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"Electric Mining-Machinery, with Special Reference to the Application of Electricity to Coal-Cutting, Pumping, and Rock-Drilling."

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THE employment of electricity in mines for pumping, hauling and coal-cutting, is a subject which has already received some attention in Papers read at the meetings of the more strictly mining Institutions. The Authors have been, during the last four years, constantly connected with the applications of electricity to mining, and have spent a considerable amount of time underground, both in making experiments, and in teaching those who would have to take charge of the Electrical Machinery. They propose in the present Paper to show in what way the conditions of mining work differ from those of other industries, and how the problem has been dealt with, illustrating the subject by describing some of the machinery now in actual use.

The principal uses to which electrical power is likely to be put in coal- and metalliferous mines, and in quarries, are the driving of pumps, of hauling and underground winding-machines, of coal-cutting machines, of drilling-machines, both rotary and percussive, and in certain cases of fans for subsidiary ventilating purposes. It will be unnecessary here to dwell at any great length on the question of the relative merits of different methods of transmitting power in mines, practical experience having shown that compressed-air is almost the only rival to electricity, although in particular instances other systems are still in use for certain purposes. Compressed-air has one advantage, on which much stress has been laid, namely, that the exhaust product is in itself a valuable assistance to ventilation; but from circumstances that will presently be described, it would appear that the method of ventilating a mine by first compressing air, transmitting it under pressure, and then expanding it, is the most costly that can be devised. If power must be spent in ventilation, the best way to do it is to deliver a given volume of air, with the proper difference of pressure between the intake and the up-cast. In using compressed air, in order to keep the machinery as small as possible, and at the same time to limit the expense of the piping, it is necessary to work at as high a pressure as is feasible. On the other hand, increase of pressure, which in a steam engine conduces to greater economy and efficiency, is, in the case of compressed air, the one item which reduces the efficiency.

The following Table[1] gives the result of experiments made some years ago by Messrs. J. Fowler and Co., of Leeds, who have had considerable experience with air-compressors.

GROSS EFFICIENCY OF COMPRESSED AIR IN THE TRANSMISSION OF POWER.

Air-pressure. Lbs.	$\text{Efficiency} = \frac{\text{Brake HP. of Motor.}}{\text{I. HP. of Compressing Engine.}}$ Per Cent.
40·0	25·8
34·0	27·1
28·5	28·5
24·0	34·9
19·0	45·8

The above results are borne out by the experiments made more recently by Professor A. B. W. Kennedy, F.R.S., M. Inst. C.E., on the transmission of power by compressed air in Paris on the system introduced by Mr. Popp.[2] These experiments show that the brake HP. of the motor (10 HP.) is 31 per cent. of that of the engine driving the air-compressor if the air is not heated before it is used in the motor. If the air is heated and expanded before passing into the motor this efficiency is increased to 45 per cent. In mining work it is generally difficult to do this, and consequently engineers are content if they can obtain the lower result.

The great advantage of heating and expanding the air before passing it into the cylinder was so far realized by Mr. Frederick Hurd, in 1872, that he devised an arrangement for placing a heating apparatus inside the valve-chest, in which the oxygen for the combustion of the fuel (a mixture of coke and scrap-iron) was supplied by the air working the motor. By this means the possibility of exploding fire-damp is completely overcome, and the formation of ice is avoided.

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[1] "On Compressed-Air Machinery for Underground Haulage." By Mr. William Daniel. Proceedings of the Institution of Mechanical Engineers, 1874, p. 210.

[2] See Report of the British Association, 1890.

In practice 40 lbs. or 50 lbs. is about the pressure now adopted for working compressed-air machinery, although in the case of rock-drills, where lightness, portability of the machines, and smallness of the connecting hose, are of greater importance than efficiency, 70 to 90 lbs. per square inch is frequently used. The final result, however, of experiments at these pressures, agrees with that already given, namely, that it is impossible with compressed-air to transmit to the distant motor more than from 20 to 30 per cent. of the power expended in the engines, and probably, taking due account of the friction and loss in the piping, which, however, is not often excessive, the average efficiency of compressed-air as applied to mining work would be below 20 per cent. In the case of electrical transmission of energy, except when distributed into very small units, there is little difficulty in obtaining 50 per cent. of the power expended in the engine, and there are cases in which no less than 75 per cent. is transmitted without any extraordinary precautions being adopted.

These figures are frequently contradicted by the advocates of compressed-air, but after the precise particulars which have been published of experiments with electricity, and in view of the scanty information obtainable as to actual trials of compressed-air, the onus lies with its advocates to show that the results which can be obtained in regular working by this method exceed those already given. In addition to this lower efficiency, which means not only a greater expenditure of coal but also a large increase in the dimensions of the engine, and consequently in the price of the generating-plant, there is the cost of laying and maintaining the connecting-pipes. To make the matter clearer, a simple case has been chosen, and Table II, Appendix, prepared, showing the comparative economy of these two methods of transmitting power.

It must be borne in mind that the size of the cable plays a large part in determining the efficiency of the electric transmission of power. In the case of steam, compressed-air or hydraulic transmission, the losses in the pipes are frequently neglected, as they are usually small. This cannot be done with electrical plant, first, because the cost of the copper conductors forms a considerable item in the whole, and it is therefore desirable to have them as small as possible under the particular circumstances of each case, and secondly, because, unless the cables are proportioned to the power to be transmitted, they may become heated and damaged by the current passing through them.

In dealing with dip-draining pumps the Authors have given a Table showing the loss of power in the cable in two particular cases, with small machines, but they think that a similar Table dealing with large machinery and varying sizes of cable may be of interest. They have, therefore, in Table I, Appendix, given the losses in each part of an electrical pumping system, first, with a pump delivering 350 gallons per minute against a vertical lift of 900 feet and a pipe line 1,800 yards long of 6-inch pipes, and secondly, with a similar pump delivering 200 gallons per minute to a height of 480 feet through the same pipe line. It will be seen that an efficiency of 67 per cent. can be readily obtained even when transmitting nearly 100 HP. to a distance of more than 2 miles, and without any attempt being made to get specially good results, the whole plant being such as can be worked by unskilled men.

The results given, are, it is true, now recognized to a large extent as being, in the abstract, correct statements of the facts; but in the minds of the owners and managers of collieries and mines, there still exists a doubt as to when they are justified in adopting the use of electricity. One of the most important points which has been raised in this connection, and which was brought very strongly to the front in the discussion on a Paper by Mr. Blake Walker,[1] read at a meeting of the Midland Institute of Mining Engineers, is the question "of the safety, or otherwise, of an electric motor in a coal-mine, in view of the fact of the explosive nature of the gases existing in some parts of most mines."

The problem resolves itself into two parts—First: Will a motor, working under ordinary and satisfactory conditions, be likely to cause an explosion, assuming that it is placed in the positions where motive power is usually required in mines? Secondly: Is it possible under what may be termed extraordinary, but perfectly realizable conditions, to produce an explosion under similar circumstances?

A variety of opinions on the subject have been given, and some experiments have been tried bearing upon it, and the Authors consider that the following may be taken to be a correct summary of the results obtained.

In the case of an ordinary motor working up to, say, 500 volts, having the brushes properly adjusted upon the commutator,

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[1] Transactions of the Midland Institute of Mining Engineers, vol. xi. p. 317. "Electricity as a Motive Power," with special reference to its application to mine-locomotives, December 1889

no sparking can be perceived, but if from wear of the contacts during long runs, or variation in the load, slight sparking should occur, it is produced in contact with large masses of a highly conducting metal (copper), with the result, that the rise of temperature is not sufficient to fire explosive mixtures of coal-gas and air, or ordinary marsh-gas and air. The temperatures required to explode these gases at ordinary pressures may be taken to be, for a mixture of 1 volume of coal-gas, with 5 volumes of air, or for a mixture of 1 volume of marsh-gas with 9·4 volumes of air, from 900° to 1,100° Centigrade.

Copper combines with oxygen in air so as to produce oxide of copper at about 700° Centigrade, and as under normal conditions the formation of this oxide is not observed, either on the collector or on the point of the brush, this fact may be taken as further evidence that the temperature there existing is not sufficient to fire an inflammable mixture of gases. It may be said then, that under normal conditions, an electric motor is not a dangerous machine to use even in an atmosphere charged with considerable quantities of explosive gases; but having shown this, it may be admitted that supposing a brush, for example, is worn so far that it ceases to be in contact with the commutator, or supposing it to become seriously displaced from its proper position, an amount of sparking may ensue, which will cause a temperature sufficiently high to oxidize the copper of the brushes, and farther, to ignite inflammable mixtures. The question then arises, how is it possible to obviate the danger which may arise from this cause?

The Authors, having devoted considerable attention to this matter, have adopted the methods illustrated in Figs. 1, 2, 3, 8, &c., as a means of excluding from the armature the atmosphere in which the machine is working. It should be taken as an axiom that the machine will not normally be placed to work in an explosive mixture; but that what has to be guarded against is, in the case of a motor which perhaps is not attended to for some hours at a stretch, the accumulation of such gases in its neighbourhood during this time. Moreover, where a motor is in use at the coal-face or in a heading, means should be adopted to allow the machine to be stopped if, in the working of the coal, or from the fall of a roof or other reason, an inrush of fire-damp should take place, before this explosive gas has had time to come in contact with the commutator and brushes.

To effect this purpose, the Authors have adopted the practice of enclosing, either the whole armature together with the commutator and brushes, or when this is inconvenient, the commutator and brushes only, in a casing which is air-tight, or practically so. It has been objected to this plan, that although it may be feasible in the case of small motors, it is impracticable with machines of any size, owing to the diminished ventilation of the armature and commutator. The Authors have, however, adopted the method with success for a motor which has developed up to between 40 and 45 HP., and with no greater difficulty than in the case of one as small as 1 HP. In the winding of field-magnets, it is now recognized that any desired temperature of working may be obtained by allowing well-defined amounts of external cooling-surface for the dissipation of the heat developed. This proportion, for a final temperature of 70° F. above the atmosphere, may be taken as 2·3 square inches per watt to be dissipated.

