10TH AUGUST, 1911.

"THE SUPPLY OF AIR FOR BLAST FURNACE AND KINDRED OPERATIONS."

BY W. H. GRIEVE.

In choosing the title of this paper, the author has endeavoured to confine his remarks to smelting operations, but in one or two points has deviated slightly.

It is always a difficult matter to choose a subject for a suitable paper, much more so to procure something interesting, and most difficult of all to procure something at least bordering on newness.

No paper, at least in recent years, appears to have been read on the subject that has been selected by the author, and he trusts that his few remarks to-night will be found of interest to members, and at least lead to an interesting discussion, as naturally such machinery is of the first importance to us in Australia.

There are few more important mechanical operations than the supply of the necessary oxygen to furnaces, the most important being blast furnaces, for the reduction of ores to a commercial product, in the shape of pig iron, copper matte, etc., and later to convert these products into steel and blister copper.

In all stages, air supply in large quantities is the most important mechanical operation. The other vital elements are more or less chemical or mechanical, comprising the proper proportion of fuel and flux to ore, and in a proper method of feeding the blast furnaces with these proportions. Nature makes it imperative to supply about three times the necessary quantity of air for a given result, on account of the relatively small proportion of oxygen compared to the non-combustible nitrogen.

This fact, in conjunction with the magnitude of present day smelting operations, has created a demand for very large and interesting machinery and methods, which it is proposed to discuss to-night.

Just to touch on the ever interesting historic side of the question, from which is learnt how the engineer has been able to meet the demand for plant of ever increasing size since the days of the earliest smelting operations, and which appear to date back to prehistoric times.

Probably the earliest form of blower was in the form of a sheep skin. Then came the bellows, which in turn were mechanically driven by a crank mechanism; the limit of the bellows was very soon reached, and soon there was a crude form of piston blower driven by water power, the cylinders being at first made of wood staves.

The introduction of the steam engine displaced the water wheel, and from that date the modern development of the steam plant has taken its course.

It is needless to emphasise the importance of the blowing engine to us here in Australia, with our multitude of mines and accompanying smelting works.

Many plants are on a small scale only, and present, therefore, a great variety of methods for economical treatment; while unlike many other industries, the prices of copper and other minerals are fixed by the world's supply and demand.

This being so, all managements are treated alike, and mines too small or poor to compete are compelled to close up or adopt up-to-date methods.

There is no doubt but that this competition with the world is very beneficial in making us take advantage of new and economical ideas, which might otherwise be neglected on account of initial cost.

The author proposes to just briefly touch on some of the theoretical requirements for economical air compression at low pressures, such as we find used for smelting and converting work, and which are in accordance with air compression for higher pressures.

The chief aim is to approach as near as possible to isothermal conditions, that is, to compress air so that no extra work is done on account of the natural property of the air under compression to expand to a larger volume, due to the natural heat of compression; in other words, that there should be no increase in temperature.

Isothermal conditions cannot, of course, be attained in practice, as it is found impossible to conduct the heat away sufficiently quickly during compression.

Adiabatic compression, that is, when all the heat of compression is retained, is also another ideal—or more correctly theoretical—condition, and cannot be attained in practice if it were desired, on account of heat losses by radiation and conduction from the compressor cylinder, piston rod, etc.

The result is, that in practice, air compression is carried on somewhere between these two extreme cases, the effort being to get as near isothermal conditions as is commercially possible.

To illustrate this, Fig. 1 shows the well known indicator

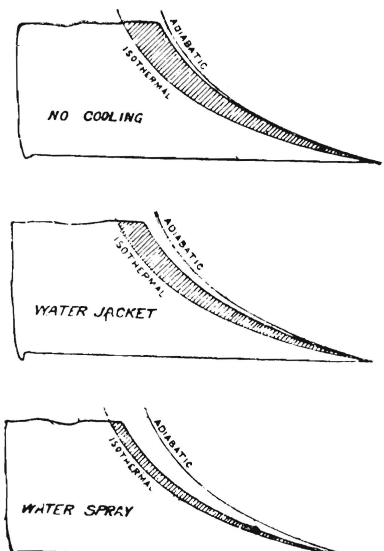

FIG 1.

cards for the two conditions, with the additional and centre curve showing good cooling conditions.

The heat loss is proportionally much greater in compression to higher pressures than it is with such pressures as are required for smelting and converting work, which generally amount in the case of blast furnaces for iron to about 10 to 12 pounds per square inch—in copper furnaces to about 3 to 4 pounds.

