ON MECHANICAL VENTILATORS FOR MINES.

By Mr. WILLIAM DANIEL, of Leeds.

In a paper on Mining Machinery read before this Institution sixteen years ago, by the late Mr. Thomas John Taylor, the Ventilation of Mines by Furnaces placed at the bottom of upcast shafts, as compared with the mechanical appliances then in use, was for valid reasons considered the best and safest method. But, notwithstanding its admitted simplicity, the rarefaction of the outgoing air by heat to produce the ventilating current has proved troublesome, expensive, and dangerous. When the injurious effect of the products of combustion on tubbed shafts is considered, and the enormous consumption of fuel (that for pits of average depth being about 60 lb. of coal per effective H. P. per hour), together with the fact that, where furnaces have to be fired continuously, furnacemen are constantly working at the bottom and additional men are required to be in attendance at the top of the pit in case of accident, some idea may be formed of the expense incurred by the use of the furnace; and a reference to known cases of the ignition of inflammable gases, and of the firing of bituminous shale adjacent to the furnace, both of which so often occur in the coal measures, is sufficient for drawing attention to the danger incurred by furnace ventilation.

Under these circumstances it is not surprising that, since the subject of Mechanical Ventilation was last brought before the Institution at a meeting six years ago, the adoption of the greatly improved mechanical appliances then described for the ventilation of mines should have been so extensive that in this country there are at present about 250 mechanical ventilators in actual use or in course of construction, of which number 180 are the Guibal fans, introduced by M. Guibal, and about 60 are the Waddle fans.

In the matter of fuel consumption, the best existing appliances will be about on an equality with furnaces when the latter are employed at a depth of about 700 yards; and the less the depth, the greater does the economy of the machine become; but, for the reasons before given, it may certainly be asserted that the furnace ought never to be employed, excepting in small mines where the duration of working and physical conditions are such as not to justify the additional outlay required for a fan.

Most, if not all, of the Mechanical Ventilators at present in use exhaust from the top of the upcast shaft in the case of pits, or at the end of the return air-course where they are employed for day-working; and they may be divided into two classes, namely, those in which a continuous current is maintained by centrifugal action, as in the fans of Guibal, Rammell, Waddle, and others; and those which intermittently discharge a definite quantity, to which class belong the species of rotary pumps introduced by Lemielle and Cooke, the piston machine of Nixon, and the reciprocating air-chambers of Struvé. All these machines excepting Cooke's have been before described in the Institution Proceedings (1856 page 251, 1858 page 63, 1869 pages 78 and 133).

Cooke's Ventilator is shown in Plates 49 to 53. Fig. 1 is a front elevation of the ventilator and engine; and Fig. 2 a back elevation. Fig. 3 is a longitudinal section with the casing open to the drift leading from the mine, showing the admission and discharge, and Fig. 4 a similar section with the mine drift momentarily closed by the rotation of the ventilator drum. Fig. 6 is a plan, with the casings and one drum shown in section and the other drum shown full.

The ventilator consists of a pair of cylindrical casings C C placed side by side, in which revolve eccentric cylindrical drums D D; two swinging shutters S S, suspended at and oscillating about the shaft A, receive motion from the crank B, lever L, and connecting-rod R, so as to be always close to, but not in absolute contact with, the eccentric drum D: the shutter S thus seals the outlet while the air is being drawn in from the drift M leading from the mine. The eccentricity of the drums D D is about one-fourth of their diameter; they are about two-thirds the diameter of the casing C, and the width of both casings and drums is about one-half the diameter of the casing. The throw of the crank B is the same as the eccentricity of the drum, the centre of the crank-pin coinciding with the centre line of the drum. The connecting-rod R and lever L are both of the same length as the radius of the casing; and the bottom of the shutter S is curved to a radius of the same length as the crank B or eccentricity of the drums, the curve being a circular arc described from the joint of the connecting-rod R with the lower end of the lever L, as shown in the diagram, Fig. 5, Plate 52. The period of inlet and discharge occupies about 235° of each revolution, and Figs. 1 to 4 show different positions of the drums, the pair of drums being placed opposite each other on the driving shaft G, so that the revolving mass is balanced and the discharge of air equalised.

The drawings show the two ventilators of this construction erected at the Upleatham and Lofthouse Ironstone Mines near Saltburn. The diameter of the casings is 22 ft. and the width of each 11 ft. 6 in.; and the theoretical discharge from the pair of casings in each ventilator is consequently about 4530 cub. ft. per revolution. The ends of the casings are constructed of cast-iron plates bolted together, the circumference being covered by plates of wrought iron, stiffened by rolled H iron joists, Figs. 3 and 4. The drums have cast-iron balanced centres keyed on the cast-iron driving shaft G, with circular flanges, to which are attached the wrought-iron arms placed radially to the drums and riveted at the outer end to T iron rings; on these rings are riveted steel plates forming the circumferences of the drums. The shutters are of wrought iron. The ventilators are driven by semi-portable engines with boilers of the locomotive type, having steam-jacketed cylinders and variable expansion valves.

The useful effect of these machines is measured by the quantity of air discharged, the degree of rarefaction necessary to overcome the friction of the passages and ensure the requisite velocity to the ventilating current, and the power expended to produce this effect.

The tabulated statements appended (Table II) contain the results of experiments on some of the different systems previously mentioned that are now working. The quantity of air discharged in each case is that given by the average of a number of anemometer measurements; water-gauge readings were simultaneously taken, and also indicator diagrams from the engines, examples of which are shown in Figs. 7 to 11, Plates 54 and 55. In all cases the observed velocities given by the anemometers were corrected for the friction of the instruments, and the water-gauges were placed on the casings of, or the drifts leading to, the ventilators.

The Leeds fan at Morley Main Colliery in experiments 12 and 13 is a modification of the Guibal fan; the inlets for the air are on both sides, and to prevent interference of the entering currents a diaphragm is placed in the centre of the vanes on the shaft; the shutter is omitted entirely, and the expanding outlet is replaced by a rectangular chimney. The drift leading from the mine to the fan has to be divided for conveying the air to the two sides of the fan; and the driving shaft for the fan requires a third bearing, unless made of excessive strength.

The only two ventilators on Cooke's plan that are at present working have been erected at the Upleatham and Lofthouse Ironstone Mines belonging to Messrs. J. W. Pease and Co., and were adopted by the manager, Mr. Wm. Cockburn, after a careful investigation of the systems in use; and the following experimental results taken from the appended Table II show that his selection was justified, the lowest as well as the highest results being given in the case of the Cooke's ventilators, and the highest alone in the case of the others.

With each ventilator an experiment was made at the ordinary working speed, for which in the case of all the Guibal fans, excepting that at Hilda Colliery, the shutters in the expanding outlets were adjusted, and the best results obtained. The fan at Hilda having been at work only a short time, the proper adjustment of the shutter had not been ascertained.

		Ventilator. Diam. Width. Ft. Ft.	Air per min. Cub. Ft.	Water Gauge. In.	Revs. per min.	Useful Effect. Per cent.
Cooke	Lofthouse	22 × 11½	101,308	1·12	26	**64·00**
			96,757	1·00	26	**59·16**
„	Upleatham	22 × 11½	88,900	3·25	27	**61·18**
			120,816	1·56	29	**58·50**
Waddle	Aberaman	36 × 1½	126,504	1·60	44	**47·10**
Rammell	Cannock Chase	32 × ½	45,280	2·10	55	**41·02**
Leeds Fan	Morley Main	40 × 10	141,534	1·80	44	**37·92**
Guibal	Farnley Wood	21 × 7	38,900	0·90	53	**50·41**
„	Liverton	36 × 12	121,688	2·55	51	**48·85**
„	Hilda	50 × 12	116,792	2·63	36	**45·81**
„	Skelton	30 × 10	52,544	0·50	28	**45·64**
„	Craggs Hall	30 × 10	56,072	1·40	43	**40·66**

In order to obtain as accurately as possible the volume of air discharged, a great number of anemometer measurements were taken at points equally distributed over the areas of the drifts. In Table I are given the velocities of the air at the respective points in the area of the drifts corresponding to the numbers on the diagrams, Figs. 12 to 18, Plate 56. Attention is particularly required to this, on account of the great variations that occur in different positions in the same air-way. For instance, at Hilda Colliery (experiments Nos. 14 and 15), out of twenty-five observations in each experiment, at the quickest speed the extreme variation was 46 per cent. above the mean and 31 per cent. below; and at the slower speed the velocities varied 38 per cent. and 25 per cent. respectively; so that, if the air had been measured at the points of maximum velocity only, the volume discharged would have been increased from 91,776 to 133,992 cub. ft., and the useful effect from 37·77 to 55·14 per cent. Again, at Lofthouse (experiment No. 6), the variations in nine measurements of the air current were 25 per cent. above the mean and 20 per cent. below; and had the former been assumed in place of the mean velocity, the volume of air would have been increased from 101,308 to 126,635 cub. ft., and the useful effect from 64 to 80 per cent. The drifts shown in the diagrams, Figs. 12 to 18, were divided by cross wires as nearly as possible into squares of equal areas, and the anemometer was held in each division for one minute.*

The consumption of fuel in most cases could not be accurately ascertained; for, according to the usual practice, steam was taken from boilers used for other purposes than that of ventilation. But the writer wishes to direct attention to the fact, that, in the majority of ventilators now working, low pressures, very little expansion, and consequently wasteful types of engines, are usually employed, where, owing to the almost constant work, a more economical type of engine might be advantageously adopted. The Lofthouse ventilator, driven by a semi-portable engine as described (indicator diagrams, Fig. 7), during 30 days' continuous working at an average speed of 26 revolutions per minute (obtained from a counter) required $35\frac{1}{8}$ tons of coal, or 3·9 lb. per indicated H. P., or 6·07 lb. per effective H. P. per hour.

Before concluding, the writer wishes to avail himself of this opportunity to thank the proprietors and managers of the different mines at which the experiments were made, for the facilities afforded and assistance rendered to him.

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* In Tables I and II the velocity V of the air in ft. per min. is calculated in each case from the observed number of revolutions R made by the anemometer in one minute, by means of the following formulæ :—

$V = \sqrt{(1{\cdot}03\,R^2 + 83{,}150)}$ for Biram's anemometer in Expts. 1 to 3, and 22 to 26.

$V = \sqrt{(0{\cdot}94\,R^2 + 99{,}210)}$ for Casella's anemometer in Expts. 4 to 16, and 18-19.

$V = \sqrt{(1{\cdot}41\,R^2 + 3{,}283)}$ „ „ „ „ Expt. 17.

By means of a table supplied with the instrument in Expts. 20-21.

TABLE I. *Velocities of Air in different portions of the Area of the Drifts.*

No. of Experiment in Table II.	Upleatham No. 5		Lofthouse No. 8		Cannock Chase No. 9		Aberaman No. 10		Morley Main No. 12		Hilda No. 14		Liverton No. 18	
Position of Anemometer.	Anemometer.	Velocity of Air.	Anemometer.	Velocity of Air.	Anemometer.	Velocity of Air.	Anemometer.	Velocity of Air.	Anemometer.	Velocity of Air.	Anemometer.	Velocity of Air.	Anemometer.	Velocity of Air.
See Plate 56.	Rev.	Ft. p. min.	Rev.	Ft. p. min.	Rev.	Ft. p. min.	Rev.	Ft. p. min.	Rev.	Ft. p. min.	Rev.	Ft. p. min.	Rev.	Ft. p. min.
1	660	713	616	675	1124	1134	579	644	1095	1107	286	420	1261	1262
2	759	800	634	690	1032	1049	620	679	870	900	338	455	1361	1356
3	784	823	538	609	1094	1106	568	634	822	857	392	494	1294	1293
4	757	799	456	543	1170	1177	597	659	973	994	399	499	1337	1333
5	805	842	414	510	1092	1104	593	655	972	994	514	590	1033	1049
6	746	789	646	701	922	948	597	659	1210	1214	572	637	1538	1524
7	751	793	680	731	1162	1170	623	683	1302	1301	491	571	1348	1344
8	963	985	748	791	1204	1209	...	...	...	...	358	469	1489	1477
9	947	971	784	823	1288	1288					301	429	1642	1622
10	834	868	726	771	...	...	...	...	...	...	305	432	1708	1685
11			684	734							331	450	1810	1782
12	...	...	544	614	...	...	...	...	...	...	403	502	1078	1091
13			612	672							546	616	1332	1329
14	...	...	690	739	...	...	...	...	...	...	591	653	1890	1859
15			956	979							662	715	1823	1795
16	...	...	1014	1032	...	...	...	...	...	...	799	836	1736	1712
17			1044	1060							861	892		
18	...	...	914	940	...	...	...	...	...	...	729	774	...	...
19			616	675							635	691		
20	...	...	586	649	...	...	...	...	...	...	662	715	...	...
21											824	859		
22	...	...	...	...	...	...	...	...	...	...	633	690	...	...
23											540	611		
24	...	...	...	...	...	...	...	...	...	...	542	613	...	...
25											741	784		
Mean	800	**837**	695	**744**	1121	**1132**	597	**659**	1035	**1047**	538	**609**	1480	**1469**

Description of Ventilator		Cooke								Rammell	Waddle		Leeds	
Name of Colliery or Mine		Upleatham Iron Mines					Lofthouse Iron Mines			Cannock Chase Colliery	Aberaman Colliery		Morley Main Colliery	
Ventilator, diam. and width	ft.	22×11½					22×11½			32×½	36×1½		40×10	
Date of Experiment	1875	Mar. 6			Aug. 25	Sep. 16	July 21		Oct. 10	June 22	July 13		July 8	
Number of Experiment		1	2	3	4	5	6	7	8	9	10	11	12	13
Anemometer, description		Biram	Biram	Biram	Casella	Casella	Casella	Casella	Casella	Casella	Casella	Casella	Casella	Casella
Do., rev. in 1 min.	rev.	969	850	560	936	800	734	836	695	1121	597	706	1035	1244
Velocity of Air (calculated) V	ft. per min.	1024	909	637	960	837	779	897	744	1132	659	753	1047	1247
Area of Drift . . . . . . A	sq. ft.	125·85	97·75	125·85	125·85	125·85	130·05	130·05	130·05	40·00	168·00	168·00	113·50	113·50
Air per min. . . A×V=C	cub. ft.	128,870	88,900	80,166	120,816	105,422	101,308	116,654	96,757	45,280	110,712	126,504	118,834	141,534
Water Gauge . . . . . W	in.	1·75	3·25	0·75	1·56	1·55	1·125	1·30	1·00	2·10	1·10	1·60	1·30	1·80
Effective H. P. $\frac{C \times W \times 5{\cdot}2}{33{,}000} = E$	H. P.	35·50	45·50	9·47	29·70	25·75	18·00	23·90	15·24	15·00	19·19	31·89	24·34	40·14
Revs. Engine and Ventilator	per min.	29·30	26·95	19·50	28·78	26·50	26·00	29·92	26·00	55·00	37·00	44·00	36·00	44·00
Cylinders, No., diam., & stroke	in.	2,15,21	2,15,21	2,15,21	2,15,21	2,15,21	2,15,21	2,15,21	2,15,21	1,26,26	1,32,48	1,32,48	1,24,54	1,24,54
Mean effective steam pressure	lb. per in.	53·14	73·57	22·07	47·05	42·65	28·92	34·62	26·125	9·20	5·92	7·88	14·62	19·50
Ind. H. P. from diagrams . I	H. P.	58·59	74·37	16·12	50·75	42·36	28·12	38·74	25·76	36·56	42·69	67·64	64·96	105·80
Effective H. P. . . . . E	H. P.	35·50	45·50	9·47	29·70	25·75	18·00	23·90	15·24	15·00	19·19	31·89	24·34	40·14
Useful Effect Ventr. & Eng. } . . $\frac{E}{I} \times 100$	per cent.	**60·59**	**61·18**	**58·74**	**58·50**	**60·70**	**64·00**	**61·69**	**59·16**	**41·02**	**44·95**	**47·10**	**37·46**	**37·92**

