LAUNCHES.

Although steam launches had been in service for a considerable period, it was not until the beginning of the present century that motor launches became a subject for the careful consideration of Naval Architects. It was owing to the fact that these early motor boats were capable of speeds hitherto unaccomplished by steam vessels of similar size, that the attention of the public was attracted. With the rapid development of the petrol-electric engine for the motor-car, came a corresponding development of this type of engine for marine work. These racing boats, showing up all defects of design in the hull and engine, brought about a rapid improvement, greater seaworthiness, and with commercial interests closely following the path of the pleasure seeker, we find, in 1906, a speculating firm building a little 10-ton cargo-carrying launch. 1907 and 1908 reassured the value of the marine motor for this class of boat, and with continual improvements, it is not surprising to find that nowadays it is the exception rather than the rule to find launches installed with the old-fashioned high speed steam engine with the small vertical boiler.

The diversity of conditions and employment to which launches are now put, makes it an impossibility to detail each type separately in the space allotted for this class of boats. Suffice it to say only, that the most common, and, generally speaking, these can be divided into the following classes:

Type I. SEA GOING LAUNCHES, i.e., those employed upon the coast for making short trips, etc.

Type II. HARBOUR LAUNCHES, i.e., those employed on exposed waters, and in harbours.

Type III. RIVER LAUNCHES, i.e., those employed upon sheltered waters.

These three types may be further divided, each into:

(a) Launches employed in carrying cargo,
(b) Launches employed commercially, for carrying passengers,
(c) Private pleasure launches,
(d) Towing launches, etc.

It was quite common in some of the earlier types of launches, those with very fine ends and an inclination to hollow bilges towards the midship section, to find considerable differences between the prismatic and block coefficients, which when used with new boats for comparative purposes, would often lead to a great amount of trouble. The block coefficient of present-day launches varies considerably with each type. For pleasure launches it generally lies between 0.3 and 0.45, although with some very fine boats it is often below 0.25, and on the other hand, with the boats intended to carry cargo or a large number of passengers, it will often be as high as 0.65. The prismatic coefficient, which forms a greater guide for computing estimates, etc., generally lies between 0.4 and 0.6, of course, exceeding these figures for the cargo-carrying, or the very fine racing launch. As a guide, the following table may prove useful for estimating the approximate prismatic coefficients of our three types of launches:

<table>
<thead>
<tr>
<th>Type</th>
<th>Cargo Class</th>
<th>General Class</th>
<th>Pleasure Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>(a) 0.6-0.65</td>
<td>(b) 0.45-0.65</td>
<td>(c) 0.4-0.6</td>
</tr>
<tr>
<td>II</td>
<td>(a) 0.6-0.65</td>
<td>(b) 0.45-0.6</td>
<td>(c) 0.4-0.6</td>
</tr>
<tr>
<td>III</td>
<td>(a) 0.5-0.65</td>
<td>(b) 0.4-0.6</td>
<td>(c) 0.3-0.5</td>
</tr>
</tbody>
</table>

With launches, and some types of yachts, it must be noted that the block coefficient is determined from the waterline breadth of the boat, and the prismatic coefficient, except with the very broad transomed racing boats, is calculated at the section of greatest immersed area.

Some years ago, an authority upon launch design, expressing the prevailing opinion of his time, said that, when discussing the shape of a boat, it was necessary to have a boat somewhere, and the sooner it was over, the better. He implied that full bows, getting the greatest immersed section well forward, and a particularly long and fine run aft to the propeller were essential for speedy, stable, and economical boats. Modern opinion does not confirm this idea, and, moreover, experiment and experience prove that the reverse is the case. The greatest section should be substantially aft, and, for example, one may cite the recent fast launches which have passed successful trials. These boats, of French and American design, have very fine water lines forward (although the deck lines are excessively full owing to the great flare of the forward sections), and their point of greatest waterline beam is at the transom, the load waterline being more or less triangular in shape. Strictly speaking, the greater the speed of the boat, the further aft becomes the point of greatest beam, although for the types of boat which we are treating in the chapter, it is usual to provide the point of greatest beam, and, therefore, the section of greatest immersed area, at about 0.05 to 0.025 of the waterline length aft of amidships for boats of Type b and d. With Type c, where a turn of speed may be required, the proportion may be increased to 0.10, or even in some cases, to 0.15.

