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“On the Raising of Water by Compressed Air,
at Preesall, Lancashire.”

By JAMES KELLY, Assoc. M. Inst. C.E.

THE experiments described in the following Paper were carried out at the works of the United Alkali Company, Limited, at Preesall, where large quantities of water for steam-raising and other purposes, in connection with the manufacture of heavy chemicals, are raised from wells by means of compressed air. The present requirements amount to 800,000 gallons per 24 hours.

Description of the Installation at Preesall.—The water-bearing strata are the New Red Sandstone beds, which in this district are found at a depth of 80 feet to 100 feet from the surface, the overlying strata being red marl, sand and gravel, clay, and loamy soil, in ascending order. In the early days of the Company's operations in this district, sufficient water to meet their requirements was obtained by sinking wells into the gravel, but as the business developed and more water was required, two wells were sunk into the red sandstone, and were fitted with lifting-buckets and the necessary engines, etc. The cost of maintenance of this plant was very high, due, doubtless, to some extent, to the pumps being forced in order to cope with the increasing demand for water, but chiefly to sand in the water cutting up the buckets, valves and working-barrels. Having regard to this, and other peculiar circumstances of the case, namely, the necessity of raising water over a considerable area, owing to the low yield from any one well, and the desirability of having some system free from any great liability to stoppage or breakdown, it was decided to adopt the compressed-air method for the next well sunk. This well is marked No. 17 on the sketch-plan, *Fig. 1*. It is 450 feet in depth and 12 inches in diameter at the bottom, and is fitted, as shown in *Fig. 2*, with a lining-tube going down to the rock-head, and an air-tube 6 inches in diameter, with a delivery-tube 4 inches in diameter inside it, the effective cross-sectional area of the air-tube being thus the area of the annulus formed between it and the

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delivery-tube. For working this well a small Ingersoll-Sergeant air-compressor, brought from one of the company's other works, was modified to suit the conditions of work at Preesall. The machine is compounded for air, but not for steam; the air-cylinders are water-jacketed, but there is no inter-cooling, and the volumetric efficiency is consequently not very high.

The results of some preliminary working of the system were considered so promising that the installation of a larger plant capable of fulfilling all the requirements of the works was decided upon. There are now four wells equipped for raising water by compressed air; these are numbered 17, 38, 39 and 40 on the plan, *Fig. 1*. This plan is intended to show the relative positions of the wells, reservoirs, pumps and compressors. Particulars of the

dimensions of the wells, and their distances from the compressor, are given in the Appendix, Table I. The air-pipes have been designed to reduce loss by leakage or friction as much as possible, and the water flowing from the wells descends by gravity to a small brick reservoir, the position of which is indicated in *Fig. 1*. The arrangement of the pipes in wells Nos. 38 and 39 is similar to that in No. 17 (*Fig. 2*), but in well No. 40 the delivery- and air-pipes are arranged on a different plan. In this case the air-pipe passes down the well outside the delivery-pipe and is connected to it at the bottom, as shown in *Fig. 3*. A new air-compressing plant was installed, consisting of an Ingersoll-Sergeant cross-compound air-compressor, having both the air- and the steam-cylinders compounded. The speed is regulated by a governor in the usual manner, and also by the pressure of the air as it leaves the high-pressure air-cylinder. The air-cylinders

are water-jacketed, and the air from the low-pressure air-cylinder is delivered to an inter-cooler, from which it passes to the high-

pressure air-cylinder. The air suction-valves are carried on the piston, the air passing into the piston through a hollow tail-rod working through a stuffing-box and gland on the end of the

cylinder, and the delivery-valves are controlled by suitable spiral-springs. The steam-cylinders are 20 inches and 32 inches in diameter, and the air-cylinders 28.25 inches and 16.75 inches in diameter, the stroke being 24 inches. The percentage of clearance in the air-cylinders is very small. The air is compressed to 35 lbs. per square inch in the low-pressure cylinder and in the high-pressure cylinder to a pressure ranging between 80 lbs. and 120 lbs. per square inch, according to the depth of submersion of the delivery-pipes in the well or wells under operation. The machine

is rated very much higher than the present requirements, so that, should a greater quantity of water be required at some future time, more wells can be sunk and operated from the same station. The small compressor first installed is kept as a spare machine, and could be utilized in the event of the larger machine breaking down, but such a contingency has not occurred during 2½ years' working.

The small brickwork reservoir already referred to, in which the water raised from the wells is collected, is divided into two equal compartments by a wall which is lower in the middle than at the sides, *Figs. 4.*

The water flows into one compartment of the reservoir, where the sand in it is allowed to settle; it then flows over the weir formed in the centre of the mid-wall, into the other compartment, which contains the suction-pipes of the force-pumps employed for raising the water to the works-reservoir, more than a mile away, *Fig. 1.* From this reservoir the water is distributed to the different works at which it is required. A notable feature of the distribution is the carrying of the larger portion of the water across the estuary of the River Wyre, a total distance between the reservoir and the works of about 3 miles. At the point of crossing, the River Wyre is nearly

2 miles in width at high-water; at low-water the width is much less, and the difficulty of carrying the water-pipes across the estuary arises from the fact that a portion of the channel consists of shifting sand. The difficulty has been met by laying the water-pipes on both banks as far as the ground is firm, and securely fixing the ends to piles, these ends being then connected by means of a strong specially-constructed armoured hose. This arrangement has proved very successful, and the armoured hose has been found more satisfactory than flexible copper tubing, which was first tried.

Previous Experiments on Air-lifts.—The available literature on the subject of raising water by means of compressed air appears to be somewhat meagre. Professor Josse, of Charlottenburg, published a Paper on the subject in the "Zeitschrift des Vereins Deutscher Ingenieure" in 1898; a few Papers dealing with different phases of the subject have appeared in American journals; a Paper by Mr. W. H. Maxwell, Assoc. M. Inst. C.E., was read at the Annual Meeting of the British Association of Water-Works Engineers in 1903; and a Note¹ on the subject was read by Mr. P. Griffith, M. Inst. C.E., at the Engineering Conference in 1903.

