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CHAPTER VII

PREFACE

THE writer's intention in compiling the present book is to provide a technical primer on the subject of longwall coal cutting machinery which will combine the experience of both the coal face and the machine shop. The book is intended primarily for the mining student, but it is thought that much of the matter presented will be of interest to all engaged in coal mining.

It has been assumed throughout that the reader has a general knowledge of pit work and a grounding in the subjects of electricity and mechanics: the aim has been to keep to the practical aspect of the subject, and the working out of calculations has been carefully avoided.

There does not appear to be any published text-book which gives a comprehensive review of the whole subject and the student is limited in his study to such applications of machines as come under his observation in his own particular locality, to information gleaned from visits to other coalfields, and to the advertising matter of firms interested in the manufacture and sale of machines.

As regards the obtaining of information from his own locality the student is often handicapped in his efforts to extend his knowledge since a certain amount of conservatism must be laid to the charge of mining engineers in their attitude towards coal face machinery, and in numerous cases no improvements in the machine and no alteration in the method of working are attempted. Because machines are doing satisfactory work of a kind the management often considers it better to continue working on methods, the limitations of which they know, rather than to take any of the risks attendant on a change.

Visits paid to other coalfields extend the student's knowledge in many directions, but can do little to add to his judgment of the correct application of coal face machinery since a most careful study of each individual set of coal face conditions is required before any considered opinion can be formed. Visits of a few hours, or even of a few days, are of little value in this connection unless the student has a knowledge of the respective and relative influences of the many factors involved. It is hoped that this primer will assist in the study of the correct application of coal cutting machinery and in the weighing up of the influence of each factor affecting the choice of type of machine.

It may be noted that attention has been confined solely to the longwall coal cutting machine and that no reference has been made to that very valuable adjunct, the longwall coal face conveyer. The reasons for this omission are limitations of space, and the belief that the conveyer is only now beginning to attain a definite line of development: its ultimate application will doubtless be at least as extensive as that of the longwall coal cutting machine.

The author's thanks are due to the following firms for assistance in obtaining photographs and blocks for the purpose of illustration— Messrs. Austin Hopkinson, Guide Bridge; British Spiro Turbine Co., Ltd., Wakefield; Diamond Coal Cutter Co., Wakefield; Hirst & Son, Ltd., Dewsbury; Mavor & Coulson, Ltd., Glasgow.

G. F. F. EAGAR.

TONDRIDGE,

December, 1920.

CHAPTER I

THE ECONOMIC ASPECT OF LONGWALL COAL CUTTING MACHINERY

THE successful adoption of machinery at the coal face dates back not more than sixty years, though some isolated examples may be found where machines were used with more or less success earlier than this.

Since the earliest days of coal mining the use of machinery in one form or another has gradually taken the place of purely manual labour. The problems presented by winding, pumping, ventilation and haulage were slowly but sureIy solved to the mutual satisfaction of the engineers and workers of the day. The actual cutting of the coal at the face was a problem of a very different order, since it demanded the use of portable machinery and the consumption of much power: the actual operation of coal cutting calls, normally, for a considerable amount of flexibility, and no machine can possess this to any g reat extent.

The Development of Coal Cutting Machine. Machinery which would actually do the work of cutting was soon designed, but the applicat on of power to actuate the machine presented grave difficulties. Steam was tried but, as was to be expected, it proved a hopeless failure. Compressed air proved far more applicable to the peculiarities of coal face conditions and, in spite of its flagrant inefficiency, it is used to a very large extent to-day. The rapid development of the use of electric power, together with the great improvements in the method of its adaptation for coal mining conditions, have brought this source of power into great prominence for mining machinery of all kinds.

The original 'iron-man ' was practically a mechanically-operated miner's pick, and was invented by Firth: this machine was successfully at work at West Ardsley Colliery, Yorkshire, in 1862. The design of the original machine was subsequently modified, and machines of the improved type were at work at several collieries within the next few years.

A chain type of machine was introduced by Messrs. Baird & Co., of Glasgow, and worked in their own and at other collieries from the year 1874 onwards. It was claimed that better results were obtained than from Firth's pick machine.

The first practical disc machine was probably that constructed by J. Scarisbrick Walker, of Wigan, about the year 1869: this machine was working in some of the coal mines in the Wigan district, and also in some salt mines in Cheshire. (A very full and most interesting account of the development of the various types of machines is given in Mr. Sydney F. Walker's aOal Cuttin~ by Machinery in the United Kingdom (published by the Colliery Guardian Co., Ltd., in 1902).

With the development of the bar machine the name Hurd will always be associated, both father and son having taken out numerous patents and designed practical machines from the earliest days o£ its inception. The earliest known reference to the use of a bar carrying cutters for undercutting coal appears about 1856. (Patent by Johnstone and Dixon.) The underlying idea appears to have been, firstly, to reduce the amount of gearing involved in other types of machines, with a consequent reduction in the power consumption; and, secondly, to produce a machine having the least possible part under the coal.

The attention of engineers and inventors was turned so largely to the coal cutting machine because it was becoming increasingly evident that without some means of reducing the labour costs of getting coal the end of economic development was in sight in many coal producing districts. The thick seams lying at comparatively shallow depths were rapidly approaching exhaustion. Thin seams at greater depths were, in general, more difficult to 'get,' necessitating the opening out of large areas with greatly increased standing and up-keep charges. Finally, wages were rising and the selling price of coal tended to remain stationary.

The great improvements in the use of compressed air and, more important still, the realization of the wonderful possibilities of electricity as a motive power for use in mines, helped very greatly towards the successful application of machinery. The earliest forms of machines, crude as they were, had shown the possibilities of supplementing man power and, with this encouragement, the mining engineer of the day made further calls on his own ingenuity and on that of manufacturers and inventors. It took many years to establish a definite industry of coal cutting machinery, but once given a fair start the industry has never looked back. Today the works of the leading manufaeturers represent the best maehine and fitting shop praetiee and, in general, the staff of sueh firms are men of proved 'pit ' experience, the actual work required of the machine being made the subject of careful study in working out the general design and details.

The aim of the mining engineer in introducing machinery at the coal face has always been four-fold:-

(1) Reduction in working costs.
(2) Increased production from thin seams or short faces.
(3) A substitute for or supplement to man power.
(4) Improved yield of large coal.

