

## DISCUSSION.

THE PRESIDENT :—I may state that the paper of Mr. Emmet, who is not present to read it, deals with the methods devised to combine the extreme simplicity of the single-phase alternating current system with the efficiency of generation and distribution of the polyphase system, by the use of three-phase generators operating single-phase lighting combined with three-phase power, either by having a four-wire primary distribution with single-phase secondary circuits as outlined by Mr. Ferguson, or by operating a three-wire single-phase secondary, utilizing a fourth wire for motor supply. Mr. Emmet's paper also discusses the four-wire balanced three-phase secondary system of distribution.

The paper of Mr. Robb, who is also absent, describes the means for distribution of electricity in cities of moderate size, and comes to the conclusion that for smaller cities the most desirable system is the three-phase, sixty-cycle alternating current system with overhead distribution, using single-phase secondary and four-wire primaries, and operating single-phase lighting and power in small motors, while larger motors are operated on the three-phase system.

In somewhat larger cities, but still of moderate size, Mr. Robb recommends the introduction of a central continuous current distribution by underground three-wire mains, fed from the alternating system by rotary converters or other suitable means.

It is very interesting to note, in comparing this paper of Mr. Robb's with Mr. Ferguson's paper, that while starting from two opposite directions—on the one side, from the supply of a very large city by continuous currents, three-wire underground mains, gradually reaching out to the supplemental alternating current, sixty-cycle system, and on the other side by supplying a small city with alternating current, and gradually adding for the concentrated central district a continuous current distribution—the ways and means and the systems recommended by both authors are identically the same; the same four-wire, sixty-cycle, three-phase primary distribution, with single phase secondaries for the alternating part and the three-wire underground continuous current system for the continuous current part. The only difference is that due to the difference in the relative proportions of the two parts, the continuous current preponderating by far in the large cities, while the alternating current is the only system used in the very small cities, or the preponderating system in a moderate sized city. In moderate sized cities the continuous current system is operated from the sixty-cycle alternating system by converters or other appliances, while in the very large cities the alternating current system is operated from the continuous current system by converters; or both systems operated together from the same primary generating system of low frequency—twenty-five cycles. As I said

before, this is the more encouraging, as it shows that electrical distribution has reached a definite standard, since prominent electrical engineers, starting from oppositely different points, arrive at the same result.

MR. GANO S. DUNN:—Mr. Chairman and gentlemen, I have listened with interest to the papers which have been read, and while I do not wish to be controversial, I cannot agree with some of the views expressed by Mr. Scott, and I have therefore selected two points in his paper upon which I wish to speak. I have also a lantern slide, which I wish to show if time permits:

On page 845 of Mr. Scott's paper he says:—

"For variable speed work the conditions are different, the fundamental difference is due to the fact that although there is a close correspondence between the performance of the induction motor and the direct current shunt motor with constant field excitation, the alternating current motor does not have an exact analogue to the direct current series motor."

This implies that the induction motor is to a large degree an analogue to the shunt motor. The analogy is much more limited than is usually supposed, and I wish to point out its imperfection.

In the first place, as Mr. Scott has stated, the analogy is limited to a machine, with constant field excitation. By that limitation he rules out one of the principal advantages of the shunt machine which is that you can control its speed by controlling its field. To this there is no analogue in the induction motor.

The second point by which the induction motor is not analogous to the shunt motor is that you can control the speed of a shunt motor by controlling the voltage on its armature. But you cannot in anywise do this with the induction motor.

The matter of speed control, far from being insignificant, is a very important element in the constitution of power plants to-day, and because in the past we have been accustomed to fixed speed, we must not think that in the future we shall be contented with it where we can have motors that will give us throughout wide ranges, speeds controlled with perfect efficiency and stability. Multiple voltage systems are rapidly coming into use and only direct current motors can be operated with success on them.

A system that has four wires, by different combinations of them can give about six speeds, and by variations of field strength or a small amount of armature resistance can be made to give easily twelve or more speeds, all with practical efficiency and stability.

Further up on the same page Mr. Scott says:

"For constant speed work probably no one will question the superiority of the alternating current motor from the standpoint of the man who uses the motor and pays for repairs. Any objections which may be brought forward will probably be urged on account of reasons applying to the supply system such as

power factor, starting current and voltage regulation. These items may be provided for by properly designing the system, and they cannot be regarded as legitimate objections to the use of the alternating current motor."

With the last statement I differ, because if you properly design the system as he suggests, the cost of it runs away up out of proportion to what you are going to use it for, and no matter what has caused it, the high cost, if it is accompanying the use of the motor, might as well be charged to the motor.

