DISCUSSION AT CHICAGO.

A meeting of the Western members was held in room 1737 Monadnock Block on Wednesday evening, November 20. There were present about 20 members and 12 visitors. Prof. H. S. Carhart was elected Chairman for the evening. The discussion of "Storage Battery Applications" was opened by Messrs. Arnold and Abbott, who read specially prepared communications. The communications presented at New York were referred to, but not read.

COMMUNICATION BY ARTHUR V. ABBOTT AND FRANZ J. DOMMERQUE ON "ACCUMULATOR ECONOMICS."

It is true that the Europeans have made quite a large number of installations of cells, and with good success, but in this country this has not been the case as far as lighting is concerned. In the telephone service we have made of late rather an interesting application of small cells. It is in that service which formerly operated all the subscribers' transmitters at the various stations in the city by means of primary cells. A little more than a year ago it occurred to us to replace the primary cells by a small storage cell, charging the same continuously from the main office, excepting at the time when the subscriber was using the telephone in conversation. When the receiver is taken off the hook, the charging circuit opens, stopping the charging current for the time being, and allowing the local storage cell to discharge quite rapidly through the subscriber's transmitter for the purpose of conversation. Our installation has not been in service long enough to pronounce a conclusive opinion upon it as to the durability of cells of this kind. It is certainly very gratifying as far as it has gone. We have found that the maintenance of the local storage cell is less than that of the local batteries. As to whether the plates of the cell will last as long as we hope for, is a matter that future experience only can settle. In instances where the operation has been carefully made, and the installation properly and carefully attended to, we see no signs of deterioration in the plates. They seem as good to-day as they were 15 or 18 months ago. In cases of carelessness, either on the part of the manufacturer, or on the part of the users of the cells, it is unreasonable to expect that the cells will not suffer deterioration.

This, we regret to say, is the limit of our individual experience with the *durability* of storage cells. We feel that there is no question at all that they are a vast improvement, both from a service standpoint and from an economical standpoint, over the primary cell.

In the following we have taken what is perhaps a well-worn theme, and that is, the advisability, or, rather, an instance of the advisability of storage battery installation by comparing the cost

of an electric lighting plant capable of supplying the entire city of London, as indicated by this diagram, which was taken a little over a year ago, with a steam plant alone, or with a steam plant with accumulator-regulation.

In the electrical installations, whether they may be for lighting or for power distribution, electricians have been seriously hampered so far, due to the fact that their station must be sufficient to supply the maximum demand that can be put upon it. We have no form of reserve. In gas works the retort plant may be comparatively small and run 24 hours for 365 days in the year. The break of gas in the holders is reasonably inexplosive, and in the holders we may store up 22 hours out of the 24, the breaks of the retorts to it use the other two hours. With water power we may build a dam, and the stream flowing into it may increase the reservoir capacity all night long, although the wheel turns but eight hours out of the 24. In other forms of manufacture we are able to store up a sufficient quantity of material for a sudden or unusual demand during a short period; but in electrical installation this cannot be done. The demand, as indicated in the diagram, is exhaustive between, say, 4 and 7 P. M. During that time the current rises to 11,600 kilowatts. During the other 21 or 22 hours of the day it is a comparatively small demand.

There have been in Europe a good many plants that have adopted storage cells for the purpose of equalizing the load line, and for the purpose of reducing the investment and size of the steam plant.

The European installations have, as far as we know, been uniformly successful. Why it is that they have not been introduced into this country to a greater extent, we are not aware. With the exception of the Edison company, there have been almost no installations of that character.

The European engineers have investigated load diagrams thoroughly and succeeded in cutting off the peak. How did they do it? Simply by developing accumulators. They brought it down to such a point that, for instance, in the Hanover station, the accumulators are kept in perfect order by the manufacturers, for the consideration of four per cent. on the original cost, for ten years, and are handed to the city at the end of the ten years in first-class service condition, the efficiency of the accumulators being 96 per cent. in ampere hours, or 78.4 per cent. in watt hours.

