yacht measurement 532 tons; she is rigged as a three-masted schooner; her original sail area, 9200 sq. ft., has recently been re- duced to 7950 sq. ft.; her hull is *composite,* the frames being of iron and the planking of teak; her engines are compound of 70 N.H.P. Very much larger yachts have been built in recent years, such as the “ Lysistrata,” 286 ft. long, 40 ft. beam, 13 ft. 9 in. depth of hold, 1943 tons gross tonnage and 2089 tons Thames Y.M., built in 1900; and the “ Liberty,” 268 ft. long, 35 ft. 6 in. beam, 17 ft. 9 in. depth of hold, 1607 tons gross tonnage and 1571 tons Thames Y.M., built in 1908. These two vessels and many others of similar types are American-owned. The yacht "Emerald,” of 75o tons yacht measurement and 1400 H.P., built on the Clyde in 1902, crossed the Atlantic in May 1903, and was the first turbine steamer to be classed in any registry. The “ Atalanta ” (ex “Lorena”), of 1398 tons Y.M., built in 1903, fitted with turbines of 3800 H.P., was the finest turbine- driven private yacht afloat in 1910. The “ Tarantula," built in **1902,** of 122 tons Y.M. and fitted with turbines of 2200 H.P., is a high-speed vessel resembling a torpedo-boat destroyer. The “ Win- chester,” built in 1909, is of a similar type; she is 165 ft. long, 15 ft. 6 in. beam, 188 tons Y.M., and has turbines of 2500 H.P., which give her a speed of 26½ knots.

The royal yachts of European sovereigns are the largest yachts yet built. They include the imperial Russian yacht “ Pole Star,” of 3270 tons and 5600 l.H.P., built in 1888; the imperial German yacht "Hohenzollern ” (fig. 43, Plate XL), of 3773 tons Y.M. and 9500 H.P., built in 1893; the Spanish royal yacht “Giralda,” of 1664 tons Y.M., built in 1894; the imperial Russian yacht “ Stand- art,” of 4334 tons Y.M. and 11,000 H.P., built in 1895; and the British royal yachts, “ Victoria and Albert,” of 5005 tons Y.M. and 11,000 I.H.P., built in 1899, and the“ Alexandra ” (fig. 44, Plate XI.), of 2157 tons Y.M. and 4500 H.P., built in 1907.

*Propulsion by Electricity.—*In 1883 Messrs Siemens & Co. fitted up a launch, 40 ft. long and 6 ft. beam, with an electric motor driving a single propeller and operated by a battery of secondary cells, and at a displacement of 5 tons a speed of 7 knots was obtained. A launch 25 ft. long, provided with an electric motor capable of giving a speed of 7 knots, also was supplied to H.M. yacht “ Victoria and Albert ” in 1903. A number of other electric launches similarly fitted have been built chiefly for river service, the batteries being recharged from shore stations from time to time; but the method has not been extensively adopted, except in submarines, In some cases the submarine’s secondary battery has been used for propulsion on the surface as well as when submerged, being recharged from shore or from a parent vessel as required ; but in nearly all recent vessels they are used only for propulsion when submerged, the engines fitted for propulsion on the surface being arranged to drive dynamos for recharging the cells. In a number of small vessels and oil-tank steamers electric motors are fitted for driving the propeller and supplied with current from dynamos driven by steam turbines or internal combustion engines.

*Propulsion by Naphtha Engines.—*ln 1888 several launches were built on the Thames in which petroleum spirit was used for fuel in place of coal, and also as an expanding agent for driving the propelling machinery in place of steam. A number of these boats were after­wards built in England and America, and known as *zephyr* or *naphtha* boats. Further particulars of these boats will be found in a paper read by Mr Yarrow before the Institute of Naval Architects in 1888.

*Propulsion by Internal Combustion Engines.—-*Experiments have been made at various times with machinery in which the fuel is burnt or exploded in the engine itself without having recourse to the transfer of energy by means of an expanding and condensing agent such as steam or naphtha, and by these experiments the modern internal combustion engine has been slowly evolved and adapted for marine propulsion. In 1680 an engine was patented in which gunpowder was exploded, and the engine was operated by the vacuum produced by the cooling of the gases; in 1794 an engine was patented in which the explosion of turpentine spirit drove the pistons forward, and about 1823 a gas-driven vessel was run on the river Thames. In the later years of the 19th century gas engines were highly developed for use in factories, &c., on shore, and petrol engines for driving motor cars, &c., and since the beginning of the present century similar engines adapted for marine propulsion have been greatly improved and produced in considerable numbers, especially in the United States, some of the vessels being as large as 800 tons gross.

Such vessels may be considered in three groups. (1) High-speed racing boats, pleasure boats of various sizes for service on rivers and in harbours, fireboats, patrol boats and launches for river work, yachts’ tenders and sea-going yachts of light scantlings, in which highly volatile and readily exploded fuels such as gasolene, petrol and naphtha are used. (2) Vessels of low speed, in which the weight of the engine is not of great importance, such as barges for use on rivers and canals, ferry-boats, small tug-boats, slow-speed cargo vessels and slow-speed oil-tank vessels, which have been fitted with engines using kerosene or paraffin, as well as oil fuels of greater specific gravity, and of higher flash-point and requiring a higher temperature for evaporation ; in some cases these low-speed vessels have been fitted with engines using gas produced from anthracite coal, prepared charcoal and heavy oil. (3) Vessels in which auxiliary propelling machinery of low power is fitted; they

include a large number of fishing vessels, smaller numbers of coasting schooners, lifeboats and a few large vessels; in these both light and heavy oils and gas have been employed.

