

DISCUSSION ON "PARALLEL OPERATION OF HYDROELECTRIC PLANTS." CHARLOTTE, N. C., MARCH 31, 1910.

W. S. Lee: In describing some of the features that enter into the design, construction and operation of our plants here I have endeavored to present them in a general way—in a way which should be considered by every engineer who contemplates a large development consisting of a chain of power plants.

The questions that arise in this kind of work are not always strictly engineering problems. There are commercial and political questions. The problems encountered in this particular section were, principally, a great variation in flow, a scattered market, and a market for power that is used only for a comparatively short portion of the day. I believe that it will not pay to develop an isolated plant in this country, considering the rates at which we have to sell power and the distances over which we have to transmit the power, unless it is a very large one. It is true we have many small powers that can be developed and utilized close by, in cotton mills, many of which have their own plants, but when the transmission field is entered it will not pay to handle these small plants.

While these questions may not be purely engineering problems, they are problems which the engineers of the country must help solve. There is no question that whoever has to operate an isolated plant, with a variable stream, is not going to get power from that plant with the same confidence that he would if he had other plants which he could call upon, or some reserve power. We find that condition in actual experience. With due respect for my own operating department here, I find that it frequently saves the water, fearing that there will not be enough to last through the week, and as a result the water is wasted.

Chas. E. Waddell: I think Mr. Lee has well treated the subject of the economics of parallel operation of plants from the standpoint of the southern engineer, and he has equally well dwelt on the attitude of the public towards these developments. I think he is conservative in estimating the advantages of the investment have been as 5 to 1 wherever a large undertaking of this kind has been made in the South in the increased value of manufacturing sites, manufacturing itself, and of real estate in the vicinity, and I think he might well have added to the paper a corollary on the advantages of such a system to the consumer. Briefly stated these advantages are:

1. With a distribution system such as this, and the use of three transformers connected in delta, a customer has practically a duplicate plant at the cost of one; for, should a line go down or one transformer be destroyed, operation is still possible.

2. The inertia of the large system, once running, is so great that throwing on or off large induction motors does not materially affect frequency or power factor.

3. Uniformity of rates for installations of equal characteristics places all manufacturers on an equal footing, and if competition exists it must be based on factors of cost other than power.

4. The coöperation between a customer and the engineering department of the large hydroelectric companies insures the customer of engineering advice of a much higher order than a small manufacturer would ordinarily have at his disposal.

All of us will heartily agree with Mr. Lee in what he says about educating the public to the great advantages of these systems, and the necessity of passing laws that are equitable and fair and particularly to give the hydroelectric companies greater latitude in the matter of condemnation processes and the right of eminent domain. If I mistake not, it is a law in this state at the present time that power companies have the right of eminent domain for transmission lines. The legislators and the public at large already begin to recognize these interests are public utilities, and should be given powers that are ordinarily delegated to railroads and corporations of that nature. I think it is manifestly fair and right, and I think it is our duty as engineers—because we know both the public's side and the company's side of these questions—to educate the public with which we come in contact to realize the advantages of the universal development of our water resources, their harmonious operation to the advantage of all interests, to recognize the advantage of equality in the rates, and not block development by unjust or antiquated laws that apply to a former age and have no place in the century in which we now live.

Percy H. Thomas: I would like to ask Mr. Lee how the speeds of the various water wheels in the system is maintained, and incidentally, what provision is made for voltage adjustment. And a second question is as to operation—whether all lines of the same voltage are tied together and so protected that any line breaking down will be automatically cut out; or whether the plant and substations are operated in sections, so that if anything happens to one section the lines on this section can be thrown over to another section; or whether separate sections are maintained, the different sections being tied together by instantaneous circuit-breakers? These are three possible ways of operating such a system, and Mr. Lee's experience would be very valuable.

It is interesting to note to what a high voltage this plant is now carried, even though the distances to which power is being transmitted would possibly not demand so great a pressure. I believe it is a very wise arrangement; not only does it give greater efficiency and splendid regulation of voltage, but it provides a large amount of changing current which will tend to neutralize the effect of the inductance of the induction motors, and further will permit a temporary transmission of power through roundabout circuits in case of injury to some main line. Two or three times the normal distance might be traveled,

under such circumstances, without causing any particular disturbance of voltage of serious transmission losses.

