inner frame from the cutter head almost up to the driving sprocket. A take-up is provided to allow for adjusting the tightness of the chain.

The motor is multipolar, shunt wound usually for 220 or 500 volts, and is nominally of 17 horse-power, though this is only about one-half of the power which it is capable of developing. Should pyrites or other hard substance be present in the coal at the cutting level, as much as 30 h.-p. may be required for a time, and the motor is built to take this load if necessary. The usual load on the motor with clean coal is from 10 to 14 h.-p. Fuses are, of course, provided to protect the motor in case of an overload. All working parts of the motor and motor carriage are arranged so as to be easily get-at-able. The armature is of the ironclad type which insures complete protection for the winding. The field frame is of cast steel, and the field coils are thoroughly insulated and protected from injury. There is a specially designed starting switch or theostat.

The power from the motor is carried by steel machine-cut gear wheels to the chain driving sprocket as shown diagrammatically on plan "B." It will be noticed that the feed gear for the forward cut is operated through worm wheels which give a slow motion, whereas during the withdrawal of the frame from the undercut when there is no work to be done, the motion is through bevel wheels, the speed in the latter case being about four times as quick as in the former.

The overall length of the machine is regulated by the depth of undercut desired, the standard sizes being five, six or seven feet of undercut, and the corresponding overall lengths 9ft. 3in., 10ft. 3in., and 11ft. 3in. The width of the cutter head is 39in. or 44in., and the kerf about four inches.

The most vital part of the machine is the cutter chain. It is required to work in the cuttings and must be designed to withstand an enormous amount of wear and tear. It is

constructed of solid links and strap links alternately, the solid links which carry the cutters are made of cast steel, and are given sufficient set upwards or downwards to ensure a kerf being cut by the cutters wide enough to give clearance for the cutter head. The principle is the same as that on which the teeth of a saw are set to give clearance for the blade. In the case of the cutter chain, however, the full width of the cut, four inches, is divided between three or more links, and a proportional set is given to each. The solid links are connected by strap links of drop forged steel with thimble projections at each end which fit into holes drilled in the solid links, and which also form the bearing for the rivets which hold the links together.

The cutters are of $\frac{3}{4}$-in. x $\frac{1}{2}$-in. special steel, and are held in the solid links by steel set-screws. The length of projection of each cutter is fixed by a gauge before the set screw is tightened up.

In order to avoid the expense of wiring up each room in which the coal cutting machine works, a means of transmitting the power from the feed wire in the heading to the machine in the room is provided, this being done by means of a cable, which is carried about the mine with the machine. This cable is usually 250 feet long, and is wound on a reel such that an easily handled roll is made of it. It is of the twin type, two insulated conductors being laid side by side, thoroughly insulated from each other and securely bound together. On the ends of each cable are two hooks for making contact with the wire in the heading. The cable is carried into the room on the reel and with the machine, the necessary length is wound off, connection made in the heading, and the line is completed to deliver power to the machine.

In mines where the seam pitches, and the grades over which the machine has to be drawn are heavy, the question of transportation from point to point is an important one in machine mining. To overcome this difficulty a truck to be

operated by means of the motor of the machine has been designed. This consists of a frame mounted on axles fitted with wheels, and upon the end of the frame is mounted a shaft in suitable bearings, this shaft being driven from the machine motor by means of sprockets and chain, and from the shaft, power is transmitted to the axles of the truck. The cutting mechanism is arranged with a clutch which can be thrown in and out of gear when necessary. When it is desired to utilise the motor to propel the truck, the cutting mechanism is thrown out of gear, and during the "flitting" in the mine no part of the apparatus is in motion except that which is necessary to operate the truck. The motor is equipped with a reversing switch which allows the truck to travel in either direction as may be required.

Where the seam is fairly level the self-propelling attachment is often omitted from the truck and the transportation done by mules or horses, but the mechanical propulsion has much to recommend it, not the least being the fact that the machine is self contained, and independent, and is not subject to delays caused by the necessity of waiting for a horse and driver when it is required to move it about the mine.

METHOD OF OPERATION.

As an example of the everyday work which a machine may be required to do, it will be assumed that a heading ten feet wide is to be undercut by a six foot machine with cutter head 44 inches wide, the heading having been first cleaned and squared up after the previous loading out. Two men are required to operate—the runner who attends to the motor and to fixing the rear jack, and the helper who fixes the front jack and shovels the slack away as it is discharged from the cut.

The machine mounted on its truck is run up on the skip track to within a few feet of the face of the coal, and dis-

mounted by means of a bar and rachet gearing at the back of the truck. Expert workmen so arrange this unloading that the machine finally leaves the truck with a rush which carries it forward into such a position that the cutter head is almost in contact with the face of the coal. The rear end drops on to an iron surfaced skid laid on the floor parallel to the face of the coal, and the machine is barred over to a position in contact with the left hand rib, the cuts being made from left to right. A small hole is picked out of the roof a few feet behind the machine, into which the end of the rear jack pipe is placed. A similar holding place is made in the coal face for the front jack, and both jacks are then screwed up tight to hold the main frame firmly down on the floor. The twin cable is run off the reel and connected with the leads in the heading, and connection is also made between the reel and the motor. The runner switches on the current, the motor carriage advances, carrying with it the inside frame round which the cutter chain revolves at a speed of 260 feet per minute. In ordinarily clean coal, the full six feet of undercut is made in from 3½ to 4 minutes, and on this depth being reached the current is automatically cut off, eliminating any possibility of the motor carriage running too far and fouling the outside frame. The motor is then reversed, and the cutter withdrawn from beneath the coal, the return travel being done in one minute. The current is again automatically switched off at the end of the return journey.