Reduction in Working Costs. It has frequently been stated that wages cannot be forced up beyond a certain figure. When that economic figure tends to be exceeded machinery must be introduced as labour's substitute or supplement.

It is not easy to give any definite average figure for the proportion of cost of actual cutting of coal in relation to the total coal face costs; and it is useless to quote figures of eoal faee eosts taken from actual practice, beeause these are out of date as soon as they are published, owing to the persistent inerease in wages and the steady tendeney towards a reduetion of the working hours. The only factor that does not change materially is the proportion of each coal face cost in relation to the total cost. From a careful examination of a large number of colliery costs it appears that of the total work done by the miner actually at the face approximately 50 per cent. is accounted for by the operation of holing.

Taking a hypothetical case: If in a thin seam of average characteristics, worked entirely by hand, the total coal face labour costs, (That is, undercutting, getting, filling, tramming, cleaning up, timbering, packing and road making.) are 8s. per ton, the actual holing costs will be about 4s. per ton. To introduce a machine successfully into this seam there must be a reduction in this amount, and it must be remembered that the eosts involved by the use of the machine to do the holing include coal cutter attendant's time, making 'stables' at one or both ends of the face, (Sometunes no stables are made, but extra money has to be paid for " cutting up " the ends of the faees by hand) turning or 'flitting' the machine, depreciation of the machine and fittings, a proportion of the cost of laying on power, the cost of the power consumed, extensions of cables or piping, renewals and breakdowns of machinery. If, in the hypothetical case now under consideration, the total cost of all these items is less than 4s. per ton a direct saving is effected by the machine. There are also possibilities of further economies of an indirect character, as will be shown later.

Increased Production fom Thin Seams or Short Faces. Where coal is worked entirely by hand, large outputs from thin seams mean the maintenance of a much greater length of coal face than in cases where thick seams are being worked. The advantages gained by keeping the length of coal face as low as is consistent with maintenance of output are very real: maintenance charges, road making and repair expenses, costs of timbering, tub up-keep and rail costs are all reduced; supervision is easier and a lower standing charge; development work is quicker and provision is more easily made for it. To get the same output from a thin seam as from a thick seam of similar characteristics requires a length of coal face considerably greater than the actual ratio of reduction in the thickness of the seam, since the output per man employed at the coal face decreases steadily with the reduction in thickness of the seam where all the work at the coal face is done by hand. Thus, if 600yds. of coal face is required to get an output of 600 tons of coal per day in a seam 5ft. thick, considerably more than 1,200 yds. of productive coal face will be required when the seam is only 2ft. 6ins. thick, all the work being done by hand in both cases.

The use of coal cutting machines means concentration of the pit work,- and a larger output is obtainable where machines are used because the coal faces are moved forward much more rapidly. On the other hand, this concentration of output from relatively short faces increases the risk of temporary decrease in output due to breakdowns. In all cases where machines are used there must be a very rigid adherence to the regular routine of work, and this in turn throws an added amount of responsibility on the management, especially on the under-officials such as firemen and deputies.

Substitution for or Supplement to Man-Power. Little need be said on this account since, where labour is scarce or 'absenteeism' is bad, the advantages to be gained by introducing coal cutting machines are very obvious. Fromthe point of view of output alone it is important to have as many as possible of the men employed in the mine engaged in filling out coal, and to raise the output per man to the highest possible figure consistent with the maintenance of the pit in a safe and efficient condition. In this connection, too, the rising cost of all grades of labour and the constant shortening of the hours of work have an important bearing.

Where labour is scarce or where thin seams are being developed in new areas the bulk of labour has to be imported. In such cases the really skilled collier is very difficult to obtain, and such labour as can be found is not of a particularly efficient character. The actual cutting of the coal is a process which calls for the exercise of a considerable amount of skill - far more skill than is required, for instance, in merely filling out coal after it has been cut and got down. Where coal cutting machines are used intelligently the most arduous part of a collier's work is done for him, and the systematic work which must of necessity follow the use of longwall machines simplifies the remainder of coal face work, such as timbering and building of packs. The less highly skilled labour is always more easily obtainable and can more easily be employed to advantage where coal cutting machines are used.

Improved Yield of Large Coal. In the majority of coal mines there is a considerable difference between the prices obtainable for large and for small coal. Even where the actual size of the coal sent to bank is immaterial, as, for instance, where it is all sent to coking ovens, it is of benefit to send out the coal as large as possible to economize space in the tubs and maintain a high average weight per tub, and also because large coal can be filled out in a much cleaner condition than small coal. It is always of benefit to the management to maintain the average weight of coal per tub as high as possible, especially where a pit is being worked up to its maximum output as regards the number of tubs per shift that can be handled. The larger the size of coal filled out the heavier will be the tub weight averages, provided the coal be packed properly in the tub.

As regards cleanliness of the coal it is far easier to avoid filling out large lumps of dirt than it is to exclude small dirt and dust from small coal. Even where the coal is all sent to coking ovens it is usually better practice to get the coal as large as possible and send it to a crusher than to send out quantities of fine coal mixed with dirt and then send a large part of the output to a washing plant. Even the most up-to-date washers fail to effect a complete separation of the coal and the dirt, with the result that there is always some dirt left in the coal and some coal carried away and wasted with the dirt.

The use of coal cutting machines tends to produce a maximum of round coal in thin seams, especially where the cutting is done in the dirt underlying the seam or in bands of dirt or inferior coal near the bottom of the seam. The type of machine used, and the depth and position of the cut, have also ~a very important bearing on the yield of large coal. These points are discussed fully in Chapters II to V .

Factors determining Applicability of Longwall Coal Cutting Machines. The determining factors in arriving at a decision as to the applicability of longwall coal cutting machines are:-

(1) The thickness of the seam and its general characteristics.
(2) The inclination of the seam.
(3) Difficulties in working due to faults.

Thickness and Characteristics of Seam. It is obviously impossible to give any ruling as to the thickness of a seam in which it will pay to introduce longwall coal cutting machines. Every set of conditions must be taken on its merits and the direct and indirect effects of using machines must be considered most carefully. In some localities the labour question may be so acute that machine mining is a paying proposition in certain seams of coal, whereas it would not pay to introduce machines into similar seams in other districts where skilled labour is more abundant. It may be stated, however, that coal cutters are a necessity in working most seams of 3ft. or less thickness; that they may, and frequently do, effect considerable economies in seams up to 5ft. in thickness; and that where it is necessary to increase output by every available means they may prove their value in seams more than 5ft. thick.