In order to give an idea of the ratio of capital expended on accumulators, to capital expended on the rest of plant, the rating of the property as it stood at the end of the year 1893-1894 may be written down.

Lot and building.....	628,075.71	marks.
Machinery.....	296,023.28	"
Accumulators.....	125,000.00	"
Line.....	538,866.87	"
Water facilities.....	44,968.01	"

Tools, instruments and furniture.....	29,489.80	marks.
Electricity meters.....	60,600.89	"
Street lighting.....	15,758.07	"
Stores.....	16,489.4	"
Miscellaneous.....	13,439.64	"
Interest and stock market loss.....	128,634.08	"

In the case of Dusseldorf, the accumulators range higher yet, while the total installation cost is put down at 2,260,000 marks. The accumulators alone are credited with 280,000 marks.

Fig. 1 shows the combined output of the whole London central stations during the 24 hours ending at 6 A. M. on the 20th of December, 1894.

The correct level to base the calculation upon, is the day of highest load, and it will not be far out to choose the diagram of the 20th of December for this purpose.

The load curve shows a maximum load of 11,600 kilowatts, or

$$\frac{11,600,000}{740} = 15,700 \text{ H. P.},$$

and a minimum load of 800 K. W. equals

$$\frac{800,000}{740} = 1,080 \text{ H. P.},$$

the load factor being 33 per cent.

First, it may be ascertained what would be the expense if regulation was performed by shutting down part of the plant; afterward the expense with accumulator regulation will be calculated, and the comparison between the two obtained values will be the decision as to which system of regulation is preferable. In the first instance the plant has to be fitted up with machinery capable of supplying the demand at maximum load = 15,700 H. P. From the load diagram it will be seen that during about 14 hours, the load does not exceed 3,000 H. P. to any extent. This is of great importance for the choice of units. Choosing five units at 3,000 H. P. each, would take care of the maximum load also, as for a very short time during the day the engines and dynamos could be overloaded a trifle; the necessity of doing this would only occur in a few winter days anyhow.

The items required to determine the expenses would be:

Cost of fuel per year.

Cost of labor.

Cost of supplies and repairs.

Interest and depreciation on plant.

It has been ascertained by Mr. Fritsche that the average load throughout the year is 16.375 per cent. of the maximum load, hence,

$$.6 \times \frac{15,700 \times 16.375}{100} = 1,543 \text{ H. P. per hour},$$

or,

$$1,543 \times 24 \times 365 = 13,513,180 \text{ H. P. per year};$$

the amount of coal used per H. P. hour being about $1\frac{1}{2}$ lbs. For such large units as are used in this case, it would require $13,513,180 \times 1\frac{1}{2}$ lbs. per year, but to maintain banked fires, when part of the boilers are shut down, and bring the fires to average working condition again, an allowance should be made, which in the present case, where 3,000 H. P. is always required, does not amount to very much. Assume an addition of 20 per cent. on the 3,000 H. P. for the 14 hours, or $600 \times 14 \times 365 = 3,066,000$ H. P. hours per year. The total H. P. hours would equal $13,513,180 + 3,066,000 = 16,579,180$ H. P. per year, and the amount of coal used would equal $16,579,180 \times 1\frac{1}{2} = 24,868,770$ lbs., or 12,435 tons (of 2,000 lbs.). The price of coal per ton may be taken at \$2.25, then the cost of fuel per year equals $12,435 \times 2.25 = \$28,000$ in round numbers.

The cost of labor is determined as follows: One attendant is required per unit, or five in all, at 25 cents per hour, equals an expense per hour of \$1.25. Ten firemen and two helpers at the same rate, or an outlay of \$3.00 per hour. This fixes the cost of labor at \$4.25 per hour. Add for superintendence \$1.50 per hour, obtaining a total of \$5.75 per hour, or $\$5.75 \times 8,760 = \$50,370$ per year.