In the Paper by Professor Josse, installations are described which have been put down in various places in Germany, and Tables are given showing the results of tests made under different conditions. The efficiencies obtained are very low, the highest recorded efficiency being 28 per cent.² An experimental plant, which was installed at the Technischen Hochschule, Berlin, for the purpose of determining the best conditions of working for raising water by compressed air, is also described. The well was 98·4 feet in depth and 6·14 inches in diameter, the normal level of the water being 13·1 feet below the surface. The first experiments on this plant were made in order to determine the relative merits of smooth and corrugated delivery-tubes, of various diameters, and working at varying rates, with different ratios of depth of submersion to height of delivery. Under similar conditions, the highest efficiency obtained with the smooth tube was 45 per cent., whereas the corrugated tube gave only 25·5 per cent. These experiments effectually disposed of claims advanced in favour of the corrugated delivery-tube. The results of the experiments with the smooth delivery-tube are given in the Appendix, Table II. In another series of experiments made on this plant, the height of

¹ "Raising Water by Compressed Air." Minutes of Proceedings Inst. C.E. Supplement to vol. cliv. p. 162.

² The efficiencies given in this Paper, except where otherwise stated, represent the ratio of the work done in raising water to the work indicated in the air-cylinders of the compressor.

delivery and depth of submersion were kept constant, whilst the volume of air delivered per minute varied. The results obtained are given in Table IIA. (Appendix). On examination of these results it will be observed that the quantity of water raised per minute rose to a maximum value and then began to fall, as the volume of air delivered per minute was increased. The efficiencies have not been given, but the results of experiment No. 25 are probably the best, experiment No. 24 having been carried out at too low a rate of working, the air having passed through the well, to a certain extent, without lifting the water high enough to overflow. Professor Josse noted results of this kind also in the working of compressed-air lifts at some factories where this method was in use, and he concludes that the highest efficiencies are to be attained at a moderately low rate of working, and that the efficiency diminishes as the quantity of water delivered, or the height of delivery, is increased.

Messrs. Brown and Betro, in a Paper read before the Technical Society of San Francisco, claim to have obtained an efficiency of 50 per cent. on an experimental air-lift plant; whilst the engineers of the Rotherham sewage-scheme have obtained an efficiency of 45 per cent. In both these cases the lift and the quantity of water raised were comparatively small, but the results, taken in conjunction with Professor Josse's experiments, appear to show that it is quite possible, with low lifts and low rates of working, to obtain an efficiency of nearly 50 per cent. Mr. E. A. Rix, in a Paper read before the same Society, states that the efficiency falls rapidly as the output is forced. A submersion of 50 feet and a height of delivery of 25 feet gave, at varying rates of working, 4 to 15 cubic feet of water raised by a volume of free air varying between 7.5 and 105 cubic feet, being at the rate of 1.8 to 7.0 cubic feet of air per cubic foot of water delivered. In another set of experiments which he carried out, with lifts ranging between 43 feet and 230 feet, and depths of submersion of 92 feet to 400 feet, the volume of free air required varied between 2.5 and 5 cubic feet per cubic foot of water raised. Mr. Rix concludes that with lifts not exceeding 20 feet, 1.5 cubic foot of air will be required for each cubic foot of water raised; for lifts of 20 feet to 50 feet, 2 to 3 cubic feet; and for lifts of 50 feet to 100 feet, 3 to 4 cubic feet will be required. He also, as does Professor Josse, limits the velocity of the water entering the pipes to 4 to 8 feet per second.

Mr. Maxwell, in his Paper, gives the results of many tests of the working of a plant for raising water by compressed air at the water-works of the Tunbridge Wells Corporation. The height of the lift is more than 100 feet in most of the tests described, and an efficiency of 46 per cent. was obtained in one case. The cost for fuel, at 25s.

per ton, was 0.95d. per 1,000 gallons raised 100 feet. A notable feature of this case was the larger quantity of water obtained by this method as compared with the quantity which would have been obtained by means of ordinary lifting-pumps from a well of the same size. In a trial run of $10\frac{1}{2}$ hours 31,402 gallons per hour were raised under a head of 133 feet, whereas an ordinary single-acting pump, such as could have been fitted in the well, would not have given more than 18,300 gallons per hour.

Mr. Griffith, in his Conference-Note, indicates the general principle to be followed in the installation and working of a plant of this kind, and the cases in which it can be most advantageously employed. He emphasizes the desirability of engineers in charge of works of this kind carrying out tests and publishing the results, in order that some standard may be arrived at in the design of such works.

The Papers published on this subject show a want of uniformity in the methods employed of tabulating the results of tests, and it would be a great advantage if some uniform method of stating such results were adopted, in order to facilitate comparison of one set with another. The results of the experiments at Preesall are tabulated in the same manner as some of those given by Professor Josse, certain columns having been added which appear to render the information more complete. These Tables, in the Author's opinion, contain all the information necessary for comparison of results from different wells.

Experiments at Preesall.—In making the experiments, the water raised was measured in the small brickwork reservoir, *Figs. 4*. The compartment containing the suction-pipes of the force-pumps having been pumped nearly empty, the force-pumps were stopped. The reservoir was then allowed to fill up to a given level with water from the air-lift, the time occupied in the operation being noted. Meanwhile the level of the water in the well had been determined, in order to ascertain the "lift," or height of delivery. In the engine-room, indicator-diagrams were taken from the steam- and air-cylinders, the speed of the compressor was registered by means of a stroke-counter, and the air-pressure was read off from the gauge. Thus all the data necessary for calculating the results were obtained. Each set of results tabulated is the mean of two, and in some cases three, sets of concordant observations.

The first series of experiments was made in January 1903, on the well marked No. 17 in *Fig. 1*. At that time the delivery-pipe of this well was carried 40 feet above the surface of the ground, the original intention having been to run the water by gravitation to the works-reservoir directly, instead of employing intermediate force-

pumps as at present. The total length of the delivery-pipe was 433 feet. The results obtained are given in the Appendix, Table III. The Table is self-explanatory, with perhaps the exception of the last two columns. These columns give the velocities of the air and water entering and leaving the delivery-pipe. The values are obtained by calculating the volume of the air used per minute, at the pressure at which it enters or leaves the delivery-pipe, adding this to the volume of water raised per minute and finding the velocity with which the mixture must pass through the pipe in order to deliver the combined volume in 1 minute, assuming this volume to remain constant during the operation. The Table shows that with the compressor working at speeds ranging between 17 revolutions per minute and 29.6 revolutions per minute, the number of gallons of water raised per minute was practically the same at all rates of working; that, as the rate of working was increased the volume of air used per cubic foot of water raised increased very rapidly, and the efficiency fell off at a proportionately rapid rate. This set of experiments indicated the futility of forcing the output of a well, and also that the series had been started at too high a rate of working, and that increased efficiency might be obtained at lower rates of working. In order to obtain, if possible, a higher efficiency, the 40-foot length of delivery-pipe projecting above the surface of the ground was removed and a 60-foot length was taken out of the well, reducing the length of the delivery-tube to 323.5 feet. This made the ratio of height of delivery to "dip" (i.e. depth of submersion) approximately equal to that recommended by Professor Josse, namely 1:1.5. Another series of experiments was then made, the small compressor being used for the first two sets of experiments in order to obtain a lower rate of working, and the large compressor for the remaining four sets. The results are given in Table IV. (Appendix). The highest efficiency obtained in this series of experiments was 24 per cent., which, although still low, was a decided improvement on the results obtained in the first series.