As regards the total height required by a machine on the coal face due allowance must be made for the decrease in height where bars have to be set to the roof. In many seams the roof has a tendency to 'cut off' at the coal face, i.e. to bend down over the packs and wastes; in other cases the floor may tend to 'puck ' or heave as soon as the coal is removed. The ove~rall height of most standard makes of longwall machines made to cut at floor level is from 17ins. to 22ins.; in addition, many manufacturers build special low type machines down to 13ins. or 14ins. total overall height. It is usually inadvisable to adopt these very low built machines where the standard machines can be put to work, because the cutting down of the overall height results in a loss of general accessibility of the parts and, in some cases, a reduced efficiency of the machine. This is particularly the case where electric motors are used.

In some cases the introduction of longwall machines is opposed on the ground that the roof is too bad to allow the machine to work efficiently without increasing the danger from falls of roof. This argument is correct only in a small percentage of cases. Numerous cases can lae quoted where the systematic work following the use of longwall coal cutters, the straight line of cut with straight lines of timbering, and the much more rapid advance of the face, have turned what was really a bad roof under hand working conditions into quite a good roof where machines are used.

In practically all cases where the floor is very soft and causes much trouble due to heave or 'creep,' the use of machines has greatly improved the conditions at the coal face; this result can generally be attributed to the more rapid advance of the coal face, resulting in less weight being thrown on to the span of roof open between the coal and the packs.

The Inclination of the Seam. The conditions under which longwall coal cutting machines will show to the best advantage are where the measures are level or only gently inclined. Seams lying at inclinations up to 1 in 22 are, however, being cut successfully and economically by machines. It is now generally recognized that wherever the longwall method of working can be adopted successfully the inclination of the seam, however great it may be, does not necessarily prevent the successful adoption of the longwall coal cutting machine. It may, however, in some cases be advisable to lay out faces for machines at an angle, in relation to the line of 'strike' of the measures or the line of full rise and dip, which is different from that giving the best results where purely manual labour is employed, though the precise bearing of the faces will also be influenced considerably hy the line of 'cleat ' of the coal and by the numerous other local conditions that affect the working of the seam.

In considering the influence of the inclination of the measures in relation to the economy possible by machine mining it must be remembered that, where the inclination is considerable, it is often impracticable to cut coal with the machine working to the dip, though in some cases the difficulty has been got over by fixing the haulage post behind instead of in front of the machine and counterbalancing the weight of the machine by making it pull a heavy weight against the gradient as it progresses downhill. Loss of time and labour expended in pulling an idle machine down inclined faces must be taken into account in calculating the expense of cutting coa1 by machinery in inclined seams.

Difficulties in Working due to Faults. Where a seam is much disturbed by faults the conditions as regards applicability of machines are far from ideal, but the limitations to the use of machines under such conditions are generally exaggerated. A machine can never possess the full flexibility of hand labour, and where the faults are close together, run at varying angles to the line of the coal face, and have displacements greater than the thickness of the seam, the economic use of machines may be quite impossible. On the other hand, where the general direction of fault lines is the same, and where they are not too close together, it is often a paying proposition to introduce machines. Where the faults are a considerable distance apart it is often possible to open up an economical length of face free from faults between the dislocations of the seam.

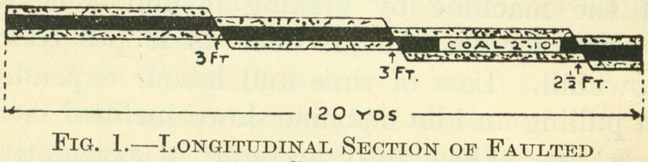


FIG. 1.—LONGITUDINAL SECTION OF FAULTED SEAM.

The section of a face shown in Fig. 1 is taken from an actual colliery working, and represents what can be done under adverse conditions as regards faults. The thickness of the seam was 2ft. 10ins., the length of face open was 120 yds., and the displacement of the faults was from 2ft. 6 ins. to 3ft. A further fault, with a displacement of 4ft., was encountered subsequently on this face and was negotiated successfully by the machine (in this case a bar type coal cutter) until the fault ran out.

Numerous other instances of the successful working of longwall machines through faults can be quoted for all three types af machines.

In many cases it is inadvisable to continue working a machine through faults having a displacement of more than the thickness of the seam, but where the face is for development work, as in the case quoted above and illustrated in Fig. 1, it may be economical practice to continue work with the machine as long as possible. Where the material in the hade of the fault is very hard it may prohibit the use of machines to cut through a fault line. An alternative, possible only with chain and bar machines, is to swing the cutting part out of the cut while negotiating the fault and rack in again on the other side of the dislocation. The disc machine working in faulty ground must cut its way right through a fault and, in this respect, it is at a disadvantage as regards the chain and bar types of machines. On the other hand, the disc machine will generally stand up to harder holing conditions, such as are frequently met with in faulty ground, than machines of the other types.

In conclusion, it may be stated that the presence of faults hinders the working of machines, but by no means prohibits their successful adoption. The main effect of faults on the economical aspect of machine mining is rather to alter the methods of working and the general lay-out of a mine than to preclude the use of longwaL1 coal cutting machines.

