ON THE MODE OF WORKING
AND THE MECHANICAL APPLIANCES EMPLOYED
IN THE MIDLAND COALFIELD.

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One of the principal advantages of holding the annual meetings of this Institution in different localities is the opportunity that is afforded for the examination of the engineering operations of the district, and particularly those in which the same end is accomplished by very different means in different localities. The annual meeting of last year was held in the Northern Coalfield, and much was seen on that occasion of the modes of work there practised. The present meeting takes place at the extreme end of the Midland Coalfield; and as coal is the food of mechanical power, and as the extraction, hauling and winding of it to the surface are all engineering operations, it will be felt that the subject of this paper is a suitable one for the present occasion.

Working.—The initial problem in all coal mining is the mode of dealing with the load of the different strata which overlie the coal seams, and which impose a statical pressure upon the unwrought seam in the ratio of its depth below the surface. There are two principles upon which this question can be dealt with; and both of these when applied in practice may and do receive very numerous modifications. In the early days of coal mining there does not appear to have been any intercourse between different mining districts; and it is somewhat remarkable that, whilst in some places the leading idea in the most ancient workings appears to have been to work the coal in galleries and support these by leaving pillars on either side of them, in others the coal was removed entirely, and the necessary openings or working places along the edges of the solid seam were secured by taking advantage of the resistance

which the overlying rocks oppose to vertical fracture or shearing. In some localities therefore methods of "pillar" work appear to be indigenous; in others the practice has always been to remove the whole of the coal at one operation, or as it is commonly called to work it "longwall."

These two modes of working are illustrated in the sectional diagrams Figs. 1 and 2, Plate 42. The statical pressure of the overlying strata upon the seam of coal A A is equal in round numbers to 1 lb. per square inch for each vertical foot of depth. By the method of pillar work, Fig. 1, narrow portions B B are removed, and the weight previously supported by them is thrown upon the pillars left between. In the method of longwall work, Fig. 2, the object in view is to encourage the subsidence of the strata over the whole wrought area C, and thus reduce to a minimum the additional pressure thrown upon the solid seam at the face of the working D: and to this end the areas of extraction of the coal are made large, and the working face is kept in a straight line in order to facilitate the formation of lines of fracture in the superincumbent mass. Thus supposing a longwall face of say 500 yards length is advancing across the section D A, Fig. 2, in the direction of the arrow: as the coal is removed, the superincumbent weight is thrown upon the seam in advance of the working face, until it is sufficient either to bend down or fracture the rocks immediately behind the face so that they rest on the floor of the wrought mine. Practically a sagging or bending of the strata first takes place, and then a line of fracture is formed, as in Fig. 2; this resolves itself ultimately into a sort of wave or undulation of the strata higher up, which follows continually the advancing face. It is therefore evident that the longer and straighter are the advancing faces, the more promptly will this subsidence of the strata and consequent relief of the extra pressure on the unwrought coal ensue; and the principal point in longwall mining is to reduce to a minimum the additional pressure that is thrown upon the unwrought coal by the act of working. The absolute amount of this additional pressure, and consequently the difficulty of keeping the working places open, is but slightly affected by the vertical depth of the seam below the surface; for although the weight of the overlying rocks is thereby

increased, the thickness to be fractured and therefore also the resistance to shearing are increased in the same ratio.

In the actual working of a longwall mine, the first operation is to drive headways in the solid coal; and when these have attained a sufficient length, working faces or stalls are started from the side of one of them, and the coal is removed in a series of slices parallel to the headway course. To support the roof of the working places, timber props are set, and pack walls of loose stone are built up at regular intervals. As the faces advance, the timber props are removed, and the roof settles down, often without fracture, upon the pack walls. The roadways for the conveyance of the coal are carried at intervals of 20, 30, or 40 yards between pairs of pack walls; and as the roof settles down and squeezes everything tight, the requisite height for the roadway is maintained by ripping or cutting up into the roof. The roadways therefore of a longwall coal mine are carried through the goaf or wrought area, and practically in the roof of the coal seam.

Haulage.—The application of power for the underground haulage of coal presents many interesting points for the consideration of engineers. No successful experiments have as yet been made in direct traction by a locomotive; the heat and smoke would not only vitiate the ventilation, but also introduce the risk of fire, and in most cases soften and break down the roof of the roadways. It seems improbable therefore that direct steam traction will ever be used, except in a case where there is an arched roadway, moderately level, and which can be provided with a distinct ventilation: a combination of circumstances that is not likely to occur often in practice. Attention may now be confined accordingly to stationary engines driving ropes or chains.

The simplest case of underground haulage is when a loaded train is drawn up an incline by a *single rope*, and the weight of the empty train is sufficient to take the rope out again. The method of hauling by *main and tail ropes* is a modification of the foregoing, designed to work roads which are either level or of mixed rising and falling gradients; and it consists simply in adding a second or

tail drum to the single drum of the former method. The main drum hauls the load towards the shaft, and the tail drum draws the empty wagons back again by means of a tail rope, which is led away from the drum to the extreme end of the roadway, passes round an end turning pulley there, and is attached to the tail end of the train of wagons, the arrangement consisting virtually of two drums pulling at opposite ends of the same rope. A third method of haulage is by the *endless rope*, which is driven either by a clip pulley or by grooved wheels; the wagons are attached in trains to the rope by means of clip tongs, which grip the rope and enable it to draw the train. In all these methods the power is applied by means of a rope supported on carrying rollers which are fixed at intervals along the floor of the roadway, and the wagons are connected together in long trains, as shown in Fig. 3, Plate 42. A fourth method, which has an important superiority in economy of power, is shown in Fig. 4, and consists in using an *endless chain*, and running the wagons not in long trains, but singly, spaced one by one at intervals along the roadway, and carrying the chain, which rests upon them instead of running upon rollers.