Fig 2 shows plotted the final temperatures in degrees Fahrenheit, in adiabatic air compression to 10 atmospheres.

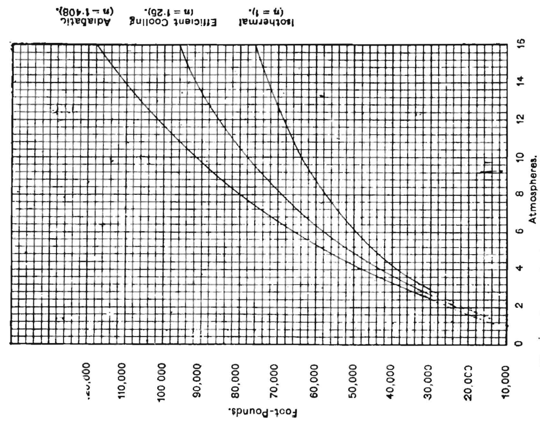

Diagram showing the Amount of Work Required to Draw In, Compress, and Discharge 1lb. of Air from 14·7lbs. per square inch and 60° Fah.

FIG. 3.

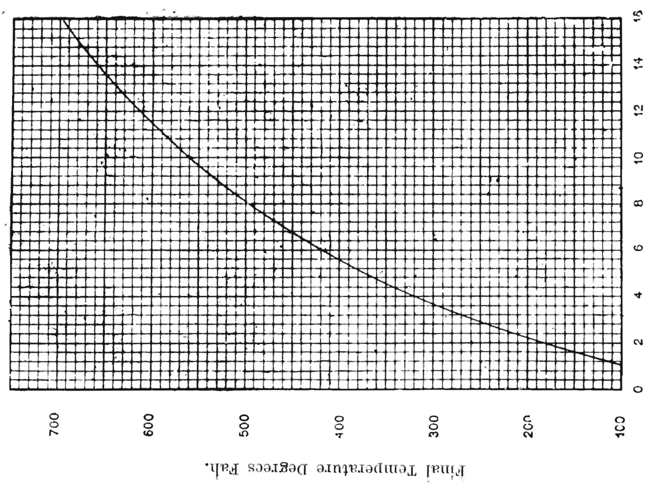

FIG. 2.

It will be noted that this curve has a tendency to approach the horizontal; in other words, the temperature rise is not proportional to the pressure rise.

Fig. 3 shows graphically the foot pounds of work in drawing in, compressing, and discharging, one pound of air from atmospheric pressure at 60° Fah. under the three cycles, namely—adiabatic, efficient cooling, and isothermal, the index for each being 1.408, 1.25, and 1.0 respectively.

These curves show again the relatively greater losses at higher pressures, as seen by the rapid divergence of the three curves, and also shows in a very clear way the great heat losses in the two top curves, compared with the ideal isothermal with the index of unity. Approximately speaking, good cooling reduces the possible adiabatic loss by about 50%.

The author feels that possibly he has gone into too much detail regarding the points already referred to, but he was anxious to show that in low pressure compression, such as required for copper blast furnace work, water jackets are not so essential as in air compressions as commonly known, namely—for working pneumatic tools, etc.

In fact, for very low pressure blowing calculations, rectangular compression is often assumed, that is, the increase of pressure being so low, and compression almost negligible, the air horse powers can be worked out with small error, as for an incompressible fluid—in other words, Boyles Law is said to hold good. So, in ordinary low pressure blowing plants, water cooling is, as a rule, dispensed with.

He referred to such machines as the "Root s'' blower, and modifications of the Root s rotary principle. The same remark also applies to the other type of rotary machine, which has of late years come very largely into use—the steam turbine driven centrifugal blower for blast furnace work.

In converter blowers of the centrifugal type, the pressure is sufficient for manufacturers to go to the expense of providing water cooling with the idea of improving the efficiency of compression.

THE STEAM TURBINE BLOWER.

There are three distinct types of plant for air blowing, such as we are considering:—

The Rotary Displacement System.
The Engine-driven Reciprocating Blower and the Steam Turbine-driven Blower.

This includes Roots' system, which originated from tooth gears after many evolutionary stages, in which were included the "Bakers" blower, and with it the many modifications of the "Roots," but which all work on the same principle, that is, air is compressed by rotating pistons. The same principles govern the operation as in the case of reciprocating machinery, but they possess many advantages over the reciprocating design, the chief being the relatively low cost of construction, the complete absence of valves, and in addition to these, the supply of air is a less fluctuating one, a very important consideration. The efficiencies of these two systems, however, cannot be compared.