TABLE II. *Ventilator Experiments (continued.)*

Description of Ventilator		Guibal												
Name of Colliery or Mine Ventilator, diam. and width	ft.	Hilda Colliery 50×12				Liverton Iron Mines 36×12		Craggs Hall Iron Mines 30×10		Skelton Iron Mines 30×10		Farnley Wood Colliery 21×7		
Date of Experiment	1875	July 24		Sep. 30		Sep. 17	Oct. 9	Mar. 7		Mar. 8		Mar. 30		
Number of Experiment		14	15	16	17	18	19	20	21	22	23	24	25	26
Anemometer, description		Casella	Casella	Casella	Casella	Casella	Casella	Casella	Casella	Biram	Biram	Biram	Biram	Biram
Do., rev. in 1 min.	rev.	538	348	628	651	1480	1669	94	275	589	272	708	967	327
Velocity of Air (calculated) V	ft. per min.	609	462	685	775	1469	1648	131·6	319·5	665·5	400	774	1022	440
Area of Drift . . . . . A	sq. ft.	150·70	150·70	150·70	150·70	73·84	73·84	175·50	175·50	131·36	131·36	50·26	50·26	50·26
Air per min. . . A×V=C	cub. ft.	91,776	69,623	103,229	116,792	108,470	121,688	23,100	56,072	87,157	52,544	38,900	51,366	22,114
Water Gauge . . . . . W	in.	2·10	0·80	2·40	2·63	2·35	2·55	0·225	1·40	1·50	0·50	0·90	1·65	0·35
Effective H. P. $\frac{C\times W\times 5\cdot 2}{33{,}000}=E$	H. P.	30·36	8·77	39·00	48·40	40·16	48·89	0·82	12·37	20·60	4·14	5·51	13·35	1·22
Revs. Engine and Ventilator	per min.	32·00	20·00	34·00	36·00	46·93	50·73	14·75	42·75	50·00	28·00	53·33	71·60	32·00
Cylinders, No., diam., & stroke	in.	1,42,42	1,42,42	1,42,42	1,42,42	1,30,30	1,30,30	2,14,16	2,14,16	1,24,24	1,24,24	1,18,18	1,18,18	1,18,18
Mean effective steam pressure	lb. per in.	8·55	3·45	8·95	9·98	16·85	18·42	6·96	28·44	17·08	5·91	8·86	16·13	3·69
Ind. H. P. from diagrams . I	H. P.	80·38	20·27	89·73	105·66	84·69	100·07	2·54	30·42	46·81	9·07	10·93	26·71	2·73
Effective H. P. . . . . . E	H. P.	30·36	8·77	39·00	48·40	40·16	48·89	0·82	12·37	20·60	4·14	5·51	13·35	1·22
Useful Effect Ventr. & Eng. . . $\frac{E}{I}\times 100$	per cent.	**37·77**	**43·26**	**43·40**	**45·81**	**47·42**	**48·85**	**32·28**	**40·66**	**44·00**	**45·64**	**50·41**	**50·00**	**44·68**

Mr. Daniel mentioned that in the ventilator experiments, of which the particulars were given in Table II, the same Biram anemometer had been used in Nos. 1 to 3 and 22 to 26, while in all the rest, except No. 17, the same Casella anemometer had been employed; and if therefore there were any slight difference in the agreement of these two instruments, the quantities of air measured in the several experiments with either anemometer would be relatively correct, but might differ slightly in relation to the experiments made with the other instrument. The same remark applied to No. 17 experiment, at Hilda Colliery, which had been made with another Casella anemometer. When practicable it was of course desirable to take all the measurements with the same instrument.

Mr. E. H. Carbutt observed that great pains had evidently been taken by the author of the paper in making such a large number of anemometer experiments for measuring the velocity of the air in the mine drifts; and he should have been glad if some information could have been given as to the extent of rubbing surface over which the air currents had had to pass in travelling through the several mines where the measurements had been made, as upon this the amount of friction would greatly depend. In the working of rotary blowers he had found that, in the case of two air passages, having their areas in the proportion of 1 to 4 and their circumferences as 1 to 2, in order to drive equal volumes of air through them in the same space of time, the velocity of the air would require to be fourfold in the smaller passage; and the power expended, from increase of friction &c., would be thirty-two times as great in the smaller as in the larger air passage. The new ventilator now described, acting by displacement of the air, seemed to him a step in the right direction for the ventilation of deep mines, or of old mines with narrow passages. But there were no doubt small and shallow mines which stood in need of mechanical ventilation, but could not afford the cost of such a ventilator as that now described; and for cases of that kind he was now applying a rotary blower acting upon the same principle of displacement, and was obtaining by that means a vacuum of 6 in. water gauge, instead of only 3¼ in. which appeared to be the highest that had been realised in the ventilator experiments described in the paper. The principal dimensions of this blower upon Root's system, to give 200,000 cub. ft. of air per minute, were 25 ft. diameter of revolvers and 13 ft. width, the centres of the shafts being 16 ft. apart; and the outlet orifice for the escape of the air was 44 ft. long by 13 ft. wide, allowing the air to escape at slow velocity.

Mr. E. J. C. Welch remarked that—whereas a sliding piece, bearing against the periphery of the eccentric drum, and constrained to travel along a line forming a radius of the circle of revolution of the drum itself, would derive a true harmonic motion from the same—the shutter was stated to be driven by a crank and connecting-rod, by which only an approximate harmonic motion could be obtained; and he enquired therefore how the curve formed at the end of the shutter was determined.

Mr. A. Paget said it would be of interest if some information were given respecting the amount of play or windage between the eccentric drum and the shutter, and between the drum and the casing; some clearance he supposed was left to allow of warping, and the amount would be an important item in calculating the effectiveness of the ventilator.