Launches, as a rule, are designed upon a geometrical curve of areas. It is not intended to explain here the mathematical significance of this curve, sufficient is it to mention that waves displaced by a vessel moving in water follows the curve of versed
The position of the Centre of Buoyancy is to a great extent governed by this curve, but many Designers make some modifications whereby the C.B. can be brought into the position they wish. There is considerable variation in its position with different classes of launches, and there are a number of opinions among Launch Designers, some preferring the C.B. to be forward, and others for it to be aft of amidships. The position, however, is more a matter of compromise, and more often than not, the correct draughts, etc., are made up by ballasting, in the pleasure boats, and by trimming, etc., in the case of the passenger and the cargo launches.

With launches plying in exposed waters, the forward sections should be a combination between the V and the U forms.

V-shaped sections, while giving a fine speedy entrance, lack ability to give the necessary lifting power and buoyancy, whilst U sections giving ample buoyancy produce a clumsy entrance and would make a most uncomfortable boat, owing to pounding. To have the V-sections merging into the U or to have one superimposed upon the other, produce an economical, efficient and comfortable forebody.

There is a great difference in the shape of midship sections for different classes of launches. Passenger launches working under Types I and II, have fairly full sections, with a good round of bilge, and considerable rise of floor, while launches working upon rivers (Type III) and where there is usually some restriction on draught, have practically a flat floor and very hard bilge. Tumble home is not desirable, nor is it necessary, except in very high-speed boats.

Launches with built-up sterns, i.e., counter and canoe sterns, should possess a fairly fine run aft to the propeller, which, of course, will give rise to hollow bilges in the after sections, but with transom-sterned launches, and with those having the slipper, or such like stern, both the waterlines and the sections are very full.

Fig. 72 gives the sheer draught of a vessel of Type I, and Fig. 73 that of a vessel of Type II. Their differences in character may be easily seen. With the smaller boat, the after body, it will be noticed, is much fuller, and the same will be seen with the sections of the river launch, given in Fig. 74.

A good sheer is needed for vessels which are intended for service around the coast, or at the mouths of large rivers, but with the smaller rivercraft, sheer is more a matter of appearance than necessity. For launches coming under the Board of Trade survey, of certificate, there are certain requirements. Vessels plying under the Class St. 6, certificate need a minimum freeboard of 15 inches when fully loaded, for a vessel of 20 feet in length, increasing proportionately to 22 inches for a vessel of 40 feet in length. This freeboard is measured to the top of the covering
which is the ladies' and gents' toilet. The engine room is amidships, forward of which is the Galley, which leads directly into a small dining saloon. The crew are accommodated abaft the small chain locker. Except for the steering house, which is situated above the engine room, the deck is almost clear for passenger accommodation.

The arrangement of the "May," Fig. 78, shews a somewhat smaller vessel coming under Type II.

Here the engine is situated well forward under a casing, which will pass the Board of Trade, providing it is efficiently made. The fuel is stored in circular tanks strapped to the beams under the forward deck. A long cockpit accommodates the passengers, and it will be noticed that by the arrangement shown, the greatest seating is obtained.

A usual type of river launch is shown in Fig. 79. The engine again is situated forward, while at the end of the lengthy forward cockpit is fitted a small house, complete with two sofa-berths, cupboard and stove. Another cockpit is abaft the house, and a small locker for spares, etc., is fitted under the after deck.

Although steel is gradually being used for some classes of launches, the construction is still mainly made in wood. For small craft, wood has a distinctive advantage over steel, inasmuch that the construction is both lighter and cheaper, and, to a degree, simpler. Steel plating for launches is of very light scantling, and is apt to show any light damage it may receive, and an after season's hard work, would present a very unsightly appearance, and also, steel, having a greater conductive power of heat, would in summer, make a small cabin almost unbearable. It would be impossible to define any limit of where wood vessels should finish, and steel commence, it is more a matter of conditions of service.

In wooden boats, the keel and hog-piece should be of Oak, or other hard wood, although Pitch, Oregon and Kauri Pine are used in some of the cheaper boats, and in some large vessels English Elm is sometimes used with satisfactory results. Stem and stern pieces should be of natural grown Oak crooks well scarphed to the keel or hog-piece, and well through fastened with yellow metal bolts. The floors, which are of grown Oak crooks, should be of sufficient length to take one through fastening with the bilge stringer. In larger craft, steel plate floors are often used with advantage, and these, of course, must be galvanised, preferably by the hot-process, after working.

Except with small vessels, up to about 40 feet in length or to 50 feet in river craft, cut timbers of English Oak, spaced at about 4 feet apart, centre to centre, form the main framing, smaller steam-bent frames of American Elm being worked between to stiffen the outside planking, and to supplement the main framing. These small bent timbers should extend from gunwale to gunwale, in one piece, passing over the keel or the hog-piece, wherever practicable.

