position, and they became the type of screw engines in general use. This ship had a screw-well and hoisting gear for the screw. In 1845 the importance of the screw propeller for ships of war became fully recognized, and designs and tenders were invited from all the principal marine engineers in the kingdom. The Government of that day then took the bold step of ordering at once nineteen sets of screw engines. Six of these had wheel gearing ; in all the rest the engines were direct-acting. The steam pressure in the boilers was from 5 to 10 lb only above the atmo­sphere, and if the engines indicated twice the nominal power it was considered a good performance. The most successful engines were those of the “Arrogant” and “ Encounter” of Messrs Penn. They had a higher speed of piston than the others, and the air- pumps were worked direct from the pistons, and had the same length of stroke. These engines developed more power for a given amount of weight than other engines of their day, and were the forerunners of the many excellent engines on the double-trunk plan made by this firm for the navy. The engines with wheel-gearing for the screws were heavier, occupied more space, and were not so successful as the others, and no more of that description were ordered for the British navy.

Up to 1860 neither surface-condensers nor superheaters were used in the navy. The consumption of fuel was about 4 1/2 lb per one horse-power per hour. In that year (1860) three ships, the “ Arethusa,” “ Octavia,” and “ Constance,” were fitted respectively by Messrs Penn, Messrs Maudslay, and Messrs Elder, with engines of large cylinder capacity to admit of great expansion, with sur­face-condensers aud superheaters to the boilers. Those of the “ Arethusa ” were double-trunk, with two cylinders ; those of the “ Octavia ” were three-cylinder engines ; and those of the “ Con­stance ” were compound engines with six cylinders ; the first two were worked with steam of 25 lb pressure per square inch, and the last with steam of 32 lb pressure. All these engines gave good results as to economy of fuel, but those of the “ Constance ” were the best, giving one indicated horse-power with 2 1/2 lb of fuel. But the engines of the “Constance ” were excessively complicated and heavy. They weighed, including water in boilers and fittings, about 5 1/2 cwts. per maximum indicated horse-power, whereas ordi­nary engines varied between 3 1/2 and 4 3/4 cwts.

For the next ten years engines with low-pressure steam, surface- condensers, and large cylinder capacity were employed almost exclusively in the ships of the Royal Navy. A few compound engines, with steam of 30 lb pressure, were used in this period with good results as to economy, but they gave trouble in some of the working parts. Compound engines, with high-pressure steam (55 lb), were first used in the Royal Navy in 1867, on Messrs Maudslay's plan, in the “Sirius.” These have been very successful. In the Royal Navy as well as in the mercantile marine, the compound engine is now generally adopted. They have been made rather heavier than the engines which immediately preceded them, but they are about 25 per cent. more economical in fuel, and, taking a total weight of machinery and fuel together, there is from 15 to 20 per cent. gain in the distance run with a given weight

Wrought-iron is largely used in the framing in the place of cast- iron, and hollow propeller shafts made of Whitworth steel. By these means the weight is being reduced, and it is to be hoped that a still further reduction may yet be made by the use of high- class materials in the engines and steel in the boilers.

Mr Thornycroft, of Chiswick, and others, by means of high rate of revolution, forced combustion, and the judicious use of steel, have obtained as much as 455 indicated horse-power with a total weight of machinery of 11 3/4 tons, including water in boilers. The ordinary weight of a seagoing marine engine of large size, with economical consumption of fuel, excepting a few of very recent construction, would be six or seven times as great. By closing in the stoke­holes and employing fans to create a pressure of air in them capable of sustaining from one to two inches of water in the gauges the consumption of coal per square foot of fire-grate per hour may be raised to 130 lb and upwards. The indicated horse-power which can be obtained in ordinary cases with the steam-blast in the chimney to quicken consumption does not exceed ten. But by the forced draft above described it can be raised with ordinary boilers to 17 to 18 indicated horse-power per square foot of fire­grate. In torpedo boats with locomotive boilers over 28 horse­power per foot of fire-grate is attainable.

The following observations on efficiency are taken from the work of Mr Sennett on *The Marine Steam Engine :—*

“In every machine there are always certain causes acting that produce waste of work, so that the whole work done by the machine is not usefully employed, some of it being exerted in overcoming the friction of the mechanism, and some wasted in various other ways. The fraction representing the ratio that the useful work done bears to the total power expended by the machine is called the efficiency of the machine; or—

. Useful work done.

