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:

1. To supply portable electric lamps.
 2. To take up fluctuations and thus steady the voltage or current.
 3. To furnish energy during certain hours of the day or night and enable the machinery to be stopped.
 4. To aid the generating plant in carrying the heavier load which usually exists for only an hour or two.
 5. To make the load on the engines more uniform by charging the battery when the load is light
 6. To transform from a higher to a lower potential by charging the cells in series and discharging it in parallel, or *vice versa*.
 7. To subdivide the voltage and enable a three or a five-wire system to be operated with a single dynamo.
 8. To supply current from local centers or sub-stations.
- Each of these applications will be considered separately in the above order.

1. *Portable accumulators*.—The accumulator is practically the only means of supplying portable electric lamps or those which are not connected to a dynamo even if they are stationary.

The primary battery is expensive and troublesome to operate, and it has never been commercially successful for electric lighting, except where only a few small lamps are required. Nor is there any other satisfactory primary source of electrical energy except the dynamo driven by mechanical power. It is therefore practically essential to adopt accumulators wherever portable electric lamps are used.

The serious drawback with portable accumulators is their great weight. For example, a standard size which weighs 100 pounds, yields ten volts and five amperes, or 50 watts for ten hours, which is just sufficient to feed one ordinary incandescent lamp of 16 candle power. This weight would be prohibitive in most cases in which the only way to carry the battery was by hand, but it might be allowable for lighting railroad trains, where the weight would not be so objectionable.

Their great weight would also discourage in most instances the use of accumulators for supplying lamps in places which are not connected to a generating plant, the batteries being carried back and forth from a charging station. This method might be resorted to on special occasions, such as a fete, to which ordinary commercial limitations do not apply, but for regular lighting it would be troublesome and expensive.

Small accumulators are used to feed miniature lamps for medical or dental purposes, in which case their weight is not a serious difficulty in view of the importance of the work and the small amount of energy required. Small batteries are also employed for theatrical lighting effects in which the lamps and batteries are carried by the performers when it is not convenient to supply lamps by a wire connection.

2. *Accumulators for preventing fluctuations*, due to unstead-

ness in the driving power, are often applied successfully. A dynamo driven by a gas engine, for example, may vary periodically in speed because of the explosive action of the gas in the cylinder, and a battery connected in parallel with the dynamo will have the effect of steadying the voltage. But improvements in design and construction tend to reduce unsteadiness of speed, and by the use of a heavy fly-wheel, and an elastic connection between the engine and dynamo, the result is sufficiently satisfactory in most cases to make a battery unnecessary. An accumulator is generally installed in connection with a small gas engine lighting plant, to enable the engine to be stopped for a considerable portion of the time and thus save labor and attention, in which case the battery may also act to prevent fluctuations, but its principal function is the former one which will be considered next.

A windmill electric lighting plant absolutely requires an accumulator or some other means of storing energy not only to eliminate fluctuations in speed which are constantly occurring, but also to bridge over the considerable periods of calm weather.

3. *Accumulators to enable machinery to be stopped* during certain portions of the day or night. The advantage of this application depends upon the fact that in almost every electric lighting plant there are long periods during the day and late at night when the number of lamps lighted is so small that it may not pay to run the generating machinery.

This plan also allows the machines to rest and cool down which greatly facilitates cleaning and repair. In a hotel, residence, or on board of a yacht it may also be very desirable to stop the machinery and avoid the vibration and noise during the night. On the other hand, the addition of an accumulator to an electrical plant renders the latter heterogeneous, since the battery and its management differ so radically from the machinery and the handling of the same. It must also be remembered that the total investment is increased by the cost of the battery and its accommodation, because the generating plant is perfectly able to carry the load put upon the battery, since by hypothesis, this load is a light one. Hence the machinery might be run all the time, in which case the battery would be entirely unnecessary and sufficient rest for the machinery could be secured by using different machines for the periods of light load on successive days. These statements are based upon the supposition that the battery is not used to help the dynamos at the time of maximum load, since this case will now be considered separately.

