Title: The Advantages of Electricity for Mining Purposes

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Issue Date: Nov-1890

Citation: Ohio Mining Journal, no. 19 (November, 1890), 16-23.

URI: http://hdl.handle.net/1811/32607

Appears in Collections: Ohio Mining Journal: Whole no. 19 (November, 1890)

The Advantages of Electricity for Mining Purposes.

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In all the industries it has been the desire to replace as much as possible, expense of manual and animal labor by machinery. Most of the appliances, however, at present used in mines have very serious drawbacks, due either to the great expense attached to, or the limited area covered by them. The greatest disadvantage they are under is caused by the fact that the sources, from which the power for them is derived, can only in a few instances be put near to the place where they are to be used. In most cases the ducts, taking the power from the places of production to those of consumption, have to be long and tortuous, requiring, therefore, a well developed and economical system of long distance power-transmission and distribution.

It is, for this reason, not unnatural that, with the growth of electrical engineering, a remedy to most of the difficulties to be met with was expected by the introduction of the electric system of power-transmission, and the large number of applications of the most varied nature, in which this system has proven its superiority over all others, justified this expectation. Quite a large number of electric mine installations are already now in daily, successful operation, and much knowledge and practical experience has been gained of this field, only recently opened to electric appliances.

The work carried on in a mine can be divided into three classes; namely, that of mining proper, of conveying the products of the mine from the place of production to daylight, and last but not least, that of rendering the mine fit for the miner and his helpers to remain and work in it.

It is quite unnecessary, before this audience, to say anything in detail, concerning so familiar topics, as the present methods of accomplishing these three classes of work. The mining proper is done by hand, by blasting or by mining machines. The coal is brought to daylight by mules, rope haulage or locomotives. The purification of the mine is accomplished by means of fans, generally driven by steam power. It is clear that the most desirable power plant for a mine would undoubtedly be one by which the power generated at one conveniently placed station can be economically and easily distributed over the entire extent of the mine. So far it has only in few cases been found possible to do this. The general disadvantages of conveying steam long distances are well known, but with regard to mining some special features are introduced which render this system still more unfavorable. Without great inconveniences to the traffic it is not always possible to take the large steam pipes through much-used passages, so that often it becomes necessary to drive special ways (steamways) for them. The heat given off by these pipes is very hard on the roof of these steamways, and often it happens on turning on steam in newly laid pipes, or in such that have been out of use for some time, that the roof is damaged to such an extent as to cause it to fall in numerous places. Especially when the work has to be carried on in slopes it is a difficult matter to properly lay the pipes and follow all the turns and angles in the small space given.

Owing to the large distances the steam sometimes has to be transmitted, the loss in pressure at the engines in the mine is such that the latter must have much larger cylinders than would be required near the boilers, and this necessitates large excavations to gain the necessary room. After the steam has done the work in the engine the very serious question arises of what to do with the exhaust. It would of course not be practical to let it out into the gangway, as that would make the latter and possibly a large number of chambers unfit for the men. Wherever a water pump of sufficient size is near, the exhaust can be let into it; if this is not the case, the steam has again to be conveyed a long distance, until it gets to some suitable pump, or a special opening to the surface has to be provided for. Only very small engines might be allowed to exhaust into the gangway, if the latter has a large quantity of air passing through it, or if it is on a return air current (i. e. the current of air goes from the gangway direct to the surface of the mine without passing any places where men are working). Steam inside the mine has mostly been used for the purpose of running pumps, hoists and ropes for hauling on gangways, sometimes also for small fans when in favorable location. But it has seldom been used for running drills or cutters on account of the difficulty of getting rid of the exhaust, and because for this kind of work the mine has to be fitted up with a network of distributing ducts, allowing a supply of power at a very large number of places, none of which are in constant use, and to do this with steam would be difficult and uneconomical. For this purpose compressed air distributions are mostly used, and it must be acknowledged that the completeness with which the details have been worked out by the different companies, manufacturing the appliances for this system, make it well adapted for mining purposes, as far as withstanding the rough usage, and entrusting it to the hands of the miners is concerned. This system has, however, serious drawbacks which limit its use. First of these is the large cost of the plant, and to this is added the limited distance to which the power with economy can be transmitted. A mine having chambers one-half mile or more from the power supply station can hardly afford to use compressed air machinery in these, as the cost of the pipes and of the power required rapidly increases with the distance, and would soon counterbalance the profit derived from the use of machinery. One advantage claimed for this system, which seems very feasible, is soon, however, found to be of no value, and that is that the fresh air supply to the mine is materially assisted by it. The amount of air furnished this way is however very small, and an artificial air current by other means has always to be provided for. The machines also do not work constantly in the same place, but sometimes are changed from place to place about every hour, work of other nature however going on all the time.

