Figs. 1 and 2.—In the left hand illustration is seen the crusher plant, and the system of track and switches leading to different parts of the quarry. All of the cars shown are being operated from the controlling tower by one man. On the right hand is seen a steam shovel that is served by a succession of single cars, as required, instead of by long trains.

An Electric Haulage System*

Controlling Cars at a Distance From a Central Station

By F. E. Woodford

I AM going to assume that all present are familiar with the general methods of hauling earth or rock and shall not go into descriptions of cable systems, suspension or tractive, or try to draw pictures of a noisy little locomotive puffing its head off as it brings its regular burden around a curve or up a slight incline; but will proceed at once to a consideration of centrally controlled electric haulage systems.

The system of haulage I wish to consider in detail consists in a method of operating a multiplicity of cars used in industrial haulage, from a central controlling tower by remote control, and is applicable to such industrial haulage as is found in stone quarries, open mines, clay and gravel pits and other places where the distance is not too great and where the operation of the cars can be seen for at least part of the time from the controlling tower.

The cause which led to the development of this system was a study of haulage methods which have prevailed for a great many years in the institutions mentioned. Where the tonnage required it, locomotives have been used for industrial haulage almost universally. It is true that a few cable ways have been installed, but owing to the necessity of track shifting and other conditions prevalent in quarries and open mines, these systems are very rare.

In a certain locality in the South it was attempted to operate a number of cars over a circular track without motormen or operators upon the cars. The cars were to be loaded upon one portion of the circle and unloaded at a fixed point upon another part of the circle. The cars were equipped with three-phase induction motors, using the track rails for one line and two other rails as "third rails" for the other two lines. It was intended to place a certain number of cars upon the track at regular distances apart, starting and stopping all the cars at the same time, one being loaded and the other being dumped. The operation was by starting switches at a remote point. This attempt failed completely on account of the high starting current of the induction motors and the enormous overload imposed upon the generating plant by starting all the units at the same time, as well as the fact that it was impossible to maintain the regular positions of the cars in their respective places.

A partial success for handling a smaller amount of material than was intended was finally accomplished by using one third the original number of cars and by equipping each car with a starting switch. By this method and by running the cars very slowly, a man at the loading point was able to pull the switch on a single car, stopping it for loading, while another man at the dumping hopper was able to do the same thing.

In another instance in the West it was attempted to install a haulage system operated by remote control, using direct current motors and solenoid brakes. While it was very easy to operate the motors by remote control, the brakes failed to work; and, as the cars were

stopped in one place only, a sliding element under the cars was installed at this point and operated by a lever. This sliding element was a retarding device such as is commonly used to stop cars operated upon scenic railways, roller-coasters and the like.

The motors were started and stopped like traveling cranes operated from another part of the building, in which both armature and field leads connect with a traveler running on separate third rails or feeders, thus supplying the means of operating in both directions, but compelling the use of four separate feeders for the entire length of track.

To develop a system of central control, therefore, which would be adaptable to industrial haulage of all kinds, and which could be installed and maintained at a cost not to exceed that of locomotive haulage, it was necessary to develop apparatus for the cars that would enable them to perform all the functions of the motor car with an operator upon it, or cars that could be operated in both directions and be stopped and started upon any part of the track, and such operation be accomplished by using a single third rail, which could be placed in the center of the track and not be an encumbrance to track shifting and track extension.

Considering the stone quarry as an example where probably the greatest tonnage of material in any industry is handled, we find that during the past few years their equipment has been increased in size and capacity perhaps more than any other industry, until, at the present time, we find initial crushers that will take from 5,000 to 6,000 tons of stone in ten hours. With the average distance from the quarry to the plant, this capacity requires from twelve to sixteen 35-ton locomotives and perhaps seventy-five cars carrying ten cubic

yards each. These locomotives mean upward of 500 tons of dead weight transported over the track at each trip with the corresponding power required to propel them. This is in addition to the cars and the product to be carried.