4. *Accumulators to aid in carrying the maximum load.*—If accumulators are substituted for a certain portion of the dynamo capacity, the question arises whether the substitution secures any advantage. In regard to first cost, authorities differ widely. These discrepancies probably arise from the confusion between k. w. and k. w. hour of output. Most accumulators have a normal time of discharge of about 10 hours, hence the cost per k. w.

hour is only one-tenth of the cost per k. w. of output, and this would, of course, vary with any change in the time of discharge. In many cases it is specious and leads to mistakes, to speak of k. w. hours, to appreciate which fact we have only to realize that the k. w. hour capacity of a dynamo is almost infinite, since it might run for twenty years. The actual k. w. of output, or in short, how many lamps can be simultaneously fed, is the question in electric lighting. Moreover, in most cases, the time of discharge of an accumulator is unnecessarily long, and this is particularly true when it is used to help carry the heavy load which usually lasts only one or two hours. In this case the remaining hours of available discharge are of little or no use. If it be attempted to discharge more rapidly, both the capacity and efficiency are reduced, and in many types the condition and very life of the battery are injuriously affected by a high rate of discharge. What is needed for the maximum load or "peak of the load diagram" is an accumulator with a normal time of discharge of two or three hours and having a correspondingly smaller first cost, bulk and weight, that is, about one-quarter of those of the ordinary forms of battery, but certain types of cell are capable of discharging at this rate. It is evident that the time of charging need not be made as short as that of discharging, if it happens to be more convenient to charge less rapidly.

The use of accumulators to enable the machinery to be stopped, which is a case already discussed, usually demands a time of discharge of from 10 to 14 hours, which agrees quite well with the normal discharge rate of the ordinary forms of battery, but even then the time is unnecessarily long, since the average rate of discharge would rarely exceed one-half of the maximum rate. Consequently the battery would either be incompletely discharged, or the rate would have to be made excessive at certain times.

5. *Accumulators to maintain uniform load on the engines.*—Steam engines are very inefficient at light loads. This inefficiency, in fact, is one of the chief sources of loss in an electric lighting plant, and the principal object of the engineer who designs and operates a station should be to reduce this waste to a minimum. The accumulator is the most important means of accomplishing this result, although there are other methods such as gas, thermal (hot water) and steam storage, all of which have been carefully compared by Mr. Nelson W. Perry in a paper before the National Electric Light Association, February, 1895, "Storage of Energy Essential to Economy of Working Central Stations." Judicious selection of the number and sizes of the engines would enable them to be worked at a considerable fraction of their full capacity nearly all of the time, and it would seem that the same care that would be required to manage the battery might enable this to be accomplished. Nevertheless the accumulator gives more flexibility to the plant, and where introduced it often seems to considerably increase the

economy of the engines by making their load more uniform and nearer their full capacity. According to the figures given by Mr. Perry in the paper cited above, an electrical horse power costs \$48.68 per annum when developed steadily, and costs \$117.78 per annum with a variable load similar to that of an electric light station, that is, the latter costs about 2.4 times as much as the former. This ratio seems very high, but is borne out by statistics¹ which give a very large coal consumption for most electric light stations.

Under these circumstances almost any method of making the engine loads more uniform, should increase the economy of working. Doubtless an accumulator would benefit any plant in which an engine runs for any considerable portion of the time at less than half of its full power.

If a plant is so small that it contains only one engine, it may be necessary to run it a great deal of the time far below its full load. But even with two engines it is generally possible to select the sizes so that the smaller one runs economically during the periods of light load, the larger one alone is suited to medium loads, and both are used for the maximum output, the times during which any engine is very much underloaded being very short. With a greater number of units, it becomes still easier to properly apportion the load, and when there are five or more engines as is usually the case in large stations, the loss from this cause should be trifling. To be sure the waste of energy which occurs from using boilers for variable loads still remains, but according to the figures given by Mr. Perry this is less than that due to the engines, and general experience shows this to be true.

6. *Accumulators used as transformers.*—If the cells of a battery are arranged in series while being charged, and in parallel for discharging, a high voltage current will be required for charging and a low voltage current will be given out. The total amount of energy measured in watts is the same minus the loss of 15 or 20 per cent. which always occurs in accumulators. The result is similar to that obtained by an alternating current transformer or motor-dynamo. Such a method of transformation of potential might be employed in connection with long distance transmission of energy, the current being sent over the line at high voltage and converted to low voltage by accumulators for local distribution. For potentials of several thousand volts which are commonly employed in transmitting long distances, the number of cells required would be so great as to make this of doubtful practicability compared with the ordinary stationary or rotary transformers, but it would give uniformity in load and other advantages which may be secured by the storage of energy.

