approaching the lower of the speeds named is entirely out of the question, and a little consideration will show why this so.

Putting aside the question of pumps worked by rods from an engine at surface, and having a piston-speed with a limit of about 100 ft. per minute, attention may be confined to pumps designed for erection at the shaft-bottom or in underground workings. These are of many forms, and single, double, treble, and quadruple in their action. Those of the single and duplex direct-acting types, as well as those of the three-ram type, have short strokes: fly-wheel pumps—*i.e.*, ordinary single or coupled engines with pumps directly connected—usually have long strokes; but in neither case is the piston-speed high. In this respect the last-named type can be worked to greater advantage than the former. With the ordinary style of short-stroke pumps it is necessary to have numerous valves both at the suction and discharge. This plainly means that the water has to flow through several passages of restricted area, and is thereby throttled in its course. A very slight calculation will prove that the friction of water flowing through one passage of given area is very much less than where the same superficial area is made up of a large number of passages, and *vice versâ.* The extent of this will be seen from the following example: One passage 6 in. in diameter has an area of 28·27 square inches, and a circumference of 18·85 in.: with passages of one-third the diameter—viz., 2 in.—nine would be required to give an equivalent superficial area; but the combined circumferences are no less than 56·54 in., or practically three times more than the circumference of the larger passage. The circumference multiplied by the length of the passage gives the area of frictional surface. In estimating the frictional resistance through pump-valves the divisions in the valve-box have, of course, to be taken into consideration.

The numerous valves already referred to in short-stroke pumps have a low lift, and are generally fitted with springs to secure quick return to the valve-seats at each change of direction of stroke. The strength of the springs—which has to be overcome each time the valves open—combined with the extra friction of the water through small passages, has an appreciable (if only slight) effect on the engine-power. With a longer stroke the valves are fewer in number and larger, but there still remains the fact that even with a long stroke the piston-speed is limited. This feature is due to the loss or "slip" which takes place at each return of the valves to their seats—a condition which has a decided tendency to cause a series of hydraulic shocks, or what is popularly known as "hammering." A high rate of speed under these conditions endangers the safety of the pump-valves, and so the piston-speed becomes reduced to a point below what, in the case of a steam-engine, is economical in steam-consumption. It will thus be seen that steam-pumps of the fly-wheel type, having long strokes, cannot compare favourably with modern marine and other engines as regards economy in their consumption of steam. This is still more marked in the case of short-stroke direct-acting steam-pumps without fly-wheels, although in both cases advantages may be gained by compounding or by triple expansion where circumstances permit. In order, therefore, to obtain more economical resuls, it is quite evident that some form of pump-valve which will admit of a higher rate of piston-speed, combined with freedom from slip and hammering, will have to be used.

The invention (by Professor Riedler) of mechanically controlled pump-valves has made it possible to work pumps at a piston-speed, which only a few years ago would have been considered incredible. Pumps so fitted are now in successful work in various parts of the world, and some of them are driven at piston-speeds which range from 300 ft. to 700 ft. per minute. Without the means adopted were such as to reduce the hydraulic shocks or hammering to a minimum, such speeds would be entirely out of the question; but the very fact of their having been attained with safety is proof in itself that the desired object has been accomplished. The method of control is simple, and each pump-valve has a positive action: it must make its full lift and sit down on its seat with only a thin film of water between the two faced surfaces.

This action is obtained from the motion of an eccentric on the fly-wheel shaft in the following manner: At a convenient distance back from the fly-wheel (or crank) shaft a disc or rocker is fitted on a fixed centre and connected with the eccentric by a rod. When working, the disc or rocker describes the arc of a circle. To crank-pins fitted on the disc two connecting-rods are secured, and communicate motion to rocking-levers, which raise and lower the pump-valves through the medium of spindles working in bonnets. These spindles—which work through packed glands—are horizontal, and therefore at right angles to the lift of the valves. They are fitted at their interior end with suitable forks for giving the valves the required motion. A thick rubber buffer is also fitted to each valve in such a manner as to prevent injury to the mechanism in the event of any obstruction between the valve and its seat.

An important feature in the Riedler system is that, notwithstanding the high speed attained, only the fewest possible number of valves is used, and in this respect is on a parallel with the large slow-speed Cornish draw-lift or ram pump. The valves are made of ample area for the work required, and have a high lift to prevent throttling of the water. The mechanical arrangement by which the valves are controlled opens the latter automatically; they remain open practically the entire length of the stroke, and are closed again mechanically at the proper moment, thus preventing slip. In this manner a high rate of piston- or plunger-speed becomes possible and valves so operated work satisfactorily against very high pressures. The valves are easy of access, and it is stated that from a record of over fifteen hundred pumps the average life of a Riedler valve is found to be about five years. The illustration (Fig. 1) of a small-sized Reidler pump, connected by gearing to an electric motor, will show how the control of the valves is effected, the principle being the same whatever the size of the pump or nature of the driving-power may be.

Fig. 2 gives a sectional view of a Riedler pump built on the "differential" principle, and, as very few, if any, pumps built on this principle have been yet used in this colony, I quote from a description courteously supplied me by Messrs. Fraser and Chalmers, of London and Chicago, the builders of Riedler pumps, as follows:—