Beam shelves, stringers, etc., which should be of American Elm or of Pine, should be fitted on the face of the cut-timbers, if these are fitted, or on the face of the bent timbers; they are through fastened with copper nails, of substantial size, and clenched over on the inside, on copper rooves. Longitudinals should be carried the whole length of the boat; scarphs should
The powering of launches is an important and difficult problem. Many launch owners require high speeds owing to their greater advertising value, while on rivers there is generally a Conservancy Board which imposes some speed limit. However, it may be safe to say that the normal speed of a launch lies between 6 and 8 knots. Fig. 85 gives speed and power curves for launches of Type I. and II. These are based upon vessels having fairly fine lines, and with prismatic coefficients as shown in the table on page 111. The admiralcy coefficient formula, I.H.P. = \( \frac{D^\frac{3}{2} \times V^3}{C} \)

is often used for computing horse power, although it is necessary to make some allowance, generally about 10 per cent., for using the B.H.P. instead of I.H.P. The midship area is often used instead of the two-thirds power of the displacement, in which case, the coefficient, \( C = \frac{A \times V^3}{\text{I.H.P.}} \) and varies between 100 and 250 according to the class of launch. The speed length ratio, \( \frac{V}{\sqrt{L}} \), lies between 1.3 and 2, for moderate speeds, increasing to 3 and 4 for very speedy boats. A reliable formula for speed and power is given by \( M = \frac{\sqrt[3]{R^2 \times D^2}}{B} \)

where, \( L = \) the overall length of vessel, in feet, 
\( B = \) the greatest breadth of the vessel on the waterline, in feet, 
\( M = \) the speed of vessel in miles per hour, 
\( c = \) constant varying between 9.5 in moderate speed boats to 8.5 in high speed boats.

The design of the propeller is important, but up to the present there are no reliable formulae for giving the diameters and pitches, etc., and it is more a matter of experiment to find the most efficient proportions. The high number of revolutions per minute of motors, need a special type of propeller. The small pitch ratios, generally between 0.6 and 0.8, are essential. It is a comparatively easy matter to determine the pitch of a propeller, since with launches there is usually a slip between 15 and 20 per cent., although this latter figure may be exceeded with some of the very full, slow boats. But having fixed the pitch, the Designer finds himself between two problems which require the most careful consideration. In determining the diameter, care must be taken to see that it is sufficient to give the necessary area, while on the other hand, by increasing the diameter the pitch angle is reduced. It is most essential that the pitch angle shall not be reduced below a practical limit, else an inefficient propeller will be the result, and since in practice an angle of 43 degrees at two thirds of the diameter has proved to give most satisfactory results under all-round conditions, it may be unsafe to exceed this. In regard to the diameter of the propeller, many use Mackrow’s formula for the slow speed steam engine, and therefore some allowance must be made for using B.H.P.

\[ P = 737 \sqrt{\frac{\text{I.H.P.}}{R^2 \times D^2}} \]

where, \( P = \) the pitch of the propeller, in feet,
\( D = \) diameter of the propeller in feet,
\( R = \) the revolution of the propeller per minute.

Here again the formula was meant for the slow speed steam engine, and therefore some allowance must be made for using B.H.P.

As with most of the fast running propellers, the blade area should be as near the tips of the blades as possible. The greatest width of a developed blade is usually at about two-thirds the diameter, and it is often twice the width at one third the diameter. The blade area generally totals to 0.25 to 0.33 of the disc area, while the centre of area is about at 0.28 to 0.40 of the diameter Fig. 86 gives curves showing the approximate diameter and pitches for propellers up to 1,000 revs. per minute and up to 200 B.H.P.

It will be noticed that only motors have been mentioned as the means of propulsion, and although it is only here and there one hears of steam installations, the reader requiring information on these is referred to the Chapter dealing with River Passenger Vessels. It is general to fit the petrol-electric type of engine in the private passenger launch, although for a boat coming under the Board of Trade for passenger certificate it is essential to install a paraffin motor, since the Board require motors using fuel with a flash point of not less than 73 degrees Fahr. They allow, however, a small quantity of petrol for starting purposes.