It is not intended within the limits of the present paper to attempt a detailed analysis of the advantages and disadvantages of these different methods of hauling, but simply to call attention to what may be considered the mechanical aspects of the question. A roadway driven in a coal seam has rarely the chance of being both level and straight. Even in districts where the strata have one general direction of dip, there are minor undulations which would require that a roadway driven along a level line should take a somewhat circuitous course in order to follow the seam of coal; or if driven straight, in the mean direction of the level line, that it should have a rising and falling line of section. In arranging any general system of underground haulage it is necessary to carry main roadways not merely on a level course but to the rise or dip, or indeed in any direction which may be dictated by the position of the coal to be worked in reference to the winding shafts. Any method of hauling trains of wagons evidently obtains its most favourable circumstances when the roadway is at once level and

straight, as the useless work to be done in both directions consists in overcoming the friction and bending resistances of the ropes on the rollers and turnwheels, and these resistances are least under those circumstances. If to keep a roadway level it is made more circuitous, the friction of the wagons remains approximately the same, but each additional bend increases the rope friction and wear and tear. If to avoid this increased rope friction the roadway is taken straight, with rising and falling gradients, the state of circumstances approaches that shown in the rough section, Fig. 3, Plate 42, representing a roadway of undulating gradient, on which the haulage is effected by main and tail ropes or endless rope. In ascending the bank E the engine has to overcome the gravity of the loaded train, the friction of the tubs, and the friction of the ropes and drums. In descending the slope G the gravity of the loaded train is probably sufficient to overcome its own friction, and to make it necessary to apply the break to the tail drum in order to prevent the train from over-running the engine. In the return of the empty train there is a reversal of the strains; the power of the engine must now be transmitted to the extreme end of the roadway and brought back to the tail end of the train, and the action of the load in traversing the ascending and descending gradients has much the same character as before. Practically upon a roadway of moderate length and with its extreme ends at the same level it is found necessary to expend nearly as much power in returning an empty train as in bringing out the loaded one.

In the case of the "endless-chain" haulage, shown in Fig. 4, Plate 42, the strains are of a different character; and the contrast between this method and the preceding will be clearly brought out by supposing the endless chain applied to effect the haulage over a roadway with the same ascending and descending gradients as in the previous case, Fig. 3. The chain being now carried by the wagons, Fig. 4, has no direct friction on the roadway, and increases the wagon friction by the mere addition of its weight. The wagons in fact serve as running rollers to the chain, and by their height prevent it from touching the ground. The loaded wagons descending the incline G transmit a hauling power minus their wheel friction to

the wagons ascending the bank E. The same state of balance exists between the empty return wagons spaced uniformly along the road; and as the turnwheels at the ends of the roadway connect the two chains of wagons together, a complete equilibrium of load would be established if both were empty. This holds true whatever are the undulations of the roadway, and whether the ends of it are at the same level or not. Consequently the work to be done when one of the lines of wagons is loaded and the other empty is merely to overcome the gravity of the load and the wheel friction of both lines of wagons. The average coefficient of friction of pit wagons is about 1-50th of their weight; and it is found that if an endless-chain roadway has a mean fall with the load of 1 in 30, the gravity of the full wagons supplies sufficient hauling power to overcome the whole wheel friction and to take the empty wagons up.

In the practical working of this mode of hauling it is usual for the chain to lie on the top of the wagons, resting on their ends; and the chain drops loosely into a fork on one of the ends, for connecting the wagon. But in the collieries of this district, it is the practice to send out large blocks of coal, which rise considerably above the top of the wagon, and the loading of these is facilitated by leaving one end of the wagon open. On this account in the Hucknall Colliery, of which a general design is shown in Fig. 9, Plate 44, the chain is carried by a small hook H attached to the middle of the outer side of each wagon, Figs. 5 to 7, Plate 43; and the tendency of the wagons to twist on the rails is found to be insignificant, and is also checked by the tension of the chain which extends all along the side of each wagon. The chain of its own accord lifts itself off the hook as each wagon in succession approaches the end turning pulley, as seen in Fig. 6. The speed of the chain is slow, rarely exceeding 3 miles per hour, and the tubs are spaced at intervals of from 20 to 25 yards along it. In the colliery diagram, Fig. 9, M M represent the main roadways of the mine, along which as the workings extend the chain haulage is to be applied, as indicated by the dotted lines in the roadways; and J J represent short branch ways through which the coal is conveyed from the working faces to the chain roads.

Raising.—The application of steam power to the raising of coal is not one that is favourable to the realisation of a high percentage of useful effect from the gross power expended. Although it is possible to balance accurately the weight of the cages, tubs, and ropes used in winding, yet the large amount of power expended in bringing this great weight of machinery from a state of rest into rapid motion every time a load is drawn to the top is unavoidably lost. The general method of winding coal is by the alternate wrapping and unwrapping of a pair of ropes coiled in opposite directions on drums or rope-rolls driven by the engine, as shown in Fig. 15, Plate 46. As one rope is wound up, the other is unwound, and thus the cages attached to them are approximately balanced. In deep shafts however the weight of the ropes exceeds the net load, and it is usual to balance them either by a third special drum and counterbalance chain, as in Figs. 12 and 13, or by coiling them upon a double conical drum, as in Fig. 14, the angle of the cone being such that the moments of load with empty cages are at every position of the cages approximately the same. The actual working of a colliery winding engine consists of a rapid series of alternate motions in opposite directions. In raising a large tonnage of coal, each journey of the cages is effected in less than a minute, and in each journey it is necessary to put the machinery into motion and to bring it to rest within that space of time; and when cages are used having two or more decks or flats, these have all to be raised and lowered to their proper positions for loading or discharge.

For the purpose of elucidating some points of interest in connection with this class of machinery, experiments have been made by the writer with three engines of different descriptions, at work at collieries in the Midland coalfield, and each capable of raising coal at the rate of 100 tons per hour.

No. 1 is a 40-inch single-cylinder high-pressure vertical engine of 5 feet stroke, shown in Figs. 12 and 13, Plate 46, which is fitted with a pair of cylindrical flat-rope drums DD 12 feet diameter, and a small balance drum and chain B, the action of the balance chain being to assist the engine until the cages meet, and then to absorb power during the remainder of the run; a weight W of 24 cwts. is

suspended at the bottom of the balance chain, which works in a small pit. This engine is at work at the Cinderhill Colliery near Nottingham. The depth of the shaft is 222 yards, and the weight of the rope is 16 lbs. per yard, giving $31\frac{3}{4}$ cwts. as the total weight of rope suspended in the shaft. Each cage weighs empty $25\frac{1}{2}$ cwts., and contains three coal tubs weighing 5 cwts. each; and the weight of coals drawn in each lift is 33 cwts.

