PUMPING WATER BY COMPRESSED AIR.

THOSE interested in mining and hydraulics will be glad to have some account of the Pohlé system of raising water from non-flowing wells, mines, etc., which has been introduced into Canada by the Ingersoll-Sergeant Drill Company, of Montreal.

The following description is given by the makers:

The pump proper consists of only two plain open-ended pipes, the larger one with an enlarged end piece constituting the discharge pipe, and the smaller one let into the enlarged end piece of the discharge pipe constitutes the air inlet pipe, through which the compressed air is conveyed to the enlarged end piece to the under side of the water to be raised. No valves, buckets, plungers, rods or other moving parts are used within the pipes or well.

In pumping, compressed air is forced through the air pipe into the enlarged end at the bottom of the water pipe, thence by the inherent expansive force of the compressed air, layers or pistons of air are formed in the water pipe, which lift and discharge the water layers through the upper end of the water discharge pipe. At the beginning of the operation the water

work, and that this pump is a perfect expansion engine.

As the weight of the water outside of the discharge pipe (the head) is one-third greater per square inch than the aggregate water sections within the pipe when in operation, it follows that the energy due to this one-third greater weight is utilized in overcoming the resistance of entry into the pipe, and all the friction within it.

The Pohlé "air lift" pump gives ninety per cent. of efficiency from the air receiver in water pipes of large diameter, and as a rule, above eighty per cent. It retains this efficiency without repairs, or until the pipes rust through, whereas ordinary bucket and plunger pumps gradually lose efficiency from the first stroke they make, and lose it rapidly if the water contains sand or is acid in character. It has been estimated by competent experts, that under favorable conditions and large diameters of water and air pipes, 1,000,000 gallons of water can be raised 100 feet high with one and a half tons of good coal.

The air reservoirs are all strongly made of homogeneous steel, tested and guaranteed at working pressures of 110 pounds; they are provided with the proper

openings for inlet and outlet pipes, manhole and head, drain cocks, pressure gage and safety valve.

As the pump has no valves, no standing water remains in the pump column after the operation of pumping; it recedes into the well, and there is none left to freeze in cold weather. The capacity of the pump is unlimited, and with the proper proportions of air to the water, will work efficiently in pipes several feet in diameter. Estimates have been made which indicate that a thirty-inch pipe will deliver 16,660 gallons per minute, equal to 1,000,000 gallons per hour.

As sand, silt, gravel and bowlders in water form no obstacles to interfere with the action of the pump, its adaptability for dredging is suggested as well as its utility for pumping sewage. Experience has proved that by the use of this constant upward flow of water, artesian wells have been freed from their accumulated sedimentary deposits, as well as that lodged in the fissures and crevices of their wall rock, and have been thus made to yield greater quantities of water than they ever did before. For chemical uses, and for the liquids of the arts, there is no superior method than the "Air Lift." It is used successfully for raising sulphuric acid of high specific gravities, and is well adapted for ore leaching works, vinegar works, sugar refineries, dye works, paper pulp works, etc.

As an irrigating pump for raising subterranean water in the arid regions of the West, its field of usefulness is very promising, for with one air compressing plant at a central station, a number of wells, widely separated from each other, may be simultaneously pumped by branches of air-conveying pipes, taken from a main air pipe from the air compressor; for compressed air may be conveyed for miles without material loss of power.

It often happens that a single well does not yield the quantity of water desired, but that a number of wells would give the satisfactory result. By the old fashioned deep well pump, each well would require a separate "steam head," separate sets of rods and the other paraphernalia, which, with the condensation of the steam, when conveyed to the several steam heads, would be very costly in the first outlay, and very wasteful of power in its maintenance, to say nothing of loss of time in repairs. By the Pohlé process, but one air compressing plant is required, and this may be placed in the engine room or the boiler house, directly under the eyes of the engineer, from whence the air may be conveyed to the several wells, all of which may be pumped simultaneously and economically.—Canadian Engineer.

[FROM THE CANADIAN ENGINEER.]

PUMPS AND PUMPING MACHINERY.

By WILLIAM PERRY, Montreal.

THE date from which we commence the history of pumps is the year 200 B. C. Previous to that period there is no mention made of them. Nor has there been discovered any portion that can be judged appertaining to such a machine; the heathen Chinese cannot claim any priority in this special branch, which is peculiar, the more so when we consider their manner of irrigation. A pump is even now a rarity with them.