The armatures of ordinary dynamos and motors are constructed to revolve in contact with the air, and the continual cooling thus obtained allows the surface for each watt to be dissipated for the same rise of temperature, to be diminished to about 0·7 square inch. In the case of the Authors' mining motors, it is only necessary to revert to the basis adopted for the field-magnets, that is to say, to allow a cooling-surface on the exterior of the armature-casing of the proportions which would be adopted for a stationary magnet-coil, in order to obtain the same result as to temperature. The armature revolving inside quickly brings the contained air to the same temperature, and this, being in rapid movement, conveys the heat to the external casing, from the surface of which it is dissipated by radiation and convection. It is true that to obtain a proper proportion between the cooling-surface and the heat generated, it has been necessary to be careful as to the magnetic and electrical design of the armature, but with these precautions, the Authors have found that the temperature of the armature of these enclosed motors at the end of a long run does not exceed that of the field-magnets.

Having thus disposed of the objection which has been raised by electrical engineers to this method, it remains to consider the question from the point of view of the mining engineer. The argument of the mining engineer is that if these casings should become filled with an explosive mixture and ignited, the result would be as disastrous as if they did not exist. The answer to this objection is as follows:—Seeing that under certain sections of the Coal Mines Regulation Act it is not allowable to work where the proportion of explosive gas exceeds about 1 in 30, it is not likely that any electric motor will be placed in such a position as to be run continuously in an explosive atmosphere for a longer period, at the outside, than two or three hours. The casings with which they are provided are tightly fitted at all the joints, many of them being packed with rubber, and it is not likely that an inflammable mixture could penetrate to a dangerous degree within that time. Should there, however, be any leakage into the covers, as soon as the proportion of marsh-gas in the air reaches 3 or 4 per cent., combustion will take place quietly, producing carbonic-acid gas, which will tend to prevent explosion.

If, however, it is required to work for long periods in such an atmosphere, the Authors would provide means for the introduction into the armature of an inexplosive mixture. The simplest method of producing this result would be to attach to the motor a steel cylinder containing carbon dioxide under pressure, and to connect this with the armature-casing by a pipe which should allow a slow but constant stream of this gas to reach the interior of the casing. The efficacy of this method may be judged when it is pointed out that the presence of 14 per cent. of carbonic acid gas in the most explosive mixtures of fire-damp renders them absolutely uninflammable. The Authors consider that this method of protecting the armature and commutator, and preventing the ingress of an explosive mixture, is generally more satisfactory than that of enclosing the commutator and brushes only as mentioned before. Conditions may, however, arise which render this latter method desirable. In that case the point to be aimed at is to produce a cover which shall give a similar protection to that afforded by a safety-lamp, and allow the ingress of the explosive atmosphere, but prevent the egress of flame. In order to do this it is necessary that the volume of the enclosed gases should be small, and that the passages through which the flame can escape should be of sufficient length, and the metal surfaces close enough together to cool it below the point of combustion. If the commutator were enclosed by a cylindrical case or otherwise, so that the volume of gas was small to begin with, yet as it wore away the space would increase to an undesirable extent. The Authors have therefore designed methods by which it can be contracted and the volume of gas kept constant. But the brushes are not the only part which should be protected, for if a wire on the armature should break, or the insulation give way, or if anything should get between the armature and the pole-pieces, sparking might occur, and such a contingency should be provided for.

There now remains the question of the switches connected with the motor, which will, of course, develope a spark on opening the circuit, when the current is flowing. This, in the opinion of the Authors, is a more serious difficulty than the former one, and they have endeavoured to meet it in two ways, namely, by diminishing, as far as possible, the tendency to sparking, and by arranging a switch which, even in the event of a spark, would be safe under any conditions likely to occur. The first idea that occurs is that by using a shunt-wound dynamo as a generator and a shunt-wound motor, the self-induction in the circuit is so far diminished that little sparking is likely to occur. But for many purposes, the conveniences arising from using a series-wound motor, as will presently be pointed out, are such that this method is in general to be abandoned, although the principle underlying it may be adopted. The reason of the diminished sparking with the shunt-wound dynamos and motors is, that the self-induction of the cable circuit is insignificant, and that of the armatures is also small, whilst the circuits of the magnetizing coils in both dynamo and motor, which have large coefficients of self-induction, are always closed through the armature. Thus, although on breaking the circuit the current in the magnet-coils tends to continue, it has a path of discharge through the armature of low resistance and of small self-induction. The Authors have therefore adopted the following plan: In the case of a series-wound dynamo they have provided a resistance-coil of small self-induction, which is always connected to the ends of the magnetizing coil, so as to form a path through which a current in the latter may continue, even when the main circuit is broken. In the same way, they have arranged the switch in such a manner that before breaking the circuit the coil of the magnets is short-circuited. By this means, the act of breaking the circuit reproduces the conditions which exist in the case of a shunt-wound generator and shunt-wound motor, and the only sparking which results is that due to the self-induction of the line and armatures. In order further to diminish this, the switch itself has, on its lower side, a resistance coil connected to the several points with which it makes contact, the wire being large enough to carry the current for the short time during which the switch is passing over them. By this means, even when the generator is short-circuited, the current is so far diminished that if the switch be moved slowly over the contacts, it is less than what has been termed the critical magnetizing current of the dynamo. The result is that by the time the circuit is open the series-wound dynamo has practically ceased to excite itself, the electromotive force and current are very small, and the sparking practically nil.

As an additional safeguard, the switch itself is constructed in the form of an air-tight box, which, in the same manner as the commutator covering, will exclude an explosive mixture for many hours. Although the Authors have never tried the experiment, they have reason to believe that the amount of gas which could be possibly contained in the switch is not sufficient, should it ignite, to blow the cover off; while the surface of contact between the cover of the base and the cylindrical hole, through which the handle passes, are sufficiently long to cool the escaping gas below the temperature of ignition. This switch is illustrated in Fig. 19. These precautions, which have been carried out successfully in practice, are, in their opinion, amply sufficient to meet all objections on the point of safety in connection with the application of electric motors to mining work.

Having so far dealt with the general question of the applicability of electrical power for mining machinery, and having indicated the methods adopted by the Authors in their designs, it is proposed now to illustrate the application of these principles by some actual examples. Full descriptions have been already given of the application of electric power to mining work under conditions analogous to those existing in ordinary power transmission installations above ground; for instance, Mr. A. Snell, Assoc. M. Inst. C.E., has elaborately described a large pumping plant working at Normanton,[1] and, in a paper previously mentioned, by Mr. G. Blake Walker,[2] the application to locomotive work of accumulators has been fully discussed. The Authors, therefore, propose to confine their attention to two or three illustrations of the use of electrical power, both in fixed plant and in machinery which is constantly moving from place to place whilst at work. For this purpose they have selected some dip-draining pumps, which are portable but are fixed whilst working; and they propose also to describe electrical coal-cutting machinery, electric coal-borers and electric rock-drills, as examples of constantly moving plant.

The earliest example of the application of electricity in mining work was its adoption by Mr. W. B. Brain, for draining a certain part of the Trafalgar colliery in the Forest of Dean.[3] An ordi-

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[1] National Association of Colliery Managers, September 28, 1889.

[2] Transactions of the Midland Institute of Mining Engineers, vol. xi. p. 317.

[3] Proceedings of the South Wales Institute of Engineers, vol. 13, p. 277.

nary horizontal pump was driven by a belt from the motor, which was fixed upon a permanent bedplate. The arrangement has worked well, and given satisfaction; but, in the opinion of the Authors, the use of belts in coal-mining work, unless under very exceptional conditions, is entirely out of the question, owing to want of space and the difficulty of keeping them in good working condition in dirty and wet situations.

In Figs. 1, 11, and 12, Plates 4 and 5, are illustrated two dip-draining pumps, a horizontal and a vertical form, designed by the Authors, and constructed by Messrs. W. T. Goolden and Co. In each case three-throw ram-pumps are used, the reason being that it is important in using electric motors that the load should be as regular as possible throughout the revolution. The pumps are mounted upon a bed-plate, which is extended to carry the motor. The motion is communicated from the motor-shaft to the pump-shaft by gearing. This method of reducing the speed is perhaps more noisy than the use of belts, but in practical working this is not of much importance; and, provided that the armature is properly constructed for the purpose, ample strength being given, and proper materials being used to avoid the result of the jar or shock, gearing may be confidently recommended. It requires no adjustment, and is so compact that the whole machine is self-contained, whilst, when the pinion on the motor, which is subjected to the greatest wear, is worn out, it can be replaced in a few minutes at a trifling cost.

Table III, Appendix, gives the data of one pump of each of these patterns, and shows the relative efficiency of the various parts, together with the size of rams. The gross efficiency is not very high, owing largely to the power used being small. But it was specially intended to produce a durable machine, suited for the rough conditions under which it was likely to be worked, and adapted also to be handled by persons who have not the necessary knowledge to keep any delicate mechanism in adjustment. These considerations necessitated the adoption of a large clearance for the armature, ample space for insulation, &c., all of which tended to diminish the efficiency. The motors, it will be observed, are of the Authors' enclosed type, the field-magnet coils being lagged with steel to prevent mechanical damage. These machines have, in some cases, run for many weeks, day and night together, with no attention beyond an occasional feeding up of the brushes and lubrication. This form of pump is well adapted for mines where the electric light is already installed, and in this connection attention may be drawn to a point which is worthy of note. In the use of electricity for motive power and for lighting, it has often been objected that the variations in the load upon the motor cause a considerable alteration in the lights upon the same main at some distance from the dynamo. The remedy for this is simple. By employing a well-governed engine, and compound-wound dynamo, the electrical pressure at the terminals of the generator may be kept constant; if then, a separate pair of mains is run for the motors, the pressure on the wires feeding the lamps is constant, whilst any variation at the terminals of the motor is not a matter of importance. These electrical pumps appear to meet every requirement of practical mining work, and have replaced steam and hydraulic pumps with considerable advantage.

Turning to the application of electricity to movable machinery, the Authors have for the last four years been constantly engaged in the design of electrical coal-cutting plant, and the results of the work done in this direction will now for the first time be published.