No. 2 is a horizontal high-pressure engine, shown in Fig. 14, with a pair of 36-inch cylinders and 6 feet stroke, fitted with a double conical round-rope drum D, the cone increasing from 20 feet to 30 feet diameter. This engine is at work at the Kiveton Park Colliery near Sheffield. The depth of the shaft is 406 yards, and the weight of the rope is 9 lbs. per yard, giving $32\frac{1}{2}$ cwts. as the total weight of rope suspended in the shaft. Each cage weighs empty 20 cwts., and contains two tubs weighing $5\frac{1}{2}$ cwts. each; and the weight of coals drawn in each lift is 22 cwts.

No. 3 is a horizontal high-pressure engine, shown in Fig. 15, with a pair of 36-inch cylinders and 6 feet stroke, fitted with a pair of cylindrical flat-rope drums DD 14 feet diameter, without counterbalance, the drums being constructed of wrought iron. This engine is at work at the Hucknall Colliery near Nottingham. The depth of the shaft is 413 yards, and the weight of the rope is $14\frac{1}{2}$ lbs. per yard, giving $53\frac{1}{2}$ cwts. as the total weight of rope suspended in the shaft. Each cage weighs empty 30 cwts., and contains four tubs weighing $6\frac{1}{4}$ cwts. each; and the weight of coals drawn in each lift is 45 cwts.

These cases afford therefore instances of a conical drum, and of balanced and unbalanced cylindrical drums. The accompanying Tables give the details of the experiments, as to gross and net moments of load, effective steam pressure and engine power, in each revolution of the engines; and the diagrams, Figs. 16, 17, and 18, Plate 47, show these moments of load and the power actually expended in raising one load or cage of coal. The horizontal lines in these diagrams represent the successive revolutions of the engine, the dotted line shows the moment of the load throughout its ascent, and the full line shows the corresponding moment of the power

TABLE I.

No. 1 Winding Engine. Single Cylinder, 40 ins. diam., 5 ft. stroke.

(Cinderhill Colliery.)

Moments of Load and Engine Power in each Revolution. (See Figs. 12 and 16, Plates 46 and 47.)

No. of Revolution.	ASCENDING LOAD.				DESCENDING LOAD.				Net Load on Engine WITHOUT Balance Chain.	BALANCE CHAIN.				Net Load on Engine WITH Balance Chain.	ENGINE POWER.	
	Weight of Cage, Tubs, and Coal.	Weight of Rope.	Distance travelled.	Moment of Load.	Weight of Cage and Tubs.	Weight of Rope.	Distance travelled.	Moment of Load.		Weight at bottom of Chain.	Weight of Chain.	Distance travelled.	Moment of Chain.		Effective Steam Pressure, Lbs. per sq. in.	Total Engine Power.
No.	Lbs.	Lbs.	Ft.	Ft.-lbs.	Lbs.	Lbs.	Ft.	Ft.-lbs.	Ft.-lbs.	Lbs.	Lbs.	Ft.	Ft.-lbs.	Ft.-lbs.	Lbs.	Ft.-lbs.
1	8232	3552	41.6	490,214	4536	257	48.1	230,543	259,671	2700	60	10.7	29,532	230,139	32.8	411,968
2	"	3332	42.1	486,844	"	513	47.6	240,332	246,512	"	140	10.1	28,684	217,828	28.2	354,192
3	"	3109	42.6	483,127	"	766	47.1	249,724	233,403	"	228	9.5	27,816	205,587	28.2	354,192
4	"	2883	43.1	479,056	"	1016	46.6	258,723	220,333	"	324	8.9	26,914	193,419	26.9	337,864
5	"	2654	43.6	474,630	"	1263	46.1	267,334	207,296	"	428	8.3	25,962	181,334	20.4	256,224
6	"	2422	44.1	469,841	"	1507	45.6	275,561	194,280	"	540	7.7	24,948	169,332	20.4	256,224
7	"	2187	44.6	464,687	"	1748	45.1	283,408	181,279	"	660	7.1	23,856	157,423	20.1	252,456
8	"	1949	45.1	459,163	"	1986	44.6	290,881	168,282	"	...	6.8	...	168,282	20.1	252,456
9	"	1708	45.6	453,264	"	2221	44.1	297,984	155,280	"	660	7.1	-23,856	179,136	20.1	252,456
10	"	1464	46.1	446,986	"	2453	43.6	304,720	142,266	"	540	7.7	-24,948	167,214	17.1	214,776
11	"	1217	46.6	440,323	"	2682	43.1	311,096	129,227	"	428	8.3	-25,962	155,189	17.1	214,776
12	"	967	47.1	433,273	"	2908	42.6	317,114	116,159	"	324	8.9	-26,914	143,073	16.4	205,984
13	"	714	47.6	425,830	"	3131	42.1	322,781	103,049	"	228	9.5	-27,816	130,865	-25.0	-314,000
14	"	458	48.1	417,989	"	3351	41.6	328,099	89,890	"	140	10.1	-28,684	118,574	-24.3	-305,208
15*	"	199	38.1	321,221	"	3552	38.1	308,153	13,068	"	60	10.7	-29,532	42,600	-10.0	-94,200
Totals			666.0	6,746,448			666.0	4,286,453	2,459,995			131.4	...	2,459,995	Net	2,650,160

* The last turn is only about three quarters of a revolution, and the effective steam pressure is estimated at -10 lbs.

TABLE II.

No. 2 Winding Engine. Two Cylinders, 36 ins. diam., 6 ft. stroke.

(Kireton Park Colliery.)

Moments of Load and Engine Power in each revolution. (See Figs. 14 and 17, Plates 46 and 47.)