With the larger type of launch, the heavy oil engine seems more suitable, and the heavy oil upon which they run reduces the chances of fire.
For boats coming under the Board of Trade, it is well to note that it is not allowed to have fuel tanks enclosed within the engine room, but to have some special compartment divided off by watertight, steel bulkheads. Efficient trays should be fitted under engine and tanks, and it is essential to see that sufficient fire-extinguishing appliances are supplied. Piping, wherever possible, should be of copper, and the exhaust pipe well jacketed with asbestos roping.

**Fig. 85. Speed and Power Curves, Launches.**

**Fig. 86. Propeller Diameters and Pitches, Launches.**

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**Chapter 9.**

**Passenger Vessels.**

The idea of passenger boats is always associated with early steamboats, which obtained considerable public attention in the early nineteenth century, and no doubt Robert Fulton can claim by his "Clermont" to have been the designer of the first passenger steamboat. Progress was rapidly made, for in 1810 we had regular passenger services between Scotland and Ireland, from Dover to Calais, besides the numerous services on the Hudson, and other North American rivers. The idea of the passenger boat was always accompanied with the idea of the large, cumbersome paddle wheel, and although this means of propulsion is still employed in many parts, it is gradually being displaced by the marine screw.

Where a vessel is on service in running short trips, and having constantly to stop at piers or jetties, and where it is necessary to manoeuvre in congested waters, the side paddle wheel undoubtedly holds considerable advantage over the screw. If the vessel is working in very weedy parts or where there is only a small depth of water, the efficiency of the wheel exceeds that of the propeller, even should the latter be enclosed within a tunnel, and furthermore, repairs to a wheel are far cheaper and simpler, and it is for this reason that vessels intended for tropical waters, where these are difficult, are almost invariably fitted with the wheel.

All boats intended to carry twelve or more passengers must, before being put upon service, hold a Board of Trade certificate. These certificates are based upon the conditions of service in which they are intended to put the vessel, and it is important here to mention that it is necessary for the designs of all vessels over 35 feet in length to be approved by the Board before construction is commenced, and furthermore, the building throughout should be done under the Board's Surveyor. Failure to do this may incur considerable trouble afterwards, in the granting of the certificate. Of course, if the boat be built under a classification society, the boat comes under the Board of Trade only as far as accommodation and equipment are concerned, although certain statutory rules are laid down in reference to water-tight bulkheads, etc.

The certificates which we are concerned here are as follows:

Certificate St. 3., for vessels plying along the coast within defined limits, during daylight, in fine weather, between April 1st, and October 31st.
Certificate St. 4., for vessels plying in partially smooth water.
Certificate St. 5., for vessels plying in smooth water.

Passenger vessels, therefore, are conveniently classified into three distinct types, which for purposes of this book may be as follows:

Type I.—Excursion vessels, working along the coast under the St. 3 certificate.
Type II.—Vessels working in exposed areas, such as, short coastal work, in harbours, at the mouths of large rivers, etc., under the St. 4 certificate.
Type III.—Vessels working on rivers, and in sheltered waters, under the St. 5 certificate.

Except where it may be intended to carry a considerable amount of cargo, when it is necessary to have a fairly full hull, there is a good scope for the Naval Architect, in designing vessels of this class, to produce an efficient, seaworthy boat, and at the same time, give a very handsome, speedy craft. There is considerable variation in the block and prismatic coefficients, probably greater than is met with in vessels of other types, and this is, no doubt, owing to the fact that with many passenger boats there are considerable restrictions in depth and draught, which are instrumental in producing, in order to give sufficient displacement, a very full hull, and, consequently, a high value for the coefficients. For ordinary purposes the block coefficient seldom exceeds 0.6, with a corresponding value of 0.55 to 0.6 for the prismatic coefficient, while on the other hand, it is inadvisable to go below a value of 0.35 for the block coefficient, except with a very small craft, working on upper reaches of rivers. While it is desirable to have the under-water body as fine as possible, it must, nevertheless, be borne in mind that the under-water body should be only as fine as is practicable.

The length-breadth and length-depth ratios vary considerably with this type of vessel, especially with craft working upon restricted waters. It will be noticed that the Board of Trade primarily base the passenger accommodation upon a function of the clear deck area, and since this is an important consideration with owners of excursion and such-like boats, it is not surprising to find, therefore, owners attempting to obtain the greatest deck area on a given length, and thus giving, as great a breadth as is consistent with seaworthiness. If this be carried to excess, the draught must necessarily be small, else the displacement would be far too great, or the block coefficient ridiculously small, and the under-water body fine, and unstable. Fig. 87 gives the sheer draught of a Paddle Boat, which is a fair example of its class. The midship section, it will be noticed, is of good stable shape. The rise of floor is normal, and there is given a good turn of bilge. The forward waterlines show a fine, speedy boat, and while considerable flare is given to the sections in order to keep

FIG. 87. SHEER DRAUGHT PADDLE BOAT.
Fig. 88. Sheer Draught Passenger Vessel.

