in hand (1843), and fitted her with a screw propeller instead of paddle-wheels as originally intended. The success of this and other vessels was sufficient to largely influence public opinion in favour of the propeller, and the Admiralty took the important step of building the “ Rattler,” a vessel of 888 tons and 200 H.P., to test the system. She was practically a repeat of the “Alecto,” as far as her hull and the power of her machinery were concerned, but she was propelled by a screw propeller, whereas the “ Alecto ’’ was propelled by paddle-wheels. These vessels were tested together at sea in March 1845, when the “ Rattler ” proved the faster vessel; but the great test took place on Thursday, 3rd April following, when the two vessels were secured stern to stern, and it was found that with the engines of both ships working at full power the “ Rattler ” towed the “ Alecto ” astern at a speed of 2½ knots.@@1 In a few years the screw almost entirely superseded the paddle-wheel for war vessels, and in 1854, during the war with Russia, Great Britain possessed a screw steam fleet, including all classes of ships, built of wood.

The performances of the *Great Western* and other vessels had demonstrated that ships could traverse the oceans of the world by steam power alone, but great advance had to be made in the marine engine before the ordinary trade could be carried on by its means with economy. In the early marine engines only one cylinder was provided, and various means were employed for transmitting the power to the paddle shaft; later came the oscillating cylinder engine and the diagonal engine, the latter being the type of paddle engine now most frequently adopted in Great Britain. With the introduction of the screw propeller the arrangements became much modified. At first the engines were run at com­paratively low speeds, as in paddle-boats, gearing being supplied to give the screw shaft the number of revolutions required, but direct-acting two-cylinder engines gradually replaced the geared engines. The compound engine was first adapted successfully to marine work by John Elder in 1854, and in time direct- acting vertical engines, with one high and one low pressure cylinder, became the common type for all ships. The boiler pressure, moreover, in 1854, had been raised to 42 lb per sq. in. The further change, accompanying still higher pressures of steam, from compound to triple-expansion engines was, like many other changes, foreseen and in some measure adopted by various workers at about the same time, but the first successful applica­tion of the principle was due to Dr A. C. Kirk. In 1874 he fitted a three-crank triple-expansion engine in the *Propontis.* The boiler used proved a failure, but in 1882 he fitted a similar set of engines in the *Aberdeen,* with a boiler pressure of 125 lb, and

the result was entirely successful.

Continuous improvements have enabled engineers to produce machinery of less and less weight for the same power, and at the same time to reduce the spaces required for its accommoda­tion, the vibration due to the working of the engines, and the consumption of fuel per horse power. For engines of high power, quadruple expansion has sometimes been adopted, while scientific methods of balancing have been employed, improved qualities of steel and bronze have been introduced, the rate of revolution has been increased, and forced lubrication fitted. In the boilers higher steam pressures have been used, superheating in some cases being resorted to; the rate of com­bustion has been accelerated by supplying air under pressure in the stokehold or in the furnaces, and in some cases by placing fans in the exhaust to draw the air and products of combustion more rapidly through the fires; the former being known as *forced draught* and the latter as *induced draught.* In the Navy, with the view of saving weight, water-tube boilers have been adopted, but boilers of this type have not yet been generally fitted in the mercantile marine. Steam pressures now in common use vary from 100 to 180 lb per sq. in. in cargo ships; from 140 to 220 lb in passenger ships, including the large Atlantic liners; from 210 to 300 lb in large warships where water-tube boilers are used; while in destroyers and other classes of warships in

which small tube water-tube boilers are used it varies from 180 to 250 lb per sq. in.

A century ago the reciprocating steam engine was slowly making its way as a means of propulsion as an auxiliary to, or as a substitute for sail power—the steam being obtained by burning wood or coal. In 1815 nine small steam vessels, having an aggregate tonnage of 786 tons, were built and registered in the United Kingdom; in 1825 24 steam vessels were built, having an aggregate of 3003 tons; in 1835 86 vessels were built, having an aggregate of 10,924 tons. In 1910 the reciprocating steam engine, after reaching a very high degree of perfection and universal adoption, was being largely replaced by the turbine, coal was being replaced to a considerable extent by oil as a fuel for raising steam, and steam itself was being challenged as a motive agent by the development of the internal combustion engine.