A pump is not a very intricate machine in itself, and its parts are comparatively few. But its action, or want of it, sometimes makes it seem most mysterious. To those readers who have not considered the question of water dispensation, the remark that pumping machinery stands prominent among the various branches of engineering may seem to allow of discussion. A few instances will very soon give ample proof. How could our coal be obtained and our mines worked, if not for the pumping plant? Our water supply obtained, or our sewage and chemical works carried on? When man enters Nature's storehouse in search of wealth, he finds water ever ready to dispute his supremacy; it may be in a constant stream, varying only with the season; oftentimes vast quantities are stored in crevices of the rocks. Some idea of the quantity of water raised will be given when it is known that often its weight is double and treble that of other

material raised, and is frequently 30 per cent. in coal mines.

Rude nations have not possessed the machine, simple as it is, but have always resorted to a more laborious method to obtain water. In the early ages it does not appear to have been known to the Greeks or Romans. Although the pump was invented 200 B. C., it was not until the beginning of the seventeenth century that its true principles were understood; although in 1636 fire engines were built in Holland, and from which, as far as general principles are concerned, no improvements have been made. In 1582, Peter Morris, a Dutchman, contrived a water engine to supply the residents of London from the Thames, and threw water over the steeple of St. Magnus church, at the north end of London Bridge. The introduction of machinery for domestic use commences from May, 1582. The first patent record in England of a pump is patent No. 6, year 1618, by David Ramsay and Thomas Wildgoose. The air pump was invented by Otto de Guericke in 1654. In 1660 Robert Boyle made many improvements in the air pump.

Sir Samuel Morland, Master of Mechanics to King Charles II, in the year 1674 invented and patented the plunger pump, made of cast iron in 1675. He threw water 60 feet high at the rate of 60 barrels per hour, with 8 men, in 1681; the king presented him with a medallion portrait set in diamonds. 1695 is the first notice I have of ship pumps. In 1732 Mr. Demouin invented a pump like a V. In 1741 James Creed secured a patent, No. 579, for making three different machines for making lead pipe for pump use. The first oscillating pump was patented in the year 1750, patent No. 658, by W. Perkins.

The pumps commonly used for raising water from wells may be divided into two classes—lifting pumps and forcing pumps. The lifting pumps may be again subdivided into two varieties, namely, those with a hollow piston and those with a solid or plunger piston.

1. Lifting pumps with a hollow piston, called also atmospheric pumps. This variety, in its simplest form, consists of the following parts:

A cylinder or tube, in which is fixed a valve opening upward, and above which works a piston provided with a valve also opening upward. The part of the cylinder in which the piston works is called the body of the pump, and is the only part which need be bored with any great accuracy. The top of the cylinder may be opened or closed, it matters not which, but somewhere above the level to which the piston ascends there must be an orifice for discharging the water.

The action of the common atmospheric pump is so simple, and is so well known to every school boy, that it will be unnecessary here to dwell upon it. The cylinder is made of various materials, as wood, iron, or copper, and frequently the lower part below the fixed valve is a mere iron pipe furnished with a strainer at its lower extremity. The fixed valve in this kind of pump must be placed at such a level that the depth from it to the surface of the water in the well must never exceed the height of a column of water which will balance the atmospheric pressure or weight of the atmosphere. This weight is measured in the barometer by a column of mercury, which varies in different parts of the world, and at different altitudes, from 28 to 31 inches. Thus, an atmospheric pump at the level of the sea may have its fixed valve several feet higher than a similar pump working on the top of a high mountain. The height at which the mercury stands in a barometer at any given place affords, in fact, a tolerably practical measure of the height to which water will rise in a vacuum when pressed by the external atmosphere. Thus, in theory, where the mercury stands in the tube of a barometer at a height of 30 inches, the sucker or fixed valve of an atmospheric pump may be placed 30 feet above the surface of water in a well. In practice, however, owing to imperfection of materials, fluctuations of level in the water, and other causes, this difference of level is too great, and should not really exceed 25 feet. In shallow wells, therefore, which are not more than about 27 feet in depth, the part of the cylinder or pump above the fixed valve need never exceed the length of the slope or space through which the piston works. In deep wells the ascending part of the cylinder above the body of the pump in which the piston works may be, theoretically, of any height. There are difficulties, however, connected with the valves in the movable piston which render it inconvenient to have the lift in this kind of pump much more than 100 feet. Whatever may be the height of the column of water above the movable piston, it is evident that the absolute weight of this whole column has to be lifted at each stroke of the piston, and for this reason atmospheric pumps, which are worked by hand, have scarcely any of the pump above the piston, as otherwise the weight of water to be lifted at each stroke would be too great for the power to be applied. This practically limits the height to which water can be raised from wells by common atmospheric pumps worked by hand to about 25 feet.

In deep wells, however, when pumps are worked by horse or steam power this objection does not apply, and if the power be sufficient to raise at each stroke the whole column of water above the piston, the length of the cylinder above this piston is only limited by the practical considerations before alluded to in connection with the valves. It should be observed that the common atmospheric pump is seldom or never used in waterworks for the purpose of raising water.

ON CALCULATING THE POWER OF PUMPING ENGINES.

The work performed by steam engines is commonly expressed in what is termed "horse power," that is, an engine is said to be equal to the work performed by a certain number of horses. The standard which has been fixed on to represent the work of one horse is equal to 33,000 pounds raised through a space of one foot high in a minute. This is equivalent to saying that a horse walking at his most effective speed of $2\frac{1}{2}$ miles an hour, or 220 feet per minute, and attached to a weight of 150 pounds freely suspended over a pulley, will raise this weight at the same rate of 220 feet per minute. Using, then, this standard for computing the work of engines—a standard which has been agreed to by the mechanicians of all countries—we obtain a very ready method of determining the horse power required to raise any given quantity of water to any required height. The data required for this purpose

surface outside of the pipe and the water surface inside of the pipe are at the same level; hence the vertical pressures per square inch are equal at the submerged end of the pipe, outside and inside. As air is forced into the lower end of the water pipe, it forms alternate layers with the water, so that the pressure per square inch of the column thus made up of air and water, as it rises inside of the water pipe, is less than the pressure of water per square inch outside of the pipe.

Owing to this difference of pressure, the water flows continually from the outside to within the water pipe by gravity force, and its ascent through the pipe is free from shock, jar or noise of any kind.

These air sections or strata of compressed air form watertight bodies, which, in their ascent in the act of pumping, permit no "slipping" or back flow of water. As each air stratum progresses upward to the spout, it expands on its way in proportion as the overlying weight of water is diminished by its discharge, so that the air section, which may have been say 50 pounds per square inch at first, will be only 1.74 pounds when it underlies a water layer of four feet in length at the spout, until finally this air section, when it lifts up and throws out this four feet of water, is of the same tension as the normal atmosphere; thus proving that the whole of its energy was used in

are the quantity to be raised in any given unit of time, and the height to which it is to be raised. The quantity is simply to be reduced to the weight in pounds raised per minute; this weight is to be multiplied by the height in feet, and the product divided by 33,000, in order to find the horse power required to perform the work in question.

A gallon of distilled water, at a temperature of 60° Fahrenheit, weighs exactly 10 lb. avoirdupois, so that by adding a cipher to any quantity expressed in gallons, we obtain its weight in pounds. Suppose now, it be required to find the horse power capable of raising 350 gallons of water per minute to a height of 170 feet. Here we have $350 \times 10 = 3,500$ lb. to be lifted per minute, and $3,500 \times 170 = 595,000$ lb. lifted one foot high per minute, and $\frac{595,000}{33,000} = 18$ horse power.

When the quantity is expressed in gallons to be raised to a given height in 24 hours, it is necessary to divide this quantity by 1,440, in order to bring it into the quantity per minute, and as $33,000 \times 1,440 = 47,520,000$, if we divide the gallons per day of 24 hours by one-tenth of this, or 4,752,000, we obtain the horse power required to lift it.

The history of the steam pumping engine commences with the atmospheric engine, which is known as the Newcomen type. This is single-acting, the steam raising the piston, and the atmosphere forcing it down where a vacuum is formed by condensing the steam below the piston. This was improved by Watt, who substituted for it, first, his single-acting engine without a crank, and afterward his double-acting engine; but its greatest development has occurred during the present century.

The oldest water works in the United States are supposed to be those at Bethlehem, Pa., which were built in 1754 by Hans Christopher Christiansen, a millwright, a native of Denmark, and being of historic interest, I will enter into the description of it somewhat in detail.

The water was taken from a spring issuing from magnesian limestone, near the banks of the Menogassi Creek, as it was then called. The water was conducted 350 feet through an underground conduit into a cistern, whence it was pumped by a lignum vitae pump of 5 inches bore, through bored hemlock logs to a height of 70 feet, into a wooden tank in the village square. Trouble was experienced from the bursting of the pipes, and one and one-quarter inch pipes of sheet lead soldered along the edges and buried in a cement of pitch and brick dust and laid in a gutter were tried, without much success.

