cient to exclude air a head of water equivalent to 30 feet is sup­plied by the atmosphere, as has been pointed out by Prof. Osborne Reynolds. Experiments on the model of the Thornycroft screw have shown that the efficiency, which is as much as 70 per cent. when properly immersed, falls to about 50 per cent. when breaking the surface of the water. As a result of a change from a diameter of 5 feet 10 inches to 4 feet 6 inches the speed of the first-class torpedo boat was raised from 18 to 20 knots, other conditions re­maining the same.

"There is no doubt that the stern is the best position for the screw. As a vessel passes through the water the friction imparts motion to the layer of water rubbing against the side. This layer increases in thickness towards the stern, so that, after the vessel has passed through, a considerable quantity of water is left with a motion in the same direction as the vessel. If the screw works in this water it is able to recover some of the energy which has been expended by the ship in giving it motion. The speed of this water, which Rankine estimates may be as much as one-tenth of the speed of the vessel, does not depend upon the form but upon the nature and extent of the surface. As it is a necessity that there should be such a wake, it is a distinct advantage to place the propeller in it and allow it to utilize as much as possible of the energy it finds there. It is important not to confound this watet, which has had motion given to it by the side and bottom of the ship, with the wave of replacement, that is, the water filling in behind the ship. It should be the aim to interfere as little as possible with this motion, as such interference augments the resist­ance of the ship very considerably, even in well-formed ships. The propeller should therefore be kept as far away from the stern as possible.

“ In the small high-speed stern launches the propeller has been kept outside the rudder, with advantage to the speed. What is required is that before reaching the screw the water shall have given out upon the stern of the ship the energy put into it by the bow. If a screw propeller is placed behind a bluff stern so that its supply of water is imperfect it will draw in water at the centre of the driving face, and throw it off round the tips of the blades, like a centrifugal pump, thus producing a loss of pressure upon the stern of the vessel. For very high speed vessels several propellers would enable the weight of the machinery to be kept down. The weight of an engine of a given type per indicated horse-power varies inversely as the number of revolutions per minute ; that is, the greater the number of revolutions the less the weight per indicated horse-power.

“There is a certain quantity of work which must be lost with any propeller, and it is equal to the actual energy of the discharged water moving astern of the propeller with a velocity relative to still water. As this energy varies as the weight multiplied by the square of the velocity, if we double the quantity of water acted upon we double the loss from this cause, but if we double the velocity with which the water is discharged we increase the loss fourfold. This shows the advantage of acting upon a large column of water, and leaving it with as small a speed as possible relative to still water. For this reason the screw is a more efficient instru­ment than a paddle-wheel, and the jet propeller, with its small area of jet, is so much inferior to the screw. From the above con­siderations it would appeal that the larger the diameter of a screw and the smaller the slip the greater the efficiency would be. There is, however, another element of loss which has to be con­sidered, which imposes a limit to the size of a screw in order to obtain the best efficiency. This element is the friction of the screw blades. How large the effect of this element may be is shown by the case of H.M. S. ‘Iris.’ This ship was originally fitted with two four-bladed propellers, 18 feet in diameter, and with 18 feet pitch or velocity of advance per revolution. She obtained a speed with these propellers of 15 3/4 knots with an ex­penditure of 6369 horse-power. Two blades were then taken from each propeller, reducing the total number from eight to four. The indicated horse-power then required for the same speed was 4369, or two thousand less horse-power. This amount had been lost in driving the four additional blades.”

" The causes of loss of work incidental to propellers of different kinds may be summed up as follows:—(1) Suddenness of change from velocity of feed to velocity of discharge. Propellers which suffer from this cause are the radial paddle-wheel and the common uniform pitch screw ; while those which in varying degree avoid it are the gaining pitch screw, the feathering paddle-wheel, Ruthven’s form of centrifugal pump, and the oar. (2) Transverse motion impressed on the water. Propellers which lose in efficiency from this cause are ordinary screw-propellers, which impart rotary motion, radial wheels, which give both downward and upward motion on entering and leaving the water, and oars, which impart outward and inward motion at the commencement and end of the stroke respectively. This loss is greatly reduced in the guide- propeller, as the guides take the rotary motion out of the water and utilize it in so doing. (3) Waste of energy of the feed water. This is experienced in the jet propeller as generally applied.”