Although this use of electric power has only recently become an accomplished fact, it is interesting to note that the idea presented itself to Mr. Henry Wilde, F.R.S., of Manchester, one of the earliest pioneers in the development of the dynamo machine, as long ago as 1873, when he described the application of electric power to coal-cutting machines of various forms, in a provisional patent taken out by him in that year.

It was in 1887, so far as the Authors know, that the first machine was built for the purpose of cutting coal by electricity. It had a cutter of the bar type revolving on its own axis, a form which it appears was first introduced by Mr. Grafton Jones, and was driven by a motor designed for the purpose, and made by Messrs. W. T. Goolden and Co. (Fig. 6). The original experiments were conducted at the collieries of Messrs. T. and R. W. Bowers, and the conception of thus employing electricity is due to Mr. F. Mori, Electrician, of Leeds, and Mr. J. Blackburn, manager to Messrs. Bowers. Considerable difficulties were, as was natural, found in adapting power to conditions so novel, and so outside all ordinary experience; and, in order to obtain full information as to the obstacles to be overcome, the Authors devoted a good deal of time to practically working at the coal-face the various machines that have been constructed. These difficulties have been twofold: namely, electrical and mechanical. Fig. 6, Plate 4, shows one view of the original machine designed by Mr. J. Blackburn, containing the motor arranged to fit it. This was a three-coil vertical motor, adapted to work in a horizontal position, one of the side coils being removed. It was of 6 HP., and was driven by a dynamo having a normal output of 10 HP., the motive power being the engine of a hauling-machine, situated at the bottom of the shaft. The distance between the dynamo and the motor was about a mile.

The original dynamo and original motor were both compound-wound, the series-coils on the motor consisting of sufficient turns of thick wire to nearly saturate the magnets with the large current developed on first closing the switch; but when running at a normal load this series-coil had little influence on the magnetization, which was then affected by the shunt-windings; so that the regulation as to speed was almost as good as if the winding had been simply shunt. This arrangement is convenient as giving a good starting power, and at the same time ensuring satisfactory speed regulation; but in the case of coal-cutting machines the Authors have a decided preference for a series-wound dynamo and series-wound motor, for reasons previously described, namely, that when the motor is being stopped, by the insertion of a proper resistance, the electromotive force may be reduced nearly to zero before breaking the circuit; and further, if it is desired to handle the cables or to disconnect them, or to handle any part of the circuit of the machine after it is stopped, there is no liability to a shock should the insulation at any other point be defective. This is of great importance in a motor intended to be used by inexperienced miners, who are easily frightened, even by a moderate shock, so that they neglect to adjust the brushes, &c., even if they are not so far afraid that they will not work the machine at all. This first plant, which is still working satisfactorily, was, it will be noted, practically unprotected from dirt, dust, or explosive gases, and it was in connection with this that the Authors first devised their system of enclosed motors.

The next machine built by Messrs. Goolden is shown in Fig. 15, Plate 5, and in that case, as it was desired to cut into the coal at a height which was suitable for using direct driving without the intervention of gearing, the armature-shaft itself was made to carry the cutter-bar. The opinion, however, which the Authors now hold is, that although this method of working is quite feasible, it is on the ground of expediency not desirable. It is difficult to construct armatures with shafts large enough to carry the strain put upon them by a cutter-bar of the description used without cramping the space for wire and insulation.

Figs. 10, 13, 14, and 16, Plate 5, show still later developments of this class of machinery, in which the cutter-bars are mounted on a separate shaft, and driven by steel double helical gear-wheels. The point to be noted is the combination of the electrical structure with the more strictly mechanical framework, thus providing the greatest amount of strength and electrical power with minimum weight and size. The dimensions of the heading along the coal-face are generally so small that it is only by great compactness that the use of these coal-cutting machines is rendered possible.

Fig. 9, Plate 4, shows in plan the general method of working. The machine, mounted on its wheels standing on the rails laid along the face, is adjusted by means of the turn-table and worm-gear, so that the cutter-bar points along the heading; the current is switched on, and the bar, revolving rapidly on its axis, is turned through an angle of 90° so as to enter the coal. The worm-gear and table being then locked, the machine is drawn along, by means of a winch and wire-rope, cutting its way as it goes. Automatic methods of winding have been devised, but that of pulling in by hand is probably the simplest in the end, and has the advantage of enabling the man at the winch to tell whether the machine is cutting in hard or soft material, and accommodate the rate of movement accordingly. Automatic winding-gear is usually arranged to work at a fixed speed, which must necessarily be that at which the machine will cut in the hardest material to be dealt with, so that with softer material the progress is obviously less than it need be.

The Authors have suggested an automatic winding-gear intended to obviate this objection. It consists of a ratchet-and-pawl motion, the pawl being under the control of an electro-magnet. Since the load on the motor is accurately measured by the current flowing through it, the magnet can be so adjusted, that if the load should exceed the desired limit, the pawl would be lifted out of gear, and the feeding stopped until the machine had eased itself again to its normal load, when the pawl would commence to feed it forward.

All the motors used for these coal-cutting machines are entirely enclosed as to every working part. The field magnets are lagged in steel coverings, the switches with their resistance frames are placed in iron boxes, and from the outside it would be difficult to see that the machine was an electric motor. Furthermore, precautions have been taken to thoroughly enclose the gearing, and all bearings and their parts into which grit can obtain access, and the system of lubrication is such that the oil passes from the armature-shaft to the cutter-shaft and thence is drained into the gear-box, which has an oil-tight joint, so that the gear eventually revolves in oil.

Fig. 16, Plate 5, shows a particular arrangement of machine, which was required to cut at any height from 9 inches to 33 inches from the road-level. This was effected by bolting to one of the pole-pieces a casting with two segmental slots. The cutter-bar was carried in a support moving on these slots, and by these means could be raised and lowered to any height, remaining at the same time in fixed relation to the armature-shaft from which it is geared.

It is interesting to point out to electrical engineers how the somewhat difficult problem of arranging this machine, so as to avoid the magnetic short-circuiting of the poles, has been met. The leakage from such extended pole-pieces is considerable, but not nearly so excessive as might at first sight be thought.

Several forms of armature have been tried in these machines, with both "drum" and "Gramme" windings, and the Authors are of opinion that on the whole, the "Gramme" armatures are best adapted for the work; the reason being that it is very difficult to secure the wire across the ends of a drum-winding in such a manner as to ensure their being positively driven, and in the absence of such positive driving it seems only to be a question of time when the insulation will become abraded by the excessive vibration. One form which has been much used in these machines is shown in Fig. 10. The armature-core is deeply notched to receive the coils, and when these have been wound in place the whole is covered with a layer of annealed charcoal-iron wire. By this means a notched armature, giving a low magnetic resistance in the air-space, is obtained, whilst the production of eddy-currents and consequent heating of the polar horns is avoided, and the armature is of a form which can be handled and laid on the ground, if necessary, without any damage occurring to the wire or its surface.

It soon became evident that the ordinary brushes used on dynamos and fixed motors were useless, owing to the excessive vibration to which the machines were subjected, whilst various forms having butt-contacts, in which the brush was pushed forward by springs, gave rise, both with metallic and with carbon blocks, to excessive heating, due, as far as can be ascertained, partly to the friction on the commutator, and partly to the inferior electrical contact thus obtained.

Brushes of a type which has been successfully used in launch and tramway work, and was originally designed by Mr. Holroyd Smith, composed of blocks of metal carried by light steel fingers or springs, were also tried with similar results, and finally the Authors have adopted various forms in which the necessary elasticity is given either in the brush itself, or in a light steel back, there being however no movable hinge or knuckle which would allow it to chatter as a whole on the commutator.

The chief mechanical problem in connection with these coal-cutting machines has been: First:—What is the best form of gear to use? and Secondly:—What is the best form to give to the cutter-bars and cutters? As to the gear, the Authors have tried chains of every description and strength, and have had to abandon them all; they have also tried phosphor bronze gearing of ordinary forms, but have finally adopted, as working more smoothly and with less noise, and giving a maximum of strength, cast steel double helical wheels, shrouded nearly to the pitch line. By mounting one of such a pair of wheels in a manner free to slide to a small degree upon its shaft, the perfect alignment of the wheels is secured and the running leaves little to be desired.

Although the several machines illustrated in this Paper have been made to cut above the floor-level, at heights specially suited to each particular case, so as to work in the bands of shale or dirt and thus save the coal, yet the form with a bar-cutter is eminently suitable for cutting at the level of the floor itself, and the Authors have designed machines for this purpose, the rails being laid directly on the surface thus formed. The form of cutter most usually adopted in such cases is that of a large disk or wheel with the tools fixed into its periphery. This disk is carried on a bracket projecting from the side of the machine, and is caused to revolve by a pinion gearing into teeth either cut in its horizontal surface, or into teeth formed on its periphery, the teeth of the pinion being then made sufficiently long to allow the tools to cut clear at the bottom. The tools are spread out so as to cut the material clear of the disk.

Machines on this principle have been used with considerable success in several places, but the Authors consider the bar cutter is to be preferred for several reasons.

First, there is a considerable amount of difficulty in making a machine with a disk cutter to turn round so as to cut its own way under the coal, and in fact in most cases this is done by hand.

Secondly, when the tools are blunt, they have to be taken out and replaced by sharp ones while the disk remains in the coal, a matter of some difficulty in the confined space and with the small amount of light available. With a bar-cutter, on the other hand, since the bar is only held by four bolts at the coupling, it is turned out of the coal and a fresh one with a complete set of new cutters substituted, the other being sent to the bank to be reground.

Thirdly, if the coal or roof is at all tender there is a great tendency for it to fall as soon as it is undercut; to avoid this, wedges are inserted in the groove to keep it up, but the distance from the front of the cut to the back of the disk is considerable, and as a consequence the coal often falls before it can be wedged; this of course jambs the cutter, which then has to be dug free, involving a loss of time. Now with a bar-cutter the wedges can be inserted close behind the bar, only a few inches from the front of the cut, and the coal supported, so that even if it falls it cannot jamb the cutter.