CHAPTER II

TYPES OF LONGWALL COAL CUTTING MACHINES - DISC MACHINES

THERE are at the present day three distinct types of longwall coal cutting machines in successful operation, namely:-

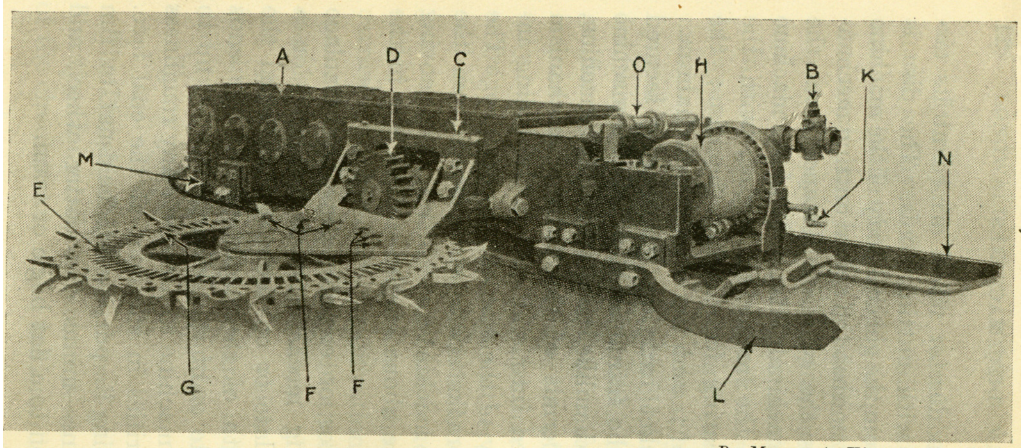
(1) The Disc Machine.
(2) The Chain Machine.
(3) The Bar Machine.

Each of these three types of machine has been evolved by approaching the problem of coal cutting from different view points. A11 three types have similar general characteristics, their essential differences lying in the methods of holding and actuating the cutters. Each type of machine is adapted for a certain set of conditions and will do better work than the other types when set to work under those particular conditions.

Some manufacturers make one type only of longwall coal cutting machines and claim that their machine will adequately meet all conditions. The contention is an impossible one. It may be clever salesmanship to persuade a buyer that an unsuitable type of machine will meet all his requirements, but the result can only be detrimental to the salesman's reputation, the purchaser's temper, and the manufacturer's business.

In some cases there is a lack of co-ordination between the manufacturer and the user. The manufacturer is concerned primarily in building up and maintaining a profitable business, and for this purpose he standardizes his products as far as possible; but the machine which is practically ideal for one set of conditions may require extensive modification to get even average good results under other conditions, and the general resu]t of this lack of co-ordination is either that the machine is kept at work under unsuitable conditions, that the user carries out his own modifications, or that coal cutting by machinery in that particular case is declared to be a failure. In any case the practical experience which would be invaluable to the manufacturer is lost to him and the more general adoption of coal face machinery is hindered.

The Disc Machine. In broad principles the disc type longwall coal cutter is an adaptation of the circular saw. The modern. disc machine consists of a disc or wheel armed at its circumference with cutting tools. The disc is supported from the general body of the machine by a bracket so that the actual cutting mechanism projects the requisite distance from the side of the machine. The body of the machine consists of the motor or engine, with the requisite gearing for driving the disc; the haulage gear; and the starting mechanism.



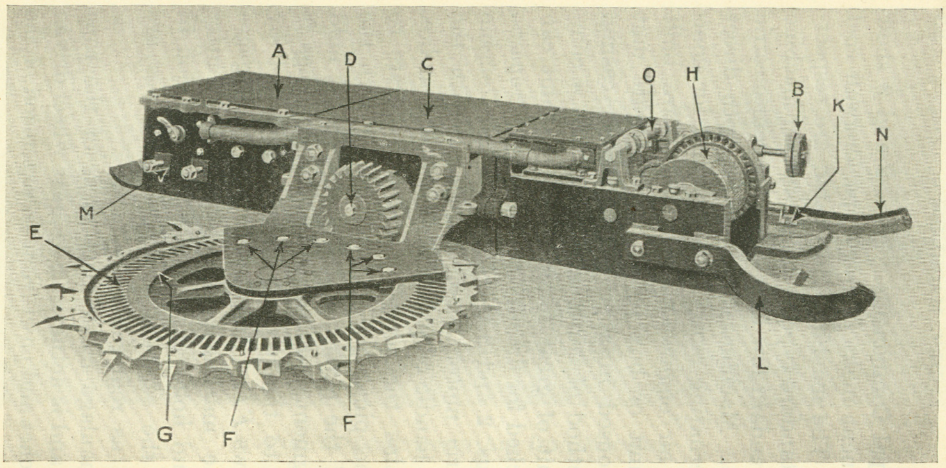
By Messrs. A. Hirst & Son, Ltd.

FIG. 2.—COMPRESSED AIR DISC MACHINE.

A = Compressed air engine.
B = Starting handle.
C = Gear box.
D = Pinion.
E = Cutter wheel.
F = Set screws.
G = Machined groove in cutter wheel.
H = Haulage mechanism.
K = Handle actuating cam plate for varying rate of haulage.
L = Front fender.
M = Seating for front fender when running in reverse direction.
N = Tail or side rail.
O = Shaft carrying loose pulley for haulage rope.

The bracket carrying the disc is secured rigidly to the frame or body of the machine by bolts, and, unlike the chain and bar machine, does not permit of the cutting mechanism being moved into and out of the holing independently of the test of the machine. The disc and bracket can be removed from the body of the machine for 'flitting,' or moving the machine about on the surface and in the pit.

The motor or engines, gear box, haulage and starting mechanism are mounted on a flat base plate or on skids which extend the whole leno,th of the machine, and the ends of this plate or of the skids are turned up to enable the machine to pass over any roughness or irregularities in the floor at the coal face. For 'flitting' purposes it is usual to run the machine - minus the cutter wheel and bracket - on to a flat bogie or tram.



By Messrs. A. Hirst & Sons, Ltd.

FIG. 3.—ELECTRICALLY DRIVEN (DIRECT CURRENT) DISC MACHINE.

A = Electric motor.
B = Switch handle.
C = Gear box.
D = Pinion.
E = Cutter wheel.
F = Set screws.
G = Machined groove in Cutter Wheel.
H = Haulage mechanism.
K = Handle actuating cam plate for varying rate of haulage.
L = Front fender.
M = Seating for front fender when running in reverse direction.
N = Tail or side rail.
O = Shaft carrying loose pulley for haulage rope.

Principal Components. Figs. 2 and 3 show a prominent make of disc type longwall coal cutter. The machines illustrated are respectively a standard type of compressed air machine and a st3ndard lowtype direct current electric machine. Machines are built for both direct and alternating current motors and for compressed air engines. All machines are built up in unit or box form, each separate unit being housed in a strong cast steel casing. This method of construction provides a complete unit of great rigidity and any unit can be detached for flitting purposes or for repairs.