As examples of class (1) may be mentioned the racing boats “ Ursula,” built at Cowes in 1908, 49 ft. 6 in. long, 5 tons total weight, fitted with petrol engines of 800 H.P., driving twin screws at about 950 revolutions, and giving a speed of 38½ knots; and “ Columbine,” built on the so-called hydroplane principle in 1910, 26 ft. long, 65 H.P. and over 30 knots speed; the American yacht "Kalmia,” 83 ft. long, 14 ft. 3 in. beam, 3 ft. 9 in. draught; and the yacht “ Swiftsure," 70 ft. long, 11 ft. beam, 38 tons gross, 3 ft. draught, 160 H.P. and 16 knots speed, built at Cowes in 1909 and navigated under her own power to St Petersburg.

Examples of class (2) are the double-ended ferry-boat "Miss Vandenburg,” employed on the St Lawrence, 100 ft. long, 20 ft. 9 in. beam, 9 ft. depth, 5 ft. draught, 150 tons displacement, fitted with two paraffin engines each of 75 H.P.; the yacht “Bronzewing” (fig. 45, Plate X.), built at Sydney in 1908,110 ft. long, fitted with three paraffin engines each of 105 H.P. ; the “ Lochinvar,” a West of Scotland passenger vessel of 12 knots speed, 145 ft. long, 200 tons gross, fitted with three paraffin engines each of 100 H.P.; and the “ Manatee ” (fig. 46, Plate X.), 93 ft. long, 16 ft. beam, 5 ft. 6 in. draught, fitted with two paraffin motors of 75 H.P., giving her 10½ knots speed, built at Cowes in 1909 for service as a mail and passenger boat in Southern Nigeria, which was navigated to Forcados, a distance of 4000 m., under her own power and without escort.

Amongst examples of class (3) may be mentioned the three-masted topsail schooner “ San Antonio ” of Rotterdam, 165 ft. long, 27 ft. 3 in. beam, 9 ft. 2 in. depth and 410 tons gross, fitted with engines of 160 H.P., using crude heavy oil and driving a single screw; the “ Modwena ” of Glasgow, a barque-rigged sailing yacht of 400 tons, fitted with paraffin engines of 200 H.P., giving a speed of 9½ knots, the “ Carnegie,” already referred to under surveying vessels, which is fitted with gas engines of 150 H.P., driving twin screws; and the yacht “ Lady Evelyn,” of 366 tons Y.M., fitted in 1910 with heavy oil engines of 500 H.P.

The power of individual internal combustion engines completed up to 1910 was somewhat limited, and great difficulties had been encountered in the use of heavy oil fuels; but great advances and improvements had been made which were opening up the way for the more extensive adoption of motors of large power using heavy oil fuels. An ocean-going motor-driven cargo vessel of 9000 tons and 12 knots speed, was in I910 being built in Germany for the Hamburg-American line, and fitted with heavy oil engines of 3000 H.P. driving twin screws, while engines of 10,000 H.P. were also being manufactured.

V. War Vessels

The adoption of iron and steel as the material for shipbuilding, and the development of the steam engine, have influenced warship construction in the same manner as they have influenced the construction of ships for the mercantile marine; but, in addition, the introduction of armour for the protection of ships, the great advances made in its manufacture, and, above all, the marvellous improvements in explosives and in the design and manufacture of guns and torpedoes, have changed the conditions of naval warfare, and called for corresponding changes in the design of warships. Those who are concerned in such questions may refer with advantage to an interesting comparison between the old “ Victory ” (fig. I, Plate XIII.) and a modem battleship instituted by Sir Andrew Noble in his address to the Mechanical Science Section of the British Association in 1890. Sir Andrew Noble’s remarks in this connexion are the more weighty, coming as they did from the director of the great arsenal of Sir W. G. Armstrong, Whitworth & Co., and from one whose scientific research has incalculably advanced our knowledge of artillery and explosives. Sir Andrew follows up this comparison by the following reference to the condition of things just before the Crimean War:—

“ The most improved battleships of the period just anterior to the Crimean War differed from the type I have just described mainly by the addition of steam power, and for the construction of these engines the country was indebted to the great pioneers of marine engineering, such as J. Penn & Sons, Maudslay, Sons & Field, Ravenhill, Miller & Co., Rennie Bros., &c., not forgetting Messrs Humphreys & Tennant, whose reputation and achievements now are even more brilliant than in those earlier days. Taking the 'Duke of Wellington,’ completed in 1853, as the type of a first-rate just before the Crimean War, her length was 240 ft., her breadth 60 ft., her displacement 5830 tons, her indicated horse-power 1999, and her speed on the measured mile 9∙89 knots. Her armament consisted of 131 guns, of which thirty-six 8-in. and 32-pdrs. were mounted on the lower deck, a similar number on the middle deck, thirty-eight 32-pdrs. on the main deck, and twenty short 32-pdrs. and one 68-pdr. pivot gun on the upper deck. Taking the ‘ Caesar ’ and the 'Hogue ’ as types of second- and third-rate line-of-battle