The present condition of the case of screw steamship propulsion appears, according to Mr Froude’s estimate, to be that, calling the effective horse-power (that is, the power due to the net resistance) 100, then at the highest speeds the horse-power required to over­come the induced negative pressure under the stern consequent on the thrust of the screw is 40 more ; the friction of the screw in the water is 10 more ; the friction in the machinery 67 more ; and air- pump resistance perhaps 18 more ; add to this 23 for slip of screw, and we find that, in addition to the power required to overcome the net resistance = 100, we need 40 + 10 + 67 + 18 + 23, making in all 258; *i*.*e*., at maximum speeds the indicated power of the engines needs to be more than two-and-a-half times that which is directly effective in propulsion. (N. B.)

*Boatbuilding.*

The foregoing article may be supplemented by a brief account of boatbuilding. The distinction between this and shipbuilding is not of a marked character and cannot be sharply defined. But for all practical purposes the builder of a vessel without a deck, or but partially decked, and propelled partly by sails and partly by oars, or wholly by oars, may be defined as a boatbuilder.

The boats in general use at present may be classified as racing boats, pleasure boats, or boats used for commercial purposes. Racing boats (compare Rowing) are generally built of mahogany, and are the most perfect specimens of the boatbuilder’s art. The out­rigger sculling boat measures from 30 to 35 feet long, 12 to 14 inches in breadth, and 9 inches in depth, weighing only from 35 to 45 lb, and the eight-oared outrigger, being from 55 to 65 feet long by 2 feet 2 inches to 2 feet 5 inches in breadth, weighs about 300 lb. Pleasure boats vary in form and dimensions, from the 15-feet row­ing boat used on the sea-coast to the gondola type found principally on the canals of Venice and used occasionally on the Thames, &c., for ceremonial pageants. Boats used for commercial purposes embrace fishing, canal, and ships’ boats. Fishing boats (compare Fisheries) are gradually passing from the sphere of the boat- builder to that of the shipbuilder,—the open boats of former years being in many cases replaced by large, strong, decked craft more able to withstand the gales of the British coasts. Canal boats are gene­rally long, narrow, and shallow, from 50 to 70 feet long by 8 to 10 feet in breadth, and from 4 to 5 feet in depth. All sea-going vessels are required by statute to be provided with boats fully equipped for use, not fewer in number nor less in their cubical contents than what is specified for the class to which the ship belongs. The boats vary considerably in form and dimensions as well as in material and construction, according to the service intended. The number of boats a passenger steamer of 1000 tons and upwards is required to carry is six or seven, according to the dimensions of the boats. In either case two of the largest boats must be fitted as lifeboats. If the smaller number is carried, the set will consist of two lifeboats, one launch, two cutters or pinnaces, and one gig.

Lifeboats are built both ends alike, having a sheer or rise from midships towards stem and stern of 1/2 inch to 3/4 inch per foot of length. They have air-cases of copper or yellow metal fitted in the ends and along the sides of the boat, of sufficient capacity to give each person carried in the boat one and a half cubic feet of strong enclosed air-space (compare vol. xiv. p. 570). Cutters are similar in form but of smaller dimensions than lifeboats ; pinnaces are about the same dimensions as cutters, but have square sterns. Gigs are of lighter construction and finer form than pinnaces. A service boat called a dingy is also carried, for the conveyance of light stores between the shore and the vessel. Boats, when carried so close to the funnel of a steamer as to be injuriously affected by the heat therefrom, have of late years been built of zinc, iron, or steel. Those built of steel have plates 1/16 inch thick and galvan­ized, the keel, stem, stern, and deadwood knees being of wood, to which the plating is attached.

The following is an outline of the method of construction. The designer lays down on paper the lines and body-plan of the craft, which are afterwards traced full size on the floor of the drawing- loft. From these full-sized sections moulds are made. The stem and stern posts, having been cut out to the shape designed, are tenoned into mortices in the keel. Two knees overlap, and bind the stem and stern posts to the keel, and are bolted with through bolts and clenched outside over a ring or washer. A stout batten of wood is then nailed between the stem and sternpost heads to connect them together, and a line is then stretched from stem to sternpost to represent the water-line. The keel, stem, and stern posts being in position on the stocks, the stem and stern posts are then plumbed and secured by stays of wood. The rabbets in the keel, stem, and stem posts are then cut out with a chisel, after which the moulds are put into their proper places, plumbed with the water-line, and kept in position by stays. The planking is then proceeded with, strake after strake, and when the boat is planked up to the top strake the floors and timbers are put in. The floor extends across the keel and up to the turn of the bilge. They are fastened through the keel with copper or yellow metal bolts and to the planking with copper nails.