths and plotting it to scale at that depth, a series of points will result, through which a curve may be drawn. This curve of pressures is a straight line since the widths are constant and the center of gravity of the triangular area between the pressure curve and the bulkhead is two-thirds of the submerged depth below the surface. It is possible to calculate the strength of bulkheads, but the assumptions made require considerable detailed computations. Ordinarily the thickness of plating and size of stiffeners

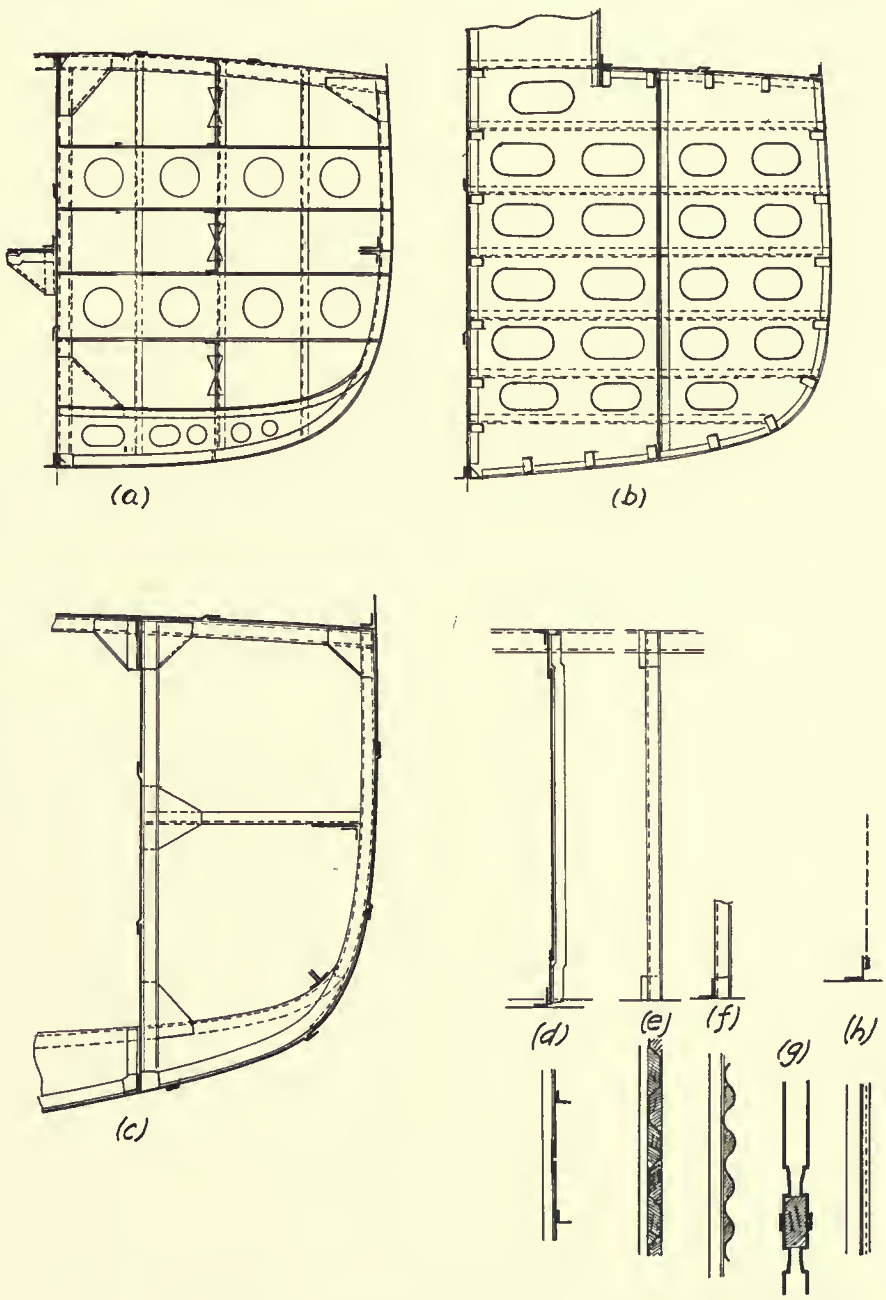


FIG. 67—CONSTRUCTION OF TANK BULKHEADS FOR OIL AND WATER; ALSO METAL BULKHEADS FOR MINOR COMPARTMENTS

is taken from previous successful practice.

The vertical stiffeners of longitudinal bulkheads are located at each transverse ship's frame and are of the same size as those for transverse bulkheads of the same depth.

Web stiffeners are on every fourth transverse frame of longitudinal bulkheads and on every keelson at transverse bulkheads. These web frames are formed of a tapered plate secured to the bulkhead by a vertical angle and having double face angles on their vertical outer edges. Flanged bracket plates connect the lower end of web stiffener plates to the transverse floor plates and to the deck plating.

Wing Tank Bulkheads

In deep tanks it is necessary to support the vertical stiffeners midway of their depth. This is done in wing tank bulkheads by angles sprung between the side stringers and the bulkhead on alternate frames (Fig. 67-c). Bracket plates connect these stay angles to the stiffeners and to the side stringers if the latter consist of two shapes on the inside of frames. If the stringer has a wide shelf plate as shown in the figure, the stay angle is riveted directly on top of this plate.

The intermediate stiffener support for bulkheads on the ship's center line and for deep transverse bulkheads, is provided by a plate shelf as in Fig. 67-a. Brackets support this shelf from the bulkhead at every stiffener.

Bulkheads in vessels with longitudinal framing have horizontal stiffeners at the same level as the hull side frames and bracketed to these at their junction. Deep vertical web stiffeners are at every deep "transverse" at distances of from 8 to 10 feet apart in the tanks.

Minor Steel Bulkheads

Minor compartments may be enclosed by three types of steel bulkheads extending transversely or longitudinally:

(a) Steel plate.
(b) Deformed steel.
(c) Wire mesh.

Minor steel plate bulkheads consist (Fig. 67-d) of an upper and lower coaming plate connected to the decks by angles. Lighter plating is fitted between these coamings with vertical butt seams which are covered with a wide butt strap as shown. This construction has a paneled appearance on the side where these seam straps are. Vertical stiffening angles support these bulkheads at intervals of three feet and wooden sheathing or paneling may be fitted on the stiffener side by nailing it to furring strips bolted to the stiffeners.

Partitional bulkheads of deformed steel are shown in Fig. 67-e, f and g, being composed of galvanized sheet metal which is corrugated or paneled. The corrugated types (Fig. 67-e and f) require no vertical stiffening but present difficulty in fitting at the decks. The upper and lower margins may be of wood or steel angles and the corrugations are nailed, riveted or spot welded where they touch these margin moldings. The space between the margins and the hollows of the bulkhead sheathing may be filled with wood blocks or with light cement.

Sheet metal panels may be nailed to wooden framework to form a very attractive bulkhead (Fig. 67-g).

Spaces requiring ventilation and light such as galleys, bakeries, etc., may be fitted with partitions of heavy galvanized wire mesh with a metal frame bolted to angles at the decks. (Fig. 67-h).

CHAPTER X

Hull Planks—Fenders—Bilge Keels

THE hull planks of wooden vessels are usually put on with the longitudinal seams butted, forming a smooth exterior surface. These are called "carvel" planked hulls (Figs. 57, 62, 63 and 65).

Small boats are sometimes "clinker" built, that is, the longitudinal hull plank seams are lapped and riveted together. Clinker built boats are not caulked and require careful workmanship to construct properly since the frames must be notched to fit the inside of planking.

The more commonly employed carvel system of hull planking has all seams calked with one or more threads of cotton or oakum, the number of threads depending upon the plank thickness. Calking and fastening of planks will be subsequently discussed.

One or more planks immediately next to the keel are made thicker than the rest of the hull planking and are called "garboard planks" or simply "garboards."

Small vessels (up to 50 feet long) have but one garboard plank from six to eight inches wide and from 1¼ inch to 2½ inches thick. Vessels from 50 to 100 feet long have two garboards from 2½ to 4½ inches thick and from 6 inches to 12 inches wide. Larger vessels have two or three garboards up to 6 inches thick. Occasionally, when two or more garboards are fitted, the plank next the keel is of maximum thickness and the second or third garboard has a thickness between this and that of the hull planking.

The Garboard Planks

Where oak can be obtained in long lengths, garboards are of this material, but yellow pine and fir are most often employed. Garboard planks are rabbeted to the keel as has been shown and should be edge bolted thereto if practicable. The ends of garboard planks if 2 inches or more thick should be scarphed, the scarph length being three times the plank width. Garboard plank ends less than 2 inches thick are butted between frames, a "butt block" to which the plank ends are riveted, being fitted between the frames at the butt. End butts or scarphs of garboard planks should be well clear of those on the neighboring planking, keel and other longitudinals.

The uppermost hull plank follows the line of sheer and is sometimes made of oak. It is usually wider than the remaining hull planks and is cut and bevelled to fit the sheer profile. It is called the sheer plank and is of the same thickness as the other hull planking.

Hull planking between the garboards and sheer plank is generally of uniform thickness (from ¾ inch to 5 inches) depending upon size of vessel. Sometimes in large vessels the bottom planking is from ½ inch to 1 inch thicker than the side planking. The width of these planks varies from four to eight inches in vessels with curved frames. Greater widths than eight inches are not employed in this case because it is difficult to fit the inner surfaces to the outer edges of the transverse frames. Thin planks may be steamed and bent to this transverse curvature but thick planks are slightly hollowed with an adz, since they tend to split when bent transversely as well as fore and aft. Vessels with straight or slightly curved frames such as barges and shallow draft craft have planking up to 12 inches wide, the objections to transverse bending being absent.

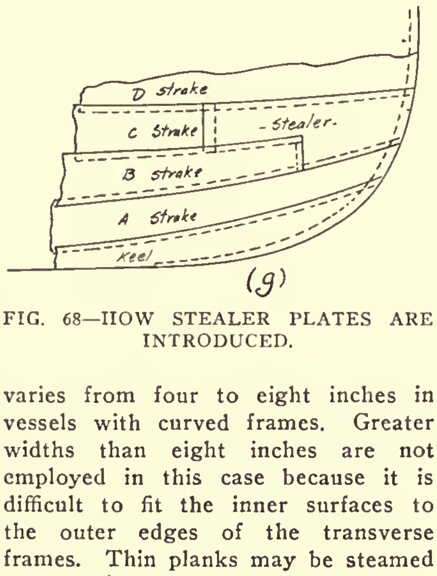


FIG. 68—HOW STEALER PLATES ARE INTRODUCED.

Tapering the Planks at the Ends

In fitting hull planks they are spaced off (girthed) on the midship section and are of maximum width at this section. The number of planks is then counted and the girths of several end sections of the vessel are divided into the same number of parts. The planks are tapered to fit fair at or near these points of division, but should not be too greatly reduced in width at the end frames. A minimum width for the reduced ends of one-half the midship plank width is good practice.

Where the girth of end sections is so much less than the midship section that excessive reduction in plank widths would result if the same number of planks were used at the vessel's extremeities, the number of planks may be reduced by fitting one wide plank at the ends of two narrow ones. Such a plank is a "stealer" and is fitted with a butt block covering the two planks which it replaces.

The extreme forward ends of hull planking fit into a rabbet on the stem and the workmanship at this point should be very accurate. The after ends of planks in transom sterns cover the ends of the transom planks and are fastened to the transom rim log. A sheet metal flashing is tacked over the after plank ends at transoms to protect the ends of wood grain against wear and decay. In overhung or fantail sterns where the after plank ends terminate on the horn timber, the plank ends are notched to a rabbet on that timber, care being taken that the nibbed ends are not too nearly a feather edge.

If the planks cannot bend to the hull form due to the warped nature of the surface, it is necessary to "steam" them. This is done by building a box long enough to take the longest planks and closing the ends. The whole is then calked and a steam pipe introduced at one or both ends with a drain pipe at the center. After the planks or other timbers which are to be bent, have been put into the box, usually through one end, the steam is turned on and permitted to flow until the planks have become pliable. This time is less for timbers of small section than for large timbers. A hot water bath may be used for light planks instead of the steam box.

Hull planking may be secured to the framing by:

(a) Screws
(b) Rivets
(c) Spikes
(d) Bolts

Screws and rivets are used in small vessels where the plank thickness is not over two inches. Brass screws are best and should have heads countersunk in the planking, the holes being closed with wooden plugs in thick white lead. The screws should extend two-thirds of the way through the framing.

Copper or galvanized iron rivets should have their outer ends over washers in countersunk holes plugged as for screws. The inner rivet ends extend through the frames and are hammered or clinched over washers.

Galvanized iron spikes with round heads may be used in very heavy planking in conjunction with through bolts. One or two spikes and one bolt are introduced in each plank at every frame. The spikes should be driven in holes drilled slightly smaller than the spike and the [illegible]ke shank may be "ragged" or roug[illegible]o reduce the tendency to w[illegible] out. Planks up to eight inches wide have two fastenings per frame. Those more than eight inches wide have three.

The butt joints of hull planks should be between frames and butt blocks are fitted between the frames at the plank ends. The plank ends should be through fastened to the butt blocks and butt joints should be widely placed in neighboring planks, to prevent loss of strength in the hull structure.

Hull Plating

The various methods of fitting hull plating to the frames are shown in Figure 68 (a to f). The "in and out" system of plating (Figure 68 a and b) is perhaps the most common, the longitudinal seams being lapped as shown necessitate that the plates be fitted in this manner. The frames may be joggled so that the shell flanges fit over the staggered shell plates (a). If the frames are bent to a fair curve liners must be fitted between their shell flanges and the outer hull plates (b).

Joggled hull plates (c) avoid the use of shell liners with "faired" frames. Clinker plates (d) are not extensively used but it is necessary to employ this system at the vessel's ends when "stealers" which will be taken up shortly, are introduced.

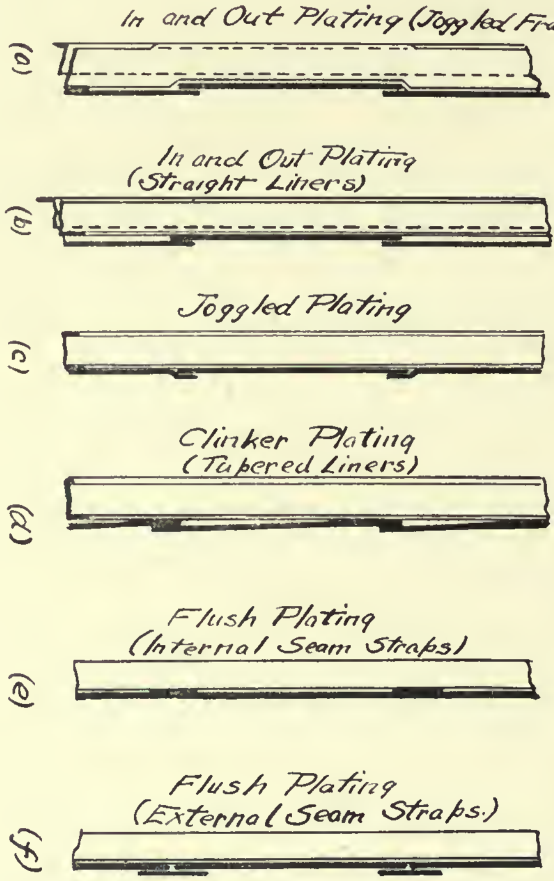


FIG. 68-A—METHODS OF FITTING HULL PLATING TO FRAMES

Flush plating (e and f) is not commonly employed. Yachts and other vessels where the appearance of plate seams would be undersirable, are built as in (e).

The lowest "strake" of plating next to the keel, is the garboard strake and is sometimes thicker than the other bottom plating. It is edge lapped to plate keels and flanged to bar keels.

The uppermost continuous hull plate against which the upper deck stringer is fastened, is the "sheer-strake." It is heavier than the lower side plating and extends above the deck to a height permitting two rows of rivets in the sheer strake butt joints to be above the stringer angle. In large vessels the strake of plating below the sheer strake is made heavier than the remainder of the hull side plating to the upper turn of bilge. Ordinarily the side plates from sheer strake to bilge are of one weight and the bottom plates from the garboard strake to the bilge are of one weight, slightly heavier than the side plating.

Since the greatest tensile and compressive stresses are amidships, the plating at bow and stern may be lighter than that for a distance of one-fourth the vessel's length on each side of the midship section. Where severe local stresses are encountered due to panting at the bow and around the propeller bossing at the stern, the hull plating is made the same thickness as amidships on the same strake.

If the vessel is to operate in heavy ice floes doubling plates are fitted at the bow near the water plane. Doubling plates are also introduced where openings in the hull entail loss of strength, such as at large ports or sea suction and discharge orifices for machinery piping connections. At the points where long bridges, forecastles and poops end, diagonal doubling plates are fitted to prevent weakness arising from the sudden loss of material in the cross section of the hull.

Where the girthed section of the hull is so reduced at the bow and stern that the number of plating strakes fitted amidships would become very narrow, stealer plates are introduced to replace two strakes (Figure 68-g).

Laying Out the Hull Plates

The laying out and ordering of hull plates is done by arranging the stock widths as obtained from the plate tables of the steel company, on the girth of the midship section. Care must be taken to include the width of lapped joints in the width of strakes. It is undesirable to rivet more than two thicknesses of metal together because of the difficulty in making tight rivet connections. For this reason the shell angles of keelsons, tank margins, stringers or other longitudinal framing should be located between the longitudinal seams of the hull plating.

If the vessel has a flat bottom and sides, the plating can be ordered from a drawing called the "shell expansion." This drawing is made by "expanding" the transverse frames at their proper position on the vessel's length and drawing in all frames (transverse and longitudinal), decks, keelsons, stringers, bulkheads, margin angles of double bottoms, bilge keels, side fender angles, etc. For the length of the parallel middle body the bottom plates are then drawn in with their edges parallel to the center of keel and having the width at the midship section. The side plates are drawn in parallel to the expanded sheer line in the same way. The girthed frames beyond the parallel middle body are divided into the number of equal parts in which there are plates on the midship section, and fair lines representing the center line of longitudinal plate laps are drawn through the points of division. Stealer plates as necessary are introduced at the extreme ends.

The above shell expansion cannot be applied in ordinary plates for vessels having the usual shipshaped hull, because such a hull has a "warped surface" which means that it cannot be "expanded" or rolled out onto a plane. Plates for these vessels are ordered from a model on which the shell has been laid out just as it would appear when fitted in place.

The longitudinal seams of hull plating are single riveted in small vessels, double riveted in medium sized ones and treble riveted in largest ones. Butt joints of hull plates are double, treble or quadruple riveted. At one quarter of the vessel's length, from the bow and stern, the shearing stresses in the hull plating are maximum, so that in large vessels it is common to introduce an additional row of rivets in the hull seams at these localities.

The size and spacing of rivets is given in riveting rules published by the American Bureau of Shipping.

Hull rivets usually have countersunk points on the outside, the rivet filling the hole in the plate and being slightly convex. The countersinking extends nearly through the plate. All rivet holes should be punched from the faying surface and slightly smaller than the rivet diameter. The holes should then be reamed to proper size for the rivet, the reaming removing the weakened steel immediately around the punched hole. No holes in curved or furnaced plates at the bilge or the stern should be punched. These holes are drilled after the plate has been fitted to the hull. Where two thicknesses of plating are riveted together, the size of rivet should be governed by the thicker plate.

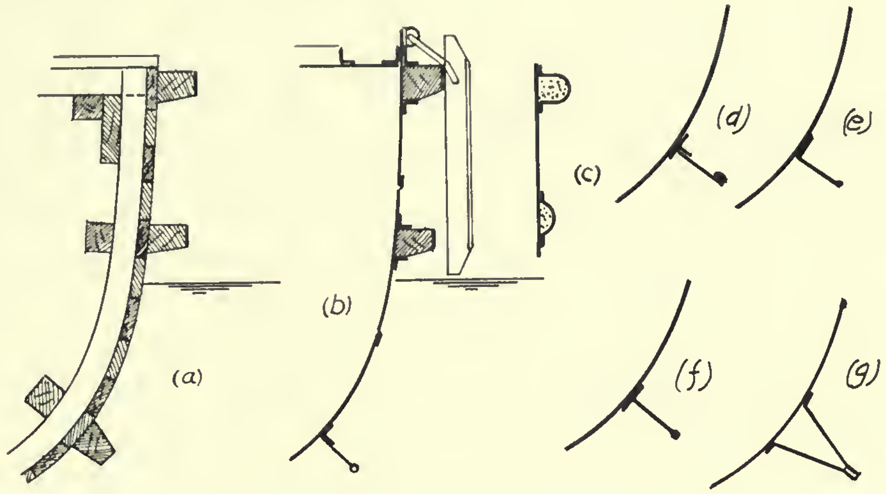


FIG. 69—CONSTRUCTION OF FENDERS AND BILGE KEELS

Fenders

All harbor vessels should be fitted with side fenders to protect the hull when rubbing against docks or other vessels. These fenders are constructed of heavy wood securely bolted to the hull structure and having a flat or oval facing strip of metal which is spiked to the fender logs with round spikes having countersunk heads. The number of fenders varies with the freeboard and they are usually from three to six feet apart.

The upper fender is at or near the upper deck and follows this deck from stem to stern. The lower fender is near the water line at the lowest point of sheer and is usually parallel to the upper fender over that portion of the hull which is vertical or nearly so. The lower fender is not necessary at the bow or stern where the sides overhang to such a degree as to render it superfluous.

Tugs are an exception to this rule since they have the lower fender running to the bow with sometimes an additional bow fender. Tugs also have the space between the upper and lower fenders filled with wood as in Figure (69-a). This minimizes the likelihood of damaging the hull if the fender on a vessel alongside is between those on the tug. This crude precaution is improved upon by "swinging" fenders of hard wood which are suspended from pad eyes as in (Figure 69-b). When not in use these fenders are swung up on the deck to reduce the resistance which would be considerable if their ends dragged in the water. Fenders of steel with hollow half round section may be riveted to the hull (Figure 69-c). The space between these steel fenders and the hull may be empty or filled with cement.

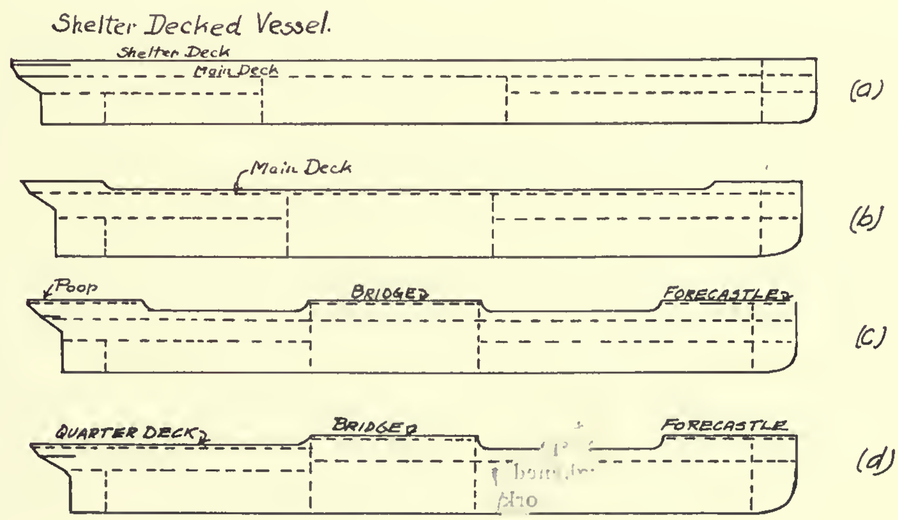


FIG. 70—HOW DECKS ARE CLASSIFIED

The degree and period of rolling in a seaway may be considerably reduced by "bilge keels" which serve as a paddle surface in the direction of roll. The further these bilge keels are located from the center about which the vessel rolls, the greater will be their effect. Care must be observed that they are far enough under the bilge curve not to project beyond the vertical hull sides and thus strike docks, etc. They must also be far enough up on the bilge so that their outer edge is not below the line of the vessel's bottom. These considerations limit the width of bilge keels, whose construction is shown in cross section by Figures 69 a-b-d-e-f and g. These keels are located at the middle of the vessel's length and lie in a diagonal plane. They should coincide with the flow of the stream lines so that they do not introduce resistance to propulsion. Usually it is satisfactory to place the bilge keel in the plane of a bilge diagonal. Their length is from one-third to one-half that of the vessel and the ends should be faired into the hull surface by a curve which gradually reduces their width.

Sometimes bilge keels carry away (are torn loose) in heavy weather or by striking a submerged obstacle. For this reason they are attached to steel hulls with tapped rivets so that no serious leakage will occur in this event. If the bilge keels are formed of a plate attached to angles or tee bars, the rivet connections to the hull are stronger than those between the bilge keel plate and the connecting bar so that if the plate is torn off the hull rivets will hold the structural bar.

Wooden bilge keels and fenders are usually through bolted to the vessel's frame and sometimes to clamps, stringers and bilge keelsons. (Fig. 69-a).

Steel fenders and bilge keels are riveted to the shell plating and may be of a single bulb angle or tee angle (Figure 69 e and f). They may be formed of a bulb plate connected to the hull by single or double angles or a tee bar (Figure 69 b and d). Sometimes a plane plate is employed, the outer edge of which is re-enforced with a steel half round bar on one or both sides (Figure 69-d). Large vessels have bilge keels formed of two flanged plates with a stiffening bar at their outer edge and the space between the plates filled with yellow pine in pitch or with cement (Figures 69-g).

Decks may be classified according to their location as those in the hull proper and those in the superstructure above the hull. Their number varies from one in small vessels, to eight in the largest. The names of decks vary with their location and the purpose which they serve, there never having been a standardization of the terms applied. It is becoming popular to letter or number them in order, from the topmost down or the reverse. The confusion in naming decks forming a part of the hull has not been as serious as that concerning those in the superstructure.

Hull decks contribute structural strength to the vessel, while superstructure decks are merely light platforms or shelters.

If the vessel's sheer line is continuous from bow to stern, the upper hull deck is made watertight except inside of deck houses which may be built upon it. This upper deck is usually the most strongly constructed of them all (Figure 70-b). When the continuous upper deck is not the main strength deck, the next deck below it constitutes the top of the hull proper. Then the hull sides between the second or "main" deck are lightened and merely serve as a shelter to the space between these two decks. Such a lightened upper deck is a "shelter," "shade," or "awning" deck and is found in vessels carrying cargo above the main deck. The freeboard of such vessels is considered from the second or main deck to the water plane (Figure 70-a).

Cargo vessels often have "deck erections" (Figure 70-c) where the hull sides are extended above the main deck to produce a "forecastle," "poop" or "bridge." If these erections (sometimes called islands), are short, they do not assume the stresses set up in the hull by hogging or sagging on the waves, being therefore of relatively light construction. When longer than one-tenth of the hull length, however, it is necessary to strengthen their construction since the hull stresses are transmitted to their structure. The depressed spaces on the main deck included between the poop, bridge and forecastle, are termed "wells."

Poop decks are sometimes only half of the normal deck height of eight feet above the main deck. Such lowered poops (Figure 70-d) are called quarter decks.

CHAPTER XI

Decks for Wood and Steel Boats

ALL decks exposed to the weather should be properly drained and should afford a foothold when wet. The first of these results is obtained by fitting drainage pipes or "scuppers" in gutters or "waterways" around the deck margin and by the introduction of large openings or "freeing ports" in the bulwarks if the vessel has these.

Rounding decks up athwartships is frequently resorted to for drainage purposes. The round up (called "camber" or "crown" of the deck) is a measure of the deck height at the center line above the level at the ship's side and a customary determination thereof is one-quarter inch per foot of deck width at each point in the length. The deck is then arched to the arc of a circle which passes through the points at each side of the deck and the raised point on the vessel's center line. (Fig. 71-a.)

Instead of this rounded form, the decks may be sloped on each side of the center line where a circle joining the sloped sides eliminates the sharp ridge which would otherwise appear. (Fig. 71-b.)

Since a vessel is very seldom on an "even keel" that is perfectly upright, and because even with cambered decks the water does not drain well when the vessel is listed, the decks may be perfectly flat athwartships. (Fig. 71-c.) This avoids the expense of sawing or bending wooden or steel deck beams and affords a deck which is satisfactory for all practical purposes.

"Sheer" is the upward curve of the decks at the bow and stern of a vessel and is common to most vessels. The lowest point of the curve showing the deck elevation is called the "lowest point of sheer" and is located amidships or else between the midship section and the stern. (Fig. 71-d.) The heights of the forward and after deck ends above the lowest point of sheer are called the "rise of sheer forward" and "rise of sheer aft," respectively. The rise of sheer is greater at the bow than at the stern, while the degree of sheer is greater in small than in large vessels. The lowest point of sheer is usually between the midship section and the stern.

How Sheer Is Determined

Amount of sheer is arbitrarily determined and is governed by

(a) The type of vessel

(b) The appearance

Given a certain depth of hold it is apparent that the raised forward and after deck will result in greater freeboard, so that the decks will be relatively dryer in rough water. Double ended vessels such as ferry boats have a "reversed sheer," i. e., the deck is higher amidships than at the ends.

Straight sheer lines (Fig. 71-e and f) are becoming very common in vessel design. The principal advantages are (a) simplicity of construction, (b) increased depth of hold amidships for a given freeboard at the bow and the stern. Naval vessels, power yachts and the famous English "turret deck" ships first employed straight sheers.

There are three methods of adapting this design to vessels. The first is applicable to small vessels operating in choppy water where more freeboard is needed forward than aft. The deck is pitched as in (Fig. 71-e) and the degree of rise varies from one foot for every 25 feet of length, down to one foot in 50 feet of length. The larger pitch applies to shorter vessels.

If the profile of the vessel with sheer lines the deck is horizontal (Fig. 71-f) and a forecastle is constructed at the bow. This forecastle may be from 18 inches to eight feet above the main deck. The low forecastles are used in small boats and the ones of maximum height in larger vessels.

If the profile of the vessel with straight sheer appear inferior to that with curved, the bulwark rail may be curved as in (Fig. 71-g) and the deck made straight.

Wooden Decks

Wooden decks are most frequently employed in all types of vessels, mainly because of the good foothold which they afford when wet. In many steel vessels the weather deck is of wood and decks in the hold are of steel either bare or covered with a suitable material.

The thickness of deck planking and method of its installation depend upon the deck where fitted. If the deck is a part of the hull and contributes to the vessel's strength, and if the traffic on the deck is heavy so that excessive wear in the deck planking may be expected, the planks are made from two to four inches thick. The width of deck planks varies from 2½ to 6 inches.

All decking should be laid with the grain of the wood vertical and wherever planks rest on beams, plates or other structural members, the bearing surfaces should be painted before the planks are laid. The plank seams may be straightened parallel to the longitudinal center line of the deck, or they may be curved parallel to the side of the deck.

The outer boundary of deck planking is fitted with a wide "margin plank" against which the deck planks are butted with "nibbed" ends at the bow and stern or where curved deck openings cut the plank seams at an acute angle. (Fig. 72-a and b.) Planks laid parallel to the deck side have a wide "king plank" on the center line against which the plank ends are nibbed over wooden butt blocks fitted underneath.

Material Used for Decks

Yellow pine, white pine, teak, mahogany, oak or fir are the woods used for decking. Of these the pines and fir are most general in commercial vessels. Oak is sometimes used for margin or king planks. Teak and mahogany are employed in yacht work.

The lumber should be close grained, free from knots, checks and other defects and well seasoned. Planks should be planed smooth on all four sides, the vertical edges being slightly bevelled to allow for calking.

Planks up to 1½ inch thick may be blind nailed or screwed to the wooden deck beams, screw heads being countersunk and plugged with wood. Light wooden decks on steel beams or

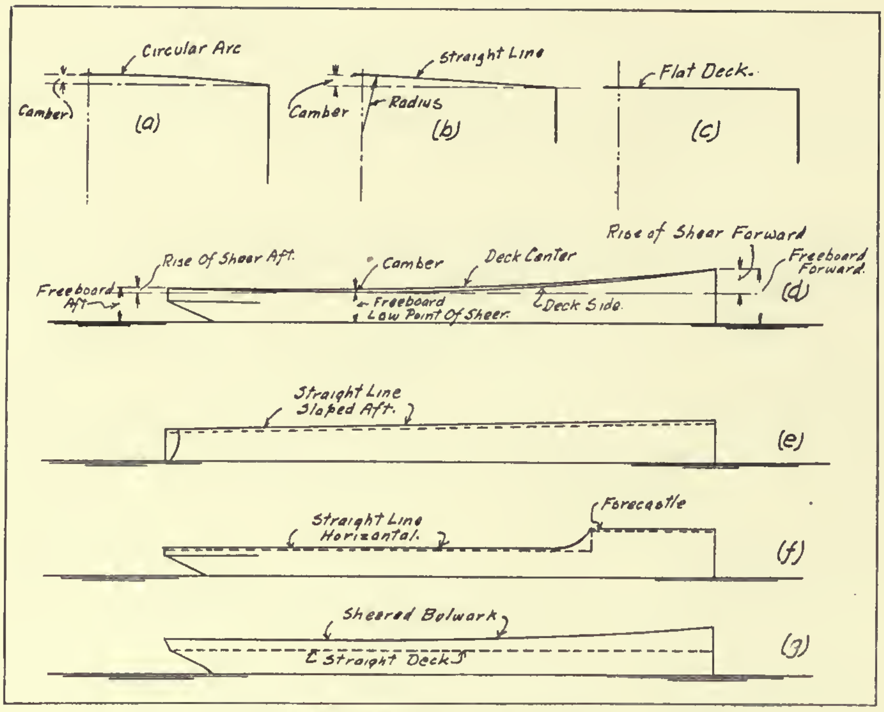


FIG. 71—DRAWINGS SHOWING CONTOUR OF DECKS AND SHEER

plating should have wooden nailing strips bolted to the beams under the planking.

Decks from two to four inches have carriage bolts (round headed) countersunk in the planking with the nut under the beam. A cotton thread dipped in white lead is fitted as a ring under these bolt heads and is called a "grommet." Deck plugs over bolt heads should have their grain parallel to that of the planking and be dipped in white or red lead.

Planks from 1¼ inch up to 4 inches thick have the seams calked with from one to three threads of cotton or oakum, after which the seams are filled (payed) with pitch or seam cement. The deck surface is then planed and sandpapered smooth.

Planks on weather decks less than 1¼ inch thick are of tongue and grooved material over which canvas (No. 6 or No. 8) is tacked on thick paint, marine glue or felt. The canvas must be tightly stretched before tacking with galvanized or copper tacks and is finally given three coats of lead paint, the final coat being buff, gray or other approved color.

Fig. 73 (a to h) shows wooden deck construction, (a) to (d) being for superstructure decks, (e) and (f) for main decks, (g) and (h) for lower decks and cockpit floors respectively.

The superstructure deck planking is laid on beams spaced from 15 to 20 inches apart and resting on the house cap log as shown. The inner house sheathing or panelling extends between the beams, filling blocks being fitted in the space over the cap log. Lead sheets are tacked on; the canvas under all deck fittings, or wooden blocks may be substituted to protect the canvas and prevent cutting it with the sharp base of the metal filling. Scuppers are located to drain these decks.

Main decks (Fig. 73-e and f) in wooden vessels have extra heavy beams, particularly in tugs or other vessels which must withstand side crushing. These beams are from 18 to 24 inches apart and their attachments have been discussed under stanchions, clamps, shelves and knees. These decks are always calked watertight.

Lower decks (Fig. 73-g) are watertight in living spaces but not in cargo holds. When such lower decks are very short platforms, they are called "flats" and may be fitted locally over hold beams or built up as separate structures on suitable stanchions, carlings and beams only partly across the hold. Flats in the engine room may have gratings or corrugated plating substituted for the wood planking, or sheet copper hammered rough may serve to protect the wood against the damage due to placing heavy machinery parts on the flat when conducting repairs. Copper is not recommended because of the slippery surface caused by grease.

Linoleum Is Good Covering

Linoleum forms an excellent covering for hold decks in living quarters since it is warm, easily cleaned and neat appearing. It varies in thickness (good quality Navy) from ⅛ inch to ¼ inch and should be carefully laid at a temperature of about 70 degrees. In unrolling cold linoleum cracks will develop. The linoleum should be rolled out flat in the compartments where fitted and be allowed to lie unfastened for several days. After this it may be cemented or nailed to the deck (steel or wood) and no bulges will develop. All hatches or other deck openings in the linoleum should be fitted with sheet brass bounding strips at least ¾ inch wide.

The decks in galleys, toilets and lamp rooms should be cemented and are usually tiled. In wooden vessels the deck planks are first covered with watertight sheet zinc or lead which is flashed up the bulkheads to a height of 6 inches. Then from ¾ inch to 1¼ inch of neat cement mortar is placed on the metal and finally the nonporous or glazed tiling is placed on the cement. The tile is hammered down level by striking a plank laid thereon and a thin grouting or cement wash is applied to fill the cracks between the tile. It is well to use rounded tile in the edges formed at the bulkheads and to carry the tile

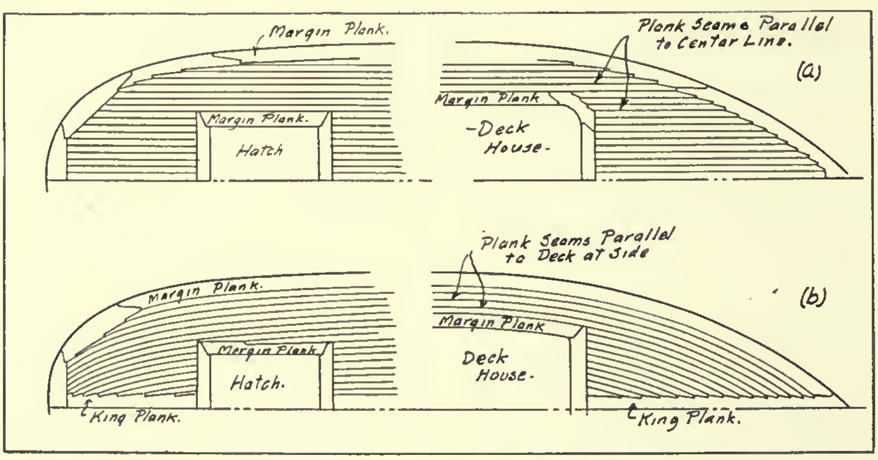


FIG. 72—METHODS OF LAYING DECK PLANKS

up the bulkheads. This permits washing down the deck. Drainage scuppers should always be installed in cemented or tiled spaces.

Cockpit floors (Fig. 73-h) are below the level of the main deck and are not usually fitted in vessels more than 65 feet long. They should always be at least six inches above the load water line so that the sea water can drain freely through scuppers if waves should be shipped. Such cockpits are termed "self bailing." Sometimes ball or flap check valves are fitted in the scupper pipes and these prevent the sea water from flooding the cockpit by washing back through the drain pipes. A watertight base board is installed all around the edges of cockpit floors to a height of from six to twelve inches, while tongue and groove vertical ceiling sheaths the sides of cockpits up to the main deck. A deep coaming extends all around the cockpit at the main deck. (Fig. 59-c.)

Decks—Steel Vessels

Steel vessels' decks may be wooden planking on steel beams, steel plating on steel beams or composition cement material on light steel plating. In (Fig. 74-a to c) the construction of superstructure decks and decks on house tops are shown. (a) is house top with tongue and groove planks nailed to wooden battens which are fitted in the bosom of the steel beam angles. These angles have their horizontal flanges at their lower edges and are riveted to margin plates around the upper deck house and coaming. The wooden beam strips are side bolted to the vertical steel beam flange with countersunk bolts. The house top overhangs the side and end house bulkheads and a continuous molding angle is clipped to the overhung beam ends. A margin plank extends around the deck edge and the canvas covering is lead flashed to it. The scuppers are close against the margin plank and their pipes pass through the overhang to the deck below.

Fig. 74-(b) shows a house top which overhangs to the vessel's side, forming a shelter to the deck below. The beams of the lower deck house are similar to those in 74-(a) and terminate in a steel stringer plate which is riveted through a stringer angle to a sheer plate. Stanchions of pipe, solid round bars, angles or other structural steel shapes support this marginal deck girder from the deck below. Three alternative constructions of the margin girder are shown.

Fig. 74-(c) is a steel house top with light plating joggled over steel beams and riveted to them. The plating is 7.6 pounds to 10.2 pounds per square foot (3/16 inch to ¼ inch) in small vessels such as tugs and has an overhang formed by two angle bars as shown or by a channel (Fig. 74-d). Sometimes no overhang is introduced, the house margin being plain as in Fig. 74-(1) or having the house side plating extended up to form a waterway. (Fig. 74-m.) The house top plating in large vessels may be covered with wood planking or a composition deck cement (Fig. 74-e). Half round steel molding bars are usually riveted at deck edges for appearances as shown in the figures.

Hull decks exposed to the weather in steel vessels are more strongly built than the superstructure decks. They may be composed of steel beams partially plated over and covered with wood planking; of steel beams covered with steel plating; or of steel beams covered with light plating on which a cement or bituminous compound is laid as a substitute for wood.

Decks planked with wood may have their beams fitted on alternate frames, the timber being stiff enough to support itself over the intervening span with ordinary loads. Steel plated or cemented decks should have beams on every frame.