7. *Accumulators used for subdividing voltage.*—This application is similar in principle to the preceding. The most import-

1. See Report of Committee on Data to National Electric Light Association, *Electrical World*, March 2d, 1895, p. 273.

ant practical case is that in which a dynamo of 220 volts charges a battery of corresponding potential, a three-wire system being supplied from the battery, the neutral wire of which is connected to the middle point of the battery. This arrangement avoids the necessity of running two dynamos, and allows the battery to be placed in a sub-station near the districts to be supplied, so that it is only necessary to run two conductors to that point instead of three. The same principle may be applied to the five-wire system.

8. *Accumulator sub-stations.*—The plan of installing battery plants at local centers which are charged from the main station, enables some of the conductors to be saved in a three or five-wire system, as already stated. It also makes it possible to reduce the size of these conductors, because the current which flows over them can be kept practically constant, so that it is not necessary to have them large enough to carry the maximum current consumed by the lamps which may be several times the average value. This, of course, gives the same steady load on the generating machinery as if the battery were located near it.

The batteries at the various sub-stations may be connected and charged in series or in parallel. The former plan is similar to case 6 and would require far less copper in the conductors, since the voltage is multiplied by the number of batteries in series, and the current is the same as for a single battery. On the other hand, this high difference of potential would exist between the first and the last batteries of the series, and if either of them became grounded, any person connected to the earth and touching a wire supplied by the other battery would receive a shock due to the total voltage. This would demand that the maximum difference of potential should not exceed 500 volts, or, in other words, four batteries of 110 to 125 volts each, might be charged in series and could be connected to the lamp circuits at the same time. This would practically amount to a five-wire system using accumulators to subdivide the potential as explained in case 7. If the batteries were entirely disconnected from the lamp circuits while being charged, the latter would be free from danger of the high pressure which might therefore be 1,000 or 2,000 volts if desired, the batteries being charged during the day and supplying the lamps at night. For continuous working, two batteries would be necessary. Accumulator sub-stations not only save copper in the feeders but also reduce the cost of, and lost voltage in the distributing conductors because the batteries can be placed near the lamps to be supplied with current.

Accumulators used for two or more of the above named purposes.—Each of the different uses of the storage battery has been considered separately, to avoid the confusion with which this subject is often beset, but as a matter of fact the employment of the accumulator for several of these purposes is the most common

practice. By thus combining these different applications, the plant may be rendered not only more economical but also much more flexible. For example, the battery may be utilized to help out the generating machinery at times of heavy load or when the latter is partially or wholly disabled. It often happens that it is difficult to produce or maintain sufficient steam pressure owing to poor draught or other circumstances, in which event a battery enables the boilers to be temporarily relieved of some or all of the drain upon them while the pressure is being raised to the proper point. It may also be necessary or desirable to shut down the machinery or a portion of it for a few minutes to make some repair, adjustment or change of arrangement, connection, etc.

It is also possible to feed some of the circuits from the battery, while the others may be supplied at a higher or lower voltage by the machinery. In these and many other ways an accumulator may be a very convenient adjunct to an electric lighting system. The fact that it is so radically different from the machinery in its nature and action, makes it very unlikely that the entire plant will be crippled at any one time, since the two sources of current are not exposed to the same dangers. An accident to the steam piping, for instance, might shut down all of the machinery but it probably would not affect the battery, and *vice versa* an accident to the latter is not likely to extend to the former.

COMMUNICATION BY CARL HERING ON "PAST AND PRESENT
OBSTACLES IN THE STORAGE BATTERY DEVELOPMENT."

The great and numerous advantages of a satisfactory electric storage battery have been described so often, and are so well recognized and admitted by the unbiased, that it seems unnecessary to again enumerate and discuss them here. The question which the engineer and constructor should discuss at present is not "Is a battery desirable?" but rather "Why is it that storage batteries seem to have been unsatisfactory?" and the question which concerns the capitalist is "Does it pay in dollars and cents to use the storage battery even if it is kept in a satisfactory condition by the makers?"

The latter question can be disposed of here in a few words. If the makers guarantee to keep the battery in a satisfactory condition for a certain rate per annum, or if they rent them, then it becomes a mere matter of calculation to find whether it pays or not; but this calculation must be made for each specific case, as the cost of the batteries and their maintenance seem at present to be such, that an estimate for a general case can hardly be considered conclusive, the margin being in many cases too small. In some specific cases it will be found to be decidedly cheaper, in some it will be doubtful, and in some, decidedly too expensive. Limiting ourselves to this country and judging in a gen-