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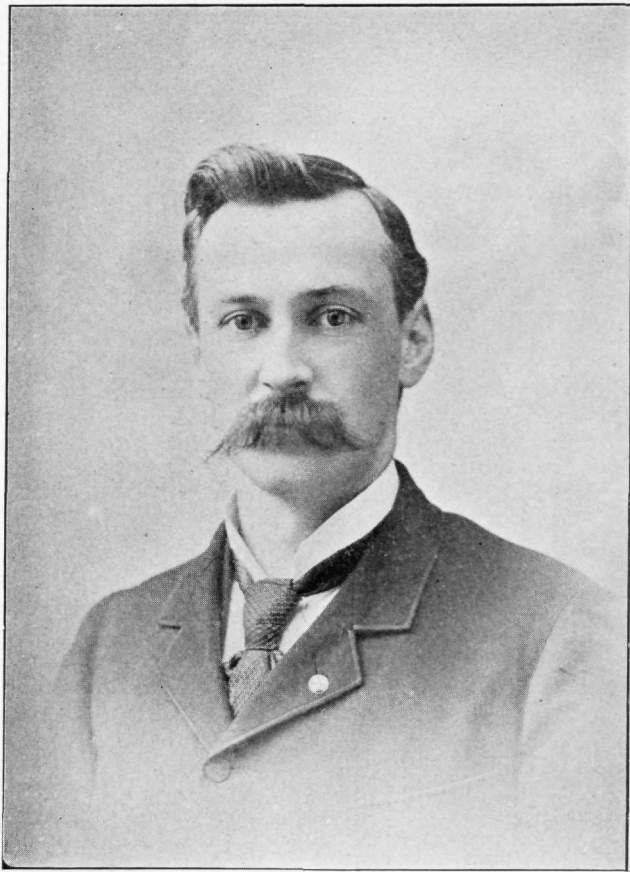
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CHAS. R. THOMAS

ADAPTATION OF MULTI-PHASE ALTERNATING CURRENT SYSTEM OF POWER TRANSMISSION TO MINING APPARATUS, COAL CUTTERS IN PARTICULAR.

BY C. R. THOMAS.

You are all sufficiently acquainted with the different mining machines which employ compressed air and electricity as a motive power, to obviate the necessity of my going into a detailed explanation of them, except to call your attention to the electrically driven type. The electric system you are most familiar with is that known as the "direct current" transmission, and which, until late years, was the only available one at your disposal. The direct current motor, with its commutator and brushes, while being superior to a compressed air engine, has, no doubt, given many of you more or less trouble on account of burn-outs, sparking, etc. It is a recognized fact that the commutator on a generator, or motor, is the weakest part of the machine and requires constant care to obtain the best results. You now have for consideration what is known as the "multi-phase alternating" system of electrical transmission. Please bear in mind that a direct current generator without the commutator is a simple alternator. Therefore, when developing the commercial type of alternating generators, you have but gone back to first principles. The essential difference between the commercial alternator and that which your direct current would be without the commutator, lies in the increased number or more rapid alternations per second; the alternations or cycles being the result of the number of poles multiplied by the speed. The alternating current generator is as simple as it is possible to render copper bars and sheets of iron combined with steel castings. The induction or alternating current motor has neither brush, commutator nor other moving contacts. The armature rotates by means of an induced current, the external circuit being admitted only to the field coils of the motor, the field coils being energized, magnetize the poles or set up magnetic lines of force corresponding to the number of poles in the motor, which lines of force pass

through space into the armature and induce a current of low potential in the armature coils, the windings of which are only copper bars driven into slots on the periphery of the armature, those bars being short circuited in a systematic manner, and grouped in sections to correspond with some multiple of the number of poles in the field. The tendency of the current that is induced in the armature coils is to push and pull the periphery of the armature into and out of the magnetic field, resulting in a constant rotary motion. The potential in the armature being low, it is practically impossible to burn it out, the field coils being of such resistance, that, taken with the counter-electric motive force induced in the coils, prevents a sudden rush of current, thereby preventing a burning out of the fields. Each motor is subjected to what is technically termed a "static impedance" test, which is nothing more than the ability of the coils to withstand a given amount of current without injury while the armature is in a state of rest. In operation the induction motor can be started, stopped and reversed under full load without injury. In starting, the motor comes up to speed gradually. There is no sudden jump from a state of rest to full speed, as some of you no doubt have been led to believe. A motor will work at a certain per cent. of overload which is pre-determined in design. When such a pre-determined percentage of overload has been reached, the armature is pulled out of step with the field and comes to a dead stop, breaks down, misnomer. You will readily appreciate the advantage of this characteristic when the induction motor is applied to a coal cutter, as when the cutter meets with a resistance to overcome which would require an extraordinary overload, sufficient either to burn up a direct current motor or smash the cutter, the induction motor will very intelligently stop, permitting the operator to open the circuit, throw off the feed mechanism and withdraw from under the coal and move the cutter to a more favorable position. The induction motor being without commutator or brush, and practically indestructible, can be placed in the hands of the most ignorant workman and satisfactory results obtained. It is smaller and of less weight than direct current motor of same capacity, and being of slow speed permits of single reduction gear to the cutter mechanism.