A wide heavy "stringer plate" forms a marginal girder for all decks in steel vessels and is connected to the shell plating by a continuous stringer angle (Fig. 74 (f) and (g).) In lower decks where the frames pass up through the stringer plate, the continuous stringer angle is fitted inside the frames and riveted to the reverse frame or to a clip on the frames if these are of bulb angle. (Fig. 74-h.) Intercostal clips join the edge of such stringer plates to the shell plating and the space between frames outside of the continuous stringer angle is filled with a

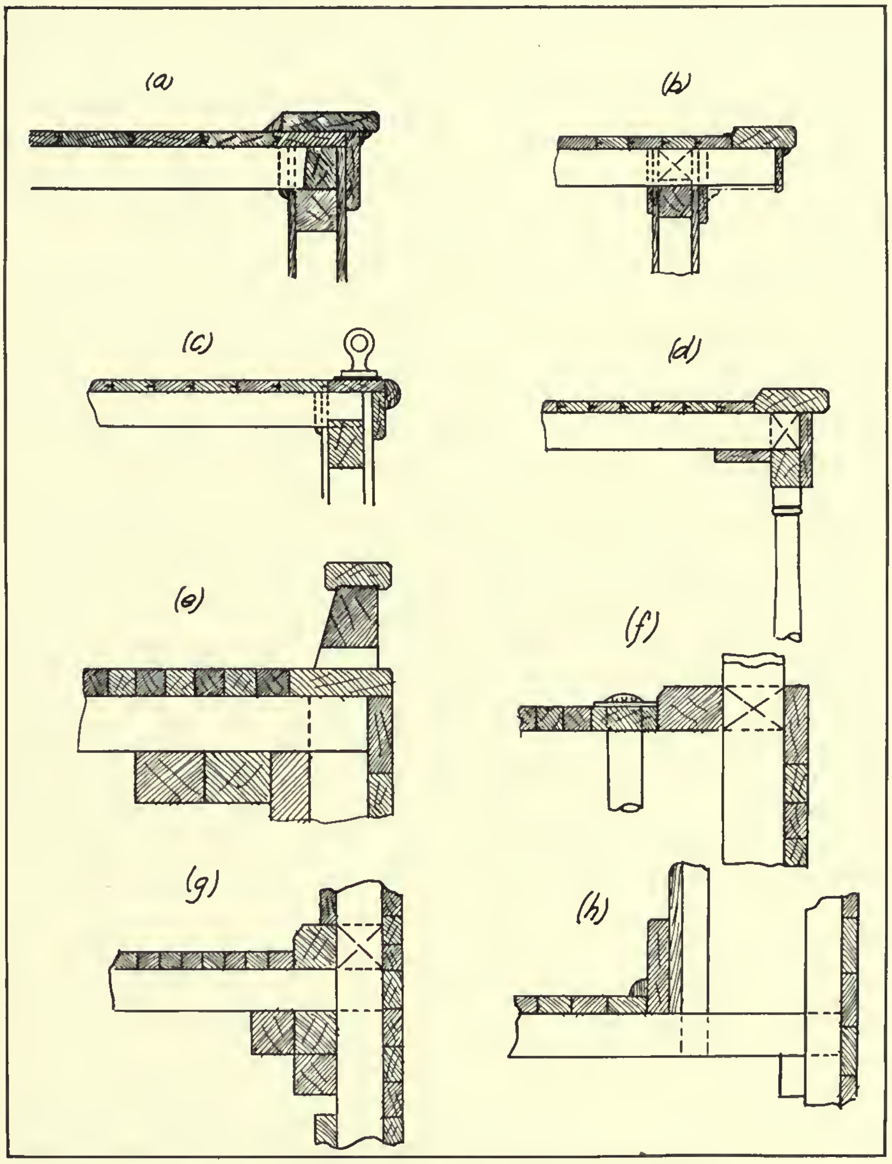


FIG. 73—CROSS-SECTION OF WOODEN DECK CONSTRUCTION

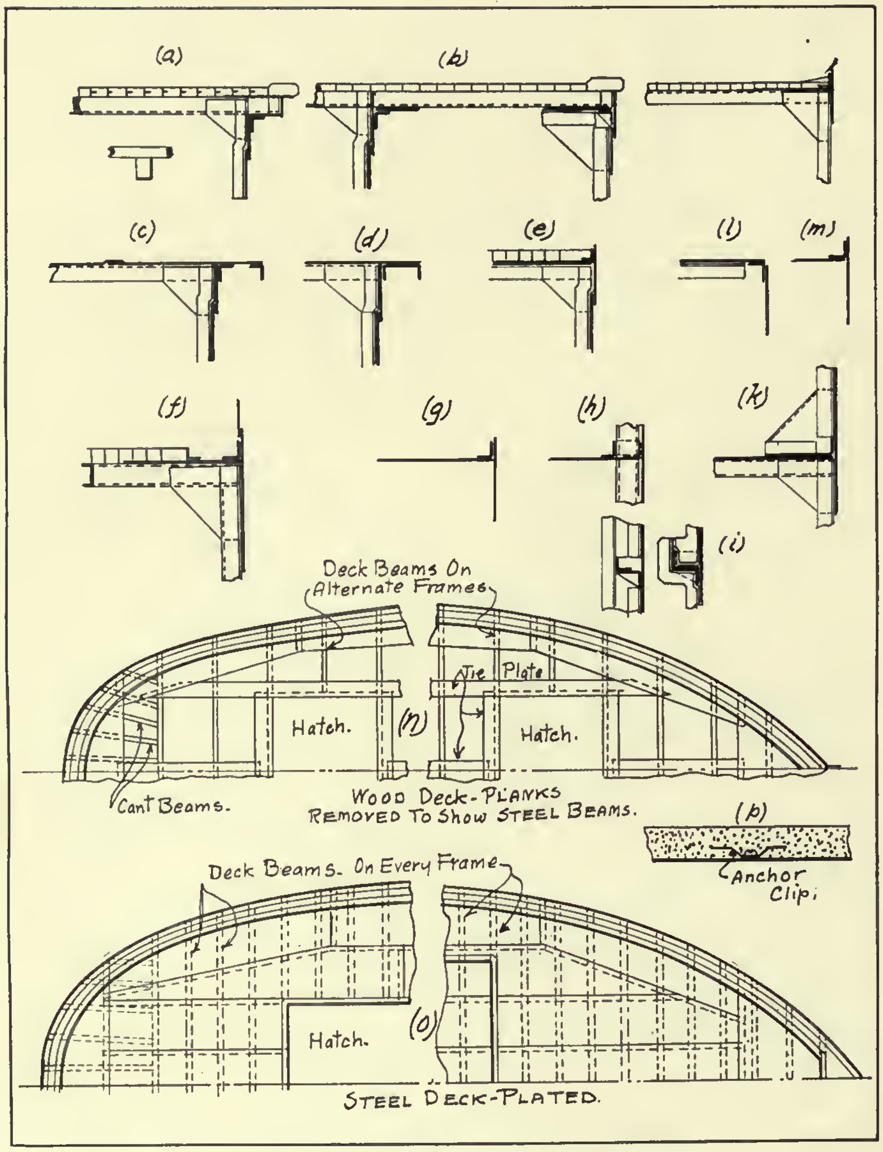


FIG. 74—CONSTRUCTION OF DECKS OF STEEL VESSELS

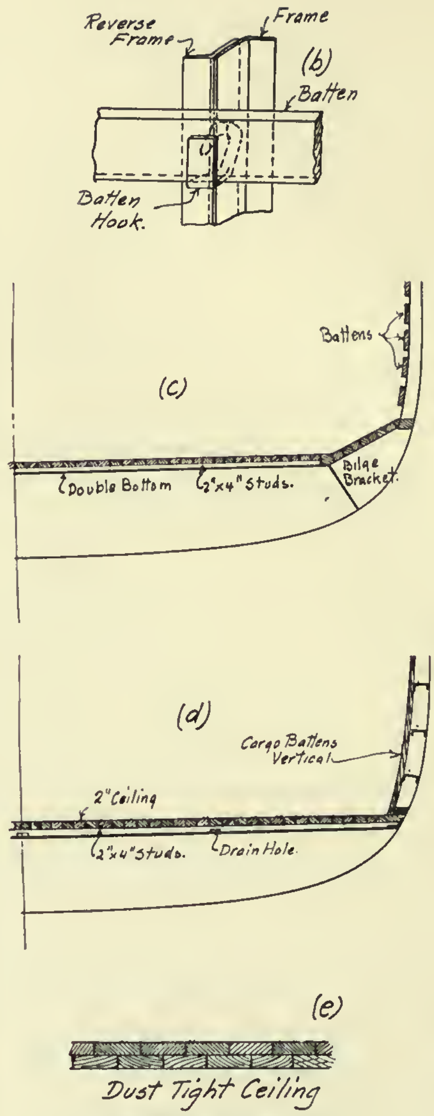


FIG. 75—CONSTRUCTION OF CEILINGS AND DOUBLE BOTTOMS

wood block, cement or a forged or a cast shoe of angle section.

Tie plates from six to eight inches wide are fitted under the deck planking and serve to connect the deck sides and ends. Margin plates are fitted around all deck openings to take the planking ends and to re-enforce the locally weakened structure. (Fig. 74-n.) The deck planks are cut to fit over all deck plates and are bolted to the deck beams as in the case of wooden vessels.

Covering for Steel Decks

A waterway angle (Fig. 74-f and n) is fitted from 9 to 12 inches inboard of the stringer angle against the margin plank or the composition deck covering. The object of fitting planking or other deck covering over steel decks is to afford a secure foothold when the decks are wet.

Asphalt cement mortar or numerous patent compositions may be substituted for planking. If asphalt is used it should be specified to the consistency employed in the street paving of cities in the locality in which the vessel is to operate. This will insure good wear and provide against undue softening in warm weather.

Bonding clips of flat metal are bolted or spot welded to the deck plating before putting on the deck covering (Fig. 74-p). The thickness of composition deck covering is from one to two and one-half inches.

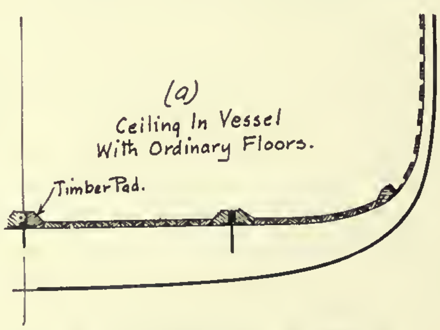


FIG. 75—CONSTRUCTION OF CEILINGS

Steel weather decks are sanded while the paint is wet to provide a footing.

Watertight lower decks are fitted over deep tank tops and are completely plated over with steel beams on every frame. Where side deck margins butt against the hull plating or steel bulkheads pass through them, it is necessary to fit a continuous stapled margin angle around the frames and the bulkhead stiffeners (Fig. 74-i). It may be necessary, particularly if the hull has a slope as at the stern, to cut the frames or the bulkhead stiffeners and bracket them above and below the deck (Fig. 74-k). In this case a continuous margin angle passes all around the deck and the frame; brackets are cut to clear this angle. These brackets are at least three times the depth of the frame or stiffener angles to which they are fastened and have their inner edges flanged.

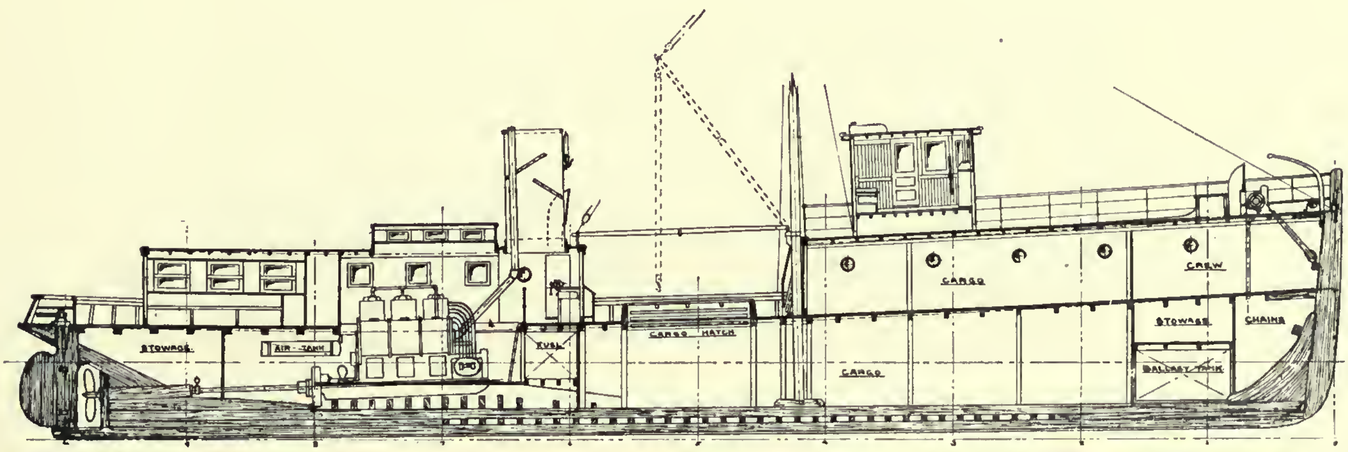
All steel deck beams except those

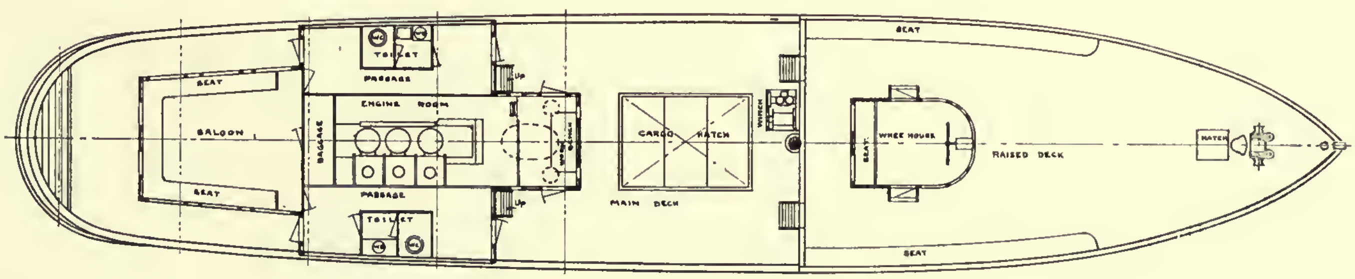
abaft the transom (in overhung sterns) extend athwartships. The beam at the frame to which the sternpost is connected is called the transom beam. Aft of this the beams radiate (Fig. 74-n and o) to coincide with the cant frames previously described. These "cant beams" are bracketed to the transom beam and to the cant frames.

In cargo holds it is necessary to prevent package freight or bulk solids from getting between the vertical floors and keelsons of the ship's bottom. This is done by building a wooden platform called a "ceiling" on the floor tops (Fig. 75-a). Ceiling timbers are framed together in sections which can be removed for inspecting, cleaning or painting the bilges. The planks do not contribute strength in steel vessels and are about two inches thick. If dry bulk cargo such as grain or coal is carried, the ceiling should be "dust tight" by building it of two thicknesses of one inch planks with the seams staggered. Where keelsoms project above the floor tops in single bottomed vessels, it is necessary to fit padding timbers to protect the structure and cargo from damage.

Ceiling on double bottoms is raised some two inches above the inner bottom plates by "sleepers" of 2 x 4 timbers which extend athwartships and are spaced about four feet apart. This is to permit moisture on the inner bottom to drain the bilges without damaging the cargo. Filling timbers are fitted between the frames where the ceiling joins the hull sides and "cargo battens" are installed inside the vertical side framing and on the bulkhead stiffeners in package or miscellaneous cargo holds. These battens may be in built up sections bolted to the reverse frames, in single strips bolted to the reverse frames or in single strips supported by "batten hooks" (Fig. 75-b). Cargo battens in steel ships longitudinally framed are fitted vertically (Fig. 75-d). The battens are usually 1½ x 4-inch timbers spaced about 6 inches on centers.

Large wooden vessels have permanent ceiling inside the frames. Tank vessels have no ceiling, the liquid cargo occupying all the spaces between the framing.





ONE OF THE FAMOUS "ARK MODEL" FISHING BOATS BUILT AND OPERATED BY THE SOUTHWEST FISH COMPANY OF VERMILION, OHIO

CHAPTER XII

Constructing the Deck House

DECK houses are usually fitted above the hull proper to provide living or operating accommodations. They are usually of wood in wooden vessels and of wood or of steel in steel vessels. The structure is made as light as possible without being too weak to withstand the rough seas or to support other houses, lifeboats, etc., which may be above them. This light construction is in order not to raise the vessel's center of gravity by the presence of excessive topside weights, for if made too heavy, especially in small vessels with large deck erections, the vessel would be rendered unstable.

The house tops usually follow the sheer line of the upper hull deck, being sheered and cambered or straight and flat as previously described under "decks." The forward end of deck houses are sometimes perpendicular to the sheer line at that point or else they are at an angle half way between a vertical line and one perpendicular to the sheer at the point where their lower edge strikes the deck (Fig. 76-a). The after ends of deck houses are usually vertical. For structural simplicity, particularly with straight sheers, the forward and after deck house ends may be square to the deck. Another reason for this will be discussed under "doors and windows."

Deck Houses Generally Rounded

In plan view the forward and after deck house ends may be straight across the deck and joined to the house sides with a radius of from nine to eighteen inches. This is nearly always done at the after end, but the forward end, particularly of pilot houses is more often rounded. In lower deck houses the rounded forward end is laid in by taking a radius equal to the forward width of the deck house. An arc is drawn with this radius, its center being on the vessel's longitudinal center line. This arc is then joined to the house sides by one equal to one-quarter or one-third of the forward house width. Pilot house fronts may also be drawn in this way or by a semi-circle whose diameter is the width of the pilot house. No gain is experienced by rounded house ends particularly in low speed vessels, and it is becoming customary to make the house front straight with rounded corners. This affords more room in the house and simplifies construction.

Deck house sides may be parallel to the upper hull deck side, at a distance in from the rail sufficient to afford a passageway beside the house. This passage is from 18 inches to 24 inches wide in small boats and up to five or six feet in large boats. Sometimes the house side is straight and parallel to the longitudinal center line, but unless the vessel has a long middle body, care must be taken not to reduce the interior house room too greatly. It may be possible to build the forward house sides straight and parallel, tapering the after sides to keep the outside passage at nearly a constant width.

Height of Deck Houses

The usual height of deck houses, measured from the top of the planking under foot to the top of the planking overhead, is from seven to eight feet. Sometimes in shallow draft river vessels the height is more than this, as much as 10 or 12 feet. Pilot houses are usually higher than other deck houses which may be abaft them on the same deck. This permits of placing transom windows in the after end of the pilot house above the top of the other deck houses, so the helmsman can see astern. Pilot house floors are raised above the normal deck level to enable the wheelman to see through these windows and close down over the bow.

Small boats may not have sufficient depth of hold to permit the machinery to be entirely below the upper hull deck. In this case head room and ventilation are obtained by building a low deck house or "trunk" whose height is from two to four feet above the upper hull deck.

The length and width of deck house in a given boat is determined by the accommodations it must enclose as well as the external deck arrangement which is influenced by the service which the vessel is to engage in. For example, although a certain number of staterooms, galley, messroom, upper engine room and toilet spaces could be placed in one deck house on the upper deck, there must be a passage outside the house on each side of the vessel, or a large hatch may be required on the forward deck. These factors will limit the width and forward ending of the house.

Then perhaps a mast with a heavy boom and hoisting winch may be needed forward, further affecting the forward end of the house. If the vessel is to tow astern, heavy towing bitts must be placed on deck behind the deck house. These bitts should be located as far forward of the stern as possible to permit of easy steering while towing. This will affect the after end of the deck house.

Wooden Deck Houses

Figure 76-d is a cross sectional elevation of a typical wooden deck house side. The lower coaming or "sill" is of heavy timber and is securely bolted on top of the deck planking, the bolts passing through the beams of the deck below. A stopwater of flannel dipped in thick white lead should fit between the sill log and the deck planking to prevent leakage under the house sides into the cabin. In Fig. 76-e the house is a trunk built over a deck opening and the sill is bolted directly to the carling which supports the cut beam ends. Here the deck planking is fitted close beside the outer edge of the sill and the seam thus formed is calked in the same way as for the other deck seams.

A frame work of vertical stanchions is erected on the sill. These stanchions are from two to four inches molded and usually four-inch sided, having their lower ends notched into the sill and their upper ends into the "cap" or upper coaming timber. The vertical stanchions are spaced from two to three feet apart. At the height of the window sills, it is common to fit horizontal strut timbers between stanchions and

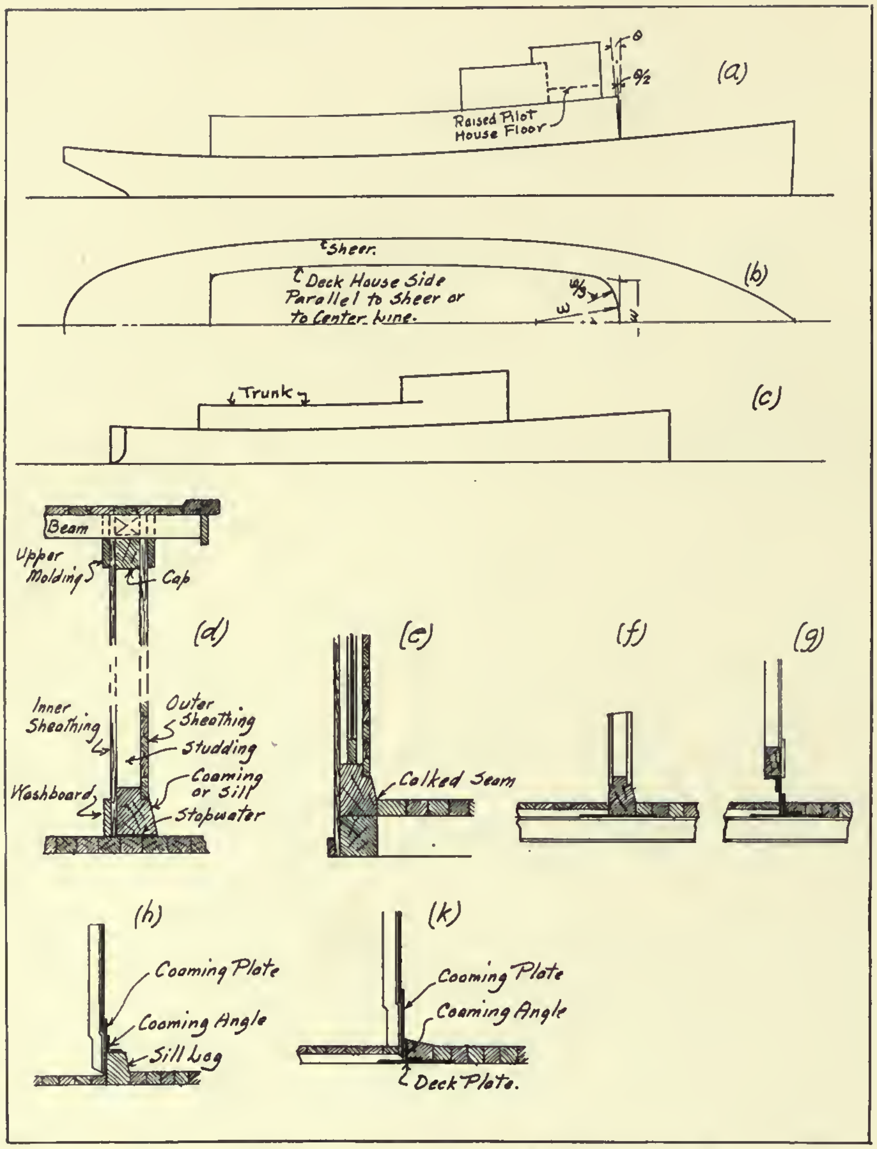


FIG. 76—CONTOUR AND CONSTRUCTION OF WOODEN DECK HOUSES

sometimes diagonal brace logs are built into the house framing.

The cap is above the tops of window frames and may be under the house top beams with filling blocks between them, or may be at the ends of the beams. Various wood house tops have been considered under "decks" in Chapter XI.

Long steel holding down bolts are passed from the upper side of the cap to the under side of the beams or carlings on the deck below. These rods are from ½-inch to ¾-inch in diameter with nuts over washers on their upper and lower ends. The rod spacing is from six to eight feet and they should be located close to a heavy stanchion so that when tightened up they will not cause a spring in the cap or carling.

How Sheathing is Fastened

Deck house sheathing is fastened outside and also usually inside of the framing. The material used in commercial vessels is usually pine although mahogany or other hard woods are still employed in yachts, especially for the inside sheathing. Formerly the sheathing was panelled, but it is now usually of tongue and grooved planks.

The outside sheathing is from ⅝-inch to ⅞-inch thick, the planks run horizontally and the whole is usually painted a light color. A half round molding may be fitted at the level of the window sills.

Inside sheathing is panelled in passenger vessels but it is becoming more usual to make it of V chamfered tongue and groove planks built in vertically. The thickness of inside sheathing is from ⅜-inch to ⅝-inch and the finish is natural wood or stained. A "wash board" or lower molding plank from four to six inches high and ½-inch thick extends around the inside of deck house sheathing and partition bulkheads as in Fig. 76-d. A similar upper molding, notched around the beams is often fitted. Sometimes a quarter round molding strip is substituted for this upper molding.

Care should be taken that the seams of inner and outer sheathing planks are parallel to the edges of doors and windows. All sheathing should be blind nailed to the studdings and hammer marks should not show.

The deck overhead in a deck house is sometimes panelled but only in saloons of passenger boats. Usually it is sufficient to finish the under side of the house top planking in a smooth and neat manner. Deck beams are sometimes boxed in with light sheathing to make them appear massive.

Where considerations of draft render it desirable to eliminate unnecessary structural weight, the inside sheathing is omitted entirely or is composed of composition wall board. This compressed pulp material is from 3/16-inch to 5/16-inch thick and should be treated so that it will not absorb moisture. It is obtained in sheets from three to five feet wide and should be carefully fitted. Molding strips of stained wood, ¼-inch thick by 2 to 4 inches wide should fit over the joints and the intermediate nailings. Wallboard should be nailed at not more than 6-inch intervals along the edges and intermediate rows of nails should be not over 18 to 20 inches apart so that buckling will not ensue.

Pilot Houses of Wood

Wooden deck houses are sometimes fitted on steel vessels as in the case of pilot houses or of light deck houses in shallow draft steamers. Pilot houses of wood are to minimize the effect of surrounding steel on the compass needle. All metal within a radius of 15 feet from the compass should be non-magnetic to render the error in reading less marked. Even with this precaution a steel vessel which pursues a fixed course for a considerable period, or which lies at a dock, will become polarized by the earth's magnetic lines of force, so that the vessel itself is one large magnet which will act upon the compass needle just as two magnets affect each other. In order to overcome this source of error in the compass reading, compensating magnets are fitted in the binnacle stand which carries the compass and the ship is "swung at her anchorage" or turned around from time to time. If the modern gyroscopic compasses are used, these troubles are avoided. Pilot houses are often made of steel regardless of the above discussion, for purposes of strength and because of the relatively slight increase in error when the rest of the ship is steel and when the compass is properly constructed and attended to.

Fig. 76-f shows the attachment of a wooden pilot house to a steel deck. Observe the deck plate to which the house sill is bolted and also the firring strips on the steel deck beams to which the light decking inside of the house is nailed.

The lower deck house or "texas" of a shallow draft river vessel is sometimes attached to a vertical steel coaming plate as in Fig. 76-g. Here the coaming plate is riveted to a deck plate by a coaming angle and the sill timber is bolted on an inverted angle bar several inches below the top of the coaming plate. The outer sheathing should cover the top of the coaming plate and a molding strip be fitted for sightlines as shown. The extreme after end of the "texas" is exposed to constant splashing from the stern wheel and is therefore made watertight. This can be done either with two thicknesses of closely fitted tongue and groove planking running at right angles to each other, or by making the bulkhead of light sheet steel or galvanized corrugated steel.

Steel Houses for Tugs

Deckhouses of steel are sometimes fitted on wooden vessels such as tugs which navigate rough waters. The lower attachment of such a house to the wooden deck is shown in Fig. 76-h where the steel lower coaming plate is bolted sidewise through a heavy sill log. The lower coaming angle is riveted to the coaming plate and secured to the deck by bolts with countersunk heads which pass vertically through the sill log and deck beams below. A canvas stopwater dipped in thick white or red lead is inserted between the coaming angle and the sill log to prevent leakage.

An alternative construction is given in Fig. 76-k in which a steel deck plate is fitted on the beams under the deck planks. This plate is through bolted to the deck beams and the lower house coaming angle is riveted to it and to the lower coaming plate.

Steel houses in steel vessels (Fig. 77-a, b and c) have their side and end bulkheads composed of:

1. A lower coaming plate which is secured to the deck plating or to a tie plate under the deck planking by a lower coaming angle.
2. An upper coaming plate which fastens to the house top with an upper coaming angle in one of the ways already described.
3. House side plating which fits between the upper and lower coaming plates and is stiffened by vertical angle bars bracketed at their tops and sometimes at their bottoms.

The lower coaming plate is usually ¼-inch to $\frac{5}{16}$-inch thick (weighing from 10.2 to 12.8 pounds per square foot). Its height above the deck beams is from 9 to 12 inches, so that it need not be cut where doors are fitted but the door sills rest on its upper edge. The lower coaming angle is of the same thickness as the lower coaming plate. The vertical flange of this angle is deep enough to project above the deck planking, being from 2½ to 3½ inches high and secured to the coaming plate by a single row of rivets. The deck flange of this lower coaming angle is single riveted to the deck or tie plating and is from 2½ to 3 inches wide. The tie plate is from 8 to 15 inches wide and weighs from 7.6 to 10.2 pounds per square foot.

The upper coaming plate is from 7.6 to 10.2 pounds per square foot and from 6 to 9 inches high. The upper coaming angle is of the same thickness and has flanges from 2½ inches by 2½ inches to 3 inches by 3 inches, single riveted to the coaming plate and the house top. The tops of window and door frames fit against the lower edge of the upper coaming plate.

The intermediate house side plating weighs from 5.1 to 7.6 pounds per square foot (from ⅛-inch to $\frac{3}{16}$-inch thick) and is cut out where windows and doors are fitted. Sometimes this plating extends to the house top and no upper coaming plate is fitted. The exterior of the house side plating may be flush with butt straps fitted to the seams on the inside (Fig. 77-c) or it may present a paneled appearance by fitting these butt straps on the outside of the seams between the upper and lower coaming plates (Fig. 77-a and b).

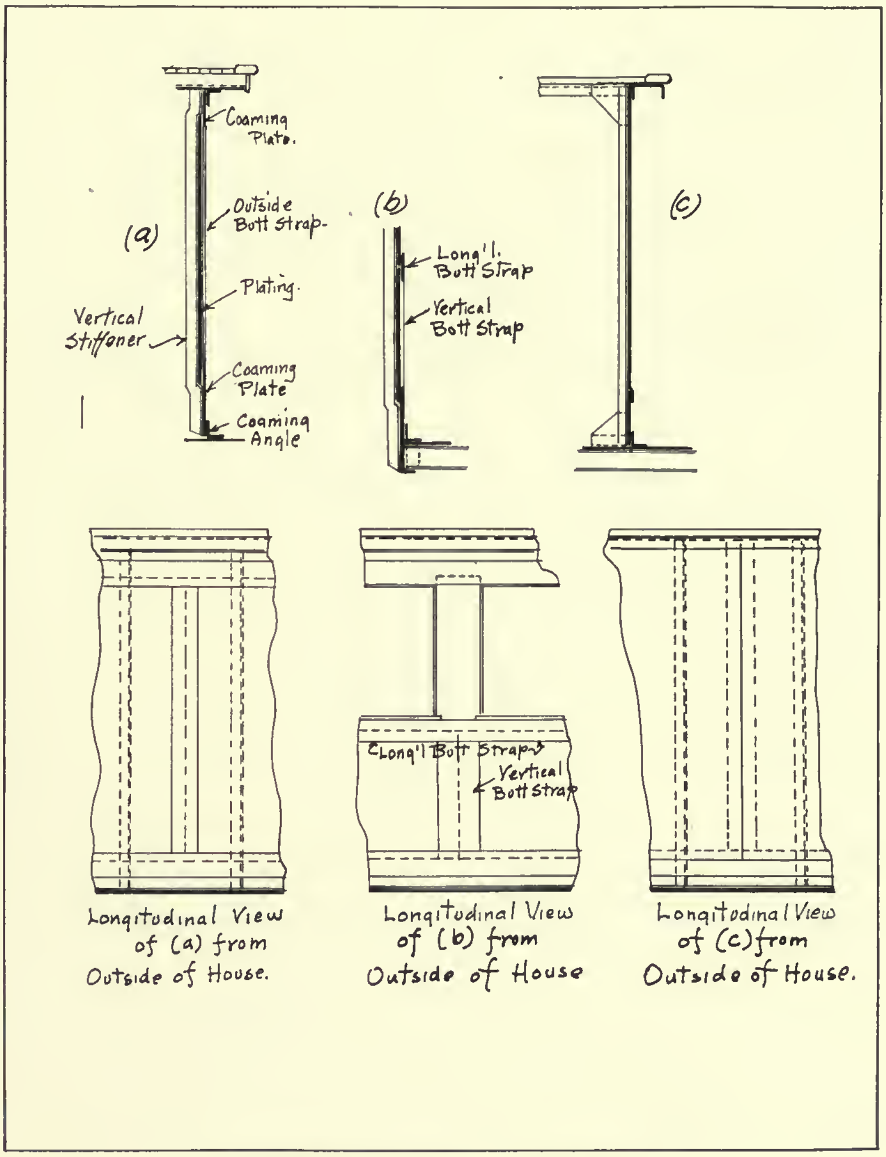


FIG. 77—CONSTRUCTION DETAILS OF STEEL HOUSES

Doors are of the same material as the bulkheads through which they afford a passage, except that sometimes wooden doors are fitted in steel bulkheads. Watertight doors are usually of steel and are fitted to watertight bulkheads. They are arranged to hinge and clamp shut with dogs or to slide vertically or horizontally.

Fig. 78-a is a hinged watertight door on a steel bulkhead. The door opening is 2 feet 2 inches wide by 5 feet 6 inches high and has rounded corners to prevent weakness at these points. A continuous forged frame angle is riveted around the opening or "arch" to make up for the strength lost by cutting out the bulkhead plating. This frame angle bears against a rubber gasket on the door, the gasket being secured to the door plate by rabbeted steel strips fastened with composition machine screws. The door plate is stiffened by an angle around the edge or the plate may be "bumped" out as an alternative. When closed the door is held tight by "dogs" which clamp over bronze wedges on the door plate with handles on each side of the bulkhead as shown. The bolt about which the dogs pivot, passes through a bronze bushing and has a nut on one end to permit removal.

Vertical sliding watertight doors are most frequently used in large vessels and may be operated from the deck above or from below. They slide in cast steel guides riveted to the bulkhead on each side of the "arch" and have wedges on the door which bear against sloped flanges on the guide castings and force the door against the bulkhead when closed. The door may be raised and lowered by means of a pinion and rack or by a threaded spindle passing through a fixed nut on the door. The rack shaft or the spindle are turned by an endless chain on a sheave or by electric motors. Sometimes a releasing device is attached so that the door may drop quickly in case of accident.

The hinged watertight door is most common in tugs and other commercial power boats.

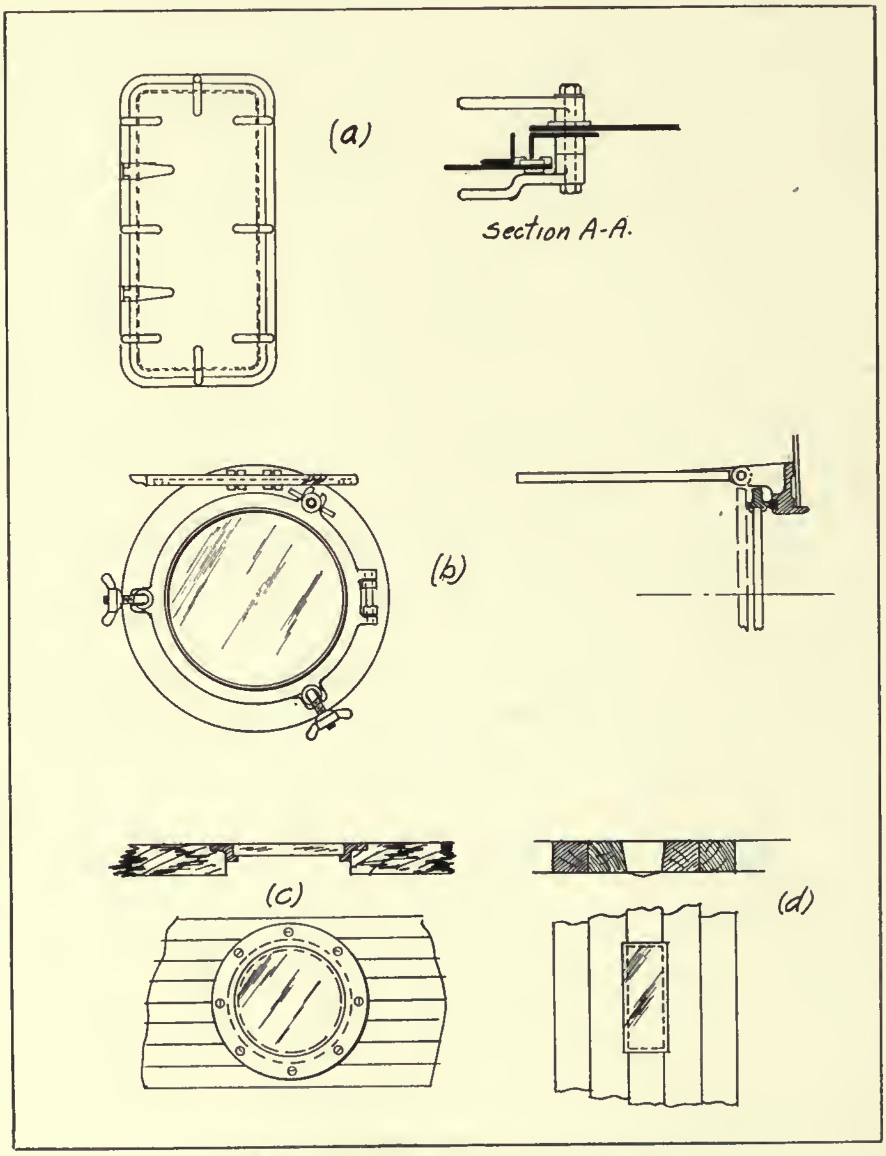


FIG. 78—WATER TIGHT DOORS, AIR PORTS AND DEAD LIGHTS

Interior Doors

Interior doors through joiner bulkheads are similar to those used in building construction, being of wood and panelled. They are usually heavier than doors of buildings and should be carefully fitted. Sometimes horizontal sliding doors are used where space is restricted, such as in staterooms, but this type is not satisfactory in practice since difficulty in opening or closing arises if the door leaves the guide runners.

Deck house doors of wood or steel sometimes are in halves so that the upper part may be opened for ventilation. The upper and lower halves bolt together and the lock is on the lower half. A sliding bolt holds the upper and lower halves of such doors together. Pilot house doors may have glass fitted in the upper half, but if care is not taken the glass will be broken frequently. Wired plate glass offers a solution of this difficulty.

Deck house doors have their upper and lower edges parallel to the sheer and their sides vertical. This custom renders doors very expensive unless the sheer is a straight line when all doors are similar.

Occasionally it is necessary to fit a bulkhead in passages for strength only, in which case passage through the bulkhead is afforded by an open "arch" re-enforced by a bounding angle and the door is omitted.

Openings in the sides of the hull are called "ports" and are employed for loading cargo or for furnishing light and air to the living spaces.

Cargo ports are not fitted in wooden vessels and should be as small as possible in steel ones, that the hull strength may not be seriously reduced. Coastwise vessels with "well" decks have large swinging ports at the sides of the wells. These are not common to power vessels and will not be studied.

Small side ports often also serve as doors to the upper between decks in large vessels and are in halves with a deadlight in the upper portion. They are held watertight by strongbacks or by dogs around the edges and a gasket is fitted on the rim which bears against the angle framing arch. This type is seldom employed in power boat construction.

Construction of Air Ports

Air ports (Fig. 78-b) consist of a circular glass plate in a metal frame which is hinged to a casting riveted or bolted to the hull. The glass is from ⅜-inch to ¾-inch thick, depending upon the diameter. The size of an airport is expressed by the clear diameter of the glass and ranges from 6 inches in small boats to 18 inches in large vessels.

The rim in which the glass is fixed is usually of polished brass or composition metal, although galvanized cast steel is sometimes used. The glass is secured to the rim by a circular brass ring of quarter round cross section which is held in place by small machine screws. Cement is usually introduced between the glass and the rim to prevent leakage. Sometimes a cast metal cover or "deadlight" is hinged over the glass rim on the inside of the vessel. This is usually hinged up and hooked to the deck overhead. Its use is to close the port hole in case the glass becomes broken. A rubber gasket is packed into a groove around the edge of the deadlight cover and a similar gasket is on the frame casting which is riveted to the hull.

Circular ridges on the glass rim bear on these gaskets when the port is closed and when the cover is down and prevent the èntrance of water into the vessel. Three hinged eyebolts provided with butterfly nuts are equally spaced around the edge of the port and the cover and swing into lugs on the rim of these. The ports are held tight against the hull by screwing down on the nuts. A gasket is fitted between the airport frame and the hull on the outside, while a ring over this gasket fits securely to the frame. The frame casting passes from the inside of the inner sheathing to the outside of the hull planking or plating. Usually a square wooden frame surrounds the airports on the inside of the hull and in large wooden vessels this frame should be bevelled to afford maximum light diffusion. This is because of the excessive thickness of the hull.

Air ports should be spaced midway between the frames which should not be cut in fitting the ports. Care should be taken not to locate air ports in the hull closer than two and preferably three frame spaces apart.

Stock air ports are carried by most ship chandlers and can be selected from their catalogs.

Fixed ports or "side lights" admit light only to spaces in the hull which are near the water line or are placed in steel doors of deck houses. The circular glass is in a watertight frame of bronze which is riveted or bolted to the hull and does not hinge open.

Air ports and fixed ports near the hawse pipes are protected by steel bars or as will be studied under "anchor handling."

Wire Glass for Windows

Windows of the drop or hinged type are commonly fitted in deck houses. Their advantage is in the increased light and ventilation which they afford, although they are more liable to breakage in rough seas. This danger was formerly reduced by fitting wooden storm shutters outside of the windows. The shutters could be taken down and stowed away. Since the introduction of "wired plate glass," shutters are not needed if the panes are of this material. The glass is poured with a woven wire mesh in it, and acts in the same way as re-enforced concrete. It will shatter under a direct blow but does not fall out. Pilot house doors should be fitted with wired glass in all cases.

Drop windows when open, fit into a pocket between the inner and outer house sheathing. A recessed grip in the top of the sash should project above the sill so the window can be raised. The sill may form a hinged cover over the window pocket, to present a pleasing appearance. The pocket is lined with sheet copper or galvanized sheet iron with a drain to the outer deck. The sash

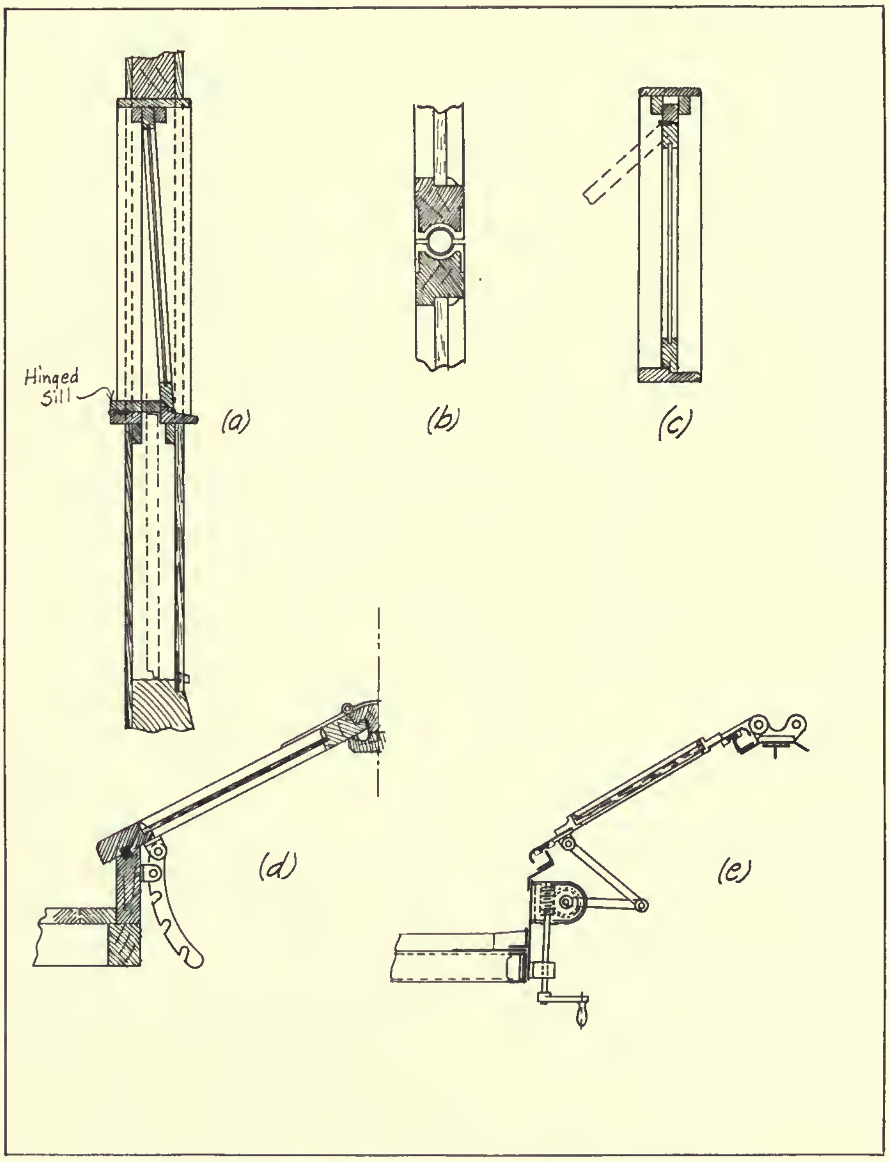


FIG. 79—CONSTRUCTION OF HINGED WINDOWS AND SKYLIGHTS

C. WASHINGTON COLYER, ROCKAWAY BEACH EXCURSION BOAT

This craft powered with a 6-cyl., 7½ x 9" Automatic, carries 200 passengers and is operated by a captain and two hands

slides in a groove in the sides of the frame and the bottom pushes out over a ridge. (Fig. 79-a). Pilot house windows sometimes slide on vertical brass rods (Fig. 79-b). Windows with curved panes at house corners are sometimes installed, but should be avoided if possible because of the cost of the special panes and sash.

Hinged windows (Fig. 79-c) have the upper part of the sash in two sections hinged together. There is a deep channel at the top of the frame with clearance enough for the sash to raise over the ridge on the sill before hinging open. A hook on the house beams keeps the window open. Hinged windows are mostly fitted in the bunk cabins of small vessels or in the after end of pilot houses which are raised above the deck house enough to permit the helmsman to see astern.

Skylights of wood (Fig. 79-d) or steel (Fig. 79-e) usually hinge up and may be opened or closed from within by means of a lifting gear. The covers are hinged at the center and the frames must be watertight.

How Skylights Are Fitted

Wooden skylights have a wooden coaming bolted to the carlings and end beams of the skylight opening. Engine room skylights should be portable to permit removing machinery for shop repairs or renewal. The gabled skylight ends are connected at the tops by a heavy ridge timber to which the hinges are screwed. A drainage groove fits all around the edge of the sashes to prevent drip into the cabin below. This groove drains to the deck at the ends of ridge timber and at the sides of the sashes. Unless the light panes are of wire glass it is necesary to fit a metal grid over them for protection againt breakage by falling objects. A canvas cover or "tarpaulin" fits completely over the skylight and is lashed to the coaming in heavy weather.

Steel skylights (Fig. 79-e) usually have circular ports in the sash. The steel coaming is riveted to a plate top which is cut out in way of the hinged sashes, the opening being surrounded by an angle bar. The edges of the sash are flanged downward to minimize leakage and a rubber strip or "gasket" extends around the edges. Light metal strips screwed to the sash secure the gasket. Stiffening angles or tee bars re-enforce the coaming and tops of the skylights. The coaming is riveted to an angle bar and is clipped to the ends of deck beams which have been cut. A margin plate surrounds the skylight opening and is riveted to the beams and the coaming angle. In small skylights through which it is not necessary to remove machinery or fittings, the deck beams extend across the opening to maintain the necessary strength of the deck.

Skylight lifting gear (Fig. 79-e) may be of several different types but a usual one consists of a vertical shaft having a handwheel which can be turned from within the cabin. One or more bearings support this shaft and its length varies according to the point from which the skylight is desired to be opened. A worm at the upper end of this vertical shaft actuates a worm wheel keyed to a horizontal shaft. The worm and wormwheel may or may not be enclosed in a casing (Fig. 79-e).

The horizontal shaft has one or more levers keyed to it at one end and pinned to the lower end of a corresponding number of links as shown. The upper ends of the links are pinned to bearings on the skylight shutters so that rotation of the levers by means of the worm, wormwheel and horizontal shaft, will raise or lower the skylight shutters. The wormwheel acts as a lock on the worm for any amount of opening of the skylight.

Some skylights have a slotted quadrant bar pinned to the shutter as in (Fig. 79-d). The slots in the quadrant engage a pin on the skylight coaming and the shutter is lifted from the deck above to the required amount of opening.

Deck lights (Fig. 78-c and d) are fitted over compartments where ordinary airports, sidelights or skylights cannot be provided. They may have a cast bronze frame in which the circular glass is cemented watertight (Fig. 78-c), the frame being screwed to the deck planks or plating. A less desirable type has a thick prism of rectangular glass with beveled edges in thick white lead between deck planks (Fig. 78-d).

MANHATTAN WITH A DECK LOAD

Another Rockaway Beach excursion boat with same power and capacity as *Colyer*

CHAPTER XIII

Companions—Hatches—Rails—Awnings

COMPANIONS are openings in the deck which afford access to the compartments below or above it. They may be in the sides of the deck-house or may consist of a hut-like hood over a hatchway having a ladder leading downward.

Fig. 80-a is a sliding companion hatch of wood. It consists of a small house built upon an opening in the deck. A carling at each side joins the deck beams at the ends of the hatch and the intermediate beams which were cut are notched into the carlings. A coaming is bolted all around the hatch to the deck beams and carlings. The front of the companion has double doors which vary in height from 30 inches to 6 feet 6 inches. If these doors do not afford full headroom, the top of the companion slides back as shown to permit entrance.

The sliding top may slope straight back, traveling on girders as shown or it may be rounded as in Fig. 80-b. The minimum width of deck opening should be 30 inches and the length varies according to the slope of the ladder so that the head of an average man would not strike the deck of the opening in coming up.

Companion Slides

Deck houses and trunks of small vessels where the height above the coaming or sill is not sufficient to permit the fitting of doors which are of full headroom height (6 feet 6 inches above the deck), have a companion slide or hinged hatch over the low doors (Fig. 81-a and b). The slide is the same as for companion hatches and has brass metal strips fastened to wooden guide pieces with countersunk screws (Fig. 81-b). The door closes against the front of the sliding top and is usually secured by a hasp and padlock. If the hatch is on a cambered deck and slides athwartship, drain holes are cut in the slide strips as shown. If the companion top is hinged, the construction is the same except that the slides are omitted and hinges are fitted to the cover at the side away from the door.

It is also desirable to install hinged rods at the sides of the hinged cover so that it may be opened to a degree affording headroom without throwing it completely back upon the deck. Companions of this type are difficult to screen properly and should be avoided if possible.

Fig. 80-b is a full height steel companion hatch with deadlights in the sides. The coaming plate and connections at the deck are the same as for deck houses and a continuous corner angle bar is riveted to the sides, front and back. The steel door closes against this angle at the top and sides while a reversed angle at the top of the coaming plate forms a sill. The side and back plates together with the door are of from 5.1 to 10.2 pound plating (⅛ to ¼ inch thick) with single riveted "equal" angle bars and stiffeners of the same thickness.

Companion doors may be single, double or divided. The latter two types are as in Fig. 81-c and d. They are resorted to where the pas-

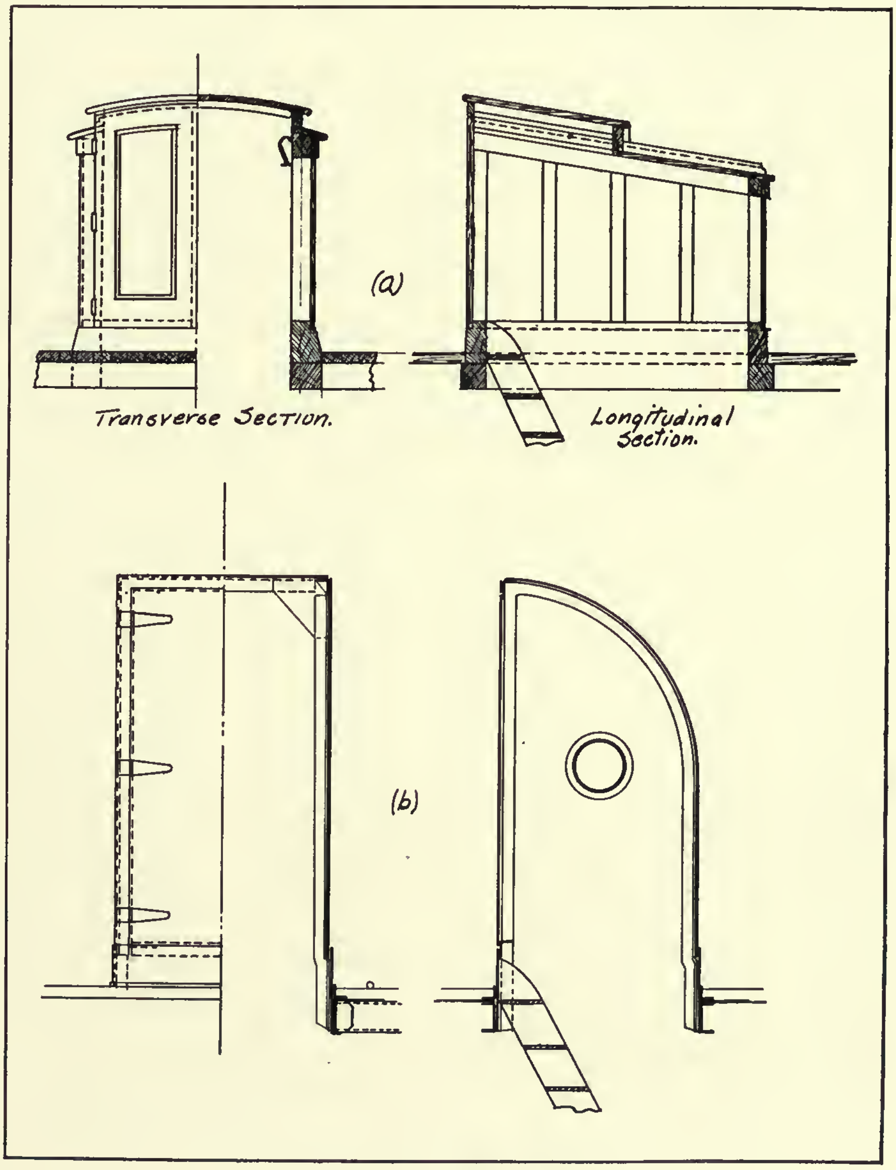


FIG. 80—WOOD AND STEEL COMPANIONS

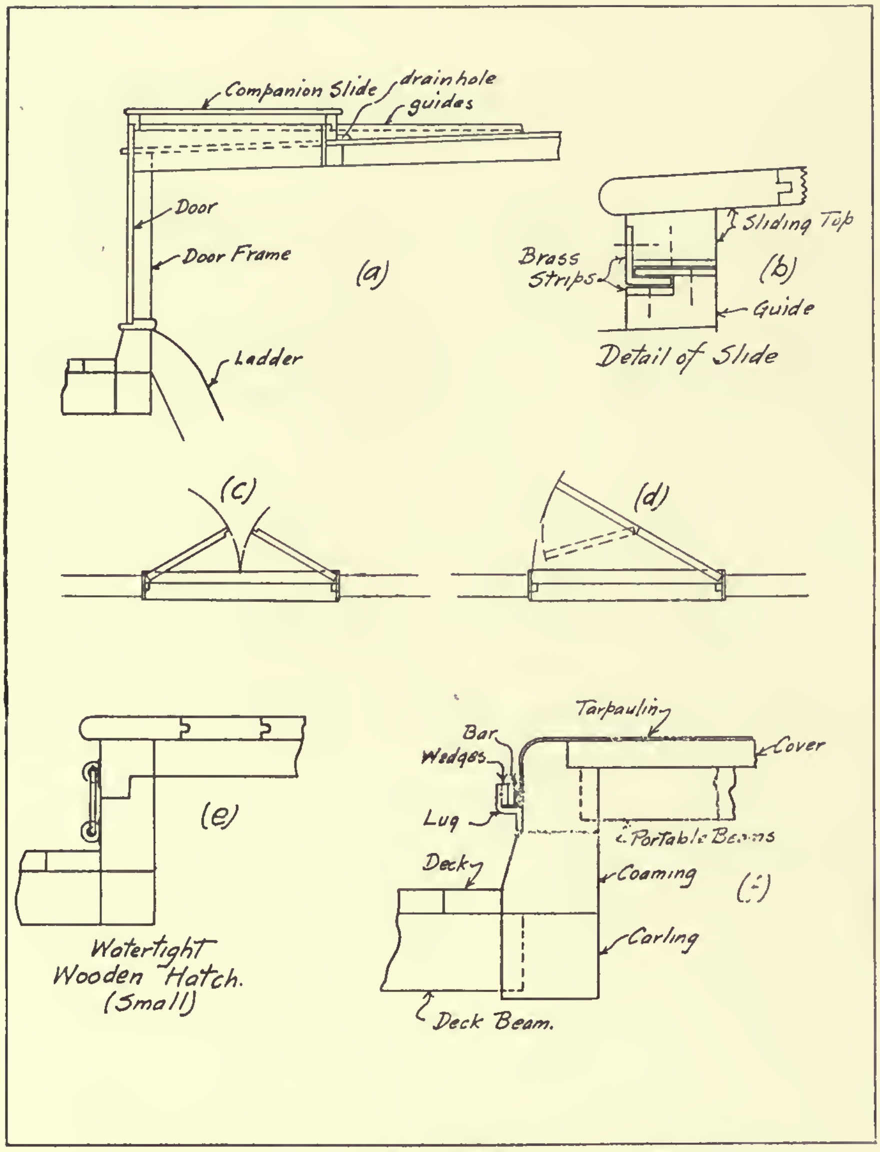


FIG. 81—DETAIL CONSTRUCTION OF COMPANION SLIDES AND HATCHES

sage into which they swing open is restricted. The hinges and locks should bè extra heavy and arrangements should be made to hold the doors open by brass hooks or by spring catches. Rubber topped buffers should be on all doors which open against interior or exterior joiner work having a fine finish.

The deck immediately in front of companion doors is subjected to severe wear so that treads of hardwood strips are fastened to the decks at this point. Sometimes cast brass or iron plates which are roughened by a pattern or which have a cement or lead filling in grooves, are used in the deck in front of doors.

How Hatches Are Classified

Hatches may be roughly classed as watertight, non-watertight, flush or raised. Watertight hatches are fitted over all compartments opening onto decks exposed to the weather.

Wooden hatches are difficult to keep tight. They consist of a coaming bolted to the carlings and beams around the deck opening. This coaming has a rabbet on its upper edge and the hatch cover fits securely into it. If the hatch is small the top may be in one piece, usually rectangular, composed of tongue and grooved planks with a rabbeted frame and short beams. Hooks on the coaming engage eyes on the cover frame and clamp the hatch closed. Sometimes hinged hasps on the cover fit over staples on the coaming, and pins through the staple hold the cover down. If the hatch is hinged, a padlock on one staple may be used and the hooks also be fitted at the sides. (Fig. 81-e.)

Large wooden watertight hatches have sectional covers on portable beams resting in the notched and rabbeted upper coaming timber. A heavy canvas tarpaulin is stretched tightly over the closed hatch by means of an iron bar which is wedged into metal lugs on the coaming. (Fig. 81-f.)

Watertight steel hatches when small are called "manholes" or "scuttles" and may open into tank compartments below decks as well as to the weather. Manholes to tanks which are seldom entered should be bolted closed as in Fig. 82-a. The opening should not be less than 11 inches wide by 15 inches long with circular ends. A forged channel or double angle ring encloses the opening, the cover plate bolting on the upper flange as shown. A gasket of hemp or canvas fits between the cover and the coaming ring. The tank, bulkhead or deck plating which has been cut at the manhole, has a re-enforcing plate or "doubler" riveted all around the opening to compensate for the lost strength.

Manholes of Various Types

Manholes fitted with "strongbacks" are common to tank compartments. The elliptical manhole plate is in two thicknesses, the upper of which is narrower than the lower. The plates are riveted together and a gasket is fitted on the shoulder as shown in Fig. 82-e. Two shoulder bolts are riveted through the cover plate and "strongback" bars fit over the screwed ends of these bolts, extending across the narrower dimension of the manhole. Nuts over washers tighten the cover against a flanged manhole ring.

Hinged manholes fitted with "dogs" are as shown in Fig. 82-c. They may be square, round or elliptical and have a number of forged lugs which engage hinged bolts with wing nuts around their edges. The hinges have an oval slot on the pin to permit of tightening the cover.

This type of fastening is employed for steel watertight or oiltight hatches with hinged covers. A plate coaming from 9 to 48 inches high surrounds the hatch opening and has a coaming angle at the deck. If the coaming height exceeds 20 inches it is necessary to stiffen the plate with brackets and angle clips. A rubber gasket at the upper edge of the coaming plate is clamped thereto by an angle or by a flat iron bar. Cast or forged steel lugs riveted to the coaming, attach the hinges and the ring bolts.

If the hatch is more than 24 inches square, the cover plate should be strengthened by an angle around the edge. Hatches smaller than this usually have a flat bar around the edge of the cover for strength. Hatches more than 48 inches square should have stiffeners of angles or bulb angles across the cover at intervals of 24 inches.

Deck scuttles are of cast steel or composition metal, not less than 18 nor more than 24 inches in diameter. They consist of a flush ring casting, bolted or riveted to the deck planking or plating and having a depressed circular ridge on which a rubber gasket in the cover bears. The cover varies from ⅜ to ⅝ inch in thickness, is roughened on the upper surface and has two hinged ring bolts which lie flush in depressions and by means of which the cover may be lifted. The cover is tightened against the ring casting on the deck by means of six bolts with heads resembling horizontal cams, or else by a central bolt which screws into a bossing on a hinged strongback under the scuttle. A special wrench is provided to tighten the scuttle fastening bolts. When the cover is removed a cast iron grating fits into the opening and affords ventilation. This grating may stow in three clips on a bulkhead near the scuttle or may rest in depressed lugs under the cover when the scuttle is closed.

Steel cargo hatches usually have wooden covers which rest on portable beams in the hatch opening. A tarpaulin is stretched over the top of the hatch in the manner described for wooden hatches.

Ladders and stairways may be of metal or of wood and are vertical or inclined. Inclined ladders should not extend athwartships in vessels for rough water service, unless this arrangement cannot be avoided. This is because of the danger of falling down them when the vessel is rolling. In passengers' living spaces stairways are usually built with a slope of 45 degrees and with good wide treads and ornamental railings. These sometimes turn from two athwartship sections to a "grand stairway" opening in the saloon. Curved stairways are not recommended for use on vessels, it being better to change the direction of the stairs by introducing a landing.

All ladders are composed of two side pieces which are parallel and fastened at the top and bottom ends to the decks. Horizontal rungs or "risers" are fitted between the treads pieces and spaced about 9 inches apart in vertical direction. Sometimes "risers" are fitted between the treads to close the openings between them. Sloping ladders have hand rails of ornamental wood or of plain iron or brass pipe.

Fig. 83-a is a typical wooden sloping ladder of ash or oak. Angle iron clips are bolted to the sides and to the deck below as well as to the hatch coaming at the top of the ladder. A sheet brass covering is tacked over the door sill at the top of the ladder and the treads have a

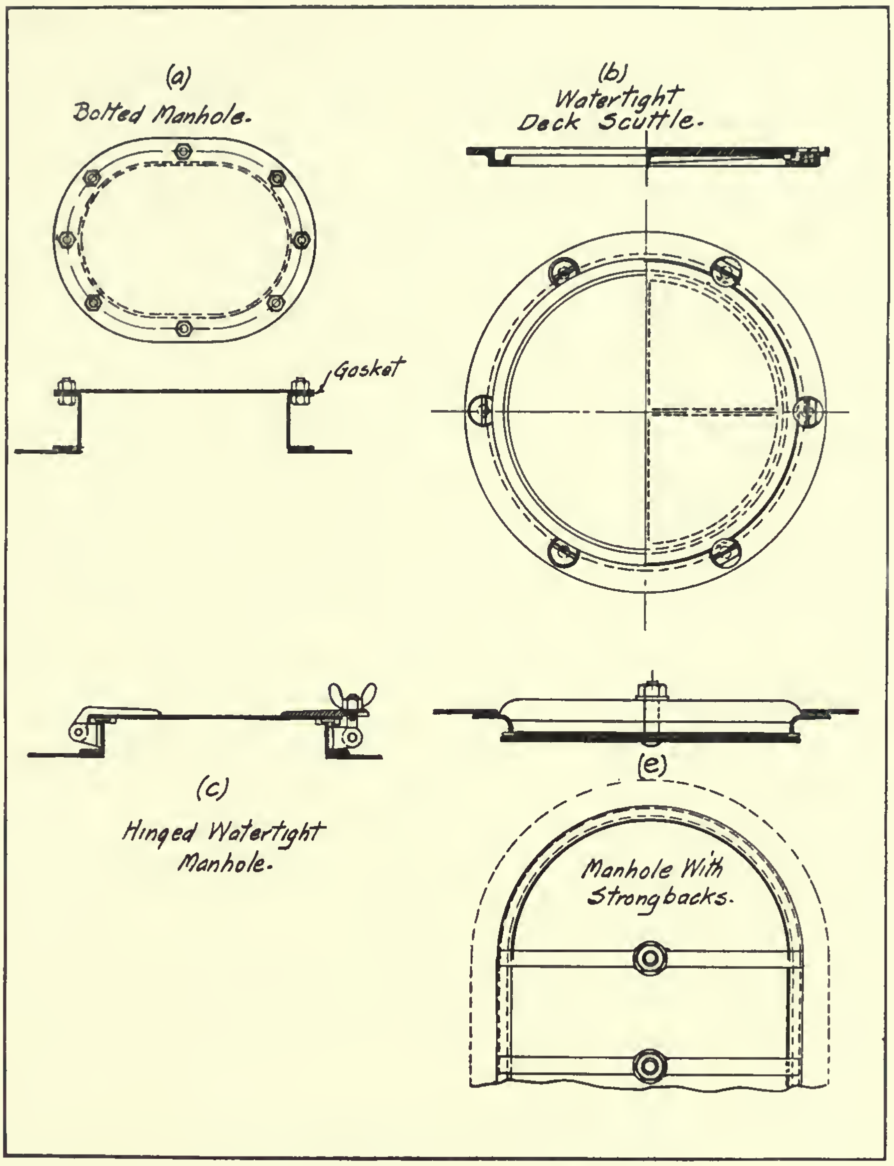


FIG. 82—WATERTIGHT HATCHES AND MANHOLES

protective covering of rubber, linoleum or of brass castings with lead or cement filling in grooves thereon. The front edges of the treads have sheet brass strips to reduce the wear. If risers are installed they are protected by polished sheet brass "kick plates" neatly tacked on. The hand rail is fitted to cast or forged sockets on the outside of the side pieces. The treads should be at least 6 inches wide.

Engine Room Ladders

Steel ladders may be similar in construction and are generally fitted in the engine rooms. The side strips are from ¼ to ⅜ inch thick and at least 4 inches wide. The treads are cast iron with ribbed or roughened top and bolted to the sides by angle iron clips. "Subway" or similar gratings form an excellent tread for such ladders. No risers are fitted and the rails are always of metal.

Vertical wooden ladders have the same construction as that in Fig. 83-a except that the risers are omitted. Sometimes a strip of canvas is lashed under open ladders to close the openings between treads, particularly in side ladders which lead from the deck to the water. Such ladders are supported by forged arms from sockets on the side of the vessel and have wooden gratings at the top and bottom. They are arranged to hoist up by a block and tackle on a small davit and to be removed and stowed in the hold during the voyage. Instead of a pipe rail a rope is led through forged stanchions around the gratings and down the sides of the ladder.

Vertical steel ladders to holds and compartments entered only at intervals, are composed of two flat bar strips with round or square bars for rungs. These rungs are riveted into the side bars. Sometimes the rungs are forged to a U shape with flattened ends which rivet to the bulkhead plating. Such rungs are at least 3

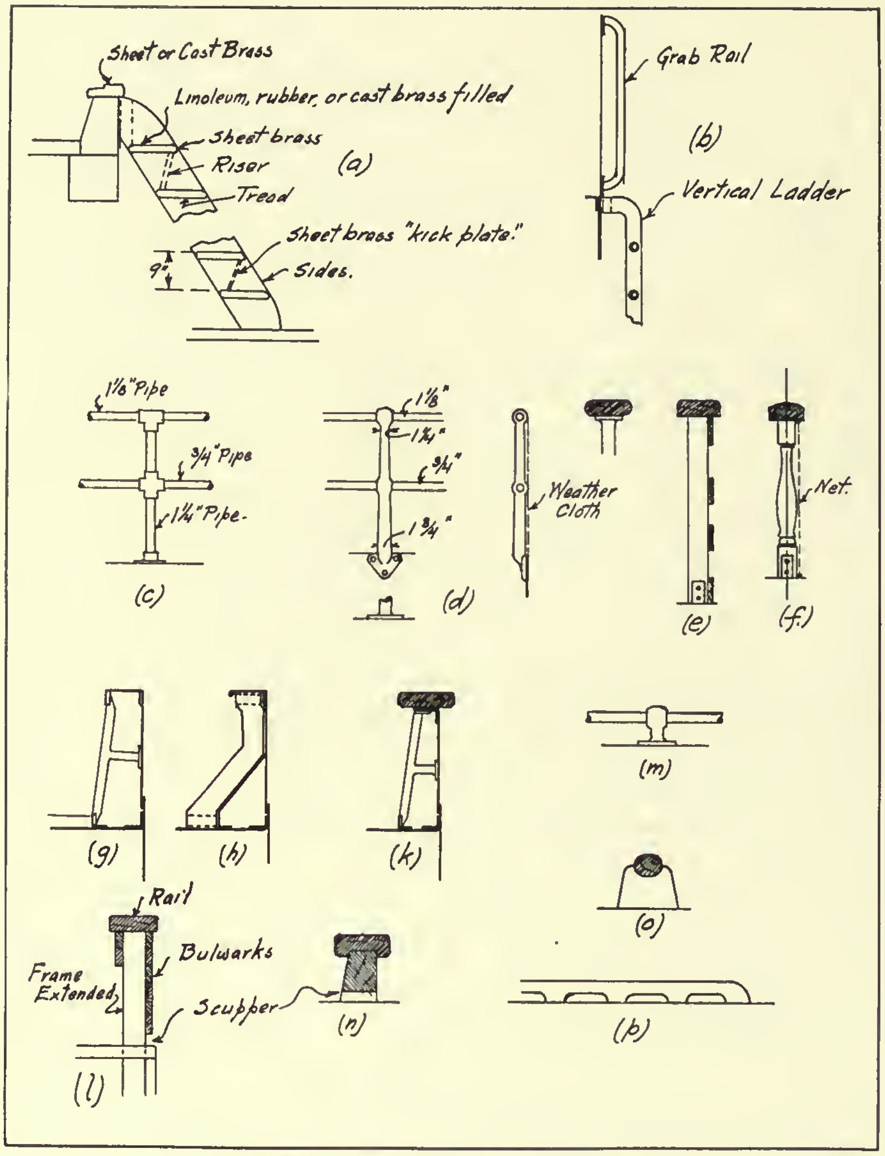


FIG. 83—CONSTRUCTION DETAILS OF LADDERS AND RAILS

inches clear of the bulkhead. Again the bar rungs may rivet through two of the vertical bars which stiffen the bulkhead and also serve as sides for the ladder.

On a non-watertight steel bulkhead forming a chain locker partition or a swash bulkhead in a deep tank, semicircular holes may be cut 12 inches apart horizontally and 9 inches vertically to form a ladder. These holes should be at least 4 inches wide to fit the foot of an average man.

Ladders are fitted on masts and in ventilators or trunks between decks to form emergency exits. Where a ladder without side rails or a vertical ladder has an open passage or a bulkhead at the top, grab rails should be fitted above the ladder (Fig. 83-b), or the rail should extend above the top of the ladder so that a person may stand erect when coming up or going down.

It is often necessary to hinge ladders at their tops in order to lift them out of the way. Means should be provided for hooking the lower ends of such ladders to the deck above when hinged up. The width of ladders constantly used should not be less than 27 and preferably 30 inches. Ladders occasionally used may be as narrow as 10 or 12 inches.

Rope ladders with wooden rungs are called "jacobs ladders" and are used for getting into small boats beside the vessels.

Rails and Their Construction

Rails should be fitted around the edges of all decks, around all openings in the deck except at the point of access, at the margins of all cabin tops or house tops which are frequented by persons. Grab rods are fitted at the sides of trunk cabins, around the front of pilot houses, in passageways and at tops of ladders.

Open rails may be of metal or wood (Fig. 83-c to f). Closed rails or bulwarks of metal or wood are shown in Fig. 83-g to l. Fig. 83-c is a rail of standard pipe (galvanized). It consists of 1¼-inch stanchions spaced from 3 feet 6 inches to 4 feet apart having standard flanges screwed to their lower ends. These flanges are screwed or bolted to the deck planks or plating. If such rails are fastened to the upper edge of a sheer strake, it is necessary to weld the lower end of the pipe to a forged palm as in Fig. 83-d. The pipe rails are from 2 feet 6 inches to 3 feet 6 inches above the deck, and there may be two or three of them. The top rail is usually from 1 to 1¼-inch pipe screwed to the stanchions by a standard "T." Where the rail turns at right angles a sight outlet "L" or "T" may be fitted.

The intermediate rails may be the same size as the top rail and the stanchions, but are usually from ¾ to 1 inch in diameter. Their connections to the stanchions are by crosses. Side outlet "T's" are fitted at turns.

Forged or cast rail stanchions may replace those of ordinary pipe (Fig. 83-d), the sizes and connections being as shown. The rails in this case should also be of standard galvanized pipe. Sometimes the pipe rails are replaced by a single wire rope or "life line" passed through the forged stanchions. Occasionally in passenger vessels the upper rail is of wood on metal stanchions as shown.

Metal grab rails (Fig. 83-m) have small forged or cast stanchions screwed or bolted to the sides or top of deck houses. Wooden grab rails are shown in Fig. 83-o and p.

Wooden rails (Fig. 83-e and f) have plain or ornamental stanchions supporting a top rail and having metal clips screwed to the deck. The sides are of light planks or rope netting.

"Bulwarks" or rails solidly enclosed except for deck drainage openings, are fitted on tugs and the lower decks of cargo and passenger vessels. They tend to prevent waves from washing over the deck but are not desirable if heavy seas are encountered, since they trap the water and make it difficult for the vessel to free itself of seas which have been shipped.

Metal bulwarks have plating from 10.2 to 25 pounds (Fig. 83-g, h and k) which is riveted to the upper edge of the sheer strake. A rail of channel or bulb angle is riveted at the top of the bulwark plating and stanchions of forged round or structural steel support both the bulwark and rail as shown. Wooden bulwark rails are fitted on passenger vessels and tugs. In the former case the rail is of 2 x 4-inch or 3 x 6-inch hardwood, bolted to an angle (Fig. 83-k), the bolt heads being countersunk and the holes plugged with wood. Tug rails are of oak 4 x 8-inch to 4 x 16-inch.

The height of bulwarks in tugs is 18 to 24 inches above the deck. In passenger vessels the height corresponds to that of open rails.

Wooden bulwarks (Fig. 83-l and n) have stanchions formed by extending the upper ends of frames through the deck. The rails are of the same height as those on steel bulwarks. Small power tugs have low rails of a single log, tapered as shown and with a rail on top. "Scuppers" or drainage ports are cut at intervals in wooden bulwarks.

Awning Stanchions and Fittings

Awnings of canvas are fitted over open deck spaces for shelter from the sun. They may be stretched over a pipe frame and lashed at the edges; or, in larger vessels, may have a wooden ride bar and spreaders (Fig. 84-a). The canvas is white or khaki colored and of No. 4 or No. 6 weight. Small boats have awnings rolling over a rounded pipe frame or of the "automobile" top type which folds down.

Vessels operating in warm climates may have double awnings with an air space between and the edges of the canvas may overhang the ship's sides.

It is conventional to install a canvas "eyebrow" over the windows at the front of pilot houses (Fig. 84-b). This is painted green underneath but does not afford real protection from the glare of the sun which is reflected upward from the water to the eyes of the helmsman. The eyebrow serves to keep rain off the pilot house windows to an extent but is not really needed.

Canvas "weather clothes" lashed to the rails at the front and sides of the bridge protect the occupants from the wind. They sometimes extend to the level of the eye (about 4 feet 9 inches above the deck).

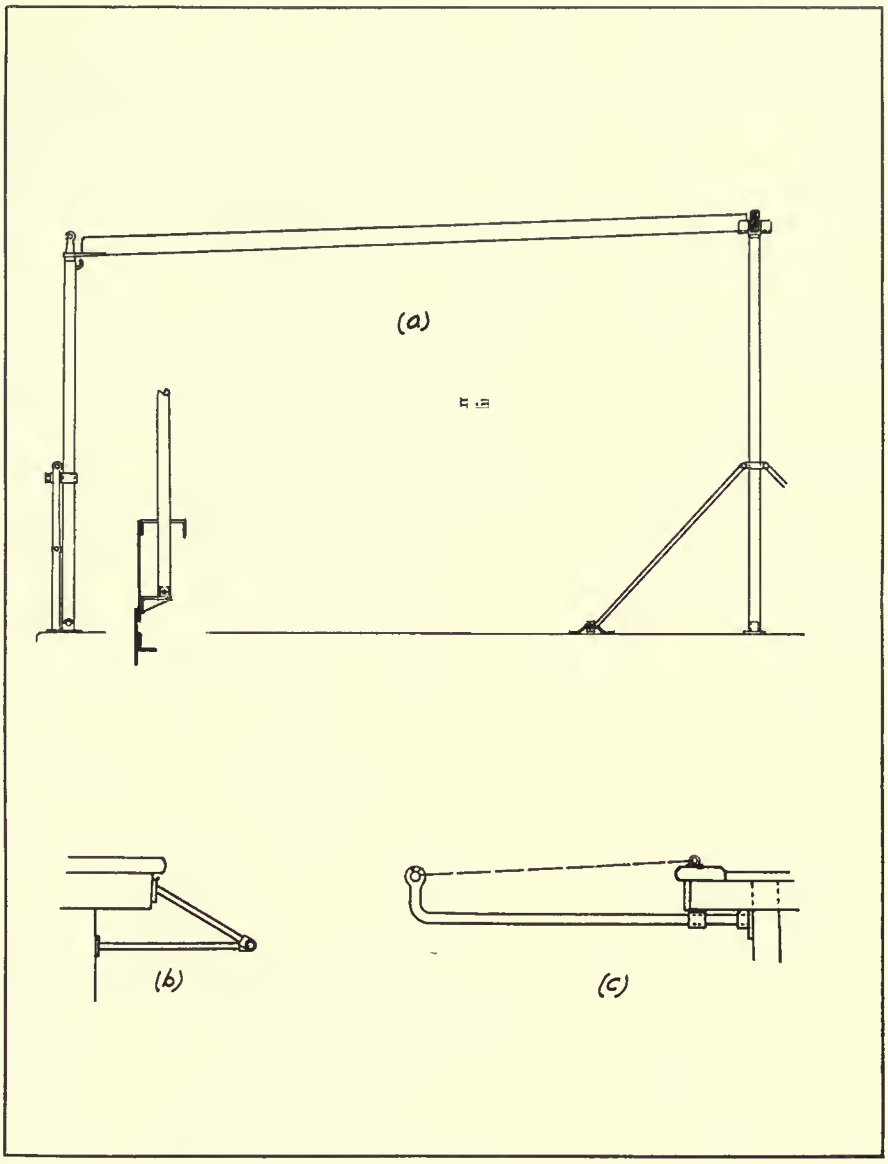


FIG. 84—AWNING STANCHIONS AND FITTINGS

Awnings and weather clothes should always be fitted on the bridge, even though not installed elsewhere on the vessel.

OYSTER DREDGE FANNIE W., OWNED BY SPRAGUE & DOUGHERTY, OYSTER PACKERS OF INWOOD, L. I., N. Y.
35 feet O. A. by 10 feet beam. Buffalo 2-cylinder 6 by 7½ inches bore and stroke, 13-15 horsepower. Heavy duty type. Columbian propeller 20 by 24, Style B, 350 revolutions per minute. Double ignition, separate plugs; starts on Delco batteries with Bosch magneto. Gasoline fuel; about 1½ gallons per hour. This work boat is at least 20 years old and her present power plant has been in service for more than six years and is still in excellent condition. She has a capacity of 400 bushels of oysters and when loaded makes about 8½ miles per hour.

CHAPTER XIV

Masts—Davits—Winches—Windlasses

IN MOST commercial power boats the sole use of masts and rigging is for cargo hoisting and for signaling either by flags or by radio telegraphy, commonly known as "wireless." Vessels rigged to carry sails and fitted with engines for propelling them in calms or to assist the sails in a light breeze, are not properly "power boats" and will not be considered in detail here. The rigging is complicated and caries considerably according to the method of fitting the sails. In general the sails are carried by from one to four masts in vessels which are "square rigged" and from one to seven masts on "fore and aft" or "schooner" rigged vessels.

The masts are named up to four and beginning at the forward one as "fore," "main," "mizzen" and "jigger" or "jury." So, if there are two masts, the forward one is the "foremast" and the after one the "mainmast." If there are three masts, the forward one is the "foremast," the center one or second one the "mainmast," and the third or after one is the "mizzenmast." The fourth mast or "jigger" is not common in square rigged ships and has its sails fore and aft as a rule.

Masts and Rigging

Masts are a single pole or in two lengths on modern vessels. If in two lengths, the lower piece is the lower mast and the upper section is the top mast. The point at which the topmast is fastened to the mainmast is also that at which the strong athwartship guys or "shrouds" support the mast. This point in all masts is the "hounds." It is also necessary to fit longitudinal guys called "stays" to the masts. These are "backstays" if on the after side of the mast, "forestays" if on the forward side and "springstays" if horizontal or nearly so between two masts. The stays and shrouds are fixed and have no blocks or tackle on them except means for tightening or loosening; they are termed "standing rigging." Ropes used for hoisting and lowering sails, spars or cargo booms are fitted with block and tackle and known as "running rigging."