In Figs. 2 and 3 the compressed air engine or electric motor is shown at A, with the starting handle or switch at B. The gear box ~ contains the necessary reduction gears to drive the pinion wheel D, meshing with the teeth of the cutter wheel E. A forged mild steel segment piece with gunmetal facings is secured to the underside of the bracket by set screws FF. This segment piece engages with the machined groove in the cutter wheel and holds the wheel and the pinion in mesh: the segment pieces and facings are renewed as required.

The haulage mechanism H is of the rope pattern and is actuated by a gear wheel driven by a ratchet and pawl from an extension of the bottom shaft in the gear box. The number of teeth taken by the pawl at each stroke of the haulage rod can be varied by altering the position of the slide in the disc keyed to the bottom shaft extension or, alternatively, by means of a cam plate attached to the handle K. The latter arrangement gives a range of feed varying from zero to the maximum speed without necessitating a stoppage of the machine to effect the alteration.

The machines illustrated in Figs. 2 and 3. are provided with wheels of the straight rim or pocket type in which single and forked picks are carried in slots. Alternative forms of wheel are marketed in which the picks or cutters are carried in special boxes, fitting either in recesses or lugs on the periphery of the wheel, and held in position by locking pins. For certain types of holing the cutterbox wheel is to be preferred, but for " sticky " or damp holing at floor level, the straight rim or pocket type wheel has advantages.

Operation. Disc machines cut equally well in either direction of travel, i.e. with the haulage end of the machine either in front or behind. As shown in Figs. 2 and 3, the machines are rigged for travelling with the haulage end leading; for running in the reverse direction, the picks are reversed, the front fender L is removed and bolted in position at M, and the tail or side rail N - only the front end of which is seen in the illustration - is slipped through its holders to project beyond the back end of the machine. The shaft O carries a small loose pulley to hold the haulage rope clear of the body of the machine when cutting with the haulage gear at the back of the machine.

In all makes of disc machine the bracket and wheel are rigidly connected to the body of the machine. Disc machines are therefore unable to 'cut themselves in' close up to the rib of a coal face, and " stables " or " discholes " are necessary for efficient working at both ends of the face.

Disc machines are made to cut al1 depths, rising by 6 ins. from 3ft. to 5ft. 6ins. Standard makes of machines for cutting at or near floor level range in height from 22ins. down to 13ins. Machines can, in general, be adapted to cut at any height required above floor level.

It may be pointed out that, with most makes of machines, extremely low overall height is only obtainable with a certain small loss of efficiency and a serious loss of accessibility; unless the underground conditions are such as to call for very low-built machines, they should not be used in preference to machines of more normal dimensions.

As regards the depth of undercut, it will generally be found inadvisable, under average conditions, to attempt a floor level undercut of more than 4ft. with disc machines. With greater depths than this at floor level there is a very marked increase in the power consumption due to excessive churning up of the holings after the machine has done the actual cutting;. This is particularly the case in very thin seams, where only a small proportion of the holings can be removed by the machine men as the machine is at work. Where the cutting is done a few inches above floor level the bench formed between the floor level and the bottom of the cut assists the progress of the machine very greatly by preventing the holings being dragged back into the cut. The economical depth of the cut is then limited only by the natural characteristics of the seam itself.

Disc Machines Compared with Others. By reason of its general solidity of construction, the disc type longwall coal cutting machine will withstand heavier wear and harder usage than machines of either the chain or bar type.

Coal cutting machines frequently have to undergo extremely rough usage, and the robustness of the disc type machine is a considerable point in its favour. Under normal cutting conditions, where there is not much churning of cuttings, the consumption of power per square yard or per ton of coal undercut is not higher than with chain or bar machines, but in general the maximum load will be found to be higher. There is generally more gearing down between the cutters and the engine or motor than in bar and chain machines, and the 'cutter speed,' i.e. the rate of movement of the actual points of the cutters, is lower.

CHAPTER III

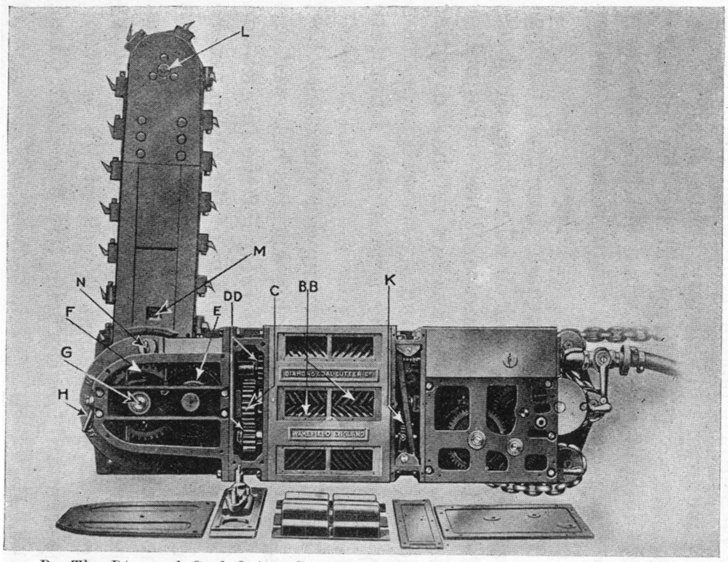
CHAIN MACHINES

THERE appear to have been more patents taken out for machines of the chain type, in the early days of the coal cutting machinery industry, than for any other type. The first chain machine which appears really to have been successful was introduced by Messrs. Wm. Baird & Co., of Glasgow, about 1874. In general principle this machine differs but little from the chain coal cutting machine of to-day. The improvements have been in the power unit, in details of design, and in the use of higher grade material; and these developments have resulted in a proved machine capable of excellent work under suitable conditions.

Principal Components. Figs. 4 and 5 show a leading make of chain longwall coal cutting machine, which can be fitted with either electric motor or compressed air turbine, as the cutting chain gear parts and the haulage gear parts are interchangeable for either type of machine. Fig. 4 illustrates the machine fitted with an electric motor. Fig. 5 shows a similar machine driven by a Spiro compressed air turbine, and in the illustration the top covers of the machine are removed to show the essential parts of the mechanism.

