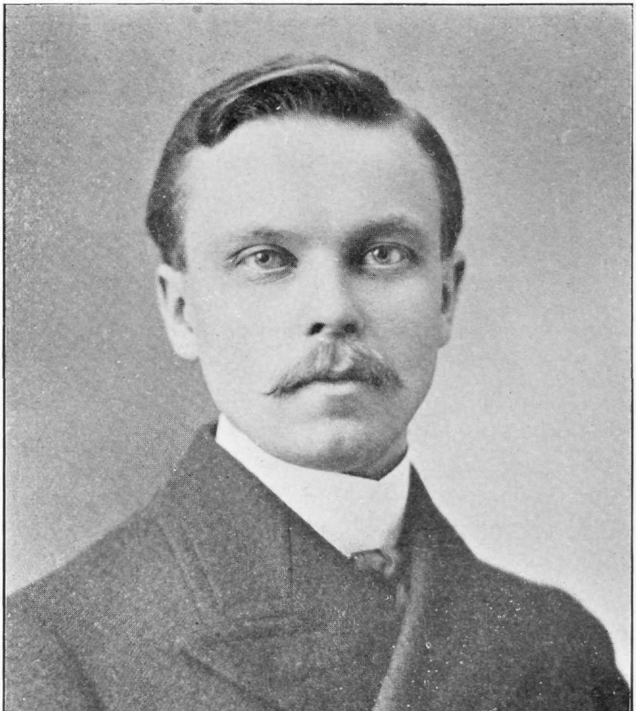

ALEXANDER PALMROS

COST OF POWER IN ELECTRIC COAL MINING.

ALEX. PALMROS, COLUMBUS, O.

Mr. President and Gentlemen of the Institute:

Coal mining with electric power has no doubt many advantages over any other power that can be applied for operating machinery, either cutting or hauling, or it would not be so popular. Many a mine paying a dividend while operating with power machinery, would be idle if returned to pick mining. The saving is brought about by doing the hard work mechanically and leaving the guiding and operating to manual labor; or in other words the generation of physical force in a comparatively efficient manner and distributing same to the working places in a cheap and simple way. I say "cheap" because when would we use the term "cheap power" if not at the coal mine, where the fuel is of no or very small expense.

The cost of fuel in generating power is anywhere from ten to seventy-five per cent. of total cost, depending largely on the locality and price paid for same.

There is a common opinion among operators and mine managers that the cost of power is so cheap it is hardly worth while to consider its value when pipes or wires are installed for transmitting this power to the working places, sometimes a long distance, and taken too small on the assumption that being so cheap a great loss can be allowed in the line and money saved on the first cost. This sounds very well, and hearing it so often I determined to investigate the matter and thus in brief will I give results.

To make these results of most value they should be founded on actual figures obtained from mine plants operating in different sections of the country. I must say that this was almost impossible, as very little data could be obtained, due most likely to operators' indifference to the question. I therefore began my investigation by collecting costs of generating power for other purposes than mining, but of somewhat similar nature. This data I have tabulated in table I, which is graphically represented in diagram A. A glance at this diagram shows expenses itemized and given in separate values. The total expenses are first divided into two parts: operating expenses and fixed charges. The operating expenses consist of fuel, wages, supplies, repairs and water. The fixed charges of interest on capital invested, depreciation of the value of total plant, insurance and taxes; all values given in Indic. P per year. The Table I also gives the average power, maximum capacity of plant, and the number of days in operation.

As a graphical representation is more readily understood, I will refer you to that. The different columns represent different plants, which I have marked numbers 1, 2, 3, etc., as in table I, columns 1, 3, 5, are costs of steam power as given by Mr. H. A. Foster in his paper read before the American Institute of Electric Engineers in August, 1897. Columns 2, 4, 6, same costs after deducting expense of fuel or assuming that the power has been generated at the coal mine, considering the fuel was of no expense to the operator. Column 7 is the writer's calculation of the cost of indicated H. P. per year at the coal mine, operating a 100 kw. plant, 200 days per year, 10 hours per day. Column 8 is the cost of power as given in 7, but assuming the fuel used under the boilers as mine run coal at $1.00 per ton.

Plant No. 1 was operating 361 days per year, and 9 hours per day; the average H. P. was 21½, or 33% of the capacity of the plant. The cost per H. P. per year is $108.27. A good sum of money, to be sure, still the expense of fuel and water is only 35% of the total; or, if we look at column 2, where the cost of fuel is entirely omitted, the total expense per H. P. a year would still be as high as $77.47, not so small that the operator would neglect it in his calculations. The greatest expense in this plant is wages, $51.09. It would seem natural that cheaper help could be employed and thereby reduce the total cost to a more reasonable figure, and this is the usual practice, but not always the best, as cheaper help generally increases repairs, supplies and depreciation; or, instead of a deducting, would perhaps have an increase in our expenses.