A coal cutter equipped with an induction motor, should give at least one hour's more cutting per shift than a like one equipped with a direct current motor, the direct current requiring constant attention on the part of the operator. When applied to pumps, you will also perceive a decided advantage, inasmuch as after starting, the pump requires not attention except to stop it at

the end of the day's run. It is especially adapted to sinking pumps where they can be submerged, working equally well under water. When applied to fans, it can be constructed to start automatically from the power-house without the attention of any one at the motor. A feature possessed only by the induction motor is the ability to reverse under full load, to do so being necessary only to reverse two wires, the third wire remaining as it was. In the economy of wiring for distribution purposes, for a given power, a given distance and loss, at a given voltage, you will require with the alternating multi-phase system but three-fourths of the amount of copper. It has been the practice with direct current apparatus to use a pressure of 250 volts, this pressure being selected as the mean that gives best results on the commutator. With the multi-phase system, the practice is 550 volts, although any voltage desired can be used, and as the amount of copper decreases inversely as the square of the increase of the voltage, and since for same conditions but three-fourths of the amount of copper would be required for the alternating system, you will perceive that less than 25 per cent. of copper would be required for the multi-phase at 550 volts when compared with 250 direct current. By the use of the multi-phase system, distance of transmission is not a serious matter, as with the step up and step down transformers, an exceedingly small wire can be used for the main feeder lines. It is not economical to install individual power plants of 4 to 6 cutter capacity, either as to first cost or cost of operation, when a central power plant of 30 to 60 cutter capacity is practicable. As for instance, assume a group of six mines within a radius of say ten miles. Suppose each mine should require four cutters. To install individual plants, the approximate cost of each would be \$10,000.00, or \$60,000.00 for the six mines. The central plant complete, including line construction and cutter for six mines would cost but \$50,000.00 approximate. The cost of operating the individual plants will approximate for labor \$175.00 per month, or \$1,050.00 per month for the six mines. For the central station, cost of labor approximate \$380.00 per month, a saving of \$670.00 per month or \$111.00 for each mine saved on labor alone. The fuel consumption, oil, waste and general wear and tear on station being less, power could be furnished by the central station at a price below what it would cost individual plant, and still make a profit for the power company. It is assumed the several mining companies would own the stock of the power company, in which case they would be earning at both ends of the line. This idea can be carried out with the greatest economy, and at the same time permit

the use of direct current cutters which are now in operation. You would carry the power from the central station overland to the mine where we will presume you already have a direct current generator operating six cutters. You may use either an induction motor to drive your present generator instead of the steam engine, or you may discard your present direct current generator, and instead of the induction motor, install a rotary converter, which will change the multi-phase alternating to direct current at any voltage which may be required. Briefly, the multi-phase alternating system is peculiarly adapted to mining operation for all purposes where power is required, and is as superior to direct current as is direct current to compressed air. In this era of enforced economies in the production of coal, the mining engineer but consults the best interests of his company when giving the alternating multi-phase system a thorough investigation. This system is used at present by many coal mining companies as well as by a large number of metal mining companies in the United States, South Africa, Peru, Mexico, Chili and Japan. [Applause.]

MR. PALMROS: I heard Mr. Thomas comparing a three-phase direct current and a multi-phase alternating current. The comparison is unfair from this point of view. He compares 550 volts alternating current with 250 volts current direct. The fact is, when you compare two systems, like the continuous and any other, say three-phase, you have to take a certain basis. For instance, you take a certain mine which has a certain length, a certain output per day or per year, and you want to decide which will be the most economical to use, the alternating multi-phase or single-phase, or continuous current. Then, of course, you would suppose that you would use the same voltage. Why should you take a different voltage? Mr. Duncan, President of the American Institute of Engineers, in his annual address, said that in comparing a continuous current to a two-phase and three-phase alternating current, under the same conditions and same voltage, compare to each other as one to one and a half to two. That is a fair comparison. You can just as well put in 550 volts continuous current and 550 volts alternating current. In fact, I would rather see 550 volts continuous current put in than 550 alternating current. I have never known of a man being killed

by 550 volts direct current, but 550 volts alternating current has killed several persons.