Electric Machine. In Fig. 4, A is a 40 h.p. (2 hr. rating), three-phase electric motor of the squirrel cage type. The starting switch is of the auto-transformer type with the control hand-wheel shown at i9. The switch and transformer coils are enclosed in a flameproof box, and tappings are arranged for at 0 5, 0 6, and 0 7 of line voltage. For coal face work the squirrel cage motor has great advantages over motors of the slip ring type, as there are no rubbing contacts in the motor to give trouble due to sparking. The autotransformer type of switch gives perfect control with extreme simplicity and great durability; this is particularly desirable in electric motors for coal cutting machines which have to start up sometimes under heavy loads.

The jib carrying the chain is shown at D. The haulage mechanism E; occupies the front end of the machine and, in common with all chain machines of this particular make, is of the chain type. Provision is made for pulling the jib into the cut by the power of the motor, the haulage chain being attached to a lug at the machine end of the jib and guided round the gear head for this purpose. The direct current and three-phase motor machines are interchangeable as the two types of motor are identical in overall dimensions and position of boltholes.



BB = Turbine drums.
C = Spur wheel.
DD = Spur pinions.
E = Crown wheel.
F = Gear wheel on chain sprocket shaft.
G = Chain sprocket shaft.
H = Lever putting F in or out of gear.
K = Gear wheel driving haulage mechanism.
L = Chain sprocket wheel.
M = Adjusting screw for chain tension.
N = Locking pin for jib.

By The Diamond Coal Cutter Co.

Fig. 5.—Chain Machine With "Spiro" Compressed Air Turbine.

Compressed Air Machine. The compressed air turbine chain coal cutter shown in Fig. 5 is driven by a Spiro turbine, a brief description of which is given on page 102. This turbine is constructed for air pressures of from 45 lbs. to 70 lbs. per sq. in., runs at about 1,800 r.p.m., and is rated at 40 to 50 h.p. Owing to its high speed it is necessary to have a double gear reduction to the chain sprocket shaft; the turbine drums BB revolve in opposite directions and the chain is run in whichever direction is required - according to which side of the machine the jib is to be used - by gearing the central spur wheel C with one or other of the spur pinions DD. The central spur wheel is keyed to one end of a shaft, having at its other end a small bevel wheel meshing with the crown wheel E; which in turn drives the gear wheel E keyed to the chain sprocket shaft G. The lever H enables the gear wheel F to be put in or out of gear so that the machine can be moved for transport or for pulling idle along the face without running the cutter chain.

The haulage mechanism is driven from one of the turbine rotors through the gear wheel K, and is arranged to give two speeds of feed or to be thrown out of gear when required, as, for instance, immediately before stopping the machine, so that there will be the minimum load on the machine when starting up again, or when moving the chain round to change picks.

The chain links are made from steel forgings and are case-hardened on all rubbing surfaces. The pitch of the chain is 72 ins. The cutter picks are carried in recesses in shaped cutter blocks on the chain, and are secured in position by set screws bearing against the front face of the cutter pick.

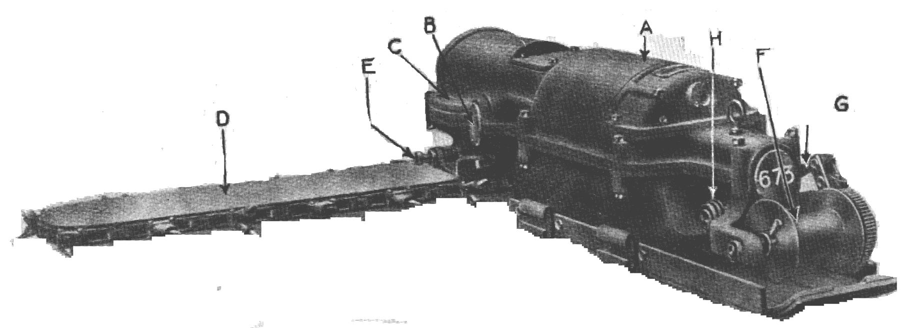
The chain is carried round a sprocket wheel L, and the centre of this wheel is hollowed out to form a large oil reservoir for the lubrication of the wheel. The tension of the chain can be varied at will by the adjusting screw M, so that the chain always runs at the correct tension. The jib is locked in position by the heavy pin N. Any desired length of jib is fitted, the standard lengths being 3ft. 6ins., 4ft. 6ins., and 5ft. 6ins.

The chain type of haulage fitted to this make of machine is partipularly suitable where the haulage mechanism is used to pull the cutter jib into the cut when the machine is cutting itself in. A further advantage of this type of haulage is, that the haulage chain can work on whichever side of the machine is next to the coal. This ensures the machine hugging the coal face and renders it unnecessary to keep the machine up to its work by using the goaf side props as a guide, and a tail rail is quite unnecessary.

It will be seen from Fig. 5 that the machine is run with the 'outboard' end of the jib leading; that is, the angle made by the centre line of the jib with the centre line of the body of the machine (in advance of the latter) is less than a right angle; this 'forward rake' of the jib also serves to keep the machine close up to the face when running.

Light Design of Chain Machine. A design of chain machine that differs in nearly every detail from other makes of chain machines is illustrated in Fig. 6. It is of exceptionally light and simple design, and under suitable conditions it does excellent work. The machine may be driven by d.c. or a.c. motor or by compressed air engine.

The direct current motors are of the four-pole series wound type, and the alternating current motors are three-phase squirrel cage.machines, the latter being controlled by means of a sixpole oil switch, which connects the stator windings, first in star and then in delta, straight on to the supply mains, without resistances or transformers. Owing to the lightness of all the parts this can safely be done without requiring a heavy starting current when the machine is starting light. The compressed air engines are of the three cylinder singleacting type, the cylinders being arranged radially.



By Messrs. Austin Hopkinson.

FIG. 6.—CHAIN MACHINE WITH D.C. OR A.C. MOTOR.

A = Electric motor.
B = Cover plate over end of cross shaft.
C = Housing for worm wheel.
D = Chain jib.
E = Set screw adjusting tension of chain.
F = Haulage drum.
G = Ratchet arm.
H = Crank shaft.