Plant No. 3 is somewhat larger and about the size now generally installed for electric coal mining. Here we find expense of fuel as 32% of total expenses, total expenses per H. P. per year being $76.45. The highest item is wages, but that is only half of wages in Plant No. 1. It is interesting to note that depreciation and repairs are higher, indicating what I have just stated regarding the employment of cheap help. If we deduct the cost of fuel, water and taxes, or bringing it to a basis of coal mining, we find the cost is $52.02, graphically shown in No. 4.

Reducing Plant No. 5 to what we may call coal mine basis, we have a total cost per indicated H. P. per year of $18.71. This figure is exceptionally low and could hardly be taken to represent an average. Column 7 represents the cost per H. P. per year generated in a mine plant of the following capacity:

100 k. w. multipolar belted generator, driven by a 16x16 simple, automatic, highspeed, non-condensing engine, running at 250 revolutions per minute at 90 pounds of steam, fed by two 66x16 return tubular boilers provided with one 4½x3x4 feed pumps, and a 225 H. P. heater; all machinery of first class design and housed in a neat, but plain brick building. In figuring the fixed charges for this plant, the first cost of plant, with exception of generator and switchboard, was considered in column 7. The cost was taken as $4,852.50, the interest on this capital invested at 6%, the depreciation as 8%, insurance ½% of three-fourths value, taxes as 1%. In operating expenses the wages are assumed to be $65.00 per month for one engineer, who also does the firing. The cost of coal (fuel) is considered of no expense, although a small expense should be counted for conveying the coal from tipple to power-house. These assumptions are all very low and rather below figures in similar conditions.

Depreciation of machinery around a coal mine is very great and should perhaps be taken a little higher. But as the tendency among mine operators seems to be toward employing higher priced labor to take care of their expensive property, this will naturally reduce the depreciation, as better care can be expected.

The number of days in operation is taken at 200 per year, each day as 10 hours, making 2,000 hours. This figure of 200 days was thought to be a good average for mine operation at the present time, giving a margin for strikes and short-of-orders. When the plant is working more than 200 days in single shifts the expense is increased very little, as the wages are unchanged, the engineers being as a rule paid a fixed rate per week or month. The only increase would be a small per cent. in supplies and repairs due to increased wear and tear. Again, when the plant is operating double shifts, the expenses are increased, but not in proportion to increase of time, as the fixed charges remain the same and the extra expense is caused by night engineer's wages, increased supplies and repairs, and the lower efficiency of plant at lower night load. The average indicated H. P. output is taken as 59, which is 35% of the plant capacity. This is indicated horse power, not electric. The reason I give engine indicated horsepower instead of electric horsepower is to be able to compare with columns 1 to 6, which are all indicated H. P.

Another reason is the fact that steam power is used for so many purposes at a mine plant, such as operation of fans, hoists, pumps and shop tools. Again, when we compare economy of electric transmission with air or rope, we have to take the same prime power as basis, and the steam is the most economical for coal mine power house without doubt.

Knowing once the price paid for indicated H. P., and the plant efficiency, it is a simple thing to figure out the cost of electric power. This I have done in column 9, taking the plant efficiency as 80%, plotted in diagram B. These two curves are actual readings of generator and plant efficiencies as working in a certain mine power house. The generator is not of the very latest type and is less efficient than machines made to-day, but I was anxious to have everything as conservative as possible and therefore decided to use this in my figures. The reason for taking the average H. P. developed as 59 H. P. is understood if we look at this diagram C, which is a load curve at a mine power house generating power for one mine locomotive, one breast machine, electric pump, emery grinder and a few incandescent lights. This curve is from a test made by Messrs. Buck & Bellesley, of Cornell University, on a mine plant in West Virginia, and I have here reproduced it with these geneltmen's kind permission. The curve is a graphical representation of readings taken every five minutes throughout the day of ten hours.

The horizontal lines represent the electrical power generated and the vertical lines the time. The red line at 22.5 H. P. is the average, which is about 31%. I decided to use 35%, as a few more coal cutters would surely bring up the average a few per cent. From observations of my own, I can say that this low average is very characteristic of a coal mine power house. This size plant of 100 k. w. was adopted, as it is generally in use and will be more and more adopted as the standard size when both haulage and cutting are done by electric power. Looking at the individual costs for generating one indicated H. P. per year, we find the operating expenses $16.82, when fuel and water are of no expense. The fixed charges are $12.63, making the total $29.45. Now, this is what is generally called "cheap power." It is cheap compared with columns 1 to 4, but perhaps not so cheap as many of you expected it to be. The cost of electric H. P. is shown in 9, when the indicated costs $29.45.

Plant No. 8 is the same as No. 7, when mine run coal is used at $1.00 per ton, which is sometimes done, due to the location of the powerhouse. The price $1.00 per ton, was taken as a matter of convenience. When any other price is paid for coal, it is an easy matter to calculate the increase of cost.