Cost of supplies and repairs is found, applying Dr. Emery's results obtained from the cotton mills of Fall River, as $13,513,180 \times \$0.0008 = \$10,810$ in round numbers.

It remains yet to determine the interest and depreciation.

Money is obtainable at five per cent., and the amount necessary to provide for depreciation should not be any more; therefore 10 per cent. is assumed. The cost of steam plant, taken at \$64 per H. P. (Emery's value) + $\frac{1}{8}$ surplus power, a plant of

$$15,700 + \frac{15,700}{8}$$

equals in round numbers 17,700 H. P., as required which will cost $17,700 \times 64 = \$1,132,800$, 10 per cent. of which is \$113,280. The cost of dynamo, switchboard and accessories may be taken at \$35 per K. W., or \$25.90 per H. P.

The cost of 15,700 H. P. will be $15,700 \times 25.90 = \$395,000$, the interest and depreciation of which, on the basis of 10 per cent., will amount to \$39,500.

The total expense, therefore, per year will be $\$28,000 + 50,370 + 10,810 + 113,280 + 39,500 = \$241,960$ for regulation by shutting down part of the plant.

To calculate the expense for accumulator regulation, the load diagram has to be studied. The kilowatts found by integrating the area below the load curve gives the watt hours to be delivered to the line; this is found to be 100,800,000 watt hours. The engines in this case have to generate an additional amount to make up for the loss in the accumulators. The total amount may be designated for the present by x watt hours; x watt hours

may have to be supplied by the accumulators, and z watt hours by the dynamos in 24 hours; z may be the effect to be produced by the dynamos in watts. If the efficiency of the accumulators is taken as 75 per cent. (which is not too high by European experience), $\frac{1}{75}y$ or $1\frac{1}{3}y$ have to be given to the accumulators to enable them to give y to the line, hence $\frac{1}{3}y$ is lost in the accumulators: z will, therefore, be equal to $100,800,000 + \frac{1}{3}y$. If there was no loss in accumulators, z would equal $100,800,000$, and

$$z = \frac{100,800,000}{24} = 4,200,000 \text{ watts.}$$

FIG. 1.

This value is plotted in Fig. 1 as a dotted line; this line cuts off the peak and would give the dynamo rating in watts, if there was no loss in the accumulators; by integration this amount is found to be 29,400,000 watt hours. This value inserted in the equation:

$$z = 100,800,000 + \frac{1}{3}y$$

gives

$z = 100,800,000 + 9,800,000 = 110,600,000$ watts per day, and

$$z = \frac{110,600,000}{24} = 4,608,333 \text{ watts.}$$

This value is plotted again in the diagram, and the new value for the area of the peak found as 28,800,000 watt hours. Inserting this value again in the equation, the value of z is found this time as:

$$z = 100,800,000 + \frac{28,800,000}{3} = 110,400,000 \text{ watts per day,}$$

and

$$z = \frac{110,400,000}{24} = 4,600,000 \text{ watts.}$$

Now the value of 4,200,000 watts for z would render z for the dynamos too low, as no loss in accumulators was assumed, and $z = 4,608,333$ watts makes it too high, as the accumulator loss is taken in that case too high, the value of $z = 4,600,000$ is nearer to the correct value, and may be taken in the present case for the correct value, though it is possible to come closer to the correct value yet. Plotting a line corresponding to 4,600,000, which may be a, b, c, d , then the area e, b, c, f, i, h gives the watt. hours delivered by the dynamos direct to the line; the area a, b, e plus c, d, f , the watt hours, charged into the accumulators.

The engine power required under the assumption of 90 per cent. efficiency of the dynamos would be :

$$\frac{4,600,000}{740} = 6,215 \text{ H. P.} + 10\% = 6,836.5,$$

or in round numbers 6,850 H. P.