There is another side to the problem which Mr. Lee has presented, and which he has of course fully considered—how far is it possible to build up a load whose load curve shall follow that of the water power available. It is, of course, desirable to utilize storage to permit the use of every possible kilowatt-hour from the river, but it is also worth while to encourage the sort of load which follows as far as possible the power available. Possibly Mr. Lee would give us a few remarks on the limitations in the control of the load curve—these limitations, of course, are very great.

What is wanted is some way of using overflow power; as for metallurgical or electrochemical work, or some other way. The ideal arrangement would be some process which can be carried on at night, and which does not require a heavy plant investment; giving some product which has a good steady market value and which is easily shipped. For example, if some fertilizer could be manufactured at night with the overflow current, and shipped in carload lots to the country hereabout, it would be a very great advantage to the power system. Apparently, at the present time there is no such use for overflow power which is really practicable and available. It would seem almost certain, however, that in the future there will be found something which will be more satisfactory.

Considering Mr. Lee's discussion of the advantages of multiple power stations, not only do we gain from having a large number of hydroelectric plants in the same system, but we will gain, as the author has brought out, by having them widely distributed not only three consecutive power houses on one river, but having the power stations on opposite sides of the distribution area allowing the source of power for any particular load to be chosen at will.

Mr. Lee has spoken of the advantage in looking ahead in laying out a large power system. There can certainly be no question about the wisdom of that principle. I think it is also true that every big power system, like every other large undertaking, is an evolution, and must have its growth guided by its past experience; and if we start with a central idea which appears best at the time, it is not wise to determine conditions too far ahead, because conditions are likely to change, and it will be better to have the development flexible enough to take advantage of the situation existing at the time of action.

D. B. Rushmore: A feature of Mr. Lee's paper deserving of particular discussion is the use of steam auxiliary plants in connection with large hydroelectric systems where the power stations are developed to a point above the minimum flow of the streams. In a few localities, such as Niagara Falls, steam auxiliary plants are needed only as an insurance against breakdown of transmission lines. Such plants may, however, perform various func-

tions, such as taking the peak loads, of supplying the wattless current of the system, etc. At the present time the development of a hydroelectric system necessarily involves the use of such steam auxiliaries.

A. M. Schoen: The points of advantage to be derived from the parallel operation of hydroelectric plants, as explained by Mr. Lee in his very able paper, are too self-evident to need discussion, but if these advantages accrue from tying together a single group of plants in a fairly circumscribed area it would seem that the extension of the same system over a wide area would accomplish results even more to be desired. One of the principal factors justifying the arrangement recommended by Mr. Lee is the fact that if, with several plants so grouped together, each stream takes its water from a different drainage area, there will be a greater tendency towards flattening out the primary power curve, thus increasing the salable primary power against the corresponding decrease in the secondary, as extreme low water in two well separated basins at the same time is unlikely, and this improbability continues to increase with the number of streams drawn upon and the increased separation of their drainage basins.

Take, for instance, one of the southern counties, the commissioners for which recently requested me to formulate specifications under which four competing hydroelectric power companies should be permitted to run their transmission and distribution systems. Two of the companies were located at adjacent points, on the same river, while the other two were supplied from entirely different streams, taking their rise and supplementary supplies hundreds of miles from each other and from the first river. Any arrangements between these four companies by which they might supplement each others' power in extreme cases would seem to be mutually beneficial, as such an arrangement would result in increasing the salable primary power to a greater or less extent for all four without calling for additional equipment, except in the pole lines, assuming, of course, that all were using the same voltage, periodicity and frequency. This serves to accentuate the particular point I had in mind when rising to discuss Mr. Lee's paper, namely, the need for conforming to some general standard when installing plants of this kind, for in my opinion, the time is coming when there will be some general working arrangement, even if the ownership is different, between plants of this character operated in the same section of the country. Indeed, it is hardly too great a stretch of the imagination to say that the time may come when sections rich in water power, such as the Piedmont section of the southern Appalachians, will be covered by transmission lines fed at intervals from the various power houses, thus creating one large interdependent system furnishing a maximum primary power supply to the country within reach, and under the most advantageous conditions both to operator and consumer; and should this occur,

the next step in natural sequence when such relationship between the properties existed would seem to be an arrangement of dams across streams at judiciously selected points between the mountains, resulting in the impounding of these waters by means of artificial lakes and a consequent increase in the water stage of the streams affected with corresponding increase in primary power.