I have a lantern slide here which was not prepared for this discussion but which shows the relative performance of constant speed motors, induction and direct current, and if I have time I should like to show it.

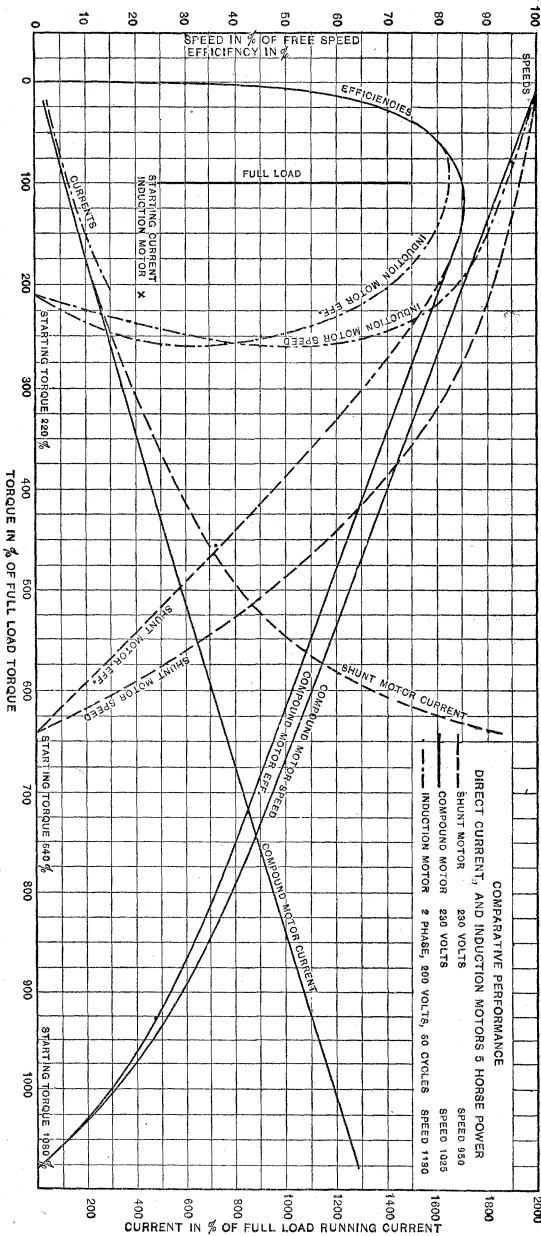
(Slide showing curves exhibited. See page 872.)

The three sets of curves show the performance of the motors with respect to running current, efficiency and speed. The abscissae are torques expressed in percentage of full load running torques, and the heavy line at 100 per cent. represents normal full load for all the motors. The ordinates are current, efficiency and speed, also expressed in percentages, for comparison.

The speed and current tests of the direct current motors were made by applying a Prony brake to the motor running free and gradually tightening it until the motor stalled.

You will note that at full load the running current of the induction motor is about 10 per cent. greater than that of the direct current motors. The starting current for the induction motor is at the mark "x," and is nearly twice as much as required to give the same torque in the direct current motors. The efficiencies of all the motors are about the same up to two-thirds load, after which the induction motor efficiency falls off very rapidly while the direct current motor efficiencies are tolerably well maintained. The speed curves, which originate in the upper left hand corner, show that at full load the shunt motor falls off about  $4\frac{1}{2}$  per cent., the induction motor about 6 per cent. and the compound motor about  $7\frac{1}{2}$  per cent. At 2.6 times normal torque, the induction motor, however, stalls, while both of the direct current machines continue to run, the shunt motor until its torque reaches 6.4 times normal torque and the compound motor 10.8 times normal torque. In the middle ranges of these speed curves of the direct current motors there was sparking, but beyond the middle, at the points of severest overloads, the sparking almost disappeared, because the speeds were so low that the commutation reactance was greatly reduced. The sparking that was present in the middle ranges was not such as would injure the commutator unless the severe overloads were maintained.

It might be argued that the compound motor does not belong in this comparison because it is not a constant speed motor. I submit, however, that a motor whose regulation is  $7\frac{1}{2}$  per cent.



Curves showing relative performance of motors.

ought to come under this category, especially as its use for constant speed work is rapidly increasing.

It may also be argued that the region of these curves beyond 2.6 times normal torque, does not indicate useful properties in the motors. This position cannot be maintained. In steel mills and similar factories, the overloads are frequent and very severe, and it is just the region of the curves in question that causes direct current motors to be appreciated for this service. For induction motors to give equivalent service, much larger sizes would have to be installed, which together with the fact that the cost per horse power is greater, would make the cost of installation very much greater.

It has been shown by other speakers that this extended region of the curves is what has thrown the elevator business into direct current, and in my opinion it is this region which has exerted a controlling effect in other ways upon the development of the two systems of distribution.

