cranks 120° apart,@@1 an arrangement greatly superior to that of two cranks in uniformity of effort on the shaft. To facilitate removing the pistons from the cylinders, the large cylinder has in some cases been set above the other.

220. The other arrangement of double compound marine engine has three cylinders set in line fore and aft. The middle one is the high-pressure cylinder ; the other two receive steam from it, and form together the equivalent of one large low-pressure cylinder. The three work on cranks at 120° apart. Besides securing the advantage in uniformity of effort which three cranks have over two, this form avoids the use, in very powerful engines, of a low- pressure cylinder of excessive size. On the other hand, the three- cylinder form takes up more space, and has a larger number of working parts. In the most powerful engines that have yet been constructed this three-cylinder arrangement is followed. The “Umbria” and “Etruria” have a 71-inch high-pressure cylinder between two 105-inch low-pressure cylinders, with a stroke of 6 feet. These engines, which were built just

before the introduction of triple expansion,

are supplied with steam at a pressure of 110

lb by gauge, and indicate 14,300 horse-power.

In this and in the ordinary two-cylinder form of marine engine, the low-pressure valve-chest and the casing of the engine be­tween the cylinders form an intermediate receiver for the steam.

221. During the last two or three years a great advance has taken place in marine engineering by the general introduction of triple-expansion engines, and by an increase in steam pressure which the system of triple expansion makes practicable. In 1874 the steamer “Propontis” was fitted with a set of three-crank triple-expansion engines, de­signed by Mr A. C. Kirk. The experiment was prevented from being fully successful by the failure of the boilers, which were of a special type. Another experiment with triple engines in the yacht “Isa” in 1877 prepared the way for their application to regular ocean service. In 1882 the steam­ship “Aberdeen,” with triple engines, de­signed by Mr Kirk, to work with steam of 125 lb pressure, supplied from

double-ended steel boilers of the

ordinary marine type, demon­

strated the advantage and safety

of the system. Since then its

use has become general in new

steamers, and in many cases the

older double engines are being

removed to give place to engines

of the triple-expansion type,

with the effect of reducing the

consumption of coal by about

25 per cent.@@2

222. In the most common ar­rangement of triple-expansion engines three cylinders are ranged in line, fore and aft, working on cranks at 120° apart.

Piston-valves are generally pre­ferred, and these are not un­commonly worked by some form of radial valve-gear instead of the ordinary link-motion. An advantage of this is that the space which would be taken up by eccentrics upon the shaft is saved, and longer main bearings are in consequence possible, without spreading the engines in the fore-and-aft direction. An objectionable feature of the three-cylinder triple engine is its length; on the other hand, the high speed and high pressure which are features of modern practice make long bearings indis­pensable.

223. To avoid the length of the three-crank engine, Mr Brock and others have made engines of the triple-expansion type with two cranks, by putting the high and the intermediate pressure cylinders above and tandem with two low-pressure cylinders. Mi-Brock has also built four-cylinder *quadruple*-expansion engines of a similar form (with two cranks), and esti­mates that they show an economy in coal consumption of 5 per cent. as compared with triple-expansion engines

working with the same pressure of steam.

224. Steam-jackets are retained by some but not by

all builders ; where they are employed the boiler steam is usually reduced in pressure before admission to the intermediate and low-pressure cylinder jackets and to the receiver-jackets. The feed-water is frequently heated to about 200° F. by Weir’s plan of condensing in it, by common injection, a quantity of steam taken from the second receiver ; this has the advantage of freeing it of air, and of preventing local chilling in the boiler. In present-day prac­tice the boiler pressure, for a triple- expansion engine, ranges from 120 to 170 lb per square inch (by gauge), and it does not appear that any material increase of this is possible without a complete de­parture from the present type of marine boiler. On the other hand, with­out a material increase of pressure there is little advantage in quadruple

expansion.

225. Surface condensa­tion was introduced in marine engines by S. Hall in 1831, but was not brought into general use until much later. Pre­vious to this it had been necessary, in order to avoid the accumulation of too dense brine in the boiler, to blow off a por­tion of the brine at short intervals and replace it by sea water, a process which of course involved much waste of heat. By the use of surface condensers it became possible to use the same portion of water over and over again. The very freedom of the condensed water from dissolved mineral substances was for a time an obstacle to the adoption of surface condensers, for it was found that the boiler, no longer protected by a deposit of scale, became rapidly corroded through the action of acids formed by the decomposition of the lubricating oil. This objection was overcome by introducing a sufficient amount of salt water to allow some scale to form, and the use of surface condensers soon became universal on steamers plying in sea water. The marine condenser consists of a multitude

@@@1 See description of the engines of the “ City of Rome,” with three 46-inch and three 86-inch cylinders, with a stroke of G feet, working up to 11,890 I. H. P., *Proc. Inst. Mech. Eng.,* 1880.

@@@2 The rapid progress of the system of triple expansion may be judged from the fact mentioned by Mr W. Parker of Lloyds in a recent paper (*Engineering,* July 30, 1886), that, out of 199 engines then being built for merchant steamers, 128 sets were of the triple-expansion type. For war-ships also triple engines are being built of sizes up to 13,000 horse-power. For a discussion of several import­ant points in the design of triple-expansion engines, see a paper by R. Wyllie, *Proc. Inst. Mech. Eng.,* Oct. 1886.