The drive is by means of a bevel wheel gearing with a second bevel wheel keyed to a cross shaft which carries a worm. This worm meshes with a large worm wheel keyed to the vertical shaft which carries the chain sprocket. In Fig. 6 the electric motor is shown at A, the cover plate over the end bearing of the cross shaft at B, and the housing for the worm wheel at CI. As in all makes of chain machines, the chain jib D can be racked in and out of the cut as required. The set screw E enables the tension on the chain to be adjusted at will. The haulage drum F is actuated by the ratchet arm ()} carried on a disc keyed to a cross shaft H, the drive from the motor shaft being effected by a worm and worm wheel. These machines are extremely light and are doing excellent work under suitable conditions.

Chain Machines Compared with Others. Chain machines tend to remove practically all their holings from the cut and to deliver them on the 'goaf' side of the machine: when cutting in coal, the actual holings are appreciably larger than in the case of disc and bar machines. The power consumption per square yard or per ton of coal cut compares very favourably with the consumption of disc and bar machines; under any conditions it is appreciably less than that of disc machines when there is a tendency for the latter to churn the 'cuttings,' and generally less than that of bar machines when the 'plough' and the worm cut on the bar are used to bring out the holings by worm conveyer action (see page 43).

CHAPTER IV

BAR MACHINES

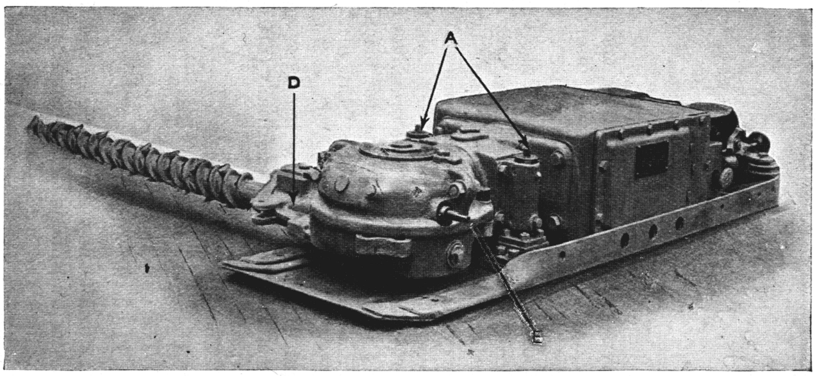
THE bar type of longwall coal cutting machine differs in its action from both the disc and chain types of machine in that the path of the cutting tools is across and not with the lines of stratification of the material being cut. A rough parallel to the actions of the three types of machinery may be taken from wood-working machinery. The disc machine resembles the circular saw; the chain machine resembles the band saw; and the action of the bar machine has been compared to that of a " saw file."

Principal Components. The bar type coal cutting machine consists essentially of the following parts:-

1) The motor or engine.
2) The gear head.
3) The cutter bar.
4) The haulage gear.

Figs. 7, 8 and 9 show general views and the details of the transmission of a bar machine. These machines are made for either electric (d.c. and a.c.) or compressed air drive, and as both electric motor and compressed air engine are contained in casings of the same overall size, and run at the same speeds, all remaining parts of the machines are the same in both eases.

The Motor or Engine. The maehine illustrated in Fig. 7 is fitted with a three-phase eleetrie motor, and the maehine in Fig. 8 is driven by a four-cylinder high speed singleacting compressed air engine. Direct current and alternating current motors and compressed air engines are interchangeable in these machines, all other parts being identical for all three types. The standard electric motors manufactured are 12 h.p., 22 h.p., and 26 h.p., according to the size of machine required. The compressed air engines are made in three sizes, having air consumptions respectively of 450 cu. ft., 640 cu. ft., and 840 cu. ft. of free air per min.; these figures are taken from the manufacturers' lists and are ealeulated for an air pressure of 45 lbs. per sq. in. at the eoal faee. Compressed air turbines are also supplied with these maehines.

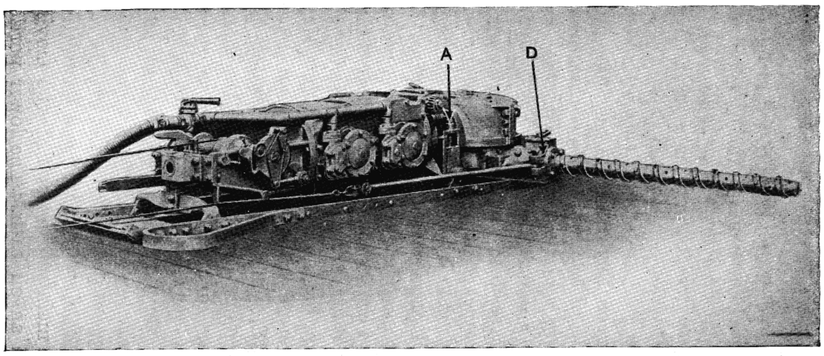


By Messrs. Mavor and Coulson, Ltd.

FIG 7.—BAR MACHINE WITH A.C. MOTOR.

A = Shaft actuating elevating and tilting screws.
D = Main bearing of cutter bar.
E = Shaft actuating rack and pinion which turns the lower half of the gear head and the cutter bar.

The Gear Head. The gear head eompletely eneloses the main gearing and all the moving parts run in an oil bath. The lower portion can be swung laterally on the upper portion which is fixed in position relative to the remainder of the machine. The lower half of the gear head carries the main bearing D of the cutter bar; an oil box surmounting this bearing provides lubrication for the revolving and reciprocating bar. The lower half of the gear head is turned on the upper portion by a rack and pinion actuated by a ratchet lever attached to the shaft E as and when required. The body of the machine can be raised or tilted, to vary the position of the cut within a range of several inches, by a ratchet lever attached to the shaft A.



By Messrs. Mavor and Coulson, Ltd.

FIG. 8.—BAR MACHINE WITH COMPRESSED AIR ENGINE.

A = Shaft actuating elevating and tilting screws. D = Main bearing of cutter bar.

The Cutter Bar. This bar is a forging of a special grade of nickel steel and is machined out of the solid. A spiral thread is cut on the bar which brings a proportion of the holings out of the cut as the bar rotates. The 'plough' (not shown in the illustration), which presses the holings up against the bar, forms a species of Archimedean screw or worm conveyer, so that a considerable proportion of the cut material is removed from the cut and delivered at the root of the bar. Either parallel sided or tapered bars are used, according to the particular holing for which the machine is required.