During the first cut alongside the left hand rib the slack is discharged under the body of the machine, and is shovelled away to the rear by the helper.

After the machine has completed the first cut and the cutter head withdrawn, the jacks are slackened off and the machine is barred over to the right, a distance equal to the width of the cutter head, in this case 3ft. 8in., the rear portion of the machine still resting on the skid, and the front

portion sliding on a fixed shoe under the outside frame. The time taken to move the machine from the first cut and make everything ready to start the second is about five minutes. The same operations are then repeated as for the first cut. Another 3ft. 8in. undercut is made, the cutter head withdrawn and the machine again barred over to make the final cut, completing the width of the heading.

It is usual to overlap the undercuts by an inch or two to guard against the chance of thin pillars being left under the coal, as such pillars would be a source of trouble by holding the coal up instead of allowing it to roll forward when the blasting is done.

The undercut, 4in. in height, is made on an incline of about 1 in 50 sloping from the machine, the bottom line of cutters starting at about 1½in. above the floor at the beginning of the cut, and coming to the floor level again at the end. The disadvantage of cutting quite on the floor level is that should the floor be of a hard stone formation, the lower line of cutters would be continually in contact with the stone and quickly blunted. It would also be inconvenient when making cut throughs or turning off headings as the cutters would hit on the rail of the mine track.

It will be seen that the chain machine has the advantage over the revolving cutter bar type that so much does not depend on each individual cutter. If it should happen that a cutter is bent back or broken off short in the link, the cutters in the links behind the broken member take up the extra work. The cutters too, while travelling idle round the sides and back of the cutter frame are kept cool by contact with the air. Again, the cutters themselves act as scrapers, and drag the slack out from under the coal as the under cut is made, thus doing away with any chance of the cuttings choking the machine.

A ten foot heading has been taken above for an illustration, but the method of operating the machine is the same

in bords of any width, and the cost of working may be taken as the same in either wide or narrow work.

After the completion of the last cut in the heading, the machine is barred over until it is opposite to its truck on the mine track, the truck is tilted up, the centre tongue piece run out and the end of it placed under the rear of the machine, which is then drawn up on to the truck by means of the ratchet gear fixed at the rear end of the truck. The whole operation of loading takes about fifteen minutes, and covers the time spent in collecting the accessories, tools, &c., including the reel, and packing them on to the body of the machine, ready for transportation through the mine, either by self propelling truck or by animal traction.

The amount of undercutting which can be done with one machine run by one man and one helper varies largely with the conditions under which the machine has to work, and with the skill of the runners. As many as 104 cuts six feet deep have been made in one shift of 9hrs. 40mins., the machine cutting in that time five rooms and six narrow places. This amount of cutting is unusual, however, and it would be a mistake to expect such results in actual daily work. The following record of a thirty-days' continuous run (Sundays excepted) in an American mine in which there are installed 30 Jeffrey electric machines, may be of interest. The coal averaged 3ft. 8in. in thickness of seam, and the cost of repairs and the number of runs made with one machine worked out thus:—There were 1,373 runs made in wide work, 201 runs in narrow work, number of days worked 26, eight-hour shifts. Average number of runs to a place 8⅓, cost of repairs per run $.0006. Number of tons for 26 days, 2449.75. This was screened coal, which in this case would be about 60 per cent. of the total tonnage as the coal was unusually friable, and in this particular vein about forty per cent would go through the screens. The cost per run was $.0004. Tons per run 1.55.

Twenty-four loaders were kept busy after the one machine. The average number of runs per day for the 26 days was 60½. The machine which did this work was a Jeffrey electric chain machine with a 5ft. undercut. This was not by any means looked upon as a record run, but simply one of thirty days in a mine having a narrow seam upon which a record was kept in order to get an idea of the cost of running and of maintenance. It is allowed that, to get results like the above the conditions of the mine must be favorable for the working and transporting of the machines.

THE AIR CHAIN MACHINE.

This machine is similar to the electric machine so far as regards the outside frame, the cutter frame and chain, but in place of the electric motor, twin powerful air engines of a combined capacity of 16 h.-p. are substituted. The connecting rods of the two engines work on to a common crank shaft, from whence the power is taken to the driving sprocket-wheel as shown diagrammatically on plan "C." In place of the reel with twin cable sixty feet of armoured rubber hose is supplied on a suitable reel for making the connection between the air pipe in the heading and the air engines on the machine.

The saving to be effected by the introduction of coal-mining machines depends materially on the conditions present in the mine, whether they are favorable or unfavorable to the efficient working of the cutters. The cost per ton of coal, machine cut and loaded on the skips, may be as much as 1/6 less than the cost per ton of hand mined coal, or the difference may be as low as 2d. or 3d.; but, whatever this difference may be, the fact that the mine manager has fewer skilled men to deal with in the pit, and can thus handle his staff better in case of trouble, is of such importance that the

introduction of coal cutting machines has been warranted for this reason only.

Another advantage to be gained by the introduction of coal cutting machines is the safety of the men. The hand miner lying on his side as he wields his pick, with a heavy mass of coal suspended over him is liable to an accident at all times from an unexpected fall, while the machine runner standing at the back of his machine is perfectly safe, and is also in a position to see the first movement of the coal and to give warning to the helper to get away from danger.

It has been stated in the public Press that the reverse is the case, and that the machine-miner runs the greater risk; comparative records of accidents in the two cases go to prove that this is not so, and to anyone acquainted with coal mining such a statement is obviously wrong.