Mr. E. A. Cowper observed that at first sight the ventilator now described recalled some of the old plans of rotary engines, which had a sliding piston or flap or some other moving contrivance always rubbing against the circumference of the casing or eccentric; but further consideration showed that the present plan was quite admissible, in consequence of there being only a light pressure to deal with, and therefore but slight leakage could occur. As the connecting-rod working the shutter was attached at one end to a crank-pin coinciding exactly with the centre of the drum, while the other end of the rod was the centre from which was struck the circular arc forming the bottom extremity of the shutter, it was evident that the sum of the two radii—of the drum and of the shutter—was constantly the same as the length of the connecting-rod; the drum and shutter would therefore work together correctly in all positions, and the amount of clearance between them might be reduced to only the thickness of a sheet of paper by carefully adjusting the connecting-rod to the correct length. With the low pressure of air in working however, the leakage was very insignificant even in the first ventilator erected, in which he understood that, owing to an accidental error in the length of the connecting-rod, the clearance between the shutter and the drum was more than an inch. As there was no rubbing between the circumference of the drum and the casing, and the ends also of the drum he supposed did not rub against the ends of the casing, it was evident that there ought to be very little friction in the working of the machine; and on this account he should have expected to hear of a higher useful effect being obtained. It appeared however that the useful effect was calculated upon the gross Ind. H. P. exerted by the engine, without deducting the friction of the engine itself by taking separate indicator diagrams from the engine when running disconnected from the ventilator. If this were done, he expected the useful effect would be found to compare more favourably with that of the best fans, from which as much as 75 per cent. useful effect was obtained; and he considered so excellent a machine as this ventilator appeared to be ought to do still better than any fan. They were much indebted to the author of the paper for the results of the extensive experiments he had made upon the working of this and other mine ventilators.

Mr. G. F. Deacon enquired which of the anemometers used in the experiments had been found to give the best results. Having himself used different anemometers for measuring the currents of air in sewers, he had found that each instrument failed at low velocities and did not give reasonably accurate results.

Mr. W. S. Hall observed that only one experiment with a Rammell fan was given in the paper, and he did not understand why it did not show as high a percentage of duty as the Waddle fan, as it was in fact only a double Waddle fan, with the advantage that it avoided the tendency of the Waddle fan to run endways. It was mentioned that there were 180 Guibal fans now in use, and 60 Waddle fans; and he should be glad to know how many Rammell fans were at work, and to hear some further particulars as to their working.

Mr. A. L. STEAVENSON said that, having had eighteen years' experience of the use of fans for mine ventilation, he had been much surprised to hear the good results realised with the ventilator now described, particularly as the Guibal fan had hitherto been generally looked upon as unapproachable in useful effect, and deficient only in the degree of vacuum which it was capable of producing. In testing the large Waddle fan at High Park Colliery near Nottingham he had obtained a useful effect of only 40 per cent.; and that construction of fan had seldom yielded better results than those assigned to it in the paper. The low percentage of useful effect obtained with the Guibal fan in these experiments might perhaps be attributable he thought to the special care taken in measuring the velocities of the air, by subdividing the current into so many portions and ascertaining the velocity of each, so as to arrive at a correct average. Excepting the Guibal fan it was evident that there was no fan which could approach the results obtained from the ventilator described in the paper.

The differences observed in the water gauge in the several experiments given in the paper represented the differences in the areas and the rubbing surfaces of the airways through which the air current had to be drawn by the several ventilators. In the ventilator now described the principle of varying capacity was carried out in contradistinction to that of the centrifugal fan. The inferiority of the centrifugal principle was seen in the fact that, if the inlet were closed, a fan would nevertheless be able to continue going round, in consequence of the slip of the air past the blades; but the ventilator now described would either stop under such circumstances or some part of the machinery would have to give way. In the Lemielle ventilator, which acted upon the same principle of varying capacities, the re-entry or leakage of air past the blades of the drum was such that at 25 in. water gauge no discharge was obtained. With the Guibal fan nothing above 5 in. water gauge had been reached, and even with the Lemielle ventilator 6 or 7 in. was not exceeded in ordinary working. The principle of varying capacities was the one that he had advocated for many years, and it appeared to be carried out in a very complete manner in the ventilator described in the paper.

Mr. JEREMIAH HEAD enquired whether the casing of the ventilator was turned or trued up inside in any way, or whether any other means were adopted to prevent leakage between the revolving drum and the casing. In Root's blower, acting on a similar principle, a mixture of tallow and black-lead was used, which he understood had a tendency to accumulate and thus make the rubbing surfaces fit truly together even after working for a length of time.

Mr. J. COOKE, as the inventor of the ventilator described in the paper, considered it had not yet by any means yielded the best results of which it was capable, and there was good reason to suppose the effect would be much increased. It had to be noticed that for ventilating a large mine it was wanted to know beforehand what number of revolutions of the engine would be required per minute; and with the Guibal fan and the other fans referred to in the paper it was a great objection to be unable to tell beforehand the result per revolution, and to be in ignorance therefore of the speed at which the engine would have to run, until the fan had been erected and an actual trial made of its capabilities. But this objection was obviated by the principle of varying capacities, because the effect per revolution was known, and consequently also the number of revolutions per minute that the engine would be required to make.

Mr. DANIEL agreed in considering that the water gauge was a sufficient indication of the resistance encountered by the air current in the passages of a mine, the height of the gauge increasing as the length of the passages and inversely as their sectional area. All anemometers should be tested in order to obtain a proper formula for correcting the readings, as he had found the tables supplied with the instruments were not to be relied on.

The amount of clearance or play between the revolving drum and the casing of the ventilator was intended to be not more than $\frac{3}{16}$ or $\frac{1}{4}$ inch at most, both at the ends and at the circumference of the casing, and also between the drum and the vibrating shutter; and in the two ventilators now erected this amount of clearance had been adhered to as regarded the ends and the circumference of the casing; but owing to an accidental error of adjustment in keying on the levers working the shutters, the clearance between the curved shutters and the drums was as much as 1 inch or more, instead of only $\frac{1}{4}$ inch. Notwithstanding this extent of clearance however, which continued throughout the whole of the revolution of the drums, it was evident that the amount of leakage must be very inconsiderable, for the actual measured discharge in one of the experiments had amounted to as much as 4166 cub. ft. per rev., and the theoretical maximum displacement amounted to only about 4530 cub. ft. per rev. The flat end-plates of the casings had been planed inside in the two ventilators now at work, so that the drums worked perfectly smooth and true with about $\frac{1}{4}$ inch clearance at each end; but in the ventilators which were now being made it was not intended to plane the end-plates, as they were found to be quite true enough if put together as cast, without planing; the end-plates were now being cast in rather larger segments than in the two first ventilators. In making the drums, the T iron rings were turned perfectly circular, and then covered with the sheeting of steel plates 1-16th inch thick. The circumference of the casing being similarly constructed, the whole of the ventilator was thus made of iron or steel, and could be erected very quickly; very slight foundations were required, consisting only of the two low parallel walls for carrying the cross girders on which the ventilator casing was fixed. The cost of the Upleatham and Lofthouse ventilators, including in each case the pair of drums and casings with engine and boiler complete, had been about £4500 each; whilst to do the same work as either of these ventilators the cost of a Guibal fan, including the brickwork, would be from £7000 to £8000.

In the experiments with the ventilators he regretted there had not been the means of disconnecting the engine and running it separately from the ventilator; and it had therefore been impossible to obtain indicator diagrams showing the friction of the engine alone. It would also have been desirable to obtain diagrams showing the power required to drive the ventilator when running without any water-gauge pressure, so as to ascertain the friction of the machine as well as of the engine; but that could only have been done by opening the air drifts close to the ventilator, which was impracticable on account of stopping the mine ventilation.

The number of Rammell fans now in use he believed was not more than six or seven; he had not been able to obtain an opportunity of experimenting upon any others than the one at the Cannock Chase Colliery.

The CHAIRMAN considered the ventilator described in the paper possessed a decided advantage over a fan in the circumstance that, like the Root's blower, it discharged a definite volume of air at each revolution, and the effect due to each revolution was thus known beforehand. As regarded leakage, whether between the drum and the shutter or the drum and the casing, he suggested that the amount might be easily ascertained by blocking up either the inlet from the mine or the discharge from the ventilator, and then putting the machine in motion and observing the speed at which the leakage would admit of its being driven under those conditions, and noting the corresponding water gauge that was obtained; this would give a true measure of the whole amount of leakage. In any case a much higher result in useful effect would be secured by this ventilator than could be obtained from any fan yet introduced. It was unfortunate that there had not been the means of ascertaining the resistance of the engines driving the ventilators, in order that the power expended in useful work might be correctly known; but they were much indebted to the author of the paper for the great pains he had taken in carrying out so extensive a series of experiments upon different kinds of ventilators.

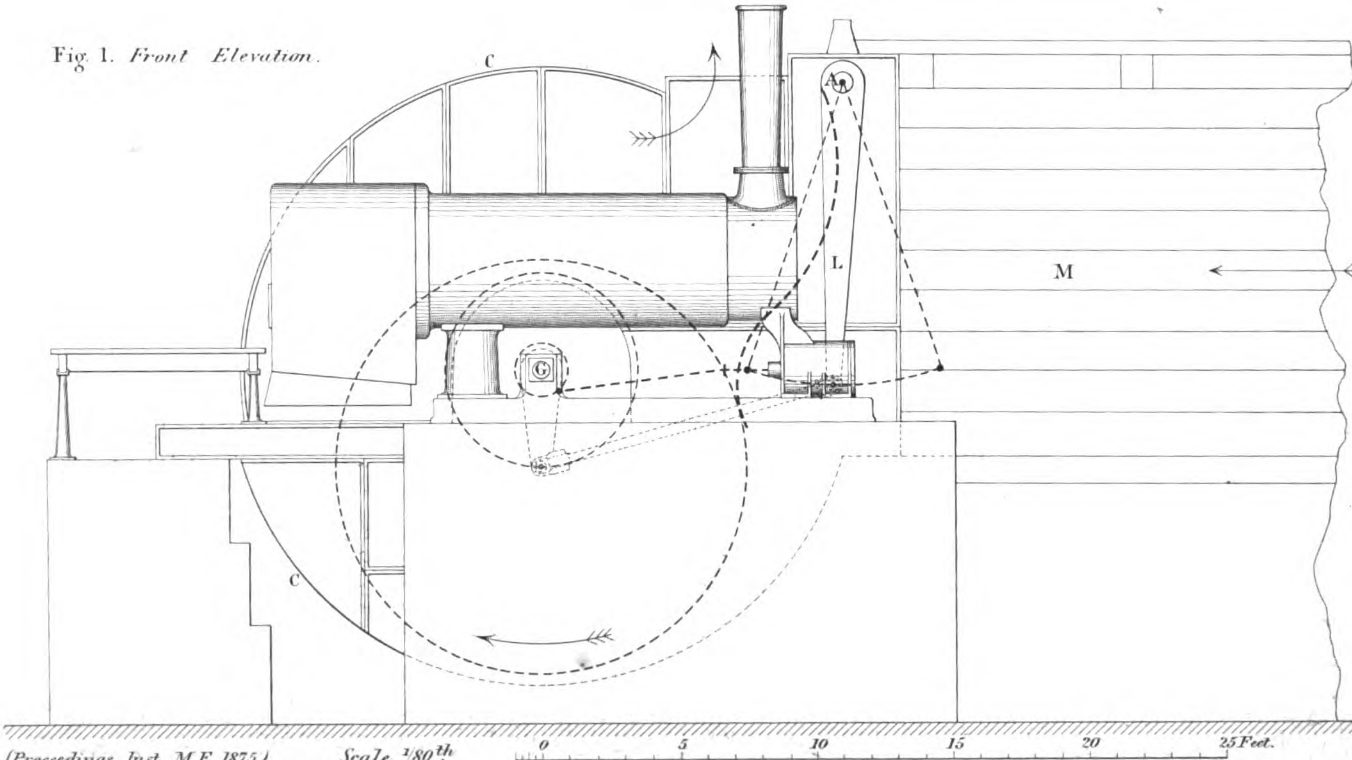
He proposed a vote of thanks to Mr. Daniel for his paper, which was passed.

The following paper was then read :—

MECHANICAL VENTILATORS FOR MINES.

Cooke's Ventilator.

Fig. 1. *Front Elevation.*



(Proceedings Inst. M.E. 1875.) *Scale 1/80th*

MECHANICAL VENTILATORS FOR MINES.

Cooke's Ventilator.