Fourthly, a bar cutter can be made to bare to a greater depth, as much, for instance, as 5 feet.

Fifthly, in order to make an electric motor of sufficient power while the weight is kept small, it is necessary to run it at a fairly high speed, and therefore, to keep the gearing compact, the cutter must also run at a high speed. This is easily attained without any disadvantage with a bar-cutter, but is quite impossible with a disk-cutter, where the speed of the tools would be so great as to seriously heat and soften them. In practice the Authors run the motors at about 700 revolutions per minute, while the cutter makes about 500 revolutions per minute. On the other hand, the disk-cutters will draw more of the fine coal out of the groove than the bars will, but this advantage is not sufficient, in the Authors' opinion, to compensate for the disadvantages enumerated above.

The cutter (Fig. 17, Plate 5) consists of a long bar, either taper or parallel, fitted with a coupling to unite it to the shaft of the machine, and having arranged on it a series of steel tools. The bar, revolving on its axis, acts like a long milling tool, each set of cutters sawing its way through the material. The form used in the coal-cutting machine known as the "Economic" was a parallel bar, having holes in it, into which were fitted steel nibs secured in place by set screws. Some years ago Mr. Grafton Jones suggested the threading of star-shaped disks on to a square or polygonal bar, with a nut at the end to hold them in place. The cutter used by Messrs. Bowers in the first machine tried at their colliery, Fig. 18, Plate 4, was upon this principle. A series of star-shaped cutters made of cast steel having an hexagonal hole in the centre, were threaded on to a steel shaft, and secured by a nut at the end, the nut having cutters screwed into it, so as to clear itself. The result was satisfactory except so far as the wear of the points was concerned. In fairly soft or friable coal, it is doubtful whether they can be much improved; but in coal which contains much dross or is hard, the cutters are soon blunted, and the power required to drive the machine becomes excessive. After some experiments, in conjunction with Mr. Hans Renold, of Manchester, the form shown in Fig. 17, Plate 5, was devised.

The object in view was to provide a bar which would admit of cutters being used of a much higher grade of steel than was possible with the star-shaped castings previously mentioned: which should have more metal for removing heat from the point of the tool, thus preventing its softening and wear: and which should take, if possible, less power, and at the same time give a more steady cutting action, and remove the debris which it formed. To effect this, the bar is drilled with a series of holes, each of which is placed in a direction nearly at 90° to the next adjacent one, but differing so far from a right angle that one complete turn is made in the length of the bar; by arranging the cutter in this manner, a left-handed spiral is produced having a pitch equal to the length of the bar, which serves to equalize the cutting action, and also a right-handed spiral, which has a pitch equal to about $\frac{1}{6}$ of the length of the bar, and forms as it were a corkscrew to draw the dirt out of the cut. These holes are tapered to about 1 in 30, and pieces of round steel are turned to fit them, the heads being shaped to form the cutter, the exact nature of which depends on the material to be cut.

The proper form to give these tools is a question to which considerable attention has been devoted. Square-shaped, flat-faced tools were tried, of such a width as to overlap one another and remove the whole of the material; it was found, however, that the power required was excessive. Both square and pointed tools of various widths were then tried, with the result that the form indicated in Fig. 17 has been found to be, on an average, the best. This cutter is of a V-shape, and is placed in the bar with a gauge, so that the surface farthest in the coal is set in such a direction as to clear itself. The edge nearest the machine slopes across the cut, so that when the tool has entered to a depth of about $\frac{1}{8}$ to $\frac{1}{4}$ inch, a wedging action commences, and the ridge of coal left between two succeeding cutters is split off. By this means only about a quarter of the total quantity removed is actually cut away, the remainder being broken off by a splitting action, and the power required for working the machine has been reduced to one-quarter of what it was. Various speeds for operating the bar have been tried, but for fairly hard coal from 400 to 500 revolutions per minute is enough, although in soft and friable coals a higher speed may be adopted. The diameter over the points of the cutters varies from about 5 inches at the front of the cut to about 3 inches at the back. The tools when blunt are driven out with a hammer, and ground on an ordinary stone in a tool-holder, in which they are set in a taper hole, the holder being mounted eccentrically, so that in grinding the proper backing is given. These cutters are made of an exceedingly high quality of steel, which is tempered dead hard, so that it will easily scratch glass.

The average length that can be cut without changing the bar may be taken in hard coal to be about 40 yards, though as much as 80 yards, in hard gritty coal, has been effected without any stoppage. The blunting of the tools, however, when the edge is once really gone, proceeds rapidly, and out of proportion of the work done, and it is bad economy to force the amount cut to too great an extent. One man or boy attends to the winch, one man follows the machine, spragging and putting up props, whilst a third devotes his attention to the cutter itself, and to clearing the road in front of it.

The amount cut by the machine varies according to the nature of the seam, and the experience of the men working it; but it may be taken that on the average, all stoppages being included, 20 to 30 square yards per hour may be cut in fairly hard coal. As a matter of actual maximum performances, the following results may be cited. At Lord St. Oswald's colliery at Nostell, 55 yards were bared to an average depth of 3 feet 8 inches in seventy-five minutes, and lengths up to 20 yards, where the road is clear for running without stopping, have been often cut to this depth at the rate of a yard a minute. And at Messrs. T. and R. W. Bowers' collieries, where a less powerful motor is used, 110 yards have frequently been bared to a depth of 3 feet 6 inches in four hours. The length of cutter-bar usually adopted is from 3 feet 6 inches to 3 feet 9 inches, but it is a matter of interest that in a trial at Messrs. Briggs & Co.'s collieries at Normanton, a bar of 5 feet in length was used, cutting underneath to that depth, an amount exceeding considerably the best performance of any previous machine.

The actual HP. developed by the motor has varied in different cases from 6 HP. to nearly 15 HP., but in the Authors' opinion, it is a mistake to reduce too far the power available, and 10 or 12 HP. would seem to be a fair average amount for working rapidly and effectively, with a reserve enabling obstacles to be overcome, without straining the machinery.

Table IV., Appendix, gives the relative cost of cutting by machine and hand-labour in certain cases; but, although trials have extended over some time, it is perhaps too early to speak of what will be the ultimate saving effected by the use of these machines. Great difficulties have had to be overcome, apart from the electrical and mechanical problems, in the prejudice of the men, and in the resistance which they offer to the introduction of labour-saving machinery; and this has reached such a pitch in some cases that the miners have actually declined to work the machines, or to remove the coal which has been cut by them. These obstacles will disappear in time, but at present they form an element which has to be considered in estimating the cost of coal-cutting by electric power.

Electric Boring- and Rock-drilling Machinery.

An early example of the use of electricity in mining was the employment of the electric motor for working rock-drilling plant. This part of the subject has, although apparently simple, proved to be one of the most difficult to deal with; the reasons of this being—first, that the amount of power required is small, and, therefore, the advantage gained by electricity not so noticeable; secondly, that very powerful and complete drills, particularly percussive drills, are in the market; and, thirdly, that the use of machine-drills is generally resorted to in cases where the necessity for at once carrying out the work is very pressing, so that the contractors are less willing to try any experimental plant.

Drilling-machines may be divided into two classes: (1), rotary, and (2), percussive. Fig. 7, Plate 4, illustrates a form of rotary drill, complete with its own electric motor, and mounted upon trolley-wheels, applicable for use for coal or ironstone boring. The motor, the framework of which is made in one with the bed, is a small $\frac{3}{4}$-HP. enclosed mining-motor, of the Authors' design. The revolving drill-bar has a thread cut along its length working through a nut which is free to revolve except in so far as it is held by an adjustable brake-band. The result of this is that if the brake be slack no feed is imparted to the drill; if the brake be tightened, so as to prevent the nut revolving, a feed of $\frac{3}{16}$ of an inch per revolution, or any intermediate amount, may be given.

The power is taken from the motor-shaft by bevelled gear, giving a reduction in speed of $1\frac{1}{2}$ to 1; it is then transmitted by the vertical shaft and through a worm-gear to another pair of bevels. The total reduction in speed is from 1,600 revolutions per minute to 50 revolutions on the drill-spindle. This drill will bore a hole 2 inches in diameter in hard coal at a speed of 12 inches per minute.

It will drill in slate at the rate of about 3 inches per minute, but the principal difficulty in dealing with material as hard as slate is to procure a sufficiently satisfactory fixing to the roof and sides to prevent the whole drill from shifting and getting a cross strain upon it. It is therefore principally recommended to be used for coal or ironstone, where rapid sinking through moderately hard material is required. The drill takes about 10 amperes of current, at a pressure of 110 volts. Some experiments made to determine the power actually developed, through all the gearing and on the drill-shaft, show that the ratio $\frac{\text{mechanical power on drill-shaft}}{\text{electrical power}}$ is about 40 per cent.

For dealing with harder rock, diamond-drills, working in a similar form of machine, may be used, but the cost of maintaining diamond-drills is so heavy that in general little economy is effected by their use. Percussive rock-drills, therefore, are generally used for this purpose. The use of percussive rock-drills driven by electricity has, so far, been limited, one of the principal difficulties being the construction of a really suitable percussive action, driven by a rotary motion. Fig. 8, Plate 4, indicates the arrangement devised by the Authors for driving an Ingersoll rock-drill, by means of an electric motor. In order to diminish the weight of the drill, it is separate from the motor, which is mounted on a trolley, the connection between the two being made by a length of about 8 feet of flexible shafting.

The drill itself is well known. It consists of a bar lifted by a crank motion, connected to the driving handle by a ratchet and pawl, in such a manner that after the drill has been lifted by the connecting-rods against the pressure of a spring, as soon as the dead point on the top centre is passed, the spring forces the drill forwards, over-shooting the driving handle, which gears again as soon as the blow is expended. Two blows, or nearly so, are therefore given for each turn of the handle, which is designed to make sixty revolutions per minute.

The driving-wheel is geared into a bevel pinion which is carried by an adjustable frame or quadrant and driven direct by the flexible shaft. The speed reduction is in the ratio of ten to one.