It will be observed, however, that the highest efficiency was obtained at the lowest rate of working, and that the volume of free air used per cubic foot of water raised was still very much higher than the volume (3 to 5 cubic feet) stated by Mr. Rix to be necessary for wells of this depth of submersion and lift.

The next series of experiments was made in April, 1903, on the well marked No. 38 in *Fig. 1*. This well is 350 feet in depth and of the same diameter as No. 17. It has, however, larger pipes fitted into it, the delivery-pipe being 5 inches and the air-pipe 7 inches in

diameter. The air-pipe has thus an effective area of 18.75 square inches. In the first four experiments, particulars of which are given in Table V. (Appendix), the delivery-pipe was 309.5 feet in length, and on working out the results it was found that the ratio of dip to height of delivery was approximately 1 : 1. This was altered by adding a 30-foot length to the delivery-pipe, after which two more experiments were made; these are numbered 5 and 6 in Table V. (Appendix).

If experiments Nos. 1 and 2 be compared with Nos. 5 and 6, it is at once apparent that the lengthening of the delivery-pipe has had a marked effect on the efficiency, the efficiency in experiment No. 1 being 29.3 per cent. and in experiment No. 5, 34.3 per cent., the same proportionate difference being observed between experiments Nos. 2 and 6, indicating the importance of the ratio of dip to height of delivery being kept nearly equal to 1.5 : 1. The best feature of this series of experiments was the increase in the efficiency to 34.3 per cent.

If the results obtained from wells Nos. 17 and 38, as given in Tables III., IV. and V. (Appendix), be compared, it is seen that the increase in the cross-sectional area of the pipes has had a greater effect than that observed by Professor Josse. He found on increasing the area of the delivery-pipe by 20 per cent. that the efficiency only increased by 1.3 per cent. The difference in area of the delivery-pipes in these two wells is about 33 per cent., and the efficiency has increased from 24.3 per cent. to 34.3 per cent.

The well marked No. 39 in *Fig. 1* was next put in operation. This well is fitted with the same size of pipes as No. 17. A series of experiments at comparative rates of working was carried out on wells Nos. 38 and 39. The experiments were made during the month of August, 1903. The results obtained from well No. 38 are given in Table VI. and those obtained from well No. 39 in Table VII. (Appendix). The rate of working well No. 38 varied between 14.3 and 32.4 revolutions of the compressor per minute, and the efficiency between 38.6 per cent. and 23.4 per cent., the free air used per cubic foot of water raised varying between 3.8 and 7.16 cubic feet. With well No. 39 the rate of working varied between 13.5 and 30.5 revolutions per minute, and the efficiency between 30.4 per cent. and 14.9 per cent., whilst the free air used varied between 5.77 and 11.83 cubic feet per cubic foot of water raised. There are two possible explanations of the difference in efficiency of these wells, namely: (1), the difference in cross-sectional area of the air- and delivery-pipes; and (2), the difference in length of the delivery-pipes. In order to ascertain whether the difference in length was the cause

of the low efficiency, a series of experiments was made on well No. 39, after reducing the length of the delivery-tube by 34 feet. The results are given in Table VIII. (Appendix). If these are compared with those in Table VII. it will be seen that shortening the delivery-pipe has had no beneficial effect on any of the factors governing the efficiency, and the conclusion seems justifiable that the larger area of the pipes in well No. 38 is the principal factor in determining its superiority over the others, and that for wells of this depth a pipe 5 inches in diameter is preferable to one of less diameter.

The diagrams in *Figs. 5* have been plotted from the data contained in Tables VI., VII., VIII., and XI. (Appendix), and show graphically the efficiency, the volume of free air used per cubic foot of water raised, and the number of gallons of water raised per minute, from each of the wells, at various rates of working. A comparison of the curves for the different wells shows the superiority of the results obtained from well No. 38.

The next series of experiments was made on wells Nos. 38 and 39 working together. These experiments were undertaken in order to determine the best conditions of working for raising volumes of water up to 40,000 gallons per hour. Some difficulty was experienced, at the beginning of the experiments, in regulating the supply of air to each well, so that they should yield a proportionate amount of water, in accordance with the results of the previous experiments. This could not be done accurately, as there was no means of measuring the flow from each well separately. The best that could be done was to approximate to the correct amounts by observing the flow from the pipes into the brickwork reservoir. The results of these experiments are given in Table IX. (Appendix). The rate of working varied between 23.7 revolutions and 39.8 revolutions of the compressor per minute. At the lower rate of working an efficiency of 36.8 per cent. was attained, the quantity of water raised being 34,200 gallons per hour; at the higher rate of working the efficiency had fallen to 26.7 per cent., the quantity of water raised being 40,300 gallons per hour; thus, by increasing the rate of working by 68 per cent., the quantity of water raised only increased by 12 per cent. Had this series of experiments been made for the purpose of finding the highest efficiency, without regard to the quantity of water raised, the rate of working should have been lower at the commencement, when doubtless the efficiency would have been higher. The results of this series of experiments are represented graphically in *Figs. 6*. An examination of the curves shows the same fall in efficiency, rise in volume of free air used, and slow rise of the quantity of water raised, with a tendency to decrease

after the rate of working reaches a certain point, as was observed in the case of the separate wells.

Figs. 5.

A series of experiments on working three wells together presented the same difficulty as was experienced when working two wells together, and to obtain a proportionate flow from each well the same

artifice had to be adopted. The object of the experiments was to find the efficiency when raising about 40,000 gallons of water per hour.

Figs. 6.

A speed of 20 to 22 revolutions per minute was found to yield this quantity of water, and two experiments were made at about this rate

of working. The results obtained are shown in Table X. (Appendix). The rates of working are so nearly equal that the average would perhaps give the truest values; but it is interesting to note in this case, as in the others, that the highest efficiency was attained at the lower rate of working.

During the month of May, 1904, the well marked No. 40 in *Fig. 1* having been started, a series of experiments was made with it for comparison with the others. As already mentioned, this well differs from the others in the arrangement of the pipes, and in its comparatively greater distance from the compressor (Appendix, Table I.). The arrangement of the delivery- and air-pipes in this well is illustrated in *Fig. 3*. The air-pipe is 2 inches in diameter and passes down the outside of the delivery-pipe. The lower part of the delivery-pipe is 4 inches in diameter, but the upper portion, for 100 feet from the surface, is 6 inches in diameter. This enlarged pipe was put in with the object of reducing the velocity of the air and water as they approached the surface, in the hope of increasing the efficiency of working. In transmitting the air to this well a fall of 3 lbs. per square inch in the pressure was observed, due to the greater distance from the compressor. The results obtained from these experiments are given in Table XI. (Appendix). If these are compared with the results from wells Nos. 38 and 39 it will be found that they are somewhat better than those from well No. 39, but very much worse than those from well No. 38. The results given in Table XI. (Appendix) are plotted alongside those for wells Nos. 38 and 39 in *Figs. 5*, which show at a glance the relative value of the results in each case. The effect of the alteration in the arrangement of the pipes in this well appears to be beneficial, and it seems probable that had a larger delivery-pipe been used, the results would have been at least as high as those obtained from well No. 38.

The next series of experiments was made in June 1904; wells Nos. 38, 39 and 40 were worked together, and the air-supply was regulated as before, so that each well gave a proportionate flow. The object of the experiments was to determine the efficiency of the system between a minimum and a maximum rate of working. The minimum rate at which the three wells could be kept running was found to be about 18 revolutions of the compressor per minute. The maximum rate at which it was considered safe to run the compressor was 50 revolutions per minute. The results of this series of experiments are given in Table XII. (Appendix). The highest efficiency, namely, 41.2 per cent., was again obtained at the lowest rate of working, the free air used being 3.01 cubic feet

per cubic foot of water raised, the water raised being 38,160 gallons per hour. At the highest rate of working the efficiency had fallen to 24.6 per cent., the volume of air used had risen to 5.22 cubic feet

Figs. 7.

per cubic foot of water raised, and the water delivered was 60,000 gallons per hour. The results are plotted in *Figs. 7*, the most noteworthy feature of which is the rapid rise of the curve for

the quantity of water, at the beginning of the series of experiments, and its very gradual rise towards the end of the series. Had it been found practicable to continue the experiments further, it appears probable that the curve would ultimately have shown a tendency to descend, as in the case of the single wells when the higher rates of working were attained.

In order to ascertain whether the action of the compressed air in an air-lift is similar to that of a piston in a cylinder, or whether the air forms an emulsion with the water, a series of observations and experiments were made on well No. 38, using the small compressor so that a very low rate of working could be attained. The results appeared to show that the air might act in either way, or by a combination of both, depending upon the rate of working. With a very low rate of working, air passed through the well without lifting the water high enough to overflow. As the rate of working was increased, water began to flow intermittently and in cycles. The water would begin to run slowly, the flow gradually increasing until the delivery-pipe was running full; then there would be a rush of air, causing the water to rise in the form of a dense spray, after which the flow would gradually diminish, and finally stop. If the rate of working was kept constant the flow continued in periodic cycles. The series of experiments was commenced at 82 revolutions of the compressor per minute, and the rate of working was increased by 20 revolutions per minute at a time, until a speed of 165 revolutions per minute was attained. The results of the experiments are given in Table XIII. (Appendix). In experiment No. 1 the cyclic period was 2 minutes 20 seconds, during $1\frac{1}{2}$ minute of which no water flowed from the well. During the remaining 50 seconds, the flow, commencing slowly, gradually increased until the rush of water and air already referred to took place, after which the flow gradually declined until it ceased altogether. In experiment No. 2 the cycle occupied 2 minutes, water flowing for $1\frac{1}{4}$ minute, and no flow taking place during the remaining $\frac{3}{4}$ minute. In experiment No. 3 the period was $1\frac{1}{4}$ minute, the stoppage in the flow lasting only $\frac{1}{4}$ minute. In experiment No. 4 the flow was continuous, but varied in volume from time to time. In these four experiments the action of the air appeared to be similar to that of a piston. In experiment No. 5 the flow of water and air was continuous, and resembled a dense spray, the air appearing to form an emulsion with the water. Table XIII. (Appendix) shows that the efficiency was lowest at the lower rates of working; that it reached a maximum in experiment No. 4; and that in experiment No. 5 it began to fall again.

The results of the foregoing experiments indicate that there is a certain rate of working wells by compressed air at which the maximum efficiency is obtained, and that the best efficiencies are obtained at comparatively low rates of working. Previous experimenters are agreed on the necessity of keeping the velocity of the water in the pipes low, and fix the limits of this velocity at 4 to 8 feet per second; but from the Author's experiments it would appear to be necessary to take into account, as has been done in the Tables given in the Appendix, the combined volume of both air and water in fixing a limit of velocity in the pipes. On inspection of the Tables it will be seen that where the highest results have been obtained the velocity of the air and water combined has been about 12 feet per second at the point of entering the delivery-pipe. As the air and water rise to the surface, the velocity continually increases, due to the increasing volume of the expanding air. Having regard to this circumstance, it has been suggested that the delivery-pipe should gradually increase in diameter from the bottom of the well to the surface. An approximation to this arrangement is that adopted in well No. 40, *Fig. 3*. A comparison of the velocity at the top of the delivery-pipe in this well with that in either of the wells Nos. 38 and 39 shows that the velocity at the top was much reduced by increasing the diameter of the delivery-pipe. What effect this had on the efficiency cannot be determined, owing to other disturbing factors. If this point could be investigated under truly comparative conditions, the results no doubt would prove interesting.

The cost of raising the water from the wells by compressed air, and to the works reservoir by the force-pumps, is 1*d.* per 1,000 gallons, including cost of labour, fuel at 12*s.* 6*d.* per ton, stores and maintenance. The total lift may be taken as 160 feet on an average, so that the cost per 1,000 gallons raised 100 feet is 0.625*d.* From the information gained from these experiments, together with alterations in the steam generating-plant, a considerable reduction of this cost is anticipated.