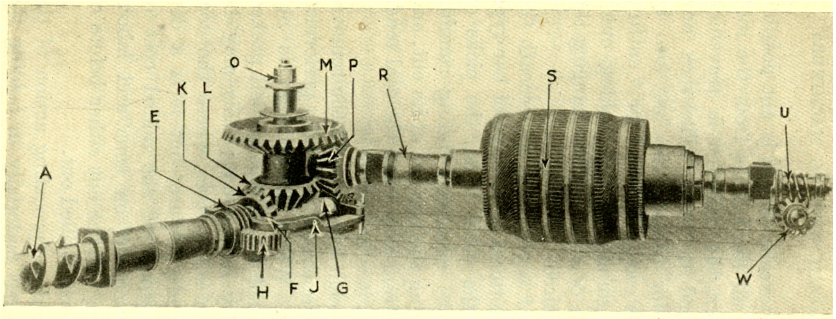
The picks are small and have a tapered shank furnished with a feather on one side. They are knocked lightly into the tapered holes in the bar, and the shape of the heads tends to fix them more securely in position when the bar is actually cutting; the feather prevents them from rotating under the reciprocating action of the bar.

Cutter bars with either right or left hand threads are provided, according to the side of the machine on which the cut has to be made, and according to whether an 'over' cutting or an 'under' cutting bar is required. The use of the terms 'over' and 'under' cutting in this connection does not refer to the position of the holing in relation to the seam, but to the direction of the path of the cutter points. The 'over' cutting bar cuts from above downwards and the 'under' cutting bar cuts from beneath upwards. In the majority of cases there is little to choose between 'over' and 'under' cutting bars as regards the amount of work done. An 'over' cutting bar is to be preferred under normal conditions, since the direction of the path of the cutters tend to ease the bar bearings from the weight of the bar. Where the holing is hard, and the bar shows a tendency to rise into softer material above the desired position of the cut, it is better to use an 'under' cutting bar.

Tapered bars are generally used in preference to parallel sided bars when the cutting is done in the coal in order to reduce the thickness of the cut as far as possible. The holings from a bar machine are generally finer than from other types of machines, and reduction of the width of cut is sometimes an item of considerable importance, especially when the cutting is done in coal.

The Haulage Gear. A worm engaging with a worm wheel (see U and W, Fig. 9) is carried on one end of the motor or engine shaft. The worm wheel W is keyed to a cross shaft carried through one side of the frame of the machine; and a disc, keyed to the outer end of this cross shaft, carries a pin which is adjustable radially from the centre of the disc. The motion Oc this pin when the machine is running is transmitted through a ratchet and pawl to a second shaft geared to the haulage drum. The rate of feed to the haulage drum is adjustable either by varying the distance of the pin from the centre of the disc or by altering the position of a cam plate on the second cross shaft; both methods control the number of teeth taken by the pawl at each reciprocation of the rod connecting the disc with the shroud carrying the pawl. The haulage is effected by rope, as in the case of the disc machines described in Chapter II.

Fig. 9 shows the essential parts of a direct current electric machine. The shaft R of the armature S carries a bevel pinion P, which meshes with the crown wheel M. The mitre wheel L revolves with the crown wheel M about the fixed shaft O and rotates the cutter bar ~4 through the mitre wheel K. The worm E is cut on an extension of the boss of the mitre wheel K and engages with the worm wheel H, carrying an eccentric F. In its bore the wheel K carries two keys diametrically opposite; these engage freely in keyways in the cutter bar so that, whilst being rotated, the bar is free to move axially, a reciprocating motion being given to the cutter bar inner bearing through the rods J. One worm wheel and one reciprocating rod only are shown in Fig. 9, the second worm wheel and reciprocating rod being on the far side of the cutter bar.



By Messrs. Mavor and Coulson, Ltd.

FIG. 9.—TRANSMISSION DETAILS OF ELECTRICALLY DRIVEN (DIRECT CURRENT) BAR MACHINE.

A = Cutter bar.
E = Worm engaging with worm wheels H.
F = Eccentric for reciprocating the cutter bar.
G = Cutter bar inner bearing.
H = Worm wheels carrying eccentrics F.
J = Rods transmitting reciprocating motion to cutter bar bearing.
K L = Mitre wheels.
M = Crown wheel
O = Vertical shaft.
P = Bevel pinion.
R = Motor shaft.
S = Motor armature.
U W = Worm and worm wheel driving haulage gear.

Operation of Bar Machines. The bar type of coal cutting machine does equally good work whether the machine is made to travel with the bar end in front or behind the body of the machine, except that it is not possible to shovel away all the holings from the root of the bar when the machine is travelling with the bar end in front. The rack and pinion gearing for turning the bar into or out of the cut is easily operated for 'cutting in' at the beginning and 'racking out' at the conclusion of a run, or for changing the picks when required.

The absence of any bearing underneath the coal is a constructional advantage of bar type machines. On the other hand, the picks or cutters cannot be examined during running except by swinging the bar out of its cut, and this may be far from easy when the coal tends to fall as soon as it is undercut.

Where the plough can be used the removal of the holings from the cut is usually performed very efficiently. Where the plough is not used a large part of the holings are left packed somewhat tightly in the cut; this may be an advantage in some cases, where the coal is of a very tender nature, but it is a disadvantage in respect of the added cost of 'getting' consequent on time and labour spent in cleaning out the cut either before or at the time the coal is filled out.

The rotary and reciprocating action of the bar does not assist materially in holding the machine up to the coal face and, except when the heaviest types of machines are used, it is usually necessary to pay particular attention to the goaf side props in order to prevent the machine pushing itself out from the face.

The actual strength of the bars used is very great, and, provided the cutters are kept in good condition, it is very exceptional to break a bar. Skilled bar machinemen can tell by the rate of progress of the machine whether the cutters require renewal. The machine must not be unduly 'pushed' by attempting to advance too rapidly.

Bar Machines Compared with Others. The power consumption of bar coal cutting machines is not greater than that of chain and disc machines; under conditions that are really suitable it is often appreciably less. There is less gearing down between the motor or engine and the bar, and the speed of the actual points of the cutters is considerably higher than in the other types. The power load is much steadier and does not show such wide fluctuations as are seen with disc and chain machines under certain conditions.