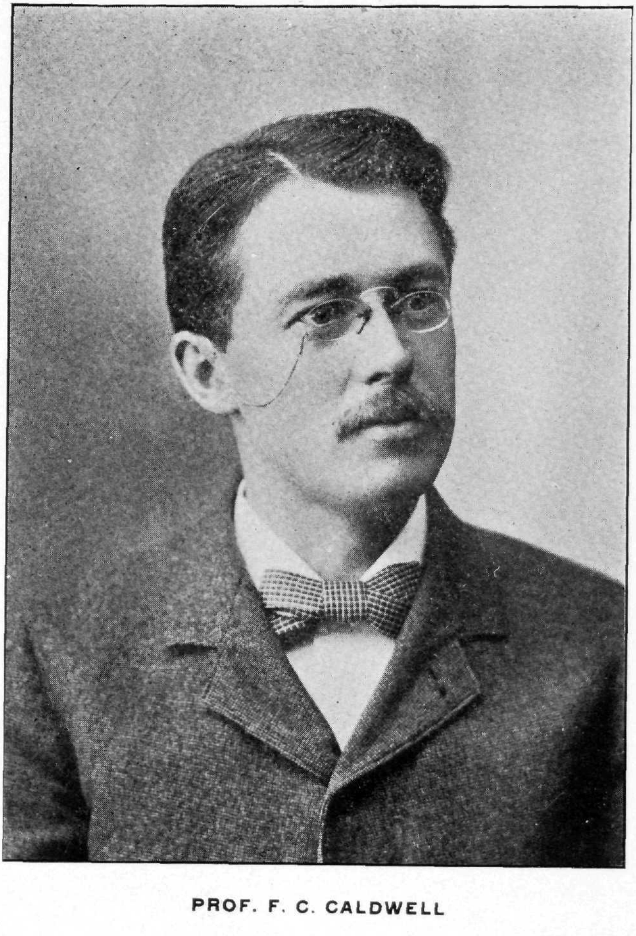
Ohio Mining Journal

Title:	The Design of Mining Motors: The Principles of Their Construction and the Points To Be Considered in Selecting Motors for Mining Work
Creators:	Caldwell, Francis Cary, 1868-
Issue Date:	1898
Citation:	Ohio Mining Journal, no. 27 (1898), 67-72.
URI:	http://hdl.handle.net/1811/32789
Appears in Collections:	Ohio Mining Journal: Whole no. 27 (1898)



PROF. F. C. CALDWELL

THE DESIGN OF MINING MOTORS.

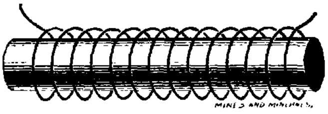
THE PRINCIPLES OF THEIR CONSTRUCTION AND THE POINTS TO BE CONSIDERED IN SELECTING MOTORS FOR MINING WORK.

BY PROF. F. C. CALDWELL, OF THE OHIO STATE UNIVERSITY.

I hope there are none here who have come with the expectation of listening to a technical paper on the nice points of motor design. There are others in the Institute whose experience would much better qualify them for such a task. But, there may be those whose work in other lines has left them little time to inquire into the wherefore of the machines they are using, and it is for them that I have tried in this paper to make evident some of the more fundamental points. In order that I may be sure of making myself clear, I must begin by reminding you of some facts concerning the construction and action of a motor. In the first place, if we surround an iron bar with a coil of wire covered with an insulating material, such as cotton, and send a current through this coil, we shall produce a strong magnet, as shown in Fig. 1, called an electromagnet, and one that is much stronger than it is possible to make a permanent magnet. Further, if we bend this bar around into the form of a horse-shoe, we shall find our magnet still stronger and the less the distance between the poles or ends of the horse-shoe, the more powerful will the magnet become.

