and the clutch engaged it always in such a way that it drew water from a tank at the low end of the boat, and delivered it to a tank at the high end. Several other devices of great ingenuity were employed in the boat; notably a special form of universal joint introduced into the line of shafting. At the after end, close to the propeller, this universal joint was fitted in such a way that the screw could be set at an angle to the line of motion, and steering effected without the aid of a vertical rudder. A torpedo containing 100 lb of dynamite or other explosive was carried outside the hull, and secured by a catch joint. This torpedo, on the submarine boat being manoeuvred into position, could be thrown off and allowed to rise and attach itself, by means of spikes, to some vulnerable part of the ship doomed to destruction. Retiring then to a safe distance, the submarine boat could explode the torpedo by the agency of an electric current.

Working in the light of his now considerable experience, Μ. Goubet built several other boats. These were of larger dimensions, having a length of 27 ft.; their material was also bronze, and they were cast in three pieces, the centre one having a thickness of I in., while the others were reduced to a little more than ½ in. at the ends. Possessing to a large extent the same contrivances as their predecessor, these improved boats were fitted also with an automatic apparatus for regulating the depth of submersion. In this regulator a piston is moved along a cylinder by the rotation of a rod with a screw thread cut in it, and so increases or diminishes the amount of water in the cylinder. The movement of the piston is effected by a small motor, and the direction of action of the motor is regulated by a commutator placed in juxtaposition to a pressure gauge. When the depth of submersion is too small, current is supplied to move the piston so as to admit more water; when the depth is too great, current is supplied in the opposite direction, and water is expelled. The speed attained by this boat was from 5 to 6 knots. Smaller boats of this type have been built for propulsion by manual power, but, however perfect the mechanism, the range of action of a submarine dependent on man-power for propulsion is very limited. Recent Goubet boats are being built, with motive- power, which it is proposed to carry on board ship and lower from davits when required.

The “ Gymnote ” was constructed at Toulon in 1888. She is a steel vessel, with a length of 59 ft. and a displacement of 30 tons; being of an experimental character only, she has no weapon of attack. The maximum speed obtainable is 8 knots. The designs of the “ Gustave Zédé ” and of the “ Morse ” were both based on those of the “Gymnote,” the former having a length of 148 ft. and a displacement of 263 tons. In both of these the hull is of bronze; one great advantage of this metal being that, like the bronze of the Goubet boats, it is non-magnetic in character, and cannot therefore disturb the equilibrium of the compass. With their large dimensions they were intended to be formidable engines of war, and were furnished for attack with Whitehead torpedoes; of these latter they each carry three of 45 cm. (nearly 18 in.) diameter, discharging them by means of a torpedo tube. The “ Morse ” and the “ Gustave Zédé,” like the “ Gymnote,” possess only electric means of propulsion, the power being derived from batteries of accumulators. No power is provided in the vessels by which the accumulators can be recharged, so that the radius of action of these boats is necessarily very limited. The “ Narval,” designed by M. Laubeuf, and the outcome of a general competition in 1897, has a length of 112 ft. and a total displacement of 200 tons. She was built at Cherbourg in 1898, and is furnished with a triple-expansion steam engine, obtaining its steam from a water-tube boiler of special form and heated by petroleum. As in the American submarines, this engine propels the boat when at the surface, and also drives a dynamo which recharges accumulators, the latter giving the reserve power for use in the submerged condition. A speed of 11 knots is obtained at the surface, and 8 knots when submerged. A new departure in the “ Narval ” is her double hull, the inner shell of which is of steel plate of sufficient thickness to resist any water-pressure to which the boat may be subjected, and the outer shell, placed at varying distances from the inner, forms a protection to the inner against attack. An armoured dome surmounts the boat, cutting through the external shell and carrying a short and narrow telescopic funnel, which, as in the case of the American boats, must be withdrawn preparatory to diving. Control in the vertical direction is obtained, when diving, by the use of two pairs of horizontal rudders, placed symmetrically—one pair forward, the other aft. By the above arrangement it is claimed that the horizontal direction of the boat is ensured, the American course of inclining the axis of the boat when diving being considered open to such grave objections that it is desirable to avoid it.

The early American boats of the “ Holland ” type, and the French boats built in the last decade of the 19th century, were the earliest really practical submarine boats, in the sense that unlike the boats which preceded them they were instru­ments of war which could be used by ordinary trained crews with the average chances of success and failure which attend all warlike operations. They owe their practicability not to any discovery of the method of controlling the movements of a boat beneath the surface of the water, as has been sometimes supposed, since the ordinary method of steering by means of a rudder or a com­bination of rudders perfectly analogous to that used for manoeuvring a ship in the horizontal plane was well known and had been applied to steering submarines in the vertical plane before; but principally to the perfection of the accumulator cell as a means of storing energy for propulsion without the expenditure of air or other weight contained in the boat, and to the introduction of the optical tube. This latter instru­ment is a telescope with the optical axis twice bent through a right angle by totally reflecting prisms or mirrors; and under diverse forms and various names, such as periscope, cleptoscope, hyphydroscope, omniscope, &c., it affords the only practical means by which objects on the surface of the water can be seen at a distance from the interior of a submerged vessel. The problem of providing means for seeing at a distance through the water still awaits solution, and when solved, if it ever should be, will enormously add to the power of submarine boats as weapons of war.

By far the greater numl>er of submarine boats in existence in 1910 were developments through a process of continuous experiment and improvement of the “ Gymnote ” and of the early Hofland boats, although the process of evolution had been so rapid and extensive that the parentage of these modern boats is barely recognizable. There are, however, a considerable number of submarines built by the Lake Submarine Boat Co. of Bridgeport, U.S.A., in the service of various naval powers. These boats are designed by Mr Simon Lake, who was also a pioneer in submarine boat construction, contemporary with Mr J. P. Holland in the United States of America. His earliest boat, the “ Argonaut,” was intended rather for running along the bottom in shallow water than for ordinary navigation; and for sending out divers rather than for discharging torpedoes. For this purpose it was fitted with wheels for running along the bottom and with an air-tight chamber having a hatch at the bottom which could be opened when the air pressure in the chamber was made equal to that of the water outside. These features arc still retained in many of the modern Lake boats, though these boats are now constructed like all other submarines, primarily for the purpose of submarine navigation.

Other boats which should be mentioned as laying claims to dis­tinctive features in matters of detail are those built by the Fiat San Giorgio Company of Spezia, designed by Colonel Laurenti, and those built by the Germania Werft of Kiel, which are understood to embody the patents of M. d'Εquevilley. The Russian government also possesses several boats generally regarded as of a distinctive type designed by Μ. Drzwiecki.

Perhaps the most outstanding distinction between different submarine boats is the amount of their submerged displacement which is devoted to carrying water ballast. This, of course, measures their reserve of buoyancy in the surface condition, which in different