When you sum up, it seems to me you reach this point; the direct current motor may require a little closer attention, but it is a great deal cheaper and can do a great deal more.

MR. LOUIS A. FERGUSON:—In listening, Mr. President and gentlemen, to Mr. Scott's paper, there were a few things that rather surprised me and I feel as if I might take exception to some of his statements.

On page 843 under the heading (1) he says that—

"Converting apparatus requires rotating machinery and the presence of attendants, and these involve first cost, operating expense, complication, and liability to interruption of service."

I would like to say in regard to that, that from our experience the operating expense of sub-stations is a mere bagatelle, and while I have not the figures at hand with me, I might say that the operation is usually accomplished by one man and runs only into the hundredths of a cent per kilowatt hour, so it cannot be a very serious objection.

On page 844 the question of arc lighting is mentioned, and he says there that—

"Arc lighting is most extensively carried on by the enclosed arc lamp, which is satisfactorily operated from direct current circuits and also from sixty-cycle alternating circuits, so that there is no compelling reason for choosing either one current or the other as far as arc lamps are concerned."

My objection to that is only slight. Of course, the power factor of alternating arc lamps is about seventy or seventy-five per cent., and the inside wiring required for alternating current lamps is greater than that required for direct current. Where alternating current lamps are put in substitution for the direct current lamps, it is found necessary to increase the size of the wiring.

He says: "The Nernst lamp, which is quite satisfactory in its

operation on alternating current, but not on direct current, gives a positive reason for choosing the former."

It seems to me that if the same amount of brains and energy were expended in developing the Nernst lamp for direct current work as have been expended for the alternating current, we might have a better Nernst lamp for direct current work, and I think that is something we may look for in the future.

Those two items that Mr. Dunn spoke of were things that I intended to speak about, so that I will only mention them. That is, on page 845 he says:

"These items may be provided for by properly designing the system, and they cannot be regarded as legitimate objections to the use of the alternating current motor."

In order to accomplish the same results with alternating current motors that we do with direct current, it is necessary to spend a great deal of money on the distribution system, and if I am correctly informed, most of the companies that do any considerable business in alternating current motor work use separate systems of distribution circuits for lighting and for power, and I think that is done in New York.

In regard to the matter of variable speed work, which was very well brought out by Mr. Dunn, I had in mind speaking of the multiple voltage system, which he mentioned.

Regarding the question of elevators, I would like to emphasize the fact that we have not at the present time, and there does not seem to be much hope of having in the future, alternating current elevators that are at all comparable with the direct-current elevator. I personally would be very glad to see them, because we need a first-class alternating-current elevator, but it simply is not to be had. The primary reason for it is that you cannot get a variable speed alternating-current motor. The stopping of alternating-current elevators is exceedingly poor, and is due to the fact that it must be accomplished by means of the mechanical brake after the current is cut off, and of course therefore it is very rough, indeed. It is very difficult sometimes to convince customers that they should put in alternating current elevators, and, instead of doing so, they install hydraulic elevators. The rotating parts of the alternating current motor are also heavier than the direct-current rotating parts, and this of course adds to the difficulty in making good stops. The starting of the elevators is also poor. The very fact that you have to stop the alternating current elevator by means of the brake limits its speed, so that at the present time we are only able to have elevators run at about 150 or 160 feet a minute, although some people say that there is a possibility in the future of getting them up to 250 feet a minute; but the experts in elevator practice tell me that there is no hope of an alternating current elevator which will do for one of your sixteen or twenty story buildings

in the City of New York, and that is the service the central station company must supply.

In the table on page 846, where there is given a list of the things that you have to use with alternating currents only and with alternating and direct current, it seems to me the comparison is not quite fair. It would appear that in a large city, as I have stated in my paper, it is necessary, in order to cover the entire city, on account of its extensive area, to use a high voltage—a higher voltage than would be admissible for ordinary distribution; and if that is the case, you will require more apparatus than is specified under the heading of alternating current only. I have just roughed out here a little table which shows that as against rotary converters, you have primary mains, transformers and housing switchboards and a double system of distributing circuits, so that you have quite as much apparatus in order to fill the same specifications for general service with the alternating current in a large city—and I am not speaking of a small city—as you do with the direct-current.