No. of Revolution.	ASCENDING LOAD.				DESCENDING LOAD.				Net Load on Engine.	ENGINE POWER.	
	Weight of Cage, Tubs, and Coal.	Weight of Rope.	Distance travelled.	Moment of Load.	Weight of Cage and Tubs.	Weight of Rope.	Distance travelled.	Moment of Load.		Effective Steam Pressure. Lbs. per sq. in.	Total Engine Power.
No.	Lbs.	Lbs.	Ft.	Ft-lbs.	Lbs.	Lbs.	Ft.	Ft-lbs.	Ft-lbs.	Lbs.	Ft-lbs.
1	5936	3654	66.7	639,653	3472	282	94.2	353,627	286,026	41.6	1,016,371
2	"	3454	70.6	662,934	"	564	94.2	380,191	282,743	37.0	903,984
3	"	3242	74.5	683,761	"	846	94.2	406,756	277,005	33.0	806,256
4	"	3018	78.4	701,994	"	1128	94.2	433,320	268,674	33.0	806,256
5	"	2782	82.3	717,491	"	1410	94.2	459,884	257,607	33.0	806,256
6	"	2534	86.2	730,114	"	1692	94.2	486,449	243,665	29.1	710,971
7	"	2274	90.1	739,721	"	1974	94.2	513,013	226,708	29.1	710,971
8	"	2002	94.2	747,760	"	2246	90.1	515,192	232,568	29.1	710,971
9	"	1720	94.2	721,195	"	2506	86.2	515,304	205,891	28.4	693,869
10	"	1438	94.2	694,631	"	2754	82.3	512,400	182,231	39.7	969,950
11	"	1156	94.2	668,066	"	2990	78.4	506,621	161,445	37.5	916,200
12	"	874	94.2	641,502	"	3214	74.5	498,107	143,395	33.0	806,256
13	"	592	94.2	614,938	"	3426	70.6	486,999	127,939	31.0	757,392
14	"	310	94.2	588,373	"	3626	66.7	473,437	114,936	17.9	437,333
15*	"	28	9.3	55,465	"	3654	9.3	66,272	10,807	10.0	30,510
Totals			1,217.5	9,607,598			1,217.5	6,607,572	3,000,026		Net 3,248,264

* The last turn is only about one eighth of a revolution, and the effective steam pressure is estimated at — 10 lbs.

TABLE III.

No. 3 Winding Engine. Two Cylinders, 36 ins. diam., 6 ft. stroke.
(Hucknall Colliery.)

Moments of Load and Engine Power in each revolution. (See Figs. 15 and 18, Plates 46 and 47.)

No. of Revolution.	ASCENDING LOAD.				DESCENDING LOAD.				Net Load on Engine.	ENGINE POWER.	
	Weight of Cage, Tubs, and Coal.	Weight of Rope.	Distance travelled.	Moment of Load.	Weight of Cage and Tubs.	Weight of Rope.	Distance travelled.	Moment of Load.		Effective Steam Pressure. Lbs. per sq. in.	Total Engine Power. H.P.
No.	Lbs.	Lbs.	Ft.	Ft.-lbs.	Lbs.	Lbs.	Ft.	Ft.-lbs.	Ft.-lbs.	Lbs.	Ft.-lbs.
1	11,200	6000	48.5	834,200	6160	287	57.3	369,413	464,787	32.0	78,824
2	"	5767	48.9	829,686	"	562	56.9	382,482	447,204	32.0	81,824
3	"	5532	49.3	824,888	"	835	56.5	395,217	429,671	32.0	781,824
4	"	5295	49.7	819,801	"	1106	56.1	407,623	412,178	28.3	691,426
5	"	5056	50.1	814,426	"	1375	55.7	419,699	394,727	28.3	691,426
6	"	4815	50.5	808,757	"	1642	55.3	431,451	377,306	28.3	691,426
7	"	4572	50.9	802,795	"	1907	54.9	442,878	359,917	28.3	691,426
8	"	4327	51.3	796,535	"	2170	54.5	453,985	342,550	24.7	603,470
9	"	4080	51.7	789,976	"	2431	54.1	464,773	325,203	24.7	603,470
10	"	3831	52.1	783,115	"	2690	53.7	475,245	307,870	24.7	603,470
11	"	3580	52.5	775,950	"	2947	53.3	485,403	290,547	21.8	532,618
12	"	3327	52.9	768,478	"	3202	52.9	495,250	273,228	21.8	532,618
13	"	3072	53.3	760,698	"	3455	52.5	504,787	255,911	21.8	532,618
14	"	2815	53.7	752,605	"	3706	52.1	514,019	238,586	21.8	532,618
15	"	2556	54.1	744,200	"	3955	51.7	522,945	221,255	19.9	486,197
16	"	2295	54.5	735,477	"	4202	51.3	531,571	203,906	19.9	486,197
17	"	2032	54.9	726,437	"	4447	50.9	539,896	186,541	15.4	376,253
18	"	1767	55.3	717,075	"	4690	50.5	547,925	169,150	5.8	141,706
19	"	1500	55.7	707,390	"	4931	50.1	555,659	151,731	- 6.4	- 156,365
20	"	1231	56.1	697,379	"	5170	49.7	563,101	134,278	- 4.5	- 109,944
21	"	960	56.5	687,040	"	5407	49.3	570,253	116,787	- 7.0	- 171,024
22	"	687	56.9	676,370	"	5642	48.9	577,118	99,252	- 1.7	- 41,534
23	"	412	57.3	665,368	"	5875	48.5	583,697	81,671	- 7.6	- 185,683
24*	"	135	23.3	264,105	"	6000	23.3	283,328	- 19,223	0.0	...
Totals			1,240.0	17,782,751			1,240.0	11,517,718	6,265,033	Net	9,877,861

* The last turn is only about half a revolution, and the effective steam pressure is estimated at zero.

exerted; the depth of shaft and the area representing the load are reduced to the same dimensions in each diagram, for the purpose of comparison of the engine power. The corresponding sets of indicator diagrams are given in Figs. 19 to 24, Plates 48 to 50.

The mode of working the engines in each case is as follows. In engine No. 1, shown in Figs. 12 and 13, the engineman works with the throttle-valve open, "hands" the engine by the handle H until fairly in motion, and then places the handle in a notch on one of the eccentric rods until the run is nearly completed, when he detaches the valve-motion, meets the piston with steam on the opposite side, as shown at A in the diagram Fig. 16, and so brings the engine to a stand. The starting, running, and stopping occupy 30 seconds. The foot break is rarely used.