The motor, which is of the pattern previously described, and is entirely enclosed, is mounted on a trolley, and has a fibre pinion driving a gear wheel, which gives motion to the flexible shaft. The speeds are as follows:—Motor, 1,500, flexible shaft, 600, drill wheel, 60. This plant may be taken to represent the present position of electric percussive-drilling, but the Authors have been for some time engaged upon effecting the design of a new machine, doing away entirely with a separate motor, giving a direct percussive action and reducing the total weight to a considerable extent. The experiments upon this drill are not yet complete, and therefore, for the present, it will only be mentioned.

Dynamo for Transmitting Power.

Figs. 4 and 5, Plate 4, show in section a class of dynamo well adapted for use in transmitting power for electric mining-work, with pressure up to 1,000 or 1,500 volts.

The bed is of cast-iron, and a block in the centre of it forms the connecting yoke of the magnets, which are of the "inverted" type, and stand upon it. The magnet cores are of rectangular section, and are made of wrought-iron. The pole-pieces are of cast-iron, or in some cases are forged in one with the magnet-bars. The armature, which by preference, is of the "Gramme" type of winding, is composed of a number of thin sheets of charcoal-iron, insulated from one another by paper, mounted upon a phosphor-bronze spider, which is notched into the plates, and firmly keyed upon a stout steel shaft. The magnet may be shunt- or compound-wound, but in the case of transmitting power from a dynamo to a single motor, is preferably series-wound. The commutator is composed either of phosphor-bronze or of hard-drawn copper, insulated with mica. The brush-holders are of a special type, enabling the brushes to be fed through the holder and adjusted by a feeding-screw at the back, thus doing away with the necessity of loosening any bolts or nuts. This is valuable in case of long runs extending over nights and days together, such as often occur in mining work.

Special point is made in these machines of the ample clearance given to the armature in the pole-piece gap; $\frac{3}{16}$ of an inch a side is usually adopted, thus allowing room for wear in the bearings, and for the expansions which inevitably take place, and obviating the annoyance and delays caused by the armature rotating against the pole-pieces. The shaft and bearings are of large dimensions, compared with ordinary dynamos, for similar reasons, and the precautions thus taken of providing ample margins, not only in the mechanical factors, but also in the electrical design, have contributed largely to the success and freedom from accident which has marked the working of these machines in mining experience. Several of them have been running for periods extending over two or three years, in the hands of persons quite unacquainted with electrical matters, without any breakdown or repairs being necessary, and with very small wear upon the commutators.

SUMMARY.

The instances described will be sufficient to show that:—

A. Electrical power is destined to become an important factor in mining mechanics, on account of—

1. The greater facility with which it can be used with machines which require to be moved from time to time as the work advances.
2. The great economy in first cost, and reduced cost of working owing to its efficiency being higher than that of compressed-air, or any other medium of power-transmission.
3. The smaller cost of maintaining the cables, as compared with piping, on shifting floors in roadways, etc.

B. That the methods described are sufficient to obviate all objections to the use of electric motors in coal-mining, either by excluding inflammable gases, or by constructions which allow of their safe combustion.

C. That the experiments, trials and practical work, extending over four years, show that—

1. Electrical pumps may be used with advantage and economy for mine-draining.
2. Electrical coal-cutters can replace hand-labour, with saving in cost, and increased production of coal.
3. Electrical drilling-machines are available in place of machines worked by hand or compressed-air.

While doubtless, on all these points, opinions may to some extent differ, and the particular methods adopted may be subjected to criticism, the Authors hope that the subject they have brought forward will be found of interest to the members of the Institution.

The electrical details of many of the machines described are due to Mr. H. W. Ravenshaw, Assoc. M. Inst. C.E., who has used considerable skill in adapting them to meet the conditions required. The Authors also have to express their thanks to Messrs. W. T. Goolden & Co., for placing drawings and results of tests at their disposal, as also to Mr. R. Hancock for his kind assistance in connection with the preparation of the drawings illustrating this Paper, from which Plates 4 and 5 have been prepared.

APPENDIX.

APPENDIX.

TABLE I.

Size of Cable.	Brake HP. of Engines.	HP. Lost in Dynamo and Belting.	Per Cent. of Total HP.	HP. Given out by Dynamos.	Volts at Dynamos.	Volts at Motors.	Distance in Yards, Dynamos-Motors.	HP. Lost in Cables.	Per Cent. of Total HP.	HP. Put into Motor.	HP. Lost in Motor.	Per Cent. of Total HP.	HP. Lost in Pipes.	Per Cent. of Total HP.	HP. Absorbed in Friction in Pump and Gearing.	Per Cent. of Total HP.	Useful Work done in Raising Water.	Per Cent. of Total HP.
2. 19/12	200	20·0	10	180·0	670	550	3,800	32·0	16·0	148	15	7·5	16	8·0	22	11·0	95·2	47·8
2. 19/14	224	23·0	10	201·0	750	550	3,800	53·0	23·5	148	15	6·7	16	7·1	22	9·7	95·2	42·7
2. 19/14	256	25·0	10	231·0	860	550	3,800	83·0	32·5	148	15	5·8	16	6·2	22	8·5	95·2	37·1
2. 19/14	192	19·0	10	173·0	644	550	1,800	25·2	13·1	148	15	7·8	16	8·0	22	11·0	95·2	49·6
2. 19/16	209	21·0	10	188·0	698	550	1,800	40·0	19·0	148	15	7·2	16	7·6	22	10·6	95·2	45·6
2. 19/17	216	22·0	10	196·0	730	550	1,800	45·0	22·0	148	15	6·8	16	7·4	22	10·2	95·2	44·0
1. 19/14	72	7·0	10	65·0	674	550	3,800	12·0	16·6	53	8	11·2	3	4·2	13	18·0	29·1	40·5
1. 19/16	83	8·3	10	74·6	774	550	3,800	21·6	25·8	53	8	9·6	3	3·6	13	15·5	29·1	35·0
1. 19/14	67	7·0	10	60·0	618	550	1,800	6·6	9·8	53	8	12·0	3	4·5	13	19·3	29·1	43·5
1. 19/16	70	7·0	10	63·2	656	550	1,800	10·2	14·6	53	8	11·5	3	4·3	13	18·5	29·1	41·6
1. 19/17	73	7·3	10	65·6	680	550	1,800	12·6	17·2	53	8	11·0	3	4·2	13	17·8	29·1	40·0

TABLE II.

System.	Brake HP. of Steam-Engine.	Brake HP. of Motor.	Distance from Engine to Motor in Yards.	Size of Cable or Pipe.	Price of Engine and Dynamo or Compressor.	Price of Cable or Pipe.	Price of Motor.	Total Cost of Plant, without Erection.	Efficiency.
				Ins.	£	£	£	£	Per Cent.
Electric . . .	15·4	10	2,000	$\frac{7}{16}$	210	192	95	497	65
Compressed air .	33·3	10	2,000	4	130	700	63	893	30

TABLE III.

Pattern of Pump.	HP. on Belt.	HP. at Terminals of Dynamo.	Volts at Dynamo.	Size of Cable.	Distance in Yards, Dynamo-Pump.	HP. Lost in Cables.	Per Cent. of Total HP.	HP. Lost in Motor.	Per Cent. of Total HP.
Vertical .	3·3	2·95	100	7/15	560	0·56	17·0	0·35	10·6
Horizontal	2·9	2·57	175	7/18	2,000	0·98	33·8	0·23	7·9

Pattern of Pump.	HP. Lost in Pump and Gearing.	Per Cent. of Total HP.	HP. Lost in Pipes.	Per Cent. of Total HP.	HP. in Water Delivered.	Per Cent. of Total HP.	Height Water is Forced.	Gallons per Minute.	Gross Efficiency Transmission.	Size of Rams.
										Ins.
Vertical .	0·6	18·2	0·165	5·0	1·260	38·4	170	24·3	43·4	3
Horizontal	0·47	16·2	0·600	20·7	0·288	10·0	19	50·0	30·7	$3\frac{3}{4}$

TABLE IV.

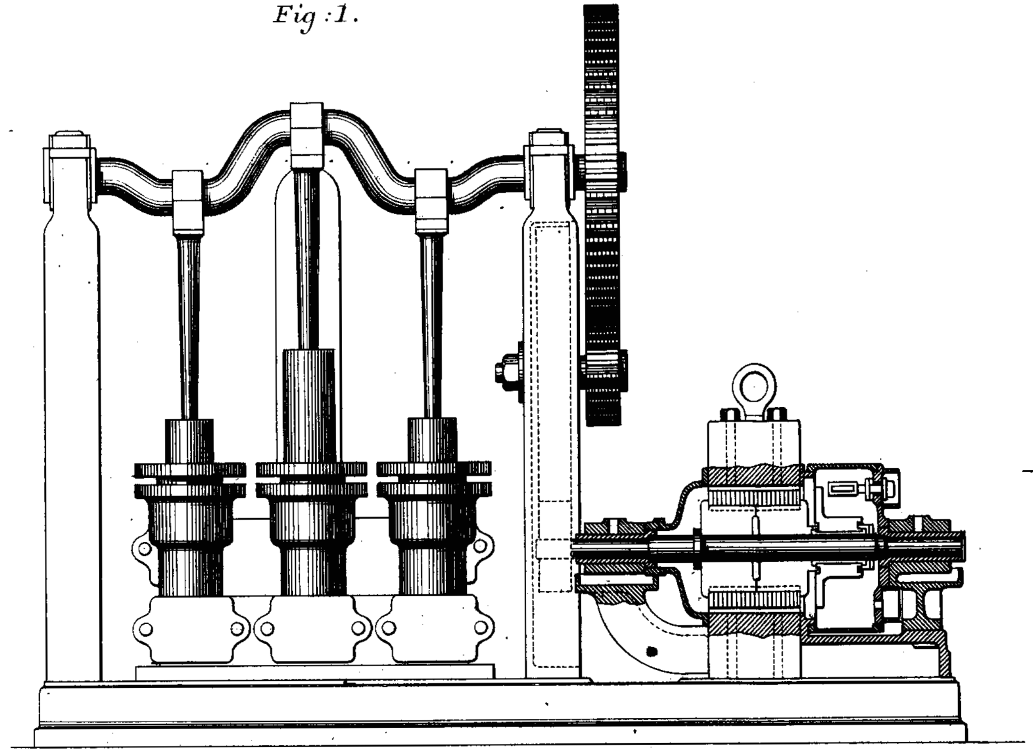
RELATIVE COST OF CUTTING COAL BY MACHINE AND BY HAND-LABOUR.