The question of storage-battery has been brought up by Mr. Scott, and in his paper he states that the storage-battery may be used in substantially the same way with alternating current that it is usually used with the direct-current system, except that the converter is between the battery and the service. I do not think that is quite so, because, as I have said in my paper, the great value of a storage battery is in its action as the watchdog of the company's service; its liability to jump into the breach without any notice whatsoever. It must always be there ready to do its work. In order to accomplish this with the alternating current, and by means of a rotary converter, you must keep the rotary converter running twenty-four hours a day in order to be able to discharge the battery into the alternating current system, and further than that, if you wish to discharge the maximum capacity of the battery—and that is what we buy batteries for; we do not buy them to discharge over a load four or five hours wide, but over a peak—if you are going to discharge it over a peak, your rotary that Mr. Scott speaks about must be as large in capacity as your storage-battery, which, of course, means that the investment will be something enormous.

In summing up, I would simply say that there is an old proverb that "the proof of the pudding is in the eating," and if you will glance over the United States you will find that the successful companies, those that have grown to large proportions and have paid dividends, are those that have operated the direct current in the downtown districts, and it seems to me that that is the best argument that anybody could offer in favor of using the direct current in that portion of the city.

MR. ARTHUR WILLIAMS:—In addition to the larger cost required for wiring for the alternating current arc lamp, suggested by Mr. Ferguson, it might be mentioned that tests made under

acceptable authority have indicated that the alternating arc-lamp is not as efficient, in useful light giving, as the direct current lamp.

There is a very unexpected statement also in Mr. Scott's paper in regard to the Nernst lamp—to the effect that the best results are to be obtained only from the use of the alternating current. I think the greatest development of the Nernst lamp, the German, has been entirely with the direct-current, and with an efficiency at least equal, in other respects than life, to the efficiency obtained on the alternating current lines from the Westinghouse lamp made in this country. The first commercial installation in New York was made in an establishment to the owner of which was demonstrated the superior economy and quality of the light given by the Nernst lamp by the adaptation of a Westinghouse Nernst lamp to and its supply from a direct-current circuit.

It occurs to me, in addition to what Mr. Ferguson has said, that the storage-battery supplied by an alternating current cannot be used as a floating regulator on the system. Then, too, I think we should consider the great value of the storage-battery in automobiling. Apart from the fad of racing and touring, both of which are mere pastimes, the future of automobiling undoubtedly lies with the development of a suitable electrical machine. Already this service is becoming of great commercial importance in the larger cities.

The importance of elevator service to the large supplying companies cannot be overestimated. In New York City there are about thirty thousand horse-power in motors applied to electric elevators. An elevator in an apartment house—a single class—not only raises the character of the house, but very largely adds to the lighting revenue of the supplying company. The tendency in putting in electric elevators is to wire the building throughout for electric light, and to add two or three floors, which also, equipped for electric light, become new territory for the supply company. The electric elevator also is oftentimes a deciding factor when the question of isolated plant competition is involved.

Compared with the direct-current elevator the first cost of the alternating current elevator is higher; the accelerating current is from two to three times as great; the speed is limited to a maximum of about 150 feet a minute; it takes a great deal of time to acquire speed—sometimes the car will pass the second floor before reaching full speed; it lacks the safety feature of the solenoid brake; it does not stop with the same precision; it is very noisy, and the operating cost is probably double.

Thus I have given eight points of inferiority; to my regret, because our interests would be glad to have and have long hoped to find an alternating current elevator in every respect equal to that of the direct current.



A MEMBER:—Doubtless in this discussion Mr. Scott will be amply able to look after himself, but there are two matters I wish to refer to which appear to me not altogether detrimental to the use of the alternating current. One is the matter of electric elevators. I am not fully satisfied in my own mind that electric elevators in themselves are the thing, and I do not see why a hydraulic elevator operated by a pump driven from an alternating current motor is not a pretty good thing in a way.

In regard to the rotary converter which Mr. Scott speaks of as an added complication, I do not see that it is an added complication, for the very good reason that the use of storage batteries always requires the use of a "booster," even when the current is direct, and I do not know of any place or any instance except in railway service where a battery can be floated directly across the lines and take in current and give it out at a constant potential which would do for lighting. To do that we would have a battery with absolutely no internal resistance, and it appears to me that that rotary converter would be merely a substitution for the booster, and, aside from the instability that might be created, I think on the rotary that would be no objection.

PRESIDENT STEINMETZ:—Regarding the much-mooted question of alternating and continuous current distribution, I desire to say a few words. Whatever I say, however, applies only to densely populated districts, because, in sparsely settled districts, as the outlying suburbs of large cities and the small cities, the comparison becomes meaningless, since the continuous current is excluded to begin with, and only alternating current can be used.