It is even claimed that the air given off by this machine is injurious. In some exceptional cases the compressed air system has been chosen to make use of natural power resources located at a short distance from the mine, but the results are far from encouraging. Prof. Rothwell, in a paper read at the Buffalo meeting of the American Institute of Mining Engineers, October, 1888, states that at the Chapin and Ludington mines at Iron Mountain, Mich., turbines aggregating 3,700 horse power are used for the purpose of transmitting, with the help of compressed air, power from the Quillisee Falls of the Menominee River to the mines, over a distance of about three miles. Of this power only 25 per cent. is available at the mine, or in other words of 3700 horse power generated only 925 can be used. The cost of the plant is estimated at about $500,000, the cost of the power at the mines is equal to that derived from coal at $5 a ton. From the above it is not to be wondered at that the mine owners should be anxious for some new system, which will overcome, if not all, at least most of the difficulties, and the question arises can this be done by electricity. The numerous applications made of electric machinery have clearly demonstrated that it is not only a most efficient system for long distance power transmission, but also the best of all known at the present time. This by itself would be of sufficient value to warrant its use in mines; it has however the further advantages of not only being able to transmit power to all the appliances in the mine, supplied at present by steam or compressed air, but it can also, on account of the small expense attached to the required conductors and the laying of the same, be used for most small fans and pumps which so far have had to be driven by hand. It can also furnish light at any desired place and means for blasting from a safe distance. It is therefore possible with this system to generate at one station all the power required in the mine, and then distribute it to the different places where the same is to be used. As distance, within the limits to be met with in eastern mines, does not materially add to the cost of the plant, this station can be placed at some convenient spot, where water and fuel are easily accessible, and several mines even can be supplied from one station, if within a distance of only a few miles from each other. It also offers a much desired solution of the problem of procuring cheaper power for such places in the west, where fuel is not to be had near the mine, but would have to be carted long distances, or where water power is available.

In the mine itself the flexibility of the electric system allows a proper distribution to be made over large areas, thus enabling all and every machine to be driven by it. The conductors are small, and the efficiency is not decreased by making abrupt turns; it is unnecessary therefore to provide special gangways for them. The machine proper takes up but a small space as compared with that required by steam or compressed air machinery of equal power, and is better adapted for many classes of work owing to its smooth rotary motion. No heat is given off by the conductors, as is the case with steam pipes, and no damage is therefore done to the roof of the gangways, nor has this system to contend with any difficulty comparable to that of getting rid of the exhaust steam.

The electric locomotive offers the same advantages for hauling purposes as a steam locomotive over mules and rope. But whereas the steam locomotive can only work in the return current, the electric locomotive can work anywhere, as it gives forth no steam or gases to vitiate the air. Locomotives requiring large currents and using the track rails as return conductors seem to have a higher tractive power than steam locomotives of equal weight. At any rate a 6-ton electric locomotive with which I have replaced a 9-ton steam locomotive has demonstrated on numerous occasions its ability to handle trains weighing one-third more on certain places than could there be managed by the latter, without slipping off the wheels. Other advantages of the former are simplicity of construction, absence of danger of setting the mine on fire, no bad effects on roof and timbers, as no gases and steam are given off, and a saving of labor as only two men are necessary (driver and conductor or patcher).