The relatively low efficiency of the Root s system is not difficult to account for, and their almost universal adoption to within recent years for low pressure work, can only be justified on the score of cheapness and convenience.

Its near relation—the rotary displacement steam engine—has never yet found favour. This type of blower is not suitable for pressures above 35/40 oz. pressure per square inch.

The tendency in copper smelting at the present time is to increase the blast pressure. Take for instance, the two largest copper smelting companies in Australia: Mount Lyell and Mount Morgan.

It has been found in both these cases that the loss in efficiency with Roots plants primarily designed for pressures up to 30 oz. per sq. inch—even if they could have attained the blast pressure required—was much too serious, the marked reduction in efficiency when blowing at any higher than the designed pressure being due to the greatly increased slip between the rotating members and the casing.

Wear in this type of blower must inevitably take place at the ends of the revolving elements, grit is constantly drawn in with the air and mixed with the oil, which always finds entrance, and simply grinds the ends of the impellers and cylinders away.

The leakage across the circumference can, to a certain extent, be regulated by adjusting the case to the impellers, but it will be understood that no end adjustment is possible.

To form an idea as to the possible extent of the air leak, it is quite common to put a rope grummet round the shaft between the bearing and the end case, to stop the oil being blown out of the bearing.

The most modern large Roots blowers are driven from both ends, usually by cross compound engines. Thus with the crank discs of the engine mounted on the blower shafts, one side of the engine would run over, and the other side under.

A small flywheel at each end serves to equalise the impulses of the engine. The crank pins are located in the centre line of the lobes of the impellers, so that each impeller is balanced at the same time that the engine driving it, is on the dead centre, and the impeller is in a vertical position, doing its maximum work when the engine crank is at right angles to the centre line of the engine.

By this means, the blower receives and delivers four impulses per revolution, and there is practically no transmission through the blower gears, these serving only to keep the impellers in their proper relative position, and to transmit any excess of horse power generated by one of the cylinders.

Slip is approximately proportional to the square root of the difference in pressure between the atmosphere and the imprisoned air.

Running two or more of this type of blower in series, does not appear to have been successful, largely on account. the author thinks, of the difficulty in running two separate machines at the same speed, and under the same conditions regarding slip, etc.

The author has not heard of two or more of this type having been coupled together on the same shaft to run in series.

For pressure below 40 oz., and in plants of small capacities, this type is still likely to be used, but for large capacities, and higher pressures, the future lies with the pure "Rotary" system, which does not depend for efficiency upon pistons and packing rings.

It came as a surprise to the author that he was unable to discover many results of actual efficiency tests of the Roots and kindred systems, which is all the more surprising when the great number installed is taken into consideration, and if any member has come across reliable working figures on the subject, he should be glad to hear of them.

One well known maker states that a figure as high as 85% has been reached, but does not mention the air pressure, but states that it should be taken as an average of about 65%—a difference of 20%.

The lower figure of 65% however, appears to be much too high, as in at least one test, the efficiency only amounted to 42%, so that the author thinks it safe to state that it generally only amounts to between 40 and 50% at the designed pressure.

It generally happens that in smelting operations, more air is required from a machine than is at first expected.

To procure more air from the Roots type of plant, means an increase of speed, and to show how enormously the efficiency of a Roots blower falls away with the increase of pressure, results are given of tests of a moderate size plant designed for 24 oz. pressure per square inch.

Fig. 4 gives the Test figures. Fig. 5 shows the Temperature Volume and Pressure Volume Curves, and Fig. 6 the Efficiency Pressure Curve.

TEST OF ROOTS' BLOWER, 6th MARCH, 1910.

No. of Test.	Temp. Inlet θ F.	Temp. Outlet θ F.	Pressure H.G.	Ozs.	Size of Orifice.	Velocity per ft. sec.	Quantity Cub. ft. per min	Revs. per min.	Efficiency per cent.
1	68	73	.51	4	14½ x 10½	192.3	7609.	100	65 5
2	68	76	1.02	8	9 3/16x10½	247.05	6274.6	100	54.9
3	68	79	1.53	12	7 1/16x10½	308.36	6087.	102	51.4
4	68	83	2.04	16	5 3/16x10½	349.13	5107.1	100	44.
5	68	88	2.55	20	4¼ x 10½	397.8	4791.5	100	41.3
6	68	94	3.06	24	3 3/16x10½	427.1	3884.5	100	33.4
7	67	101	3.57	28	2⅝ x 10½	466 6	3172.1	100	27.3
8	68	109	4.08	32	2 x 10½	490.8	3080.	100	26 5
9	68	117	4.59	36	1 9 16x10½	527.4	2364.	99	20.5
10	68	127	5.10	40	1 3/16x10½	557.3	1295 7	100	11.2
11	68	137	5.61	44	¾ x 10½	588.9	997 6	100	8 6

Barometer 29.55. Free Air per revolution = .116 cub. ft.