Regarding the question of the arc lamp brought up, the supposed superiority of the continuous current arc in efficiency has been very severely challenged in the last few years, and I believe rightly, from the point of view of illumination. While the total flux of light of the continuous current arc is greater than that of an alternating enclosed arc—I mean in either case of equal power consumption—the distribution of the light of the alternating arc is such that with the same power consumed in the arc and the same distance between the arc lamps the minimum intensity of illumination midway between the arc lamps is higher than with the continuous current arc, although the maximum intensity is considerably lower. What determines the usefulness of a lighting system is not the maximum but the minimum intensity of illumination, and in addition thereto the more uniform the intensity is throughout the illuminated area the better is the illuminant.

Coming to the matter of the comparison of alternating and continuous current in densely populated districts, here it is true the alternating current system appears the simpler, requiring no intermediary converting apparatus, while the continuous current system requires a rotary converter where the power is supplied from a large central station system. This apparently is a disad-

vantage of continuous current distribution, since the problem of successful and proper engineering is primarily to reduce the number of complications to the least amount. At the same time, where complications are unavoidable, it is desirable to concentrate the complications in the station and sub-station; that is, to confine them to as few points as possible where the apparatus and the system can be properly taken care of. Now, what I desire to state is, that whatever additional complication is introduced in the continuous current system by the rotary converter is more than made up by the complication and the difficulties incident to the alternating system at the place where they cannot be controlled *i. e.*, in the house-wiring and secondary distribution.

The supply wiring and installation in the continuous current system is as simple as possible—as simple as gas or water supply. All that is necessary is from the mains or from the station to maintain the resistance below a certain value in correspondence to the load; that is, to know the load or approximate load, and then know the length of conductor, and therefrom the size of the conductor, and any wireman can easily learn that without any special intelligence. Different it is with the alternating current system. Here it is not sufficient to know simply the length and size of conductor, but in addition, you must not run the conductor through an iron pipe; you must not run conductors beyond a certain size, or you get an additional drop of voltage by self-induction; you must not run the conductor and the return conductor too far apart; you must not run them close along an iron beam or through a hole in an iron beam; in short, you must not do a number of things which are harmless in a continuous current installation, and while all this is self-evident to an engineer understanding alternating currents, it is utterly hopeless to expect a wireman to understand it, and if a wireman has intelligence and capacity enough to learn it, then he will not stay a wireman very long, but will aspire to a higher sphere.

This is what I consider the most serious objection to the low tension alternating current distribution of large magnitude, and this additional complication, the necessity of care and attention, I consider as more than compensating for the absence of the complication of the rotary converter which, after all, is not so very serious.

MR. DOUGLASS BURNETT :—A previous speaker has suggested the desirability of employing hydraulic elevators driven by alternating current motors. I think that this suggestion may be dismissed as the electric motor driven type of hydraulic elevator has already proven itself impracticable for any service except the most intermittent. There are probably not more than half a dozen such machines in New York in business or apartment buildings, and we know of two which were replaced owing to the high cost of operation. In practice they are used chiefly for office build-

ings employing central station electric service at night and steam-driven hydraulic elevators in the day time. The comparison may be stated on the basis of current consumption, which would be, for standard direct-driven electric elevators from two to four kilowatt hours per car mile; and for motor-driven hydraulic elevators from three to nine kilowatt hours per car mile. The figures apply to direct current apparatus and could be no less with alternating current machines.

MR. LOUIS A. FERGUSON:—I would just like to correct an impression in regard to the matter of rotary converters in connection with the storage-battery. The point that I wished to make was not an objection to using a rotary converter for the purpose of charging a storage battery for an alternating current system, although a booster would still be required, but to show that if the rotary converter were used in discharging the storage-battery for the purpose for which the storage-battery is ordinarily employed in direct-current systems, it would be necessary that the rotary converter should be as large in capacity as the storage battery would be at its one-hour rate of discharge.

I would also like to say for the gentleman who spoke that the direct current companies all over the country, or at least the companies operating direct current either in a portion or in their entire system, are keeping the batteries floating on the system, and do so by means of end cells which keep the potential of the battery the same as the potential of the system at all times.

A MEMBER:—I would like to ask Mr. Ferguson how he charges the battery and the end cells.

MR. FERGUSON:—The battery may either be charged by a booster or directly from generators, or by the rotary converter and booster from an alternating current system.

MR. FREDERICK V. HENSHAW:—The question we are discussing this evening is as to the best methods of distributing power for large cities or small cities, for that matter, and the primary object is to secure the business of the city and secure it all, and distribute the power as cheaply as possible.

In examining various central station plants in this country a curious thing will be noticed. There are some cities where the central station has practically all the business; where you have to hunt around to find an isolated plant. There are other cities where practically every large building has its isolated plant. Mr. Ferguson has pointed out that in Chicago the electric elevator business is twelve and a half per cent. of the total, and that the electric elevator, which, off-hand, seems a small unit, will, if we examine into it, I think, turn out to be a very large unit, because if you are going to supply a large office building from a central station, one of the things you have to do is to supply it with electric power for its elevators unless it has hydraulic elevators.