It has sometimes been claimed as a disadvantage of the electric engine that it cannot go anywhere like a steam locomotive, but has to confine itself to the gangways fitted up with conductors. This, however, is not the case in mines. A big locomotive, no matter what its source of power is, for economical reasons, never used to collect its trip, but has certain routes only given it which it never leaves, and these alone are fitted up in such a manner as to allow it to work in them. The rails, for example, in all other places would be much too light. As a matter of fact it is easier to let an electric locomotive enter a chamber or go to the face of a gangway by means of wires attached to the working conductors than a steam locomotive, on account of the steam and gases the latter emits.

Installations in mines have to overcome many difficulties that are not encountered in other places. The insultation of machinery as well as conductors has to be of the very best quality, as the mine air is generally very damp. In coal mines the fine dust floating around and settling on the insulators makes matters still worse. Proper insulation, which is of prime importance in any electric work, is therefore doubly so in mining work, and even with the best precautions leakage cannot be avoided in collieries. The mine water generally contains strong mineral acids and great care has to be taken to protect the conductors from the same. Even should the water fall on the wire drop by drop only, it would be sufficient to eat through the copper in a comparatively short time. For this reason only such insulating materials ought to be used for the conductors that will withstand the action of the water.

As the room in the gangways is very limited, there are not many places to choose from for the wires, and unless they are protected by being boxed in, they cannot always be placed out of reach of the men. Unless such precautions are taken, it is therefore not advisable to use a stronger electromotive force than 450 to 500 volts in these wires, as, no matter how often warned, the miners will sooner or later either willfully or accidentally come in contact with them. The above mentioned voltage has proven to be entirely safe, as within two years not a single accident from it has happened to a man or boy in a mine using the track rails as return and having bare conductors, although coming in contact with the latter has been a daily occurrence.

The greatest damage to the wires is caused by breakdowns in the mine, and against this there is no remedy. The only thing to be done is to place the wires on that side of the gangway least affected by these disturbances, and to make the method of suspending them such that a break in them can easily be repaired. In mines in which the vein is on a pitch, the best place for the wires is on the lower side, provided there is no large open gutter there, as in that case the dampness arising from the same will cause considerable leakage.

Wherever a bare conductor has to be used as for hauling purposes, I consider it best to use iron in some convenient form instead of copper. The former having only ⅙ the conductivity of the latter will therefore be at least six times as large in section, and is for this reason capable of withstanding the influence of the mine water much longer. In most cases also the damage done to these conductors by breakdowns will be slight, unless very large masses are falling, they, at the most, being bent. But to straighten them is no difficult task for the repairmen, whereas to splice a copper wire properly and so that the line is tight, and to place it on the insulators would often require more skill than is to be found amongst the men hastily summoned to the spot to clear the gangway, and the breakdown may have happened so far from the station that it might take a long time before help could be summoned from there, especially if slopes or shafts have to be used to get to the place.

Another reason for using iron conductors for mine railways is because the gangways are often not much higher than five feet and only wide enough to give sufficient room to miners to keep out of the way of passing cars. It would therefore be impossible in such cases to suspend the wire from the roof, so as to allow the use of a self-supporting trolley, and for similar reasons an arm with a wheel pressing against the wires either upwards or sideways would be impracticable. Curves and turns in the gangway would also interpose serious difficulties in properly placing a wire. Of course these objections do not hold good in all cases, for there are some mines having perfectly straight gangways with a nearly uniform height all the way, of eight feet or more, and in such a place, especially if the roof is good a wire may be the best thing to use.

An installation in a mine, to be thoroughly reliable, ought to be treated like one in a building. In other words each part ought to be so protected that a break or stoppage in one part of the mine does not affect machines working elsewhere. Fans and pumps ought to be put on separate circuits from those running other machinery.