Since the wind pressure against the sails tends to bend the masts forward, they are inclined backward so the backstays will have a greater spread and the mast be subject to less strain. This backward inclination is from $\frac{3}{8}$-inch to $\frac{5}{8}$-inch per foot of height in common practice and is called a "rake." Pole masts in vessels without sails need not be raked except to conform with custom which has affected judgment of appearances.

Most sailing vessels have a bowsprit at the stem to afford great spread of the forestays and permit

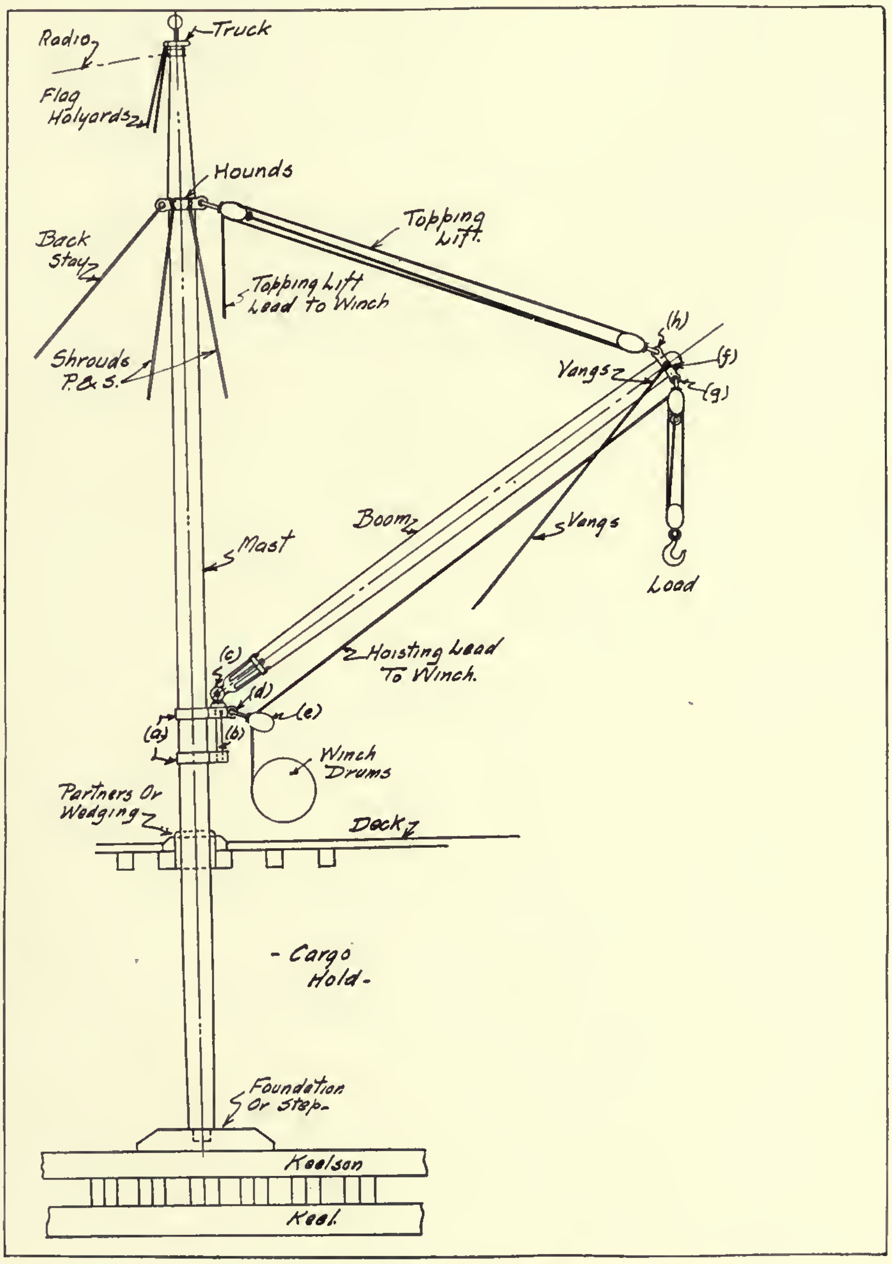


FIG. 85—HOW POLE MAST AND BOOM IS FITTED

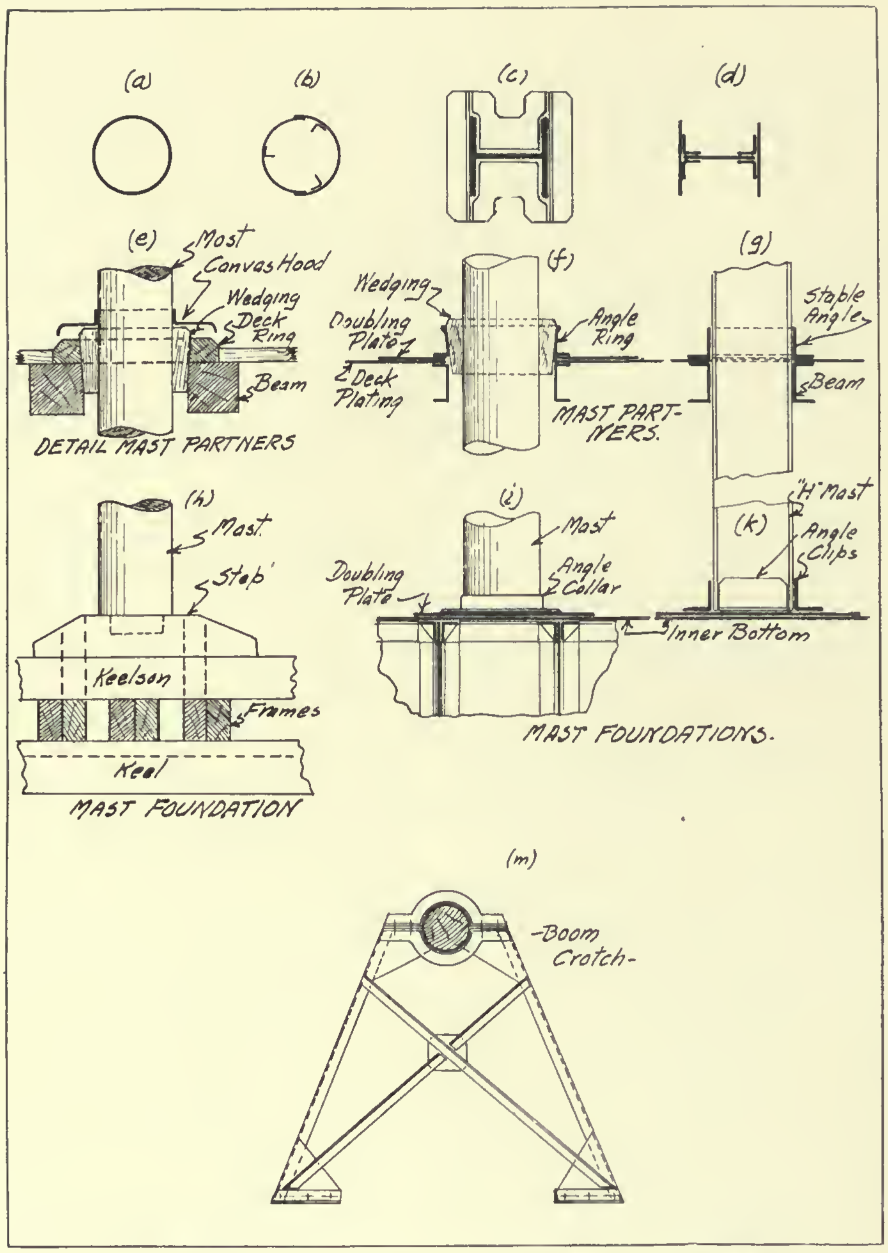


FIG. 86—CONSTRUCTION AND INSTALLATION OF STEEL MASTS, ALSO BOOM CROTCH

carrying jibsails of larger area. Sometimes the bowsprit has an extension spar or jib boom at its outer end.

The "rig" of a vessel is named from the cut and position of its sails. Where these are rectangular and hung from a spar at their upper edge, the spar being fastened at its middle to the mast, the vessel is called "square rigged." When the forward vertical edge of the sail is attached to the mast, the vessel is "fore and aft rigged" or "schooner rigged."

Pole masts as fitted to commercial power boats are similar in arrangement to Fig. 85 and are usually of wood in vessels up to 150 feet long, that is where the pole is of such height as to be obtained in a single length of the proper maximum diameter to withstand the stress due to the loads. The cross section is circular and is greatest at the point where the mast passes through the upper deck. Here strong wedging called the "partners" is fitted, the mast tapering upward to the hounds and downward to the foundation or "step." The reduction in area at the hounds is about 18 per cent of that at the partners.

Steel masts are not usually fitted in power boats, being confined to large seagoing vessels. The mast may be a solid steel tube, a built-up tube stiffened inside with angle bars, a structural or built-up "H" section, or a latticed girder. (Fig. 86-a, b, c, d).

The lower end attachment of masts is known as the foundation or "step." It is usually fitted on the center keelson as in Fig. (86-h-i and k), although sometimes where the hold is deep the masts extend to one of the lower decks or the top of a shaft tunnel. In this case it is necessary to fit heavy stanchions under the deck supporting the mast or to introduce a transverse bulkhead. The foundations must be braced athwartship by heavy knees in single bottomed vessels, but steel vessels with double bottoms require merely a heavy doubling plate on the tank top at this point.

Wooden masts should be mortised into the foundation timbers. Steel masts are riveted to the foundation girders by angles as shown.

At the point where masts pierce the upper or main strength deck they must be rigidly secured against deflection by a structure called the "partners." This consists of deck beams forward and aft of the mast with connecting longitudinal carlings close to the deck opening. There should be but one set of "partners," the spar being free to deflect between this point, the hounds and the foundation. The decking is locally strengthened by margin planks in wooden vessels or by doubling plates with an angle ring or clips in steel vessels (Fig. 86-e-f and g).

Partners on weather decks must be made watertight at the wedges by fitting a canvas or metal hood. Structural masts have stapled partner angles without wedging and calked watertight. If the mast passes through a deck house top which is of light construction the partners are on the next lower strength deck and a flexible canvas hood is tacked watertight around the opening where the mast pierces the light superstructure deck.

Cargo Booms for Workboats

The power workboats it is customary to fit cargo booms on the mast thus facilitating the loading of heavy cargo. The boom is pivoted at its lower end to a point on the mast just above the partners as in Fig. 85. This point is pivoted in two directions so the outer end of the boom can be either elevated ("topped") or swung horizontally in transferring the cargo from the wharf to the vessel's deck. Two forged rings (a) are fitted tightly to the mast and a strong vertical pin (b) with an eye and shoulder at its upper end is passed through vertical bearings on the forward side of the mast rings. A nut or split pin is at the lower end of the large vertical pin to prevent it from jumping out. A pronged forging is tightly fitted to the lower end of the boom and engages the eye in the pin on the mast by means of a strong horizontal bolt or pin (c). The upper mast ring has an additional eye (d) for attaching the guide pulley (e).

The boom is usually of wood although it may be a steel eyebeam or a latticed steel girder. At the free end of the boom is a forged ring (f) with usually four eyelets. The lower of these eyes (g) receives the lifting tackle (usually multiple effect). The upper eye (h) secures the lower block of the "topping lift" tackle which raises or lowers the boom. Swinging the boom from ship to dock is done by the "vangs" which attach to the eyelets on each side of the end ring. The vang on the side toward the dock is of fixed length so the boom with its load is free to swing toward the wharf but cannot swing outward beyond the hatch opening. When the vessel is under way the boom is lowered to a horizontal position and supported at its outer end by a "boom crutch" (Fig. 86-m). This is a portable structure of forged bars or structural shapes with a semicircular depression at the top into which the boom fits and is held by a cover piece hinged or bolted over. The lower ends of the crutch bolt to flush castings or angle clips on deck.

Davits

Davits are really small cranes and are employed for hoisting or lowering anchors, lifeboats or companion ladders. Occasionally where light cargo is handled a davit with block and falls is installed on deck at each side of the hatch instead of the customary mast and boom. Fig 87 (a) shows a typical davit made of a forged round bar. The head is shaped at the sides as two eyes for attachment of guys and stays while a hole is drilled vertically to take the eye bolt from which the lifting gear is hung. A cleat is welded to the davit below the curve of the overhung arm for securing the hoisting line. Sometimes this cleat is served to the davit with wire. A support bearing is situated on the vertical shank just below the curve of outreach. This bearing should be metalline or bronze bushed as shown and is usually an independent forging or casting securely bolted to the deck house, cabin trunk or bulwark rail, depending upon the location and utility of the davit.

If the davit passes through a deck at the support bearing, a canvas hood is fitted above this bearing to prevent leakage. The lower end of the davit is rounded and rests on a hardened steel button in a step bearing casting. Some vessels with open bulwarks have the davits at the rail, making it necessary to fit a single casting which acts as a combined support and step bearing. (Fig. 87-b).

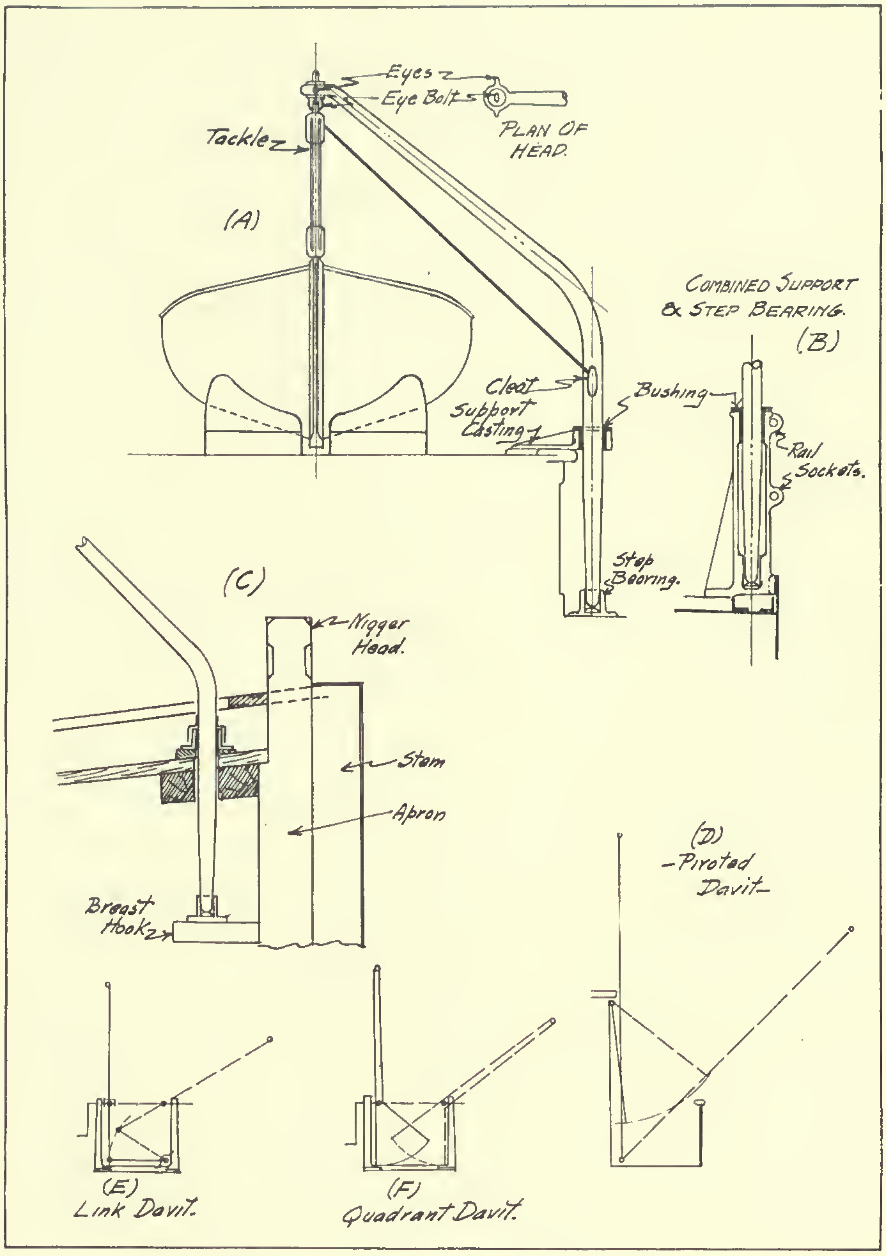


FIG. 87—DAVITS AND HOW THEY ARE INSTALLED

Boat side ladder and cargo davits are as in Fig. 87 (a and b). Fig. 87-c is an anchor davit.

Large vessels with heavy boats sometimes have rotary davits of structural I-beams bent to shape. Special davits of the pivoted, link or quadrant types (Fig. 87-d to f) are also used in large vessels but will not be described in detail since they are too bulky and expensive for use in most smaller vessels.

Life boats should be carried by all power boats and should accommodate the maximum number of persons which the vessel is apt to carry.

The lifeboats for large vessels are usually of the double ended "whaleboat" type of wood or steel. They have a rated carrying capacity of one person for each 10 cubic feet of hull volume and have air-tight compartments at the ends and under the thwarts to afford safety against sinkage. The cockpit floor is above the water level and is water tight. Check or flap valves which open outward are in drain pipes from the cockpit, so that water shipped over the side will quickly run off and lighten the boat. Oars with rowlocks for pulling and steering purposes are in the boat, also a "breaker" or small cask of water and a tin of sea biscuit. A light line with cork buoys is fitted through eyes all around the gunwale and a portable rudder with tiller is provided.

The entire lifeboat is stowed on wooden or light metal "boat chocks" or cradles and a davit is at each end of the boat. The lifting tackle is shackled to patent quick-releasing hooks at each end of the boat. These hooks will collapse and release the tackle when the boat is water borne or when a tripping device is operated by one of the occupants. The outer boat chock is collapsible or hinges down so the boat will swing outboard with a minimum of hoisting and its attendant delay.

Ordinarily the boat is secured in the chocks by lashings from a canvas cover which stretches over a ridge bar and is fastened all around the gunwale. In times of danger when the boat may be needed quickly, it is swung out over the vessel's side and lashed to a spar fitted with heavy pads, which spreads between the davits. This spar is known as a "pudding boom."

A solid metal rod with shackles and turnbuckles, spans from the head of one davit to the other when the boat is stowed inboard. Wire rope guys with turnbuckles and thimbles are secured to the outside of each davit head and to pad eyes on the deck. The davits are thus held in position when not in use.

Lifeboats are carried on the house tops or trunk top in most power boats. When the distance between the rail and the deck house is great, causing an excessive outreach of the davit arm by the usual method of boat stowage, skid beams are fitted over the passage at the house side and the boats stowed on a slatted platform over these beams. By this arrangement the davits can be at the vessel's side and the boats dropped clear of the rail.

Large vessels should always have at least one lifeboat fitted with a gasoline engine. It may not be possible to accommodate all the passengers in boats but liferafts are then stacked on the deck house to make up the shortage. These rafts may be of pontoons with slatted wooden platforms on top and underneath, with buoyed life lines, oars and rowlocks. Modern types resemble large elliptical ring buoys and have rope nets in the center.

Small power vessels use their lifeboats for dinghies and such boats are either flat bottomed or dories. They are lashed bottom up on the cabin trunk and have light davits, or if light enough, are lifted over the side by hand.

In general, precaution should be taken that wooden lifeboats are put into the water frequently so that the seams will not leak due to drying out of the planking. Metal lifeboats should be kept well painted. Tackle and releasing gear should be frequently overhauled and kept free from paint. The crews of all boats should be schooled in rapidly manning, launching and rowing the boats.

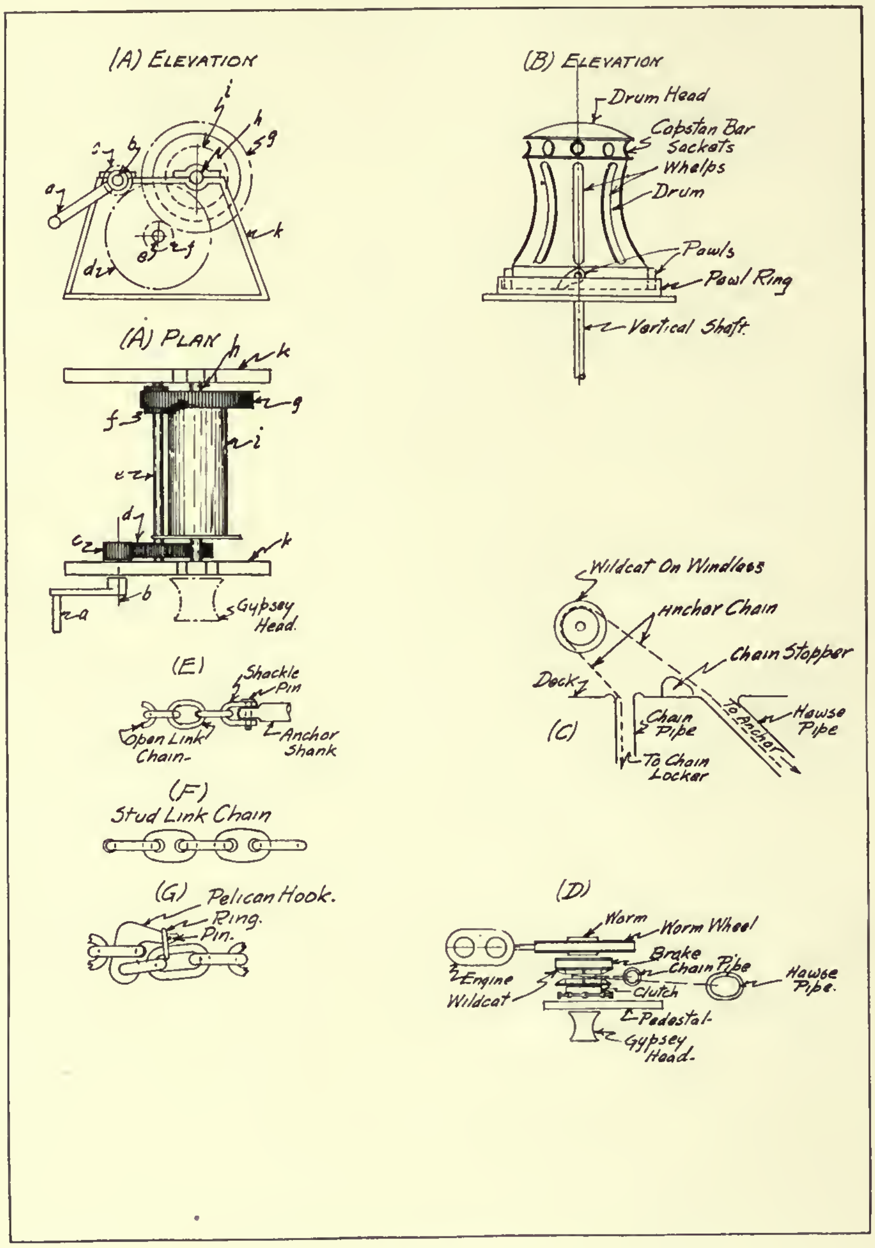


FIG. 88—WINCHES, WINDLASSES AND GROUND TACKLE

Winches for Hoisting Cargo

Winches are machines for hoisting cargo and are fitted at the base of masts or derrick posts close to hatches. They may be hand, steam or electric driven and consist of one or more drums attached through mechanical gearing.

Fig. 88-a is a hand powered winch for small boats. The power is applied by turning crank (a) which is keyed to shaft (b) and also carries the pinion (c). The spur gear (d) is keyed to the countershaft (e) which also carries the pinion (f). The shaft (h) has spur wheel (g) driven by the pinion (f) and carries the drum (i) on which the hoisting rope is wound. The entire mechanism is supported by bearings in the pedestal castings (k) which are bolted to the deck through a bed plate. Gypsy heads may be fitted on each end of the drum shaft (h) and are used for swinging the boom. If the winch is to be used for topping the boom an additional drum is necessary to take the lead from the topping lift. If the winch is of higher power, driven by gasoline, steam or electricity, the principle is similar to this but the crank (a) is replaced by the crank pins of two horizontal steam cylinders, or a worm shaft driven by an electric motor or gasoline engine. A countershaft with clutch may drive

the winch from the main propelling engine. The winch is controlled by throttles or controller for regulating the applied power and has brakes for holding the drums. A clutch is fitted to the shafts of all drums if more than one is on the winch.

Capstans (Fig. 88-b) are used for handling towlines at the towing bitts or on the forecastle and for warping the vessel. They consist of a drum with whelps driven through a vertical shaft by an engine or motor usually below decks. They may be hand operated by inserting long wooden capstan bars into the sockets shown and having the crew push these bars when walking around the barrel. Small electric capstans with motor inside the drum may be obtained and work very satisfactorily.

Windlasses are used solely for anchor handling and warping the vessel. They are hand operated and fitted in combination with mooring bitts on small vessels. Windlasses with independent motor or engine are used on large vessels. The location is near the bow close to the hawse pipes.

A typical windlass has a horizontal shaft supported by bearings in pedestal castings. Gypsy heads are usually keyed to the outer ends of this shaft and revolve with it. One or two "wildcats" are on the horizontal shaft inside of the pedestal bearings and a screw operated cone clutch thrown in or out by a wheel causes the wildcats to revolve with the horizontal shaft or to remain stationary while the shaft turns. A brake on each wildcat holds it fast if desired. The main shaft is driven through a worm and worm wheel by a motor or engine which may be close to the windlass on the same deck or, in large vessels, on the deck below.

Fig. 88 (c) and (d) is a diagram showing a typical windlass in relation to the mooring or anchor gear. The anchor chain is stored in a compartment called the "chain locker" at the forward end of the vessel. The inner end of the chain is securely shackled to a ring or pad eye on the bottom of the chain locker. If there are two anchors it is necessary to fit a central bulkhead in the chain locker so the two chains will not become tangled. The chain leads up through a chain pipe which pierces the deck and has a removable wooden or sheet steel cover fitting snugly around the chain to keep water out of the chain locker in wet weather.

The chain then passes around the wildcat, which is merely a large chain sheave with jaws fitting the links. The wildcat may be on a horizontal shaft as shown or it may be on a vertical shaft under a capstan. From the wildcat the chain passes to the upper end of the chain pipe in large vessels, or through a chock on deck at each side of the bow in small vessels. A chain stopper is installed between the wildcat and hawse pipe on large vessels, to prevent the chain from running out too rapidly. The chain is attached to a shackle on the upper end of the anchor shank.

Anchor chain consists of links, the size of chain being designated by the diameter of the bar of which the link is composed. Figs. 88-(e) and (f) show "open link" and "stud link" chain, the two types universally used. A shackle with its pin connection to the anchor is shown by (Fig. 88-e). Sometimes provision is made for letting go the anchor chain in an emergency by a "pelican hook" (Fig. 88-g).

Hawse pipes are of cast iron or steel and consist of a deck ring casting to which is rabbeted the pipe itself. The deck ring is extra heavy on the after side to allow for wear by rubbing from the anchor chain. Doubling plates and closely spaced beams with carlings form a foundation under the deck ring casting. The holding down bolts are countersunk on the upper ends with grommets and washers under the nuts.

The lower end of the chain pipe is bolted or riveted to the hull by an elliptical flange with rolled face and the frames are extra strong at this point. Usually one or more of the transverse frames are cut to pass the hawse pipe, in which case short local stringers join the cut frame ends to the adjacent intact frames. A doubling plate is fitted under the shell flange of the hawse pipe, to strengthen the hull and provide against wearing away when hoisting or lowering the anchor. All airports near the anchor should have heavy bars outside to protect the glass from breakage.

Hawse pipes are not usually fitted on vessels less than 125 feet long, in which case the anchor chain passes through a mooring chock (Fig. 89-f), passing through the bulwark or forecastle side. If there is no bulwark, an open chock usually with a roller on a bronze pin (Fig. 89-g) is used to hold the anchor chain in position. In small vessels the anchor is attached to a wire rope or manila hawser instead of to chain.

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CAMOUFLAGED 110-FOOT UNITED STATES SUBMARINE CHASER

Over 400 of these boats were built since June, 1917, mostly by yacht and boat builders in the United States—They penetrated every part of the war zone, and made a wonderful record for seaworthiness and reliability

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A southern Alaska canning company's herring seiner and cannery tender

CHAPTER XV

Anchors—Bitts—Towing—Deck Drainage

ANCHORS are varied in type (Fig. 89-c-d-e) and are of cast or forged steel. Stocked anchors (Fig. 89-e) were originally the prevalent design. They consist of a metal shank with two curved metal arms terminating in strong triangular flukes. The upper end of the shank has the usual shackle for attaching the anchor chain and just below this is a stock of wood or bar iron, turned at right angles to the plane of the arms. This type of anchor is still considerably employed in vessels without hawse pipes.

An anchor davit must be used to lift this anchor on deck by means of a block and falls which is hooked to the "catting shackle," located at the anchor's center of gravity on the shank. The anchor is lashed securely to wooden chocks on deck when not in use. Sometimes a "billboard" or sloping platform is built on each side of the deck close to the bow. The stocked anchor is then lashed in place on the billboard and arranged to launch itself when a tripping device is released by pulling a lanyard. With this arrangement the anchor chain may lead from the anchor down over the vessel's side to a hawse pipe, through which the chain returns up to the windlass on deck. This, however, is much less convenient than using stockless anchors as below described. Whenever a hawse pipe is fitted, and sometimes even in small vessels without this pipe, a stockless anchor (Fig. 89-A-C) is used. This is the most prevalent of anchors at this writing. It consists of a forged shank with chain shackle at upper end, catting shackle at point of balance and a pin at the lower end. The flukes are shaped as shown with a swelled body connecting them and hinged about the pin. The flukes can open to 45 degrees on each side of the shank but are prevented from swinging beyond this by stop lugs on the fluke body. Stockless anchors are housed in the hawse pipe when not in use (Fig. 89-A).

Mushroom anchors (Fig. 89-D) are mostly used on small vessels and lightships. While their holding powers are perhaps the most certain it is difficult to stow them in the larger sizes because of their bulk. Lightships have the hawse pipe through the stem at or near the water line and the anchor can consequently be housed securely without fouling the ship's side. A hole cut in the dished blade serves to take the hook on the catting tackle.

The size of all anchors is specified by stating their weight in pounds.

Bitts for Towing and Mooring

Bitts or "bollards" (Fig. 90-A to D) are mainly used for towing or for mooring large vessels. Towing bitts are usually of cast steel (Fig. 90-A) with two posts on opposite sides of the vessel's center line. Strong bolts through the base secure the bitt to a heavy foundation under the deck. If fitted on a steel deck the deck plates should be increased in thickness or have a doubling plate under all bitts. On wooden or concrete decks a pad of timbers from 1½ to 3 inches thick should be under the bitts. The metal posts are cored out to decrease the weight.

Sometimes in small vessels the towing bitts are single or double hard wood posts with rounded corner edges. These wooden bits extend through the deck planking to the floors or keelsons and are through bolted to a heavy deck beam fitted against their after sides.

Large tugs may have a mainmast to which is secured a strong steel hook for towing. The hawser is looped over this hook and a hinged "keeper bar" is closed over the hook opening so the hawser cannot jump off the hook.

The towing bitts thus far discussed are located aft of the deck house or trunk and are used only when the towed vessels are astern of the one doing the pulling.

Three precautions should be taken:

(a) Locate the bitts as far forward as practicable so that the vessel will not be difficult to steer if the tow "yaws" or swings to one side or the other.

(b) Make the deck under the towing bits extra strong.

(c) If the vessel does much towing in open water, have the bitts high enough above the deck so that the hawser may not bear too heavily on the rail at the stern, in which case following seas would come on deck.

Large deep sea tugs have a towing engine which automatically winds or pays out the hawser

TUG FOR GOVERNMENT WORK

A type of boat in which towing and deck equipment is given particular attention.

keeping it at a constant tension. They also have a yoke or frame of structural or cast steel which guides the hawser to the bitts or towing engine and keeps it raised above the stern rail.

The towing hawser when not in use may be coiled on the ash grating over the rudder quadrant at the after end of the deck, or it may be reeled on spools under an overhang of the deck house top, thus being kept out of the weather. All power workboats should have towing bitts and hawsers for use in emergency.

On the western rivers of the United States the towboats having stern paddle wheels push the barges which are securely lashed together and "stacked" against the wide forward deck. Two strong posts called "stack knees" (Fig. 90-E) brace the towboat bow against the nest of barges.

In harbors and fairly crowded waters the barges are towed alongside of propeller-driven power boats and "side bitts" (Fig. 90-B and C) are fitted at about one quarter of the vessel's length from the bow and stern at each side of the deck. With a high bulwark rail the bitts are as in (Fig. 90-B), the rail timber being widened locally to embrace them. Flanges on the bitt casting provide for bolting securely to the rail, bulwark and deck. Sometimes the bitt has only one post instead of two as shown and the castings are always cored out for lightness.

With a low bulwark rail or an open pipe rail, ordinary mooring bitts (Fig. 90-C) may be used for towing. In small wooden power boats the side bitts may be hardwood posts through the deck and securely bolted to the framing, clamps, etc.

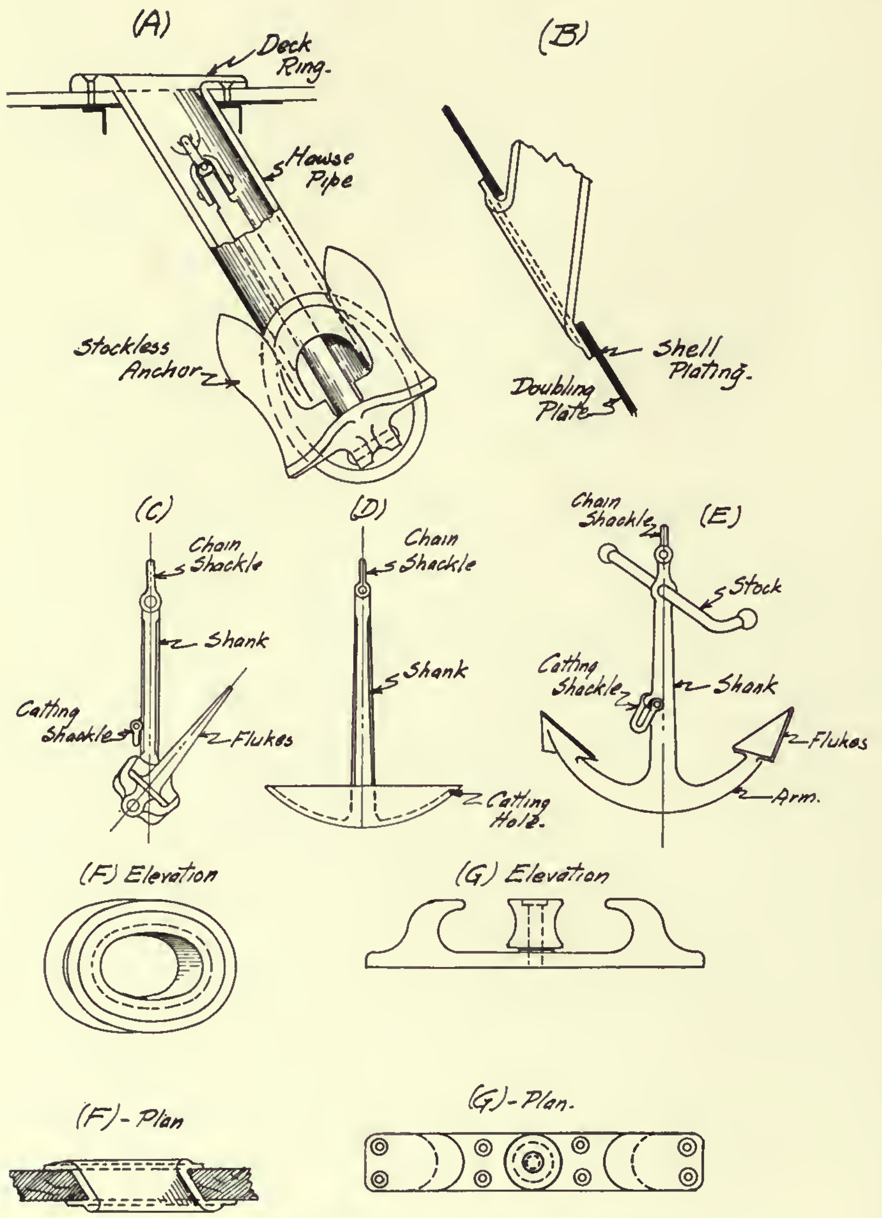


FIG. 89—ANCHORS, CHOCKS AND HAWSE PIPES

A set of bitts are usually located on the deck center line near the bow, for riding at anchor or towing when backing away from the vessel being pulled. These bitts of steel or wood usually have the windlass secured to them in vessels up to about 130 feet long. Larger vessels have an independent windlass.

Niggerhead on Tugboats

Finally the practice of extending the stem or apron up to form a "nigger head" (Fig. 90-D) is common in tug boats. This may be of steel bolted on top of the deck and extending above the rail, or of wood as shown on the sketch. The size of a bitt is indicated by the diameter of its posts.

"Cleats" or cavels (Fig. 91-A) are used for securing mooring lines on deck or for running lines and lanyards on spars in the rigging. They are of cast steel or cast iron and their size is stated as the length in inches from tip to tip of horns. When on deck they are located at the quarters just inside of the water way or the deck margin.

The lines lead from the cleats on the mooring bitts through "fairleaders" or "chocks" (Fig. 89-F and G) (Fig. 91-B and C). "Mooring ports" or "Bulwarks Chocks" are similar to Fig. 89-F, but usually lead straight through instead of at an angle as shown for this special one which is at the bow.

Open chocks (Fig. 91-B) are usually one forward and aft of each mooring bitt or cleat. Closed chocks (Fig. 91-C) are less frequently used due to the difficulty of passing lines through them. They were designed to prevent the line from jumping out.

Roller Chocks on Large Vessels

Roller chocks (Fig. 89-G) are mostly used in large vessels and have been previously described. They are apt not to function if care is not taken to keep the roller well oiled and the pin clean. Roller chocks are sometimes fitted on top of the rail aft and the towing hawser led through instead of being free to slide on the rail log from side to side. If the towing hawser rests on the wooden bulwark rail in towing, there should be two half round or half oval iron bars on top of the rail to prevent excessive wearing of the wood. These guard irons are fastened to the rail log with countersunk head screws.

Scupper Ports for Draining Decks

Decks and housetops exposed to the weather are provided with means for draining the rain or sea water by "scuppers" and "freeing ports."

Scuppers are openings in the deck

at the low points. They consist of a deck casting with a slotted bronze strainer and have a pipe leading down which carries off the water. Light superstructure decks and house tops have the scupper pipes discharge onto the lowest weather deck. The downcomer pipes are of copper or lead, from 1 to 2 inches in diameter and spaced at intervals of 6 or 8 feet around the edge of the deck. Deck house and trunk tops have the pipes close to the house sides and turned outward at the bottom ends. Light upper decks with wide overhangs have the scupper pipes close to the stanchions supporting these decks at the vessel's sides.

The lower weather deck in small boats is drained directly through long shallow ports cut into the log rail. If there is a ridge at the deck margin, caused by the deep margin planks, the waterway thus formed is drained by scupper openings with strainers. Pipes lead from these openings down into the hold and out through the vessel's sides. The main deck scuppers in steel vessels are usually elliptical to fit between the waterway angles and still be large enough to carry off the water. The lower end of the scupper pipe at the ship's side has a casting with a projecting lip and a flap valve to prevent sea water from coming on deck through the scuppers. If scupper pipes have right angle turns in them, there is a screwed plug at each corner for cleaning out purposes.

Freeing ports are large openings in high bulwarks to quickly free the deck of water which comes aboard through waves. The ports sometimes have a hinged flap opening outward, but modern practice is to just cut a large opening and stiffen the edges with a bar. A grill of iron rods is fitted over such open ports.