As far as the electric elevator goes, there is no difficulty in making a direct current elevator motor which will start in four

or five seconds from rest, and accelerate to full speed without taking any more current than the normal full load running current. This, there does not seem to be any present prospect of accomplishing with alternating current motors.

Another point that occurs to one, in connection with this difference between the amount of business secured by central stations, is that the city where the central station supplies nearly all the energy used in electric lighting and power would seem on the face of it to have the best system, but when we look into it we do not find that they have this ideal single alternating current distribution. The most marked instances, I think, are Chicago, Boston and Providence. Every one of them distribute their power by means of the direct current. That, of course, is not at all a conclusive argument, but it is one which is drawn from practice, and is apparently an indication of the desirability of direct current for power distribution.

MR. JOHN W. LIEB, JR.:—Mr. President and gentlemen: From the drift of the remarks this evening, we seem to be in full sail on the sea of the old discussion of alternating current versus direct current distribution. I think that if the members whose opinions favor one side or the other of this problem, will look at it in all its phases and state the pros and cons with entire frankness, the result will be the clearing away of a good many misconceptions, and perhaps the final conclusion will admit the lack of universality of either system, and that it would be hazardous, indeed, to undertake a pronouncement in favor of either on purely general lines. The local conditions will have to be most carefully considered in each case before deciding which system is to be preferred.

I do not wish, in this discussion, to say much on one side of the question or the other, but the argument has been developed rather along the lines of problems of large cities with very dense and important industrial centres, than of smaller cities. It is unquestionably true that, in these large cities, with dense industrial and business centres, the isolated plant is one of the most important and serious problems with which the central station manager is concerned, and it is also true that the electric elevator is the key to the acquisition of a strong position in meeting their competition. While elevator service, in itself, may not seem to be an important source of revenue, the satisfactory and economical operating of electric elevators is of great importance in meeting and overcoming isolated plant competition.

I will just add one word as a parting statement. Mr. Scott has drawn a very interesting picture of the recent electrical development in Greater New York, and he states it demonstrates the various problems on a magnificent scale. He might have added just a few words to complete the picture he has drawn. He is depicting the conditions in greater New York, and he goes on to tell us that it is notable that all of this varied service

is to be supplied from alternating current generators. I think he might add, in conclusion, that almost all of the distribution is by direct current.

MR. ARTHUR WILLIAMS :—May I ask just one question further in regard to the future? I think it is unquestionably true that the great future power development will be on the lines of direct application of motors to machines; for instance, to printing presses, to lathes, and to machines of all sorts, as well as to elevators, all of which require minute and flexible regulation, and I would ask Mr. Scott, in answering the inquiries of the evening, to include a statement as to the prospect of getting good regulation for alternating motors applied to that class of work, and how the result in his judgment will be accomplished.

THE PRESIDENT :—If there is no further discussion desired I shall give the floor to the authors of papers to conclude the evening, and I call upon Mr. Ferguson to make some closing remarks on his paper.

MR. FERGUSON :—Mr. President and gentlemen, I don't think I need to say anything more than I have said; I have talked a good deal already this evening.

THE PRESIDENT : Mr. Stott, I call upon you.

MR. STOTT :—There has been no discussion on my paper, and therefore I have nothing to say.

THE PRESIDENT : Gentlemen, I believe we have said so much on the mooted question of alternating versus continuous current that we have not discussed several of the papers. These papers supplied us with a number of important and valuable facts while the other papers dealt more or less with practical experience and with theories regarding which discussion was feasible; so, naturally, the discussion has drifted into certain lines. I call upon Mr. Buck.

MR. BUCK :—My position is very much that of Mr. Stott's; my paper has not been discussed, and therefore I have nothing to say.

THE PRESIDENT :—Mr. Scott, I am sure, has something to say.

MR. SCOTT :—Mr. Chairman, when I received the papers for this evening I thought that mine was rather out of line as it simply contained a few generalities, while others had dealt with particular points, and had contributed something of interest and value; but it seems that the generalities have been rather popular to-night.

The paper is a general presentation of the subject on broad lines and it seems to me that the burden of proof is legitimately placed upon the advocates of the direct current. We start with alternating current; we then ask, are there good or sufficient reasons for transforming to direct current, and the direct current people have undertaken to defend their cause, and they have done it well.

I would be the last one to assert that the alternating current can

in all respects equal the direct current for everything. I do not wish to take the position of a partisan, but on general grounds to present the two sides of the case. It should not be concluded because direct current has been used longer, or is used in a good many places that we should therefore decide it should always be used in other cases without reviewing the ground. The direct current advocates should show good reason for the faith which they have, and this they have been doing this evening.