In 1762 Christiansen, aided by John Arbo and Marshall, constructed larger works. An eighteen foot undershot wheel drove three single-acting force pumps of iron of 4 inches bore and 18 inches stroke. The force main was of gum wood, and the distributing pipes of pitch pine. The latter had to be renewed in 1769. In 1786 lead pipes were substituted for the gum wood force main and for most of the distributing pipes.

The last pitch pine pipes were abandoned in 1791. The reservoir was a wooden tower in the "little square." This was removed in 1803, and a stone tower built on Market Street about 15 feet high, in which was a tank at an elevation of one hundred and twelve feet above the spring.

In 1832 a reservoir was constructed on higher ground, and the water tower abandoned. Also the triple pumps were replaced by one double-acting pump.

In 1868 steam power was used for pumping. In 1874 the wooden conduit from the spring to the pump house was replaced by an 18 inch iron pipe.

Until the year 1800, there were in the United States, including Bethlehem, only eight water works, as follows, in the order of the year of their construction: Providence, R. I., 1772; Salem, Mass., 1796; Geneva, N. Y., and Portsmouth, N. H., 1797; Worcester, Mass., 1798; Morristown, N. J., and Peabody, Mass., 1799.

From 1800 to 1810 there were eleven water works built; from 1810 to 1820, seven; from 1820 to 1830, thirteen; from 1830 to 1840, eighteen; from 1840 to 1850, twenty-five; from 1850 to 1860, fifty-six; from 1860 to 1870, one hundred and three; from 1870 to 1880, three hundred and eighty-one; from 1880 to January 1, at the beginning of 1894, there were over 2,100 water works in the United States, and over 120 in Canada. The proportion of water works in which water is pumped by steam is rapidly increasing, and the subject of pumping engines to do this work is becoming more important every day, but the conditions under which they operate are so varied that it is impossible to go into details in this letter, and I shall, therefore, treat the subject in a general way.

The first requirement of a pumping engine is that it must be able to pump water under the peculiar conditions which it has to work, and to do this continually, successfully, and economically. Its ability to operate day after day, year after year, under the varied requirements of the service, with the least possible expense of repairs and delays, is the most essential fact to be taken into consideration, but, at the same time, it must be capable of easy management, and take care of itself to a great extent after being properly adjusted and started at its work.

The second requirement is economy of steam. Economic use of steam is, of course, important and desirable, but it must not be accomplished at too great expense of repairs and the necessity of continual attention and adjustment on the part of the attendant. The cost of a pumping engine is another important consideration, and is the "stumbling block" of water works companies and committees generally, when a few thousand dollars more of first cost has many times outweighed the above-mentioned qualities, and it has been demonstrated to their sorrow and cost that to own some pumping engines is sufficient to bring great loss and almost ruin, even if the engine had been taken as a gift, on account of the bills for repairs which are contracted, that things may be kept moving.

Pumping engines may be divided into two general classes—crank and fly wheel or rotation, direct-acting or non-rotation, and are made of almost endless variety as to details, the particulars of which I do not care to enter into in this letter. Just where to draw the line that a crank and fly wheel engine should be used and not a direct-acting engine, appears to be debatable ground, and where engineers, like doctors, disagree. It therefore behooves me to handle this part of my

letter with great care, and endeavor not to tread on the toes of any pumping engine manufacturer.

The history of the pumping engine construction commences in this country, as in England, with the Cornish engine. This engine gave fine results in the department which it originated—mine pumping. The engine was inordinately large for the work, and made only a casual stroke now and then, as demanded by the flow of water into the mine, the water being delivered at the surface with no force main, and there being no demand for uniform flow.

A glance at the conditions under which it works will explain the otherwise unaccountable fact that a pumping engine without a rival in one place has a failing reputation in another. Its honors were never qualified until it was transplanted from the home of its usefulness to do duty in a service where water was to be discharged through a long main to a great height above the pump, and under the requisition of continuous and uniform delivery. This was the very requirement which, from its nature, the Cornish engine was unfitted to meet. The Cornish engine is in its nature precarious, requiring constant watchfulness on the part of the engineer, and cannot safely be trusted for a minute without this care and supervision. This uncertainty of its action, great first cost, and expensive repairs, has finally led to its abandonment for water works. The crank and fly wheel engine was the first and most obvious alternative. While emulating the economy of the Cornish engine, it was positive in its motion and safer in its character. In the crank and fly wheel engine, steam is cut off at a certain fraction of the stroke, while the remainder is finished by expansion, aided by the momentum of the

well as inexpensive repairs, and small expense of replacing any important part—makes them in a majority of cases the most economical to use.