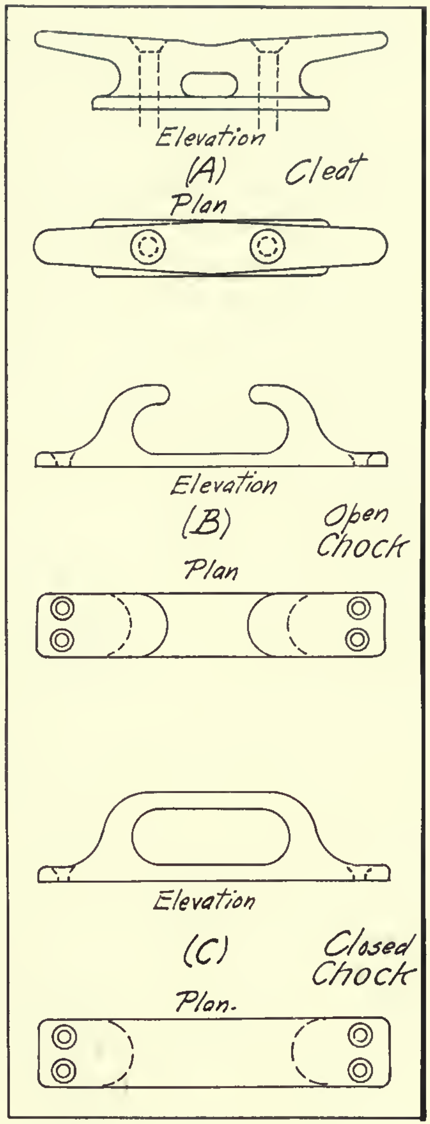


FIG. 91—CHOCKS AND CLEATS

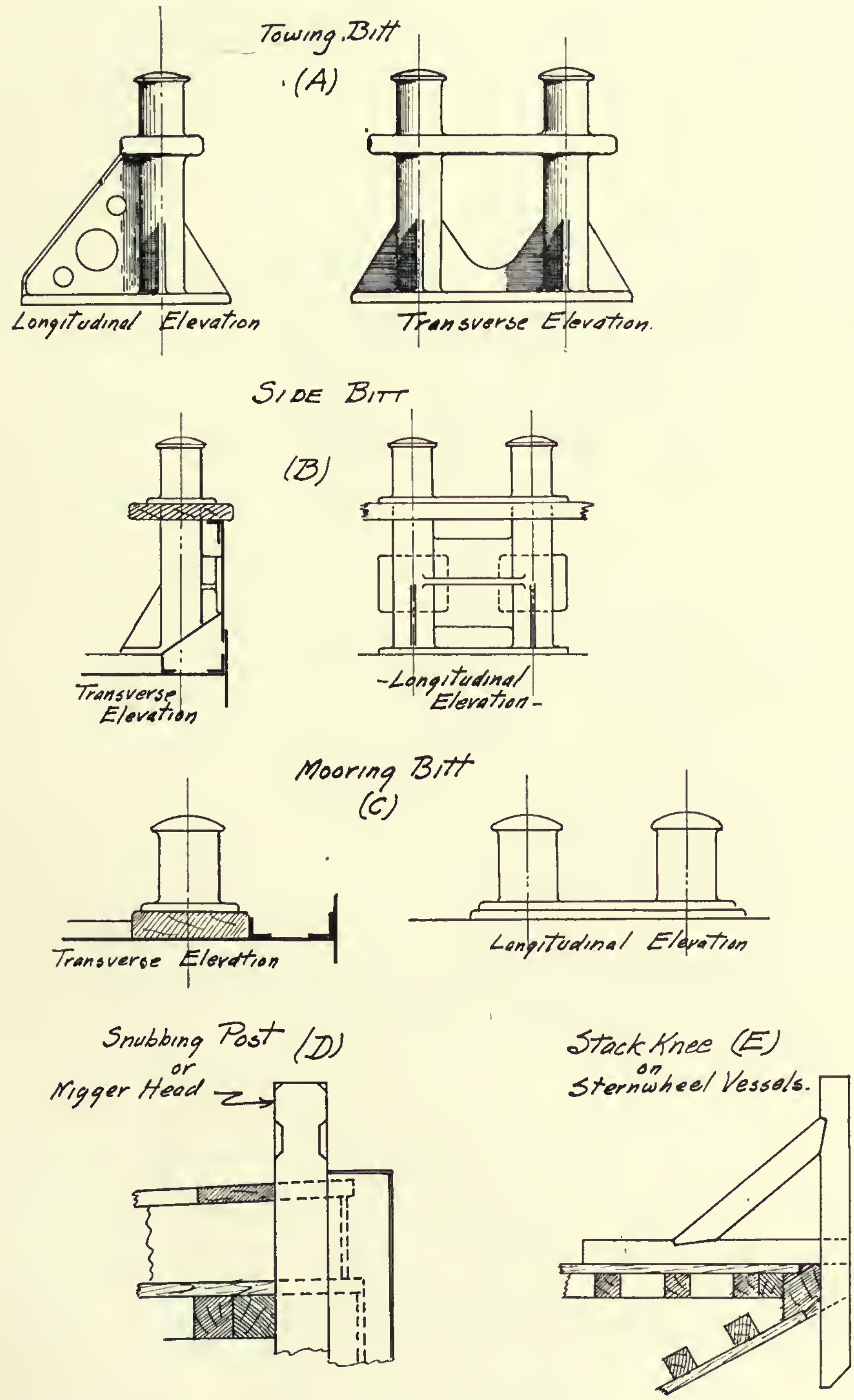


FIG. 90—TOWING BITTS AND KNEES

Typical "Handliner" Power Fishing Boat

Fleet of Seine Fishermen and Handliners at Boston Fish Pier.

Crew Opening Mussels and Baiting Trawls. There are 400 Hooks to Each Tub.

Unloading a Catch at the Fish Pier.

CHAPTER XVI

Tanks—Auxiliary Machinery—Quarters

TANKS may be used for carrying liquid cargo, fish, fuel, potable (drinking) water, lubricants, and to afford a storage hydrostatic head in gravity plumbing or heating systems.

Large steel vessels have parts of the hull especially constructed to form cargo, fuel and drinking water tanks. Such construction has been considered in previous articles. Concrete vessels also have their tanks formed by the hull.

Wooden vessels are not used for liquid cargo to any extent. While large tanks have occasionally been built in such hulls by calking the wooden ceiling and bulkheads, the practice is not considered advisable because the water is acting on both sides of the hull structural surface so that deterioration is more rapid.

As a rule the tanks in wooden hulls are separate watertight steel compartments. These may have flat sides, properly formed to fit into the hull and re-enforced by stiffening plates, or else they may be cylindrical drums which are riveted or welded.

Built-in tanks have their sides, top and bottom re-enforced by angle stiffeners at two-foot intervals, while transverse and longitudinal swash diaphragms spaced six to twelve feet apart, prevent excessive motion of the liquid contents. Swash plates have holes to permit flow of the liquid through them but not enough metal is cut away to prevent their reducing the "wash." The flat heads are flanged to the side plates and the plate edges should be planed before calking.

Heavy transverse foundation timbers or "cradles" support the tanks as indicated while chocks at the sides and ends prevent lateral motion. For painting or coating of tanks see Article XII.

Cylindrical tanks are composed of a rolled shell with a lap riveted longitudinal seam and "bumped" or "dished" heads. Some tanks are "seamless welded," meaning that they consist of two deep capsule shaped ends with a circumferential seam at the middle of the length. This seam is welded and re-enforced by an external butt strap, also welded on. The dished heads have a spherical form and may be welded or lap riveted to the cylinder shell.

All tanks should have filling pipes, drain pipes, gage pipes, vent pipes and manholes or hand holes.

Vent pipes should lead to the outside air in petroleum tanks and should have a return bend at their upper end, fitted with a wire mesh screen. Naturally the vent should connect to the highest point in the tank.

Filling pipes may lead to screw plates in the deck arranged to receive the contents of the tank through a hose or a large funnel with strainer. If such a pipe is too long there is danger of its breakage through unequal expansion and vibrations of the hull and tank top. Therefore, the filling pipe sometimes ends just below the deck plug and has an independent cap. Such a filling connection may serve as a vent for water tanks if small holes are drilled just below the cap.

Gage connections vary according to type of measuring instrument used and are sometimes dispensed with if the contents are measured through the filling pipe by means of a calibrated sounding rod. In this case a small re-enforcing plate should protect the tank bottom where the rod strikes. The kind of gages depend upon size of tank and accuracy of measurement desired. Gage columns of the simple tubular glass type are subject to danger of breakage and should be protected by vertical rods or a vertically slotted metal pipe around the glass columns. Reflex gages consist of heavy plate glass in a metal frame. The front glass has vertical "V" grooves in it and causes the liquid to appear dark as it rises between the two glass plates. Float gages have a twisted metal ribbon extending from a horizontal dial in the tank top to the bottom of the tank. The upper end of the ribbon strip has a needle attached. A small cork or hollow metal float slides up or down the ribbon as the level of liquid varies, but the float is prevented from turning by vertical guide rods. As a result the ribbon turns the pointer as the float rises or falls. Pneumericators are frequently used in large tanks and afford the advantage of having the tank contents observed at some remote point.

Drainage connections are for suction pipes to the point at which the tank contents are utilized or discharged. Sometimes a screw plug is fitted to a flange at the lowest point so that the tank may be entirely emptied and dried out.

Sediment chambers may be fitted to fuel tank discharge lines to catch and retain impurities or foreign matter. The suction is at a point near the top of such chambers and a clean out plug is at the bottom. This precaution is not considered necessary if the fuel is strained through fine copper screen as the tank is fitted.

All pipe lines should have offsets or bends to permit of expansion without

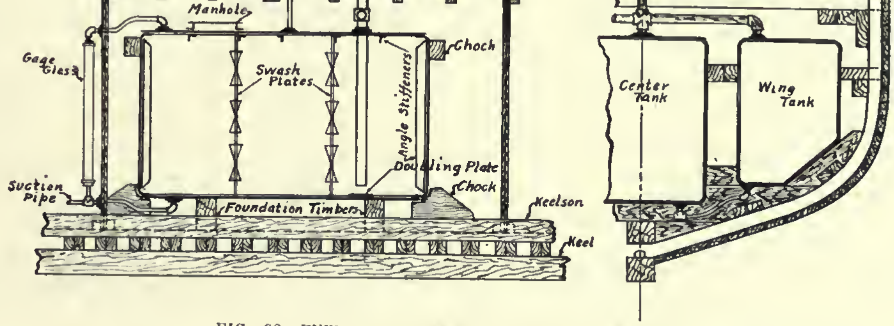


FIG. 92—FUEL OR WATER TANKS, FLAT SIDE TYPE

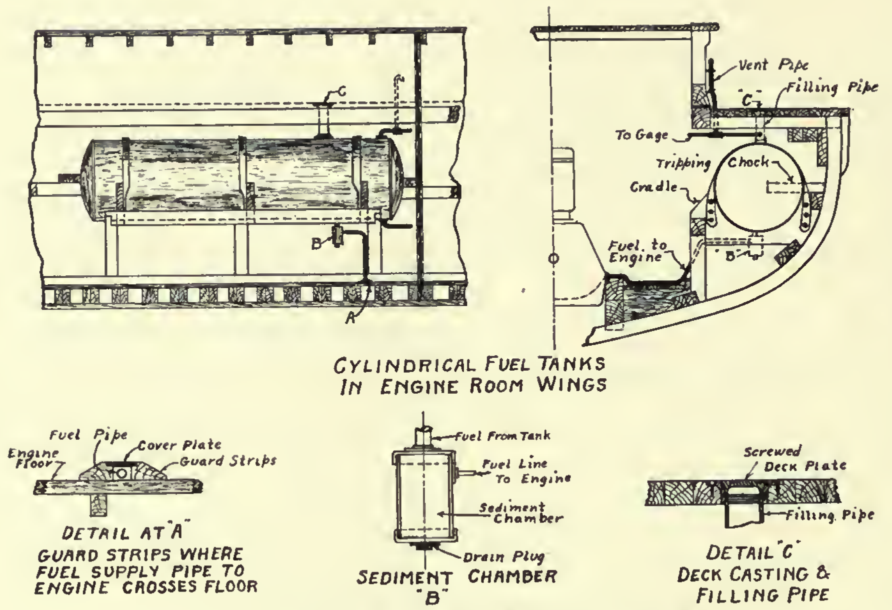


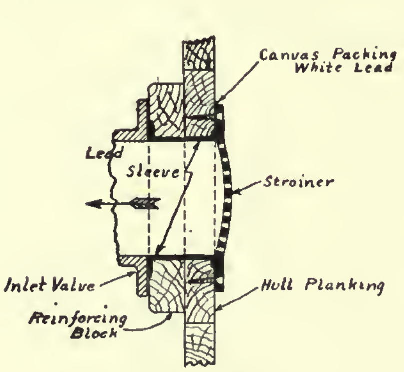
FIG. 93—INSTALLATION AND EQUIPMENT OF FUEL TANKS

straining or breaking the pipes and connections. Valves and pipes should be within access at all times and clearance around the outside of tanks should be sufficient to permit of cleaning and painting the tanks and surrounding hull structure. No pipes should be threaded to the tank plating, but riveted flanges of cast steel or heavy plating should take the screwed connections.

Auxiliary machinery for hoisting purposes has been discussed in a previous article. That for pumping, lighting and miscellaneous purposes is located in the engine room if possible and is usually a part of the engine.

Electric Generating Sets

Electric generating sets vary from one-half to five kilowatts capacity and are driven by independent internal combination engines or by a silent chain or belt from the main engines. Independent sets of standard commercial makes are preferable, since they do not require running the main engine if light is desired when the vessel is not under way. The capacity of the set varies with the number of lights on the vessel. A storage battery is usually "floated in the line" from the generator, so that it becomes automatically charged and may afford current when the generator is idle. A switchboard of slate or other nonconducting material is fitted near the generator and has the usual volt meters, ammeters, rheostat, switches, fuses, ground lights, automatic cutouts, etc. The various circuits should be arranged to lead direct from the switchboard and to be independent. This is particularly important in the case of the running lights and the searchlight. A "telltale" should be in the pilot house so the helmsman can see that the running lights are in order. All running lights if fitted for electric equipment should have duplicate oil lamps which are used in case of emergency.



DETAIL OF INLET CONNECTION FOR PIPE SUCTIONS FROM SEA

The number and location of running lights are regulated by the Bureau of Navigation, Department of Commerce, Washington, D. C. They vary with the size and type of vessel.

Searchlights may be of the arc or the incandescent filament type. The latter are considered ample for the average small work boat, since their power consumption is less and they are not expensive or complicated.

Lights in the living quarters should be tasteful and ornamental. Frosted globes add to their attractiveness and soften their glare.

Lights in machinery spaces, passages, holds and on deck are in vapor tight fixtures and should be guarded by wire. In the engine room, cargo holds and tank spaces, plugs should be fitted so that portable hand lights may be connected when needed. The cable for these lamps should be sufficiently long to insure being able to see any point which may require examination or repairs.

If there is electric power at the docks where the vessel ties up, and the voltage of the ship's circuit agrees with that on shore, it is well to fit plugs outside the deckhouse so that current may be taken from the dock lines if the boat is tied up for extended periods.

The wiring on decks and elsewhere except in the living quarters should be in metal conduit, with standard metal junction boxes. Wood molding may be used in the living spaces.

Pumps and Drainage

Piping for the "Pumping and Drainage Systems" has the following uses:

(a) Draining the bilges,

(b) Filling and emptying water tanks,

(c) Providing pressure to plumbing fixtures, fire lines, wash deck connections, etc.

The main engines are usually fitted with two water pumps of the plunger or the centrifugal type, driven from the crankshaft or the camshaft. One of these pumps circulates the water for cooling the engine cylinders. It draws its supply from overboard through a sea connection on the hull, near the turn of bilge. Be careful that this location will provide against danger of stopping up due to the vessel's grounding and that it will always remain below the water. A strainer covers the pipe opening to prevent solids from entering and clogging the pipe line to the circulating pump. A valve in the suction pipe, close to the sea connection, provides for closing off the sea water in case of damage to the pipe line, or if the pump is to be used for draining the bilges.

The cooling water passes from the circulating pump to the cylinder jackets and discharges overboard at or near the water line. Frequently the cooling water discharge pipe is tapped into the exhaust pipe from the main engine.

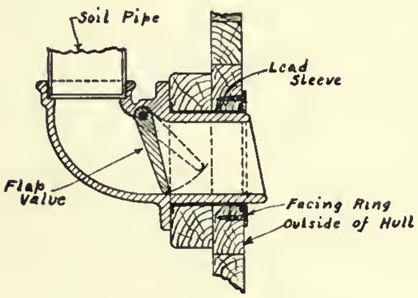
The suction pipe to the circulating water pump may be arranged to draw from the bilges by connecting to the bilge manifold. This gives the boat additional pumping facilities in case of emergency, when the sea injection valve may be closed and the bilge water discharged through the cylinder jackets of the main engine.

The second pump above mentioned is not fitted to all engines particularly in the smaller sizes. It serves as a bilge pump, drawing directly from the bilge suction pipe lines and discharging overboard. It may also be piped to the sea connection which admits water to the circulating pump, and thus used to provide sea water on deck for washing down or fire purposes.

Power tugs from about fifty feet upwards in length usually have an auxiliary gasoline engine which drives a generator and sometimes an air compressor and water pump as well. This pump is piped to the bilges, the fire and deck service and the sanitary service, through a manifold in the engine room.

A hand-operated bilge pump should be fitted on all power boats.

The sanitary system is piped to flush closets, urinals, for water supply to baths, wash bowls and even for cooking purposes, on boats operating



DETAIL OF
SOIL PIPE DISCHARGE
CONNECTION

Note: Drain pipes and Scupper Outlets from levels well above water line need not be fitted with flap valve.

in fresh water. Salt water vessels use sea water for flushing and bathing only, fresh water being taken from the tanks for cooking and potable purposes.

Pressure is provided through an overhead gravity tank which may be on top of the deck house or the cabin trunk. Connections to the sanitary supply tank are a filling pipe, a discharge line, an overflow, a vent pipe and a drain plug. It is essential that the tank be protected against freezing. Boats with a ventilating stack may have the tank in this.

Mention has been made of pipe connections on deck for washing down and fire uses. Brass capped plugs at the sides of deck houses, with hose racks on the bulkheads nearby, should be on boats from about 75 feet long upward. Vessels smaller than this have fire buckets in racks on deck and chemical fire extinguishers, located where readily reached in case of fire.

Fire Losses Are Preventable

The majority of fire losses in power boats are preventable by proper design and the observance of due precaution when in service. Most fires are due to one of the following:

(a) Improper ventilation of the fuel tank and engine room.

(b) Leaks in the fuel pipes and fittings because no allowance is made for vibration and expansion, or the pipes and fittings are inaccessible for repair.

(c) Collection of grease, oil and inflammable gases in the bilges, with no provision for their removal or drainage.

The first of these causes will be taken up under ventilation; the second has been discussed under fuel piping and the third may be avoided as follows. Fit a sheet metal drip pan under all fuel and oil tanks and under the engines. This pan may be of black or galvanized iron or copper, and of width and depth to catch and retain all drip from the machine under which installed. A slight drainage slope should be given the bottom of the pan and there should be a large well or "sump" at the low end, from which the drippings may be pumped, bailed or swabbed.

All water piping may be galvanized wrought iron with malleable screwed fittings. Valves should have composition seats.

Air pumps, supplying pressure for starting the main engines, blowing the whistle, affording a head in the water or fuel tanks when these are low down in the hull, are sometimes driven from the main engine or by the auxiliary gasoline set.

Power boats in northern waters should have some form of heating system. When less than 50 feet long small oil flame heaters, securely fastened to the deck may be in each compartment to be heated. The deck and bulkheads near all heaters should be protected against the heat by a sheet of asbestos board covered with sheet metal.

Larger boats have central heating plants of the hot water or steam type, with piping to the radiators in heated spaces. Such heaters may burn coal or oil and should be in the engine room or the galley. A small galvanized or black iron smoke pipe carries the heater gases to the stack, when such is fitted. Otherwise the smoke pipe projects above the cabin or trunk and has a metal cap or hood to exclude rain water. Sometimes this hood turns with the wind thus increasing the draft by ejection effect.

There should be about one square foot of heating surface in the radiators to each fifty or seventy cubic feet of space to be heated.

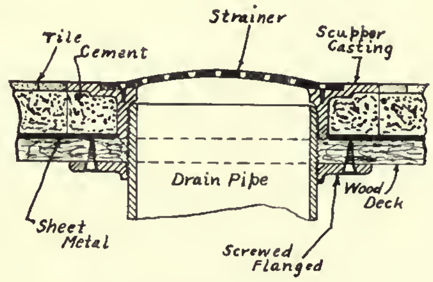
Hot water systems require an expansion tank located in the top of the engine room or the stack. This tank has an overflow connection to the deck outside and is piped to the radiators and to the cool water inlet of the heater. The heater should be below the level of the radiators if possible, so that the hot water leaves the top of the heater, flows upward through the radiators to the expansion tank and then down to the heater again.

A coal bin or fuel tank is located close to the heater.

The heater is provided with the following fittings:

Thermometer,
Pressure gage,
Water gage,
Safety blow valve,
Damper,
Drain plug.

Air relief valves should be on all



DETAIL OF
SCUPPER FROM TILED
TOILET SPACE

radiators and the entire system should be carefully drained through cocks at the low points, in case the vessel is laid up during freezing weather.

Steam heating systems are similar in arrangement and fittings except that the expansion tank is lacking.

In large vessels, thermostatic controls may be fitted in the heated compartments to automatically regulate the temperature.

Radiators vary from ordinary pipe on brackets, to cast iron, pressed steel or brass ones of the upright or the wall type. Pilot house radiators and piping within ten feet of the compass should be brass, because of the effect of iron or steel on the magnetic needle.

Insulating pipe covering should be on all heater pipes, on the exhaust pipes from machinery and on all hot pipes where extreme temperature will endanger personal safety or result in loss in efficiency.

Tubular boilers on large diesel engined vessels sometimes derive their heat from the exhaust gases of the main engines, generating steam for auxiliary engines and for heating.

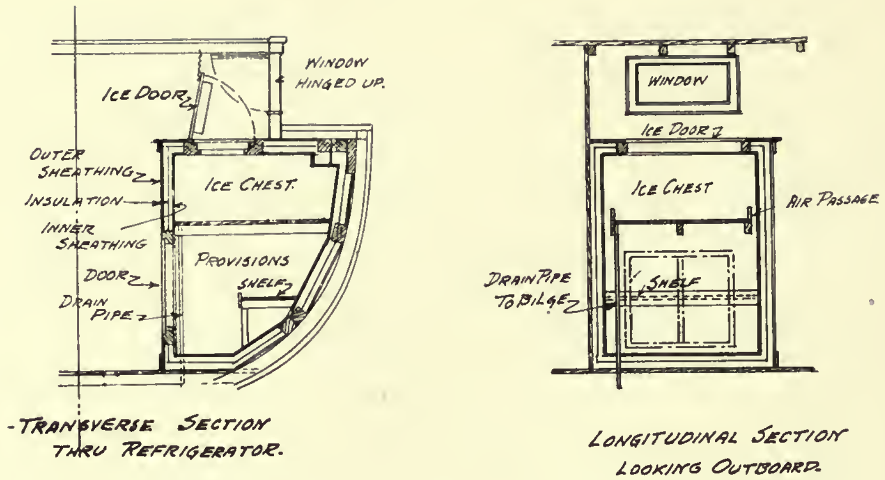


FIG. 95—BUILT-IN REFRIGERATOR IN CABIN TRUNK OF 50 TO 75-FOOT POWER BOAT

Vessels of this type use electrical pumps, winches and other auxiliaries, the current being supplied by a generator driven by a diesel engine.

Plumbing Fixtures

Plumbing fixtures are too often not installed where their presence would introduce low additional cost while affording real comfort and sanitary surroundings. This applies to nearly all power workboats, which should at least have a self-flushing water closet and lavatories with running water.

If the crew is quartered on board it is imperative that bathing and galley plumbing fixtures be fitted; for a clean and well fed crew means a neat and well kept ship.

Water closet bowls should always be located in a well lighted and ventilated space, partitioned off from the rest of the living quarters by odor tight bulkheads. There should be at least one bowl for every twelve or fifteen persons. The discharge or "soil" pipe should be large (at least three inches in diameter). Too much emphasis cannot be laid on this point, for clogged bowls are a cause of dissatisfaction and disgust. The flushing water should be taken from the sea and the bowls located above the load water line if practicable. This will eliminate the necessity for pump type closets if the boat has a sanitary pressure system. Bowls if below the water line, should always be of the pump type.

Urinals are fitted in larger vessels and should be of a type readily cleaned, not subject to clogging.

All sanitary fixtures should be as close to the ship's side and to the source of water supply as practicable. Lavatory and toilet spaces should be easily entered without undue disturbance of the privacy of living quarters.

Water supply pipes may be galvanized wrought iron, with valves having bronze stems and seats. Discharge or "soil" pipes may be wrought iron or lead, terminating in cast iron flap valves at or near the water line on the hull. If the pipes have bends (which should be avoided) there should be a clean-out plug at each turn in the pipeline.

The deck in toilet spaces should never be of wood or other material which tends to absorb moisture and odors. Tiling in cement or plain cement are best suited for such decking. Wooden decks should be protected against the likelihood of moisture getting under the deck covering, by having a watertight sheet lead, zinc or galvanized iron pan fitted tightly all around the compartment and extending at least up onto the bulkheads. This "flashed" metal should extend at least six inches above the top of the tile or cement. Plain cement decks in toilet spaces should have portable gratings of oak or ash.

The corners of all toilet space decks should be generously rounded (coved) and drainage provided at the low corners by scupper openings having perforated brass strainers. Pipes discharge from these scuppers into the soil pipes or the deck scupper pipes.

Where bathtubs or showers are fitted, these should be located apart from the toilet spaces and should have running hot or cold water. The supply for these is usually from the sea, but on salt water ships fresh water is from the ships' tanks and salt water is provided as well.

Lavatories and sinks in galleys or pantries should have spring faucets to minimize waste of water. They discharge into the soil pipes and sometimes into the bilge.

All toilet fixtures above mentioned should be of porcelain enameled iron, with nickeled brass fittings so they can be kept clean and sanitary.

Hand pumps of brass or with brass linings, are fitted to galley sinks from the fresh water supply system.

In some harbors the discharge of waste from plumbing fixtures is prohibitive and vessels navigating such waters require a large tank in the hold. The waste matter from these tanks is forced overboard by compressed air, steam, or a pump for that purpose, after the vessel has got away from the prohibitive waters.

Messing Equipment

Messing equipment is that devoted to feeding the crew, including the storage of unprepared food in storerooms and refrigerators; the preparation of the food in the galley and the serving of the food.

Canned food supplies or those such as rice, beans, flour, sugar, etc., which keep relatively long without refrigeration, are termed "drystores." Lockers or storerooms with shelves and bins for such stores may be located in the hold and should be dry and well ventilated.

Vegetables should be placed in grilled boxes or bins, in the open air if possible but with covered tops. Such vegetable lockers may be located on top of the cabin or trunk to which they are securely fastened. They consist of oak or pine slats with a rainproof hinged top. Vegetable lockers of strong wire mesh are desirable in larger vessels.

Small bins or jars in the galley should be fitted to provide an immediate supply for cooking.

Perishable supplies such as fruit, eggs and other dairy products, meats, etc., are carried in refrigerators. These should be easily reached from the galley and may be either built into the ship or of standard commercial type strongly secured in place.

Refrigerator capacities average from 2.5 to 3 cubic feet of volume for each person for which cold stores are provided.

CHAPTER XVII

Food Storage, Heating and Lighting

SMALL refrigerators in vessels shorter than 100 feet, are usually cooled by ice carried in a compartment within themselves. Larger ones are cooled by refrigerating machines, using ammonia, carbon dioxide, sulphur dioxide, ethyl chloride or dense air as the cooling medium. The smallest of such machines have a capacity of one-quarter ton of ice per day. They are driven by electric or internal combustion motors.

The outside refrigerator walls are of steel or wood, usually tongue and grooved, from ⅞ inch to 1⅛ inch thick. The inside of these bulkheads has a layer of tarpaper or building paper. A layer of insulating material is inside the paper and is from four to eight inches thick. The best of such materials is pure block cork, usually fitted in two layers with the seams staggered. Sometimes a second layer of thick paper is between the two thicknesses of cork, while a final paper coat is always inside the insulating material. Ground pressed cork, mineral wool or even air cells are often used to form the refrigerator walls but these are not recommended. The insulation should be packed tightly and fastened by cement, *not by nails or other metal fastenings which conduct heat.* The inside refrigerator walls are of sheet zinc, porcelain enameled iron, glass, or wood soldered or cemented in place.

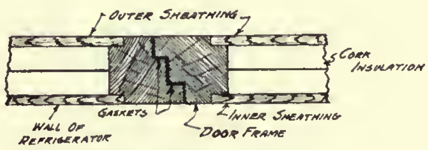
In designing refrigerators remember that cold air from the ice or the cooling coils always settles to the bottom and replaces warmer layers. Therefore, the ice or coils should be at the top of the box to insure circulation. The air in refrigerators should be kept as dry as possible.

If ice is used it is placed in the upper part of the refrigerator on a metal shelf which has pipe drains to the bilges. Air spaces above and at the sides of the ice provide cooling circulation.

Refrigerator doors are double rabbeted with rubber gaskets. Small boats may have refrigerator boxes opening on top located in the holds or under locker seats. A convenient arrangement where there is a separate galley, is to have the refrigerator in one corner with its top just below the windows of the cabin or trunk. The ice and cold stores may be passed through a window directly into such a box. Still larger vessels with galley on the main deck may have a door in the deck house at the refrigerator. Both these arrangements prevent the soiling of interior of the cabin or trunk when stocking up the ice box.

Drystores

Canned food supplies or those such as rice, beans, flour, sugar, etc., which keep relatively long without refrigeration, are termed "drystores." Lockers or storerooms with shelves and bins for such stores may be located in the hold and should be dry and well ventilated.



SECTION THRU FRAME OF REFRIGERATOR DOOR.

FIG. 96—CONSTRUCTION OF REFRIGERATOR DOOR

Vegetables should be placed in grilled boxes or bins, in the open air if possible but with covered tops. Such vegetable lockers may be located on top of the cabin or trunk to which they are securely fastened. They consist of oak or pine slats with a rain proof hinged top. Vegetable lockers of strong wire mesh are desirable in larger vessels.

Small bins or jars in the galley should be fitted to provide an immediate supply for cooking.

Galley ranges vary from small blue flame kerosene stoves with one or two burners to large ranges burning oil or coal. The small stoves may be in a drawer lined with sheet metal so that the stove is out of the way when not in use. A small fuel tank is usually fitted to such kerosene stoves and sometimes there is a small hand operated air pump to generate pressure in the tank.

Oil burning ranges use fuel oil of heavy gravity and are used only in vessels with diesel engines or in large vessels. The burner atomizes the fuel by air, steam or mechanical means.

Coal ranges are usually fitted in vessels above 100 feet long. There is a fuel locker close to such ranges and they have a tank attached for heating water. This may be piped to the hot water sanitary system if desired.

All ranges are securely fastened in place by screws, angle lugs, or stay rods. There is a nickeled guard rail on top of the ranges to prevent pots and pans from sliding off.

The deck and bulkheads near ranges are protected against the heat by sheet asbestos covered with galvanized iron.

A stack over the ranges carries off gases and odors.

Dressers for Food

Beside the ranges, sink and plumbing thus far mentioned, galleys have dressers for preparing the raw food for cooking. This dresser may serve as a mess table with hinged stools attached or arranged to stow underneath. Lockers and drawers under the dresser and the sink afford stowage for cooking utensils. Racks and shelves on the bulkheads are provided for the dishes. These shelves have covered fronts with a Y-shaped slot in them so that dishes are put in at the top and cannot slide out when on the shelf. Cups and other china dishes with handles are hung from hooks underneath the shelving.

The decking of galleys in small boats may be linoleum, while in larger ones it is usually tile.

When meals are not served in the galley there may be a saloon, although this is not common in workboats.

Berthing accommodations are not needed in boats which have short runs but it is well to provide sleeping facilities for emergency use. To this end hinged bunks of galvanized pipe may be installed in the forehold or even in the wings of the engine room. The berths may have lashed canvas or spring bottoms and mattresses. Bedding is stored in lockers nearby.

Sometimes cushioned seats or "tran-

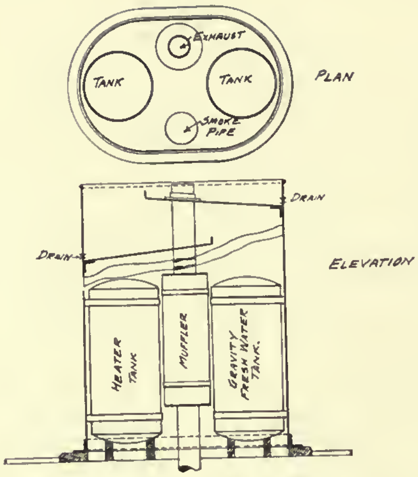


FIG. 97—INTERIOR OF STACK WITH TANKS

soms" are arranged to slide out forming berths when extended. The cushions are designed to fit the extended transom and serve as mattresses. Cushions are filled with hair or buoyant fibre such as kapok. They may be covered with leather, imitation leather or velvet. The imitation leather is recommended as being durable and best for ordinary workboats.

Lockers, drawers and shelving should be provided wherever possible by utilizing unoccupied corners or spaces under berths and seats.

Means of Ventilation

The usual means for ventilation are: (*a*) Cowl ventilators, (*b*) mushroom ventilators, (*c*) wind chutes, (*d*) vent pipes or "goosenecks," (*e*) skylights and hatches.

Cowl ventilators may be fixed or portable and are arranged to be turned 'into the wind" by shafting and gears operated from below or by handles on the cowl itself. They are of sheet iron, galvanized or painted. Small cowls on yachts are sometimes of polished brass. The cowl is mounted on a fixed trunk fastened to the deck by an angle ring. This trunk may extend to any desired distance below the deck and the part below the deck ring may be circular or rectangular. Sometimes it is necessary to offset the trunk below decks so it will not prove an obstruction. The cowl opening is usually twice the diameter of the ventilator trunk and the upper edge projects slightly beyond the bottom of the opening. The metal forming the cowl is bumped and welded or riveted to shape. A split pipe or half round bar re-enforces the edges of the cowl opening.

Mushroom Ventilators

Mushroom ventilators are not "wind catchers" as is the case with the cowl type. They are merely "up comers," meaning that they release impure air but do not admit a fresh supply. They consist of a short pipe fastened to the deck with an angle ring. A screw down cap covers the top of this pipe and seats on a watertight rubber gasket or a ground joint. A central rod with acme or square screw threads in a guide is turned from below by a handwheel or crank, thus raising or lowering the cap. The cap projects over and down around the outside of the pipe, so the vent may be opened slightly in rainy weather. Mushroom vents may be of cast steel or bronze. They are usually fitted over toilet spaces or living quarters where mild circulation of the air is preferable to

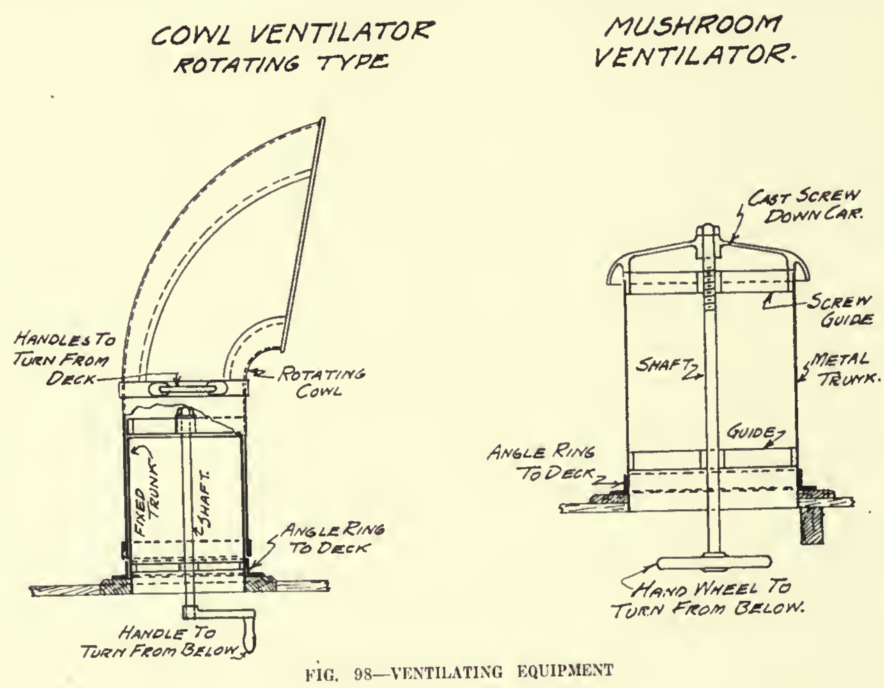


FIG. 98—VENTILATING EQUIPMENT

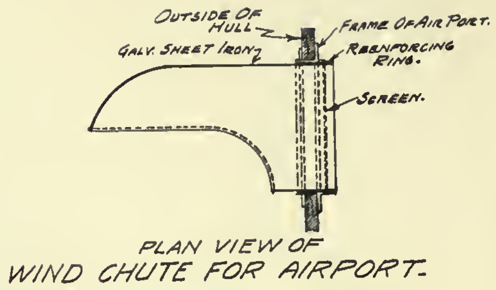


FIG. 99—VENTILATING EQUIPMENT

the direct draft afforded by the cowl type.

Types of Windchutes

Windchutes are of two types; the canvas ones for ventilating holds and other spaces not requiring permanent vents, and the "airport type" which may be used in living quarters.

Canvas windchutes are used in cargo vessels and are simply a long canvas trunk which has an opening near the top. Wing flaps at the sides of the opening help catch the air and force it down through the trunk. The entire canvas windchute is suspended from the mast or rigging by its hooded top and the lower end passes through a hatch into the compartment which is being aired out.

Airport windchutes are of galvanized sheet iron, scoop shaped and designed to be pushed through open airports so that air will be deflected laterally into the compartments of the hull. They sometimes have screens at their inner ends.

Ventilators of various types are sold by ship chandlers in stock sizes.

Vent pipes or "goosenecks" are placed over tank spaces and consist of standard pipe extending above the deck with a return bend at the top. A standard pipe flange connects the lower end of the pipe to the deck.

Forced ventilation is employed on large vessels but not in the conventional power workboat. Such a system has a central blower plant taking air from vent cowls and forcing it to remote spaces in the hull through sheet metal ducts or conduits.

A few of the cardinal principles of ventilation might well be discussed and should be borne in mind when designing power workboats.

First: Warm and impure air is lighter than cool fresh air. Therefore, the supply ventilator trunks should lead well down into the ventilated compartment, while exhaust vents open from the highest points therein. Skylights form good exhaust but poor supply ventilators.

Second: The motion of air currents

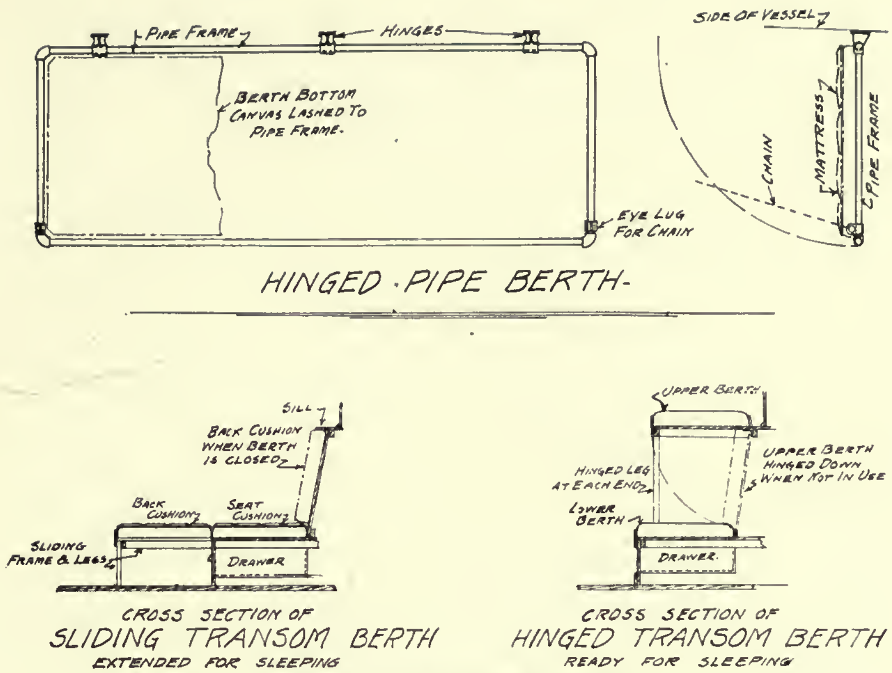


FIG. 100—PIPE AND TRANSOM BERTHS

inside the hull is from aft forward so that supply vents should be at the after end of compartments and exhaust vents at the forward ends.

Third: A mild air current well distributed is more effective than a strong current which is local. Do not forget the corners of compartments and see that the circulation is diagonally upward by staggering the supply and exhaust vents about the compartment's centerline.

Fourth: Gasoline fumes are heavier than air and tend to accumulate in the bilges. Arrange for circulation low down in engine or fuel tank spaces by using an open rather than a ceiled type of structure.

MARY P. RUTH, POWER FISHING SCHOONER

Owned by Cape Ann Cold Storage Co. Equipped with 80-horsepower Wolverine engine. Under command of Capt. Patrick Murphy. This has been one of the most successful craft in New England waters

CHAPTER XVIII

Painting Structure and Sheathing

MEASURES must be taken to protect a boat's structure against the various elements tending to cause deterioration. Wood will decay or be attacked by marine growth and animals. Steel will corrode, decompose by electrolic action or become fouled with marine growth.

First consider briefly the causes and prevention of decomposition in wood. Decay is brought about by microscopic plants called "molds" or "fungi." These tiny organisims grow in the wood fiber as parasites, and their growth is aided by oxygen, water, heat and food, just as in the case of other plants. If wood is kept absolutely dry or constantly submerged in water, it will not decay. If the wood is in a moist atmosphere at ordinary temperatures, it will decay rapidly. If moisture is held in the wood and cannot escape (as when green timber is painted) decay will set in. Sapwood decays more rapidly than that from the heart.

Different Forms of Decay

Different forms of decay are "dry rot", "wet rot", "sap rot", "brown rot", and "blue stain". The latter is not seriously detrimental to strength of the timber and occurs in the sapwood of pine or other evergreens. Such timber is treated by dipping into a solution of 5 per cent solution of carbonate of soda heated between 130 and 150 degrees Fahr.

Decay which exists in the heartwood of living trees, ceases when the tree is cut and does not spread to other sound pieces of wood nearby.

Softwoods which are exposed to the weather wear away. This is known as "weathering."