MR. THOMAS: Mr. President, I will reply to the gentleman's first assertion that my comparison is unfair, or, as he followed it up by saying, untrue. This is a matter that is susceptible of mathematical demonstration. It would ill become me, representing the company I do, although I am a member of the Institute, to appear before you and make a misstatement. My company would not permit me to do such a thing. In fact, the statement I made is absolutely correct. It is demonstrated by an installation of 500 horse-power in operation to-day. You have but to write to the various users of these plants. I know of a continuous system plant where they are using 500 volts which is not giving very great trouble.

Again, we are enabled to use 550 volts, because there is absolutely no danger of burning out our motors. We can guarantee absolutely against burning out when using an induction motor.

Again, to the last, but most serious charge brought by the member, that no person had been killed by the direct current while several had been killed by the alternating current,—I deny that most emphatically. There has never yet been a well authenticated case of death by 550 volts alternating system. The gentleman who made the assertion cannot substantiate it by facts. The mere assertion does not represent a fact. It is an easy matter to say a poor devil was roasted to death by electricity, but quite another thing when the facts come to be known.

Your Honorable Secretary was telling me of a case that happened in the Hocking valley not many years ago. He said that one day a line man went into a mine to extend a wire or repair something. He had hold of two ends of wire supposed to be charged with current of 220 volts, and as he brought them together the poor fellow dropped over dead. Of course there was a great rumpus about it and I believe the Chief went down on a special train to look into the matter. In about ten minutes after he arrived, the Chief found there had been no power that day and the man had died of heart disease. I tell you this, that

you may see how easy it is to start such a rumor, but a death by 550 volts alternating or direct current has never yet occurred to my knowledge, and I have given the matter a great deal of research.

So far as 500 volts is concerned, I have received it so many times I would not pretend to enumerate them. I will admit it is not very pleasant, but it is not dangerous. I never was hurt by it and of the many thousand men in our employ who handle the system day after day, innumerable ones receive shocks and I know of no one who has met with a serious injury.

MR. PALMROS: I would like to answer Mr. Thomas. In regard to comparing the two systems, I think I have given indisputable authority, and at the meeting spoken of, two months ago in New York, the General Electric Company's representatives were present and none objected to those figures.

In regard to the question of killing, that is an old one. It is a thing which cannot be settled. It depends altogether on conditions and, I suppose, on a man's resistance and whether the mine is wet or dry; but the fact is that people are killed by 550 volts alternating current and even less.

MR. DOE: I do not know that I care to enter into a technical discussion of this point, but I have had some little experience, having used 220 volts for many years, and having installed 500 volts direct current system, and also 550 volts alternating current system. From a practical standpoint I will say in regard to quantity of wire, that it has been demonstrated by practice that we can transmit with the alternating system as much current over a 0 wire as it would take a 0000 wire to transmit with direct current. I installed a plant of eight mining machines, in some Guernsey county mines last summer, four in the Trail Run mine. I placed the power plant at the Trail Run mine, then carrying the current overland 11,000 feet, sinking it into the drill hole into the Hartford mine and transmitted the current 2,000 feet further. To do that I used 0 wire. In Trail Run mine we transmitted the current about three thousand feet and used a number two wire. If we had been placing the direct current sys-

tem there we would have had to use a much larger wire. As regards the point of killing people, I made a thorough investigation of that question before installing this plant, and also before installing a plant of 500 volts direct system. I failed to find any authentic record of death caused by 500 volts electric current. If there is such a case, I failed to find it. There have been many so-called deaths from electric shocks, but the reports have not been substantiated. In this instance which Mr. Thomas related in the Hocking valley, the man's friends said that he was killed by electricity, when the fact was there was no electricity in the mine whatever. I have seen men hold wires carrying a current of 220 volts in their hands, and on bringing the wires together to fasten them; I have seen the lights flash into brilliancy on either side. On one occasion I asked the man how he stood it. He replied, "The current is passing through my body, but I do not feel it. But," he says, "I have had so much to-day I am getting sick at my stomach and will have to quit."