We account for this by thinking of the magnet as being the seat of a flow of magnetization in the form of a circuit, and by saying that iron offers much less resistance, or, as it is technically called, "reluctance," to the flow than does air; and so the less the distance of the flow, or flux, has to pass through the air, the more of it there will be with a given number of turns of wire and a given current; that is, with a given magnetomotive force. The bearing of this on the design of the motor we shall see later. Suppose now, that we take such a horse-shoe magnet, and in the space between the poles, place a wire carrying a current; this wire will experience a force tending to drag it across the space in one direction of the other, according to the direction of the current, as you see in Fig. 3. We speak of this space between the poles of the magnet as a magnetic field; and, if our magnet forms part of a motor or generator, we call the whole magnet the field of the machine, and the insulated wire wound around it, as on the spools, the field current. Suppose that instead of a single wire or conductor, we have a rectangle of wire A, Fig. 4, and place it in the cylindrical space occupied by the magnetic field; because the current is flowing in opposite directions in the two slides of the rectangle, one slide will be forced up, while the other is forced down, till the rectangle stands at right angles to the field. If, then, we reverse the current, the position of the rectangle will be reversed. Suppose now, that we have a split cylinder soldered onto the ends of the rectangle, and two brushes arranged as in Figs. 2 and 4, so that just as the rectangle comes to a position at right angles to the field, the current will be automatically reversed, then the ring will keep on revolving in the same direction. Now, we have the elements of a motor, the only difference between this and any other being, that instead of one turn we have a number arranged at different angles on an iron core, which core is put in so as to reduce the distance that the magnetization must pass through the air, and instead of a split cylinder with two segments, we have one with many to correspond with the many turns, and called now the commutator b, Fig. 2. This revolving part as you know, is the aramture of the motor a, Fig. 2; and this being placed on a shaft with bearings and a pulley, and having current sent through it from the supply lines, is dragged round by this force existing between the magnetic field and the current in the conductors, and thus converts the electrical energy supplied to it through the wires, into mechanical energy at the pulley.

So much by way of introduction. Now, we all know that the first requisites of a mining motor are lightness, strength, and the faculty for standing a good deal of knocking around without getting into trouble, and that a mining motor must have these qualities to a much greater degree than a motor to be used for stationary work. What then, must be the peculiarities of a design to produce such a motor? First, as to the material of the field magnet. I spoke of it above simply as iron, but that is a very comprehensive term. Now, any kind of iron would be better than air or any other substance, for iron is the only material that is notably magnetic. Three kinds of iron are, however, principally used, cast iron, wrought iron, and soft steel. The two latter are very much alike magnetically, and mechanical considerations would only determine between them. Nowa-



MINES AND MINERALS.

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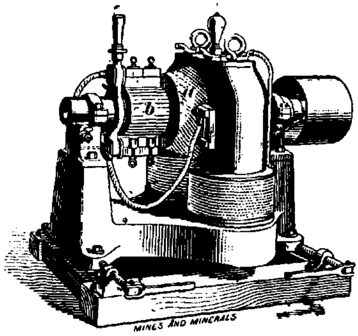

MINES AND MINERALS

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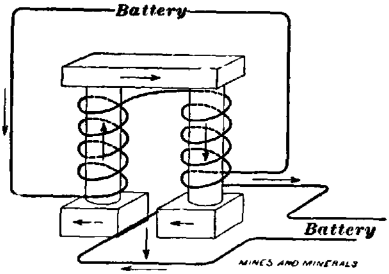

MINES AND MINERALS

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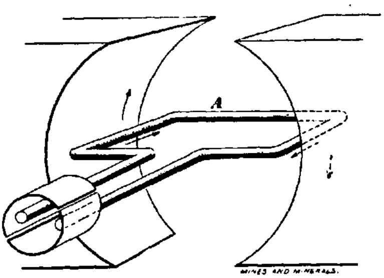

MINES AND MINERALS.

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days the latter, either wrought or cast, is coming to be the most common. Between these two and cast iron, however, a great difference exists, namely, that, with the same number of turns and current in the field, that is, with the same magnetomotive force, you get more than twice as much magnetization in the wrought iron, or steel, as in the cast iron; and this you will see has a decided influence on our present question; for, while in a stationary motor it would do no harm to have twice as much cross-section of iron, in the mining motor it would be fatal to lightness. Hence, it follows that our magnets must be built of wrought iron, or better, of soft steel, either wrought or cast, and the softer the better. Along this same line comes the question of what density of magnetization we shall use, i. e., how much per square inch. If we are designing an iron rod to carry a weight, we may use different factors of safety, according as strength or lightness is of greater importance; thus, if great reliability were not very important but lightness were necessary, we might go as high as 20,000 pounds per square inch, while in the reverse case, we might have only 6000. In somewhat the same manner we might vary the magnetic density, according as we desire great lightness or high efficiency; for, the higher the density, the more current we must send through our field turns. But, in coal mining, high efficiency is of relatively small importance, for fuel costs very little, and a low efficiency is objectionable only in making a larger plant necessary by taking more power to run the motors; hence, it follows that we must use a higher density, that is, more magnetization per square inch than in a stationary motor.

So much for the material of our magnet. Next, in what form shall we put it? In the example shown, you notice that the field is a sort of U form. This is quite a good style and very much used in stationary motors, but you see that it is not a strong form, nor one to stand rough handling without getting out of shape. A much better for such a case is that in which the field magnet is divided into two parts, and placed on each side of the armature, thus making a frame of "box" section, and, hence, a very rigid one, and at the same time, by surrounding it, protecting the armature from external injury.