In engine No. 2, shown in Fig. 14, the engineman also works with an open throttle-valve, and regulates the engine with the link motion. In starting the engine he puts the link-block at its extreme travel, moves it backward as the speed increases, and in the last five strokes reverses it so that the pistons pump steam back into the boiler, as shown at B in Fig. 17. The steam break is used in case of need.

In engine No. 3, shown in Fig. 15, the steam and exhaust valves are all driven through a link motion; the throttle-valve is a double-beat valve actuated by a worm. The engine is worked in full gear, steam being given at starting through the open throttle-valve: when the run is nearly completed the throttle-valve is nearly closed and a partial vacuum is consequently formed on the steam side of the piston, the engine still being in forward gear. The principal agent in bringing the machinery to rest in this case is the vacuum behind the piston, as shown at C in Fig. 18; and this explains the different character of the line of steam power in Fig. 18 as compared with the two other diagrams.

Direct economy of fuel consumption is not in itself a point of much importance in colliery engines, the supply of fuel being abundant and on the spot: it is rather a question of boiler room, and wear and tear of boilers. It is a matter of much importance

however to have the machinery so constructed that the engines may develop a maximum of useful effect, and that they may do this with the least amount of strain upon the working parts. The most important point is the effect exercised by the weight of the machinery that is put into rapid motion and stopped in such short intervals of time. In the case of the engines Nos. 1, 2, and 3, the loads are drawn from the depths of 222, 406, and 413 yards in 30, 45, and 45 seconds of time respectively. The mean speed of the cages is therefore about 22, 27, and 27 feet per second; but as about one half of the revolutions are either accelerating or diminishing in velocity, the maximum speed of the cages is probably 27, 36, and 36 feet per second. The weights in motion in the three cases may be estimated at 27 tons in No. 1 engine, 60 tons in No. 2, and 30 tons in No. 3, these amounts being made up as follows:—

	No. 1 engine. Tons.	No. 2 engine. Tons.	No. 3 engine. Tons.
Flywheel and Drums	15	45	12
Ropes	4	4½	7
Cages, tubs, and coal	6	4	8
Pulleys	2	6½	3
Total weight in motion, tons . .	27	60	30
	==	==	==

These different parts travel, some at a higher, some at a lower speed than the coal, the mean being probably about the same as the coal.

The power absorbed in getting this mass of machinery into motion is equal to the weight in motion multiplied by the height a body must fall through to attain the same maximum velocity; and taking the period during which this maximum velocity is produced to be approximately represented in each case by the portion of the lift during which the engine continues to exert an accelerating action, it is seen from the diagrams that the time in which the velocity is got up amounts to 84, 66, and 79 per cent. of the whole time of the lift in Figs. 16, 17, and 18 respectively. Thus in engine No. 1, the maximum velocity being 27 feet per second and the mass in motion 27 tons, the result is 688,905 foot-pounds; and as this force is exerted in 84 per cent. of $\frac{1}{2}$ minute, it amounts to 50 effective horse power expended in getting up the velocity of the machinery. In engine No. 2, the maximum velocity is 36 feet per second and

the mass in motion 60 tons ; the result is therefore 2,721,600 foot-pounds exerted in 66 per cent. of $\frac{3}{4}$ minute, giving 166 effective horse power. In engine No. 3, the maximum velocity being also 36 feet per second, but the mass in motion 30 tons, there are 1,360,800 foot-pounds expended in 79 per cent. of $\frac{3}{4}$ minute, equal to 70 effective horse power. The power thus stored up in the moving parts is in the case of No. 2 engine expended during the last five strokes in forcing steam back into the boiler ; in engine No. 3 it is taken up in moving the engine without steam and with a partial vacuum behind the pistons ; and in No. 1 engine it is neutralised by the full boiler pressure opposing the motion of the pistons. Thus in all these cases the engine is employed usefully in raising the load during only about two thirds of its working time, and during the remaining one third it is exerting a retarding action ; this is more especially the case with No. 2 engine having the conical drum, owing to the great weight of the drum that has to be stopped.

It is obvious that if the machinery were so designed that the work of the engine was constant during the whole of its journey, a smaller and therefore less expensive engine would be capable of performing the same amount of useful work, and would be free from the extra strain which is unavoidable when the engine is reversed under steam. It is therefore a question of some importance to determine the design of a machine which would accomplish this end. With a conical drum a perfect equilibrium of load can be obtained in every position of the cages ; but it is seen from the diagrams of No. 2 engine, Figs. 17, 21, and 22, Plates 47 and 49, that the conical drum brings with it the disadvantage of a great increase in the weight of the moving parts. Much may indeed be done by so designing the machinery that a maximum of strength may be obtained with a minimum of weight ; but the improvement must extend further in the direction of reducing the load on the engine at the commencement of the run and expending the momentum usefully at its termination in raising the load. The following may be suggested as one method of accomplishing this end. Suppose the full lines in Fig. 8, Plate 43, represent the contour of a conical drum in which there is perfect

statical equilibrium between the ascending and descending loads throughout the entire run; and let it be assumed that by an economical method of construction the whole moving mass is kept within 40 tons moving at the maximum speed of 36 feet per second in the shafts. The point to be arrived at is so to modify the contour line of the drum, that in the first strokes of the engine its greatest available power shall be exerted in bringing the machinery into motion, that in the middle strokes it shall just lift the load and overcome the friction, and that in the last strokes the leverage of the load shall be so much increased that the momentum of the moving parts shall be usefully expended in assisting the engine to complete the lift. This end would be approximately obtained with a drum in which the contour lines received the modification indicated by the dotted lines in Fig. 8, simply increasing the steepness of the cone. With this drum the weight of the empty cage acting on the large radius at the commencement of the run would be in excess of the full cage and rope acting on the small radius, and the surplus or excess of balance over the load would assist the engine in getting up the momentum of the moving parts; whilst at the termination of the run, the circumstances being exactly reversed, there would with the proper angle of cone be an equal amount of load unbalanced to absorb usefully the momentum of the moving parts. By this means not only would the engine be made to do useful work during the whole series of revolutions, and hence be capable of raising a larger net load, but the extra strain unavoidable in reversing the steam whilst in motion, or the total annihilation of power consequent upon using the break, would be avoided. The engine would also sooner attain its full speed, and would be more quickly brought to a stand; and hence the duration of each journey would be diminished.