It has not been found possible to determine directly what fraction of the cost should be assigned to the compressed-air plant, but an approximation to the cost for fuel may be arrived at in the following manner. In a steam-consumption test of 8 hours' duration, the compressor was found to take 29 lbs. of steam per I.H.P.-hour at a pressure of 90 lbs. per square inch, the rate of working being such as would give 40,000 gallons of water per hour from three wells working together. In experiment No. 1, Table XII. (Appendix), 38,000 gallons of water were raised 100 feet, approximately, for an

expenditure of power equal to 51 I.H.P.-hours. Assuming the steam-plant to be capable of generating 29 lbs. of steam for 4 lbs. of fuel, then 38,000 gallons of water could be raised 100 feet for 204 lbs. of fuel, which, with fuel at 12s. 6d. per ton, gives a cost of 0.36d. per 1,000 gallons lifted 100 feet. Before the compressed-air plant was installed, the total cost of raising water by the lift-pumps was 0.9d. per 1,000 gallons delivered to the works, or 0.562d. per 1,000 gallons lifted 100 feet. The lift-pumps were believed at that time to be giving an efficiency of 80 per cent., but this is probably much too high; in a recent test they gave only 58½ per cent. efficiency, but under more favourable conditions the efficiency would probably have been about 65 per cent. Experience of the working of these air-lifts has amply justified the installation of the system, since the extra cost for fuel is nearly balanced by the saving in maintenance-costs alone, leaving out of account the saving due to freedom from stoppages, and the interest on the cost of extra plant which would have been required had the system of lift-pumps been extended to meet the present and future requirements.

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The Paper is accompanied by seven drawings, from which the Figures in the text have been prepared; and by the following Appendix.

APPENDIX.

TABLE I.—PARTICULARS OF AIR-LIFTS AT PREESALL.

Number of Well.	Depth.	Diameter.	Area of Delivery.	Effective Area of Air-Tube.	Depth of Delivery.	Distance from Compressor.
	Feet.	Inches.	Sq. Ins.	Sq. Ins.	Feet.	Feet.
17	450	12	12·56	16·2	323·5	600
38	350	12	19·63	18·75	339·5	600
39	350	12	12·56	16·2	347·0	825
40	350	12	12·56	3·1416	326·5	5,400

TABLE II.—RESULTS OBTAINED BY PROFESSOR JOSSE ON AN EXPERIMENTAL COMPRESSED-AIR LIFT AT THE BERLIN HOCHSCHULE.

Number of Experiment.	Diameter of Smooth Delivery-Tube.	Ratio of Dip to Height of Delivery.	Height of Delivery.	Dip.	Quantity of Water Delivered per Minute.	Actual H.P. in Water raised.	Volume of Air per Minute at Atmospheric Pressure.	I. H.P. in Air-Cylinders.	Air used per Cubic Foot of Water raised.	Efficiency Ratio between H.P. in Water raised and I. H.P. in Air-Cylinder.
	Inches.		Feet.	Feet.	Gallons.		Cubic Feet.		Cubic Feet.	Per Cent.
1	2½	4:3	50·5	69·2	47·54	0·740	18·98	1·664	2·490	44·5
2			51·3	68·5	69·33	1·094	35·00	3·156	3·170	34·7
3			51·6	68·2	75·38	1·197	45·70	4·300	3·780	27·9
1	3	4:3	48·4	71·3	72·63	1·084	30·02	2·730	2·580	39·7
2			48·6	71·2	77·03	1·154	34·19	3·390	2·760	34·1
3			49·1	70·6	88·04	1·332	45·21	4·346	3·200	30·7
1	2½	3:2	46·7	72·9	51·06	0·737	20·06	1·778	2·450	32·9
2			48·3	71·4	74·72	1·111	36·05	3·380	3·010	27·2
3			48·5	71·3	79·23	1·183	44·28	4·356	3·480	25·6
1	2½	1:1	57·8	62·0	39·18	0·698	20·74	1·651	3·300	42·3
2			58·8	60·9	56·67	1·026	35·05	2·930	3·850	35·0
3			59·2	60·5	62·73	1·143	46·97	4·216	4·670	27·2
1	3	1:1	59·3	60·4	60·09	1·097	35·25	2·950	3·660	37·2
2			59·4	60·3	67·57	1·235	45·21	3·980	4·170	31·1

TABLE IIIA.—RESULTS OF EXPERIMENTS BY PROFESSOR JOSSE ON A COMPRESSED-AIR LIFT AT THE BERLIN HOCHSCHULE.

Number of Experiment.	Water delivered per Minute.	Height of Delivery.	Dip.	Volume of Air at Atmospheric Pressure.	Air used per Cubic Foot of Water raised.
	Gallons.	Feet.	Feet.	Cubic Feet per Minute.	Cubic Feet.
24	24·21	24·60	49·21	7·63	1·96
25	66·03	"	"	18·58	1·75
26	80·33	"	"	28·11	2·18
27	85·84	"	"	29·07	2·11
28	93·76	"	"	44·31	2·94
29	96·84	"	"	50·53	3·25
30	96·84	"	"	55·79	3·59
31	96·84	"	"	57·21	3·68
32	88·04	"	"	105·95	7·50

EXPERIMENTS ON WELLS AT PRESALL.

Number of Experiment.	Dip of Well.	Height of Delivery.	Ratio of Height of Delivery to Dip.	Area of Delivery-Pipe.	Effective Area of Air-Pipe.	Quantity of Water raised per Minute.	Gallons.	Cubic Feet.	Mean Revolutions of Compressor per Minute.	Mean Air-Pressure per Square Inch.	Actual HP. in Water raised.	I. HP. in Steam-Cylinders.	I. HP. in Air-Cylinders.	Efficiency between I. HP. in Air and Steam-Cylinders.	Per Cent.	Efficiency between Work in Water raised and I. HP. in Air-Cylinders.	Per Cent.	Volume of Free Air used per Cubic Foot of Water raised.	Velocity of Air and Water entering Delivery-Pipe.	Ft. per Second.	Ft. per Second.	Volume of Free Air used per Cubic Foot of Water raised.	Efficiency between Work in Water raised and I. HP. in Air-Cylinders.	Per Cent.	Cubic Feet.	Ft. per Second.	Velocity of Air and Water leaving Delivery-Pipe.		
1	277·0156·0	$\frac{1}{1\cdot77}$	1	12·56	16·2	172·3	285·5	17·0	102	8·17	45·0	42·4	94·2	18·15	19·30	10·35	13·2	59·8											
2	277·0156·0	$\frac{1}{1\cdot77}$	1	"	"	173·0	290·5	17·3	103	8·20	45·7	43·3	94·8	17·93	18·90	10·45	13·4	60·8											
3	278·0155·0	$\frac{1}{1\cdot79}$	1	"	"	177·0	326·0	19·5	104	8·31	49·6	46·6	94·0	16·75	17·80	11·55	14·3	67·6											
4	277·0156·0	$\frac{1}{1\cdot77}$	1	"	"	179·0	420·0	25·1	103	8·48	69·9	65·2	93·5	12·13	13·00	14·70	17·1	85·7											
5	277·0156·0	$\frac{1}{1\cdot77}$	1	"	"	173·1	498·0	29·6	104	8·20	89·0	82·5	92·6	9·2	9·93	17·95	18·5	100·5											