Come now to the windings on field and armature, and here is where the weak point in dynamo machinery lies. In no other kind of machinery are we obliged to rely on so soft a metal as copper for important parts, and still less on such material as is used for the insulation, that is, cotton, paper, and shellac. But, as it takes power to force water through a pipe, so it takes power to force electric current through a wire, and experiment has shown that it takes much less power with copper than with any other available material; again, all metals will conduct electricity more or less, so that we cannot use any of these to confine the current to its path through the turns of the winding but use for insulation such materials as paper and cloth or, where their nature will allow, glass, porcelain, etc. It therefore becomes imperatively necessary that we do not let the motor become so hot that it will char these combustible materials. I said before, that it requires power to force current through the wire; but what becomes of this power that is so used? It is converted into heat, just as the energy that is expended in forcing water through a pipe is converted into heat and carried off in water. In the wire, however, this heat can only get away by being given off from the surface into the surrounding air, or other material. And now I must call your attention to a point that is of great importance in the design of all kinds of dynamo machinery. If heat is produced in any body it raises the temperature of that body till it has reached a certain number of degrees above the temperature of the surrounding air, this number depending both upon the rate at which heat is being produced and the nature of the surface of the body. When this temperature has been reached, it remains constant as long as the conditions remain so. Now, the maximum temperature at which cloth and paper can be kept without charring sooner or later, is about 180 degrees F. You notice, then, that the rise of temperature which we may allow, depends upon the temperature that we start at. With 100 degrees atmospheric temperature, we can only allow 80 degrees rise; but, if we are never to run in a higher temperature, than say 70 degrees, we can allow a rise of 110 degrees; while the former case would be that of an ordinary stationary motor for use above ground, the latter could be taken as the conditions for a coal-cutting motor. Now, to return to our windings, the smaller the wire, the greater will be the resistance to the passage of current; also the greater will be the amount of heat produced in the wire but, since we have found that we can allow a considerably greater rise of temperature in the motor to work underground, it follows that we can use a finer wire, and thus also by this means make the motor lighter than its counterpart above ground and in the heat of the summer; but still another consideration makes this possible, namely, that while a stationary motor is often called upon to run for many hours under full load all the time, the mining motor only runs intermittently, probably not more than half of the time on average, and has the rest of the time to cool of. Of course this greater production of heat means a greater loss of power; but, as indicated before, we can afford to burn a little more coal, if thereby we can increase the facility with which our coal-cutting machine can be handled. The coils on the fields should be thoroughly covered with a waterproof covering to protect them from moisture, for water is a conductor of electricity; and if it gets into the insulating material will, while there, entirely ruin it for the purpose, and further, is liable to cause the current to jump from one turn to another, thus burning the cotton, and spoiling the insulation permanently.

Lastly, a few words with regard to the armature. This, in all the best modern dynamos, is made with slots parallel to the shaft in which the current-carrying wires are placed. This has two great advantages, the first, that by reducing the distance that the magnetization has to be forced through copper and air, it reduces the number of turns of wire necessary to the field, and, hence, the weight; and secondly, that it protects the wire from mechanical injury and also affords a positive action in the driving around of the armature core by the conductors; for it must not be forgotten that it is the conductors upon which the turning force is exerted. There still remains the commutator and its brushes, and this is apt to be the most troublesome part of the machine. In all good machines the segments of the former are insulated from each other with mica, it being the only material that will stand. The brushes should be of carbon, and their holders should be of such a design as to allow the brushes to move freely and to permit them to be pressed against the commutator by a spring. When the motor is run there should be no sparking, no matter what the change of load within the limit of the machine.

The above are some of the points that have to be borne in mind in deciding upon the claims to excellence of any machine, and it is always well to remember that it is much safer to judge of a motor when you see it running, than when its friends are talking about its good points.

SECRETARY HASELTINE: What I do not know about electricity would fill a large book, and with all respect to the gentlemen who have presented papers here in the past on the subject, I must say that I have enjoyed Professor Caldwell's paper, his description of the mode of producing motion, more than any paper I ever heard read by anyone. He has talked plainly and not tried to impress upon us his scientific knowledge of the subject: he has talked in plain language which we can all understand. The Institute owes him a debt of gratitude for his talk.

Upon motion of Secretary Haseltine a hearty vote of thanks was extended to Prof. Caldwell for his instructive paper.

Upon motion, meeting adjourned until to-morrow at 8:30 A. M.

THIRD SESSION—JANUARY 20, 8:30 A. M.

Immediately upon the assembling of the Institute, the reading of the following paper by Mr. Coxe was listened to.