III. Statistics

For some years before 1870 the total tonnage of sailing ships built each year in the United Kingdom had been about equal to that of steam ships, but then a great change took place;

541 sailing vessels, amounting to 123,910 tons, were added to the register of the United Kingdom, while 433 steam ships, amounting to 364,860 tons, were added ; the steam tonnage, thus added being nearly three times that of sailing vessels. A uniform rate of increase of production of steam vessels was on the whole maintained after 1870, but, as will be seen by referring to Table I. and fig. 3, considerable fluctuations have occurred, the falling off in steam tonnage being simultaneous with increases of sailing tonnage and vice versa down to 1895. The dotted lines on fig. 3 show approximately the average output for 50 years of sailing and steam tonnage separately and combined. Roughly speaking, it may be said that from 1860 to 1895 the output of sailing tonnage fell from about 200,000 tons per annum to 100,000 tons; during the later ’nineties the falling off was more rapid, and between 1900 and 1910 the output varied between 15,000 and 30,000 tons.

The average tonnage of the sailing vessels built in the United Kingdom in 1860 was 206 tons; this increased with a fair degree of regularity to 532 tons in 1890, 749 tons in 1891 and 963 tons in 1892, after which a rapid decrease took place, and by 1898 the average size had fallen to 75 tons; there were fluctuations after this date, but the average never rose above 163 tons; and these vessels are practically restricted to the coasting trade and pleasure purposes.

Although the building of large sailing vessels of wood and steel has almost ceased in the United Kingdom, the sizes of the largest of such vessels built abroad have continued to increase. Under the influence of the shipbuilding bounties granted in France between 1895 and 1902 something like 150 sailing vessels of from 2000 to 3500 tons each were built, but few since. In Germany and in America a few large sailing vessels continue to be built.

Lloyd’s Register for 1841 gives a table of “the Steam Vessels belonging to England, Scotland and Ireland in the years 1814 to 1839," which shows that in 1839 there were 720 vessels of a total tonnage of 79,240 tons owned in the United Kingdom. Between 1839 and 1860 considerable numbers of steam ships were built for various services, and the production from 1860 is shown by fig. 3 and Table I. The tonnage added to the Register in 1860 amounted to 93,590 tons, rising over four years to 293,140 tons in 1865; after a gradual decline extending over three years to 100,000 tons it again rose till 1872, when nearly 500,000 tons were added. In 1876 it had fallen to about 200,000 tons; then came the great rise extending to 1883, when it reached a maximum of 885,495 tons. A rapid decrease followed, and in 1886 it had fallen practically to what it had been ten years before. In another three years the figure was again what it had been in 1883; and for a period of seventeen years, with much smaller fluctuations than previously, great increases were maintained. In 1906 a maxi­mum of 1,428,793 tons was reached, when another rapid fall occurred —over two years—the minimum reached being 600,837 tons in 1908.

The fluctuations in output, shown by fig. 3, synchronize approximately with the improvements and depressions in trade.

The average tonnage of British steam vessels rose slowly from 80 tons in 1815 to 102 tons in 1830, and to 473 tons in 1860, reaching a maximum of 1442 tons in 1882. During the next four years it fell gradually to 896 tons, rising again to 1515 tons in 1890, and the average tonnage built since 1890 has remained, with a certain amount of fluctuation, nearly 1500 tons. These figures may be taken as roughly repre- senting the average tonnage of the ships produced throughout the world ; but as in these averages large numbers of comparatively small vessels are included, the vast increase in the numbers of large-sized vessels which have been built, especially during recent years, is not adequately represented. Of the vessels built in 1890 only 1% exceeded 8000 tons in displacement, whereas the vessels of over 8000

@@@1 The original propeller used by the ,' Rattler ” is now to be seen in the Victoria and Albert Museum.