TABLE IV.—EXPERIMENTS ON WELL No. 17 (DELIVERY-PIPE SHORTENED), JANUARY, 1903.																														
1	201·0122·5	$\frac{1}{1\cdot64}$	12·56	16·2	163·7	204·4	88·5 ¹	86	6·01	28·5	25·0	88·0	21·3	24·3	7·8	11·8	44·0													
2	200·0123·5	$\frac{1}{1\cdot62}$	"	"	168·7	239·7	103·8 ¹	86	6·30	33·3	28·8	86·5	18·9	21·8	8·1	14·7	50·9													
3	189·0134·5	$\frac{1}{1\cdot40}$	"	"	193·5	253·7	15·1 ²	74	7·88	36·0	32·5	90·2	21·8	24·2	8·18	15·7	54·3													
4	188·0135·5	$\frac{1}{1\cdot38}$	"	"	211·2	356·6	21·2 ²	74	8·60	51·9	48·5	90·3	16·5	17·5	10·5	18·3	74·6													
5	195·0128·5	$\frac{1}{1\cdot51}$	"	"	232·5	441·8	26·3 ²	84	9·10	69·3	65·1	93·9	13·2	13·9	11·8	22·1	91·5													
6	195·5128·0	$\frac{1}{1\cdot52}$	"	"	251·0	525·8	31·3 ²	85	9·70	84·2	78·7	93·4	11·5	12·3	13·0	25·5	108·1													

¹ Small air-compressor.² Large air-compressor.

EXPERIMENTS ON WELLS AT PRESSALL—continued.

Number of Experiment.	Dip of Well.	Height of Delivery.	Ratio of Height of Delivery to Dip.	Area of Delivery-Pipe.	Effective Area of Air-Pipe.	Quantity of Water raised per Minute.	Volume of Free Air used per Minute.	Mean Revolutions of Compressor per Minute.	Mean Air-Pressure per Square Inch.	Actual HP. in Water raised.	I. HP. in Steam-Cylinders.	I. HP. in Air-Cylinders.	Efficiency between I. HP. in Air- and Steam-Cylinders.	Efficiency between Work in Water raised and I. HP. in Steam-Cylinders.	Per Cent.	Volume of Free Air used per Cubic Foot of Water raised.	Velocity of Air and Water entering Delivery-Pipe.	Velocity of Air and Water leaving Delivery-Pipe.
	Feet.	Feet.		Square Inches.	Square Inches.	Gallons.	Cubic Feet.		Lbs.				Per Cent.	Per Cent.		Cubic Feet.	Ft. per Second.	Ft. per Second.

TABLE V.—EXPERIMENTS ON WELL No. 38, APRIL 1903.

1	176.7132.8	$\frac{1}{1.33}$	19.63	18.85	278.0	285.5	17.0	73	11.2	41.5	38.2	92.0	27.0	29.3	6.4	12.6	40.3	
2	159.5150.0	$\frac{1}{1.06}$	"	"	310.0	364.6	21.7	68	14.4	52.8	47.2	89.3	26.7	30.0	7.3	15.9	50.6	
3	158.0151.5	$\frac{1}{1.08}$	"	"	348.8	463.7	27.6	68	16.1	68.5	64.4	94.0	23.3	24.9	8.3	19.3	62.5	
4	158.0151.5	$\frac{1}{1.04}$	"	"	356.0	574.6	34.2	68	16.3	88.3	82.3	93.2	18.5	19.8	10.0	22.4	77.2	
5	202.0137.5	$\frac{1}{1.47}$	"	"	354.0	295.7	17.6	87	14.46	45.3	42.1	93.0	31.9	34.3	5.2	12.5	43.1	
6	207.0132.5	$\frac{1}{1.56}$	"	"	405.0	369.6	22.0	87	16.8	51.2	52.3	90.6	31.0	32.1	5.68	16.2	56.4	

TABLE VI.—EXPERIMENTS ON WELL No. 38, AUGUST 1903.

1	196.0113.5	$\frac{1}{1.45}$	19.63	18.85	393.0	239.2	14.3	97	13.5	39.8	35.0	88.2	35.0	38.6	3.80	12.2	36.9	
2	187.0122.0	$\frac{1}{1.54}$	"	"	431.0	344.4	20.5	93	15.9	55.6	49.8	89.7	28.6	32.0	5.0	15.2	50.54	
3	183.5125.5	$\frac{1}{1.46}$	"	"	449.0	425.0	25.3	92	17.1	68.0	62.2	92.0	25.1	27.3	5.90	17.2	60.7	
4	182.0127.0	$\frac{1}{1.43}$	"	"	478.0	516.7	30.7	92	18.4	83.5	76.4	91.5	22.1	21.1	6.70	19.6	72.5	
5	178.0131.0	$\frac{1}{1.36}$	"	"	475.0	544.0	32.4	90	18.8	90.4	80.4	89.0	20.8	23.4	7.16	20.4	75.8	

EXPERIMENTS ON WELLS AT PRESALL—continued.