Where the Teredo Works

There are small marine animals of various kinds in the salt waters of warm climates which attack wood by boring. The teredo worm is best known of these. It has a hard horny head, a long body and a feathery tail of gills. When it has penetrated the surface of a timber, the teredo works along the grain and does not cross seams which have been tarred or calked. Fresh water kills the teredo worm and vessels are sometimes taken into rivers to eliminate the pest. When properly sheathed with metal, hulls are not attacked by the teredo or that other insect, the wood louse (limnoria). The teredo is not found in cooler salt waters (temperatures below 55 degrees), nor in brackish waters.

The wood louse is found along the coasts of New England, the Gulf of Mexico and the northern Pacific states. It lives only in pure salt water. Dirty water will kill it.

How to Prevent Decay

Prevention of decay in timber has its initial step in seasoning or drying out the moisture from the green wood. Green wood contains from half to three-quarters of its total weight in water. Seasoned wood (air dried) has from 10 to 20 per cent of its dry weight in contained water. This reduction of moisture content lessens the tendency for fungi to grow and assures a minimum of shrinkage and warp after becoming part of the vessel's structure.

Timbers being air dried have a tendency to split or "check." This is minimized by painting or creosoting the ends of the logs, or else by driving "S" shaped wedges about ⅛-inch thick at the base onto the log ends. Small timbers are sometimes put into a concentrated salt solution where they remain from a day to a week to prevent their checking while seasoning. They may be dried in bone charcoal which also prevents checking.

Kiln drying is usually done in a large heated and ventilated building through which the lumber passes in successive steps. It comes in at one end as green wood and leaves at the other end of the building in seasoned condition. Soft woods can be dried more rapidly and at higher temperatures than hard woods, without loss of strength.

Seasoned timber after incorporation in the hull structure is protected by saturating with various compounds to exclude moisture and decay or by coating with elastic waterproof pigments. The saturating process is little used in boat building, the preservative chemicals mostly employed being "creosote", chloride of mercury and chloride of zinc.

Creosote is Best Preservative

Creosote (creosote oil or dead oil of coal tar) is the best of these preservatives. Owing to its penetrating odor it is only used on vessels where the cargo (if subject to taint) and the living quarters are remote from the treated timbers. Vessels such as shallow draft lighters or self-propelled barges, which do not carry cargo in the holds, may be creosoted. The wood should be cut and trimmed to fit before being treated. It is then creosoted.

Creosote is a by-product from the manufacture of coke or illuminating gas. It is the residuum of tar after the light oils have distilled off. Its chemical composition is very involved. It varies in weight as purchased and the heavier grades are the best. The timber to be treated has the coal tar creosote forced into its wood cells under pressure.

A number of compounds with trade names such as "carbolineum" are applied with the brush as substitutes for creosote.

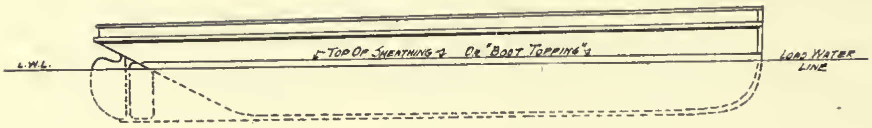
The seasoned and cut timber is placed in a heated chamber wherein a partial vacuum is then created. This expells moisture from the ducts and cells in the wood and the creosote oil is forced in to replace it. There are various methods for performing the processing, some more economical as regards use of the fluid or less apt to break down the structure of the wood contributing to strength, than others.

Surface Preservatives

Surface preservative coatings for wood are divided into (a) fillers, (b) paints, (c) varnishes.

Fillers are used to close the pores of woods which are to be given a high polish. As such polished finishes do not find general application except for furniture, models, musical instruments, etc., they will not be discussed here.

Paints for wooden surfaces contain a basic pigment of lead or zinc, mixed with an oil, a thinner and a dryer.



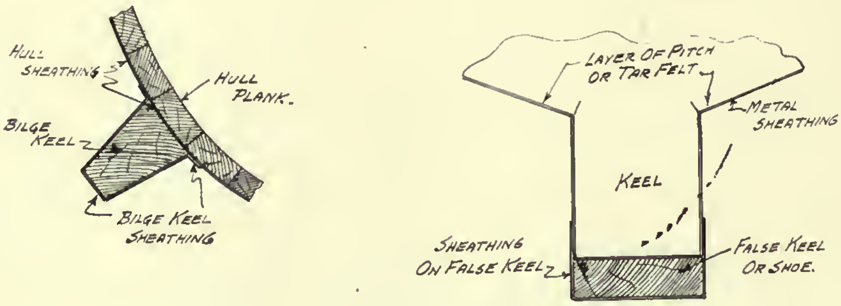


FIG. 101 – BILGE KEELS AND SHEATHING

White lead, zinc white (oxide of zinc) and leaded zincs (mixtures of zinc oxide and sulphate of lead) are used for the pigments. The lead and zinc pigments are mixed in best paints because zinc alone sometimes causes check and scale, while lead gives rise to scales or blisters. These basic pigments in paint are improved by adding small percentages of finely ground crystal salts, barium sulphate (barytes), oxide of silicon (silex) and aluminum silicate (climaclay), being most often used.

The desired tint is obtained by adding colored pigments, the more usual of which are lampblack, umbre, ochre, sienna, chrome yellow and prussian blue.

Pure raw linseed oil is the best for general paint use on wood. It causes rapid drying and gives a hard finish. Boiled and raw oils are mixed for metallic paints.

Substitutes for linseed oil are menhaden fish oil, used in marine paints because it resists moisture. It is apt to darken and to take dust. China wood oil is used for water proofing paints after being tested with driers by heating. Corn oil and cotton seed oil are sometimes used but dry very slowly. Injurious effects are brought about by use of petroleum or rosin oils. These tend to produce checks and dry slowly.

Paints are sometimes sold in paste form to be thinned when used by adding oil. Chief among these are zinc iron and lead oxide pastes.

Red lead is bought dry as a rule and is mixed with free litharge to get best protective results. About 10 to 15 percent of litharge is added to the red lead and causes the formation of a hard waterproof skin.

Turpentine is the most commonly used paint thinner although petroleum distillates of about the same weight and quickness of evaporation sometimes give good results.

Driers when mixed with paint attract oxygen of the air, thus hastening the drying. They are made by boiling manganese and lead oxides in oil.

Varnishes are made by melting tree gums in oil and thinning with turpentine. For outside work use a "long oil" varnish, i.e. one containing a large amount of oil. The best interior varnishes contain small amounts of oil. The best way to select a varnish is by comparative tests under working conditions or by experience of the user or his friends. Many so-called "varnishes" are not at all satisfactory for marine use.

Painting Wooden Hulls

The following is a brief outline of the usual painting procedure for wooden work boats.

All parts of the structure to be permanently covered over, such as where timbers are joined or on the inside of hull and outside of ceiling in a ceiled vessel, should be carefully painted before assembling. Where wood and steel surfaces come together a thick coating of red or white lead and a layer of tar felt should be used.

All surfaces to be painted should be sand-papered smooth. Knots should be touched up with shellac. Wood bruises caused by heads of fastenings should be plugged with wood if large or puttied up if small. All calking and filling of seams should be done before painting begins.

First fill all seams over calking, plane the surface fair and smooth, mark on the "water line" which is really above the level at which the boat floats. This line is the upper limit of the "boot topping."

The hull below water if not sheathed with metal, should get at least two coats of good copper paint, but do not apply this paint to iron surfaces.

The hull above water should receive a priming coat and two finishing coats of the selected color. Black, white, dark green are the usual hull colors used for work boats. Boot topping is red or bright green.

Wood rails, fender logs, wood decks, gratings and trim are usually finished natural. All these except decks and gratings should be varnished.

Deck houses and superstructure are sometimes of the same color as the hull above water. Often lighter shades are used, white, gray, reds and buffs being most frequently employed. Canvas decks are finished in grays or buff after laying.

Spars are usually varnished. Stacks may be any distinctive color with markings or insignia. Life boats are of the same color as deck houses. Rails, fixed awnings, life rings, etc., are mostly white.

Inside finishes should be in light shades, such as white, french gray, light green, light buff or natural varnished.

Two or three coats are the usual practice for all painted surfaces.

Painting Steel Structures

When steel is received from the mills it has a coating of "mill scale" or iron oxide which protects it temporarily. After being built into the hull most of this scale has rusted off. Before any steel parts are riveted together, clean the contact surface with wire brushes and apply a thick coating of red lead or other steel priming paint of approved commercial grade.

All surface irregularities can be filled smooth with good trowel cement made for steel. The first coat is the red lead or other selected anticorrosive, after which parts above water receive two finishing coats of the desired color.

The final coat below water line is "anti fouling" paint containing chemicals, principally mercury oxides, iron oxides and zinc oxides dissolved in shellac and alcohol. Anti fouling paints dry quickly and can be put on during a day in drydock. The usual marine growths are retarded in their tendency to attach to the vessel by these paints, but the effect wears off and the paint must be renewed after the steel has been scraped, usually once every six or nine months.

Wooden hulls to be used in salt

water infested by marine borers should be sheathed with metal or wood.

For a time sheet copper was used as the only metal sheathing. It is still employed in high class work but not so extensively as heretofore, due principally to the prohibitive cost of raw material. Yellow metal (copper alloys) has also found extensive use.

For power workboats an excellent and relatively inexpensive metal sheathing is galvanized sheet iron. This has an added advantage of greater strength and consequently less danger of being torn when striking subsequent obstacles.

All metal sheathing is from 1/32-inch (about No. 20 B. & S. gage) to 1/16 inches thick.

The wooden hull is calked and then coated with thick pitch to the top limit of the metal sheathing. This is usually from 4 to 12 inches above the load water line. A layer of tar felt is sometimes used under the sheathing instead of pitch.

The metal sheets are then fastened on with tacks of similar material. Care should be taken that all seams lap and are tight. No buckles should be in the sheathing and this is avoided by fastening successive sheets from the center to the edges. The entire area of each sheet is studded with tacks at intervals of four to six inches in each direction.

Sometimes if the sheathing is on too tightly it will split after the vessel has been launched. This is due to expansion of the hull planking when absorbing a certain amount of sea water. If there is no danger of damage to the wood from borers where the boat is built, it is well to launch the hull before sheathing is applied and later haul it out for sheathing before delivery.

How to Prevent Galvanic Action

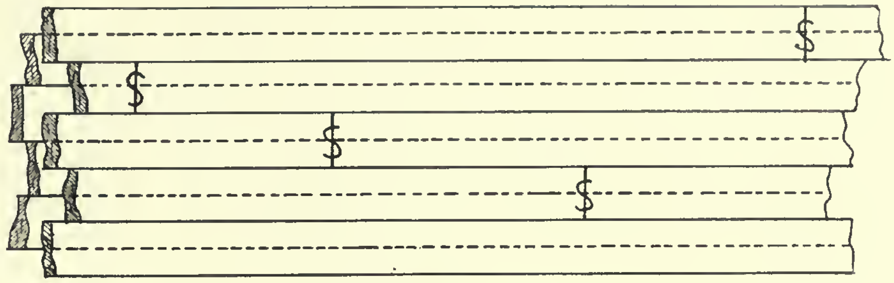
If the propeller and other underwater fittings are bronze when iron sheathing is used, or if of iron when copper or brass sheathing is fitted, protection against galvanic action in salt water should be provided by using zinc strips on the iron or steel parts near the copper or bronze. These strips are rapidly eaten away and must be renewed about every six or nine months when the boat is drydocked. It is best to avoid this source of weakness by making all underwater fittings of the same or electrically similar metals.

Wooden rudders are sheathed in the same manner as the hulls to which fitted.

Where bilge keels or false keels are used, they are apt to wear off or break off frequently. The hull sheathing should therefore be between these appendages and the hull itself and the sheathing for attached parts is put on after they have been fastened in place. (Fig. 101).

Wood sheathing was formerly used in large wooden ships and is still often employed on barges or very heavy workboats. It is usually of the same wood as the hull planking and is fitted with the seams and butts of the sheathing planks staggered with those of the hull timbers. (Fig. 102).

The sheathing is bolted to the planking and is of about half the hull plank thickness. Thick pitch is applied between the outside of hull and the wood sheathing. Lag screws with heads in recesses which are plugged attach the sheathing to the hull planks and should not extend through the latter. Plank sheathing may be creosoted to advantage.



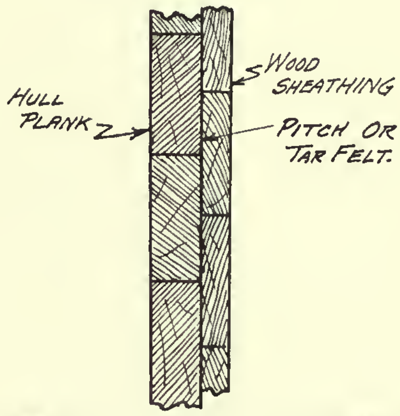


FIG. 102—HOW WOOD SHEATHING IS FITTED ON WOODEN HULLS

"ELIZABETH C." of Greenport, N. Y. A 16 ton Auxiliary Schooner owned by Capt. S. B. Bushnell. Carrying a cargo of 200 bushels of potatoes. Mainpower plant four cylinder 40 H. P. Frisbie engine equipt with a Paragon Reverse Gear. In service seven years.

CHAPTER XIX

How Concrete Power Boats Are Built

CONCRETE as a boat building material has been employed to some extent for years, particularly in barges and for small boats. The results in service of such vessels have shown that a very long life may be anticipated, that hull repairs are practically eliminated and that such vessels are highly satisfactory. When one takes into account that very little is known of this material in ship work, such results would seem to warrant a hearty endorsement of concrete small boats of every type, especially if numbers are constructed from the same design.

Several widely advertised boats have been crudely designed although successful with respect to strength, carrying capacity and seaworthiness. This may have resulted in a popular impression that graceful designs cannot be made of concrete. As a matter of fact, the concrete vessel can be as well designed as those of other materials and it possesses the added advantage of being monolithic (seamless), a result striven for since the origin of shipbuilding.

Concrete itself is a mixture of Portland cement with coarser aggregate such as sand and gravel or stone. In marine work, lighter materials are sometimes substituted for the sand and gravel, thus lightening the concrete without appreciable loss in strength. In an ideal concrete the particles forming the mass are graded as to size, the theory being that the voids between the coarse material are filled by the finer and that the cement fills the smallest voids and thoroughly coats each particle in the mass. The ingredients are mixed with water to a pasty consistency, then poured between wooden molds or "forms" and allowed to harden or "set." The amount of water used has a marked effect on the ultimate strength, best results being when the mixture starts to flow on a slope of 35 degrees from the horizontal and will just stay on a shovel. Concrete alone is strong in compression but weak in tension. Steel rods or mesh are therefore imbedded in the mass and so distributed as to absorb all tensile stresses. This steel is called the "re-enforcing" and concrete so strengthened is termed "re-enforced concrete." Sheering strains are also absorbed by the steel rods which run in two directions; longitudinally and transversely. Sometimes wire mesh or metal lath is used in conjunction with steel rods to prevent formation of hair cracks. The steel should be well protected against corrosion since it will expand and crack or "spawl" the surrounding concrete and give rise to rust streaks. There is no danger of this if the rods are at a depth of 1¼ times their diameter from the surface and have been well coated with the cement. Pockets and porous spots are avoided by tamping the concrete around the steel and vibrating the rods during pouring.

Since there is scant data to determine structure from previous boats such as has been the case in steel or wood designs, it is necessary to make careful strength calculations not only for hogging, sagging and sheer but also to ensure ample strength in resisting local strains.

First the usual weight, buoyancy, load, sheer and bending moment curves are calculated for both light and load displacements with the vessel assumed floating on a wave whose length from crest to crest equals that of the vessel. This well known and lengthy calculation is clearly explained in books on naval architecture as previously noted. In these calculations the vessel is taken as a floating girder and the strength of section most severely stressed is derived from the formula:

$$M = \frac{S\ I}{c}$$

Here M is the bending moment in foot tons.

S is the maximum unit tensile or compressive stress.

I is the moment of inertia of the midship section.

C is the distance from neutral axis to extreme upper or lower point of the section under stress.

For cargo vessels and others of ordinary form,

$$M = \frac{W \times L}{30 \text{ to } 35}$$

Where W is the displacement in tons,

L is the length of vessel in feet.

30 or 35 are constants.

For vessels of unusually shallow hold depth the constant may be as low as 20.

The unit stress S is taken as 16,000 pounds per square inch tension for re-enforcing steel and 850 pounds per square inch compression for concrete. The section of greatest sheer is at about one-fourth of the length from each end. The greatest allowable sheering stress is 250 to 300 pounds per square inch in the concrete.

Longitudinal hull girders are included in the calculations for moment of inertia in hogging or sagging. Transverse frames are not but should be spaced as determined from local "slab" calculations. Here the hull surface is divided into rectangles preferably twice as long as they are wide.

Then from slab strength formulas (see "Hoole & Johnson" on re-enforced concrete) the stresses and proportions of concrete and steel are determined.

Deck strains in slab calculations are obtained from deck loads or if none are carried, a head of water of four feet may be taken on the main deck as representing a wave which has come aboard.

Slab loads on the sides are due to the combined downward thrust of deck load and the side thrust of the water outside, whose head is equal to the molded depth.

Bottom loads are net from downward weight of hold cargo, downward thrust of deck load through sides and stanchions and upward thrust of buoyancy on outside due to head equaling the molded depth.

In all calculations the number of steel rods is found by assuming them to be of standard commercial diameters (from one-sixteenth of an inch upward in round bars). After the total sectional area of steel has been calculated to withstand the tensile and sheering stresses, the number of rods and their spacing are derived by dividing this required total area by the area per rod of the selected size. Usually it is most economical to use rods between 3/8" and 5/8" in diameter. Larger rods are used in stanchions and framing. Smaller rods are used in hulls of unusual thinness (less than 1¾" thick).

Types and disposition of re-enforcing will be considered under "Constructions."

The theories and factors affecting calculations for strength of re-enforced concrete are complex and cannot be discussed here at length. Prospective builders or owners are referred to the numerous articles and typical plans on concrete ship design published within the past year. Radical departures from these designs or even conventional ships where best results are desired should be referred to some competent authority on the subject of concrete vessels.

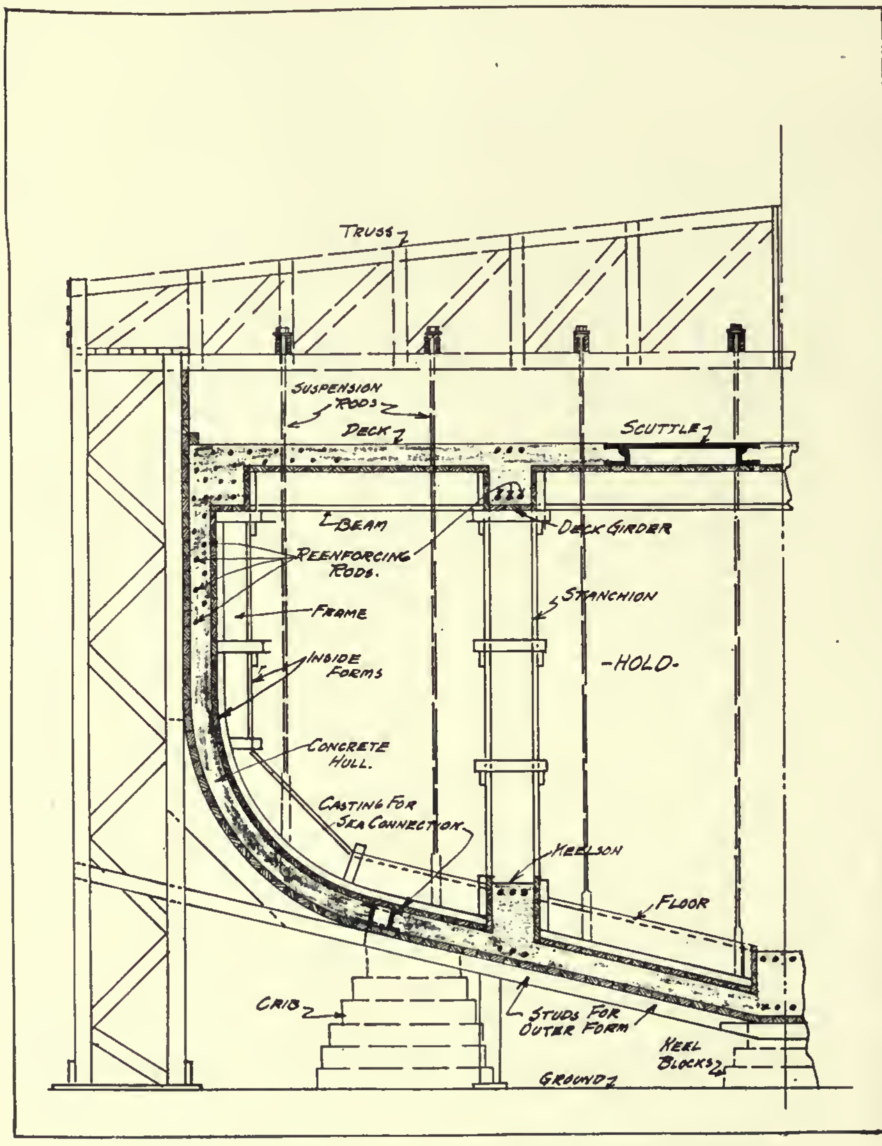


FIG. 103—TYPICAL SECTION OF A CONCRETE HULL UNDER CONSTRUCTION

Fig. 103 is a typical section of a concrete hull under construction on the building ways. Notice that the concrete hull with its reinforcing bars and structural framing is encased in wooden molds or "forms" which are supported by cribbing, scaffolding, trusses and suspension rods.

The inner surface of the outside forms is smooth and shaped to the exact molded surface of the hull. These outer forms are of varied construction but (for medium sized vessels) are from 5/8-inch to 2-inch thick pine or fir planks with closely fitted edges. Tongue and groove lumber may be used on flat surfaces.

The framework and scaffolding outside of the forms should be strongly designed but readily removable without material damage to the timbers.

The forms may be in panels with framing all around the seams to prevent getting out of line. When the hull has been molded and the concrete has hardened or "set", the forms are removed or "stripped" by taking down the scaffolding and sections of form above the bilge, then unbolting and stripping the bilge forms; and finally the bottom forms are stripped as follows: First take down alternate cribs under the bottom, strip the forms which the removed cribs had supported, replace the cribs under the exposed concrete, after which the remaining cribs and panels may be taken down and all the cribs replaced under the bare hull.

The reinforcing steel is placed inside of and supported by the outer forms. Then the inside forms are put up as the pouring of concrete progresses. Owing to the cut up and framed nature of the inner hull surface these forms are in small sections so they can be quickly erected, and also to permit their removal through whatever size hatch, scuttle, door or other opening may be in the particular compartment after molding is finished.

When the forms have been erected and the reinforcing steel and all fittings piercing the hull are in place the next operation is molding the concrete. A coating or wash of lime is applied to forms so they will not adhere to the hull. Then the concrete is molded by (a) pouring, (b) gunning or (c) a combination of the two.

Before taking up molding, consider the various types of reinforcing members and their disposition within the concrete. The main strength is in the basketlike network of rods encased by the hull. This is augmented by girders, beams, frames, floors, keelsons, stanchions, stringers and bulkheads; so that the surface of the hull consists of a number of relatively thin panels or "slabs" supported by the internal framing. Usually the hull steel runs longitudinally and transversely, although some ships have been built with the rods diagonal and and at right angles to each other.

There are many kinds of rods and more methods of spacing and securing them in place. Rods or bars are of two principal kinds, (a) the plain rounds and (b) the deformed bars. The plain round bars are sufficient for all practical purposes. Some engineers contend that deformed bars are more securely bonded to the concrete and perhaps this is so. At any rate, the round bars if properly spaced and secured give excellent service and are therefore considered by the writer as answering all requirements.

Regardless of the type of rod selected these must be supported at the correct distance from the surface of the concrete and at their proper spacing between centers in both directions. If rods are not securely held in place they will sag toward or to the surface of the concrete, thus becoming exposed when forms are stripped and requiring the concrete to be cut out at such spots so the rods can be bent into place. The rods are also apt to slide on one another and become irregularly spaced when molding takes place. This will locally weaken the structure and produce undesirable voids. The simplest and usual way to support bars is by small concrete blocks or metal clips between them and the outer forms (Figs. 104 and 105). These are spaced closely enough to carry the rods without appreciable sag and remain imbedded in the concrete after forms have been stripped.

The rods are prevented from slipping on each other by wiring them together at alternate intersections or by welding them at these points. These are the methods usually employed for shore structures of concrete where most of the surfaces are flat slabs of simple curvature. They have been used in many concrete vessels but are not considered the most positive and economical for this purpose. Some type of molded guide bar of flat iron, angle or other structural shape which can be bent to the curvature at any transverse section and then slotted or punched to receive the rods, would be better.

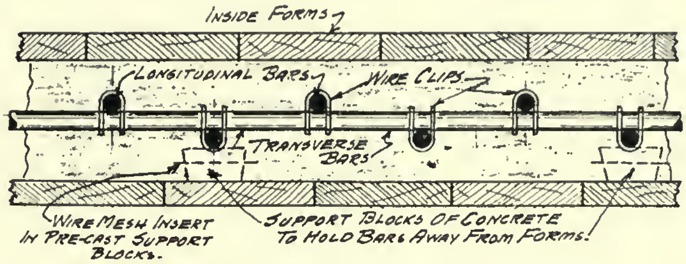


FIG. 104—METAL CLIPS USED TO SUPPORT LONGITUDINAL RODS

Such a system has been employed satisfactorily in a number of concrete hulls with excellent results and is shown in Fig. 106. The supporting framework of transverse and longitudinal angles is riveted together and erected in the forms. The spacing of these angles is about four feet in each direction and they are very light. The round bars are then threaded through or laid into the punched slots by unskilled labor.

Bulkheads are constructed and reinforced the same as the shell. All door frames, pipe stuffing boxes or other aperatures must be located in the forms before molding begins.

The number of rows of reinforcing depends on the steel required. A general rule is that diameter of rods should be less than one-fifth of the thickness of concrete in which imbedded. Fig. 104 shows two rows of longitudinal and one row of transverse bars. Figs. 105 and 106 show one row of bars in each direction. Sometimes wire mesh or expanded metal is fastened to the outer row of bars to prevent the formation of hair cracks in the concrete.

Columns or "stanchions" and girders are constructed as in Fig. 107. Extra heavy rods (from ¾ inch to 1¼ inches in diameter) take the principle stresses being run up and hooked over as shown. Stirrups and binding wires of light steel rounds (from ⅛ inch to ⅜ inch in diameter) absorb the sheering stresses in each member. The girders and stanchions are calculated to withstand the loads on deck, side and bottom slab areas which they support. For stanchions this area is the distance between them in each direction. For frames it is their spacing on the ships side in bending and half the distance between ships side and the first row of stanchions in compression. For beams and girders it is their spacing times their span. Details of beam and column calculations are in texts on reinforced concrete construction.

Reinforcing rods should be as long as possible and the lapped or butted ends should be well staggered to prevent local weakening of the structure.

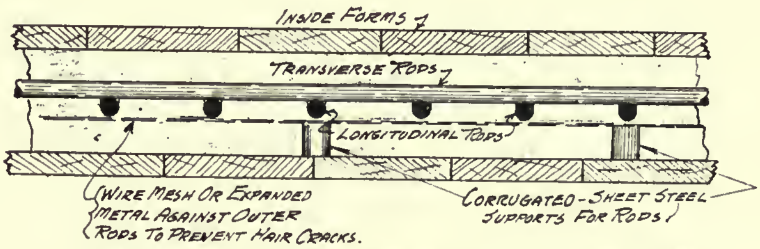


FIG. 105—METHOD USED IN HOLDING RODS IN PLACE FOR POURING FORMS

The simplest way to join rod ends is by lapping them at least 40 diameters and binding them with wire. Special clamps are made which grip the butted ends of rods similarly to an outside pipe nipple. Best of all the butted ends can be welded.

Since the girth of cross sections on the hull becomes less toward the bow and stern than it is amidships, the rod spacing will vary throughout the length of all types of vessels except those with box sections such as the simplest barges. When the rods

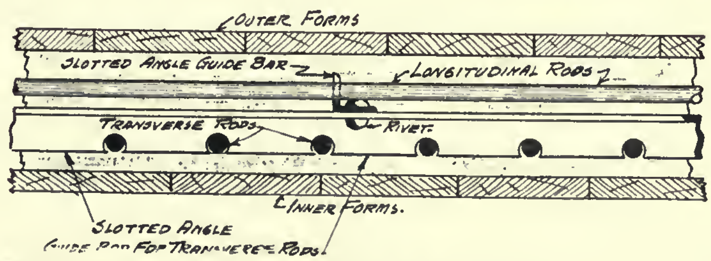


FIG.106—MOLDED GUIDE BAR PUNCHED TO RECEIVE RODS. THIS IS A VERY SATISFACTORY METHOD USED WITH EXCELLENT RESULTS

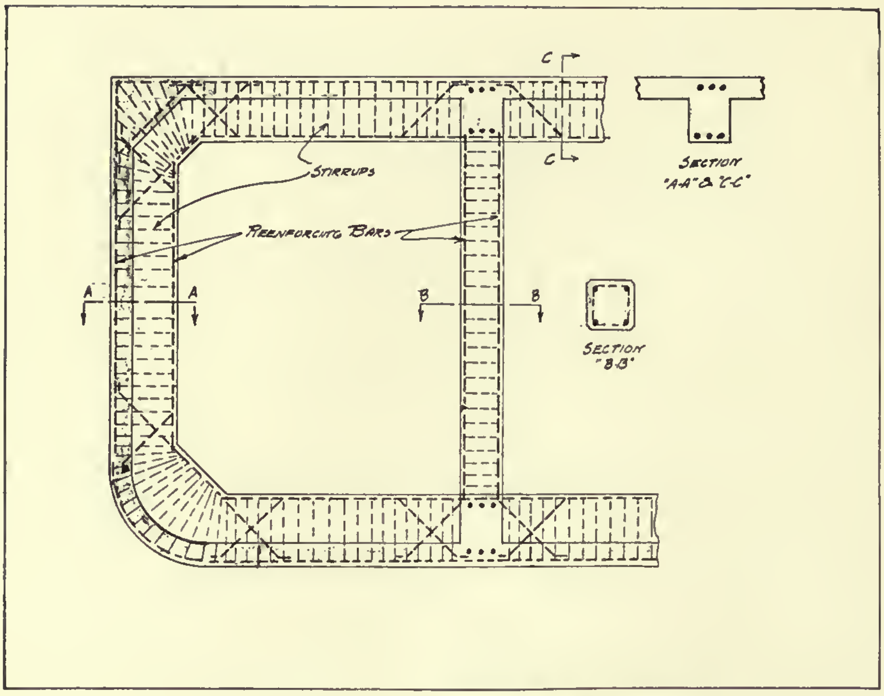


FIG. 107—CONSTRUCTION OF STANCHIONS AND GIRDERS

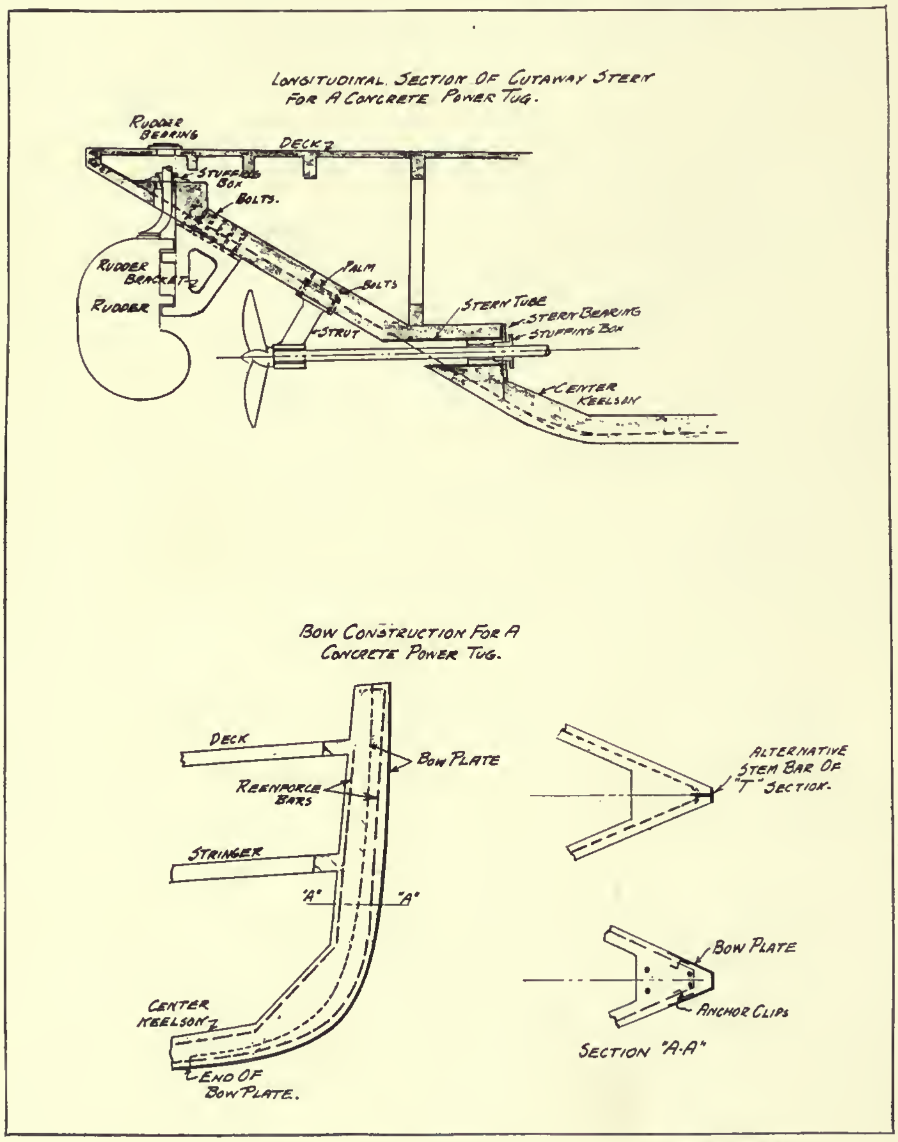


FIG. 108 AND 109—BOW AND STERN CONSTRUCTION FOR A CONCRETE WORKBOAT

come closer than half their spacing amidships, they are dropped.

Rods at the stem and stern are run over to the other side of the hull and hooked into the steel structure at these points. Fig. 108 shows bow construction for the workboat of concrete. A "V" shaped steel plate or a "T" bar form the cutwater and are anchored into the concrete as shown (107-b and c). The rod ends pass through the anchors and hook over.

Stern construction is a point to be carefully studied. If the conventional "deadwood" type is followed, it is necessary to support the forged or cast steel stern frame by large steel plates anchored into the hull. There must also be a deep and heavy block of concrete which contributes no strength, reduces the cargo deadweight and is very crude.

Fig. 109 is a type considered stronger, simpler and lighter. It was used in two classes of concrete vessels designed by the writer and has proven successful. The line of counter is produced to its intersection with the keel which it joins by a circular arc. The cross sections at any point of this stern are "V" shaped. Care should be taken not to have flattened sections which would cause eddying in the vessel's wake and render it difficult to steer properly. The rudder is balanced and supported by a cast steel bracket which has a large palm through bolted to the hull. A strut supports the propeller, being secured as shown for single or twin screw vessels. Iron pipe or sheet steel tubes form the rudder trunk and also receive the stern tube.

All hull fittings are similar to those previously described and are bolted through the concrete with wooden pads on the deck to which they are attached. Short lengths of pipe one-eighth inch larger in diameter than the bolts are inserted in the forms before molding and the flanges for attaching the fittings can be drilled from templates taken of these pipes after the concrete has set. No anchor bolts should be used if possible and then only where the attached equipment is not likely to need removal for repairs or replacement.

Portland cement, sand, coarser aggregate and water are used. The cement should be such that about 78 per cent of it will pass through a wire gage of 200 openings per inch. The sand should be clean (free from loam or other impurities) and should feel sharp when rubbed between the fingers. The coarse aggregate should be not over ½ inch in size while for hulls less than 2½ inches thick, it should be under ¼ inch.

The proportions used vary considerably but the following will be found good for all watertight parts of the hull such as shell, bulkheads, watertight decks, tanks etc.

Two-thirds of a part of cement, one part of sand, one and one-third parts of gravel. The aggregate components are screened to size before mixing and are thoroughly mixed while dry before adding the water. Concrete mixing machines are used for large work and the work of molding should not stop when it has been once started on watertight work. The mixture or "batch" is poured through chutes and conveyed to the proper point in wheelbarrows. The first of these schemes is best calculated to produce good results.

The concrete is carefully tamped in place and the reinforcing rods are vibrated during pouring to release all air bubbles and prevent formation of voids.

A leaner and cheaper concrete (1 part cement, 2 parts sand and 4 parts gravel) may be used for stanchions, girders and other structural members where strength but not watertightness is required.

Fused shales and clays have been used for hull concrete and found amply strong. They result in a reduction of weight from about 145 pounds for ordinary sand and gravel to between 100 and 120 pounds for the fused aggregates.

Thus far the concrete has been used for hulls only, deckhouses and other superstructure having been of wood or steel. There is, however, no reason why concrete cannot be used above decks except in the lightest partitions.

There are many reasons why concrete barges and workboats should be used in the future, especially if the main points of design for particular sizes and types become less numerous through compromise and quantity of production.

Regardless of whether power boat hulls are wooden, steel or concrete, the writer feels that their present number and types will be constantly increasing. When we begin to realize the many advantages of power workboats over those propelled by steam, besides the many uses which could profitably be found for such craft, particularly in the central and eastern portion of these United States; when we awake to their even greater importance than their numerous blood sisters, the pleasure power boat, a prosperous future presents itself.

Power workboats could and should be used wherever there are waterways. They relieve congestion in crowded sections and can do the transporting more cheaply than the rail or truck methods. They promote commerce and can bring the market to many now isolated producers, whether these be farmers, manufacturers, fishermen, commuters or any others who rely on cheap means of transportation.

It is hoped that the details described herein will work for more and better power boats and will answer some of the many questions constantly to be met by the practical boat builder and owner.

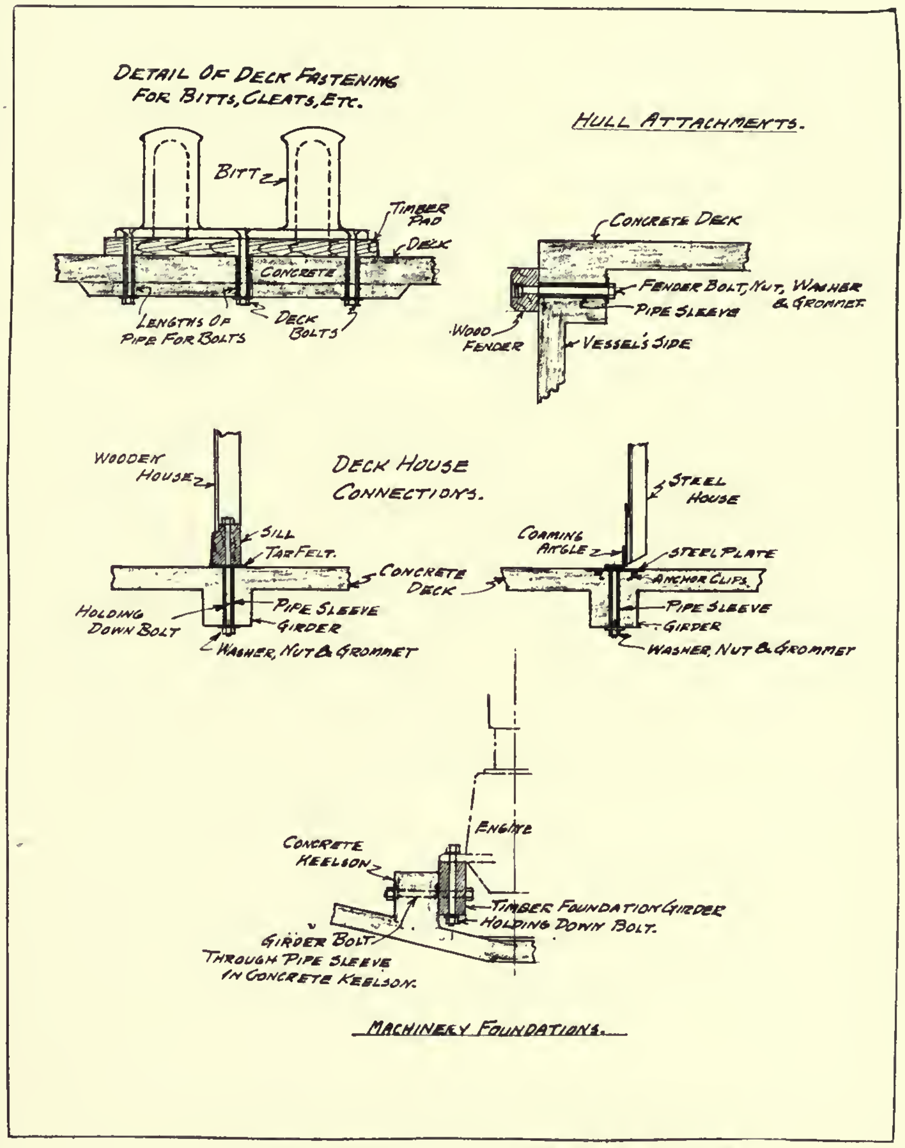


FIG. 110—DETAILS FOR ATTACHING MISCELLANEOUS FITTINGS

APPENDIX I

Working Tables of Scantlings for Power Workboats from 20 to 100 Feet in Length, Including Tugs, Tenders, and Other Heavy Duty Vessels

For Scantlings of Sizes Between Those Given, Use Averages to Standard Timbers

NOTE: TABLES ARE FOR TUGS, TENDERS & OTHER HEAVY DUTY VESSELS. FOR SCANTLINGS OF SIZES BETWEEN THOSE GIVEN USE AVERAGES TO STANDARD TIMBERS.

