pump must be placed at such a level that the depth from it to the service 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 2½ 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 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 lbs. 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 $350 \times 10 = 3{,}500$ lbs. to be lifted per minute, and $3{,}500 \times 170 = 595{,}000$ lbs. lifted one foot high per minute, and $\frac{595000}{33000} = 18$ 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 afterwards his double acting engine, but its greatest development has occurred during the present century.

The oldest waterworks 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 vitæ 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 an Marshall, constructed larger works. An eighteen feet 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.