the work under moderate heads, up to 100 ft., is done in a satisfactory and efficient way.

The pump consists of one or two cylinders with inlet and discharge valves for water, and a valve mechanism controlled by floats or other means for admitting compressed air directly to the surface of the water within the tanks, and for exhausting the air after the water has been expelled. The tanks must be submerged in a suitable sump or cistern properly protected, of sufficient depth to insure that the pump tanks will fill properly by gravity. It will be seen that the pump is really a simple apparatus. Water enters through the large inlet valves at the bottom. Air pressure entering at the top is alternately delivered to the chambers, expelling the water in them through the discharge valves and pipe. When a tank is nearly empty the contained air is exhausted through a port in the valve mechanism, while water replaces it through the foot valve as soon as the air pressure is relieved, the alternate discharge being entirely automatic.

The proper field of this device is that calling for the pumping of water at some distance from the source of power, where there is an unobstructed supply and a limited lift. Valves in the power house on the air line to the pump, or to as many of them as may be needed to pump from a number of sources, control the operation, and pumping must continue as long as air is supplied.

The advantages are that these pumps can be easily installed, and where an existing supply of compressed air is available the cost of equipment is low. There is no pump house to build and maintain at the water supply; the operation is controlled in the engine room; there are no piston or plungers to repair and renew, and the wear on valves is less than in any ordinary direct-acting mechanical pump. Neither lubrication nor packing is required and the attention charges are reduced to a minimum. Its working is not affected by muddy or gritty water.

These facts adapt the pump for dye works, bleacheries, pulp mills, and for handling solutions. It may be used to take water from a cistern or reservoir filled by the air-lift from wells, or placed in a remote sump in a mine or quarry, it can be employed to deliver water to the main pumps.

Since the pump operates by the direct displacement of a volume of liquid by a volume of air under suitable pressure, it follows that simple rules can be given for arriving at the volume of air and pressure needed to do the work.

Reduce the quantity of water in gallons per minute to cubic feet. Multiply the total head (static head plus water-pipe friction) by 0.434; this gives the working air pressure at the pump. Next find the ratio of air pressure to atmosphere, which multiplied by the cubic feet of water per minute gives the cubic feet of free air per minute needed at the pump to displace this volume of water.

Knowing the volume of free air required, 5 to 10 per cent. should be added for leakage and clearance according to the special conditions.

This is net, actual free air and not piston displacement of compressor; therefore, in figuring on a compressor to do the work, volumetric efficiency must be taken into consideration, following the general practice in such cases, according to the pressure, size and type.

Problem.—Source of supply, a river; distance from power house, 1,000 ft.; lift, 60 ft.; diameter discharge main, 4 in.; quantity of water required per minute, 150 gal.

$$150 \text{ gal.} = 150 \div 7.5 = 20 \text{ cu. ft.}$$

Static head ....60 ft.
Friction head 150 gal. per minute in 4-in. pipe 1,000 ft. long ....16 ft.

Total head ....76 ft.

$$76 \times 0.434 = 33 \text{ lb.}$$

$$\text{Ratio } r = \frac{33 + 15}{15} = 3.2$$

Free air $= 20 \times 3.2 = 64$ cu. ft. per minute.

Allow 10 per cent. for leakage and clearance = 70 cu. ft. net.

If the compressor selected will show a volumetric efficiency of 80 per cent., the piston displacement required will be $70 \div .080 = 88$ cu. ft. per minute.

$$\text{Theoretical horsepower} = \frac{150 \times 8.33 \times 76}{33,000} = 2.88.$$

I.H.P. in steam cylinder of compressor = 8.5.

Total efficiency $= 2.88 \div 8.5 = 33$ per cent.

Return Air System.—The elevation or transfer of water and other fluids or semi-fluids by direct displacement with compressed air is so natural and self-evident a proposition as to need almost no suggesting. It appeals at once merely on the ground of convenience and simplicity. But the principle as ordinarily applied has been open to the objection that it was not economical.

One characteristic of the ordinary, plain, displacement pump is waste of power entailed by direct release of the displacing air after the fluid is ejected from the pump tank. This air, after doing its work, is still at practically full pressure, therefore having all its potential energy of expansion. Its direct exhaust into atmosphere after displacement is the throwing away of this expansive power without any useful effect.

If air pipes are carried back from the pump to the compressor so as to add the residual pressure after displacement to the reverse side of the compressor piston, where it will help in compressing air into the pump tank, we have a return-air, expansive displacement pump, operating at good economy.

Mr. Abrams emphasizes, at this point, the fact that both the plain displacement pump and the "return air" system have the following advantages which are unique in that, while other pumping systems have some of them, no other systems combine them all to such remarkable degree:

1. Simple in construction, installation and management.
2. Wholly automatic in operation.
3. Under instant and complete control from the compressor room, however distant.
4. No delicate mechanism exposed to corrosive or abrasive action.
5. No oil or other lubricant required by the pump.
6. Not affected by any excess submergence except that operation is improved under a hydraulic head.
7. Applicable to the pumping of all fluids or semi-fluids, as well as mud, sand, or any debris which will pass the valves.

Where water is to be pumped, the field of the pneumatic displacement pump and the return-air system is that in which large volumes are to be handled from a generous source of supply, where complete submergence can be secured, such as in a river, lake, mine or quarry sump, large spring or an excavated well. This, at once, opens to them the supplying of water for small municipalities, shops, mills, factories, etc.

The fact that these systems will handle anything sufficiently fluid to pass their valves adapts them also to the handling of solutions in salt works and bleacheries; the moving of semi-fluids, as in pulp mills; the handling of cement, slurry and marl; the pumping of glass sand for glass factories; elevating salt solutions in salt works, and the pumping of sewage.