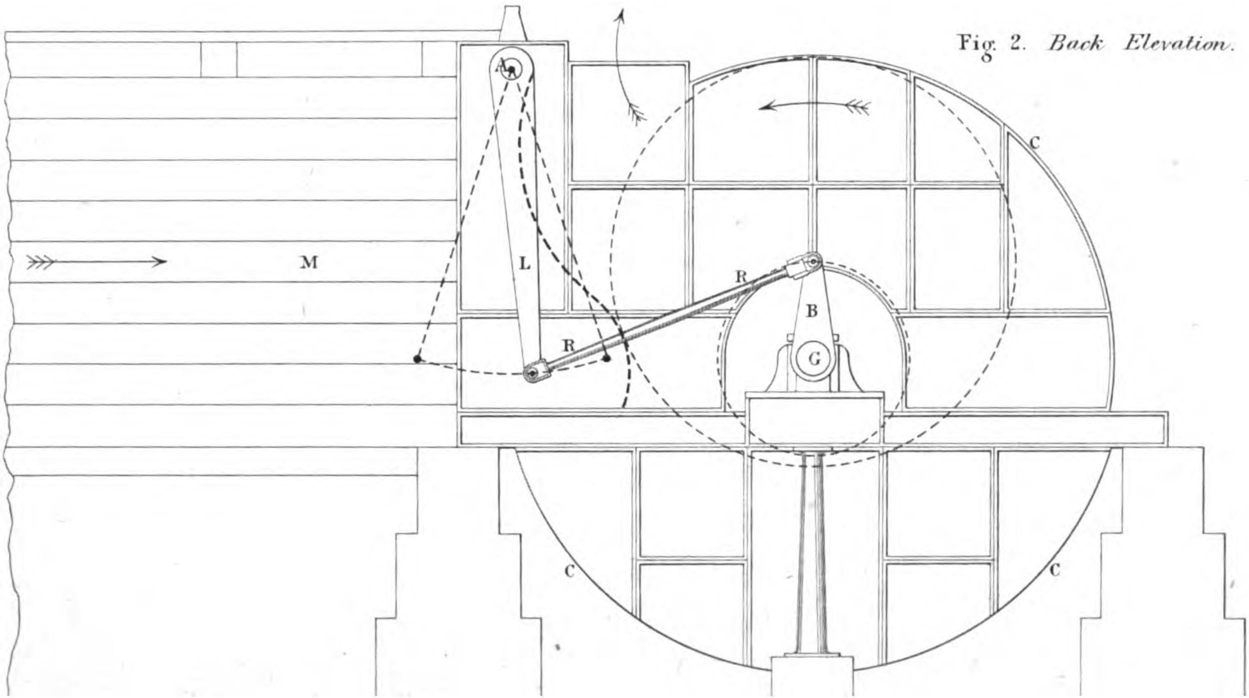


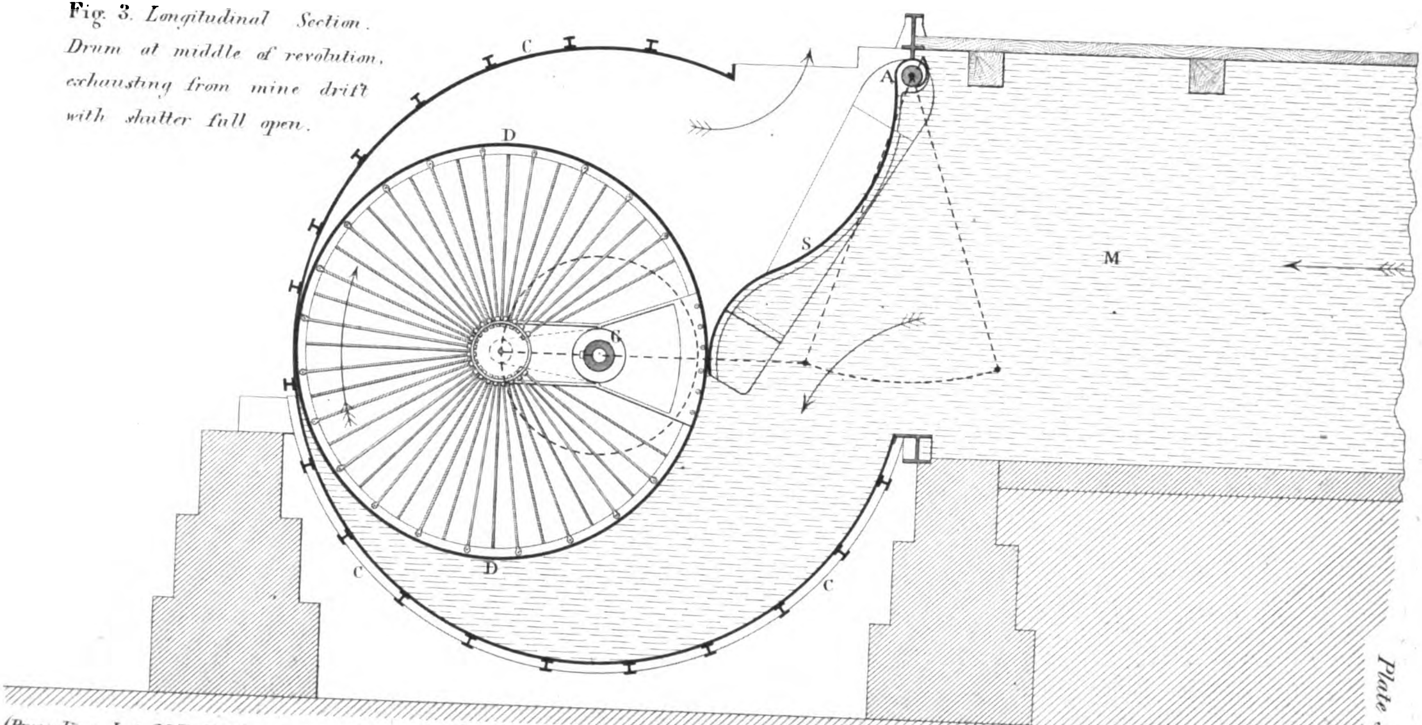
Fig. 2. *Back Elevation.*

MECHANICAL VENTILATORS FOR MINES.

Cooke's Ventilator.

Plate 51.

Fig. 3. *Longitudinal Section. Drum at middle of revolution, exhausting from mine drift with shutter full open.*



(Proceedings Inst. M.E. 1875.)

Scale 1/80th

0 5 10 15 20 25 Feet.

Plate 51.

MECHANICAL VENTILATORS FOR MINES.

Cooke's Ventilator.

Plate 52.

Fig. 4. *Longitudinal Section.*
Drum at beginning of revolution with shutter closed.

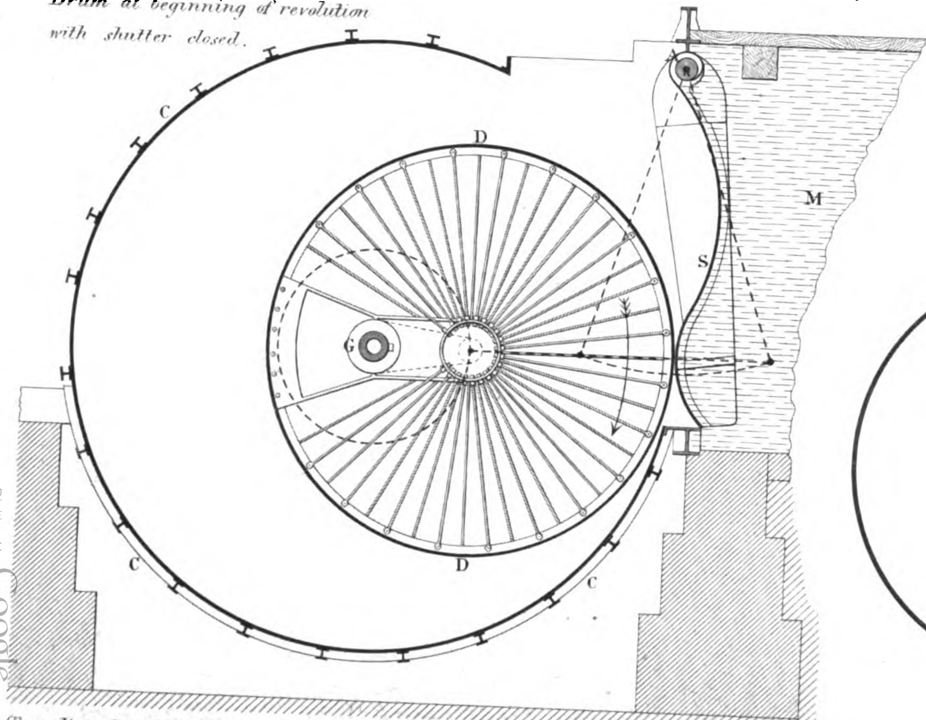
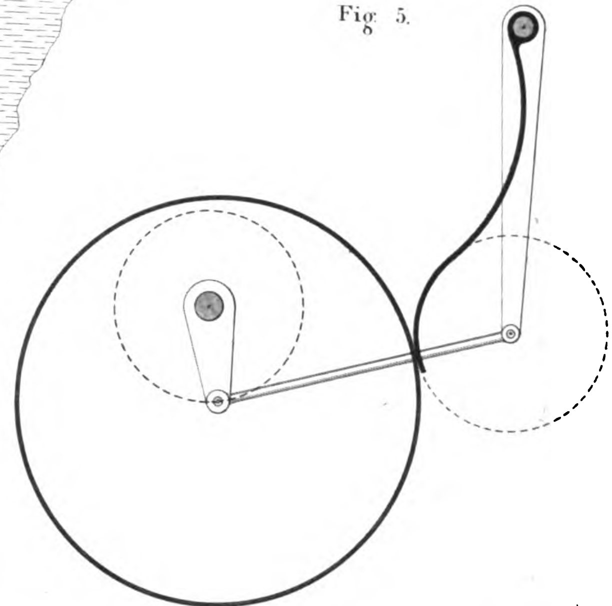


Fig. 5.



