the barometric pressure; the temperature of the water pumped; the size, length, and course of the suction and delivery-pipes; the area, weight, and lift of valves, etc. The height above sea-level, and therefore the existing atmospheric pressure, limits the height to which water may be drawn by suction or the velocity with which it will follow the piston or plunger, thereby limiting the speed of the pump for a given suction lift. The higher the temperature of the water the less will be the admissible suction lift, because if the reduction of pressure at the upper end of the suction-pipe be sufficient, the water will begin to boil at a temperature much below that at which it would boil under atmospheric pressure, and give off steam, which will fill the pump-barrel, instead of the water doing so. The suction lift must therefore be kept so low that the pressure will be sufficient to prevent steam from forming. The suction height is the vertical distance from the level of the suction water to the highest point of the piston displacement and spaces connected with it. The greater also the head pumped against the less is the admissible speed, because with the longer column shocks are more severe.

Starting Pumps. In starting a reciprocating pump it is necessary to remove the air from the pump-barrel and the spaces communicating with it. Where these waste spaces are large compared with the piston or plunger displacement, and the head pumped against is high, the air, particularly in high altitudes, will not be sufficiently compressed on the working-stroke to lift the discharge valve and escape into the discharge-pipe in case it is full of water. Again, if atmospheric pressure exist at the beginning of the suction-stroke, the air in the pump may not be sufficiently expanded and lowered in pressure on completion of the suction-stroke so that the outer air can lift the water in the suction pipe, cause it to force open the suction-valve, and enter the pump.

Priming and Draining. The operation of expelling the air from a pump and filling it with water is called *priming*. Means are generally provided in a by-pass pipe with a cock for priming the pump from the discharge-pipe in case the latter already contains water, the escape of air being then generally effected through a cock near the highest part of the space communicating with the working-barrel. When no air-escape is provided, the air will be forced out through the discharge-valve into the discharge-pipe as soon as the pump is put in motion. When there is no water in the discharge-pipe, pumps with large waste spaces generally require independent means for priming them, such as an opening with a funnel, through which water may be poured. Pumps placed below the supply from which they draw do not require priming. Pumps and pipes should be fitted with means for draining them to prevent freezing and to draw off sediment.

Methods of Driving Pumps. Main pumps for shafts are either operated through rods from a motor or engine at the surface, like in the familiar Cornish system of pumping, or, as in more modern methods, by transmitting power to motors directly coupled to the pumps, either through pipes, in the form of steam, compressed air, or pressure water, or as electricity through wires. Some one of these modes of transmission is required, where, as is usually the case, pumps or other machines are used to raise water from winzes or low places, and force it up to the nearest station-tank at the pump-shaft. Hand pumps are also similarly used to raise small quantities of water from low places into launders in the drifts. Pumps should be started in motion gradually, and not in such a manner as results from throwing them suddenly into gear with driving machinery already in motion.

Distribution of Pumps. The distribution of pumps along the line of the shaft depends, first of all, upon the lift allowable for the individual pumps. This condition determines the spacing of pumps in the Cornish system, in which they are generally 200 ft. to 250 ft. apart. Where, however, the pumps are capable of working against a very high head, as in some of the modern direct-acting types, they should, for economical reasons, be spaced according to the levels at which water issues.

Though the water which is generally encountered in sinking a shaft does not always issue at the lowest point, it is nevertheless usually necessary, if pumps are put in, to have the lowest pump so arranged that it can follow close to the shaft bottom as it goes down, in order to be prepared to handle any water that may be struck there, or which may flow down from upper levels. Pumps used for this purpose are called sinking-pumps.

When the sinking-pump has been lowered so far that the limit of its admissible lift is reached in raising water to the next higher pump, another permanent pump is put in near the bottom of the shaft. The sinking-pump then delivers its water to this lowest fixed pump, and is made ready to proceed with further sinking.

Desirable Features of Mining Pumps. The welfare of a mine, if subject to influx of water, depends largely upon the reliability of the pumps. These should therefore be so constructed and arranged that there may be the least possible chance of their failure. The following are some of the main desirable features: (1) They should be capable of running a long time without requiring packing, repairs, or adjustment; (2) They should, if possible, be capable of being operated and repaired under water. This is particularly desirable in the lowest, or sinking pump; (3) They should be able to handle sandy and sometimes acid water, without too rapid wear or deterioration.

1.1.19. In addition, they should be so arranged with reference to the driving power that they can be operated for a wide range of capacities to adapt them to the varying conditions of the water production of the mine.

PIPES.

Pipes used in connection with mining pumps are, firstly, those for conveying the water handled by the pumps, constituting in reality a part of the pumps; and, secondly, those used for conveying power to the motors operating the pumps, in the form of pressure water, steam, or compressed air. While the main object of this chapter is to treat more at length of the former, it is proper, though perhaps to a more limited extent, to consider also the latter, as they are intimately connected with the operation and care of pumps in mines.

The suction- or inlet-pipes and the discharge-pipes of a pump or hydraulic pumping-engine affect the working of these to a great extent, and it is necessary to consider them in a different manner from ordinary continuous flow water-pipes, in order to fix upon the most advantageous arrangement, size of pipes and pumps, and admissable speed of the latter.

Material of Pipes. Cast-iron, formerly used exclusively for larger pipes subjected to pressure underground, is now rarely employed in American mines for this purpose. While this material is less subject to corrosion than either wrought-iron or steel, the pipes made from it have to be very heavy, with a proper factor of safety to withstand the pressure, and the sections are therefore more difficult to handle.

The cheapness of wrought-iron pipes, their greater security under water-hammer, and the facility with which sections of any length can be cut off and fitted to place at the mine, have led to their utmost universal use in general practice.

1.2.05. In cases where the corrosive action of the mine-water on the iron pipes is very strong, and their destruction rapid, pipes of other materials have been used.

At the Barranca Mine, Mexico, drawn copper tubes were put in at great cost. Wooden pipes, where the pressure is not great, or, for higher pressure, iron pipes lined with wood, are sometimes used.

Wrought-Iron Pipe. Formerly, column-pipes larger than 14 ins. in diameter for mine use were made of boiler plate, riveted hot, often with butt-joints and lap-strips; the rivets being counter-sunk on the inside. Now, iron and steel lap-welded tubes up to 24 ins. diameter can be obtained, and manufacturers are preparing machinery for sizes up to 30 ins. in diameter.

Welded pipes are either lap-welded or butt-welded. The latter should be used only for smaller sizes, and for moderate pressure, as they are liable to split open at the weld. Lap-welded tubes or hot-riveted pipes of boiler plate are the only wrought pipes suitable for pump columns in shafts, and for all purposes where heavy pressures and water-hammer are encountered. Lap-welded tubes are also used for steam and compressed air pipes. Iron boiler plates, including those of which welded tubes are made, have less strength in the direction of their width than their length, which latter is the direction of strain when manufactured into a welded pipe. Sheets of mild steel are homogeneous in this respect, besides possessing greater strength; therefore, for larger sizes steel pipes are nearly always used. Welded pipes may be obtained in lengths up to