In raising a large tonnage of coal from a considerable depth, it is found desirable to bring out a maximum of coal for each journey, and to reduce to a minimum the time occupied in loading and unloading the cages. The winding gear shown in Figs. 10 and 11, Plate 45, was designed with this object, and is in use at the Hucknall Colliery, near Nottingham. At this colliery it was desirable for the sake of ventilation to reduce the area of the cages, in order

to prevent them from retarding the air current in the shafts; and for this purpose each platform of the cage holds only one tub of coals, and is equal in area to 1-5th of the shaft. There are however four of these platforms or decks in each cage; and to save part of the time occupied in moving the cages for loading and emptying them, there are two levels for loading and discharge, both at top and bottom of the shaft, so that all the decks can be loaded and emptied with only one change in the position of the cages. The whole time occupied in loading and emptying is thus not more than 20 seconds in each journey, and the engine can raise from 180 to 200 wagons of coal per hour, each wagon containing from 9 to 15 cwts. of coal.

Mr. FOWLER mentioned that the winding gear shown in Figs. 10, 11, and 15, and the winding engine No. 3, from which the diagrams Figs. 18, 23, and 24 were taken, would be seen in action by the members visiting Hucknall Colliery that afternoon.

The CHAIRMAN observed that in the diagrams representing the work of the engines (Figs. 16, 17, and 18), the power exerted appeared to be in excess of the load through fully two-thirds of the run, which would cause the speed of the engine to be continuously accelerated up to that point; and as the area representing the retarding power of the engine throughout the remainder of the stroke was seen in Figs. 16 and 17 to be so nearly equal to the previous accelerating power, it would appear that there must be very little friction in the shafts in those cases. In the third case however, Fig. 18, the area of the retarding power was so much smaller than that of the accelerating power, that the friction would seem to be considerably greater than with the two other engines; and he enquired whether the reason of this difference had been ascertained.

Mr. FOWLER said he had not been able at present to account for the difference pointed out in the positive and negative areas of the

diagram, Fig. 18; but he had no hesitation in attesting the general accuracy of these power diagrams, as they had been constructed from a series of indicator diagrams taken with a Richards indicator, from which those shown in Figs. 19 to 24 had been selected. In the case of No. 3 engine, the indicator diagrams shown in Fig. 23 were obtained in the first, eleventh, and sixteenth revolutions of the engine, during the period of acceleration; and the diagrams shown in Fig. 24, taken in the nineteenth and twenty-first revolutions, when the throttle-valve had been almost closed, showed a partial vacuum behind the pistons, amounting in the twenty-first revolution to 6 lbs. or 7 lbs. below the atmosphere. The indicator diagrams from No. 1 engine, shown in Fig. 19, were taken in the first, seventh, and twelfth revolutions, during which the accelerating power was continued; and the two lines taken in the thirteenth and fourteenth revolutions, Fig. 20, showed the retarding effect when the engineman had disconnected the valve-gear and worked the valves by hand, so as to make the full pressure of steam meet the piston in each stroke. In the case of No. 2 engine, the indicator diagrams were taken in the first, fourth, and ninth revolutions, as shown in Fig. 21, before the engine was reversed; and after reversing, the lines in Fig. 22 were taken in the eleventh and thirteenth revolutions, the pistons then pumping steam back into the boiler.

The CHAIRMAN observed that in the diagrams from No. 2 engine the pressure opposing the pistons after reversal rose apparently to about 62 lbs., and he enquired what had been the boiler pressure at the time those diagrams were taken.

Mr. FOWLER replied that the boiler pressure was about 50 lbs., and the excess of pressure when the engine was reversed must be due he thought to the friction in the pipes and the partial closing of the throttle-valve at that time.

Mr. F. J. BRAMWELL remarked that the working of No. 2 engine after the point of reversing was a simple instance of retardation by counter-pressure; and the excess of pressure shown by the indicator diagram to have existed at that time in the cylinders above the boiler pressure was similar to the excess that he had himself found in the indicator diagrams he had taken on the South Western

Railway, in the counter-pressure experiments of which the particulars had been given at the meeting of the Institution in January last (see Proceedings Inst. M. E. 1870 page 44). In those experiments the counter-pressure in the cylinders had amounted to as much as 150 lbs. while the boiler pressure was only 120 lbs., and the excess he considered to be due to the momentum of the steam in the steam pipe rushing into the empty space of the cylinder, and acting therefore as a steam ram in a manner somewhat analogous to a hydraulic ram. The expenditure of power by this winding engine, amounting to 166 horse power, was probably not so wasteful as it appeared in the paper to be considered, because in the counter-pressure working a large proportion of this power would be restored in the shape of increased steam pressure in the boiler, where it would thus be stored up ready to be utilised in the next run. In the case of small locomotive boilers in France he understood the rise of pressure in the boiler while running with the counter-pressure steam had been distinctly noticed.

Mr. W. BOUCH enquired what arrangement had been made in No. 2 winding engine for ensuring that it should pump back steam instead of air into the boiler in the reversed working. If it were simply an instance of ordinary reversing and pumping air into the boiler, it was true that the resistance occasioned by the compression of the air would be effectual in destroying the momentum of the moving machinery; but he doubted whether the air so pumped into the boiler would occasion any such increase of boiler pressure as had been alluded to, because the much lower temperature of the air would produce a reduction in temperature of the steam and a consequent partial condensation; and unless the boiler contained a large proportion of steam space, he did not think much power could be stored up in it by pumping air into it in the reversed working, because it was found in locomotives, that whenever air was pumped into the boiler in running reversed, the limit of pressure was soon arrived at and the safety valves began to blow off, and the air speedily made its escape there, unless the boiler was very capacious. The excess of pressure in the cylinders above the boiler pressure, as shown by the indicator diagram of the reversed working, would be

accounted for, he suggested, if the throttle-valve were at that time partly closed, which would interfere with the free passage from the cylinders back to the boiler and cause an increased pressure against the pistons.