TABLES OF SCANTLINGS
POWER WORKBOATS
WOODEN HULLS.

SHEET 1 OF 3

LENGTH OF BOAT IN FEET.
NORMAL BEAM & DEPTH IN BRACKETS.

COMPILED BY
ARTHUR F. JOHNSON

ITEM	20' [6'3"x3'3"]	30' 8'6"x4'0"	40' 11'3"x5'0"	50' 13'0"x6'0"	60' 15'0"x6'6"	70' 17'6"x8'9"	80' 20'0"x10'9"	90' 22'6"x12'9"	100' 25'0"x14'6"
APRON	Y.P. 8"M-4"S	Y.P. 4½"S	YP 4½"S	YP 7"S	OAK 12"M-8"S	PINE 18"M-8"S	OAK 12"x9"	OAK 14"-10"S	OAK 16"M-12"S
ANCHORS	1-60#	1-60# 1-35#	1-75# 1-50#	1-100# 1-50#	1-250# 1-100#	1-300# 1-150#	1-300# 1-200#	1-450# 1-200#	2-400# 1-225#
BATTENS - CARGO, IN HOLD	—	—	—	PINE 1⅛"x3"	PINE 1¼"x4"	PINE 1½"x4"	PINE 1¾"x4½"	PINE 2"x6"	PINE 2"x6"
BEAMS - MAIN DECK SPACING OF	9" OAK CENTERS	PINE 12"¢	OAK 12"¢	PINE 15"¢	PINE 18"¢	PINE 16"¢	PINE 18"C	PINE 18"C	PINE 18"¢
" - MAIN DECK	1½"M-1¼"S	2"M-1⅜"S	3½"M-2"S	4"M-4"S	9"M-6"S	10"M-4"S	10"x6"	11"x8"	11"M-8"S
" - HOUSE OR TRUNK TOP SPACING OF	12"	15"	15"	18"	18"	22"	20"	20"	20"
" - HOUSE TOP TRUNK TOP	OAK 1½"M-1"S	OAK 1¾"M-1"S	PINE 3"M-1⅝"S	PINE 3"M-2"S	PINE 3½"M-2"S	PINE 6"M-2"S	PINE 5"M-2¾"	PINE 5"M-2¾"S	PINE 5"M-2¾"S
" - COCKPIT OR HOLD FLAT - SPACING OF	PINE 2"M-1"S	12"	12"	12"	18"	16"	16"	16"	16"
" - COCKPIT OR HOLD FLAT	SPACE 9"	OAK 2"M-1½"S	PINE 2"M-1½"S.	PINE 2"M-1½"S	PINE 4"M-2"S	PINE 4"M-2"S	PINE 4"x2"	PINE 6"x2"	PINE 6"x2"
BILGE KEEL -	—	—	—	—	OAK 6"M-4"S	OAK 8"M-6"S	OAK 6"x8"	OAK 8"x10"	OAK 8"x12"
BITTS - (BOLLARDS) - TOWING	OAK. 6"x6"	OAK 6"x6"	CAST IRON 8" DOUBLE	CAST IRON 10" DOUBLE	CAST IRON 10" DOUBLE	CAST IRON 10½" DOUBLE	CAST STL 11" DBL	CAST STEEL 11½" DBL	CAST STEEL 12" DBL
" - SIDE OR MOORING	—	—	—	OAK 6"x6"	OAK 8"x8" SINGLE	OAK 10"x10" SINGLE	CAST STL 7" SINGLE	CAST STL. 7½" SING	CAST STEEL 8" SINGLE
" - FORWARD OR "RIDING	OAK 4"x4"	OAK 5"x5"	CAST IRON 6" DOUBLE	OAK-DBL 6"x4½"	OAK 8"x8"	OAK 10"x10" DBL	9" DBL	9½" DBL	CAST STEEL 10" DBL
BRACKETS - (BEAM KNEES)	—	OAK 1½" THICK.	OAK 2" THICK	OAK 4" THICK	OAK 5"S.	OAK. 6"S	OAK 8"S	OAK 8"S	OAK 8"S
BREASTHOOKS	OAK 4"M.	OAK 2½"M.	OAK 4"M.	OAK 4"M	OAK 6"M.	OAK 6"M.	OAK 8"M	OAK 10"M	OAK 12"M
BULKHEADS - TRANS. W.T. NUMBER OF	TWO	TWO IF WOODEN	TWO	THREE OR FOUR	THREE	THREE	THREE	FOUR	FOUR 25-2 W
" - W.T. WOOD - PLANKING FOR	2 THICK ⅜" PINE	2 THICK ½" PINE	1 THICK 1⅛" PINE	TWO - 2 THICK ⅝" PINE	2 THICK - ⅝" PINE	2 THICK ¾" PINE	2 THICK 1" PINE	2 THICK 1½" PINE	PINE 4"x4"
" - W.T. WOOD - STIFFENERS FOR	PINE 2"x4"	PINE 2"x4"	PINE 2"x4"	PINE 2"x4"	PINE 4"x4"	PINE 4"x6"	PINE 4"x6"	PINE 6"x6"	PINE 8"x6"
" - W.T. STEEL - NUMBER OF	—	TWO IF STEEL	—	TWO -	—	—	TWO	TWO	TWO
" - W.T. STEEL - PLATE THICKNESS	—	⅛" GALV.	—	3/16"	3/16"	3/16"	¼"	¼"	5/16"-¼"
" - W.T. STEEL - STIFFENER ANGLES	—	1½"x1½" Ls	—	2"x2"x3/16" L	2"x2½"x¼" L	2"x2½"x¼" L	3x2½"x5/16" L	3x2½x5/16"	3½x3x5/16" L
" - W.T. STEEL BOUNDING ANGLES	—	DOUBLE WOOD FRAMES	—	2"x2"x3/16" L	2"x2½"x¼" L	2"x2½"x¼" L	3"x2½"x5/16" L	3x2½x5/16" L	3½"x3x5/16" L
" - MINOR DIVISIONAL PLANKING FOR	PINE ⅜" T&G	PINE ⅝" T&G-	PINE ⅝" T&G	PINE ⅝" T&G	PINE ¾" T&G	PINE ⅞" T&G	PINE ⅞" T&G	PINE 1" T&G	PINE 1⅛" T&G
" - MINOR DIVISIONAL - STUDDING -	2"x2"	2"x2½"	2x3¾	2"x3¾"	2"x4"	2"x4"	2"x4"	2"x4"	2"x4"
BULWARK PLANKING	—	—	OAK 4"M-2½"S	OAK 8"M-3"S	O PINE 12"M-6"S	PINE 12"M-8"S	PINE 8"M-2"S	PINE 10"M-2¼"S	PINE 11"M-2½"S
" - STIFFENERS	—	—	—	—	—	—	PINE 4"x4"	PINE 6"x4"	OAK 6"x6"
CANVAS - COVERING FOR HOUSE TOPS.	#8 DUCK	#8 DUCK	#6 COTTON	#4 COTTON	#4 COTT.	#4 COTTON	#4 COTTON	#4 COTTON	#4 COTTON
" - AWNINGS & PILOT HOUSE VISOR	" "	" "	#6 "	#6 COTTON	#6 " "	#6 COTTON	#6 COTTON	#6 COTTON	#6 COTTON
CAP - (PLATE) DECK HOUSES OR TRUNK	PINE 4"M-2"S	PINE 4"M	PINE 4½"Mx3"S	PINE 5"M-4"S	PINE 4½"M-2½"S	PINE 4"M-3"S	PINE 4½"M 3½S	PINE 4½"M-4"S	OAK 5"M-4½"S
CARLINGS - AT CUT BEAMS IN MAIN DECK	OAK 4"M-2"S	OAK 4"M-2"S.	PINE 6"M-4"S	PINE 8"M-6"S	PINE 10"M-8"S	PINE 10"x10"	PINE 10"x10"	PINE 12"x10"	PINE 12"x12"
CEILING - INSIDE OF FRAMES	—	PINE ½" T&G	—	PINE 2"x6"	PINE 2" THICK	PINE 2" THICK	PINE 2¼" TH.	PINE 2½" TH.	PINE 3" THICK
CHAIN - ANCHOR	30 FATH ¼" GAL. OPEN	35 FATH 5/16" GAL.	50 FATH ⅜" GAL.	50 FATH ⅜" GAL	75 FATH ⅝" GAL.	75 FATH ¾" GAL	75 FATH ¾" GAL	150 FATH 13/16"	200 FATH ⅞"
CHOCKS - BOW & QUARTER	2-BOW 10" OPEN	2-BOW 10" OPEN	4 QUARTER 12" OPEN	4 15" OPEN	4 15" OPEN	4 18" OPEN	6 20" OPEN	6 22" OPEN	6 24" OPEN

LENGTHS ARE OVERALL - BEAM IS OUTSIDE OF PLANKING - DEPTH IS FROM KEEL AT OUTSIDE OF GARBOARD TO TOP OF DECK PLANK AMIDSHIPS - FIRST SCANTLING GIVEN IS MOLDED, SECOND IS SIDED IN EACH CASE. AND BOTH ARE FOR TIMBERS AS FINISHED IN CONSTRUCTION - WHEN ORDERING LUMBER ALLOW FOR DRESSING - FOR VESSELS LONGER THAN 100 FT. USE INSURANCE RULES.

AUG 2-1919.

TABLES OF SCANTLINGS
POWER WORKBOATS
WOODEN HULLS

SHEET 2 OF 3

COMPILED BY ARTHUR F. JOHNSON

LENGTH OF BOAT IN FEET.

ITEM.	20	30	40	50	60	70	80	90	100
CLAMP	OAK 3½"x1"S.	PINE 1⅞"S-6"M	PINE 6"M-2"S	PINE 10"M-2"S	PINE 10"M-4"S	PINE 12"M-3"S	PINE 2 8"M-4"S	PINE-2 6"x10"	PINE-3 10"M-6"S
CLEATS-(CAVELS) MOORING	GALV. IRON 4-8" LONG	GALV. IRON 6-12" LONG	GALV. IRON 8-12" LONG	GALV. IRON 4-16" LONG	GAL. IRON 4-16"	GAL IRON 6-18"	C.ST. 6 - 20"	C.ST. 6-24"	C.ST. GAL. 6-30"
COAMING-COCKPIT	OAK 5"M-1"S	OAK 1½"M-2⅝"S	—	—	—	—	—	—	—
DEADWOOD-(SKEG)-AFT	OAK 4"S	PINE 3½"S	OAK 4½"S	PINE 7"S.	OAK 8"S	PINE 8"S	PINE 10"S	PINE 12"S	PINE 16"S
DEADWOOD-(STEM KNEE) FORWARD.	4"S.	PINE 3½"S	OAK 4½"S.	OAK 7"S.	OAK 8"S	PINE 8"S	PINE 10"S	PINE 12"S	PINE 16"S
DECK-HOUSE OR TRUNK TOP-MARGIN PLANK	OAK 1"M-4"S	OAK 1⅛"M-4"S	OAK 1¼x6"S	OAK 1⅜"x6"	OAK 1⅜"x6"	OAK 1½"x8"	OAK 1¾M-8S	OAK 2"-8"	OAK 2¼"M-8"S
" - HOUSE OR TRUNK TOP-PLANKING	PINE ¾" THICK	PINE-⅞" THICK	PINE ⅞" THICK	PINE ⅞" THICK	PINE ⅞" T&G	PINE 1" T&G	PINE 1" T&G	PINE 1⅛ T&G	PINE 1⅛" T&G
" - HOLD FLATS OR COCKPIT PLANKING FOR	PINE ⅝"	PINE ⅞"x3½" T&G	PINE 1" T&G	PINE 1⅛" T&G	PINE 1¼" T&G	PINE 1½"	PINE 1⅝"	PINE 1¾"	PINE 1¾"
" - MAIN-MARGIN PLANK	OAK 1¼"M-6"S	OAK 1½"M-5"S.	OAK 1⅜"x6"	OAK 3"M-9"S	PINE 3"M-10"S	PINE 3"M-12"S	PINE 3½"-12"	PINE 4"M-12"S	OAK 4"M-14"S
" - MAIN PLANKING	PINE ⅞"	PINE 1⅛"	PINE 1⅜"M-2"S	PINE 2¼"M-2¼"S	PINE 2½"M-2¼"S	PINE 2½"M-3"S	PINE 2½"x3"	PINE 2¾"x3"	PINE 3"x3"
FOUNDATION-ENGINE	OAK 2½"S	OAK 3½"S	PINE 4"S.	PINE 8"M-6"S	OAK 12"x12"	OAK 10"x10"	OAK 10"x10"	OAK 12"x12"	OAK 12"x12"
FENDER-LOWER	OAK 3" HALF R'D.	OAK-2½"M-2"S 1½"x¼" Face Ir.	OAK-3"M-4"S 1½" IRON	OAK-4½"x4½" FACE BAR 2½"x⅜"	OAK 5"x4 FACE 4"x⅜"	OAK 6"x6" FACE 4"x⅜"	OAK 6"x6" FACE 4"x½"	OAK 8"x6" FACE 5"x¾"	OAK 8"x8" FACE 5"x¾"
" - UPPER	OAK 3" HALF R'D.	OAK-2½"M-4"S-2" IRON	OAK-3"x3" 1½" IRON	OAK-6"x6" FACE IRON 3"x⅜"	OAK 8"x8" FACE 6"x⅜"	OAK 8"x8" FACE 6"x⅜"	OAK 8"x8" FACE 5"x¾"	OAK 8"x8" FACE 5"x¾"	OAK 8"x8" 5"x¾"F
FLOORS-ENGINE ROOM	OAK-9"M-1½"S	OAK 3¾"M-1¾"S	OAK 12"M-2"S	OAK 12"M-2½"S	OAK 9"M-5"S	OAK 12"M-4"S	OAK 4½"S	OAK 5"S	OAK 6"S
" - IN HOLDS OUTSIDE OF ENGINE ROOM-	OAK 9"M-1½"S	do.	OAK 8"M-2"S	OAK 10"M-2½"S	OAK 8"M-6"S	OAK 10"M-4"S	OAK 4½"S	OAK 5"S	OAK 6"S
FRAMES-SPACING OF	9" CENTER W. OAK	OAK 12" CENTER	OAK 12" CENTERS	OAK 12" ¢	OAK-SAWN 18" ¢	OAK 16" ¢	18" ¢	18" ¢	18" ¢
" - ENGINE ROOM-SIDED	STEAM BENT 1½"	1½"	DOUBLE 2"	DOUBLE 3"	DOUBLE 2½"	DOUBLE 4"	DOUBLE 4½"	DOUBLE 5"	DOUBLE 6"
" - ENGINE ROOM MOLDED AT KEEL	1¼"	2¼"	2½"	3"	6"	6"	7"	8"	10"
" - ENGINE ROOM MOLDED AT DECK	1¼"	1¾"	2½"	3"	4"	4"	5"	6"	8"
" - IN HOLDS-SIDED	1½"	1½"	SINGLE 2"	SINGLE 3"	DOUBLE 2½"	DOUBLE 4"	DOUBLE 4½"	DOUBLE 5"	DOUBLE 6"
" - IN HOLDS-MOLDED AT DECK	1¼"	1¾"	2½"	3"	4"	4"	5"	6"	8"
" - IN HOLDS-MOLDED AT KEEL.	1¼"	2¼"	2½"	3"	6"	6"	7"	8"	10"
GARBOARD PLANKS	OAK 1"M-6"S	OAK 1¼" Th.	OAK 2"M-6"S	OAK 2½"M-6"S	PINE-TWO 12"x3"-12"x2½	PINE 3"M-12"S	2-PINE 3"x10"	PINE-2 3½x10	PINE-3 4"M-10"S
GIRDERS-MAIN DECK UNDER BEAMS	—	—	—	—	—	PINE 6"M-4"S	PINE 6"x6"	PINE 6"x6"	PINE 8"M-6"S
" - HOUSE TOPS UNDER BEAMS.	—	—	—	—	PINE 4"M-2"S	PINE 4"M-2"S	PINE 4"x4"	PINE 6"x4"	PINE 6"M-4"S
GUNWALE PLANK	OAK ⅞"x3¾"	—	—	—	—	—	—	—	—
HAWSERS-TOWING	200 FT. 3" MANILA	200 FT 3" MANILA	300 FT 4" MANILA	300 FT 4" MANILA	350 FT 5" MANILA	350 FT 5" MANILA	350 FATH 6" MANILA	400 FATH 7" MAN.	400 FATH 8" MANILA
" - MOORING	50 FT 1" MANILA	100 FT 2" MANILA	150 FT 3" MANILA	150 FT 3" MANILA	180 FT 3" MANILA	200' 4" MANILA	250 FATH 4" MANILA	300 FATH 4" MAN	300 FATH 6" MANILA
HORN TIMBER	OAK 4"S-4"M	OAK 6"M-3½"S	OAK 4½"S-8"M	OAK 7"S-10"M	OAK 12"M-6"S	OAK 10"M-8"S	OAK 10"x10"	OAK-2 10"x12"	OAK-2 12"x12"
HULL-PLANKING-GARB'D. TO BILGE	PINE-CEDAR ¾" S	PINE-CEDAR 1⅛" S	PINE 1⅜" S	PINE 1⅝" S	PINE 6"M-2"S	PINE 2¼"	PINE 2½"x6"	PINE 3"x8"	PINE 3¼"x8"
" - PLANKING BILGE TO SHEER	¾" S	1⅛" S	PINE 1⅜" S	PINE 1⅝" S	10"M-2"S	2¼"	2½"x6"	3"x8"	3¼"x8"

MATERIALS & SCANTLINS OF VESSELS IN SERVICE. FOR DIMENSIONS OF INTERMEDIATE LENGTHS SEE CURVES. CHAPTER I. DIMENSIONS, SCANTLINGS & MATERIALS CAN BE VARIED BUT THESE TABLES ARE GOOD PRACTICE FOR HEAVY WORKBOAT CONSTRUCTION.

AUG. 2. 1919.

TABLES OF SCANTLINGS
POWER WORKBOATS
WOODEN HULLS
LENGTH OF BOAT IN FEET.

SHEET 3 OF 3

COMPILED BY
ARTHUR F. JOHNSON

ITEM.	20	30	40	50	60	70	80	90	100
KEEL	OAK 4"x4"	OAK 5"M-3½"S	OAK 7"M-4½"S	OAK 9"M-7"S	OAK 8"M-8"S	OAK-PINE 8"M-8"S	OAK-PINE 10"M-8"S	OAK-PINE 12"M-10"S	OAK 12"M-12"S
" - FALSE (SHOE)	OAK 1"M x 4"S	OAK 1"M-3½"S	OAK 1½" x 4½"	OAK 1¾"x7"	OAK 2"M-8"S	OAK 2"M-8"S	OAK 2½"M-8"S	OAK 3"M-10"S	OAK 4"M-12"S
KEELSONS - BILGE	OAK 4½"M-4"S	TWO-PINE 2⅜"M-4"S	TWO-PINE 3"M-4"S	THREE-PINE 4"M-4"S	PINE-4 4"M-6"S	PINE-4 4"x6"	PINE-4 6"x6"	PINE 4 8"x6"	PINE-4 8"x8"
" - CENTER	OAK 4½"M-4"S	Y PINE 5"M-3"S	PINE 4½"M-6"S	PINE 6"x8"S	PINE 8"M-10"S	PINE 10"M-8"S	PINE 10"M-10"S	PINE 12"M-10"S	PINE 12"x12"
" - ENGINE	OAK 2½"S.	OAK 3½"S	PINE 8"M-4"S	PINE 8"M-6"S	OAK 12"M-12"S	PINE 10"M-10"S	PINE 10"x10"	PINE 12"x10"	PINE 12"x12"
" - SIDE (SISTER)	—	Y PINE 1⅞"M-6"S	(SEE ENGINE KEELSONS)	TWO-PINE 4"M-4"S	PINE 8"M-6"S	PINE 10"M-6"S	PINE 10"M-8"S	PINE 10"M-10"S	PINE 12"M-10"S
RAIL - BULWARK	—	—	—	—	OAK 3"M-6"S	OAK 2½"M-8"S	OAK 3¼"M-10"S	OAK 4"M-10"S	OAK 5"M-12"S
RIM LOG	—	OAK 4"M.	OAK 6"M	OAK 8"M	PINE 10"M-18"S	PINE 12"M-	PINE 12"M	PINE 12"M	OAK 12"M-18"S
RUDDER - AREA SQ. FT.	BALANCED 5	BALANCED 8	BALANCED 11	16	19	24	32	45	55
" - POST	—	—	—	OAK 6"M-4"S	OAK 8"M-6"S	OAK 8"M-8"S	OAK 10"M-8"S	OAK 10"M-9"S	OAK 12"M-10"S
" - SHOE BRASS OR STEEL	STEEL-BR 4"WIDE x ½"	BRASS-ST 3½"WIDE x ¾"	BR.-ST. 4"WIDE x ¾"	BR.-ST. 4"WIDE-1¼"	OAK 6"M-6"S	OAK 6"M-8"S	OAK 8"-8"	OAK 10"-9"	OAK 10"-10"
" - STOCK	BRASS-ST 1¼"DIA	BRASS-ST 1½"DIA	BR.-ST. 1½"DIA	BR-ST 2"DIA	OAK-7"DIA METAL-2½"	OAK-8"D. METAL-3"D.	STEEL 4"DIA	STEEL 6"DIA	CAST STL. 8"DIA
" - WOODEN THICKNESS.	—	—	—	OAK 4"S	OAK 6"S.	OAK 8"S.	OAK 8"S	OAK 9"S	OAK 10"S
" - PLATE - SINGLE.	BRASS 3/16"THICK	BRASS 3/8"THICK	GAL. STEEL 1/2"THICK	BR.-ST. 5/8"THICK	BR.-ST. 3/4"THICK	BR.-ST 7/8"THICK	1"	1⅛"	1¼"
SHAFT LOG	OAK 4"S.	OAK 5"S	OAK 7½"x7½"	OAK 9"x9"	OAK 12"M-10"S	OAK 14"x14"	OAK-2 18"M-8"S	OAK-2 20"M-10"S	OAK-2 24"M-10"S
SHEATHING - HOUSE OR TRUNK - INNER	PINE 3/8"T&G	PINE 1/2"T&G	PINE 5/8"T&G	PINE 5/8"T&G	PINE 5/8"T&G	PINE 5/8"T&G	PINE 5/8"T&G	PINE 5/8"T&G	PINE 5/8"T&G
" - HOUSE OR TRUNK - OUTER	PINE 5/8"T&G	PINE 3/4"T&G	PINE 3/4"T&G	PINE 7/8"T&G	PINE 7/8"T&G	PINE 7/8"T&G	PINE 7/8"T&G	PINE 7/8"T&G	PINE 7/8"T&G
" - HULL - OUTSIDE METAL	Copper Paint 20 OZ.	COPPER PAINT	COPPER 14 OZ.	COPPER 16 OZ.	COPPER 18 OZ.	GAL. IRON #18 GAUGE	GAL IRON #18 GAUGE	GAL IRON #18 GAUGE	GAL IRON #18 GAUGE
" - HULL - OUTSIDE WOODEN	—	—	—	—	PINE 3/4"	PINE 7/8"	PINE 1"	PINE 1¼"	PINE 1½"
SHEER PLANK	OAK 6"M-1½"S	OAK 1¼"S.	OAK 6"M-1⅜"S	OAK 9"x1⅝"	OAK-PINE 12"M-3"S	OAK 12"x3"	PINE-2 8"M-3½"S	PINE-3 8"M-3¾"S	PINE-3 10"M-4"S
SHELF	—	2-PINE 2½"x2"S	2-PINE 4"M-3"S	2-PINE 4"M-3"S	2-PINE 4"M-4"S	2-PINE 6"M-4"S	3 PINE 4"x4"	3-PINE 6"x6"	3 PINE 8"M-6"S
SILL - DECKHOUSE OR TRUNK	PINE 4"M-4"S	PINE 4"M-4"S	PINE 4"x4"	PINE 6"M-4"S	PINE 8"M-5"S	PINE 6"M-5"S	PINE 6"M-6"S	PINE 8"M-6"S	PINE 10"M-8"S
STANCHIONS - HOLD, UNDER M.D. CARLINS	OAK 2"x2"	OAK 2"x3"	PINE 2"x4"-SP. 3'	PINE 4"x4"	PINE 4"x4"	PINE 6"x4"	PINE 6"x6"	PINE 8"x8"	PINE 10"x10"
" - HOLD, UNDER M.D. GIRDERS	—	PINE 2¾"x2¾"	PINE 2"x4"	—	PINE 4"x4"	PINE 4"x4"	PINE 6"x6"	PINE 8"x8"	PINE 10"x10"
" - (STUDDING) - DECK HOUSE OR TRUNK	PINE 2"x2"	PINE 2"x3"	PINE 2¼x2¼"	PINE 2x4	PINE 2½x2½"	PINE 2½x2½"	PINE 2½x3	PINE 2½x3½	PINE 2¾x4¼
STEM-	OAK 2½"S.	OAK 3½"S	OAK 4½"S	OAK 7"S	OAK 8"S.	OAK 12"M-8"S	OAK 12"M-9"S	OAK 12"M-10"S	OAK 14"M-12"S
STEM BAND.	STEEL 2"WIDE x ¼"	STEEL 2¼" x 5/16"	STEEL 1½" x 5/8"	STEEL 2" HALF OVAL	BR.-STEEL 2"x½"	STEEL 2"x5/8"	STEEL 2¼" x 5/8"	STEEL 2½" x 5/8"	STEEL 3" x 5/8"
STERN POST.	OAK 4"S.	OAK 3½"S	OAK 6"x7½"S	OAK 8"M-9"S	OAK 10"M-10"S	OAK 12"M-14"S	OAK 12"M-14"S	OAK 12"M-14"S	OAK 2-8"x8"
STRINGERS - SIDE	—	PINE 2"x4" -	TWO-PINE 4"M-2"S	TWO-PINE 4"M-3"S	TWO-PINE 6"M-4"S	TWO-PINE 6"M-6"S	PINE 3 6"M-6"S	PINE-3 8"M-6"S	PINE 3 10"M-8"S
THWARTS-	PINE 1¼"M-10½"S	—	—	—	—	—	—	—	—
TRANSOM KNEE	OAK 4"S	OAK 3½"S-TWO	OAK 4"S	OAK 6"S	OAK 6"S	OAK 6"S.	OAK 6"S	OAK 8"S	OAK 10"S
" - MARGIN	OAK 1½"M x 1½"S	OAK FRAME SIZE	OAK 2½"x2½"	OAK 3"x3"	OAK 4"M-3"S	OAK 4"x4"	PINE 6"x4"	PINE 6"x6"	PINE 8"x8"
" - PLANKING	PINE-CEDAR 1½"THICK	PINE-CEDAR 1⅝"THICK	PINE 1⅝"	PINE 1⅝"	PINE 2"	PINE 2½"	PINE 2¾"	PINE 3"	PINE 3¼"

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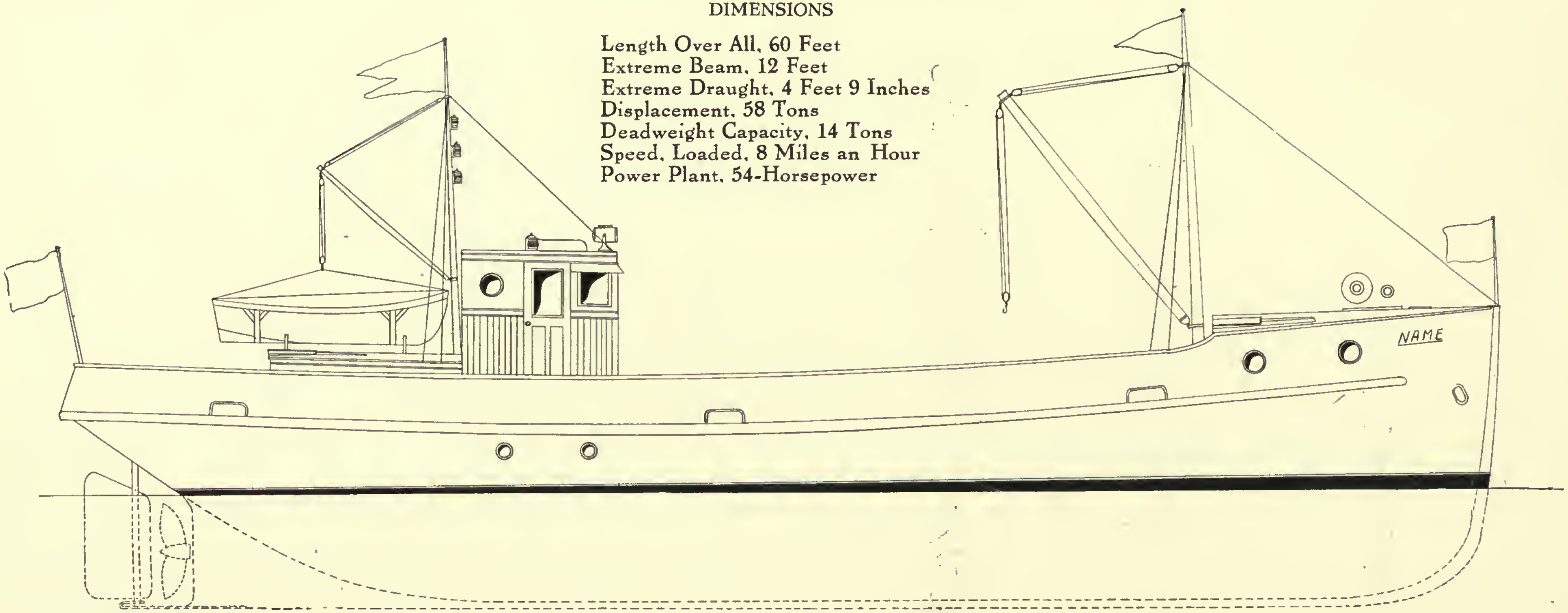
APPENDIX II

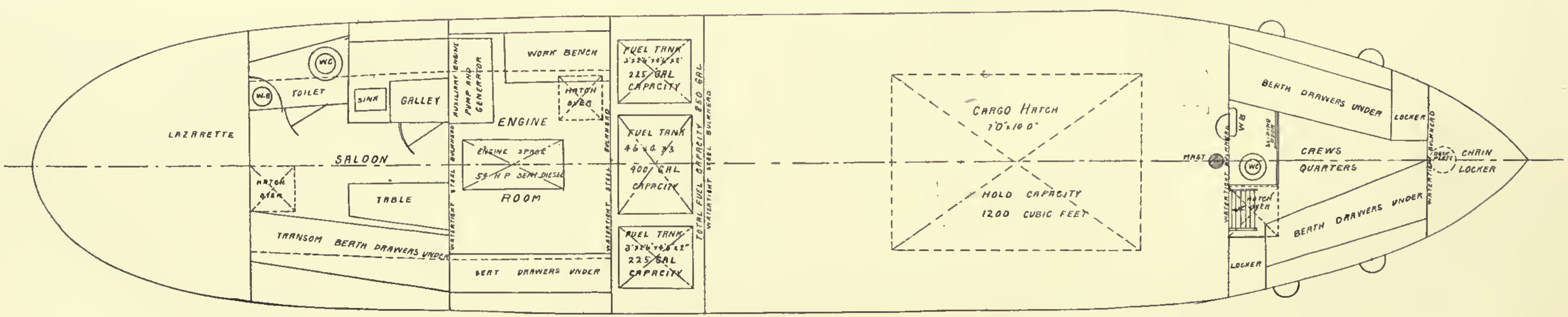
Designs and Details *of* Typical Power Workboats

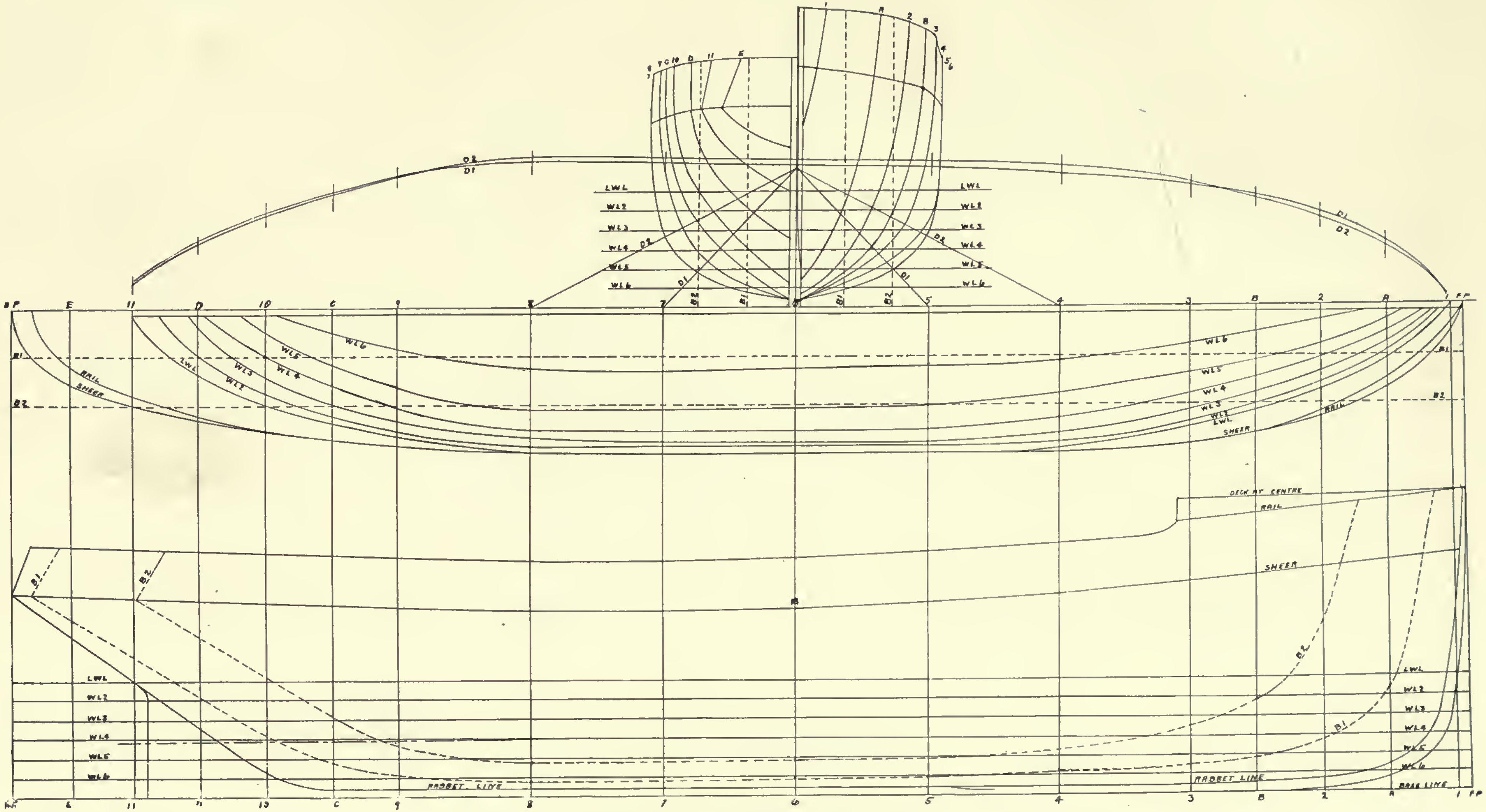
Harbor Tug and Lighter

DIMENSIONS

Length Over All, 60 Feet
Extreme Beam, 12 Feet
Extreme Draught, 4 Feet 9 Inches
Displacement, 58 Tons
Deadweight Capacity, 14 Tons
Speed, Loaded, 8 Miles an Hour
Power Plant, 54-Horsepower



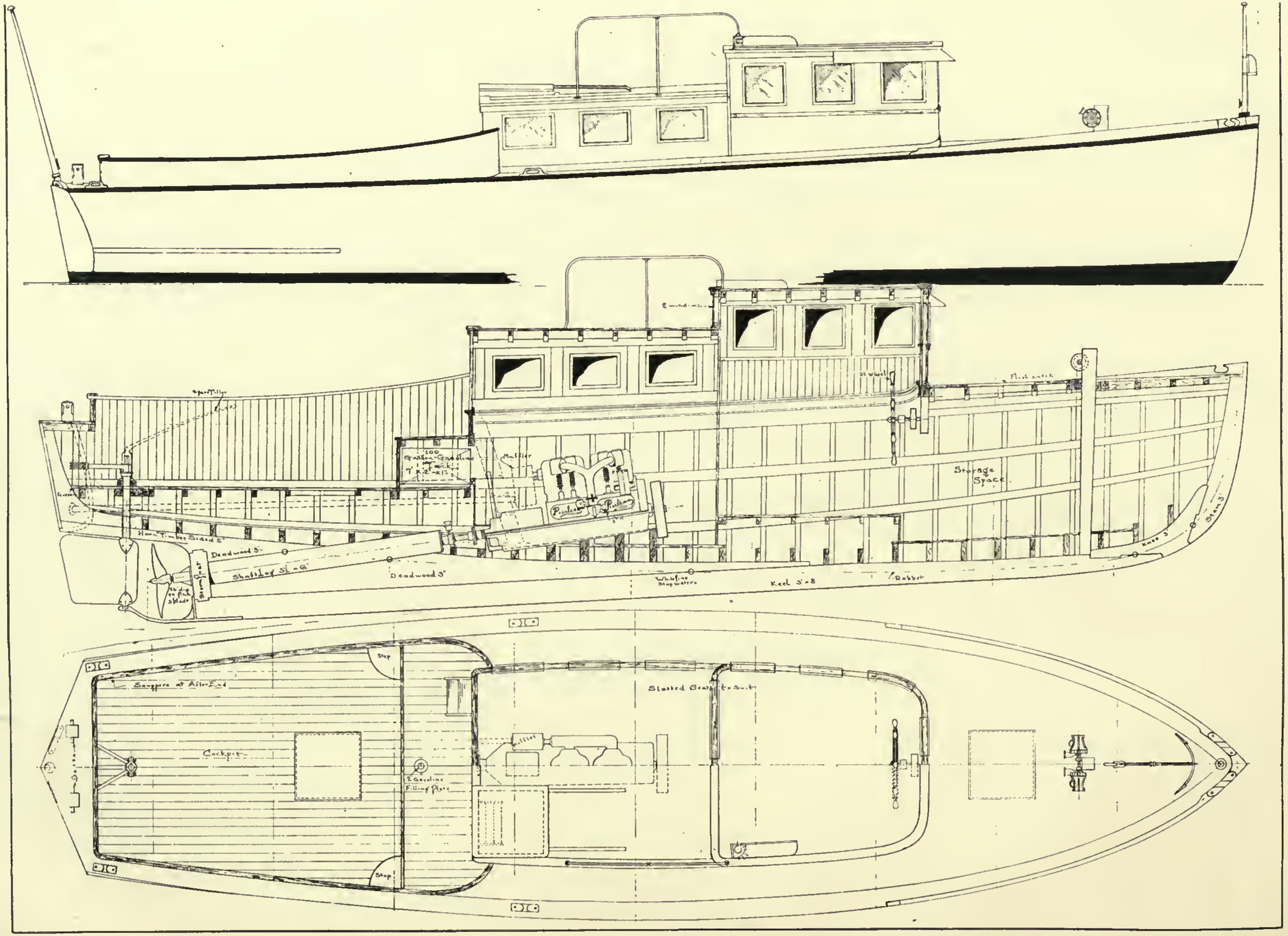


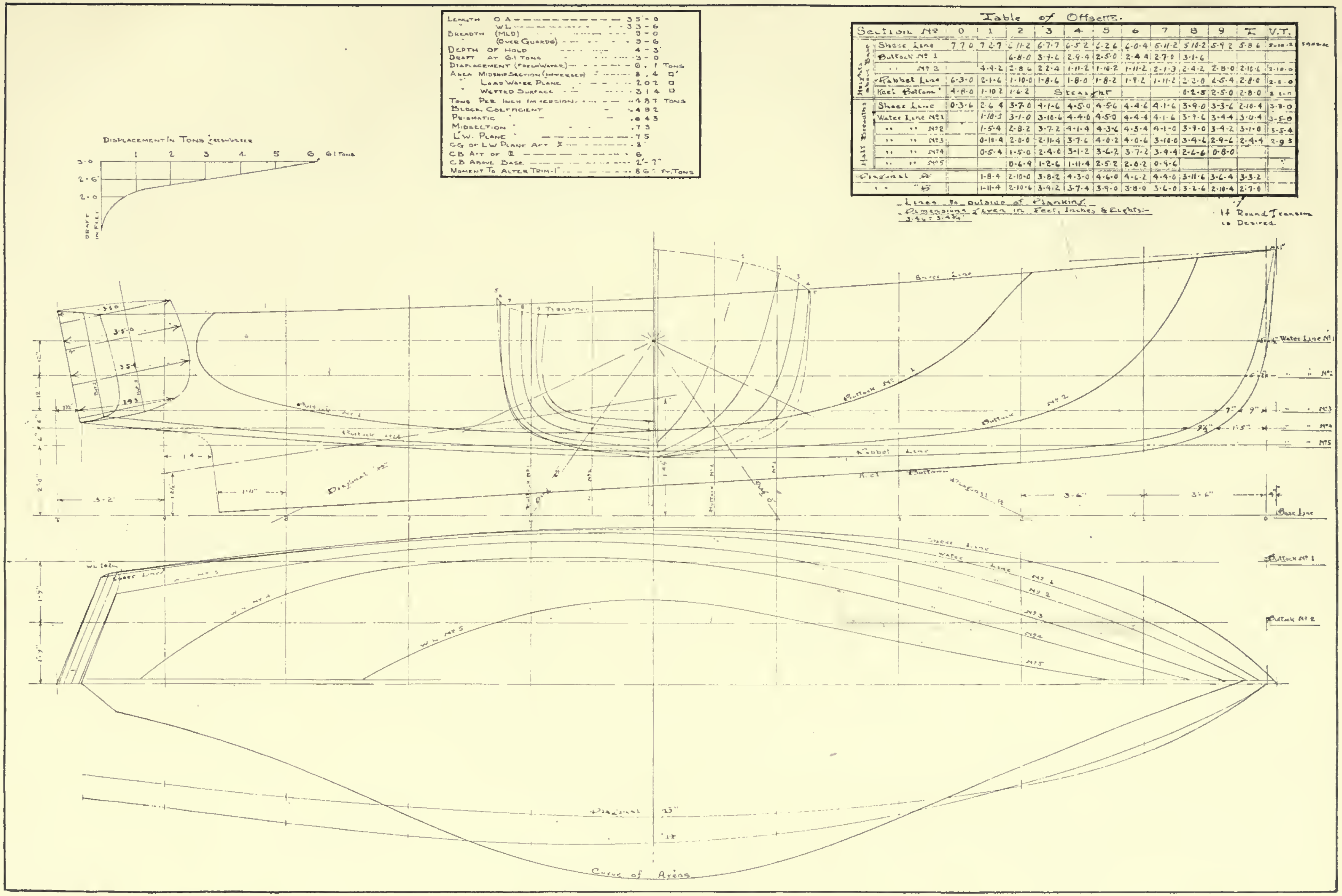


60-FOOT HARBOR TUG AND LIGHTER

The above plans were contributed by Ian L. McKenzie, Toronto, Ont. Dimensions are 60 x 12 feet and the deadweight capacity is 14 tons. The main power plant is a 4-cylinder semi-diesel marine engine of 54 horsepower of 400 revolutions per minute. Speed 8 miles loaded and 10 miles light