Fig. 89. Sheer Draught Dutch Passenger Vessel.
the forward deck dry, the tendency to the U shape at the shoulders, provides ample lifting power. The parallel middle body extends roughly the length of the boiler and engine space, and the after lines show a clean run, while the upper part of the sections flare out to provide lifting power and reserve of buoyancy to the after part.

A slightly different class of boat, the "Wyoming," is shown in Fig. 88. This vessel was designed for the Great American Lakes, and a study of the sheer draught may prove instructive. The fore body sections show a very full hull, and the U sections are continued to amidships without any variation. The midship section is full, and there is no rise of floor, and a very hard turn of bilge, probably owing to the fact that the vessel would frequently take the ground. The after lines show some relief, however, for a very fine run, with a sharp hollow in the water lines, show an inclination to a speedy vessel, with little resistance. The part of the after sections above water retain their fullness, probably because it was desirable to keep the deck area comparatively large aft.

The last design treated here is that of a Dutch passenger boat, Fig. 89, and while only measuring 75 feet overall, it is interesting to note that the boat is capable of carrying a total of 200 passengers, and installed with a 70 B.H.P. oil-engine, can speed at 9 knots when loaded. The forward lines while retaining the U section in way of the under water part of the forward length, have considerable flare introduced, which was considered necessary owing to the service for which the boat was intended. The midship section is full, the coefficient of fineness being about 0.94, and the fullness is continued for the whole of the after length, barely any hollow being introduced to the after sections to lead a clear stream of water to the propeller.

A point which presents itself in the consideration of the foregoing sheer draughts is the provision of sufficient stability. When it is remembered that the passengers are nearly always on deck in fine weather, and thus they tend to bring the centre of gravity relatively high, vertically, and while it is undesirable to have the righting lever too violent, for the comfort of the passengers, it is, nevertheless, important that ample stability should be provided. The metacentric height must be sufficiently moderate to make the vessel steady in a sea-way, and this can always be accomplished with normal proportioned vessels, and can be done consistently with other conditions being satisfied.

Sufficient freeboard and sheer are important, to provide ample strength of hull and a dry deck fore and aft. Where a boat has to pass under low bridges, it is often necessary to reduce these to a minimum, but with ordinary craft no difficulty should be experienced in this direction.

The approximate dimensions and weights of passenger vessels may be obtained from the curves, Figs. 90 and 91.

The arrangements of passenger vessels are many and varied. In some vessels, the main idea of the owners is the provision of seating accommodation, and where only short excursion trips are made, the cabins are only a provision for wet weather, and it is, therefore, unnecessary to provide any deck cabins, since sufficient space may always be found below. On the other hand, on some
Fig. 92. General Arrangement Paddle Boat.

Fig. 93. General Arrangement Passenger Vessel.
services it may be necessary to provide, at least, some passenger sleeping accommodation, when the fitting of deck cabins becomes necessary. Fig. 92 shows the general arrangement of the “Southern Queen,” a paddle vessel which was built in 1920 for South American waters. Her principal dimensions are:

- Length, between perpendiculars: 192' 0"
- Breadth, moulded: 26' 0"
- Breadth, over sponsons: 44' 3"
- Depth, moulded: 10' 0"
- Draught, loaded, aft: 6' 0"

The crew are quartered forward, abaft of which space is situated a small hold for carrying mails, baggage, etc. A fairly large dining room, fitted up with seats and tables, follows the hold, and this leads directly into the pantry and galley, which extends the full breadth of the vessel. The engine and boiler space occupies the amidship compartment, and a large saloon extends as far aft as practicable. On the main deck are two saloons, fitted with seats, and at the forward end of each is fitted a ladies' toilet. Above the engine and boiler casing are the officers' quarters, and at the forward end of the casing is situated a small steering bridge. An awning deck extends practically the full length of the vessel, and is fitted with battened seats for passenger accommodation. The “Wyoming,” a somewhat larger boat, is shown by Fig. 93. The accommodation of this boat is different from the majority of English boats. Large deck saloons for 1st and 2nd class passengers are fitted to the main deck, while each side of the engine and boiler space is situated the officers' sleeping apartments and ten state rooms for passengers. A large dining saloon, together with galley, etc., is fitted on the awning deck, forward, while at the after end are twelve more state rooms. Seats are arranged around all decks, and the two saloons below deck at each end of the engine and boiler space are fitted up for passengers in case of wet or bad weather. The crew are quartered forward, and there is a small hold for general goods at the after end of the forecastle. The principal dimensions of this boat are:

