Under normal conditions it is safe to say that the return-air system will show an average efficiency of 50 to 55 per cent., this efficiency being the ratio of horse-power of water lifted to the indicated horse-power in the steam cylinder of the air compressor, including all losses. It is easy to estimate from these figures just what they mean in terms of fuel saving.

Yet the question of fuel economy is but one argument in favor of the return-air system. Another argument is that the compressed air system may be operated with a far less boiler horse-power, with a corresponding reduction in first cost of boiler plant, interest, maintenance, repairs and firing cost. Where a plant is crippled by a shortage of boilers, the substitution of the return-air system for a less economical pumping system will relieve the embarrassment.

Continuing still further the argument for this system, Mr. Abrams notes that the tank equipment needs absolutely no care. The operation being entirely under control from the engine room, the engineer can at any time start, stop or vary the pumping. There is no possibility of drowning out the system. In fact, it operates with proportionately less power as the height or head of water above the tanks increases. It cannot become choked by such silt or dirt as may enter a mine sump.

The return-air system cannot be classed as a pump, or as machinery of the kind regularly catalogued and listed. It is a complete system in itself, consisting of an air compressor, a receiver, a reversing switch, two air lines, each leading from the compressor through the switch to one pump tank, and two pump tanks, all in a closed circuit, in which, by a regular cycle of operations, one air volume is compressed, expanded, recompressed and re-expanded, corresponding with a discharge of one of the pump tanks.

The principle of operation is simple. Compressed air is admitted to a tank filled with water, or any fluid, forcing the fluid out through a check valve and pipe line, and at the same time the compressor is drawing air from the other tank, the charge of air being regulated so that when a tank is empty, the other is full, at which time the switch reverses, thereby reversing the action of the tanks.

The cycle of operation will be better understood by referring to Fig. 2; A and B are twin displacement tanks, preferably completely submerged, though they operate if so placed as to be filled by siphon action. A^1 and B^1 are the two air pipe lines. C^1 and C^2 are discharge check valves preventing the return of the fluid ejected.

D^1 and D^2 are check valves preventing the discharge of the fluid through the inlet. E is the discharge pipe from both tanks.

F is the automatic switch controlling the pumping cycle. G^1 and G_2 are the tank risers.

H is the compressing cylinder of an air compressor. J is the automatic compensating valve which keeps the system supplied with air.

In the diagram as shown, air is being withdrawn by the compressor H from the tank B and is being compressed in tank A. At the same time the fluid is entering the tank B through check valve D^2, while it is being forced from the tank A through the riser G^1, the check valve C^1 and the discharge pipe E.

The mathematical analysis of the system is difficult. Any one interested in a full discussion of the problem will find it fully brought uot by Prof. Elmo G. Harris in Vol. 54 of the Transactions of the American Society of Civil Engineers.

In order to proportion a plant correctly, the needed data are as follows:

Q_w = the quantity of water to be pumped in cubic feet per second.

h = the total lift, or head, in feet.

l = the total length of air pipes, the distance from compressor to pump tanks.

Having these, we must compute:

Q_α = the volumetric capacity of the compressor, or the piston displacement in cubic feet per second.

V = the volume of each pump tank (cubic feet).

d = the diameter of air pipe (in inches).

D = the diameter of water pipe (in inches).

H.P. = the maximum horse-power required of the steam end of compressor.

From the formula:

$$Q_\alpha = Q_w \ [1 + 1.4 \log_e R]$$

the following Table I. has been prepared, showing the size of compressor, pipes, etc., required for various heads, based on 100 gal. of water per minute; for other quantities, the dimensions will be directly proportional. The table assumes the pump tanks to be fully submerged.

Table I.—Dimensions for Return-Air System.

Lift in feet.	Capacity of compressor in cubic feet per minute piston displacement for 100 gals. per minute.	Max. I. H. P. of air cylinder.	Max. I. H. P. of steam cylinder.	Average H. P. of steam cylinder.	Area of air pipe in sq. in. for each 100 gal. capacity of plant.	Area of water pipe in sq. in. for each 100 gal. capacity of plant.
50	39.84	2.74	3.22	2.80	0.96	7.70
60	42.78	3.28	3.85	3.37	1.03	8.25
70	45.30	3.85	4.53	3.93	1.09	8.73
80	47.70	4.45	5.22	4.49	1.14	9.12
90	49.80	5.03	5.91	5.05	1.20	9.60
100	51.84	5.67	6.67	5.61	1.25	10.00
110	53.64	6.31	7.43	6.17	1.29	10.30
120	55.44	6.96	8.18	6.73	1.33	10.60
130	57.00	7.62	8.97	7.29	1.37	10.95
140	58.50	8.30	9.75	7.85	1.41	11.30
150	59.94	9.00	10.60	8.41	1.44	11.50
160	61.38	9.75	11.45	8.98	1.47	11.75
170	62.64	10.42	12.25	9.54	1.50	12.00
180	63.84	11.13	13.08	10.10	1.53	12.25
190	64.98	11.85	13.95	10.66	1.55	12.40
200	66.12	12.76	15.00	11.22	1.58	12.65
210	67.20	13.35	15.70	11.78	1.62	12.95
220	68.28	14.09	16.60	12.34	1.64	13.10
230	69.24	14.92	17.35	12.90	1.67	13.35
240	70.20	15.68	18.45	13.46	1.69	13.50
250	71.10	16.46	19.35	14.02	1.71	13.70
260	72.00	17.24	20.25	14.58	1.73	13.82
270	72.84	18.00	21.20	15.14	1.75	14.60
280	73.56	18.80	22.10	15.71	1.77	14.20
290	74.28	19.60	23.10	16.27	1.79	14.30
300	75.06	20.45	24.00	16.83	1.80	14.40

Air-Lift System.—The air-lift system of pumping, measured on the power basis, is not an efficient method of raising water, but where it is and can be applied, it fills a certain field and in that class of work does service that no other pump can do, and does it in a most satisfactory way. This method of pumping has been most generally applied to raising water from artesian wells. There are not many underground formations in which wells can be located close together without affecting each other when pumping, and for that reason it is best to spread them out on a line of what we call the line of underground flow. Some formations are so tight that wells have but little capacity, and in such formations it is particularly necessary that the wells should be scattered and pumped moderately. For the reason that separate pumping units entail high first cost and labor for