In conclusion, I trust that I have brought out a few points which may be of interest to your readers on the subject of pumps and pumping machinery. I find in conversation with numbers I come in contact with that pumps and pumping machinery are very poorly understood, even among some of our best mechanics. But they will find, as I do, there is always something to learn, and one man does not know everything about pumps and pumping machinery.

NEW CORLISS ENGINES FOR THE LEICESTER CORPORATION ELECTRICITY WORKS.

New compound Corliss engines have been put in, constructed by Hick, Hargreaves & Company, Bolton, which are described as follows in the Engineer, London, with the accompanying illustrations.

The several engines are of the horizontal compound condensing type. They are fitted with Corliss valve gear, and each has its own condenser and air and circulating pump. The larger engines have cylinders 16 in. and 30 in. by 36 in. stroke, and run at 96 revolutions per minute, while the smaller engine has cylinders 11 in. and 20 in. by 24 in. stroke, and runs at 118 revolutions per minute.

Valve Gear.—The valve gear of all the cylinders, except the low pressure cylinder of the small engine, is of the Corliss type, of a design recently patented by the makers to meet the special conditions of electric

FIG. 1.—IMPROVED CORLISS VALVE GEAR.

fly wheel, thus producing great economy in the use of steam at the expense of intricate machinery. These engines operate either vertically or horizontally. They require expensive and massive foundations to absorb the shocks and jars incident to their working, this being especially true of vertical engines, the momentum of the fly wheel in its revolutions increasing to a large extent the accidents that would otherwise be trifling.

The use of duplex direct-acting steam pumping engines in water works dates from about 1854, and it was brought in direct competition with the Cornish, and crank and fly wheel engines. The duplex engine is horizontal in action and usually allows the steam to follow the piston throughout its stroke, thus preserving great simplicity and compactness in working parts.

The foundations required are much lighter and less expensive than that for a crank or fly wheel engine.

The duplex engine is essentially two direct-acting pumps placed side by side, their valve motions being so arranged that the motion of one pump acts to give steam to the other, after which it finishes its own stroke and waits for its valve to be acted upon before it can renew its motion. This pause allows all the water valves to seat quietly, and removes everything like harshness of motion, keeping up a uniform delivery, without pulsation or noise. The smoothness of motion and simplicity in steam valve mechanism reduces the liability of accident to a minimum. While it is not claimed that the compounding condensing duplex engine is capable of developing the highest duty, their yearly records are excellent, ranging from 50,000,000 to 65,000,000 duty, and trials have been reported as high as 120,000,000.

It is claimed for these engines that their moderate first cost—engine proper, foundation and building, as

lighting, and known by them as their "high speed gear." Fig. 1 is from a photograph of the gear of one of the 30 in. low pressure cylinders, and Fig. 3 is a scale drawing of the gear of one of the 16 in. high pressure cylinders. The special features of the gear may, perhaps, be best indicated by a statement of the respects in which it differs from the Corliss gear usually used on mill engines. In almost every Corliss gear hitherto used, the trips have been released by the opening motion of the parts, which implies that the fullest opening of the steam port will only occur on the rare occasion when the engine is working with the longest possible admission, and, as there must be some margin, this is never reached in practice, the port is never fully opened, and at light loads may be a long way from being fully opened when the cut-off takes place. For the same reason, it has hitherto been found necessary to drive the steam and exhaust valves by separate eccentrics, as, if a single eccentric is used, and set to give a suitable motion to the exhaust valves, it is then so far in advance of the crank that the fullest opening of the steam port, and, therefore, the maximum range of the cut-off, occur too early in the stroke. In the gear now illustrated, the release of the trips is effected by a separate supplementary eccentric, which, under the control of the governor, effects the release at any point between zero and the natural closing of the valve. This allows both steam and exhaust valves to be worked by a single eccentric and wrist plate, and causes the steam port to be fully opened at a very early point in the stroke.

The next point is, that the less a Corliss valve is opened the greater is the power needed to close it, because equilibrium has not been so nearly established between the upper and under sides of the valve; but in the ordinary Corliss gear the spring is compressed proportionately with the amount of opening, so that