Carl Hering: Regarding the utilization of electric power from hydroelectric plants at such times during the day, night or year when there is plenty of water and a light load, there is probably no better way to utilize that power than for some electrochemical or furnace processes which can be started and stopped at pre-arranged times, and which require large amounts of power but must get this power very cheaply in order to make the processes commercial.

It seems to me that this has not been given the attention which it deserves. Such power could be delivered very cheaply, yet with great profit, as the cost of it to the producer is extremely small because this cost should be charged with only the difference between the cost of operating with and without this extra load. If power at such low costs were offered at prices agreed upon for reasonably long terms, it would probably find a sale when the offer became generally known.

Even a furnace might be operated during a limited period every day, if enough current could be obtained during the rest of the day to merely keep it hot; and when furnaces are designed and proportioned more carefully to reduce the heat losses, as they undoubtedly will be after it becomes known how to design them properly, these stand-by losses ought to be reasonably small. A case has been reported in which this was profitable even when coal was the fuel, and it would therefore be much more so when the source is an excess of water, and when it becomes possible to design the furnaces more correctly.

H. N. Muller: It might be of interest to the people here to know that power is now being used in the off peak periods in the Pittsburgh district for the manufacture of steel, or rather the refining of steel that has been preheated and somewhat refined in the open hearth furnace, or made from the scrap, at a cost of about one cent per kilowatt-hour for current. This has been carried on for over a year, and while I do not know what the manufacturers' profit has been on this steel, which is used principally for high grade tool steel, they are still completely equipped with crucibles, and I feel they would revert to the former methods if the electric furnace was not more profitable.

W. L. Waters: Mr. Lee's paper deals in a complete, though brief, manner with the fundamental engineering and economic questions connected with hydroelectric power distribution. The only suggestion I wish to make on this subject is that the induction type of generator should be considered more frequently for such installations. The disadvantage of operating a large num-

ber of small power stations, is the increased expense due to the attendance required for each station. In large city power stations it has been found more economical and advisable to operate power stations of 100,000 to 200,000 kw. capacity, when the conditions in regard to the magnitude and location of load justifies such a size. In a well distributed water power system such as Mr. Lee has referred to a power station of this capacity is usually impossible as the water power is not located at one point.

The induction generator consists of an induction motor operated above synchronous speed, and the advantage of this type of machine is simplicity of construction and operation. The induction generator does not require any direct current exciting system or complicated switching gear. In addition there are no governor or parallel-operation troubles and the units once put on the line can take care of themselves, the load being regulated by the governor of the prime mover. The objection to induction generators is that they require a wattless magnetizing current which must be supplied by the system. Just as an induction motor takes a wattless magnetizing current from the line and delivers mechanical power, so the induction generator takes wattless magnetizing current from the system while it supplies the watt component of the whole.

Two years ago I presented to the Institute a paper on the induction generator as applied to large power station work. In this paper I dealt mainly with the application of this type of generator to large power stations operating a considerable amount of synchronous apparatus, and the question of such units in connection with large water power systems was only briefly touched on; the reason for this being that there was practically no large overhead transmission system operating with the high voltage at which the Southern Power Company is operating at the present time. The possibility of operating large overhead systems at 100,000 volts changes the situation completely. Mr. Fraser states that the capacity charging current for 140 miles of the Southern Power Company's 100,000 volt line is about 7,000 kilovolt-amperes. These 7,000 kilovolt-amperes will supply the full load wattless magnetizing current for 20,000 to 30,000 kw. of steam-turbine-driven induction generators or about one-half that capacity of waterwheel-driven units. Mr. Lee will tell us the Southern Power Company expects within the next five years to have the 100,000 volt line so extended that the charging current will probably be increased to 20,000 kilovolt-amperes. If this is the case the overhead system would be capable of supplying the full load wattless magnetizing current for from 30,000 to 100,000 kw. of induction generators, the exact capacity depending upon the speed and the voltage at which they are operated.

The commercial history of the induction generator has been comparatively brief. The first application of any size was a

1200-kw. unit installed in the Baltimore Copper and Smelting Rolling Company's plant about six years ago, while recently three larger units have been installed in the Interborough Rapid Transit Company's power station in New York City. The generators in both of these installations supply power to rotary converters which transform the alternating current to direct current. The induction generator appears to have been somewhat neglected in the past because the conditions were not favorable to its adoption. The necessity of a wattless magnetizing exciting current which must be supplied from the system, is a great disadvantage in a number of cases. But with large city power stations operating synchronous apparatus, or an extensive high voltage overhead transmission system, with large capacity charging current, the conditions are much more favorable to this type of generator. In any system such as that of the Southern Power Company the arrangement suggested would be; synchronous units installed in one or two of the large power stations and induction generators in all the smaller stations. The generator units in the smaller stations would run continuously on the circuit without attention, the governor of the prime movers regulating the load, while the voltage on the system would be controlled from the large synchronous power stations. The suitability of the induction generator for any such system would depend to a great extent on the speed at which the units operated, the voltage for which they are wound, and the power-factor of the load on the alternating-current distribution system. And, in any case, the advisability of adopting or not adopting such an arrangement of induction generators in any large complicated system such as that of the Southern Power Company could only be decided after the system has been laid out in detail, and all the economic and engineering features been given due consideration. My object in bringing forward the induction generator at this time is not that it is considered advisable to adopt this type of generator universally in such installations, but that as conditions are gradually changing and becoming more favorable to the adoption of this type of unit, it now deserves more attention than it has received in the past.

Chas. F. Scott: Mr. Lee's paper besides presenting the general conditions confronting the Southern Power Company, shows also a new stage in the development or evolution of electrical transmission.

The high tension transmission system of several years ago consisted of a generator, raising transformer, line, and a lower transformer with some distributing lines. The transmission system consisted of a single transmission line from one generator to one substation. More complicated designs rapidly developed. In one type a number of power plants supplied a single point; possibly Los Angeles may serve as an example which receives incoming power from several directions. Then, again there is another type in which power is generated at one point

and is distributed by various transmission lines in different directions, each of these lines supplying stations at various points en route; Niagara Falls is typical of this condition.

In the case of the Southern Power Company we are apt to think that operating at 100,000 volts is its great feature, but a statement of Mr. Lee's shows that there is something more notable. He says now that this is not a high-tension transmission system, but a high-tension distribution system. There are many scattered power houses, and many distribution centers.

A number of years ago, when the Niagara plant was being laid out and great interest was concentrated on the generators of mammoth and unique form, one of my colleagues, who was engaged in the development of switching apparatus, made a remark which struck me on account of its originality and novelty. He said that the great difficulty and the big problem in large electrical work would not be in the generators, but in the switching and controlling apparatus.

I have thought of that remark many times since, and I believe it is more true to-day than when it was first spoken. In a plant with high-pressure circuits and many receiving and distributing points, such as has been described this morning, the problem of switching and controlling apparatus constitutes the large electrical problem. So that this plant illustrates, not only the new commercial-political relations, as Mr. Lee has pointed out but also marks a new stage in electrical operation and the types of apparatus which are required.

In brief, the operating conditions, the inter-relation between stations and operators, involving such questions as those Mr. Thomas asked, and such questions as Mr. Waters brought out a moment ago in their discussions—these are the large and important elements upon which the success of the plant will depend.

The relation of electricity to the conservation of energy is one which has received attention at the hands of our President in one of his papers before the Institute, and it seems to me Mr. Lee has brought out some features which are descriptive, in a large and broad way, of the larger service which electricity will have in the conservation of our natural resources. It not only saves the waste of water power and enables it to be utilized, but by entering into a whole region, by making a power system of a whole state, it equalizes the different variables which occur in the operation of each individual system which Mr. Lee has pointed out. Now, by interconnecting many plants into one general electric system covering the whole stage, these individual elements or variations can largely be wiped out, and we can get that general average which means the highest general efficiency, so that we equalize power, and we save power, and furnish a better and cheaper power, as was brought out in the discussion yesterday.

With regard to the relations of the engineer to the general

problem, I would almost disagree with Mr. Lee, when he apparently limits the function of the engineer to the purely technical problems. He says in the beginning of his paper that some of the problems are commercial rather than engineering. Taking our natural resources, and applying them most efficiently under the conditions which exist, I think, like most of the things which he has brought up, can properly be placed under broad engineering. I think he is right also in stating that the proper way for engineers to handle the large conservation problem is by attacking the problem in a large way and getting efficient results. And I believe that the general common sense of the American people is such that they do not object to having things done in a large way on a sound engineering basis, but what they do object to is having them done on a false and unjust social and commercial basis. Our commercial and political friends should recognize the same kind of standard that the engineers work to, high efficiency, the greatest good to the greatest number, on a fair and just basis; in fact engineers are setting the standard of principles which should be adopted in commercial and political life, as they must practice them in their professional life.

In talking with one of the older men in this community, who has seen things build up in the South for many years, and in speaking of the new life which has come to the district, and the new methods in cotton mills, he said that pioneer work of this kind requires imagination, initiative, and nerve. He said that is what the Southern Power Company has, and I am sure we all agree with him.

Edw. W. Shedd: Mr. President and gentlemen, I have been exceedingly interested in the paper that has been presented by Mr. Lee, and I desire to offer just one suggestion which I think has not been touched upon in the discussion, but which Mr. Lee brought out in his paper, and that is the great importance of the question of transportation; and I am sure that you will all agree with me that that is a question of transcendent importance, and it is a question which must be met and worked out if the fullest development of our southern water powers is brought to pass, and it is a question which I think works in most uniformly and nicely with the question of hydroelectric development.

For nearly two years I have been working in this territory, purposely selecting the territory in which the Southern Power Company is operating, upon a system of railways which is designed to meet the needs of the territory as regards transportation, and which I think in the near future is bound to be built.

I want also to emphatically endorse the suggestion of Mr. Lee and others who have discussed the paper as to the value and importance of engineers and every one else educating the public, especially perhaps the political public, as to the advisability of giving to these quasi-public corporations sufficient rights, particularly in the way of eminent domain, to enable them to

carry out all their important developments which are in progress. It seems too bad that many valuable developments are held back by the narrow mindedness of some one man who thinks he has a big corporation to deal with; he will get fifteen times the value of his land, just because the corporation wants a right-of-way through it. Such procedure holds back development in many cases. It is the duty of every electrical engineer and civil engineer, lawyer and banker, to try to educate the public and to work with the legislators, so that a broad-gauge policy can be followed in these matters.

Speaking directly to the point, it has been suggested that we should develop something that would use the water power when the hydroelectric companies have a surplus of water, and when it is not being used for other kinds of business. It has occurred to me to-day, and it has occurred to me many times before, that one very large use, possibly of this power in the night time could be developed by operating a system of railways, particularly in the section of the country in which the Southern Power Company and other hydroelectric plants are operated, hauling the freight in the night. A large amount of power can be used at night in hauling freight, for I see no reason why the freight business could not be done in the night time when there is a surplus of hydroelectric power available. It is my purpose to use hydroelectric power for the operation of railways in the district of the Southern Power Company, carrying freight at night.

Perhaps this is not the place to bring it forward, but the idea has occurred to me that it might be desirable, if it were constitutional to subsidize such industries as water power developments, railways, etc., in the way, possibly of exempting their bonds from taxation. It might be possible in this way to induce the banks and trust companies in the south, which are pretty well supplied now with money, and find difficulty in lending it, to take some of the bonds, of these enterprises as this would make them more attractive as an investment.

It has occurred to me that this might be done by the partial or complete exemption of taxation on bonds issued by hydroelectric plants, and on railways, exclusively within the state of North Carolina, and held, perhaps, exclusively by investors residing in the State of North Carolina. It looks to me as though something of this kind could be worked out very satisfactorily, and this would make the railways and the hydroelectric plants, as you might say, a board of trade, which would be working for the development of the entire country, and at the same time furnish a more attractive investment for the money on deposit in North Carolina, to be used only in this State, and in other states, if such states do the same thing.

President Stillwell: Mr. Scott has already referred to the first of the points which I noted in listening to Mr. Lee's paper, namely, his apparent contrasting of the ideas of engineering

considerations and commercial considerations. Engineering, as I understand it, when applied to the solution of these large industrial problems, means the application of commercial business judgment, reducible to terms of dollars and cents, to those problems; that application being based, however, upon special study of the technical underlying problems which are essential as a foundation for the general solution. I think if we were to use the words "technical" and "commercial," in making a contrast, rather than "engineering" and "commercial," we should place the matter in about the right light, because we do not want the community to get into the habit, which I am sorry to say it has acquired in part, of looking upon engineers as men who are incapable of drawing practical deductions. The engineering which is of the broadest kind, is precisely the kind which Mr. Lee himself, a member of the Institute, is carrying on. He has applied broad business judgment, based on technical knowledge, to the solution of industrial and commercial problems. Immediately, that raises a question of engineering responsibility, and that is a point I want to say a word about.

We have now throughout the country an abnormal number of hydroelectric enterprises in the hands of receivers. In every case that I have had occasion to investigate or have learned about, and I have come in touch with a number of them, the failure has been due to the fact that at the outset the proper kind of commercial-engineering brains were not brought to bear on the problem. I do not know an important case where the thing that caused the enterprise to fail could not or should not have been foreseen. Engineers are too apt to allow themselves to be hurried and pressed by the promoter. In one important case where an estimate had to be revised to an extent which involved the raising of about \$2,000,000 in addition to the original amount provided for by the financiers, I am told that the engineer made the excuse that he was allowed only one week to investigate that problem. That excuse is an indictment of the engineer himself. Any man who could undertake to pass on a matter involving large amounts of other people's money, or small amounts, on a matter of such magnitude, in such a short time, ought to resign from the engineering society and get out of the business. He does not belong there.

Mr. Lee made reference to the subject of condemnation of rights for transmission lines, and also of the lines which are essential to the hydroelectric development. Now, there is a point where I believe we can use our influence, not collectively, perhaps, but individually with our congressmen and friends in the legislatures, in a perfectly proper manner, and in a manner that will redound to the benefit of our engineering organization and of engineers as individuals and of the community at large. We have in the country two classes of public utility corporations, aside from those which have to do with the cities, the gas com-

panies and the railways, and now we have to do with these great transmission and distribution systems utilizing water powers. The railways have the right of eminent domain. In general, the power companies have not. Is there any possible reason and logical common sense why they should not have this right? The gross earnings of the railways of the United States are approximately \$3,000,000,000, a year. The gross value of our manufactured products is approximately \$20,000,000,000 a year. This utilization of power means a general tendency to decrease the cost of the manufactured product. It also means in many cases, and in more cases to come, a reduction in the cost of transportation. Economically considered, therefore, every reason that exists for conferring upon the railways the right to condemn, exists with increased force in the case of the power companies distributing energy for the very many purposes to which the community applies it. Now, this question of natural monopoly must be met, and we must meet it with an effective answer. As citizens many of us are lined up on that side of the question, but we have to face the fact that, at any rate, there is going to be in this country government regulation of rates, especially the rates of public utility corporations. The right of the state has already been upheld in the case of the Consolidated Gas Company in New York, where the decision of the supreme court of the state of New York was appealed to the United States supreme court, and in that case it was definitely decided by the higher tribunal that the state has the right to regulate rates. Now it seems to me that the answer to give to those people who are objecting to a natural monopoly in water power is this—that it is absolutely unnecessary to retard the development of these enterprises at this date, for the reason that just as rapidly as they place themselves in the position where they are imposing upon the community by charging excessive or unfair rates, the state is in the position to intervene and regulate these rates. This practice of conjuring up something that might happen in the dim and distant future in the way of fixing rates is too remote an excuse for justifying any possible retardation in the forward movement of this extremely important conservation, because conservation is, in this case, most emphatically utilization; but we must have our answer, and the answer is not that our rates are moderate—they won't believe it. We can give that answer to those who will believe it, but most of the people will discount such a statement; but our answer should be this—that just as soon as this is a real danger, and not an imaginary one, the state can intervene, as established by the decisions of the supreme court, and fix just and equitable rates.

I think it is the duty and a part of the business of engineers to take a hand in public affairs. I do not see why 20,000 engineers in this country should sit back and let other people, five per cent of whom do not understand the facts necessary to the commercial solution of these problems, pass upon them, while

the engineers sit on the fence and watch them do it. The engineers should get into the game early and meet the people who are interested in these things in a social way, and otherwise, and endeavor in every possible way to educate them. That is what they need. We have talked with many of them, including Mr. Ballinger and Mr. Pinchot, and have seen none of them who do not admit that they need ideas in regard to the practical, technical and economic bearing of some of these questions, which some of us are able to give them.

W. S. Lee: Referring to Mr. Thomas' remarks, he asks about the speed of wheels. We have on the system different heads, different size ponds, and consequently the plant with the small ponds must be run a longer number of hours, and in the case of the larger ponds a shorter number of hours, but with a larger peak load. All the waterwheels permit a certain variation of head and maintain the same frequency. We endeavor to reduce these heads as little as possible, it being our practice in extremely low water to put in our steam auxiliaries in the early part rather than in the latter part of the week. While originally we had the idea that we would run the water as long as we could, and at the end of the week put in the steam to help out the week's load, we find by keeping the head up in the earlier part of the week we get more power out of the system.

Mr. Thomas also asked about voltage regulation. In order to meet the conditions with which we were confronted, that is, differences in voltage, we got out a standard set of specifications giving a list of taps which we were to have on all of our high tension transformers. This calls for a higher voltage to be run on the plant during the time of our heavy load hours. When the load goes off the cotton mills at six o'clock in the afternoon, the voltage on the whole system is lowered. This takes care of the drop in voltage in the line, the transformers being tapped with reference to the distance from the power house. The line which it is hardest to control the voltage on is the line that is not loaded.

Mr. Thomas also asked some questions about sectionalizing the system. I will say that that is a question which I have been dodging in a way. We have certain lines that go to stations or distributing points. We term them switching stations. From these switching stations the lines may branch out into a greater number of lines to cover different territory. We then go on to another point and break the line up into several more lines, supplying different points. All of these stations are provided with automatic switches or fuses. We can sectionalize the different parts of the system from time to time, putting one plant either on one side or the other.

Mr. Thomas also is rather disposed to criticise the voltage we are going to, but I do not think I will answer that because he answered that point himself. He stated that perhaps it would be a good thing to use these higher voltages to run around and come back over greater distances, where there might be a reason

for doing this. That is what Mr. Burkholder does. It is fifty miles from here to Great Falls, and Mr. Burkholder does not hesitate to take the current to Salisbury and back again, and by the time it reaches Charlotte it has traveled 150 miles.

Mr. Thomas also asked some questions regarding the distribution of load. That is a question we do not know how to answer. You may have an idea that one particular section of this system is going to develop and you will be surprised to find some other develops much faster.

Regarding the remarks he made as to the location of plants on the outskirts of the district, that is not possible, because the bulk of the power is brought up country and there may not be any water power in that particular district.

Mr. Rushmore referred to steam auxiliaries and synchronous condensers. In connection with that, I will say that we are now installing some of this apparatus at Greenville, South Carolina; we are installing a 10,000-kw. steam-turbine, which will operate as a synchronous condenser, and we are arranging to install another similar set at a point we have not yet decided upon, which will have a capacity of 6,000 kw.