Mr. FOWLER explained that in the case of No. 2 winding engine the exhaust-pipe was of very large capacity, being 40 yards long and 10 inches inside diameter, and retaining therefore a large volume of steam at atmospheric pressure; and as the pumping back into the boiler in the reversed working was from the exhaust-pipe, the pistons drew in steam alone from it at first, and but little air got drawn into the cylinders during the four or five revolutions of the reversed working.

Mr. A. PAGET concurred in the view which had been expressed, that if it were air which was pumped into the boiler in the reversed working, no advantage would be gained, because he considered the increase of pressure due to the volume of air pumped in would be far counterbalanced by the cooling effect of the air so supplied into the boiler.

Mr. FOWLER said that the object of the diagrams representing the power exerted by the winding engines had not so much been to show that the portion representing the retardation was an actual loss of engine power, as in Figs. 16 and 17; but to call attention to the fact that in raising coal it was necessary to have a winding engine capable of developing in the first two-thirds of its run the whole of the power required for raising the load through the entire height of lift. An engine so employed was in reality doing less than half of the useful work that it might accomplish if kept working regularly the whole time. Up to the point of reversal it was working usefully, but during the remainder of the lift it was only wasting its strength in doing the negative work of counteracting the very speed which it had itself got up during the earlier portion of the lift.

Mr. L. OLRICK observed that the indicator diagram taken during the first revolution of No. 2 winding engine showed a drop in the pressure immediately after the commencement of the stroke, Fig. 21, which he considered must be due to some condensation of the steam on first coming in contact with the cooler surfaces of the cylinder;

this cooling of the cylinder surfaces he thought must have been occasioned during the time that the engine had been reversed for the last third of the previous lift, at which time the cylinder had drawn in during the first half of each revolution a supply of exhaust steam of atmospheric pressure; and as this steam was very wet and on the point of condensation, it was capable he thought of robbing the cylinder surfaces of more heat than they could recover during the period of compression in the second half of each revolution from the then dry steam. The friction of the steam in the steam pipes, in conjunction with the obstructions offered to the passage of the steam by the steam-valve and partially closed throttle-valve, might be sufficient he thought to account for the whole excess of pressure in the cylinders above the boiler pressure; and in consequence of the elastic nature of steam he could not agree in thinking it possible that it should act as a steam ram in a manner similar to a hydraulic ram, as the weight of the steam was too insignificant to make up any appreciable momentum. Owing to the great length of the exhaust-pipe he thought there could be no doubt that in the reversed working the pistons would draw in steam chiefly.

Mr. F. J. BRAMWELL remarked that the total amount of obstruction presented to the passage of the steam by the steam-valve and throttle-valve was shown by the diagrams taken from the engine when working in forward gear, before reversing; from which it appeared that with a boiler pressure of 50 lbs. the pressure obtained in the cylinders was 46 lbs., showing a loss of 4 lbs. pressure in the passage of the steam from the boiler to the cylinders. In the reversed working the engine did not run more quickly, and the same difference of 4 lbs. pressure would therefore be enough to overcome the resistance of the valves and steam passages; but the actual excess of pressure observed in the cylinders above the boiler pressure, instead of being only 4 lbs., amounted to as much as 12 lbs., which was therefore much more than could be accounted for by the resistance of the valves and steam passages. The elasticity of steam did not appear to him to render it incapable of acting to some extent as a ram when its motion was suddenly checked: it must be remembered that steam, although a very light

body, was still ponderable, and that the velocity with which it moved was very great, and thus there would be in the reversed working a large amount of momentum stored up in the steam rushing into the cylinder; and on its sudden stoppage this momentum was expended in compressing the elastic substance of the steam itself, and thus increasing its pressure to the extent shown by the indicator diagrams.

Mr. JEREMIAH HEAD observed that in the reversed working of No. 2 winding engine the exhaust steam was drawn into the cylinder at atmospheric pressure and therefore at the temperature of about 212° Fahr., and was then compressed say up to the boiler pressure of 50 lbs., at which its temperature would be about 300° ; and in the next stroke the succeeding supply of exhaust steam drawn in would come into contact at once with the heated cylinder surfaces which had immediately before been in contact with the compressed steam at 300° . He did not see therefore how the atmospheric steam drawn into the cylinder could be deprived of any of its heat at the beginning of the stroke by contact with the cylinder surfaces; but on the contrary it would at that time receive heat from the hotter surfaces of the cylinder, and would afterwards restore this heat to them again in the latter part of the stroke, when itself heated by the compression.

Mr. G. D. HUGHES enquired what was the arrangement for working the valves in No. 1 winding engine, as it appeared from the indicator diagrams in Fig. 19, taken in the first, seventh, and twelfth revolutions of the engine, that the steam valve was much too late in closing, the full steam being kept on throughout the entire length of the stroke, without expansion; and also the eduction port was apparently opened much too late, producing the very large amount of back pressure shown in the diagrams, which must result in the loss of a large proportion of the effective power that the steam was capable of developing.

Mr. FOWLER replied that the steam and exhaust valves of all the three winding engines were double-beat valves lifted from eccentrics by rocking shafts and lifting fingers, and the diagrams shown in Fig. 19 were certainly very defective in the late closing of the steam valve and in the heavy back pressure.

Mr. W. HOWE observed that the diagrams exhibited, representing the power exerted by the winding engines from bottom to top of the lift, were fair illustrations of the sort of diagrams ordinarily obtained from colliery winding engines; and the economical employment of the power in such cases was of much less importance than to have power sufficient for raising with rapidity and regularity great quantities of coal. At the Clay Cross Colliery he had two double-cylinder winding engines, with cylinders of 30 inches diameter and 5 feet stroke, fitted with balanced slide-valves, and both working under exactly similar circumstances, except that in one the lap of the slide-valve was 1 inch, while in the other it was only $\frac{1}{2}$ inch. The latter was of course not quite so economical in working as the engine with 1 inch lap, but the $\frac{1}{2}$ inch lap was found much better for starting the engine at the beginning of each lift; in this instance the coals had to be raised at the rate of 100 tons an hour by each pair of engines, and it was therefore a great advantage to be able to start the engines at a good speed, and the steam was kept on till nearly the termination of the lift, when the engines were stopped by reversing, generally without requiring the break to be used. At the same colliery the endless chain for underground haulage was now being put down on an extended scale, and it had the great advantage that it was kept constantly in motion, so that the power required to be exerted by the hauling engine was nearly uniform. Another advantage was that the endless chain could be readily applied in any place, and gave the means of drawing the coal at any angle and from any part of the pit with comparative ease. It brought the wagons along one at a time to the bottom of the shaft, as rapidly as they were filled in the workings, and the winding engine was thus kept regularly supplied, without having to stand waiting occasionally; whereas in bringing out trains of wagons with the tail-rope system the bottom of the shaft was sometimes glutted with wagons, while at other times the winding engine was standing idle. The wear and tear of the endless chain supported on the wagons themselves was also much less than that of the tail rope running upon carrying rollers fixed on the ground; and the use of the endless chain saved many of the horses previously required.