It is a well-known fact that the draw-bar pull of a locomotive is directly proportionate to its weight, consequently it will readily be seen that the elimination of the locomotives and the placing of the load on top of the tractive machinery will very materially reduce the power cost of any haulage system, regardless of conditions of the track, grades or method of operation.

Locomotive haulage again requires two men for each locomotive and train, besides some switchmen, or about thirty men for handling such quantities of stone as the present crushing machinery is able to take. Labor cost consequently is greatly reduced by means of central control, where one man is able to handle all the cars in such a system.

It is very common practice in quarries of this size for locomotives to handle a train of six cars. Each car in the train, therefore, either before loading or after being loaded must wait for five other cars to go through the same process. This condition is repeated where the cars are dumped into the crusher. Each car, therefore, loses by waiting ten times the length of time required for its own operation. With tractive power upon each car, and by not having to wait at the loading or unloading point, practically only one tenth of the number of cars of the same capacity are required as for locomotive haulage, as each car makes a great many more trips than it would if the cars were handled in trains.

These three factors, reduction in power cost, reduc-

Fig. 3.—Typical plan of the arrangement of tracks in a quarry.

* A paper read before the Engineers Society of Western Pennsylvania, and published in the *Proceedings* of the Society, pp. 584-597, 1915.

Figs. 4 and 5.—On the left is the controlling tower. One of the cars is ascending the grade to the crushing plant, while the other is returning empty to the quarry. On the right is shown the switches in the tower, by which one man controls the entire transportation and dumping system.

tion in labor cost and the decreased amount of rolling stock, comprise the elements that entered into the development and perfection of a system of haulage which can be operated by one man.

As a preliminary to a general description of the elaborate system under consideration, I would give the following:

Each car carries its own motive power and control apparatus, taking current from a sectionalized third rail, which allows the car to be started and stopped, or have brakes applied at the will of tower operator, and the car to have its direction reversed at certain fixed points. Control apparatus on the car is arranged so that as the car descends grades the motors can be connected across resistance banks and the regenerative effect used for retardation purposes.

The third rail, which extends over the whole territory covered by haulage system, is divided into long or short sections, as conditions require, and an independent feeder is extended from the control tower to each section. Tower operator has two voltages, 250 volts and 90 volts, which he can apply to various sections of third rail at will. Two hundred and fifty volts are used for haulage purposes and 90 volts are for braking purposes. The regular car rails are used as a return circuit.

The tower apparatus consists of a switching mechanism by means of which the tower operator may put haulage or braking voltages on sections of third rail, or allow them to stand without applied voltage. In the tower machine there are also, when desired, control switches for operating motor-driven track switches, reversing switches and other special apparatus located at distant points on haulage system.

In order to better describe the operation of the system I would like to describe a single installation, and would therefore refer to the system installed at Kenneth, Indiana, where conditions were so varied as to make this installation meet practically all haulage conditions.

The initial crusher at this plant, into which the rock from the quarry is dumped from the cars, is one of the largest jaw crushers built at the present time. Stone is brought from two separate quarries in opposite directions from the crushing plant, over tracks of standard gage, as shown in Fig. 2. Three shovels are located in the two quarries, with double tracks leading from the shovels to the crushing plant, the location of tracks being determined by the conditions, and shifted as the quarry is developed. The track in the quarry at one of the shovels is approximately thirty-five feet below the track at the crusher, the rise being made over a 10 per cent grade on that portion of the track approaching the crusher.

The third rail, or power rail, is placed between the two track rails and insulated in the manner employed in regular electric traction practice. As stated before, the track rails furnish the return conductor and are bonded in the usual manner for service of this class.

The third rail is divided into different sections, the sections at the crusher and near the shovel being considerably shorter than those of the rest of the track. Each of these sections is bonded in the usual manner and each has a separate feeder connection with the controlling tower. The controlling tower in this instance was placed at the crusher, and one operator at this point is able to operate and dump all the cars in the system, the cars being dumped by a motor-driven hoist operated from the same tower.