Thickness of seam	3 feet.		
Cost of cutting, filling, &c., by hand .			2*s*. 6*d*.
Saving of coal by machine	20 per cent.		
Tons bared per shift	160 tons.		
Labour, steam, cutters, interest and depreciation at 15 per cent. . . .		0*s*. 3*d*.	
Cost of filling after machine, taking up floor, laying rails, &c.		1*s*. 3*d*.	
Total cost by machine			1*s*. 6*d*.
Saving over hand-labour			1*s*. 0*d*.
Saving in coal			0*s*. 6*d*.
Total saving by machine			1*s*. 6*d*.

ELECTRIC MINING-MACHINERY.

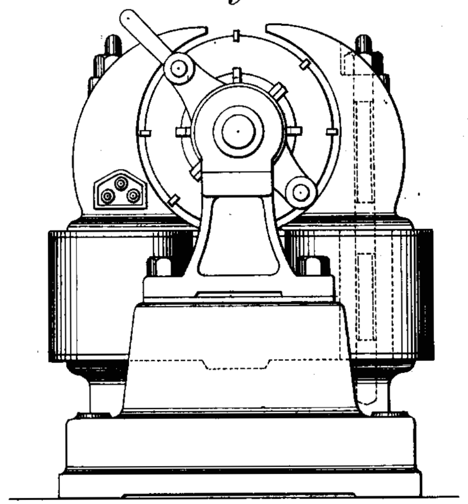
PLATE. 4.

Fig: 1.



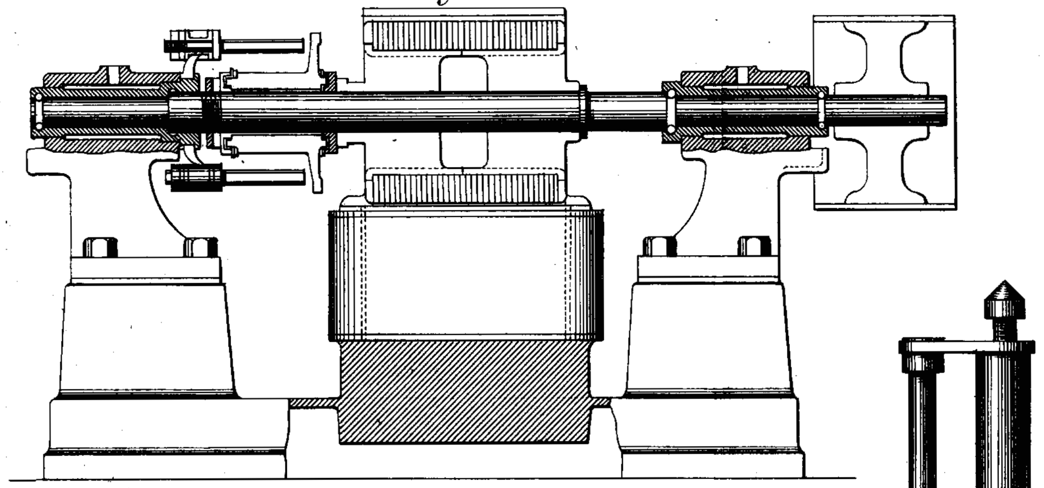
GOOLDEN ELECTRIC DIP-PUMP WITH PATENT ENCLOSED MOTOR.

Fig: 4.



END VIEW.

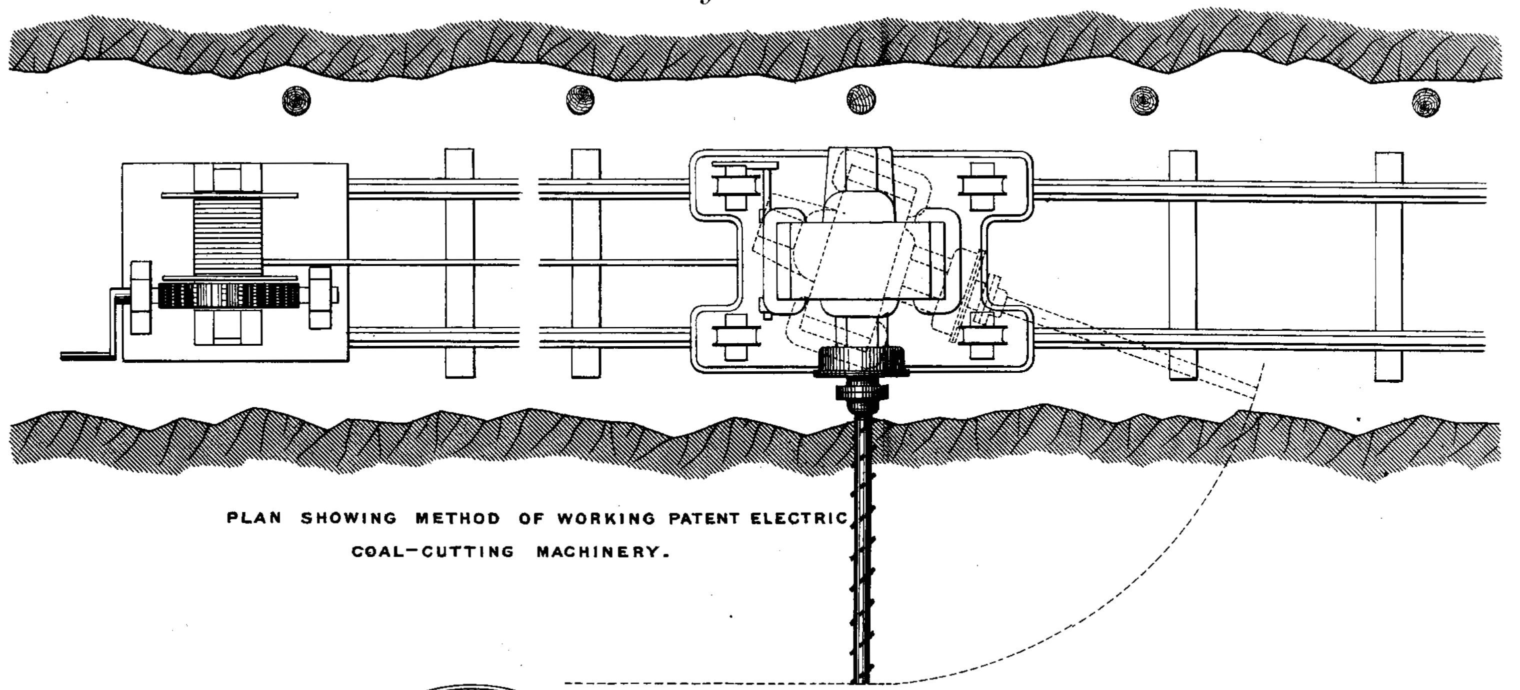
Fig: 5.



LONGITUDINAL SECTION.

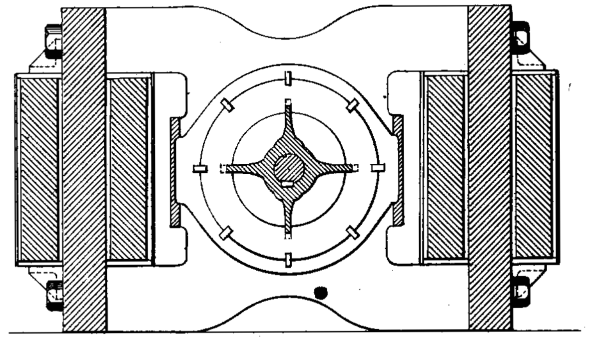
21 H.P. GOOLDEN DYNAMO.

Fig: 9.



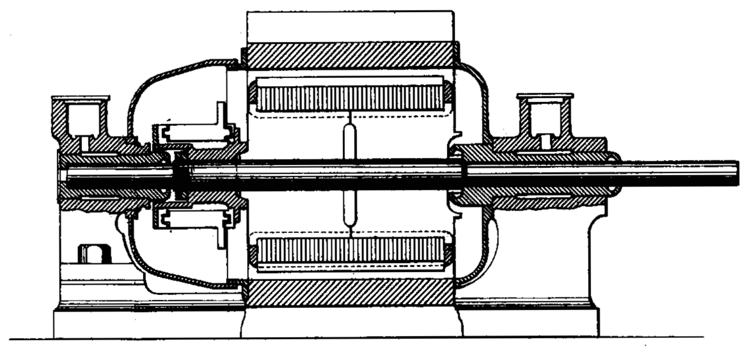
PLAN SHOWING METHOD OF WORKING PATENT ELECTRIC COAL-CUTTING MACHINERY.

Fig: 2.



CROSS SECTION.

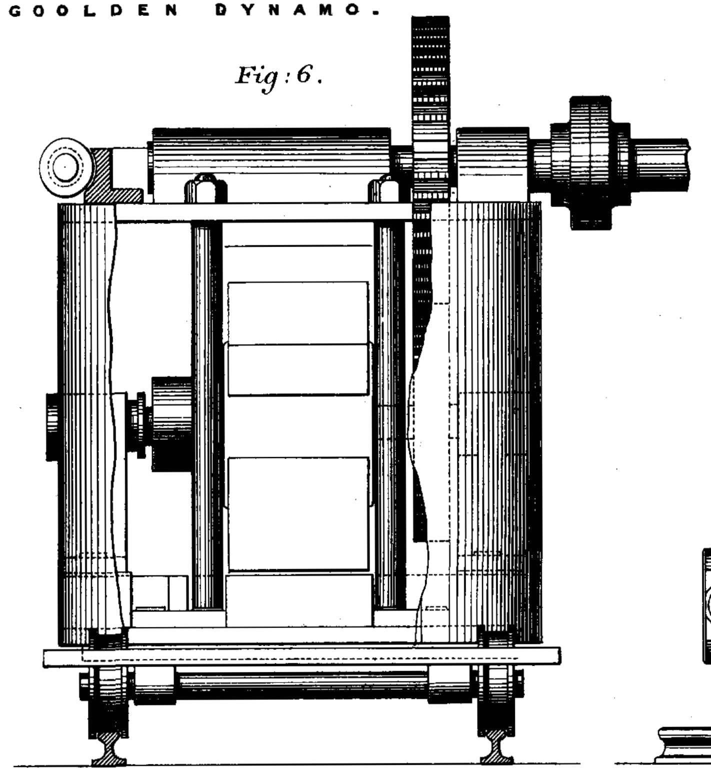
Fig: 3.