(Proceedings Inst. M. E. 1875.)

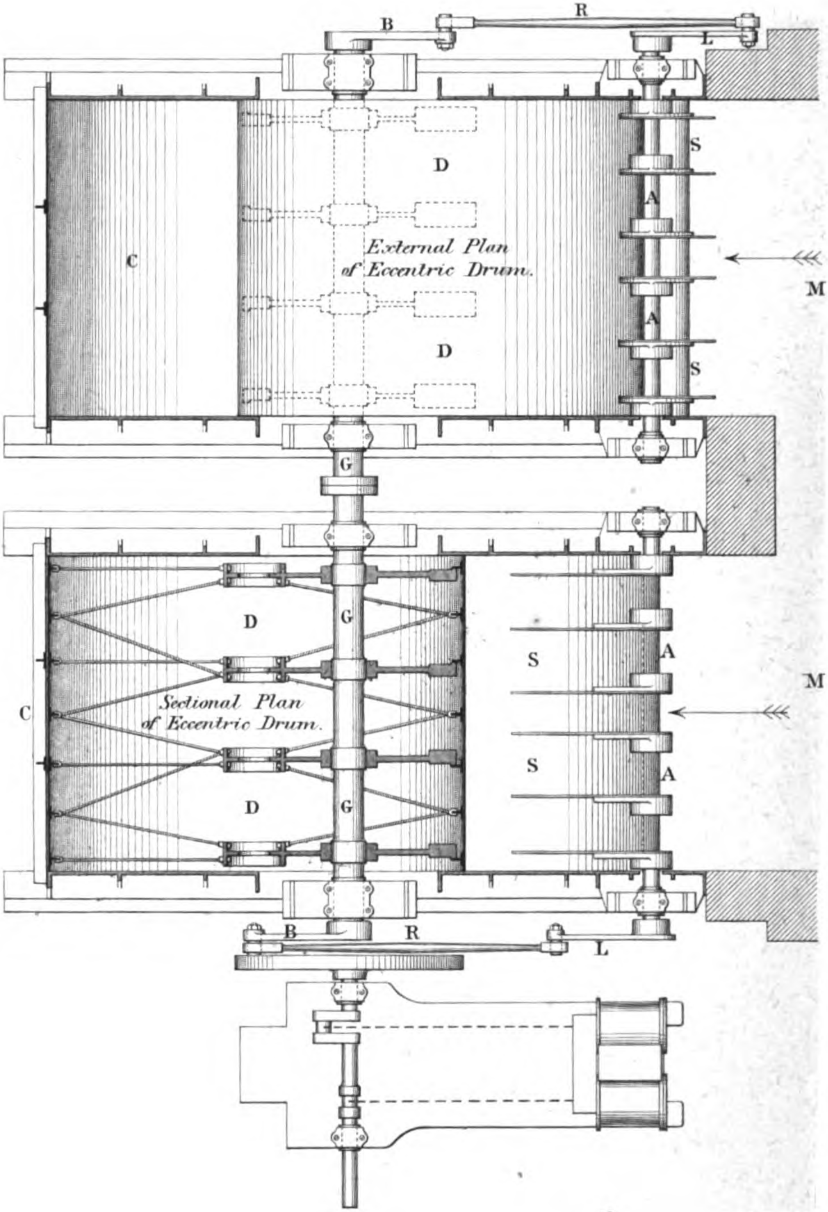
Scale 1/80th

0 5 10 15 20 25 Feet.

Plate 52.

Cooke's Ventilator.

Fig. 6. *Sectional Plan of pair of Ventilators.*



(Proceedings Inst. M. E. 1875.)

Scale 1/80 th

0 5 10 15 20 25 Feet

Indicator Diagrams from Engines driving Ventilators.

Fig. 7. *Cooke's Ventilator at Lofthouse Iron Mines.*

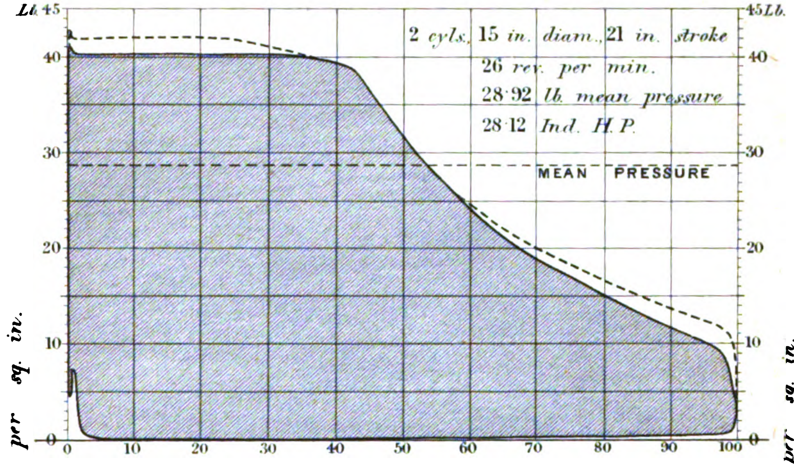
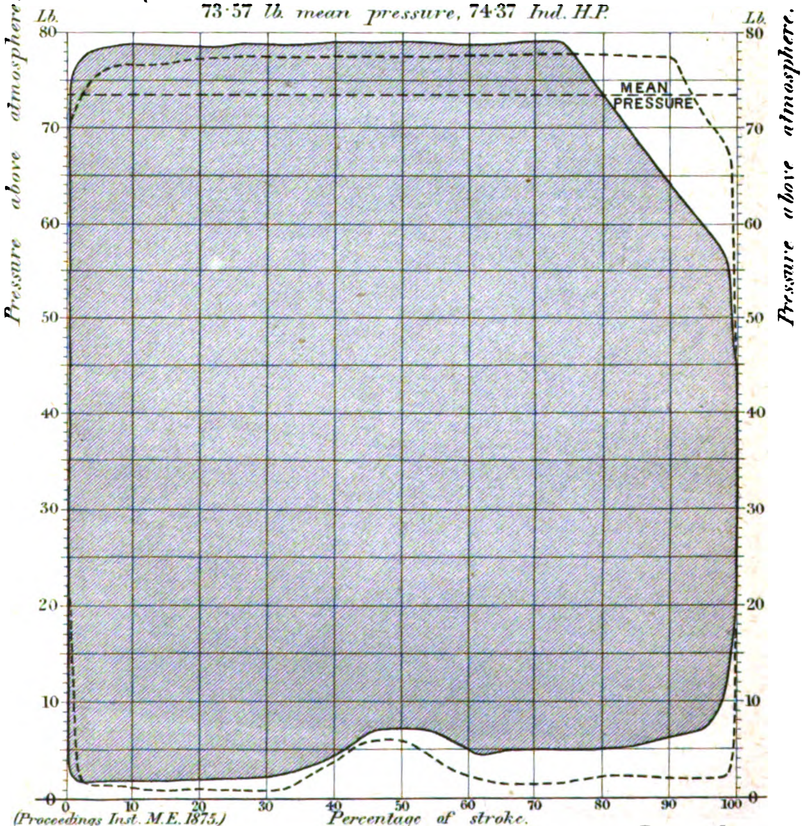