Efficiency = —i ——

Total power expended.

In the marine steam engine, in which the useful work is measured by its propelling effect on the ship, there are four successive stages, in each of which a portion of the initial energy is wasted, and these four causes all tend to decrease the efficiency of the engine as a whole.

“ In the first place, only a portion of the heat yielded by the combustion of the coal in the furnaces is communicated to the water in the boiler, the remainder being wasted in various ways. The fraction of the total heat evolved by the combustion of the coal, that is, transmitted to the water in the boiler, is in ordinary cases not more than from 5/10 to 7/10. This fraction is called the efficiency of the boiler.

“ Secondly, the steam, after leaving the boiler, has to perform mechanical work on the piston of the engine ; but this work, in consequence of the narrow limits of temperature between which the engine is worked, is only a small fraction of the total heat contained in the steam—say from 1/5 to 1/20, according to the kind of engine and rate of expansion employed. This fraction, repre­senting the ratio of the mechanical work done by the steam to the total amount of heat contained in it, is called the efficiency of the steam.

“ Thirdly, in the engine itself a part of the work actually per­formed by the steam on the pistons is wasted in overcoming the friction oi' the working parts of the machinery and in working the pumps, &c. The remainder is turned into useful work in driving the propeller. The fraction representing the ratio that this useful work bears to the total power exerted by the pistons is called the efficiency of the mechanism.

“Fourthly, the propeller, in addition to driving the ship ahead, expends some of the power transmitted to it in agitating and churning the water in which it acts, and the work thus performed is wasted,—the only useful work being that employed in overcoming the resistance of the ship and driving her ahead. The ratio of this useful work to the total power expended by tho propeller is called the efficiency of the propeller.

“ The resultant efficiency of the marine steam engine is made up of the four efficiencies just stated, and is given by the product of the four factors representing respectively the efficiencies of the boiler, the steam, the mechanism, and the propeller. Any improvement in the efficiency of tho marine steam engine, and, consequently, in the economy of its performance, is therefore due to an increase in one or more of these elements.”

Under Steam Engine will be found a discussion of the first three of the efficiencies enumerated above. Propulsion and pro­pellers have to be considered here.

“The principle upon which nearly all marine propellers work,” says Mr Sydney Barnaby, “is the projection of a mass of water in a direction opposite to that of tho required motion of the vessel. When a vessel is in motion at a regular speed the reaction of the mass of water projected backwards by the propeller is exactly equal to the resistance experienced by the vessel. When it is clearly understood that propulsion is obtained by the reaction of a mass of water projected sternwards with a velocity relative to smooth water, the absurdity is at once seen of attempting to get a pro­peller to work without slip. If there is no slip there is no resultant propelling reaction except in the limiting case where the mass of water acted upon is infinite. The whole problem therefore resolves itself into this—What is the best proportion between the mass of water thrown astern and the velocity with which it is projected, that is, if the screw propeller is under consideration, the ratio between its diameter and its pitch ? ”

“ There are four different kinds of propellers apart from sails— the oar, the paddle-wheel, the screw, and tho water jet.

“The first and oldest of them—the oar—may be used in two ways. The action may be intermittent, as in rowing, when water is driven astern during half the stroke and the instrument brought back above the water ; or its action may be continuous, as in sculling. When used as in rowing it is exactly analogous to a paddle-wheel, while the action of the scull closely resembles that of the screw. It is supposed that in the ancient galleys, which were propelled by a large number of oars in several tiers or banks, the oars hung vertically and worked inwards and outwards with a sculling action. They were not removed from the water, but served as props when the vessel was aground. The oars were always propelling the vessel, in both parts of the stroke. The rowers generally sat with their faces outwards and forwards. There was great overhang of the sides to allow of several tiers of rowers one above another. The oar as used for rowing is a very efficient instrument. To obtain the maximum efficiency out of it a con­stant pressure should be maintained upon the oar, so that the water is started gradually from rest, and the acceleration uniformly in­creased throughout the whole of the stroke. A glance at a univer­sity crew will show that the stroke is kept up with a uniform pressure and without any jerk.”

Speaking of the screw propeller, Mr S. Barnaby says:—“The speed with which water can follow up the blades of a screw depends upon the head of water over it, but when the immersion is suffi-