LONGITUDINAL SECTION.

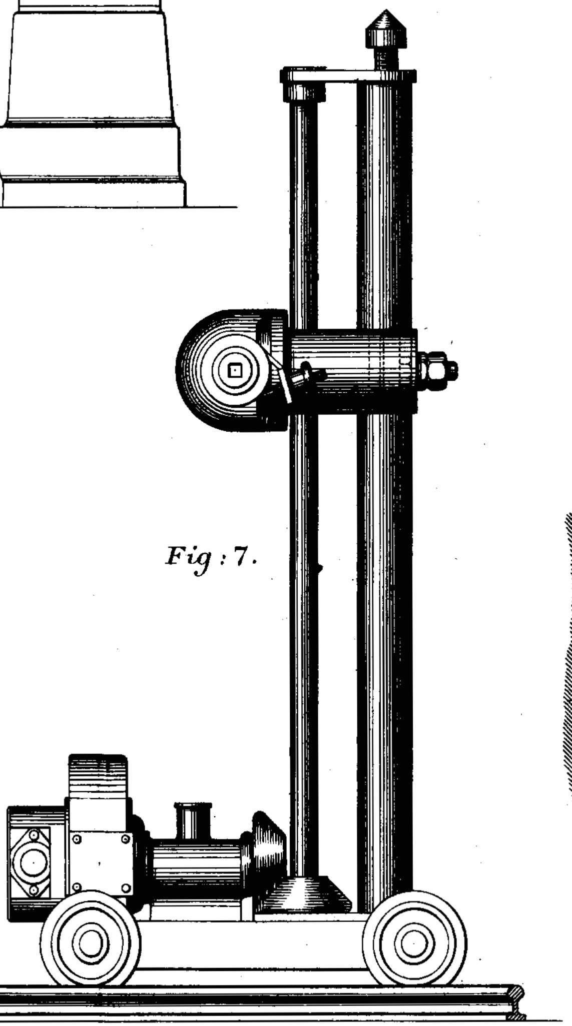
14 H.P. GOOLDEN PATENT ENCLOSED MOTOR.

Fig: 6.



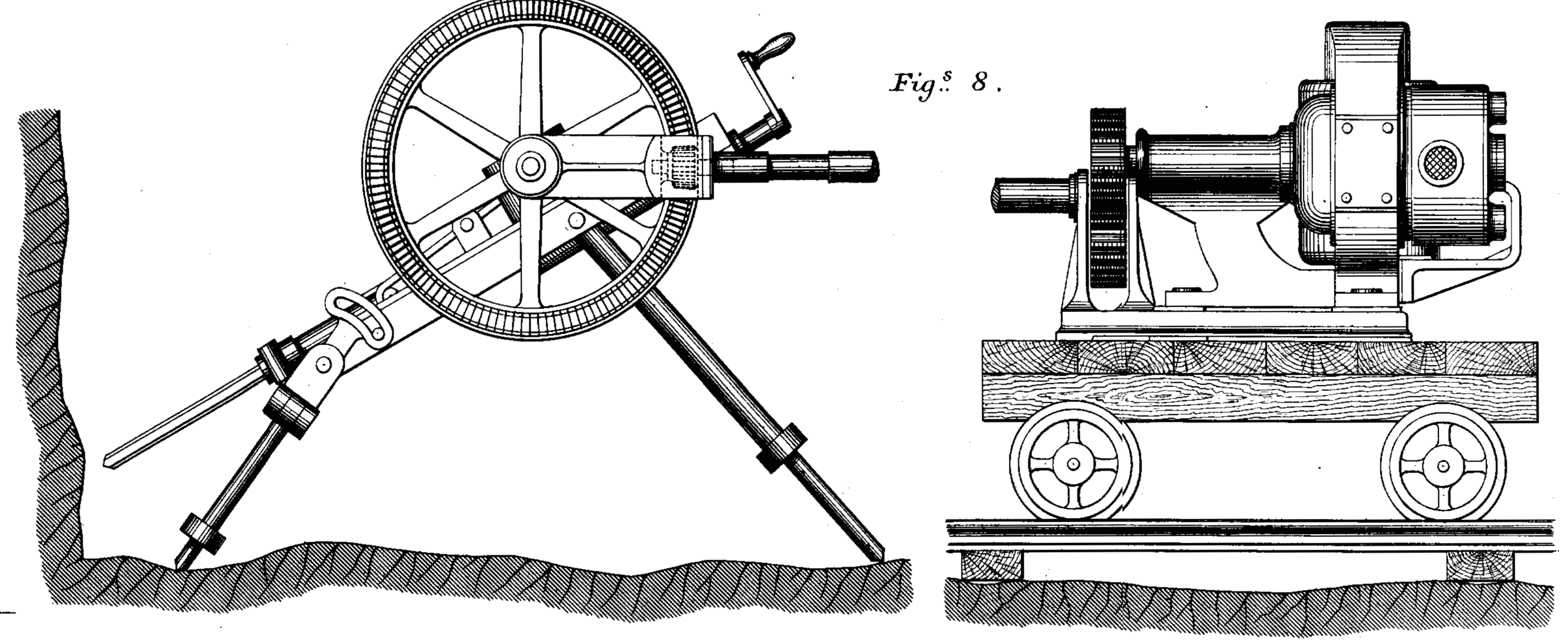
MORI-BLACKBURN ELECTRIC COAL-CUTTER, FITTED WITH GOOLDEN MOTOR.

Fig: 7.



GOOLDEN COAL-DRILL WITH ENCLOSED MOTOR.

Figs 8.



COOLDEN ENCLOSED MINING-MOTOR DRIVING INGERSOLL DRILL WITH FLEXIBILE SHAFT.

Scale for Figs 1, 2, 3, 4, 5, 6, 7, & 8 – 1 Inch = 1 Foot.

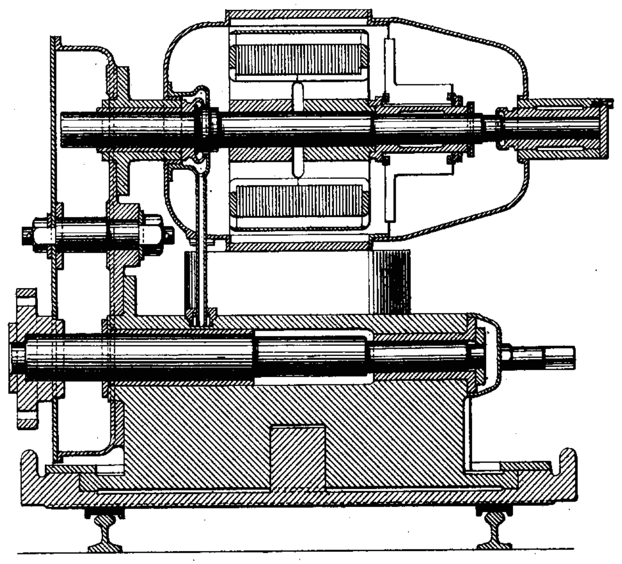
Inches 12 9 6 3 0 1 2 3 *Feet.*

LLEWELYN B. AND CLAUDE W. ATKINSON, DELT

THOS KELL & SON, LITH. 40, KING ST COVENT GARDEN.

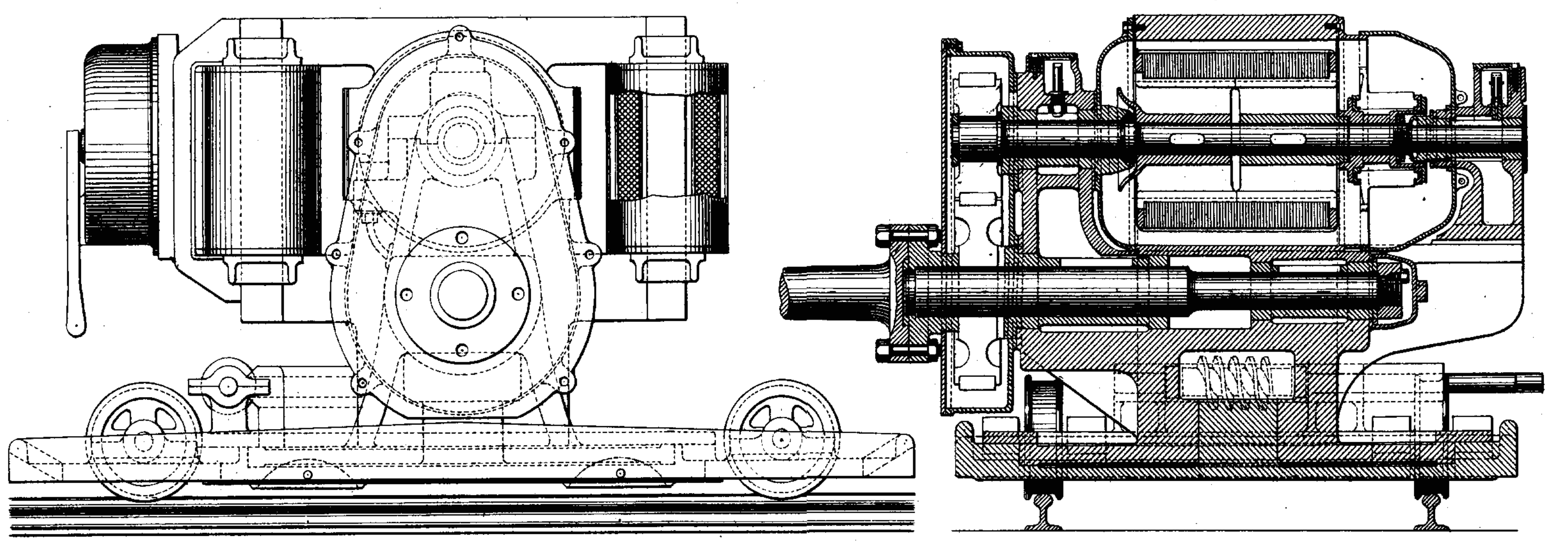
ELECTRIC MINING-MACHINERY.