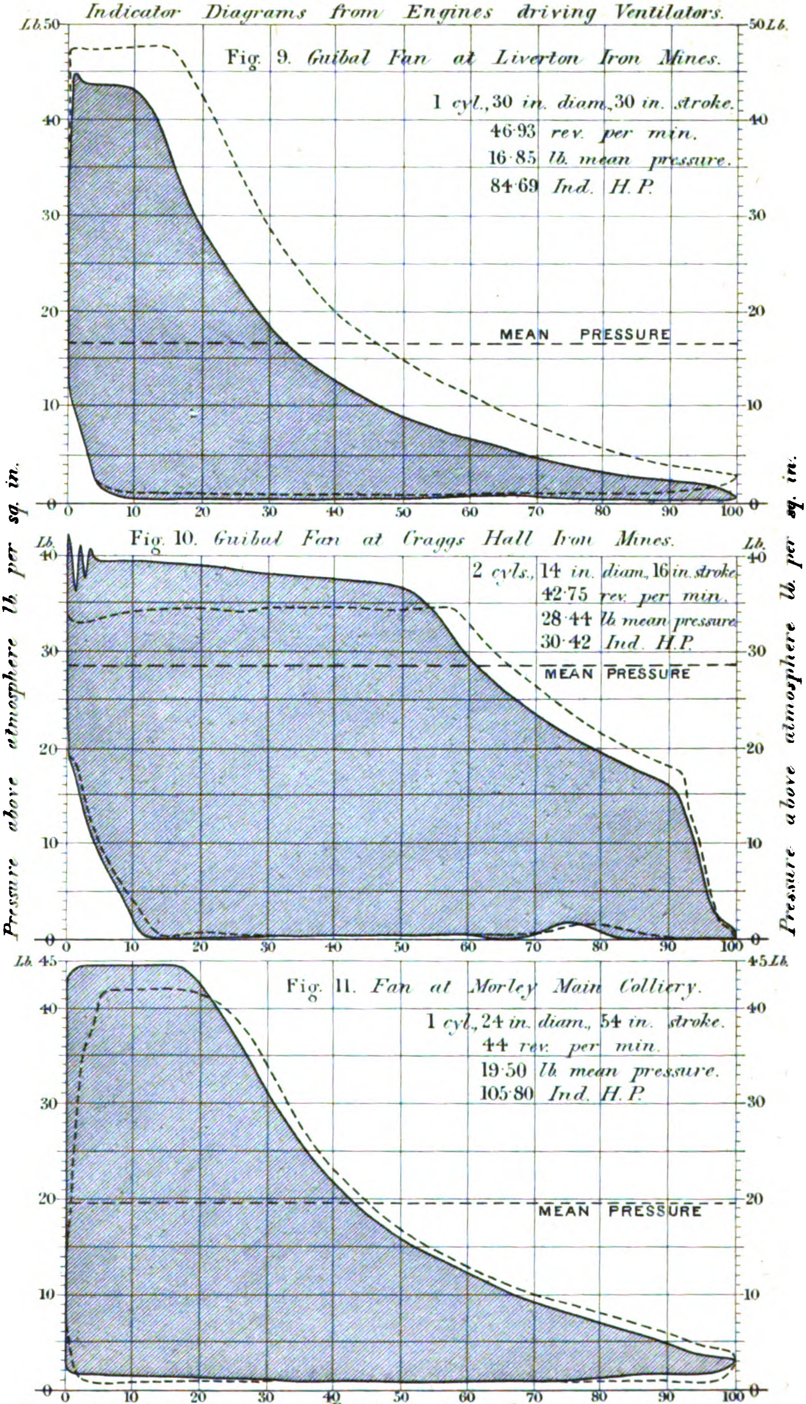
Fig. 8. *Cooke's Ventilator at Upleatham Iron Mines.*
2 *cyls.*, 15 *in. diam.*, 21 *in. stroke*, 26·95 *rev. per min.*
73·57 *lb. mean pressure*, 74·37 *Ind. H.P.*



(Proceedings Inst. M.E. 1875.)

MECHANICAL VENTILATORS FOR MINES. *Plate 55.*

Indicator Diagrams from Engines driving Ventilators.



(Proceedings Inst. M. E. 1875.)

MECHANICAL VENTILATORS FOR MINES.

Sections of Mine Drifts, showing positions of Anemometer in experiments for measuring Air currents.

Fig. 12. *Upleatham.*

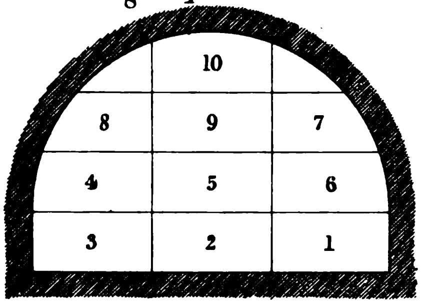


Fig. 13. *Lofthouse.*

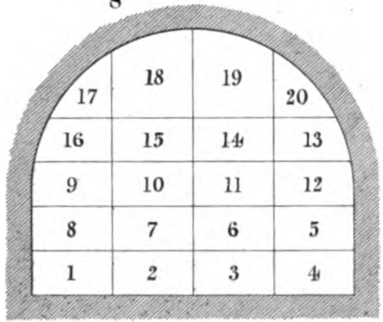


Fig. 14. *Aberaman.*

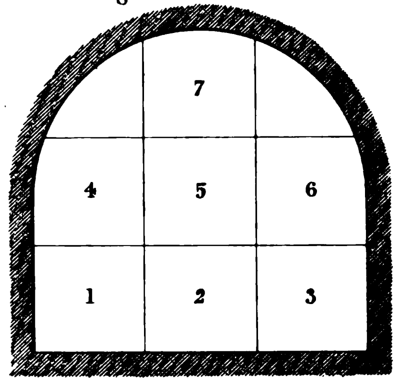


Fig. 15. *Hilda.*

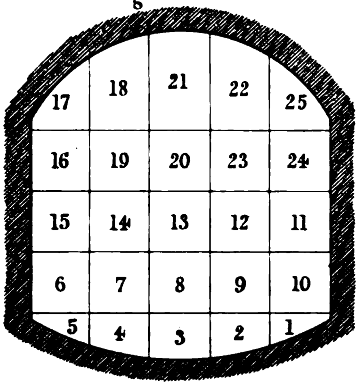


Fig. 16. *Morley Main.*

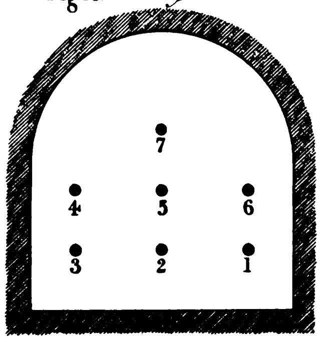


Fig. 17. *Liverton.*

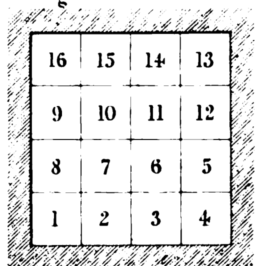
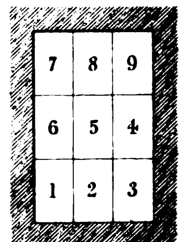


Fig. 18. *Cannock Chase.*



(Proceedings Inst. M. E. 1875.)

Scale 1/100th

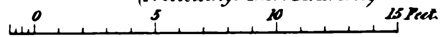


Plate 56.