- Length, between perpendiculars: 273' 0"
- Breadth, moulded: 48' 0"
- Depth, moulded: 18' 0"
- Draught, aft: 12' 0"

The next vessel, Fig. 94, is of Dutch design, and was built for passenger service on the Zuider Zee. Her machinery, which consists of a marine oil engine of the semi-diesel type, is situated amidships, while directly forward is the crew space. A ladies' saloon is fitted in the fore peak, and at the after end of the vessel is a saloon for passengers, which leads out into a small cockpit. An English design for a boat of similar size compares very favourably with this vessel. The “Swan,” built for lake service, measures 85 feet overall length, is proportionately higher powered, and is capable of carrying more passengers. Fig. 95 gives the arrangement of this boat, from which all details of accommodation, etc., will be easily seen. A useful type of passenger vessel is illustrated by Fig. 96. This vessel, the “Waddenzee,” is fitted with twin sets of Kromhout engines, developing each 40 B.H.P. The vessel was built for service in shallow water, and has propellers running in a tunnel stern. This illustration has been kindly supplied by Messrs. Perman and Co., Ltd.

Although it is usual practise to fit the bar or the side bar keel to vessels of this class, owing to the shape of the bottom, it is sometimes necessary, should the vessel often take the ground, to fit the flat plate keel, in which case the vessel has somewhat a flat bottom. While the scantlings of these vessels are, as a rule, on the light side, weight must not be lost of the fact that the strength of bottom and side are important considerations. Ample longitudinal stiffening should, therefore, be given, and it is not usual to fit an intercostal plate keelson along the centre line of the vessel, and to attach it well to a centre keelson standing on the tops of the floors, and made up of four angles and a rider plate. Sometimes in the smaller vessels, a bulb plate and two angles are fitted in lieu of the above, but it is important that the longitudinal rigidity should be preserved in all classes of construction. The garboard strakes should be proportionately heavy, and it is usual to fit a shoe-plate to the bar keel in order to take the wear and tear. If the width of the boat warrants the fitting of side keelsons, they are generally of double angles fitted back to back, on the tops of the floors, and, if necessary, an intercostal plate is fitted. The floors should be carried well round the turn of bilge, especially if the radius be large, and in the larger vessels the reverse frames must, of course, be continued up to the frame heads, although in small vessels it is common to stop them at the floors, or even to omit them, making the necessary compensation by giving an 1½ or 2ins. flange to the top of each floor.

When a vessel is frequently coming alongside a pier or jetty, there is of necessity considerable wear and tear of the side plating, and it is of importance that the sides should be well stiffened, and the plating of substantial thickness. Single or double stringer angles should be fitted on the face of the reverse frames, and where the cabin sole beams, together with their stringer plate and angles, are fitted, care should be taken that the spacing of the stringers be such that the maximum strength is obtained by their combination. Fenders are always run along the sides to take the rub, etc., and these should be of double angles and oak, but it is preferred by some to fit only the half-round or convex iron bars in exposed areas, but these do not add to the appearance of
there are various River Conservancy Boards which make statutory rules in reference to maximum speeds, and where the river is narrow, and the banks are unprotected, the speed of the vessel must necessarily be low. On the other hand, vessels plying on short excursions to sea, are under no such obligations, and the amount of space devoted to machinery is a matter of compromise between speed and passenger accommodation. This may seem a strange way of solving or attempting to solve the problem, but nevertheless, the ultimate speed of the vessel is governed by the space allotted to the propelling machinery. Figs. 100 and 101 give respectively the B.H.P. and the I.H.P. These are based upon the formula:

\[
\text{I.H.P.} = \frac{75 \times \sqrt{W \times L \times V^2}}{100,000}
\]

where \( W \) = displacement of vessel, in tons,
\( L \) = length of vessel, in feet, between perpendiculars
\( V \) = speed of vessel in knots.