Fig: 10.



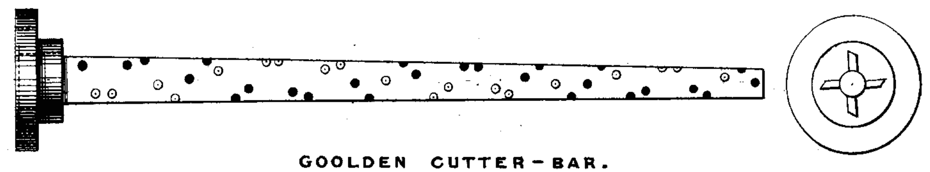
CROSS SECTION OF COAL-CUTTER.

Fig: 13. *Fig: 14.*



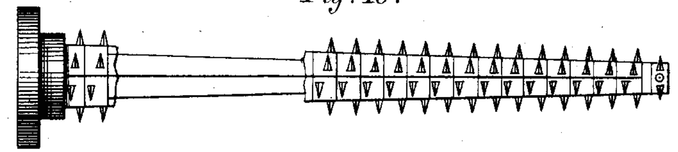
FRONT VIEW. GOOLDEN COAL-CUTTING MACHINE. CROSS SECTION.

Fig: 17.



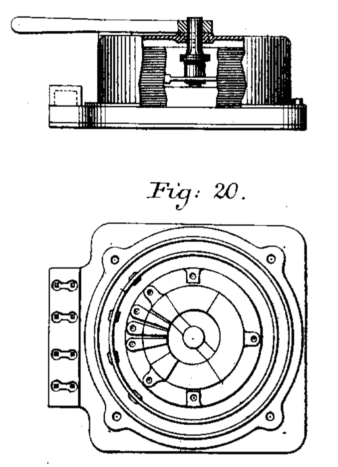
GOOLDEN CUTTER-BAR.

Fig: 18.



BLACKBURN CUTTER-BAR.

Fig. 19. *Fig: 20.*

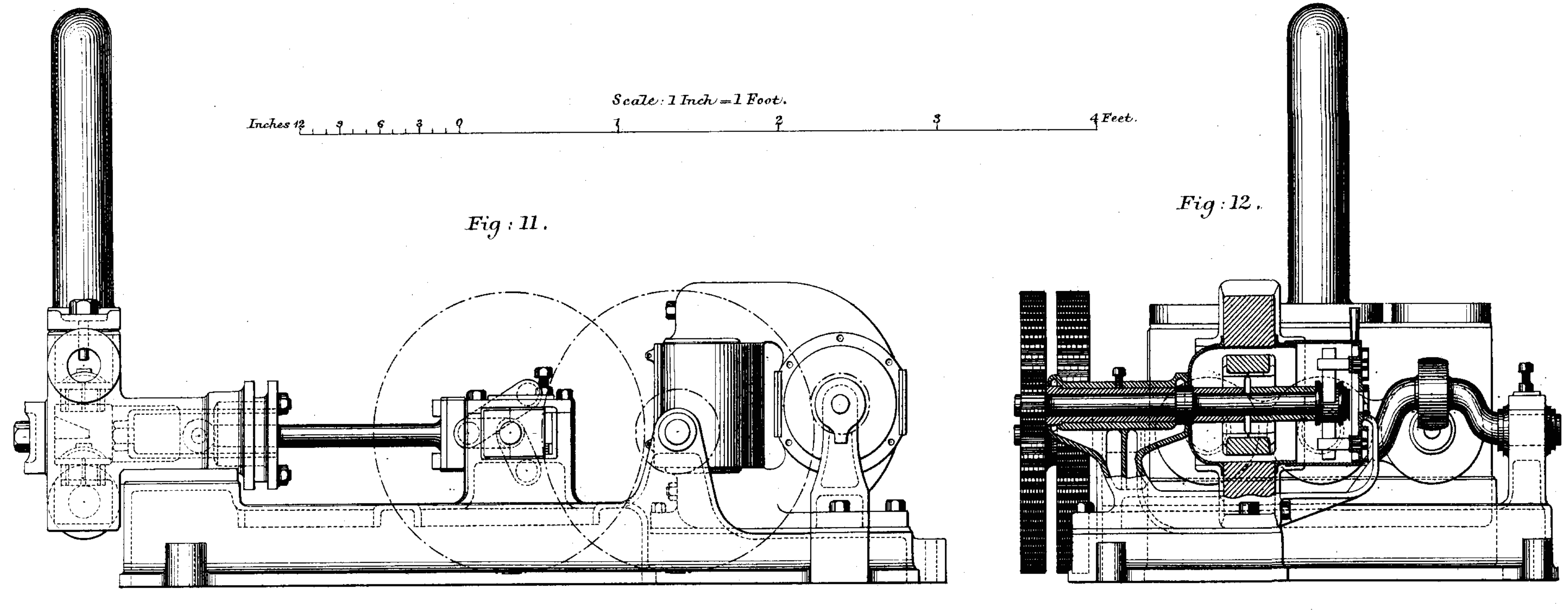


ENCLOSED NON-SPARKING SWITCH.

Scale: 1 Inch = 1 Foot.

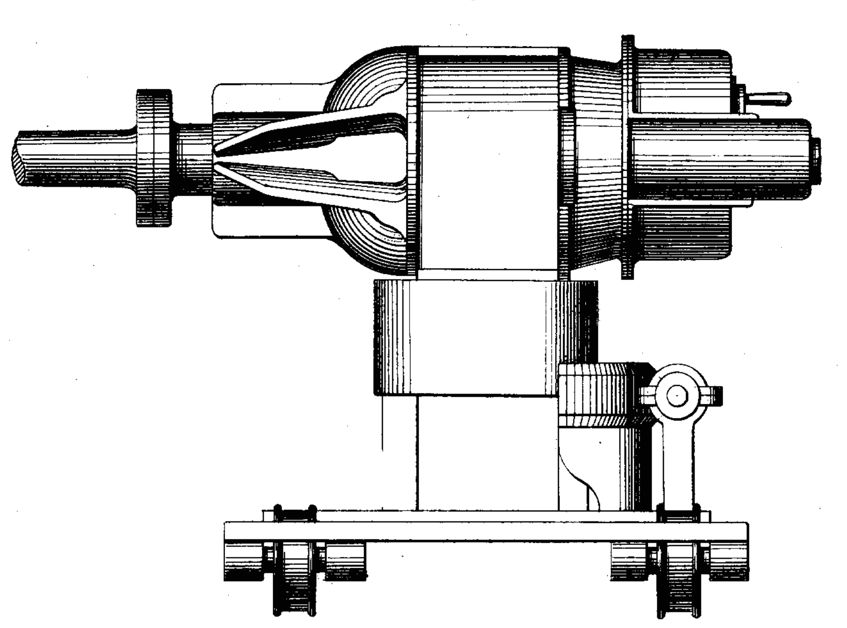
Inches 12 9 6 3 0 1 2 3 4 *Feet.*

Fig: 11. *Fig: 12.*



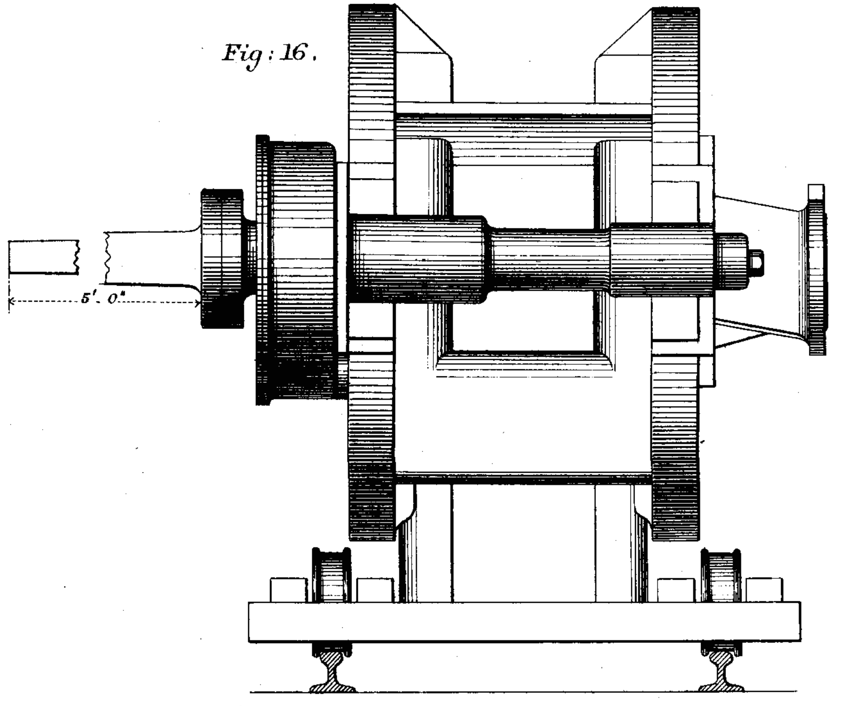
GOOLDEN ELECTRIC DIP DRAINING-PUMP, WITH ENCLOSED MINING-MOTOR.

Fig: 15.



DIRECT-ACTING COAL-CUTTER.

Fig: 16.



MACHINE WITH 5 FEET CUTTER-BAR, TO BARE AT DIFFERENT HEIGHTS.

LLEWELYN B. AND CLAUDE W. ATKINSON, DELᵀ.

THOS KELL & SON, LITH. 40, KING Sᵀ COVENT GARDEN.