PNEUMATIC PUMPING AS APPLIED TO MUNICIPAL PLANTS

By John Oliphant

TERMINOLOGY

To arrive at a thorough understanding of this subject and to facilitate the exchange of ideas, it is necessary to standardize the general terms used and determine what is meant by "percentage of submergence," "lift," etc. The following are the terms that have been generally accepted:

1. Static head. This is the normal water level when not pumping, measured from the surface on top of well casing.

2. Drop. Difference between the static head and the water level when pumping.

3. Pumping head. Level of water when pumping as compared to ground surface or top of well casing. Static head plus drop equals pumping head.

4. Elevation. Point above the ground surface or top of well casing to which water is raised.

5. Lift. Distance water is elevated from level when pumping to point of discharge. Static head plus drop equals lift when discharging at surface.

Elevation plus static head plus drop equals lift when discharging above the surface.

6. Submergence. Distance below the pumping head at which the air picks up the water.

7. 100 per cent. The vertical distance the air travels with the water from the point introduced to the point of discharge. Lift plus submergence equals 100 per cent.

8. Starting submergence. Distance below the static head at which the air picks up the water and includes drop plus submergence.

Bearing the above in mind and that 1 pound per square inch balances $\frac{2}{3}$ of a vertical foot of water and conversely 1 vertical foot of water exerts a pressure per square inch of 0.434 pound, it is easy to determine the starting pressure and operating pressure, remembering, however, that the operating pressure consists of the water pressure above the submerged end of the air pipe plus the friction in the same.

SHUT-IN PRESSURE

By the following simple method, the pumping head may be determined while the air lift is in operation.

The *operating pressure* is made up, as before stated, of two factors: (1) The weight of the water standing over the jet when pumping. (2) The friction in the line conveying the air to the jet.

By eliminating the friction, we will have the weight of water above the jet, in other words.

PUMPING SUBMERGENCE

By placing a gauge in the air line between the well and a stopcock and quickly closing the latter, the gauge will register in pounds the water standing above the jet. This converted into feet will give the submergence. The depth of the jet being known, the water level when pumping can be determined. Care should be taken, however, that the gauge is correct and the reading should be taken as soon as the valve is closed, otherwise the inrush of water into the well may cause a rise in pressure, or a leak in the air line may cause a drop.

BACK BLOWING

This is a simple but efficient method of cleaning a well and increasing its flow and may be applied to sand, gravel or rock wells.

By closing the discharge of a well, the air pressure will force the water ahead of it back through the strainer and float the finer sand; then by opening the discharge after a short interval, the flow of the water to the surface will be resumed and the floating sand carried with it before it has time to settle. By repeating this operation, a large part of the finer material outside of and adjacent to a strainer may be drawn into the well and discharged at the surface and the coarser material collected around the outside of the screen will facilitate the inflow of water. This surging back and forth of the water and sand through the strainer will clean out the openings and dislodge accumulated sand that is found to clog up strainers where the water has flown for a long time in one direction.

In rock wells, the action of the drilling bit tends to force the cuttings back into the rock crevices, which the ordinary inflow lacks force to dislodge, but which the violent surge of back blowing will accomplish.

The alternate plugs of air and water are common to all forms of air lifts where care has not been exercised in properly mixing the air and water and properly proportioning the discharge piping.

TYPES OF AIR LIFT

There are three principal systems of air lift that are commonly used.

1. The Pohle system. This consists of an air pipe carried down outside of the eduction or discharge pipe into which it is either tapped through a street elbow at a short distance from the bottom, or turned up into the bottom.

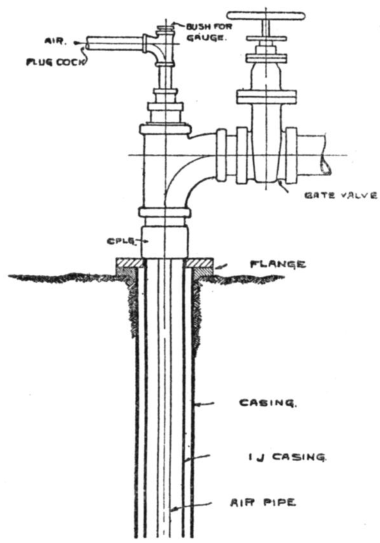
2. The central system. In which the air is carried down in a pipe suspended inside of the discharge, the water traveling up around the air pipe.