35-Foot Ship Chandler's Launch





Length O A	35-0
" WL	33-6
Breadth (MLD)	9-0
" (Over Guards)	9-6
Depth of Hold	4-3
Draft at 6.1 Tons	3-0
Displacement (Fresh Water)	6.1 Tons
Area Midship Section (Immersed)	8.4 □'
" Load Water Plane	202 □
" Wetted Surface	314 □
Tons Per Inch Immersion	.487 Tons
Block Coefficient	.492
Prismatic "	.643
Midsection "	.73
L.W. Plane "	.75
CG of L W Plane Aft ⊠	.8'
CB Aft of ⊠	.6
CB Above Base	2'-7"
Moment To Alter Trim-1"	86 Ft. Tons

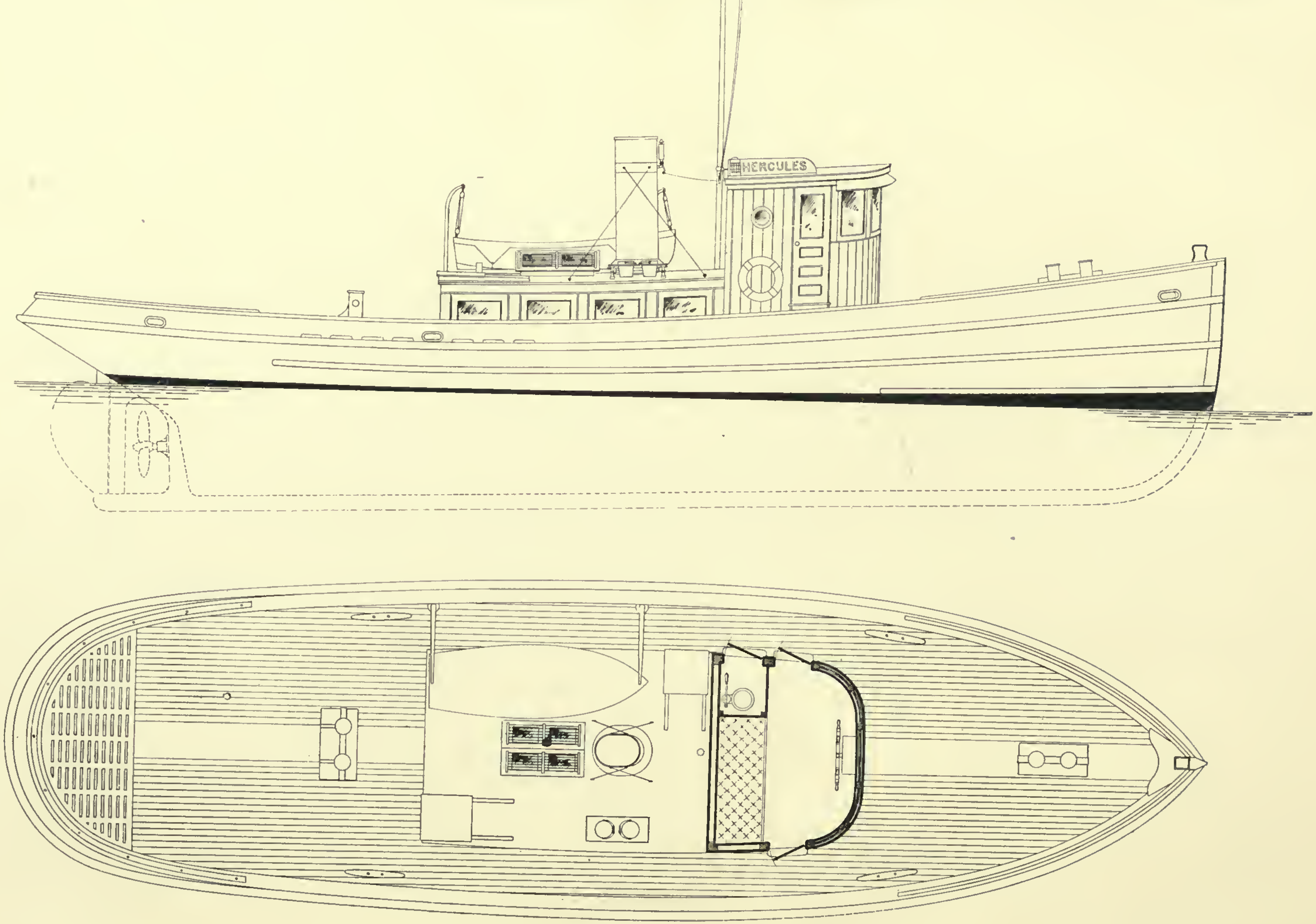
Table of Offsets.

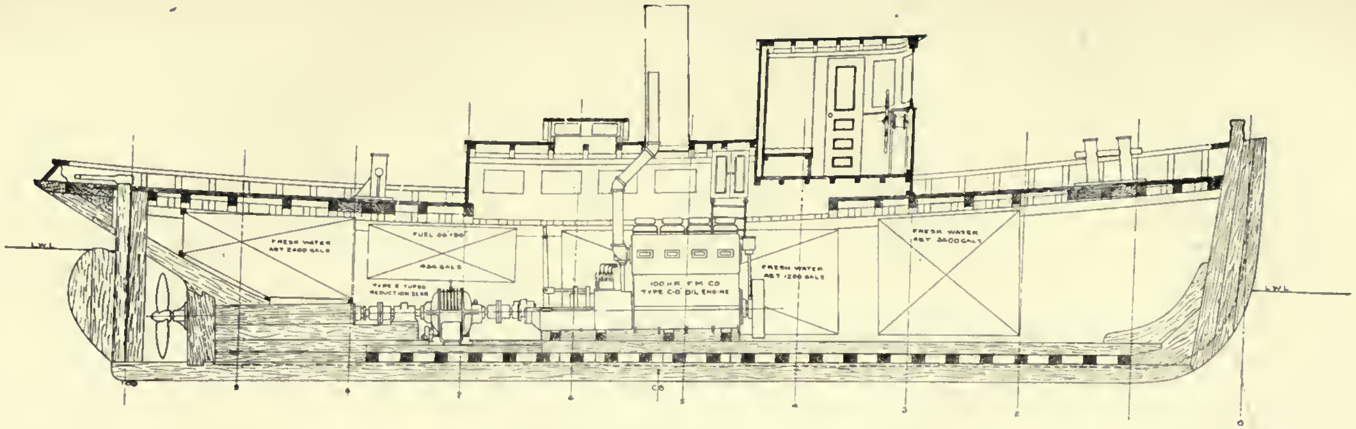
	Section No	0	1	2	3	4	5	6	7	8	9	T	V.T.
Heights above Base	Sheer Line	7 7 0	7 2-7	6-11-2	6-7-7	6-5-2	6-2-6	6-0-4	5-11-2	5-10-2	5-9-2	5-8-6	5-10-2
	Buttock No 1			6-8-0	3-9-6	2-9-4	2-5-0	2-4-4	2-7-0	3-1-6			
	" No 2		4-9-2	2-8-6	2-2-4	1-11-2	1-10-2	1-11-2	2-1-3	2-4-2	2-8-0	2-10-6	2-10-0
	Rabbet Line	6-3-0	2-1-6	1-10-0	1-8-6	1-8-0	1-8-2	1-9-2	1-11-2	2-2-0	2-5-4	2-8-0	2-8-0
	Keel Bottom	4-8-0	1-10-2	1-6-2	Straight					0-2-5	2-5-0	2-8-0	[illegible]
Half Breadths	Sheer Line	0-3-6	2-6-4	3-7-0	4-1-6	4-5-0	4-5-6	4-4-6	4-1-6	3-9-0	3-3-6	2-10-4	3-3-0
	Water Line No 1		1-10-3	3-1-0	3-10-6	4-4-0	4-5-0	4-4-4	4-1-6	3-9-6	3-4-4	3-0-4	3-5-0
	" " No 2		1-5-4	2-8-2	3-7-2	4-1-4	4-3-6	4-3-4	4-1-0	3-9-0	3-4-2	3-1-0	3-5-4
	" " No 3		0-11-4	2-0-0	2-11-4	3-7-6	4-0-2	4-0-6	3-10-0	3-4-6	2-9-6	2-4-4	2-9-3
	" " No 4		0-5-4	1-5-0	2-4-0	3-1-2	3-6-2	3-7-2	3-4-4	2-6-6	0-8-0		
	" " No 5			0-6-9	1-2-6	1-11-4	2-5-2	2-0-2	0-9-6				
Diagonal A			1-8-4	2-10-0	3-8-2	4-3-0	4-6-0	4-6-2	4-4-0	3-11-6	3-6-4	3-3-2	
" B			1-11-4	2-10-6	3-4-2	3-7-4	3-9-0	3-8-0	3-6-0	3-2-6	2-10-4	2-7-0	

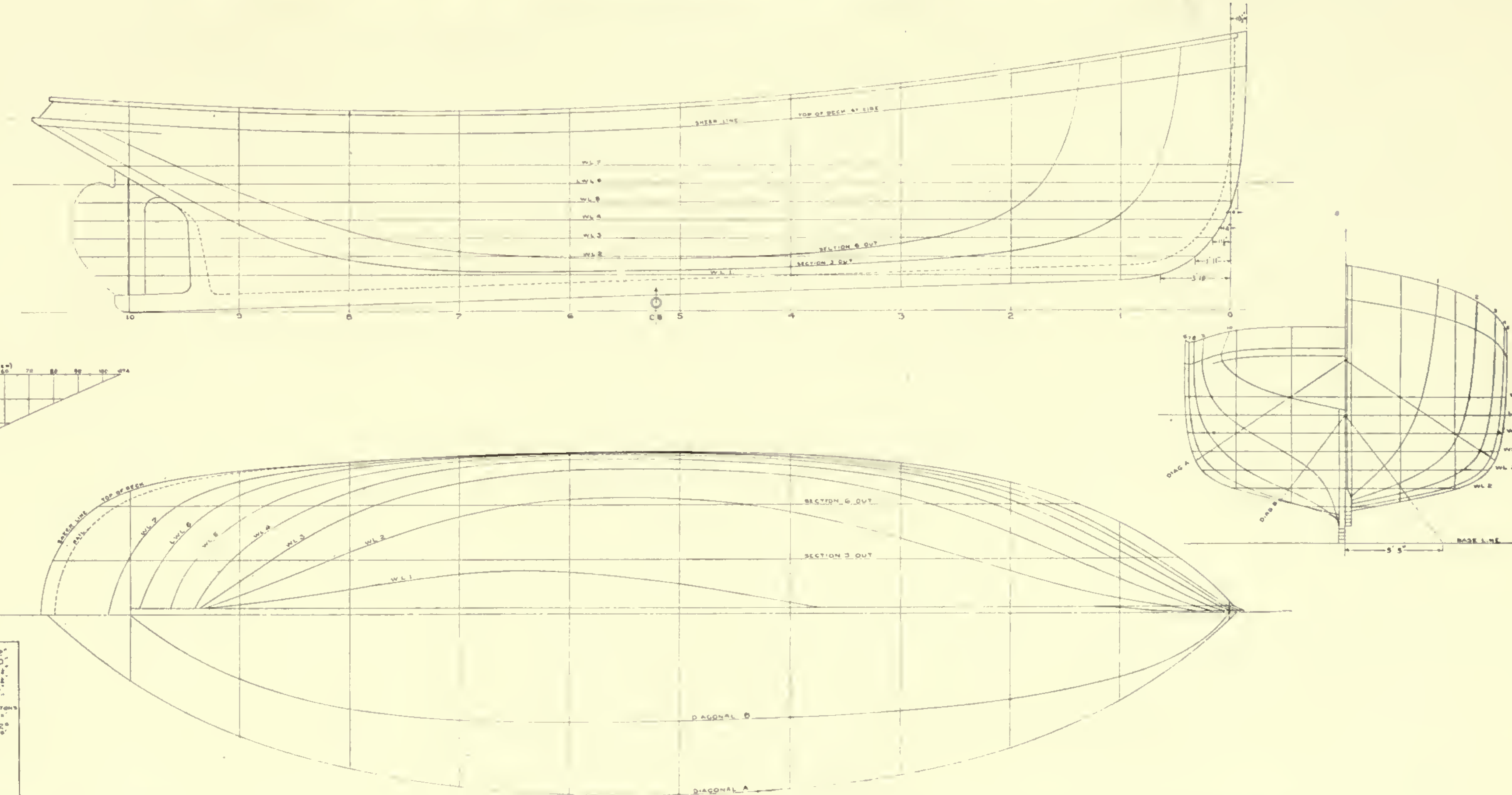
35-FOOT SHIP CHANDLER'S LAUNCH

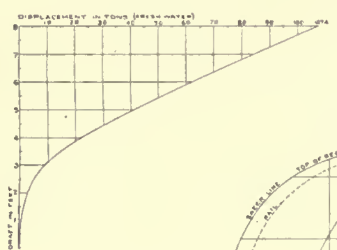
This boat, designed by J. Murray Watts, was completed by Vanderslice, the Camden builder for Bie & Schiott, ship chandlers, 112 South Second street, Philadelphia—The power plant is a 50-horsepower, 4-cylinder Peerless and the boat makes 12 miles an hour

Sixty-Six-Foot Oil Engined Tug Equipped With Reduction Gear







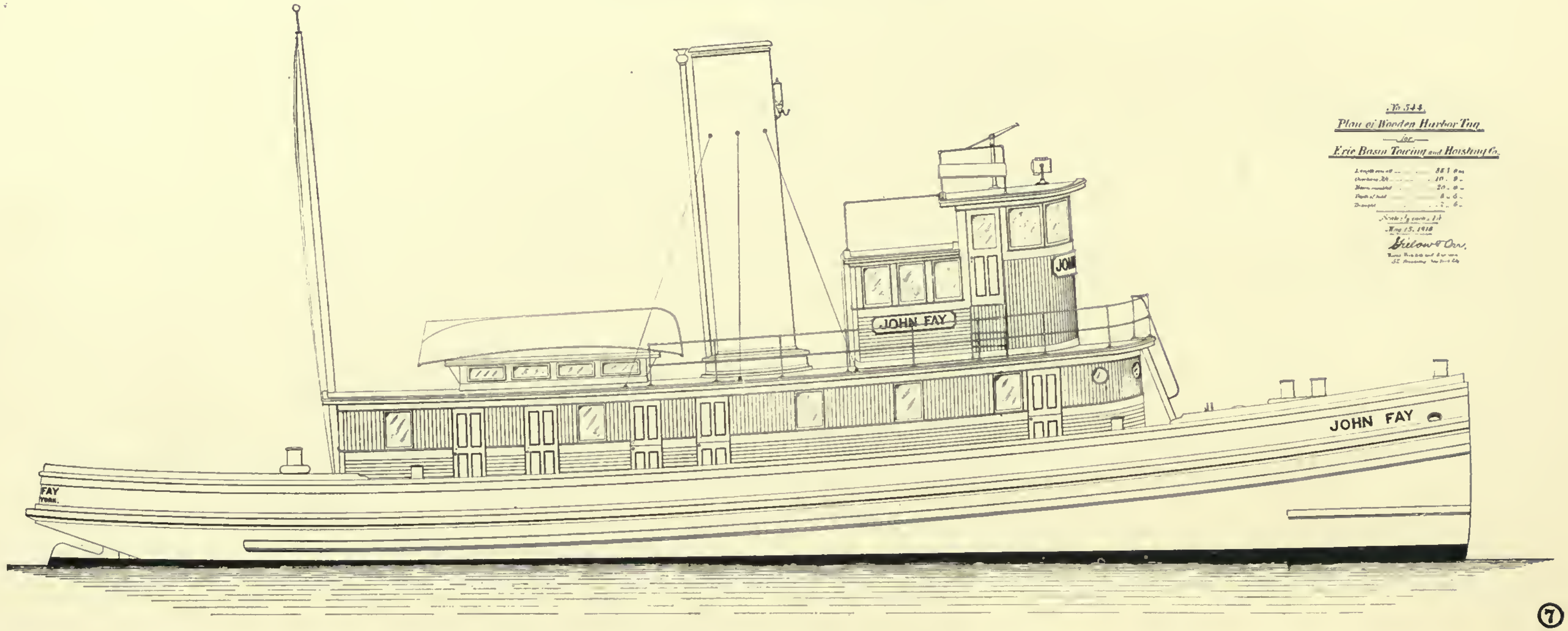


LENGTH O.A.	66' 2"
" L.W.L.	60' 0"
BREADTH (MOULDED)	17' 8½"
" (OVER GUARDS)	18' 8½"
DEPTH OF HOLD	6' 0"
DRAFT AT 84.6 TONS	7' 0"
DISPLACEMENT (FRESH WATER)	84.6 TONS
AREA MIDSECTION (IMMERSED)	74.6 □'
" LOAD WATER PLANE	828.2 □'
" WETTED SURFACE (APPROX)	1137 □'
TONS PER INCH IMMERSION	1.91
BLOCK COEFFICIENT	.842
PRISMATIC "	.671
MIDSECTION "	.657
L.W. PLANE "	.780
C.G. OF L.W. PLANE AFT ⊠	1.65'
C.B. AFT ⊠	1.33'
C.B. ABOVE BASE	4.48'
TRANSVERSE B.M.	5.56'
LONG'AL B.M.	57.7'
TRANS. B.M. ABOVE BASE	10.04'
LONG'AL B.M. " "	62.18'
MOMENT TO ALTER TRIM 1" (ABOUT)	6.65 FT. TONS

LINES AND ARRANGEMENT PLAN

The use of a reduction gear permits this 66-foot tug to compete with steam tugs on heavy towing jobs where a large, slow-speed wheel is necessary. This boat was designed by the Edwards Engineering Company

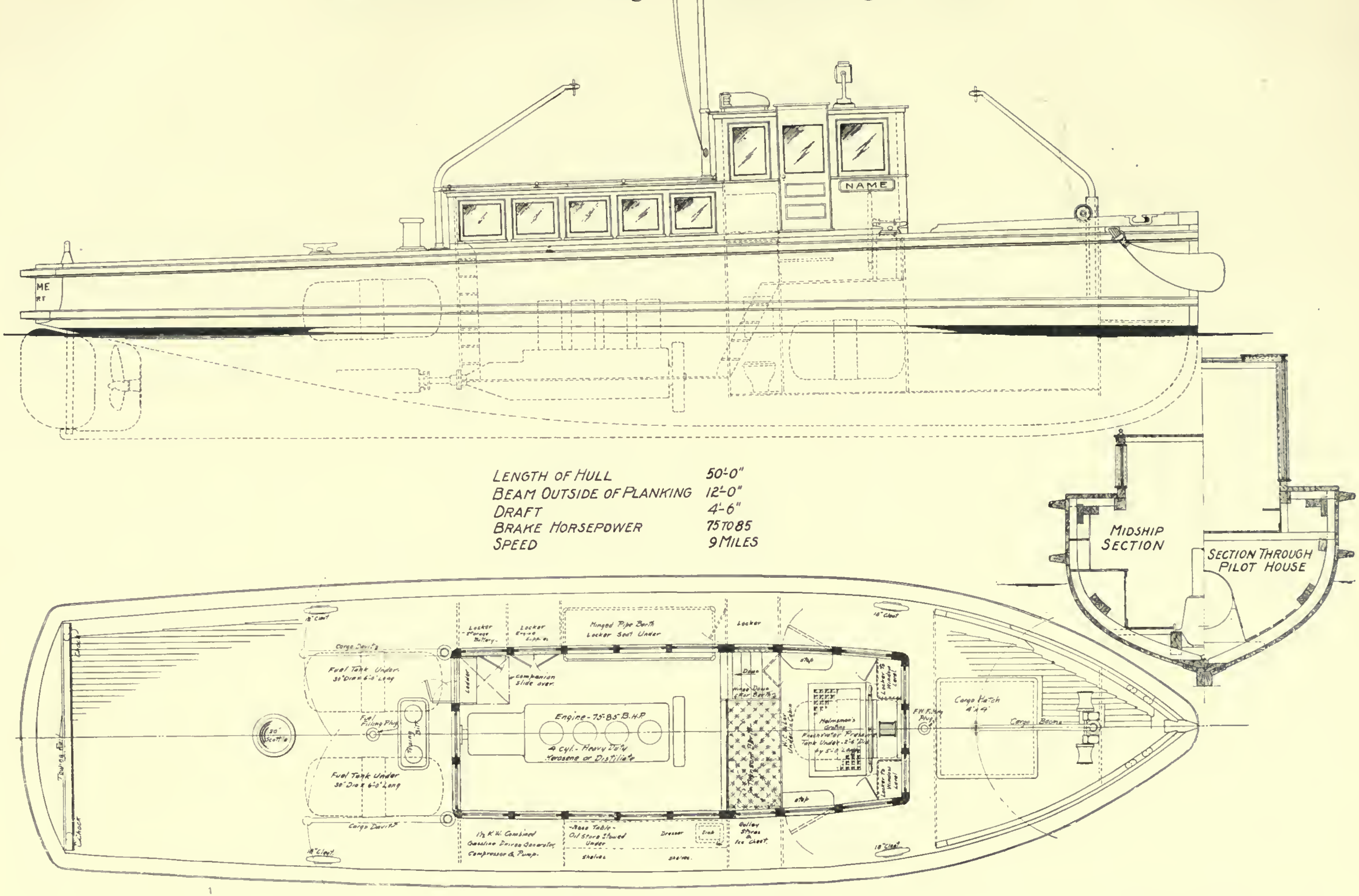
80-Foot Harbor Tug



PROFILE PLAN OF ERIE BASIN TOWING COMPANY'S TUG

Two of these boats will be put in commission soon for service in New York Harbor—They were designed by Gielow and Orr and embody the latest up-to-date ideas in harbor tug design and construction

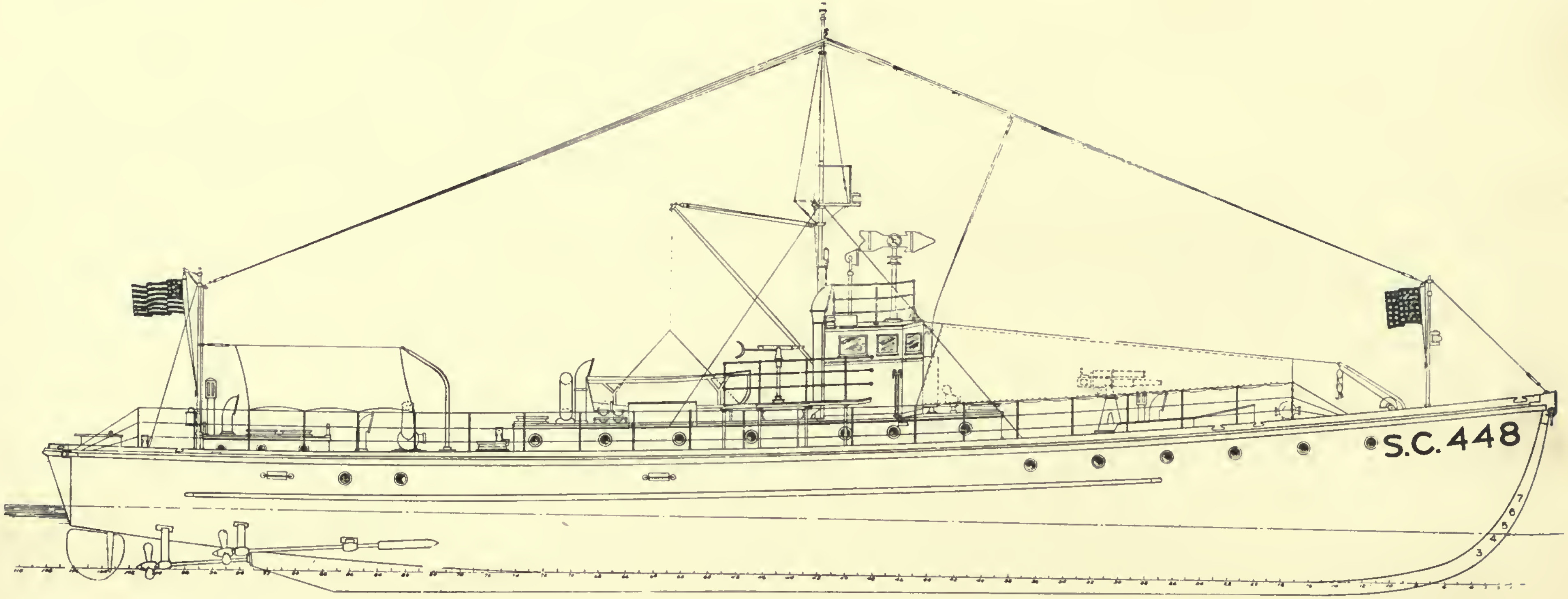
50-Foot Harbor Tug and Freight Boat

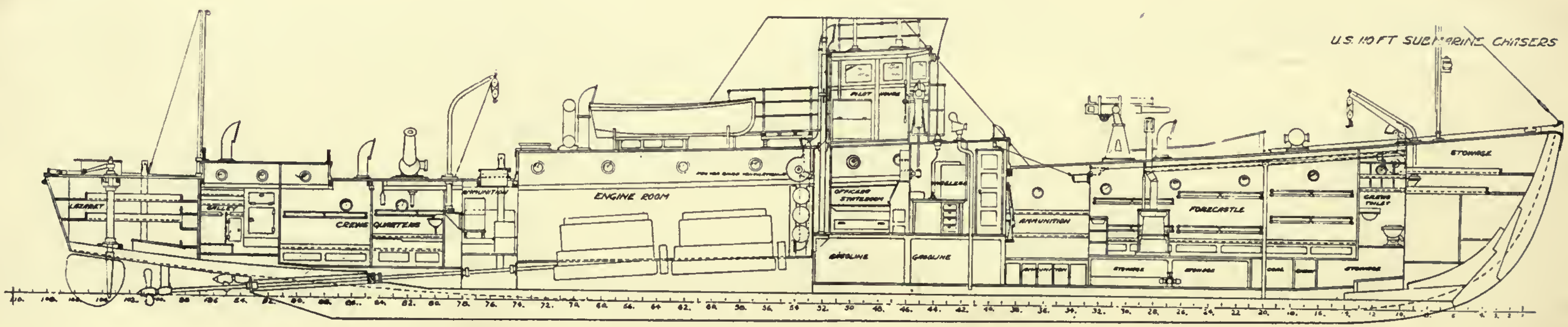


ELEVATION, PLAN AND SECTION

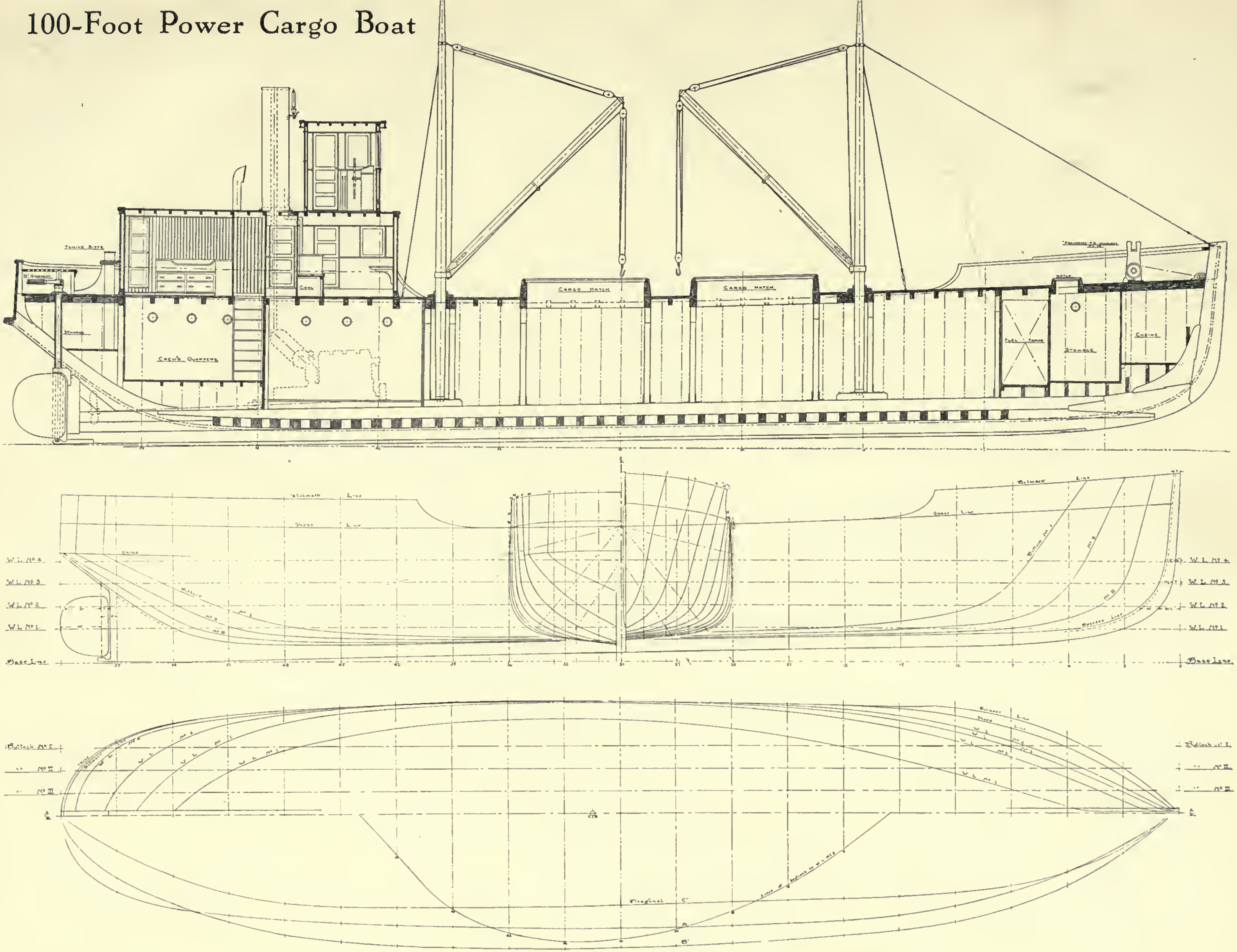
Prepared by Arthur F. Johnson, N. A. Departures noted from ordinary practice are based upon experience in producing power tug boats for the U. S. Engineers' Department and Coast Artillery tenders for mine-laying work. The towing feature is enhanced by location of bitts well forward, the clear deck aft with quadrant below it, and the straight towing rail with chocks at its ends to guide and support the hawser

U. S. 110-Foot Submarine Chasers





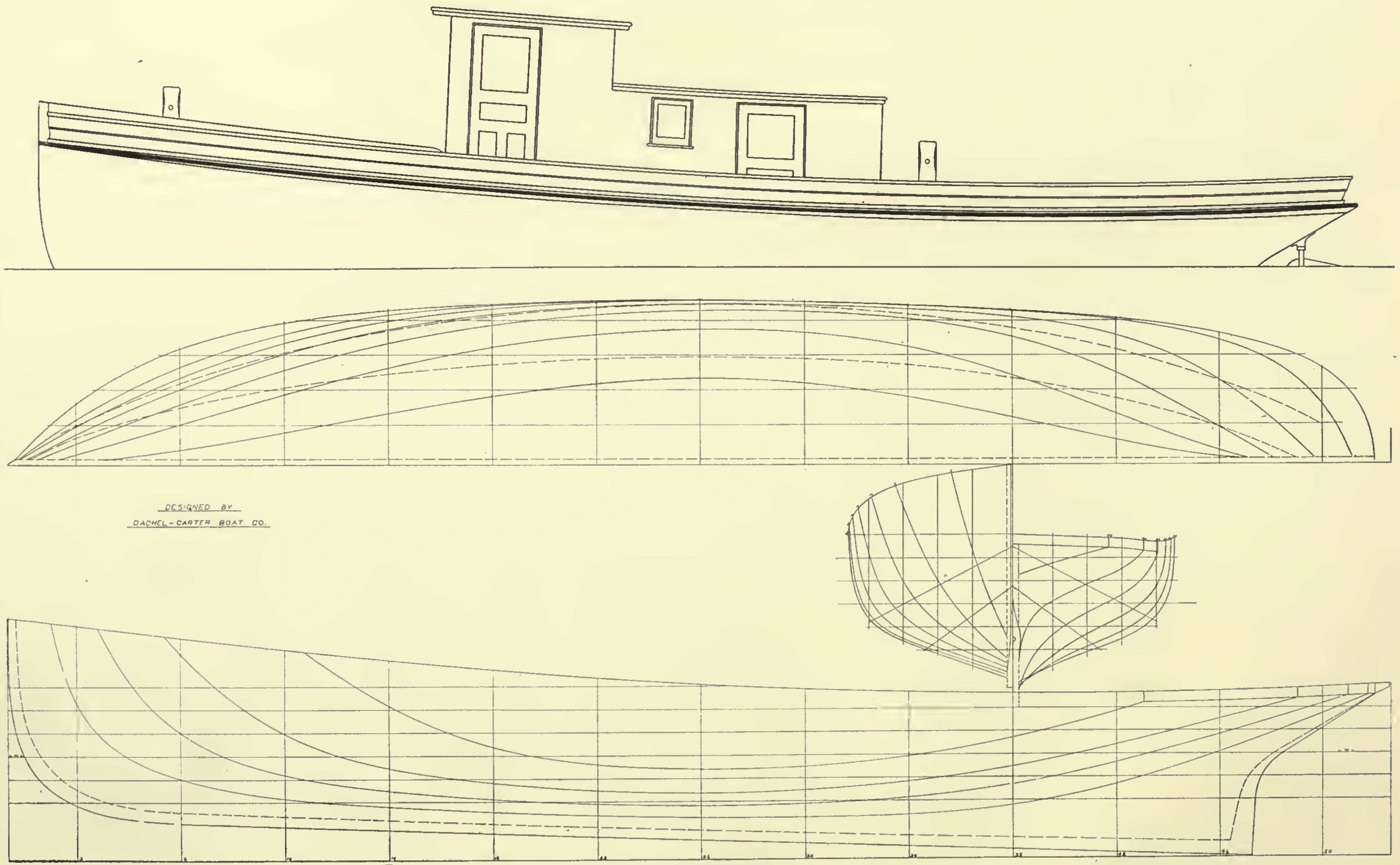
100-Foot Power Cargo Boat



150-TON CAPACITY VESSEL

The power plant consists of two 60-horsepower semi-diesel engines giving a speed of seven knots

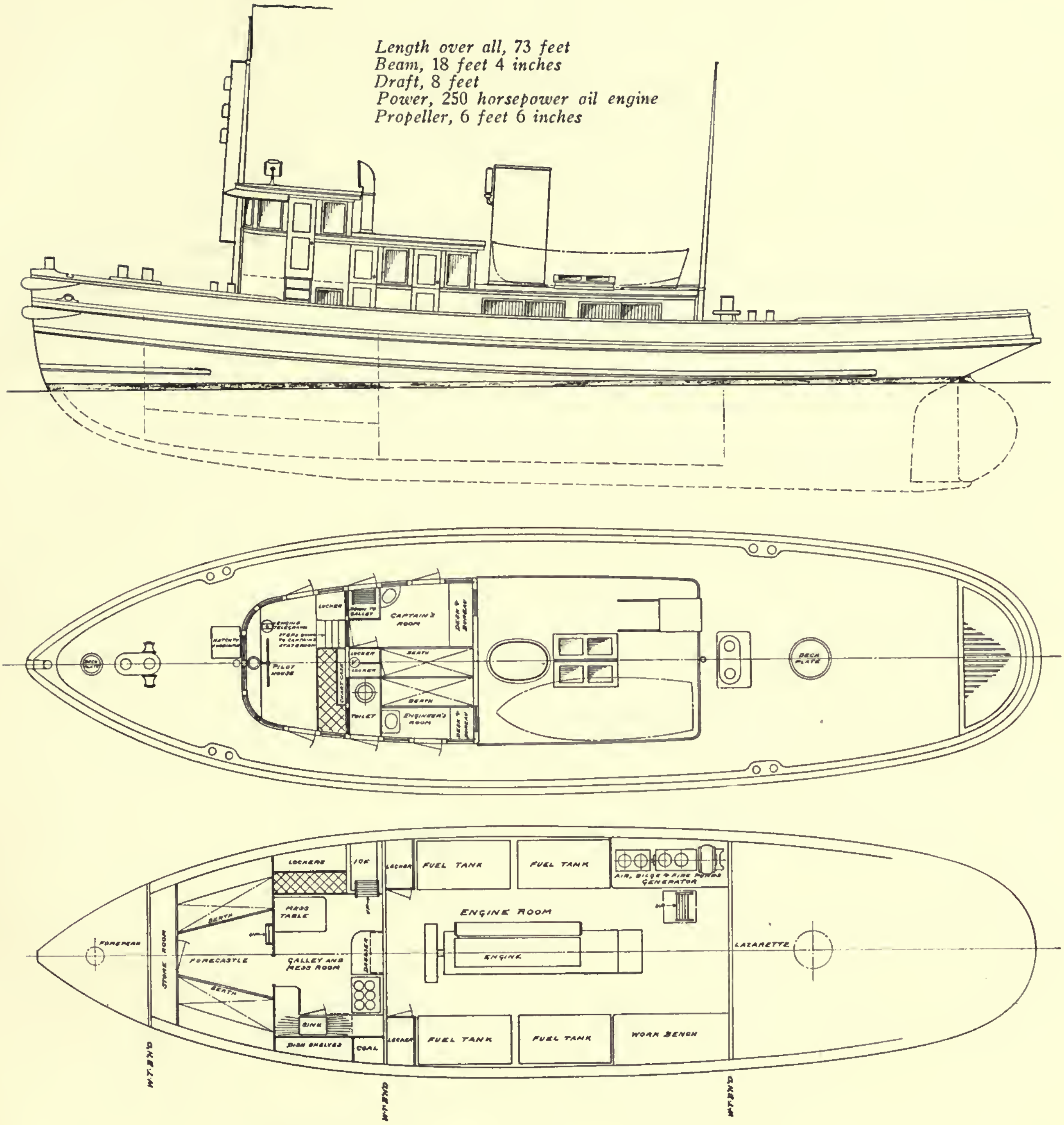
Fish Tug and Tow Boat



40 x 9-FOOT FISH TUG

Designed by the Dachel-Carter Boat Co., Benton Harbor, Mich., for service where shoal draught is desired—The boat draws 3½ feet and makes 10 miles an hour with a 50-horsepower heavy duty gas engine

Power Towboat for Harbor Work



An oil-burning engine of 250-horsepower turns a 6½ foot propeller

THE accompanying plans are those of a power towboat designed by R. E. Winslow, of Bristol, R. I. She is 73 feet over all, 18 feet 4 inches beam and 8 feet loaded draft. The follows the general design of the smaller type of steam harbor towboats, but has many interesting features and by using a gas engine running on low cost fuel she will be able to handle tows that would not pay a big steam tug to handle, as well as saving money owing to the smaller crew and no fuel expense except when under way.

She is designed to handle any ordinary work in a harbor such as a 20 per cent larger steam tug would be required to do, and can go in shoaler water than a steam tug of similar power. She would be especially adapted to canal towing and river work and still is seaworthy enough to do sound and coastwise work. Her freeboard to deck at bow is 6 feet 10 inches and least 2 feet 11 inches; at stern 3 feet 5 inches; so she will be quite seaworthy and still not high enough out of water to save unnecessary windage.