Mr. P. O. WHITEHEAD mentioned that the endless-chain system was carried out for winding the coal up the shaft at the Marsden Pit near Burnley in Lancashire. The chain was provided at regular intervals with shackles, by which the loaded tubs were hooked on at the bottom of the shaft by hand; and on arriving at the top they were unhooked again by hand and landed at one side of the shaft, while the empty tubs were hooked on the descending chain at the other side. This plan of winding had now been in use there about ten years, the depth of the shaft being 112 yards.

Mr. J. S. E. SWINDELL concurred in thinking a considerable amount of lap was not desirable for the slide-valves of colliery winding engines. What was wanted was to get the coals away as rapidly as possible from the bottom of the shaft; and for this purpose the winding engine should have but little lap of the slide-valve, so as to start promptly with the load. When the valve had much lap, the engine was sometimes not able to start at once under the load, and it had then to be backed and started again with something of a run, thereby increasing the wear and tear. With less lap the load could be started straight away; and the economy of fuel attending a greater amount of lap was not a matter of much consequence in the case of engines at collieries.

The CHAIRMAN considered the paper which had been read was of much value, giving as it did authentic particulars of colliery working in that district; and it had also led to a discussion of much interest. He proposed a vote of thanks to Mr. Fowler for his paper, which was passed.

The Meeting was then adjourned to the following day. In the afternoon Excursions were made by the Members in three parties to High Park, Moor Green, Cinder Hill, and Hucknall Collieries, and Newstead Abbey; and the Members received a hospitable entertainment from the Colliery Companies at Basford Hall, and from Mr. Samuel Thomas Cooper at Bulwell Hall.

The Adjourned Meeting of the Members was held in the Great Hall of the Mechanics' Institution, Nottingham, on Wednesday, 3rd August, 1870; THOMAS HAWKSLEY, Esq., Vice-President, in the Chair.

The adjourned discussion was resumed upon the paper read at the previous meeting in April, "On a Steam Road Roller," by Mr. W. F. Batho of Birmingham and Mr. T. Aveling of Rochester. (See Proceedings Inst. M. E. April 1870 page 109.)

Fig. 1. *Section of Pillar Working.*

Fig. 2. *Section of Longwall Working.*

Fig. 3. *Haulage by Main and Tail Ropes or Endless Rope, carried upon rollers and drawing a train of wagons.*

Fig. 4. *Haulage by Endless Chain carried upon wagons spaced at intervals, without rope rollers.*

(Proceedings Inst. M.E. 1870.) Scale 1/350th

MIDLAND COLLIERY WORKING.

Plate 43.

End Turning Pulley , for haulage by endless chain .

Fig. 5. *End Elevation .*

Fig. 6. *Side Elevation .*

Fig. 8. *Plan of Conical Winding Drum .*

Fig. 7. *Plan .*

(Proceedings Inst. M.E. 1870.)

Scale $\frac{1}{100}$ in.

10 5 0 10 20 Feet.

MIDLAND COLLIERY WORKING.

Plate 44.

Fig. 9. Diagram showing mode of applying Endless Chain Haulage to Longwall Working. (Hucknall Colliery.)

(Proceedings Inst. M.E. 1870.)

Scale $\frac{1}{16,000}^{th}$ 20 Chains per inch.

1000 500 0 1000 2000 3000 Feet.

Fig. 10. *Winding Gear
with four-deck cages
for economy of time
in loading and unloading.
(Hucknall Colliery.)*

Fig. 11. *Plan at bottom of shafts.*

MIDLAND COLLIERY WORKING.
Diagrams of Colliery Winding Engines.

Plate 46.

Fig. 14. N^o 2 Engine. Kiveton Park Colliery.

Fig. 15. N^o 3 Engine. Hucknall Colliery.

MIDLAND COLLIERY WORKING.

Plate 47.

Diagrams showing Moments of Load and Power of Colliery Winding Engines.

N^o 1 Engine.
Cinderhill Colliery.
222 yards depth.

N^o 2 Engine.
Kiveton Park Colliery.
406 yards depth.

N^o 3 Engine.
Hucknall Colliery.
413 yards depth.

0 400,000

Scales of Foot-pounds

0 500,000 1,000,000

Scales of Foot-pounds

0 700,000

Mem. — The Depth of Shaft and the area representing the Load are reduced to the same dimensions in each diagram for the purpose of comparison of the Engine Power.
(Proceedings Inst. M. E. 1870.)

Indicator Diagrams from N^o 1 Winding Engine (Fig. 16.)

(Cinderhill Colliery.)

Fig. 19. Diagrams taken in 1st, 7th, and 12th revolutions.

Fig. 20. Counterpressure Diagrams taken in 13th and 14th revolutions, after reversing.

Valves worked by hand.

The arrows show the direction of motion of the piston.

(Proceedings Inst. M. E. 1870.)

Fig. 21. Diagrams taken in 1st, 4th, and 9th revolutions.

Fig. 22. Counterpressure Diagrams taken in 11th, and 13th revolutions, after reversing.

Valves worked by reversed link motion.

Indicator Diagrams from N^o 3 Winding Engine (Fig. 18)

(Hucknall Colliery.)

Fig. 23. Diagrams taken in 1st, 11th, and 16th revolutions.

Fig. 24. Vacuum Diagrams taken in 19th and 21st revolutions.

Throttle - valve nearly closed.

The arrows show the direction of motion of the piston.