an *evaporative condenser,* consisting of a stack of pipes into which the exhaust steam is admitted and over which a small amount of cooling water is allowed to drip. This water is evaporated by the heat which is extracted in condensing the steam within. Such a condenser is placed in the open, generally on a roof where the air has free access. The amount of water it uses need not exceed the amount of steam that is condensed, and is there­fore a very small fraction of the amount required in a jet or surface condenser.

94. *High-Speed Direct-Acting Engines.—*Prior to the advent of the steam turbine the demand for engines suitable for driving electric generators without the intervention of a belt led to the introduction of various forms of direct-acting engine adapted to run at a high speed. Some of these were *single acting,* steam being admitted to one side of the piston only, generally the back, with the result that the rods could be kept in a state of thrust throughout the revolution, and alternations of stress in them and at the joints thereby avoided, together with the knocking and wear of the bearing brasses which it is apt to cause. To secure, however, that the connecting-rod should always push and never pull against the crank-pin there had to be much cushioning during the out stroke on account of the fact that from about the middle of that stroke to the end the reciprocat­ing mass was being retarded. In engines designed by P. W. Willans, which were highly successful examples of this class, the cushioning was provided by means of a supplementary piston which compressed air during the out stroke; the energy which the reciprocating masses had to part with in losing their motion during the second half of the out stroke was stored in this air and was restored in the succeeding down stroke.

Willans obtained compound or triple expansion by mounting two or three cylinders in tandem in a vertical line, with the air-compressing piston below them in the form of a trunk which served also as a guide for the cross-head. The piston-rod was hollow and within it there was a valve rod carrying piston valves for the admission and release of the steam. The valve rod was worked by an eccentric on the crank-pin which gave it the proper relative motion with respect to the hollow piston within which it works. The engine was entirely enclosed in a casing the bottom of which formed an oil bath in which the cranks splashed to ensure ample lubrication. These engines for a time had much vogue and gave good results. Many of them are in use in electric light stations and elsewhere, but the tendency now is to use turbines for this class of work, and even in cases where reciprocating engines are preferred they are now more usually of the double-acting type, which has the advantage of giving a greater output of power for the same weight.

95. *Double-Acting High-Speed Engines.—*Of double-acting high-speed engines an interesting form is that of Messrs Beiliss and Morcom, the chief distinctive feature of which is the use of forced lubrication at the pin joints and shaft bearings. In a double-acting engine, where the thrust acts alternately on one and the other side of the crank-pins and cross-head pins, high frequency of stroke tends to produce much knocking and wear unless the brasses are very closely adjusted, and in that case the pins are liable to get hot, and to “ seize” by expanding sufficiently to fill the small clearance. This difficulty, which exists when lubrication is carried out in the ordinary way, is overcome in the Beiliss engine by feeding the bearings with a continuous supply of oil, which is pumped in under a pressure of about 15 lb per sq. in. The presence of a film of oil is thereby continuously secured, and knocking is prevented although the brasses are not set very close. Notable examples in which double action is combined with a relatively high frequency of stroke are found in naval engineering practice, especially in the engines of high-speed cruisers and torpedo- boat destroyers. As a rule these engines employ triple expansion with four cranks and four cylinders, the third stage of the expan­sion being performed in two cylinders, which divide the steam between them. But in this field also the steam turbine is rapidly displacing the reciprocating type.

96. *Pumping Engines.—*In engines for pumping or for blowing air it is not essential to drive a revolving shaft, and in many forms the reciprocating motion of the steam piston is applied directly or through a beam to produce the reciprocating motion of the pump-piston or plunger. On the other hand, pumping engines are frequently made rotative for the sake of adding a flywheel.

Fig. 48 shows a compound inverted vertical pumping engine of the non-rotative class by Messrs Hathorn, Davey & Co. Steam is distributed through lift valves, and the distribution of steam is controlled by means of a cataract, which makes the pistons pause at the end of each stroke. The pistons are in line with two pump-rods, and are coupled by an inverted beam which gives guidance to the cross-heads by means of an approxi­mate straight-line motion. Engines of this kind, like the old Cornish pump, are able to work expansively against a uniform resistance without a flywheel in consequence of the great inertia of the reciprocating pieces which include long massive pump-rods. Notwithstanding the low frequency of the strokes, enough energy is stored in the moving rods to counterbalance the inequalities of steam thrust, and the rate of acceleration of the system adjusts itself to give, at the plunger end, the nearly uniform effort which the pump requires. In other words, the motion, instead of being almost simple harmonic as it is in rotative engines, is such that the form of the inertia curve when drawn as in fig. 47 is nearly the same as that of the steam curve, with the result that the distance between the two, which re­presents the net effort on the pump-plunger, is nearly con­stant. The massive pump-rods act in such a way as to form a reciprocating equivalent of a flywheel.

97. It is, however, only to deep well pumping that this applies, and a very numerous class of direct-acting steam pumps have too little mass in their reciprocating parts to allow such an adjustment to take place. A familiar example is the small donkey pump used for feeding boilers, in which the steam-piston and pump-plunger are on one and the same rod. In some of these pumps a rotative element is introduced, partly to secure steadiness of working and partly for convenience in working the valves. But many pumps of this class are entirely non-rotative, and in such cases the steam is generally admitted throughout the stroke without expansion. In some of them the valve is worked by tappets from the piston-rod. In the Blake steam pump a tappet worked by the piston as it reaches each end of its stroke throws over an auxiliary steam-valve, which admits steam to one or other side of an auxiliary piston carrying the main slide-valve.

98. *Worthington Engines.—*In the Worthington pumping engine two steam cylinders are placed side by side, each work­ing its own pump-piston. The piston-rod of each is connected by a short link to a swinging bar, which actuates the slide-valve of the other steam cylinder. In this way one piston begins its stroke when the motion of the other is about to cease, and a