Number of Experiment.	Dip of Well.	Height of Delivery.	Ratio of Height of Delivery to Dip.	Area of Delivery-Pipe.	Square Inches.	Effective Area of Air-Pipe.	Quantity of Water raised per Minute.	Volume of Free Air used per Minute.	Mean Revolutions of Compressor per Minute.	Mean Air-Pressure per Square Inch.	Actual H.P. in Water raised.	I.H.P. in Steam-Cylinders.	I.H.P. in Air-Cylinders.	Efficiency between I.H.P. in Air- and Steam-Cylinders.	Per Cent.	Efficiency between Work in Water raised and I.H.P. in Steam-Cylinders.	Per Cent.	Volume of Free Air used per Cubic Foot of Water raised.	Velocity of Air and Water entering Delivery-Pipe.	Velocity of Air and Water leaving Delivery-Pipe.
	Feet.	Feet.		Square Inches.	Square Inches.	Square Inches.	Gallons.	Cubic Feet.		Lbs.								Cubic Feet.	Ft. per Second.	Ft. per Second.
TABLE VII.—EXPERIMENTS ON WELL No. 39, AUGUST 1903.																				
1	216.5	130.5	$\frac{1}{1.66}$	12.56	15.2		246.0	222.6	13.5	95	9.73	37.6	32.1	85.2	25.8	30.4	5.77	14.2	50.0	
2	214.5	132.5	$\frac{1}{1.62}$	"	"		265.2	330.0	19.7	95	10.60	54.0	48.7	90.5	19.8	21.9	7.80	18.0	71.1	
3	211.5	135.5	$\frac{1}{1.55}$	"	"		291.5	420.0	26.5	95	11.90	70.3	63.7	90.6	16.9	18.6	9.01	21.5	89.1	
4	210.0	137.0	$\frac{1}{1.53}$	"	"		270.8	512.4	30.5	95	11.24	85.4	76.2	89.2	13.2	14.9	11.83	23.7	106.1	
TABLE VIII.—EXPERIMENTS ON WELL No. 39 (DELIVERY-PIPE SHORTENED), AUGUST 1903.																				
1	185.0	128.0	$\frac{1}{1.44}$	12.56	15.71		221.4	208.0	13.0	81	8.50	32.5	27.5	85.0	26.2	30.9	5.80	14.1	46.5	
2	182.0	131.0	$\frac{1}{1.38}$	"	"		243.6	313.3	18.6	81	9.60	48.2	42.7	88.6	19.7	22.4	8.00	18.5	67.2	
3	181.0	132.0	$\frac{1}{1.37}$	"	"		262.6	420.0	26.0	82	10.50	66.3	58.0	87.5	15.8	18.1	10.00	22.7	88.24	
4	182.0	131.0	$\frac{1}{1.38}$	"	"		249.0	503.0	30.0	82	9.90	78.6	71.7	91.2	12.6	17.5	12.60	25.17	103.6	

TABLE IX.—EXPERIMENTS ON WELLS NOS. 38 AND 39, WORKING TOGETHER, AUGUST 1903.

Number of Experiment.	Well No. 38.				Well No. 39.				Quantity of Water delivered per Minute.	Volume of Free Air used per Minute.	Mean Revolutions of Compressor per Minute.	Mean Air-Pressure per Square Inch.	Actual H.P. in Water raised.	I. H.P. in Steam-Cylinders.	Efficiency between I. H.P. in Steam- and Air-Cylinders.	Per Cent.	Efficiency between Work in Water raised and I. H.P. in Air-Cylinders.	Per Cent.	Emotion between Work in Water raised and I. H.P. in Air-Cylinders.	Volume of Free Air used per Cubic Foot of Water raised.	
	Dip of Well.	Height of Delivery.	Ratio of Height of Delivery to Dip.	Area of Delivery-Pipe.	Effective Area of Air-Pipe.	Sq. In.	Sq. In.	Gallons.													Cubic Feet.
1	190-0	119-5	1 1-59	19-63	18-85	210-7	136-3	1 1-55	12-56	15-71	570-0	398-0	23-7	102	22-1	67-8	60-0	88-5	32-40	36-80	4-37
2	190-5	118-5	1 1-59	"	"	210-5	136-5	1 1-54	"	"	593-0	440-0	26-2	99	22-9	73-4	67-0	91-2	31-07	34-20	4-60
3	190-5	118-5	1 1-59	"	"	211-5	136-5	1 1-54	"	"	629-0	512-4	30-5	100	24-3	87-8	79-3	90-3	27-70	30-70	5-09
4	187-0	122-0	1 1-53	"	"	209-0	138-0	1 1-51	"	"	669-3	583-0	34-7	97	26-4	101-0	89-8	89-0	26-10	29-40	5-44
5	185-0	124-0	1 1-49	"	"	207-5	139-0	1 1-48	"	"	672-0	666-6	39-8	97	28-1	116-5	105-2	91-0	24-30	26-70	6-20

TABLE X.—EXPERIMENTS ON WELLS NOS. 17, 38 AND 39, WORKING TOGETHER, AUGUST 1903.

Number of Experiment.	Dip of Well.			Height of Delivery.			Ratio of Height of Delivery to Dip of Wells.			Area of Delivery-Tubes.			Effective Area of Air-Tubes.			Quantity of Water delivered per Minute.	Volume of Free Air used per Minute.	Cubic Feet.	Mean Revolutions of Compressor per Minute.	Mean Air-Pressure per Square Inch.	Actual HP. in Water delivered.	I.H.P. in Steam-Cylinders.	I.H.P. in Air-Cylinders.	Efficiency between Indicated Work in Steam- and Air-Cylinders.	Efficiency between Work in Water delivered and Indicated Work in Steam-Cylinders.	Per Cent.	Efficiency between Work in Water raised and Indicated Work in Air-Cylinders.	Volume of Free Air used per Cubic Foot of Water raised.
	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.														
	17.	38.	39.	17.	38.	39.	17.	38.	39.	17.	38.	39.	17.	38.	39.													
1	Feet. 187-0	Feet. 194-0	Feet. 222-0	Feet. 119-5	Feet. 115-0	Feet. 115-0	1	1	1	12-56	19-6	12-56	16-2	18-8	16-2	625-5	378-0	22-5	104	22-1	64-7	57-2	88-5	34-2	38-7	3-77		
2	Feet. 188-5	Feet. 192-5	Feet. 233-5	Feet. 118-5	Feet. 117-0	Feet. 113-5	1-57	1-68	2-02	12-56	19-6	12-56	16-2	18-8	16-2	662-5	362-9	21-6	107	23-4	60-6	56-9	92-4	38-6	41-0	3-42		

TABLE XI.—EXPERIMENTS ON WELL NO. 40, MAY 1904.