It remains to determine the size of the accumulators. In the load diagram a dotted curve is sketched in, which is constructed on the assumption that the lamp voltage should be 110 volts with an allowable loss of 10 volts. The new curve represents the ampere load, the scale of amperes being at the right side.

The dynamos deliver all through the 24 hours 4,600,000 watts, therefore, at the time of greatest consumption, which is at 5:30,

$$\frac{4,600,000}{120} = 38,333 \text{ amperes}$$

will be the dynamo current, and the highest discharge current is obtained by subtracting these 38,333 amperes from the total current at this time: $96,666 - 38,333 = 58,333$ amperes. The total current at 4 P. M. is 50,000 amperes, corresponding to a loss of

$$\frac{50,000 \times 10}{96,666} = 5.2 \text{ volts.}$$

Hence the dynamo current equals :

$$\frac{4,600,000}{115.2} = 39,930 \text{ amperes.}$$

At 10 P. M. the total current is again 50,000 amperes, and we obtain at this time the dynamo current also = 39,930 amperes. At 8 P. M. the total current is 70,000 amperes, as seen from the curve, corresponding to a loss of

$$\frac{70,000 \times 10}{96,666} = 7.23 \text{ volts.}$$

Hence,

$$\text{The dynamo current} = \frac{4,600,000}{117.23} = 39,240 \text{ amperes.}$$

Plotting these values obtained for the dynamo current at the different hours into the diagram, the curve *k, l, m, n*, if integrated, will give the accumulator capacity = 240,000 ampere hours. From the price list of the Electric Storage Battery Company, a cell of 5,000 ampere hours capacity costs \$375. If there is such a great quantity needed, the price of \$375 would be reduced at least to \$250.

$$\frac{240,000}{5,000} = 48 \text{ cells in parallel would be required.}$$

The potential of one cell is 1.85 volts, and as a maximum of 120 volts is required, $\frac{120}{1.85} = 65$ cells as needed, hence the total number of cells = $65 \times 48 = 3,120$.

Price of cells = $3,120 \times 250 = \$780,000$; interest may be fixed at five per cent., and depreciation at five per cent.

Then interest and depreciation on accumulators = \$78,000.

For switchboards and meters a first cost of 10 per cent. on the accumulators would not be too low, the interest and depreciation on which may be taken at 10 per cent., then the annual expense for switchboard and meters equals \$10,920.

The steam plant required was found as 6,850 H. P. Taking again the cost per H. P. at \$64 + $\frac{1}{8}$ surplus power would give:

$$64 \left(6,850 + \frac{6,850}{8} \right) = 7,310 \times 64 = \$467,840;$$

interest and depreciation at 10 per cent. would give \$46,784.

The dynamo plant, figured at \$25.90 per H. P., would amount to $6,850 \times 25.90 = \$177,420$; 10 per cent. interest and depreciation gives annual expense for dynamos and switchboard as \$17,742.

The amount of coal used per annum would be $6,850 \times 24 \times 365 \times .16375 \times 1\frac{1}{2} = 12,282,887$ lbs., or 6,141 tons of 2,000 lbs. Then taking the cost per ton again at \$2.25, the expense for fuel would be $6,141 \times 2.25 = \$13,820$.

Cost of labor will be found as follows:

Three attendants at 25 cents per hour, expense per hour \$.75; four firemen and one helper, at same rate per hour, \$1.25; plus \$1.50 for superintendence, which makes a total of \$3.50 per hour, or $3.50 \times 8,760 = \$30,660$ per year.

Cost of supplies and repairs equals $6,850 \times 24 \times 365 \times .0008 \times .16375 = 5,550$ per year.

Adding all determined expenses, $78,000 + 10,920 + 46,784 + 17,742 + 13,820 + 30,660 + 5,550 = \$203,476$, against \$241,960 found for regulation by shutting down part of the plant.