3. The reservoir system. This consists of an eduction pipe suspended in a casing allowing the air to pass down between the two and mix with the water at the bottom of the discharge pipe.

In all of these systems, the principle is much the same. The pressure is built up in the air passage to a point sufficient to overcome the head due to submergence and a large bubble of air passes into the discharge, forcing the water ahead of it and holding back that behind it. This flow of air from the air passage temporarily reduces the pressure so that the water held back overcomes the air pressure and rushes up, preventing the inrush of air until it builds up, breaks through and forms another bubble. This combat of air and water becomes rhythmic in its action and forms a succession of bubbles and water plugs in the discharge.

Theoretically, the expansion properties of the air as it travels towards the surface should form a perfect expansion pump, but, unfortunately, there are other natural laws that take effect and prevent this.

1. There is so little difference between the water and air pressure that the former flows into the latter at a low velocity and the bubble must travel some distance towards the surface before it expands sufficiently to fill the pipe and form the air plug, thus sacrificing a part of the submergence.



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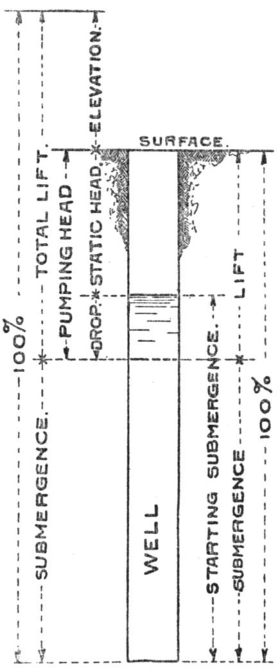

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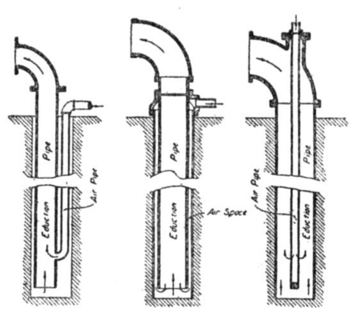

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FIG. 1. AIR LIFT TERMS
FIG. 2. ARRANGEMENT OF PIPING A WELL FOR BACK-BLOWING
FIG. 3. SKETCHES ILLUSTRATING FORMS OF "STRAIGHT AIR" LIFT

2. As the bubble of air travels towards the surface and the pressure above it decreases, it must expand, and as it is confined by the walls of the pipe, can only do this in a vertical direction, resulting in an increased velocity of flow and a greater displacement in the discharge pipe.

3. Owing to well known laws, the flow at the point of contact between a gas or liquid and the walls of passage is retarded, and, water being heavier than air, this effect upon the former is more pronounced until the water next to the walls of the pipe is pulled back around the bubble of air. The latter becomes elongated and at times slips through, joining the preceding bubble, this slippage representing a loss of efficiency and is manifested by the variation in the plugging discharge of this kind of lifts.

4. Air, like any confined gas, is always seeking a chance to escape, and any inequalities in the flow passage or abrupt changes of direction offer the opportunity it is seeking and a still further slippage results.

To counteract these defects, an air lift should be designed along the following lines:

1. A perfect mixture of the air and water into an emulsion at the point at which the air enters the water, so that the lifting effect of each minute bubble should commence at once and continue to the point of discharge.

2. An absolutely smooth passage for the air and water.

3. A properly expanded discharge pipe to take care of the air expansion as far as possible and prevent excessive friction.

4. The proper proportioning of the air and water pipes for the work to be done.

THE BOOSTER SYSTEM

The booster is a separating head or tank placed upon the top of the well to force the water to an elevation or through horizontal lines and utilize the same air that has lifted the water to the surface. The principle involved is as follows: The velocity of the air and water is always greater as it nears the point of discharge. This is demonstrated by the force of the discharge into the atmosphere. By discharging into a closed tank, the kinetic energy or sudden stopping of the column of water and air traveling under a high velocity recompresses the air and a certain amount of the power expended is returned. Compressed air under ordinary air lift conditions is wasteful if used to force water horizontally, as the air being lighter than water goes to the top of the pipe and fails to bring the water with it. In the booster arrangement, the air does not follow the water but converts its volume into pressure before being allowed to escape, thus forcing a solid stream of water through the horizontal and vertical lines. It will readily be seen, therefore, that the discharge from any number of boosters may be connected into a common delivery pipe.

Another refinement of this system is to return the air from the booster to the inlet of the compressor.

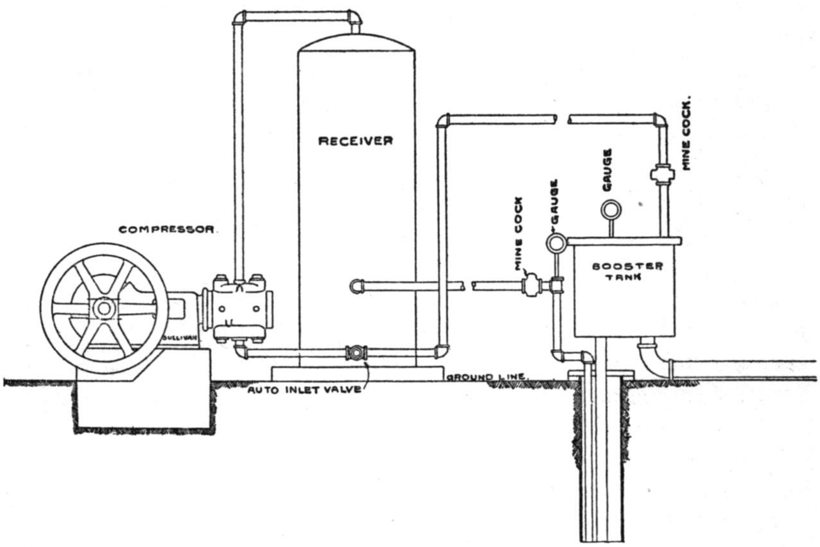

FIG. 4. LAYOUT FOR "BOOSTER" SYSTEM OF AIR LIFT BELTED AIR COMPRESSOR, AIR RECEIVER BOOSTER AND PIPING ARRANGEMENT TO WELL AND DISCHARGE

Utilizing the colder air: as every 5° the temperature of the air delivered to the compressor is reduced, a volumetric gain of 1 per cent is secured and a slight pressure; also reduces clearance losses in the air cylinder.

The following are some of the advantages of the air lift as compared to other methods of pumping from deep wells:

1. *Quantity.* It is an accepted fact that more water can be secured from a well by means of the air lift than by any other method, providing the conditions are proper for its use, on account of there

being no valves or obstructions in the discharge pipe, and a high velocity can be maintained.

2. Quality. While shallow wells may become polluted by surface contamination, properly constructed deep wells of municipal supply are found free from disease germs, as the casing driven down through hard pan above gravel formation or into rock shuts off surface contamination.

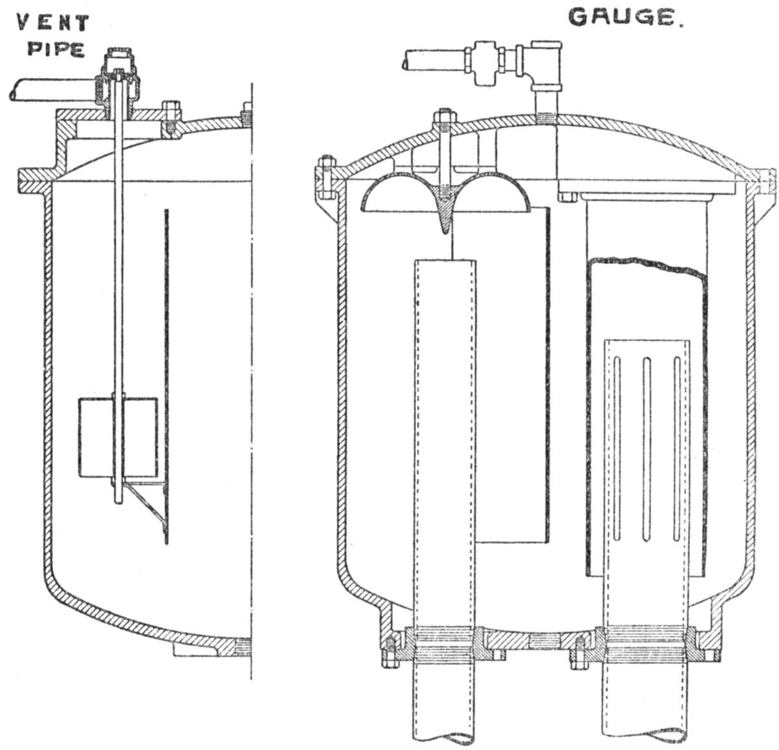

Fig. 5. Sectional View of an Air Lift Booster, to Show Principle of Operation

Gravel beds in or near a river can be made the source of a pure water supply by the drilling of wells and casing them low enough so that the water will be pulled down through the sand and gravel; the erosion of the river keeping the top of the infiltration bed clean.

Aeration is acknowledged to be one of the principal methods for purifying water.

Free sulphur gas is encountered in a large amount of underground waters. Ninety per cent of this gas is removed by the aeration of the air lift system, and the water from many sources of supply that is unfit for domestic use on account of this gas, when pumped by the direct acting pump is rendered entirely free from its odor and staining effects by the use of the air lift.

Most of the other solids contained in underground waters, while not thrown off, are rendered easier of treatment through aeration.

3. Temperature. As heat is driven from air by compression, through expansion it must reabsorb heat from whatever it comes in contact with. The expansion of the air in the eduction pipe will absorb heat from the water and lower its temperature.

4. Durability. The air lift installation is the most durable and requires less attention and repairs than any other pumping system. When once the well or wells are properly adjusted, the installation requires no further attention.

The water never comes in contact with any moving parts and the operating machinery is in the power house directly under the eye of the engineer, avoiding all pulling of sucker rods, making barrels, etc.

ENGINEERING

Although the question of pumping water from deep wells with compressed air seems to be a very simple one, and as a matter of fact, certain results are obtainable from a haphazard method of installation, yet a careful study of the conditions under which the wells are to be operated and the piping installed, as well as the compressor for the work, will repay very largely in the securing of more water at a less cost.

The question of well piping should receive careful consideration and the discharge pipe properly proportioned to the amount of water and air to be handled. For example: while one size discharge pipe may be of the proper size for lifting 100 gallons per minute at a lift of 50 feet and with 60 per cent submergence, yet to lift 100 gallons per minute with a lift of 100 feet and 50 per cent submergence, it will require more than double the amount of air than in the first instance and a larger discharge pipe should be used even for the same amount of water, to prevent high velocities and excessive friction. Then the lifting of a small amount of water through a large discharge pipe is wasteful. The pipe must be filled with water or air so that a small amount of the former requires a large amount of the latter, or it will bubble through and not bring the water with it; and to supply enough air to blow the water up is a wasteful operation.

The conditions often change in wells that have been in operation for a long time. The general dropping of the water plane will change the proportion of lift and submergence. Tests should be run and a readjusting of the piping made.

Very often screens and gravel strata may be clogged up, and back blowing as heretofore described will often bring the wells back to their original capacity.

The whole question of the well installation should receive just as careful engineering attention as the pumps, boilers, or any other parts of the plant, and this attention will be productive of a greater increase in efficiency, because it is more often overlooked or neglected; the general idea being that the air lift is bound to be inefficient and let it go at that, whereas, with slight expense, a large saving in operation can in the majority of cases be obtained.