Although the Admiralty coefficient formula is often used, the above gives reliable results for speeds up to 12 knots. The constant 75, may vary between 62 for very fine ships to 83 for full vessels with a large length-breadth ratio. A somewhat more cumbersome formula for computing speed and power is:

\[
\text{I.H.P.} = \frac{6(L \times D \times 1.7) + (L \times B \times C_b) \times V^3}{100,000}
\]

where \( D \) = mean draught of vessel, in feet.
\( B \) = the breadth of the vessel, moulded, in feet,
\( C_b \) = the block coefficient of vessel,
the other symbols remaining as above. There is little difference between the two formulae, the expression for the wetted surface simply being in different terms. The latter formula is used extensively in American yards, and apparently gives good results for low speeds. Where oil-engines are installed, the necessary allowance must be made if B.H.P. is substituted for the Indicated Horse Power, and although many allow from 10 to 15 per cent. on the total figure arrived at, it must be borne in mind that the revolutions of the engine must be taken into account, since with the high speed engine in the somewhat slower boat, and the comparative inefficiency of the propeller, due to slip, etc., greater power may be necessary. It is, therefore, necessary to acquaint oneself with the engine it is proposed to install, before taking any definite steps in the determination of the speed and power.

The fixed paddle wheel, i.e., with the fixed floats, which was formerly introduced, is now seldom seen in this country, and where side wheels are used, they are generally of the feathering float type. These wheels, the invention of Elijah Galloway, were first used in 1830, and have come down unchanged in principle, to the present time. The arrangement of the floats is such that they enter and leave the water without undue disturbance and shock, this is accomplished by giving the floats when entering, leaving, and during their passage through the water, the same angular position to the vertical that they would have should they be fixed floats of a wheel of considerably greater diameter. What the diameter of the feathering float wheel should be is a matter of geometrical construction, which must take full consideration of the R.P.M., the fraction of slip, the speed of the vessel, and the relative diameters of the wheels. Should for any reason, the sectional area of the projected stream of water be restricted or reduced, there must of necessity be an equivalent increase of the rate of flow, so that the final result may be the same. The increase of the slip, therefore, can only be made in the speed of the wheel, in so far that the speed of the vessel is kept constant, and therefore, the speed of the floats must be increased in some proportion, as the area of the floats is reduced, and since the area of the floats varies inversely as the square of the speed, it is necessary with the modern high-speed steam engine, to have the floats, and therefore, the diameter of the wheel, as small as possible. Since, generally speaking, the smaller the R.P.M. of the engines, the greater the space they occupy, and bearing in mind that it is most desirable for the engines to occupy as little space as possible, it is not surprising to find with the higher speed engine, and the smaller diameter wheel, a comparatively greater slip than was usually to be found with the older fashioned boats. The value of slip, therefore, may be often found to exceed 27 per cent. although the general figure is between 15 and 25 per cent.

The diameter of the wheel, it has been said, varies according to the revolutions of the engines, the speed of the vessel, and the amount of slip.

Thus if \( D \) = diameter of the wheel at float centres, i.e., the effective diameter, in feet,
\( A \) = area of one float in square feet.
\( V \) = speed of ship in knots
\( S \) = velocity of float centres in feet per second

\[
= 2 \times \frac{\pi \times D \times \text{R.P.M.}}{60}
\]
R = resistance of ship in pounds
\[ S - v \]
\[ f = \text{fraction the slip is of } S \text{—that is } \frac{S}{S} \]
\[ v = \text{velocity of ship in feet per second} \]
\[ \frac{v}{V \times 6080} = 1.689 V. \]
\[ \frac{60 \times 60}{R. P. M.} \]

R.P.M. = revolutions of wheel per minute.

Then, the stream of water projected by each wheel = \( A \times S \times 64 \) lbs.

The mass of water = \( \frac{A \times S \times 64}{32} = 2A \times S \).

The net work done (thrust \times speed of ship in feet per minute)
\[ = 2A \times S(S - v)60v \]
\[ = 120A \times S(S - v)v \]

The speed of the wheel, \[ S = \frac{\pi D \times R.P.M.}{60} \], and by

adding the slip we get \[ D = \frac{19 \times S}{R.P.M.} \]

If the stream of water projected by the float be equal to the area of the float, and if we may presume that the apparent slip be the real slip, it is an easy matter to find the area of the floats, for if the quantity of water projected per second be

\[ \frac{A \times \pi D \times R.P.M.}{60} \] cubic feet

and the acceleration be taken as \[ fS = \frac{f \times \pi D \times R.P.M.}{60} \]

Then, mass of water = \[ \frac{A \times \pi D \times R.P.M.}{60} \times \frac{64}{32} = \]

\[ \frac{A \times \pi D \times R.P.M.}{30} \]

Thrust = \[ \frac{A \times \pi D \times R.P.M.}{30} \times \frac{f \times \pi D \times R.P.M.}{60} \]

Fig. 100. Speed and Power Curves (B.H.P.).

