indefinitely long, is disturbed by the presence of forces which vary periodically with a frequency twice that of the rotation. When three cranks, 120° apart, are employed, it will be found that the effect of the shortness of the connecting-rods in causing forces to act in the line of the stroke is reduced to a couple tending to tilt the engine in a fore and aft direction, which may in its turn be balanced by using a second set of three cranks on the same shaft, the second set being so arranged that the couple to which it gives rise neutralizes the couple due to the first set. A six-crank engine may be arranged in this way to secure an extremely close approximation to per­fect balance, and the same state of balance can be secured when the number of cranks is reduced to five.

86. The most usual arrangement adopted in marine engines, when questions of balance are taken into account, is to have four cranks, and consequently four sets of reciprocating masses. In the Yarrow- Schlick-Tweedy ” system of balancing engines four cranks are employed, and by adjusting the relative weights of the four pistons, as well as their distances apart, and by selecting suitable angles for the relative positions of the cranks (differing somewhat from 90°), a close approximation to complete balance is obtained. In triple expansion this arrangement is readily applied when two low-pressure cylinders are used instead of one, the steam from the intermediate cylinder being divided between them, and it is also of course appli­cable to quadruple expansion engines.

87. In this connexion mention may be made of a" type of engine which hás been used in various electric power stations, especially in America, in which a revolving mass might be employed to balance completely the inertia effects of two pistons. This is a compound engine in which the cylinders stand at right angles to one another, one being horizontal and the other vertical. If the piston masses were made equal it is clear that the inertia effect of a revolving mass could be resolved into two components which would balance both. It docs not appear, however, that advantage has been taken of this property in the design of actual engines of this type. In the London County Council power station at Greenwich, where the engines are of this class, the unbalanced effects of inertia are so considerable as to affect the instruments at the Observatory half a mile away. One of the conspicuous merits of the steam turbine is that it avoids the use of reciprocating parts and so escapes the inconveniences and limitations to which the inertia of reciprocating parts gives rise.

88. *Types of Engine.—*In classifying engines with regard to their general arrangement of parts and mode of working, account has to be taken of a considerable number of independent charac­teristics. We have first a general division into *condensing* and *non-condensing* engines, with a subdivision of the condensing class into those which act by surface condensation and those which use injection. Next there is the division into *compound* and *non-compound,* with a further classification of the former as double-, triple- or quadruple-expansion engines. Again, engines may be classed as *single* or *double-acting,* according as the steam acts on one or alternately on both sides of the piston. Again, a few engines—such as steam hammers and certain kinds of steam pumps—are *non-rotative,* that is to say, the reciprocating motion of the piston does work simply on a reciprocating piece; but generally an engine does work on a continuously revolving shaft, and is termed *rotative.* In most cases the crank-pin of the revolving shaft is connected directly with the piston-rod by a connecting-rod, and the engine is then said to be *direct- acting*; in other cases, of which the ordinary beam engine is the most important example, a lever is interposed between the piston and the connecting-rod. The same distinction applies to non-rotative pumping engines, in some of which the piston acts directly on the pump-rod, while in others it acts through a beam. The position of the cylinder is another element of classification, giving *horizontal, vertical* and *inclined cylinder* engines. Many vertical engines are further distinguished as belonging to the *inverted cylinder* class; that is to say, the cylinder is above the con­necting-rod and crank. In *oscillating cylinder* engines the connecting-rod is dispensed with; the piston-rod works on the crank-pin, and the cylinder oscillates on trunnions to allow the piston-rod to follow the crank-pin round its circular path. In *trunk* engines the piston rod is dispensed with; the connecting- rod extends as far as the piston, to which it is jointed, and a trunk or tubular extension of the piston, through the cylinder cover, gives room for the rod to oscillate. In *rotary* engines there is no piston in the ordinary sense; the steam does work on a revolving piece, and the necessity is thus avoided of afterwards converting reciprocating into rotary motion. *Steam turbines* may, in one sense, be regarded as an extreme development of the rotary type; but they are distinct from all other steam engines in this that their action depends on the kinetic energy of the steam.

89 . *Beam Engines.—*In the single-acting atmospheric engine of Newcomen the beam was a necessary feature; the use of water- packing for the piston required that the piston should move down in the working stroke, and a beam was needed to let the counterpoise pull the piston up. Watt’s improvements made the beam no longer necessary; and in one of the forms he designed it was discarded—namely, in the form of pumping engine known as the Bull engine, in which a vertical inverted cylinder stands over and acts directly on the pump-rod. But the beam type was generally retained by Watt, and for many years it remained a favourite with builders of engines of the larger class. The beam formed a convenient driver for pump-rods and valve-rods; and the parallel motion *(q.v.)* invented by Watt as a means of guiding the piston-rod, which could easily be applied to a beam engine, was, in the early days of engine-building, an easier thing to construct than the plane surfaces which are the natural guides of the piston-rod in a direct-acting engine. In modern practice the direct-acting type has to a very great extent dis­placed the beam type. For mill-driving and the general purposes of a rotative engine the beam type is now rarely chosen. In pumping engines it is somewhat more common, but even there the direct-acting forms are generally preferred.

90. *Direct-Acting Engines.*—Of direct-acting engines the hori­zontal type has in general the advantage of greater accessibility, but the vertical economizes floor space. In small forms the engine is generally self-contained, that is to say, a single frame or bedplate carries all the parts including the main bearings in which the crank-shaft with its flywheel turns. The frame often takes what is called a girder shape, which brings a portion of it into a favourable position for taking the thrust between the cylinder and the crank-shaft bearings and allows two surfaces to be formed on the frame to serve as guides for the cross-head. When a condenser is used with a horizontal engine it is usually placed behind the cylinder, and the air-pump, which is within the condenser, has a horizontal plunger or piston on a “ tail-rod ” or continuation of the main piston-rod through the back cover of the cylinder. In large horizontal engines the condenser generally stands in a well below, and its pump, which is vertical, is driven by means of a bell-crank lever attached by a link to the engine cross-head.

91. *Coupled Engines.—*When uniformity of driving effort or the absence of dead points is important, two independent cylinders often work on the same shaft by cranks at right angles to each other. Such engines, which are called "coupled,” can start readily from any position; the ordinary locomotive engine is an example. Winding engines for mines and collieries, in which ease of starting, stopping and reversing is essential, are very generally made by coupling a pair of cylinders on opposite sides of the winding drum with link motions as the means of operating the valves.

92. *Compound Engines, Coupled or Tandem.—*Large direct- acting engines are usually compounded either by having a high- and a low-pressure cylinder side by side, with cranks at right angles, or by putting one cylinder behind the other with the axes of both in the same line. The latter is called the *tandem* arrangement. In a tandem engine, since the pistons agree in phase, the steam may expand directly from the small into the large cylinder. But the connecting-pipe and steam chest form a receiver of considerable size, and to avoid loss by “ drop ” the supply of steam to the large cylinder is cut off long before the end of the stroke. For mill engines the com­pound tandem and compound coupled types of engine are the most usual. The high-pressure cylinder is very generally fitted with Corliss or other trip-gear.

93. *Jet and Surface Condensation.—*In land engines using condensation the jet form of condenser is common, but surface condensation is resorted to when the available water-supply is unsuited for boiler feed. When there is no large supply of condensing water a very fair vacuum can be obtained by using