A report came to me after the installation of the plant at Trail Run that a man had been killed by electricity in the Hartford mine. It was the first report from that mine and I felt a good deal worried, and there was a good deal of pains taken to find the cause of his death. A post mortem was held and the man examined by one of the professors of the State University, who showed very conclusively, so much so that the coroner gave it as his verdict, that the man died of heart disease. He was found with his hand on the wire, but the probability is, and it is a fact in my mind, that the man died before he struck the wire. He died of fatty degeneration of the heart. And there are many instances where men have dropped in the mines and have been said to have died from electric shock, when they came to be examined it was found there was trouble in the heart. I do not say that if a man with trouble in his heart should take hold of a wire it would not kill him; but I do say that a man of sound constitution can receive a shock of 500 or 550 volts and not be killed.

One word in regard to the alternating current. Those who know me know that I have had some experience in putting in direct current system. I commenced putting in mining ma-

chinery in 1875 and have continued since. I have probably put in more plants than any one in the room. I put in this plant in Guernsey county of the alternating system because I thought it the most simple, the safest and would in the end be the cheapest system to use from the fact, as Mr. Thomas says, they guarantee that you cannot burn out the motor. I have used the direct current system and I have found that a serious trouble, burning out motors, armatures and commutators. Another thing, we would take a Hungarian who never saw an electric mining machine in his life, and in three days time he would be running that machine as well as an old experienced man. It goes to prove that it does not require so high a grade of skill with the alternating as with the direct current, with its commutator and brushes.

MR. E. D. HASELTINE: I would like to ask Mr. Thomas if it is practical to apply the alternating current in such form as to run either a Harrison or a Ingersoll-Sargent machine?

MR. THOMAS: I am safe in saying that the induction motor is probably the only electric motor that renders it possible to operate a reciprocating machine, similar to the Harrison or Ingersoll-Sargent.

I will add further, for the information of the members of this Institute, that the question of voltage does not lay with us. When I say "us", I mean with the General Electric Company. It lies entirely with the purchaser. With the alternating current system we are enabled to give from five volts to 2,100 volts, just as the requirements may demand, and all from the same generator. It is absolutely impossible to do this with the direct current apparatus. This feature renders the alternating current system the most flexible and the most desirable that could be used for mining purposes.

MR. MCGOUGH: There is one phase of that question I desire to say a few words about, that is the danger to life. In regard to this man who was killed in the Hartford mine, who was supposed to have died from heart disease, he had always worked every day and no one thought there was anything the matter with him, then all of a sudden he died in that way there. Every man

who has come in contact with those wires has suffered a severe shock and only a very few could let go themselves. I have suggested a plan for the better safety of the miners working where these wires are, and that is to have a groove cut in a strip of wood and the wires placed in the groove. Then let the board be placed in front of the wires so no one can come in contact with them. I believe the company said the wires were not dangerous, but I would rather see the board put in front of them.

Week before last, in company with the Chief Mine Inspector and the superintendent, I was going through the entries where the wires were located, and we were talking some little about it, when we came to a lace where there was about eighteen inches of water. The superintendent led, the Chief was next and I was about ten feet behind. The superintendent, I presume, was walking on a rail to get through the water, when he threw out his hand and the wire caught him. I never want to hear such a sound again as he made. He was lying in the water unconscious for ten or fifteen seconds. When we brought him out of there, I said: "Do you think it is dangerous?" He said: "That's awful." That man, to all intents and purposes, was dead when I got to him, I suppose three or four seconds after he got the wire, or it got him. I do not know much about direct or alternating currents, but I am satisfied that these wires are more dangerous to life and limb than a direct current.

SECRETARY HASELTINE: There is some difference between Mr. McGough and myself in regard to the occurrence he relates. I agree with him in regard to the demonstration which this party made: it certainly would not do for a lullaby to rock one to sleep with. This man was an especially good subject for a shock: he had on a pair of rubber boots full of holes, his feet were wet, the water was ten inches above the rail and he was standing that deep in the water. His hands were wet. I was within a step of him when he slipped—I do not know whether he was on the rail or not—he held onto the wire not long enough, I think, to count four, and in his stumbling in the water over the ties and rail, he fell backwards and sat down in the water not more than two or three seconds. He looked dazed and I took him by the

shoulder and told him to get up. He stood up apparently all right, wrung his arm a few times and said "That's awful." He did not seem to feel the effects of it, but seemed mortified that with certificate of Mine Inspector of Pennsylvania in his pocket, he should make such an exhibition of himself and get his certificate wet. He seemed to regret that more than anything else. If ever a man in the world got the benefit of the full voltage of a wire, he certainly did in that case. Then he went into an explanation of the effects—it was not his first experience—and he said that if one caught the upper wire it was like some one struck you on the head with a sledge hammer. The second wire gave more of a thrilling, twisting sensation, and the lower wire gave the combined effects of the other two. He made this diagnosis of the lower wire in a mighty short period of time.