Number of Experiment.	Dip of Well.	Height of Delivery.	Ratio of Height of Delivery to Dip.	Area of Delivery-Pipe.	Effective Area of Air-Pipe.	Quantity of Water delivered per Minute.	Cubic Feet.	Volume of Free Air used per Minute.	Mean Revolutions of Compressor per Minute.	Mean Air-Pressure per Square Inch.	Actual H.P. in Water raised.	I. H.P. in Steam-Cylinders.	I. H.P. in Air-Cylinders.	Efficiency between I. H.P. in Steam- and Air-Cylinders.	Efficiency between Work in Water raised and I. H.P. in Steam-Cylinders.	Efficiency between Work in Water raised and I. H.P. in Air-Cylinders.	Volume of Free Air used per Cubic Foot of Water raised.	Velocity of Air and Water entering Delivery-Pipe.	Velocity of Air and Water leaving Delivery-Pipe.
	Feet.	Feet.		Square Inches.	Square Inches.	Gallons.				Lbs.				Per Cent.	Per Cent.	Per Cent.	Cubic Feet.	Ft. per Second.	Ft. per Second.
1	212.5	110.5	$\frac{1}{1.93}$	12.563.1416		294	318	18.9	95	9.85	45.2	40.4	89.0	21.9	24.4	24.4	6.73	18.5	31.1
2	214.0	109.0	$\frac{1}{1.95}$	"		335	348	20.7	110	11.10	53.0	47.0	88.7	21.0	23.6	23.6	6.80	19.3	34.1
3	209.0	114.0	$\frac{1}{1.84}$	"		378	417	24.8	99	13.1	69.0	60.0	87.0	19.0	21.8	21.8	6.88	23.5	41.3
4	207.0	116.0	$\frac{1}{1.78}$	"		331	460	27.3	102	11.62	79.4	69.7	89.0	14.7	16.7	16.7	8.66	23.03	43.6

TABLE XII.—EXPERIMENTS ON WELLS NOS. 38, 39 AND 40—WORKING TOGETHER—JUNE 1904.

No. of Experiment.	Dip of Well.			Height of Delivery.			Ratio of Delivery to Dip of Well.			Area of Delivery-Pipe.			Effective Area of Air-Pipe.			Quantity of Water Delivered per Minute.	Volume of Free Air Used per Minute.	Mean Revolutions of Compressor per Minute.	Mean Air-Pressure per Square Inch.	Actual HP. in Water Raised.	1 HP. in Steam-Cylinders.	1 HP. in Air-Cylinders.	Efficiency between Indicated Work in Steam and Air-Cylinders.	Efficiency between Work in Water Delivered and Steam-Cylinders.	Efficiency between Work in Water Delivered and Air-Cylinders.	Per Cent.	Per Cent.	Cubic Feet.		
	No. 38.	No. 39.	No. 40.	No. 38.	No. 39.	No. 40.	No. 38.	No. 39.	No. 40.	Sq. Ins.	Sq. Ins.	Sq. Ins.	No. 38.	No. 39.	No. 40.														Sq. Ins.	Sq. Ins.
1	240.7	241.9	225.0	98.8	105.1	98.0	1	1	1	2.43	2.3	2.29	12.63	12.56	12.56	18.8	16.2	3.14	636	307.0	18.3	110.0	0.19	39	51.0	47.0	92.2	38.8	41.2	3.01
2	239.4	246.9	209.0	101.0	100.1	114.0	1	1	1	2.39	2.46	1.83	1	1	1	780	354.5	21.1	110.0	0.23	81	63.8	58.0	58.0	90.8	37.3	41.05	37.3	41.05	2.91
3	232.3	235.8	224.5	107.2	111.2	98.6	1	1	1	1	1	1	1	1	1	849	413.0	24.6	118.0	0.27	17	75.8	68.6	68.6	90.5	35.9	39.6	35.9	39.6	3.04
4	239.0	244.2	219.5	100.5	102.8	103.5	2.37	2.37	5.12	1	1	1	1	1	1	928	460.3	27.4	120.0	0.28	76	92.7	83.5	83.5	90.1	31.0	36.5	31.0	36.5	3.1
5	233.3	236.8	214.0	106.2	110.2	109.0	2.2	2.15	1.96	1	1	1	1	1	1	937	514.0	30.6	120.7	0.30	81	98.1	90.3	98.1	92.0	31.5	34.1	31.5	34.1	3.42
6	229.0	225.5	214.5	110.5	121.5	108.5	2.07	1.85	1.98	1	1	1	1	1	1	956	538.0	35.6	101.0	0.32	85	102.0	95.4	93.5	93.5	32.2	34.4	32.2	34.4	3.9
7	226.0	222.0	209.4	113.5	123.0	113.6	1.98	1.77	1.84	1	1	1	1	1	1	976	750.0	43.5	99.0	0.34	123	2118.0	118.0	92.2	92.2	27.0	29.2	27.0	29.2	4.92
238.4	229.5	207.0	111.1	117.5	116.0	2.05	1.95	1.78	1	1	1	1	1	1	1	1,001	836.6	49.8	97.0	0.34	85	158.2	141.7	89.5	89.5	22.1	24.6	22.1	24.6	5.22

TABLE XIII. — EXPERIMENTS ON WELL NO. 38, USING SMALL COMPRESSOR, DECEMBER 1904.

Number of Experiment.	Dip of Well.	Height of Delivery.	Ratio of Height of Delivery to Dip.	Area of Delivery-Pipe.	Effective Area of Air-Pipe.	Quantity of Water raised per Minute.	Volume of Free Air used per Minute.	Mean Revolutions of Compressor per Minute.	Lbs. per Square Inch.	Actual HP. in Water raised.	I. HP. in Steam-Cylinders.	I. HP. in Air-Cylinders.	Efficiency between I. HP. in Air and Steam-Cylinders.	Efficiency between Work in Water raised and I. HP. in Steam-Cylinders.	Efficiency between Work in Water raised and I. HP. in Air-Cylinders.	Volume of Free Air used per Cubic Foot of Water raised.	Velocity of Air entering Delivery-Pipe.	Velocity of Air leaving Water Delivery-Pipe.
1	245.0	94.5	$\frac{1}{2.59}$	19.63	18.85	123.0	177.0	82.0	109	3.52	30.12	24.97	80.00	11.70	14.10	8.98	5.76	24.00
2	245.5	94.0	$\frac{1}{2.60}$	"	"	200.0	220.0	101.5	109	5.70	34.72	32.50	93.70	16.40	17.60	6.88	7.60	30.70
3	244.5	95.0	$\frac{1}{2.56}$	"	"	254.0	259.0	119.2	109	7.33	44.48	37.35	83.50	16.50	19.70	6.36	9.30	34.60
4	235.0	104.5	$\frac{1}{2.24}$	"	"	388.0	307.0	141.7	109	12.33	49.22	44.8	91.00	25.00	27.50	4.95	12.80	46.10
5	232.5	107.0	$\frac{1}{2.14}$	"	"	410.0	358.0	165.4	102	13.25	56.30	53.30	94.50	23.60	24.90	5.47	14.40	51.70