Each car truck is fitted with two railway type, 250-volt, direct-current series motors, mounted upon the axles and supported by suspension springs and connected with the axle through single reduction gears in the

ordinary manner adopted by electrical traction practice. These motors have their shafts extended at the commutator ends and carry a specially designed solenoid brake, which is applied by the action of the solenoid and released by springs. The car truck also carries three other pieces of apparatus necessary for the operation of the cars from a central point. They are a bank of resistance, a double pole double throw switch for reversing the direction of the motors, and an electric relay or selector switch. This selector switch is a solenoid-operated switch having two contacts and two positions. It is locked in its gravity position with one contact open and one contact closed. In its position induced by the solenoid it is also locked, opening the gravity circuit and closing the other circuit. The solenoid will not respond to a voltage lower than 175, but after being closed will hold in with 50 volts, or even less.

The motors are operated with the selector switch in its excited position. The circuit in the gravity position is to the brake solenoids, and the relay will remain locked in gravity position while the brakes are applied. While the relay is in the gravity position it

Fig. 6.—Dumping a car at the crusher.

also establishes a circuit from the motors on the car to the bank of resistance which the car carries. This resistance is adjusted to dissipate the current generated by the motors running as generators while the car is traveling down a grade, thus furnishing a dynamic brake for the cars which is not under the control of the operator. This feature forms a safety device should the circuit breaker go out while the car is ascending the grade, as upon circuit breaker opening the car will merely coast back down hill at a not excessive speed. While the operator has control of the brakes at all times, this feature also relieves him of governing or speeding the car while it is traveling down the grade. This feature renders the system semi-automatic, arranging its operation so that it is necessary for the operator to give very little attention to the running of the cars except where they are stopped for the loading or unloading.

Each section of third rail is excited separately by the controlling mechanism through master control. The controlling system consists of ordinary magnet switches with magnetic blowouts, a bank of distributing switches and controlling levers, assembled in units of three and four levers each. The lever is off in its central position. The forward arc controls the motors through the contactors, that section of third rail being excited as the

magnetic switches close through resistance which is placed at the controlling point. A dash pot switch is operated by the controller lever, through the arc of motor control, in such a manner as to open all the magnet switches by a backward movement of the controller lever from any control point. The backward movement of the lever from its central position is through the arc of brake control and excites the same section of third rail directly through resistance, giving a range of from thirty to a hundred volts.

These excitations from the same lever are conducted to the third rail feeder through a bank of distributing switches which consist of a certain number of hand-operated switches, one switch for each section of third rail. Thus, from the central controlling tower, placed at any convenient position, we are able to excite any section of third rail with a voltage ranging from 30 to 100 for controlling the brakes, as well as with the starting and running current for the motors. An interior view of the controlling tower is shown in Fig. 5.

A reversing switch is placed on the car so that it is operated by a lever protruding from the side of the truck in such a manner as to engage track cams placed at desired locations along the track, at track switches where all the cars are to be reversed. At points along the tracks where it is necessary for only part of the cars to be reversed, this reversing cam consists of forgings and levers having two positions and operated by a solenoid. Should it be necessary to reverse the car, this solenoid is excited from the tower by a foot switch. It will readily be seen that by this method operation in any manner to meet any conditions may be accomplished, and with track cams at the top of all grades it is impossible for a car to enter upon that grade without the reversing switch and selector switch being in proper position to cause the motors to generate current as they are propelled by the momentum of the car, and furnishing the dynamic brake, maintaining a fixed speed at all times.

At the dumping hopper or crusher another form of reversing cam has been adopted, which is thrown into different positions by a motor-driven movement. This cam carries parallel bars some 10 or 12 feet in length between which the reversing lever of the car passes so that the car may be spotted in any particular position for dumping, arriving from either direction and leaving in either direction. This motor-driven cam is also operated by push-button switches from the tower.