FIG. 4.

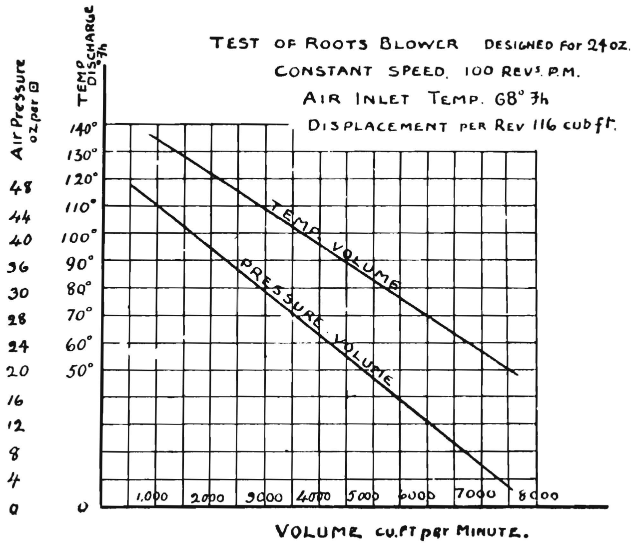
TEST OF ROOTS BLOWER DESIGNED For 24 oz.
CONSTANT SPEED. 100 REVS. P.M.
AIR INLET TEMP. 68° Fh
DISPLACEMENT PER REV 116 cub ft.
Air Pressure oz per □
TEMP DISCHARGE °Fh
TEMP. VOLUME
PRESSURE. VOLUME
VOLUME cu. ft per MINUTE.

FIG. 5.

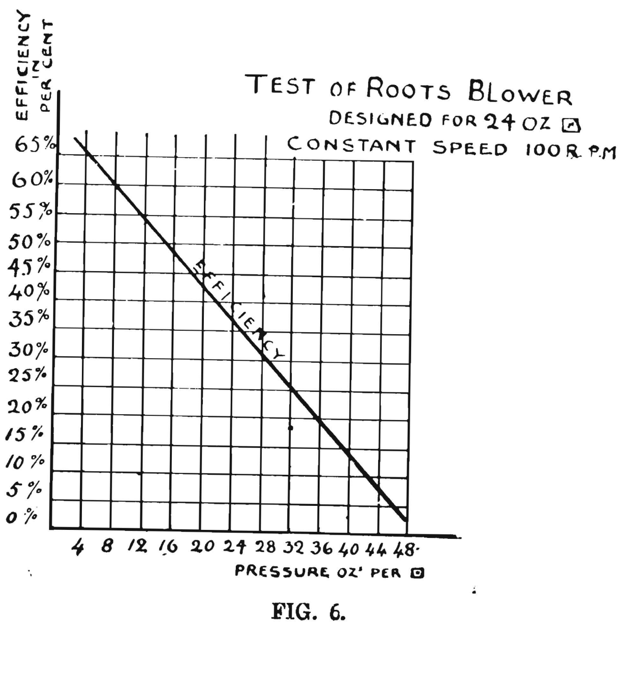
TEST OF ROOTS BLOWER
DESIGNED FOR 24 OZ □
CONSTANT SPEED 100 R. P.M
EFFICIENCY PER CENT
EFFICIENCY
PRESSURE OZ' PER □

FIG. 6.

It will be noted that when delivering 7,600 c. ft. per minute, at 4 oz. pressure, the efficiency has fallen to 65.5%, and at 44 oz. pressure it is only 8.6%. When the outlet is completely closed, the efficiency is, of course, nil. The plant tested was not by any means a new plant, but had been under intelligent supervision, and can fairly be taken as an average example.

If Roots blowers must be installed, the largest size that can be employed should be procured, a number of small units are hopeless from an efficiency point of view.