A great difficulty met with in mining work is caused by the treatment the machines are subjected to by the class of men handling them, and the dirty condition they are often allowed to remain in. That this should be so is not to be wondered at if the work the miners have to perform and their surroundings are considered. These men often do contract work, and the wages they get are not such as to allow them much time. The machines used for mining proper, like drills and cutters, have therefore to be made strong enough to withstand the roughest treatment, but above all should the electrical parts be so protected that neither insulation nor wires can be damaged, even should the machines be thrown about on a dirty and often wet floor, or be buried under falling material. To properly guard the machines against all this and keep them within the necessary limits of weight is the most important and probably most difficult part of the whole work. Simply placing an electric motor, no matter how efficient it may be, on a mining machine, does not solve the problem. Both must be designed and constructed one for the other, and above all in such a manner that they can be entrusted to the miners and be operated by them without any danger of a breakdown. As space in mines is limited and help not always at hand, all machines that have to be moved frequently ought to be made as light as possible, even at the cost, to some extent, of efficiency. Owing to all the disadvantages the entire plant is at, too much care in the working out of the details of the system cannot be taken.

It was mentioned above that the electric system furnishes means for lighting up parts of the mine. This, however, does not mean that it is possible to replace the miners' lamp except, by a portable light, fed either by primary or secondary battery. Especially in coal mines, and wherever else work is carried on in comparatively small and low chambers, it is absurd to attempt to light these by electric lights, except these are of the type mentioned above. The miner would too often be in his own light, and the wires would have to be removed every time a shot is fired. Of course in large tunnelling work, where arc lights can be used, this is different. Incandescent lamps, however, can be used to light up all such places where permanent work is going on, as at the top and bottom of shafts and slopes, at pump and fan stations, switches or turnouts, and such gangways as are used very frequently. It is also advisable to make provision for lights on all portable machines. These lamps would then receive the current from the same conductors used for the motor. Generally if extensive lighting is to be done in the mine, it is best to run separate dynamos and circuits for the lamps on account of the high voltage and often very variable current used by the power circuit, the former making multiple arc lighting very difficult and the latter series lighting impossible. The series incandescent system or the alternating are the best to be used, the former, however, is to be preferred as it allows the use on its circuit of small motors for steady work, such as driving fans, and generally requires but one wire in the gangway.

Blasting by means of electricity has long been in use in mines, and its advantages are too well known to require being mentioned here. With the introduction of electricity for other purposes, however, the magneto generators, now in use for this purpose, will become unnecessary, as the spark can be procured by suitable arrangements from the wires in the mine at any desired place. A comparison between the cost of the electric and the compressed air system would undoubtedly be of interest, and I therefore give an approximate estimate of the cost of an electric plant necessary to replace the one now in use at the Chapin mine in Michigan. According to Prof. Rothwell, the turbines in use there have a total capacity of 3,700 h. p., 25 per cent. of which only can be utilized. Putting the distance these 925 h. p. have to be transmitted at three miles, the cost of each horse power, including the erection of the turbines at $40; the generators, $45; and the motors, $50; let the cost of the copper wire, including insulation 25 cents per pound (bare wires being used outside the mines and buildings), and taking generators and motors having each an efficiency of about 90 per cent. then the cost of the plant will be as follows:

For generators and turbines, including cost of erection	$111,210
For motors	46,250
For wires (equal to about 3 wires No. 000 Bh & Sh or three wires No. 170 E. S. G.	12,930
For poles, erection of same and of wires	6,000
Total	$176,390

The efficiency of the system would be 70.7 per cent., the difference of potential at the mines 2,000 volts, and the loss in the wires 263 volts.

The cost of the compressed air system now in use is estimated at $500,000, its efficiency is said to be 25 per cent.

The figures for the price of making used in this calculation is based on the price of 50 h. p. machinery.