The dumping device, Fig. 6, consists of a motor-driven hoist turning a cam shaft, the cams of which are connected through chains to an I-beam carrying two hooks which engage the inside of the car as they are drawn up by the hoist, and this is operated from the tower through master control with limit stops, limiting its run in either direction, and requiring the operator simply to start it in either direction.

The elements described above, together with centrally controlled, electrically operated track switches, with which all are familiar, render this system of control sufficiently flexible to meet any and all conditions and brings its operating levers within the reach of a single man. A car may be switched to any track; may be run into a passing track from the main line; may be stopped and started from any point and, in fact, operated in the same manner as though there were a motorman upon each car.

The design of a car to carry this apparatus is not materially different than the standard construction of dump cars to which in many cases the motors and other apparatus have been applied.

In the operation of a steam shovel and cars of a size adapted to the shovel capacity, it has been found that four cars will serve a shovel at a distance of half a

mile from the crushing plant and keep the shovel in continuous operation. This means a great reduction from the number of cars that would be required for locomotive or train haulage. It will also be seen that the controlling levers and mechanisms are not a multiple of the car units, but are rather in proportion to the amount of track and the conditions of operation. With a sufficient amount of controlling apparatus, therefore, changes and extensions of track may be made without any other change in the system whatever, and an increase in haulage capacity may be accomplished by simply adding cars to the system. This feature renders the system adaptable to whatever conditions may arise and renders available the use of short tracks and spurs that cannot be entered by more than one car at a time.

It has also been found that the capacity of the steam shovel is materially increased by supplying cars indi-

vidually, keeping a succession of cars approaching the shovel and enabling the shovel to operate without waiting for a train to be pulled out and another pulled in, as shown in Fig. 2.

The power cost, of course, depends directly upon the tonnage, the distance from the shovels to the crusher and the vertical elevation of the crusher above the quarry floor. These three items being different in all cases, it has been impossible to obtain an exact power cost that would be useful in a general way. The power cost for each proposition, therefore, must be computed individually. But on account of the power cost being a very low item, and the fact that the labor cost of operation is the same in all instances, it has been found that a fair average for operation and up-keep of the haulage system is not over one half cent per ton mile in all except very small installations.

The installation cost compared with that of locomotive haulage has been found to be practically equal with a capacity of 3,000 tons in 10 hours. For smaller capacities the installation cost of an electric haulage system has been found to increase gradually above that of locomotive haulage, while above 3,000 tons capacity it has been found to be somewhat less.

The "safety first" principle is embodied in the fact that there are no men around the cars while loading or unloading, and it is not necessary for laborers to be on or near the tracks at any time when the system is in operation. And the flexibility of handling material while the shovel is in an end cut and such parts of the quarry as are otherwise wasted from their being inaccessible by a locomotive and train, furnishes the last of many arguments in favor of industrial haulage operated by central control.

Aurora*

Earth Currents and Magnetic Disturbances

By Otto Klotz

THESE may all be treated as a common subject or phenomenon. Let it be stated right at the outset that our ignorance of them is still vast.

The following despatch from Winnipeg on June 17, 1915, is so interesting that it is inserted in full, besides giving an opportunity for explaining some of the statements made therein:

"Aurora, more mysterious than wireless telegraphy, less constant than the visible manifestations of electrical storms, is to-day tangling up all the telegraph wires strung across the top of the continent, more especially those along the north shore of Lake Superior. There has not been such a complete tie-up in the telegraph business between eastern and western Canada for a long time, and possibly records for the month of June might be searched for many years back without finding a parallel. In fact, well conducted auroræ confine themselves to the fall and winter months, and of all the months in the year June is most immune. The record of observations in Scandinavia and Iceland, as well as the Spitzbergen Station, show no aurora at all in June, though on the North American continent it is not an unknown, though still a rare June phenomenon.

"Aurora manifestations are almost entirely confined to night, and these manifestations, whether visible or not, are commonly accompanied by magnetic earth currents, and it is these properly that affect the wires. Usually with the morning sun the whole manifestation lifts, wires surcharged with excessive and varying currents are freed and released for their daily business and the atmosphere, overloaded with electricity, becomes normal. But to-day the magnetic storm, potent though both unseen and unheard, is raging as furiously, to the tune of crackling wires at noon, as it was at midnight. The sky is heavy and overcast. When the clouds lift and sun breaks through, the whole trouble will vanish magically as it came. For generations scientists have sought the secret of aurora and earth currents but have learned little beyond the central fact of the inconstancy of all available data on the subject.

"Another peculiarity of the present visitation—a scourge alike to the telegraph companies and the daily newspapers—is that, whereas usually it is only wires running east and west that are affected by the polar visitant, on this occasion wires running north and south, such as those between Winnipeg and Minneapolis, are affected to nearly the same extent. From the meteorological point of view, this magnetic storm adds one more to the queer performances of the current month of June."

The first and natural question to occur to an observer beholding the aurora, a brilliant aurora with its dancing, shooting streamers; building, forming and dissolving; rushing from its northern arch to meet beyond the zenith; clothed, perhaps, in greenish gauzy drapery or yet in portentous red; ceaseless activity, a mysterious phenomenon, bewildering to mind and brain—what is the aurora? Beholding it, gives no answer, but when we compare the phenomenon with associated ones we learn a little of its nature. We find it to be electric in its nature, an electric discharge. But here our positive knowledge about its nature stops.

We may mention the theories that have been advanced to account for the aurora. Birkeland attributes the phenomena as due to cathode rays emanating from the sun; Nordmann replaces the cathode rays by Hertzian waves; and Arrhenius supposes negatively charged particles to be sent out by the sun and reaching the earth, ionizing the upper regions of the atmosphere and thereby

making it a good conductor for electrical discharges. The cathode rays we know travel at about a tenth of the velocity of light, hence would take nearly an hour and a half to reach us from the sun; the Hertzian waves travel at the velocity of light, i. e., 186,000 miles a second; and Arrhenius' particles would take about 46 hours, about 2 days, for transmission. The transmission time forms an important factor when an attempt is made to associate particular sun spots and solar outbursts with particular auroræ and magnetic disturbances. The solar effect is, that the discharge of the difference of potential on the earth is greatly facilitated; we have an electric current established with its consequent phenomena of auroræ, earth currents and magnetic disturbances. These are all more or less influenced by local conditions on or in the crust of the earth, and hence vary in intensity at different places. However, the strong currents encircle the earth, as we see in some notable cases, and manifest themselves particularly in magnetic disturbances and earth currents.

The electrical discharges, for, of such are the auroræ, where do they take place? Many measurements and photographs (Störmer) have been made of the aurora to determine its position—height—in our atmosphere, and it has been found that the height, although varying considerably, is of the order of 50 miles. At that elevation the atmospheric pressure is only about 1/500 of an inch, about the pressure in a Geissler tube. The discharge of electricity through highly rarefied gases and vapors in the large tubes, with the accompanying glow, at the Centennial Exposition, in 1876, impressed the writer at the time with its close analogy and resemblance to the aurora or northern lights.

We may look upon the sun, not as the source of the magnetic disturbances, but as the medium that sets loose the bound energy residing in and on the earth.