A while ago mention was made of an inquest held in Guernsey county. There never was an inquest held in the mining department in which so much expense was gone to in order to make it thorough. After I arrived there I telegraphed for Dr. Bleile at the Ohio State University, who is said to be the best authority in the State as to the effect of electricity on the body, to hold the autopsy, and afterwards held an exhaustive inquest at Hartford. We found that seventeen or eighteen people had been in contact with the wires and told startling stories of their experience on the wire. The first question I asked each one, I think, was this: "How long after you were liberated from the wire was it before you resumed your work," and the answer was from three to fifteen minutes. There was not a single instance in all the long line of witnesses there where a man was prevented from resuming work in a few minutes until the end of his shift. One man said he had been caught in his left hand and that his right arm had been interfered with ever since. Another thought his eyesight had been a little affected since his experience. There is a great difference in people in their ability to withstand a shock from an electric current. At Deerfield, in Portage county, there is a mine that is equipped with the alternating current system, put in by the General Electric Company, and there is a man there

who can grab those wires with impunity. He takes special delight in getting "suckers" in the mine, when he will grab the wire with one hand and them with the other. I believe he on one occasion put one hand on the wire and struck a mule on the rump with the other and knocked the mule down.

MR. BEATTIE: I would like to ask the Chief if the superintendent who had the tussle with the wire intimated beforehand that the certificate in his pocket would protect him from electricity?

SECRETARY HASELTINE: No; but he had assured Mr. McGough and myself that the wires were perfectly harmless and that we might handle them with impunity. But I had a tip that these fellows had it in for me and were going to give me a "dose," and I did not propose to experiment with it myself, for fear of a weak heart. (Laughter.) I kept my hands in my pockets.

MR. THOMAS: I want to say that I could, with an ordinary magneto bell, take any gentleman present—he being willing, of course—and with that magneto bell give the Chief just such an exhibition as he saw in the mine the other day. I would venture to say that it would produce the same howls, and the same squirming. At the same time the man would not be injured.

MR. MCGOUGH: What we want is to protect the unwilling victims.

SECRETARY HASELTINE: I have been in contact with a direct current wire of 220 volts, and while I do not remember distinctly about the evolutions I went through, my recollection is that I performed something very similar to what I saw in the Trail Run mine. To me an electric shock is very painful and I would as studiously avoid coming into contact with 220 direct current as 220 alternating current. I have as great a horror for one as for the other. With all the electric plants in the State, there never was an instance reported before the accident in Guernsey county of anyone claimed to be injured by coming in contact with an electric wire.

On motion of Mr. Beattie, a vote of thanks was extended to Mr. Thomas for his instructive and able paper.

PRESIDENT RAY: We will pass to the next paper, which is entitled "A Tramp's Visit to Southwestern Colorado and Northwestern New Mexico, with Durango as a Starting Point." The paper was prepared by Jacob G. Chamberlain, of Los Angeles, Cal., one of the oldest officers of the Institute, he having been President for a number of years.

Mr. E. D. Haseltine was asked to read the paper, which he did, first reading the following letter from Mr. Chamberlain:

"LOS ANGELES, CAL., January 4, 1897.

"Mr. R. M. Haseltine, Secretary and Treasurer:

"MY DEAR SIR:—Enclosed herewith you will find some observations taken from a report I made for a railroad company. If you think it of any interest to the society you can read it; if not, drop it into the waste-basket.

"The field I examined, some 300 miles in extent, prohibits me in a short paper from giving any idea of the country. I would rejoice to be with you and meet the dear old friends that struggled so hard years ago to make the society of mining engineers a success. I do not know how it is with others, but with me there is a tender feeling of sincere friendship that goes out to each one of those old members. God bless them all in the noble work they began. I trust the new members will take up the work and carry it forward with greater ability than we did. The work they have accomplished from a humanitarian standpoint has been a noble one, and from a practical and scientific standpoint one that they may well be proud of.

"Yours truly,

"J. G. CHAMBERLAIN."