I was quite interested in the curves which one gentleman presented. The alternating current motor was shown with rather meagre lines. The curves were given with no particular reference to specifications as to the kind of motors referred to or the kind of service to which they are suited or the regulating devices which accompany them. We must take the curves just as they are.

At a meeting of the INSTITUTE a short time ago great stress was laid upon one feature of the alternating current motor which was not mentioned in connection with the curves this evening, namely, "the enormous starting current." This important feature of the other discussion was hardly visible this evening. But, taking the curves just as they were presented we have the rather remarkable result that the starting current of the direct current motor is twelve times the full load current for the series motor and eighteen times for the shunt motor. Taking the curves on their face a direct current motor takes eighteen times full load current as its starting current. That beats anything I ever heard alleged about even an alternating current motor. This illustrates my point that some of the off-hand assertions about the alternating current motor may be just as legitimate as my method of reading the curves of the direct current motor.

The matter of variable speed in the alternating current motor is a thing which the direct current people don't seem to understand and the alternating current people have hard work to get. As a matter of fact, however, the alternating current motor is making its way. We might conclude from some things that are said about it that it is something that is not in use and never will be. As a matter of fact, however, it is very widely used in many factories and many industrial establishments as well as in general service. You cannot do everything with the induction motor that you can with the direct current motor, but there are lots of things that you can do with it that you cannot do with the direct current motor. Each has its own characteristics. After careful consideration of the characteristics of the induction motor it has been selected for industrial establishments and when some speed change is necessary this has been provided in the motor or external means of changing the speed has been provided while the motors run at constant speed. In the operation of machine tools, for example, a belt between the motor and the tool with cone pulleys gives a much-to-be desired flexible connection between the motor

and the machine, and devices are arranged for readily shifting the belt. I give this as a single means which is in satisfactory use for accomplishing some of the speed changes.

With regard to elevators, one would think that the alternating current motor could never get an elevator up. As a matter of fact, there are hundreds of elevators which are running by alternating current motors, and have been running by alternating current motors, some of them for several years.

We must remember that very much of the past experience with alternating current work has been on a small scale; motors have been put on generators which were of comparatively small size and which were not comparable to the large units which would be installed for a large plant. A ten or twenty horse-power motor will be, of course, relatively much larger on a fifty or one hundred horse-power generator than it would on a system having a capacity of thousands of horse-power, and that is such a system as would be installed in a large city. I must confess, though, that elevator work is getting to be something enormous when it must be estimated on "car miles." But sixteen-story buildings do not exist except in a few of the larger cities; in the cities of medium size elevator work of that kind is not the rule.

The Nernst lamp and its use with regard to a direct current has been referred to. The Nernst Lamp Company is a separate company, distinct from that with which I am connected, and I am not fully versed in the work they are doing. I am rather surprised to know that they put the lamps on any direct current circuits, and I do not know the place or the circumstances. However, Mr. Wurts, the Manager of the Company, who read a paper before the INSTITUTE not long ago, assured me he did not consider the lamp suitable at present for direct current circuits, and that they do not desire to supply lamps for those circuits.

Another point with regard to elevators I wish to speak of. A gentleman who is closely identified with direct current work, in talking over the elevator situation with me a short time ago, brought out a point which rather surprised me. He said, to change his words a little, you are not complicated enough; you have not got enough stuff along with the motor. We take a direct current motor to run an elevator and we expect all sorts of controllers and extraneous devices, and all kinds of magnets and rheostats added to it, but with an alternating current motor everybody thinks that there must be nothing at all; it must be ideal; and for that reason he thought that the alternating current motor had not had its full justice because it had not all of these regulating devices and compensating devices, and so on, that went with the full-fledged direct current elevator motor.

It has been said that the direct current motor is the thing and the only thing to run elevators. A comparison which may not hold good in all cases, but it may in some cases, would

be this: If direct current is required at an elevator, then put in a little induction motor running a direct current motor to furnish that power. If the total amount of power required for elevators is small, and the reason for getting direct current is to supply those elevators, put in a little plant for supplying that small amount of power, and not put in rotary converters for supplying all the incandescent and arc lighting and other classes of motors which would be indifferent to the kind of current. If five per cent. or ten per cent. of the power is in the form of elevators which would require the special direct current, convert for that and not for everything.

A MEMBER:—Supposing the elevator work is eighty per cent.?

MR. SCOTT:—Supposing it is one hundred per cent., then we do something else.

A MEMBER:—How about the complication of apparatus in that case?

MR. SCOTT:—The complication of apparatus? Why you have got so much with the direct current motor anyhow, that a little in addition may not amount to anything. The little motor generator for supplying ten-horse power of direct current would be simple compared with going back and putting in a rotary converter sub-station for converting several hundred horse power, the rest of it to be used for other kinds of work.

The direct current wiring has been pointed out as a very simple thing, and the alternating current wiring a very difficult thing. Not long ago, up at the Pan-American Exposition, I had the pleasure of looking with wonder at some charts which our friend Mr. Mailloux had made of a large building, showing direct current wiring, and I should say that it would take more than an ordinary engineer to do work of that kind.

A MEMBER:—If it was an alternating current it would be a great deal worse.

MR. SCOTT:—It does take intelligent work, but my point is, that it takes an expert to lay out direct current wiring on a large scale.

A friend near me said a little while ago that this reminded him of the old days, when the subject of the alternating current versus the direct current was the red flag that would start everybody to moving. In those days there was one thing which was mentioned which the direct current friends brought up first, last and all the time, but which I do not recall, has been mentioned here this evening, and that is transformer losses. The field of battle has changed. The alternating current since those old days has made a rather startling change, and as I said in my first paragraph, it is no longer a question of direct versus alternating currents, but is a question of whether the alternating current shall do the whole thing or whether the direct current shall have a little corner left; whether the direct current will be able to



hold the place it now has, or whether it will at some time have to give that up too.

THE PRESIDENT:—Gentlemen, the next paper was by Mr. Barstow. I call upon Mr. Barstow to close his discussion.

MR. BARSTOW:—There are just two points I would like to emphasize. One, as Mr. Ferguson has already explained, is the serious objection to the use of storage batteries for supply of alternating current; in fact, the idea is entirely impracticable. The second point the President brought out in relation to the use of transformers on the premises of the customers. This condition is even more complicated than the use of the sub-station with rotary transformer, because the company, in the latter case, has the transforming apparatus under special care, while in the former case it is distributed throughout the city on property not its own and beyond its control, where it cannot be watched and cannot be taken care of.

The remark that Mr. Scott made, that the burden of proof was on the direct current, I think entirely depends as to which end you view it from. If you are going to generate current and then be satisfied at its mere generation; that is one thing; if you are going to sell the current before you are satisfied, that is another. You are generating current to sell. If you generate alternating current and it cannot be purchased by the customer, what is the use of generating it? You should look at the whole question from the customer's standpoint. Those devices which are the most useful to him on the most useful system, you have got to supply in order to pay for the generating of the current; so that it is not a question as to whether the current shall be generated direct or shall be generated alternating, but as to what class of current shall be finally distributed. Mr. Scott also remarked in regard to the motors and devices for elevator work being complicated on direct current. As the cost of the motor, etc., is about the same, whether alternating or direct current is used, it means the customer gets more for his money if he uses direct current.

THE PRESIDENT:—Gentlemen, the next two papers were by Mr. Emmett and Mr. Robb. Since the authors of these papers are not present, we must leave it to them to conclude the discussion in writing. I may add, however, that both of these papers deal either exclusively or largely with alternating current distribution showing means adapted thereto, and neither of the two papers has been attacked in the discussion. This appears to me more than anything else to show that the alternating current is by no means at all yet hopelessly lost in inferiority. All the discussion we have had here about continuous current, or alternating current, refers to one particular phase only, although that place is their most important application, the supply of large cities and densely populated districts, but we all agree that in small cities and outlying districts of large cities, the alternating current reigns supreme.

The last paper was the paper by Mr. Torchio, and I call upon him to conclude.

MR. PHILIPPO TORCHIO:—I would just add, in connection with my paper, that in the application of electricity to factories, the direct current may be preferable for certain classes of work, and I should think that in such cases the five hundred volt, three-wire system is considerably more adapted than the two hundred and twenty volt system as usually adopted now. I think that the trend of engineers is toward the adoption of higher voltages whenever it is feasible, and especially in large factories, where the motor load constitutes a large percentage of the total connected load.

THE PRESIDENT.—Gentlemen, we are through with the work of this evening, and I believe, if nobody else desires to make any remarks, a motion to adjourn will be in order. I thank you for your very generous participation in the discussion.

THE PRESIDENT:—Gentlemen. The topic selected for the next meeting is "Methods of Illumination." It will comprise all appertaining to electric illumination, the character of different lamps or illuminants, the intensity, distribution of light, color of light, etc.; also the character of the supply system required for their successful operation, etc. Contributions in writing for this discussion in the form of short papers are very welcome, and should be handed in to the Secretary, or to the Committee on Papers, on or before December 6th.

[ADJOURNED.]