It will generally—although not always—be found that the center of the aurora-arch, if there be one, is in the magnetic meridian. In eastern Canada and the eastern United States this will be west of the true or astronomic north, while west of Lake Superior to the Pacific it will be east of the true meridian. Furthermore, if the streamers ascend from the north toward the zenith or beyond it, it will be found that their focus or meeting place is beyond or south of the zenith, and at a point approximately where the direction of the dipping needle intersects the celestial vault. We see here then a pretty close connection between the aurora and compass and dipping needle, which we know otherwise to exist. It is fairly safe to say that there is never a bright auroral display without an accompanying magnetic storm, and for which many cases might be cited. The inverse of the statement—that with every magnetic storm we have auroral display—is not so obvious, because the magnetic instruments are always at work, being self-registering, independent of day or night, while the aurora is a matter of visibility, and hence observations are relegated practically to the night. Here we may cite a most interesting case—that of the great auroral display and great magnetic storm of June 17 last. Prof. E. E. Barnard, in *Nature* of July 15, gives a vivid description of the aurora as seen at the Yerkes Observatory. The maximum brilliancy was reached shortly after 2 A. M., Central Standard Time, and shortly afterwards dawn blotted out further observation. While the aurora was pursuing its magic performances in the heavens the magnetic instruments all over the world were mightily perturbed, and as we know from the Winnipeg despatch quoted and other press reports, the telegraph lines were more

or less demoralized by the atmospheric electric currents. While dawn was breaking with us, night was approaching in New Zealand, so that this world-encircling phenomenon could be observed there after daylight had made it invisible in America. And this is what happened. While it was mid-Summer with us, at Dunedin, latitude 46 degrees south, longitude 170 degrees east or 11 hours 22 minutes ahead of Greenwich, it was mid-Winter, and the sun set before 5 P. M. Standard Time in New Zealand is fast on Central Standard Time 17 hours 30 minutes, so that 2 A. M. quoted by Barnard would be 19:30 or 7:30 P. M. in New Zealand.

Mr. W. E. McAdam of Dunedin writes:

"Upon that day (June 17) there was an exceptionally fine display of the Aurora Australis visible all over New Zealand. Here at Dunedin it commenced at 7:30 P. M. and lasted till midnight. The glow in the southern horizon was quite uncanny in effect, producing the illusion that the sun was about to rise in an impossible quarter of the sky, and at an impossible hour. I have been resident in the Southern Hemisphere off and on for 50 years, and have never seen anything to equal the last display of the Aurora Australis, a somewhat rare phenomenon, in the latitude of Dunedin, 46 degrees south.—(*Nature*, September 30, 1915.)"

This is a most interesting case, showing that while the "movies" became invisible in Canada, the night of New Zealand revealed their continued presence.

The aurora does not distribute its favors equally over the earth. The tropics and semi-tropics are practically devoid of them. The curves of equal frequency dip considerably farther south in America than in Europe. No country is so favored by this ethereal visitant as is Canada. From what has been said it is obvious that more auroræ will be seen and are seen during the Winter months than during those of the Summer, simply because in the former case the nights are longer and consequent visibility of the aurora, if there is one.

The aurora has often the appearance of filaments or streaks of clouds, but the distinction is readily observed by the presence of a star or stars behind; for the transparency of the former dims but little, if any, the brightness of the star, which by the latter, even if filmy, would be more or less obliterated.

In tabulating sun-spots and the frequency of auroræ over a long period of years, it is found that there is a very general agreement between the maximum of the one and the maximum of the other, and similarly between the minima, but the definite relationship between the two is not known. Auroræ, magnetic disturbances and earth currents are simultaneous phenomena, due to electric currents in the higher regions of the atmosphere. Their individual intensity is to a degree dependent on local conditions, such as difference in geological formations, and all follow in a general way the sun-spot cycle of 11 years.

In examining the spectrum of the aurora it is found that there is one rather prominent line in the yellow-green wave-length 5,571 which coincides with a prominent line in the spectrum of krypton.

The writer has seen many auroræ in our North-West, their home, and has conversed with Hudson's Bay Company officers and voyageurs, from whom information is said to have been obtained that noises have been heard during auroral displays, and which has been quoted in books and articles on the subject, yet the writer is convinced that there is no authentic record of any noise ever having been heard, although subjectively the "noises" may have been felt.

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