It was my intention originally to indicate the different ways and means to reduce these expenses connected with power generation and its distribution in the mine, but I will have to leave that until another time or this paper would be too long. Still, I will say a few words as to how a greater economy can perhaps be effected.

First, I do not see how the cost of steam power, generated with machinery as built to-day, could be reduced any, as it will always require an engineer to look after your property; and to get the best attention and save as much as possible in supplies and repairs, good or living wages must be paid. To reduce the fixed charges on the plant would mean to buy cheaper machinery,—but remember all the shut-downs and repairs which are sure to follow. Whatever system is employed for transmitting the power to working places, loss is necessary in transmitting and for economy and flexibility, electricity has no superior. It can be employed for all operations where mechanical power can be used. The question is how to do it at the ieast expense. The losses we have to reduce are: the drop of pressure from line resistance and the low economy of plant at fluctuating load. The loss in line is reduced by adding more copper, but care should be taken to not get too much of it, which happens when the interest on capital invested in the copper is greater than the power lost in the line. This important thing alone would compensate for the trouble in getting at the actual cost of your power, as it may save many a dollar in first cost, or in power every day.

The diagram C is, as I said before, a picture of what takes place in a mine power station in a day's run. The load on the machinery is very fluctuating; in a few seconds we see the load jumping from 20 H. P. to 131.7 H. P., and so on throughout the day, never steady except at noon-hour, when the electric pump is the only load. Now this way of working is not economical, as you can see if you give diagram B a few moment's attention. Here we have a load of five horse power, the plant efficiency at this output being 32%; a few seconds later we have a call for 56 H. P., and diagram B gives the plant efficiency as 78%. So you see a difference of 46%, and as the load throughout the day is up and down, we can easily see that the mean efficiency is not so high as it would be if the load was constant at its highest efficiency. This same state of affairs exists in all street railway power houses, and where coal is expensive it is the cause of lots of worry for the manager, anxious to have his road pay some dividend to the stockholders. At the coal mine, it is of less consequence, as fuel is of no expense. Still, knowing that the average load is only a fraction of the maximum, we naturally begin to think what amount of money could be saved if the load was constant. The machinery would be in proportion to the load and the money invested greatly reduced. But this is impossible, due to the nature of things. There is one way whereby we can have the plant working at its highest efficiency and still have power reserved for overloads, and that is to install a storage battery in the power house, or somewhere in the mine. The function of the battery would be to absorb all surplus power when the load is below normal and give out that reserved power when the load on generator is above normal. The action of this battery is perfectly automatic and requires very little attention. The greatest drawback is the first cost, which is rather high; but in time improvements and a healthy competition will fix that. Another good feature about a battery is that it can be used as a transformer, that is, a high voltage can be transmitted to the battery, which would be located where the power was required, and a lower voltage drawn suitable for the operation of coal cutters, locomotives, etc. This would be specially suited for low coal-vein working, or where the power house is located a long distance from the center of power distribution.

PRESIDENT RAY: This seems to be a day of good papers. Are there any questions?

MR. THOMAS: I would like to ask the writer a question. I understood him to say there was a storage battery for direct current, for 250 volts.

MR. PALMROS: A storage battery consists of sets of plates and by adding several batteries in the series, you get any voltage you want. The battery is used in street railway work as I propose it in mining work. They put in a series to get 250 volts.

MR. THOMAS: That is not altogether satisfactory to me and it is a very important question to anybody using an electric plant. The chart shows there surplus power, and seems no trouble to meet these points of emergency when probably using four or five hundred amperes; half hour after the dynamo is running light. This storage battery is the same as a receiver in a compressed air plant. I want to know whether there is anything on the market in the way of a storage battery applied to 250 direct current plant, to store up the surplus power in this way.

MR. PALMROS: There are several plants in operation in the United States and in Europe, and there are some made in this country; some in Cleveland and one in Philadelphia, the electric storage battery. It is a success but very expensive. In many cases they pay, and surely reduce the expense of power.

MR. THOMAS: How does it compare with the expense of putting in another dynamo?

MR. PALMROS: That question is brought up every time. In Philadelphia, the Traction Company have a long line, eleven miles long, which is travelled very lively certain hours of the day. It became a question whether it was cheaper to put in a power house or battery? In that case the battery was cheaper, saving them sixteen thousand dollars a year by using the battery instead of power house. Every special case must be figured out. I would not advise it in every case; it depends on condititions. There are several cases right in this state where a storage battery would be a saving.

Moved by Mr. Oyser and seconded by Captain Morris, that a vote of thanks be extended to Mr. Palmros for his able paper. Seconded: carried.

PRESIDENT RAY: I have a letter from Hon. Andrew Roy, stating that he is unable to be here, but his paper is here and will be read by his son.

The following paper was read by the son of Hon. Andrew Roy: