So much has been written during the past few months upon generalities and upon possible cases which may or may not exist, that it is sometimes valuable to brush these all one side and to confine oneself to some specific cases. This I have tried to do.

Our company has used the first battery 20 months, and one of double its capacity for six months, entirely too short a time to come to any conclusions about the depreciation, but it has given us ample time to satisfy ourselves as to the economic value. It is sufficient for me to say that if a need should arise to-morrow for additional capacity, either at our main station, at either of the annexes or in any new part of the city, within reasonable distance of our center of distribution, we should consider the question along the lines which I have just indicated. We should eliminate entirely from the discussion, the question which has distracted the public mind for so many years and decide it entirely upon its merits, placing the battery side by side, and on an equality with other modern and improved apparatus.

THE PRESIDENT:—You have heard the exceedingly interesting and important contribution of Mr. Edgar. The next communication is from Mr. Nelson W. Perry.

COMMUNICATION BY NELSON W. PERRY, E.M., ON "THE STORAGE BATTERY OR THE GAS ENGINE AS AN AUXILIARY."

Whether it is economical or not to equip a central station with an auxiliary storage battery plant, is a question which must be decided separately for each particular installation. Generally speaking, the question will be decided by the character of the load line—a broad topped curve being the most unfavorable, and a sharp peak the most favorable to storage battery economy. Again, a station having a very light day load may use the battery to good advantage even though its night load may present a broad-topped aspect.

Aside from purely economic reasons, convenience may be controlling, so that it is impossible to state unless all the conditions are known, whether the storage battery is advisable or not.

The price of the battery is an important element of course, but less so than popularly supposed, for the space which it occupies and the cost of maintenance may largely overbalance any gain in first cost over the cost of the extra boiler, engine and dynamo.

In regard to the cost of maintenance, manufacturers are willing to guarantee that it will not exceed 10 per cent. per annum, but it is well to understand just what this 10 per cent. means. It means, in the first place, that if you put in all the battery power that the manufacturer recommends, and take care of the battery exactly as he says, then the guarantee holds good. Under such

conditions the manufacturer is undoubtedly safe, but if we install a plant under these conditions we are pretty sure to find that the economy in first cost of the battery over engine and dynamo has entirely disappeared.

Then it is well to understand beforehand what the 10 per cent. means—10 per cent. of what?

Some time ago I had occasion to inform myself accurately on this subject and to this end entered into quite a correspondence with the president of the leading storage battery company of this country. As regards the guarantee, he wrote me under date of June 18, 1894, as follows:

"We send you by to-day's mail our illustrated catalogue and "would especially call your attention to the question of maintenance as contained on page 11. We undertake, in these cases, "to provide renewals when renewals are required, at a specific "price with a guarantee that this will not be required sufficiently "frequent (*sic*) to exceed an average of 10 per cent. per annum. "We have every reason to believe from our experience so far, "that the actual cost of maintenance when the batteries are used "at normal rates will not exceed five per cent."

Turning to page 11 to see what this meant, I found the following:

"This company is prepared to undertake maintenance contracts according to a scheduled rate of charges, for periods up to "ten years or longer, under which they will guarantee that the "total amount paid for renewals during the term of the contract, "shall not exceed ten per cent. per annum on the *catalogue* price "of the cells specified in the contract. . . . *In all cases of renewal by contract the old material becomes the property of "the company, and must be returned to their works free of "charge for carriage or packing.*"

[The italics are mine.]

Since the regular trade discount at that time was 20 per cent. of the catalogue price, and a further discount was offered which made the cost of the batteries comparable with that of an engine and dynamo, the guarantee assumed a very different aspect from that which it bore on its surface. When to this was added the cost of packing and carriage back to the factory, it ceased to be an attractive guarantee, and my calculations showed that in many cases where the storage battery might be recommended, if the guarantee was what it appeared to be, it would not be economical under the guarantee as it actually was.

As before indicated, there are some situations in which either convenience or extreme steadiness of current may be controlling in deciding the question of the use or not of storage batteries. But where the question is one purely of economy, I would not myself recommend their use under any circumstances, simply because there is a still more economical method at hand. I refer to the gas engine. Even if it were necessary to use illuminating

gas from the street mains it would be more economical (considering space and other factors), to take the peak of the load with a gas engine than to install a battery for this purpose. In this case there would be no standby losses and the engine would be ready at a moment's notice to be thrown into service.

It is a fact that has been amply demonstrated by others as well as myself, that a given number of lights can be produced with half the gas burned in a gas engine that is required to produce them in ordinary burners. The mechanical efficiency of the gas engine is not quite so high as that of large compound condensing steam engines, rarely ever exceeding 83 to 85 per cent., while the latter may go to 90 per cent., but the total efficiency from fuel to the pulley of the gas engine is about double that of the steam engine—reaching 25 per cent. under favorable conditions, whereas, with the steam engine it rarely equals 12 per cent. So that with the gas engine operating at anywhere near its full load, there would be a gain in efficiency, instead of a loss of say 20 per cent. where the battery was used.

As indicating the performance of a gas engine using illuminating gas at various loads, I quote the following figures obtained from a test of a 12 H. P. (actual) gas engine.

Actual H. P. developed.	Gas consumption (cu. ft.) each actual H. P.
12.....	15
11.....	15.3
10.....	15.5
9.....	16.
8.....	16.5
7.....	17.
6.....	18.
5.....	19.
4.....	21.
3.....	26.
2.....	30.
1.....	48.

These figures are somewhat better than would be obtained in practice, but go to show that the gas engine compares favorably at light loads with the steam engine under similar conditions.

Thus far I have spoken only of illuminating gas, but the power may be much more cheaply generated by using a fuel gas.

The cost of producers or generators comes to about \$11 00 per H. P. capacity—considerably less than the cheapest boiler, and an idea of the space required may be gained from a statement of Mr. J. Emerson Dawson who in estimating for a plant of 400 K. W. capacity says that if the gas plant is all on one level it would occupy a ground space of 27 feet by 54 feet, but if necessary, all except the gas holder can be placed under or over the engine room. His estimate for such a plant is, including erection, foundations and ash pit for generators \$5500 or \$10.38 per H. P.

These fuel gas generators can utilize advantageously the poorest grades of fuel, and produce from the better grades of anthracite about 160,000 cubic feet of gas of a calorific value equal to one quarter that of 16 C. P. illuminating gas, per ton of coal.

As to the standby losses of the gas producers, this has been very carefully determined in a number of cases. As an illustration I will cite a single case—by no means the best on record.

At Openshaw a generator which supplied gas for from 250 to 300 I. H. P. was shut down for 41 hours, and the fuel consumption during this time was but 3.9 pounds per hour or about one per cent. When we compare this with the stand-by losses of the steam boiler which is estimated by Prof. Kennedy at ten per cent. of the total consumption in all the boilers, we see how insignificant it is.

A situation usually considered peculiarly adapted to the storage battery is in subordinate or outlying stations where they are charged during the day time from the central station, and act as centers of supply during the night time.

But gas can much more economically be distributed to these stations than can the electric current, for Mr Denny Lane¹ has shown that with ordinary 16 c. p. gas, 3000 H. P. can be sent a mile for an expenditure of one H. P., or one-thirtieth of one per cent. of the power conveyed.

My own calculations show that a six-inch pipe will deliver 6,000 cubic feet of gas per hour at a distance of 10,500 feet under four inches of water pressure. If this be 16 c. p. gas, allowing 25 cubic feet per H. P. hour, this quantity represents 240 H. P.

Cast-iron pipe, six inches in diameter, having a thickness of $\frac{1}{2}$ inch, weighs 31.9 lbs. per foot. The total weight of this two miles (nearly) of pipe will therefore be 334,950 lbs. This would be equivalent in conductivity to about 41,869 lbs. of copper. But four miles of copper weighing 41,869 lbs. would be equivalent to about four No. 000 B. & S. wires, which would have a resistance for the four miles of 0.325 ohms. If the charging current were transmitted at 220 volts, there would be required a current of 848 amperes; but a wire having a resistance of .325 ohms will only deliver under a pressure of 220 volts $220 \div .325 = 677$ amperes, there would, therefore, be required five No. 000 B. & S. wires to deliver this energy, and the weight of this would be 53,540 lbs.

If the distribution took place at 1,000 volts, the amperes required would be approximately 180. To deliver this at the same distance with a loss of 10 per cent. would require 6,264 lbs. copper, and to deliver it at one per cent. loss would require 62,642 lbs. which would cost far more than the pipe, and still give less efficient transmission.

I think it would be very easy to prove that the gas engine with fuel gas, would prove a much more economical auxiliary to the central station for taking the peak of the load, and the loads amounting to fractions of a unit, than the storage battery, and

1. *Electrician*, Oct. 9, 1891.

when we consider the efficiency of transmission of energy in the form of gas, which will permit of the location of the gas generators where land is cheap and fuel easily procured, it seems to me that the plan must commend itself to electrical engineers.

Unfortunately the gas engine business in this country seems to be in the hands of parties totally incompetent to handle it properly, as every one knows who has ever had occasion to seek information from them.

It is probably not too much to say that every attempt thus far made in this country to adapt the gas engine to electric lighting has proved a failure. Our own manufacturers either do not know what their engines are capable of doing, or else they are afraid to make public what they will do. I believe there is not a single manufacturer who has a printed price list, and my own experience and that of others whom I know, has been that it is impossible to get prices quoted, until the manufacturer or his agent has been thoroughly satisfied of the exact purpose for which the quotations are desired. Information of any kind is almost impossible to get; and guarantees of performance, when given, are worthless. To such an extent is this true, that nearly all, if not all the recent large orders for gas engines have gone abroad where the business is conducted on business principles.

In England, Germany and France the gas engine has come into extensive use in isolated lighting, and already has been adopted with satisfactory results in several central stations of considerable size

When the business is properly handled in this country, we may expect to see the gas engine make its way rapidly in the lighting industry here also, for it has merits which need only be known to be appreciated.

THE PRESIDENT:—The next communication is from Dr. Crocker. on the "Use of Storage Batteries in Electric Lighting."

DR. FRANCIS B. CROCKER:—In spite of the fact that my communication was printed in advance of Mr. Edgar's, I think that he has really anticipated me in the subject matter, and has gone much further than I even attempted to go. He has already given you the uses to which storage batteries may be put in central stations. I have considered the matter rather more generally, that is to say, I have attempted to give the various possible applications in electric lighting, but I did not try to cover any of them very completely.

COMMUNICATION BY DR. FRANCIS B. CROCKER ON THE "USE OF STORAGE BATTERIES IN ELECTRIC LIGHTING."

The function of accumulators is to receive electrical energy at one time or place, and to give it out at some other time or place.

The principal uses to which they may be put in electric lighting are the following: