199. When uniformity of driving effort or the absence of dead- points is specially important, two independent cylinders are often coupled to the same shaft by cranks at right angles to each other, an arrangement which allows the engine to be started readily from any position. The ordinary locomotive is an example of this form. Among fixed engines of the larger kind, *winding engines,* in which ease of starting, stopping, and reversing is essential, are very gene­rally made by coupling a pair of horizontal cylinders, with cranks at right angles to each other, on opposite sides of the winding-drum, with the link-motion as the means of operating the valves.

200. Non-compound engines of so large a size as that of fig. 127 are comparatively uncommon. Horizontal engines of the larger class are generally compounded either (1) by having a high and a low pressure cylinder side by side, working on two cranks at exactly or nearly right angles to each other, or (2) by placing one cylinder behind the other, with the axes of both in the same straight line. The latter is called the *tandem* arrangement. In it one piston-rod is generally common to both cylinders ; occasionally, however, the piston-rods are distinct, and are connected to one another by a framing of parallel bars outside of the cylinders. Another con-

of compound engines, the cut-off is usually effected either by an expansion slide-valve or by some form of Corliss or other trip- gear.

For mill engines the compound tandem and compound coupled types are now the most usual, and the high-pressure cylinder is very generally fitted with Corliss gear. In the compound coupled arrangement the cylinders are on separate bedplates, and the fly­wheel is between the cranks.

201. The general arrangement of vertical engines differs little from that of horizontal engines. The cylinder is usually supported above the shaft by a cast-iron frame resembling an inverted A, whose sides are kept parallel for a part of their length to serve as guides for the crosshead. Sometimes one side of the frame only is used, and the engine is stiffened by a wrought-iron column be­tween the cylinder and the base on the other side. *Wall-engines* are a vertical form with a flat frame or bedplate, which is made to be bolted against a wall ; in these the shaft is generally at the top. Vertical engines are compounded, like horizontal engines, either by coupling parallel cylinders to cranks at right angles (as in the ordinary marine form, which will be illustrated later, § 218), or, tandem fashion, by placing the high-pressure cylinder above the other. In vertical condensing engines the condenser is situated at the base, and the air-pump, which has a vertical stroke, is gene­rally worked by a lever connected by a short link to the cross­head. In some cases the pump is horizontal, and is worked by a crank on the main shaft.

202. Engines making 400 to 1600 revolutions per minute have been extensively applied, in recent years, to the driving of dynamos and other high-speed machines. These are for the most part single-

straction, rarely followed, is to have parallel cylinders with both piston-rods acting on one crank by being joined to opposite ends of one long crosshead. In some recent compound engines the large cylinder is horizontal, and the other lies above it in an inclined position, with its connecting-rod working on the same crank- pin.

In tandem engines, since the pistons move together, there is no need to provide a receiver between the cylinders. It is practic­able to follow the “Woolf” plan of allowing the steam to expand directly from the small into the large cylinder ; and in many instances this is done. In point of fact, however, the connecting- pipe and steam-chest form an intermediate receiver of considerable size, which will cause loss by “ drop ” (§ 113) unless steam be cut off in the large cylinder before the end of the stroke. Hence it is more usual to work with a moderately early cut-off in the low- pressure cylinder than to use the “ Woolf ” plan of admitting steam to it throughout the whole stroke. Unless it is desired to make the cut-off occur before half-stroke, a common slide-valve will serve to distribute steam to the large cylinder. For an earlier cut-off than this a separate expansion-valve is required on the low-pressure cylinder, to supplement the slide-valve ; and in any case, by providing a separate expansion-valve, the point of cut­off is made subject to easy control, and may be adjusted so as to avoid drop or to divide the work as may be desired between the two cylinders.@@1 For this reason it is not unusual to find an expan­sion-valve, as well as a common slide-valve, on the low-pressure cylinder even of tandem engines. In many cases, however, the common slide-valve only is used. On the high-pressure cylinder

acting : steam is admitted to the back of the piston only, and the connecting-rod is in compression throughout the whole revolution. Besides simplifying the valves, this has the important advantage that alternation of strain at the joints may be entirely avoided, with the knocking aud wear of the brasses which it is apt to cause. To secure, however, that the connecting-rod shall always push, there must be much cushioning during the back or exhaust stroke. From a point near the middle of the back stroke to the end the piston is being retarded ; and, as this must not be done by the rod (which would thereby be required to pull), cushioning must begin there, and the work spent upon the cushion must at every stage be at least as great as the loss of energy on tho part of the piston and rod. In some single-acting engines this cushioning is done by compressing a portion of the exhaust steam ; in others the rod is kept in compression by help of a supplementary piston, on which steam from the boiler presses ; in Mr Willans’s engine the cushion­ing is done by compressing air.

203. A very successful example of the multiple-cylinder single- acting high-speed type is the three-cylinder engine introduced by Mr Brotherhood in 1873, the most recent form of which is shown in figs. 128 and 129. Fig. 128 is a longitudinal and fig. 129 a trans­verse section. Three cylinders, set at 120° apart, project from a closed casing, the central portion of which forms the exhaust. The pistons are of the trunk type—that is to say, there is a joint in the piston itself which allows the piston-rod to oscillate, and so makes a separate connecting-rod unnecessary. The three rods work on a single crank-pin, which is counterbalanced by masses

@@@1 Οr, alternatively, the adjustment may be made so that the steam undergoes equal changes of temperature in both cylinders.