Fig. 101. Speed and Power Curves (I.H.P.).
This thrust, it must be noted, is due to the effort of one wheel, so that should the thrust be calculated from the ship resistance, only half the value should be used in the above equation if two wheels are fitted.

The following formula is established from above:

\[
\text{Area of one feathering float} = \frac{\text{I.H.P.}}{f - f^2} \times \left(\frac{C}{D \times \text{R.P.M.}}\right)^3
\]

The value of \( C \) is dependent upon the efficiency of the engine and with two wheels driven by engines with an efficiency of 0.6 and where the I.H.P. is the gross power developed, its value may be taken as between 82 and 84. As the efficiency increases, however, the value of \( C \) also increases, so that with engines of 0.66 efficiency, the value would be increased to about 85 or 86.

It is of interest to note that where a single wheel is fitted at the stern, the value of \( C \) is 109.

It was usual to fit one float to every foot of diameter of wheel in the older radial wheels, but with modern practice it is usual to fit the least number possible, consistent with efficiency, etc. The number of floats is given by dividing the diameter of the wheel, in feet, plus two, by two, as given by \( N = \frac{D + 2}{2} \), but with small diameter wheels it is sometimes necessary to give somewhat more floats than is given by the formula.

The proportion of floats has received considerable attention within recent years when it has been necessary to fit wheels to shallow draught vessels. The immersion of the wheel must always be greater with sea-going boats, but those plying in partially smooth water must have, to obtain the greatest efficiency of float, an immersion of the upper edge of the lowest float below the load water line of at least half the breadth of the float. In river craft where the water is generally smooth, an immersion of only one quarter the breadth is sufficient, and with very light draught it is common to have an immersion of only one-eighth, but it is essential to have, within reason, the greatest immersion for the floats possible. This, therefore, has some effect upon the proportion of the floats, but for ordinary purposes, a proportion of length of float to breadth of 2.6:3 for floats of the feathering type, while a proportion of 4:5 is usual for the fixed radial wheel float.

As mentioned previously, the wheel has a distinct advantage, both theoretical and practical, over the screw, and in rough and windy weather, or when frequent calls are to be made at piers, etc., the greater manœuvring power is a considerable advantage over the screw, also when working in shallow waters, the wheel shows great advantage in efficiency over the tunnel screw. On the other hand, however, the paddle boxes are heavy and cumbersome, exposed to damage, and they do not in any way assist in the stability of the boat. The machinery, too, occupies a larger amount of space, and is much heavier than the usual compound condensing or the triple expansion sets in screw boats.

In the design of the screw propeller, there are not many differences from the ordinary types, since the conditions are compatible. Except with the propeller driven by oil-engines, the blade of the propeller is usually leaf-shaped, and sometimes a little set-back is given to the blade, although the slip per cent. is by no means excessive. To obtain the highest efficiency, the propellers should be of bronze, or such metal, and the cutting edge should be as fine as practicable. A large projected area of blade and a large pitch-diameter ratio is unnecessary, although several boats recently have had disproportional propellers fitted, but with indifferent results. Because there is a fine under water body, with very fine lines aft, there is no necessity to fit abnormal propellers, the best results having been obtained with normal proportioned screws. It is no doubt an advantage to fit twin-screws wherever possible, but with a very light draught vessel, where the upper tips of the propeller are not submerged, when at rest, better results seem to have been obtained with the single screw.

Chapter 10.

Ferry Boats.

It was, no doubt, to ferry service that the earliest steam vessels were put, and the call for this class of vessel has by no means relaxed during recent years. The "Clermont," Robert Fulton’s steamboat which was built on the Hudson in 1807, may well claim to be the first river and ferry boat. Her eventful history needs no elaboration here since the events of her trial trip along the Hudson River are fully recorded in the Annals of Shipbuilding and Marine Engineering. The "Philadelphia," built in 1813, was a more successful vessel than the "Clermont," and performed her duties satisfactorily for several years. It is interesting to note that while these very early vessels were built in America, the home of ferry craft is to the present day the Great Lakes and rivers of that country. Great advancements were made during the latter part of the 19th century, until large ferry boats, capable of conveying several trains, rolling stock, motors and wagons, passengers, etc., were by no means exceptions. Some years previous to the late war a large vessel—the "Drottning Victoria"—was built for ferry service from Germany across the Baltic to Sweden. This remarkable vessel, measuring 370 feet in length, was capable of accommodating eight bogie railway carriages, each of 72 feet in