Hixon, in his book on Lead and Copper Smelting, says as follows:—

> "I have never personally tested my Blowers to find out how much they would deliver per revolution, and at varying pressure, except at Anaconda, where a No. 4 Roots Blower was run with a close outlet at 20 revolutions per minute, and gave a pressure of 4 pounds to the square inch in the blast pipe, which would mean that if run against a pressure of 4 pounds, it would deliver no air at all or in other words, the leakage at 4 pounds was 100%."

He goes on to state that, "with Baker blowers, the leakage is much higher, and does not believe that they could be made to generate a pressure of more than 2 pounds before the leakage would be 100%."

Remarks like these, coming from such a reliable source, can only leave one impression, that is, that the system is very inefficient, and the whole reason of their existence can only be explained by the fact that nothing up to recent years has been able to oppose their wholesale adoption for low pressure smelting operations.

RECIPROCATING BLOWERS.

The second type to be considered is the above, as in use for such purposes as copper converting, iron blast furnaces, and the Bessemer process, all of which processes work at a much higher air pressure than in the case of copper smelting.

The Australian practice in copper converting appears to favour 10/12 lbs. per sq. inch as a maximum.

The pressure for iron blast furnaces most favoured in England is about the same, and at the Lithgow Iron Works it is about 10 pounds.

In America the blowers appear to be designed for higher pressures.

In the Bessemer steel process, the pressure is about double that of the blast furnace.

No attempt has been made to use the "Rotary" displacement type of blower for such purposes as the foregoing, and until the steam "Turbo" blower came on to the market some ten years ago, the reciprocating blower entirely held the field.

This type of plant is well known, and generally is similar to H.P. air compressing plants, the designs of the two plants being practically identical.

The blower cylinder, of course, is of much greater dimensions, and in the case of iron blast furnace blowers, cylinders of 100in. diameter and over, are quite common, with a length of stroke of 70in.

British and Continental practice favours the vertical or horizontal steam engine.

In the United States, the combined vertical-horizontal type of engine has largely been adopted for high powers.

These vertical-horizontal sets have been supplied in sizes of very large capacity, namely, to deliver 60,000 c. ft. of free air per minute, at a maximum pressure of 30 pounds per sq. inch, which represents about 8,000 H.P. The distinguishing features of each design, as in H.P. air compressors, are the types of air valves used, of which there are many designs.

The most important items in a blower, as in air compressors as generally known, are the inlet and outlet valves. The chief aim in valve designing is to construct a valve sufficiently strong with a minimum of weight, so that no great extra pressure is required to operate them when the blast main pressure is reached in the cylinder, as any excess pressure above this is pure loss.

Many well known British makers of blowing machines have mechanically operated valves, generally of the grid principle, ensuring a large opening for a small movement.

Messrs. Galloway Bros., Manchester, adopt such a design, the inlet valves being plain grids, as also are the outlet. These are automatically opened by the air pressure in the blower, operating on a small air cylinder with an actuating piston, but are positively closed by suitable gear from the main shaft.

Fig. 7 shows one of Galloway's blowers capable of blowing 22,000 c. ft. of free air per minute, against a pressure of 12 pounds to the square inch. It will be noted that the inlet valve shown in section on the bottom is actually inside the cylinder, whilst the outlet valve shown on top is on the outside of the cylinder.

An air valve which has come to the front very greatly of late years, and is almost the Continental standard, is the Höerbiger and Rögler System.

One of the great difficulties in valve design is to have reliable guidance, and to thus minimise friction losses. There is no use in designing a light valve if its guide is likely to cause friction, and thus introduce additional weight to the valve.

The Höerbiger-Rögler valve has no guide in the ordinary meaning of the word, but as shown in Fig. 8, is fixed in the centre, and is cut in such a way to allow two flexible spring arms to be its guide. They run very quietly even when fitted in high speed compressors.

Fig. 8 also shows a large blower cylinder fitted with them, also diagrams from the blower cylinder.

The loss in the suction and delivery strokes shown on the diagram on account of the weight, is small when compared to the ideal diagram.

Such valves take very little time to replace if they do break, and have proved themselves very reliable.

A distinct type of cylinder is being adopted to a considerable extent in America, named the Slick Blower, or Tub, as our cousins term it.

In this design, at least half the reciprocating blower ills have been overcome, as far as valves are concerned. There are no separate inlet valves. (Fig. 9). The cylinder barrel itself is caused to move mechanically by a system of levers operated by the engine, the cylinder heads remaining stationary, and these heads are given up entirely to the discharge valves, which can as a result be made amply large enough.