Discussion.

The President:—I would like to ask Dr. Kennelly, who obtained results similar to these, if he has any explanation for them —that the distribution of the light of an enclosed arc lamp has the general form represented in Fig. 11.

Dr. Kennelly:—In regard to the peculiar wing-shaped curve of luminous intensity, when we made the measurements to which the President has just referred, we noticed, of course, that abnormal upper development, which is absent, I believe, in the case of the naked arc, and we assumed at the time that it was due to light reflected from the inner globe upwards to a zone above the positive carbon. In other words, had the inner globe not been there, the entire prominence would have been about 45 degrees below the horizontal plane through the arc; but with the globe in place, many of the rays so transmitted were thrown back again by reflection to an upper zone.

Prof. Owens:—I would like to ask if the shape of that curve is altered by the peculiar form of the small enclosed globe?

The President:—I might answer both the statements by saying that it was suspected that the light reflected from the inner globe was the cause of that peculiar distribution, but it was not possible to prove that fact, and the test made with different forms of globe, I believe, did not add anything to the knowledge. Undoubtedly that must be the cause; there would seem to be no other, and possibly changing the form of the inner globe considerably, would prove this to be the cause: but no conclusive test has been made, so far as I know.

Mr. L. B. Marks:—I have no doubt that the form of the small globe influences the shape of the curve. By using a globe that has a very marked curvature, instead of a long flat globe, you get a different candle-power curve; that kink in the curve is not very common in globes that vary in form from the usual shape. I presume that the writers of the paper did not find much difference in the various curves, because the small bulbs which they tested are all very much the same in shape.

I have been very much interested in some parts of this paper, and note on page 427 one of the lamps I designed and some tests made on it. I find that the authors obtained results which are very much the same in some cases as those of former experimenters. Indeed the work of Thomson, and Blondel, and Nichols, and some of my own researches seem to have brought out most of the general results that are given in this paper. I have not had time to examine it very carefully, but I think perhaps a few statements in regards to some of the matters that are presented may be of interest.

On page 430 we have a curve for the relation between voltage across the arc and length of arc. While it is true that this curve is of some value in representing the ratio

alluded to, still I hardly think that it would be safe to use a curve of this kind as a basis for any important measurements, because it seems to me that that curve is really one expression of the ratio between the voltage and length of arc of this particular lamp. This ratio varies very greatly in different lamps and in fact even in the same lamp. If you take two cored carbons, for instance, you will find that the ratio varies. You will also find that a figure such as eighty-three volts corresponding to the length of .023 of an inch, as given in Tables VI., may not apply. It may be 20 or 25 per cent. off. Again the ratio will naturally depend on the position of the arc in the bulb. The authors do not give the conditions under which this particular test was made, and without these conditions the tests lose much of their value. If the arc, for instance, is at the top of the bulb, the ratio will be quite different from what it would be if the arc were at the bottom of the bulb. The ratio naturally varies with the amount of air that enters the bulb. We will assume, for instance, that in this lamp which the authors tested, the bulb is air-tight at the time, and the arc is near the top. Then take a condition in which there is a small amount of air entering the bottom, as there is in some of these lamps I presume, and we will assume that the arc instead of being placed at the top is placed near the bottom,—I will venture to say that there will be a difference of perhaps 30 to 35 per cent. between the measurements thus obtained and in the values given in this table. I have made quite a number of tests and I find that it is very difficult to give any particular curve that will come near truly representing this ratio.

The regulation of the lamps is a matter which of course requires a great deal of time to ascertain with absolute certainty. The authors have gone to a great deal of trouble, apparently, to measure the lamps, and I am glad to find they have given us the results of tests which cover a period of months instead of a period of weeks, as is often done.

There is a very interesting point in the paper which the authors have not gone into very fully—perhaps one of the most interesting points in connection with the enclosed arc, and that is the voltage at which an enclosed arc can be safely and steadily run as compared with the voltage of the mains at which such an arc can be run. The nature of their tests is very much the same as those of Professor Thomson, which were recorded in a paper read by him at the convention of the National Electric Light Association at Niagara last month. Their results are however somewhat different than his, and I may say that the results of Professor Thomson, and those given in this paper, are quite different from my own. Take Blondel's measurements made in Paris and you find these are different, and some recent measurements of one of Dr. Nichol's students at Cornell are also different. We have five or six sets of measurements none of which coincide. It

would seem to me that it would be extremely valuable for some one to take up that particular part of the table and enlarge upon it. I have no doubt that a thorough study of this one point would bring out a very valuable series of figures of which, at the present time we have no exact knowledge at least as far as published data are concerned. I may say with regard to the remarks made by the authors of the paper, that while they claim that an arc cannot be run steadily below a certain voltage of the mains, which I believe they figure here about ninety-five or so, that this is hardly true, and will depend on conditions. I presume they took the commercial lamps in the market: they used the ordinary bulb, and so on; but if you vary these conditions, that is, change the diameter of your carbon and the amount of current, change the size and perhaps the shape of the bulb and the position of the arc in the bulb, and the nature of the gas checking devices and the quality of the carbon, etc. you will find probably that an arc may be run at a voltage which is very close to that of the mains under some conditions; so that the broad statement that an arc run on mains that are below ninety-five volts is unsteady, would hardly be true; it would depend on conditions, and although the authors, to be sure, confine their measurements to certain commercial lamps, still it is rather misleading to read their statement which apparently refers to all lamps of this type. Then again as the voltage of the mains goes down, it is advisable in order to run an enclosed arc steadily, to operate at slightly lower voltage of the arc. Now the authors have adhered to seventy-eight volts at the arc. They cut out resistance and they lower the voltage of the mains, yet they keep the figure seventy-eight volts at the arc. Under those conditions it was quite natural that the arc should be unsteady at a lower voltage of the mains, and I think that if they had reduced the voltage of the arc when they reduced the voltage of the mains they would have gotten entirely different results. So that the figures here apply to a very narrow set of conditions.

I will not touch on the mechanical points they refer to, although naturally a great deal might be said. I shall try to confine myself as closely as possibie to purely technical points.

On page 435 at the lower part of the page, paragraph 3, the authors say:

" The size of the enclosing globe affects the life, it being less " by a slight amount for a smaller globe. All the other condi- " tions being the same, a lamp having a smaller globe will, during a " given run, have its globe replenished with air from the out- " side oftener than if it had a larger globe."

I think that that statement is open to question. Anybody who has experimented with various sizes of enclosing bulbs will have found that there is quite a marked difference in favor of the smaller bulb; that is, with a smaller bulb, under ordinary conditions, the life per inch of carbon is greater. True enough,

we do not get the total life of 100 or 150 hours, because there is not sufficient carbon; but the life per inch of carbon consumed is ordinarily greater, in some cases considerably greater, with the smaller bulb. Naturally in changing the size of the bulb, in order to get the best results, it is necessary to change other conditions—to change the gas checking effects for instance whatever they may be. But I believe that generally speaking, the life of a carbon is increased, or the consumption of carbon per unit time is decreased with decrease in the size of the enclosing bulb.

On page 436 we have different forms of gas caps. The gas cap is quite well known now. A few years ago I gave it the name of "gas check." All these forms of gas caps are the same in principle. They consist simply of some chamber device for holding part of the gas formed by the action of the arc, and in that way acting as a check against the ingress of air and egresss of gas.

On page 437 there is a very interesting point which Dr. Crocker alluded to, I believe, as miraculous or important.

THE PRESIDENT:—Only peculiar.

MR. MARKS:—Well I admit that at first sight it does appear very peculiar. But the explanation of it seems to be quite simple. In most lamps, as is stated in the paper, the relative life of the positive and negative carbons respectively changes as the arc descends in the bulb. Now here is an apparent exception to the rule. The average ratio is about 1 to $2\frac{1}{2}$ or 3, I believe. My own measurements are a little different from that—perhaps 1 to 4; but they find a case 1 to 10 given on Table 9, page 439. That would be accounted for in several ways. If the voltage of the arc decreases, the ratio naturally increases, and at a certain voltage of the arc and a certain current, it is possible to increase the ratio so greatly as to approach infinity. That is, instead of having a ratio of 1 to 2 or 3, or 1 to 10, you may go up to 1 to 20 or 1 to 50, or more, depending on the voltage of the arc and the current passing at the time.

Regarding the photometric tests, I think we have spent a great deal of time in photometric measurements, and it seems to me that to a certain extent it is time wasted. With the enclosed arc, the character of the light, that is, the quality of the light is quite different from that of the standard adopted in order to make the measurements comparable with others, and I think in some cases the relative measurements of candle power would be meaningless. The authors state very truly that the candle power measurements are not to be relied upon, and they give their reasons. They refer to the difference in value between the standard source of illumination and the arc, and the very marked difference in the color of the light, and point out that the incandescent lamp gives an orange light even when run at its normal voltage. They also refer to the personal error in comparing the lamps. I think perhaps more importance should be attached to this last point than is given here. Different experimenters

will get quite different results. In Ithaca we made measurements of the enclosed arcs, and we had ten watchers, and there was a difference of over 50 per cent in the maximum and minimum readings taken at the same angle. Of course this difference is enhanced by the "wandering" of the arc. I am glad to see tests given on the holophane globe. I think this is the first time that any measurements have been given of the relative value of the light with and without such a globe, that is with the enclosed arc lamp. I know that when this question was asked me abroad by Prof. Blondel I had to admit that we had not made any tests in this country.

On page 447 referring to the two bulbs, I hardly know how to account for the deposition of carbon. In case No. 2, it is noted that there is a deposition of carbon at the lower end of the bulb which the authors state was burned into the bulb. If the lamp were operating, as it does normally, it seems to me that this deposition should not occur. I do not know what lamp these bulbs belong to. In fact I do not know the key to the paper. But I have seen bulbs of this particular kind operate in service, and if I am not mistaken there are several thousand of them in New York City, and the bulb which I am referring to, certainly does not give the trouble alluded to here. We have had practically no complaints regarding the burning in of carbon or incrustation of carbon in the lower part of the bulb, and I think that if the authors had operated the lamp under different conditions, or perhaps normal conditions, they would have obtained different results. In other words, nothing but an abnormal condition would account for the incrustation of carbon. Regarding the deposition of brass or some metal in the upper part of the bulb, that is probably due to allowing the arc to play too high in the bulb, probably very close to the gas cap.

The conclusions drawn by the writers seem to cover almost all the advantages of the enclosed arc lamp. There is perhaps one point of some importance which they have neglected to allude to, and that is the ability to run these lamps singly on an incandescent circuit. They refer to that in the paper, but in summing up the advantages of the enclosed arc over the open arc lamp, they have accidentally omitted this point. In many cases, such as small stores, it was necessary formerly to run two lamps in series. Now it is possible to furnish a single lamp to meet the demand. I have a note here, stating that it is to be regretted that the lamps should have been numbered. It would have added very greatly to the paper, I think, to have stated the names of the lamps, giving us the key to the situation. I know that I for one could have discussed the paper impartially and perhaps thrown more light on some of the peculiarities which the authors found. However, I suppose that it was impossible to do this under the circumstances. That is all I have to say regarding the paper, except to add that I am very much pleased to see

that the authors have gone into the matter so thoroughly; even if they have not presented many new points they have at least chronicled facts.

MR. HOLLON C. SPAULDING:—I wish to add a word of appreciation to the paper on this subject, which has become of daily importance, and to bring out one or two points that I would like to get some more information on. Table No. 8, given on page 437 shows a condition of things rather different from what those of us who are principally on the commercial side have thought to be the fact. I would like to know whether these tests, *a*, *b*, *c*, *d*, and *e*, were made on one lamp, (suggesting also the desirability of knowing what lamp it was,) or whether the different tests were on different lamps; also referring to the statements on page 439 about the possibility of having a shellac coating on the upper carbon rod, and the reference again on page 447 to the carbon rods. It may not be out of place to call attention to the fact that one of the lamps has no carbon rod, and my own experience has been such that I feel very strongly inclined to add to the requisites of successful enclosed arc lamps on page 429, that they should have no carbon rod. Beyond that, and perhaps acknowledging the inadvisability of knowing which lamp was used for each test, it might perhaps be fair to know what carbons were used, or if different kinds were used.

THE PRESIDENT:—As to the first point I think that the tests of life on page 437 were on different lamps. In regard to the carbons, they were the ordinary carbons used by the different manufacturers, that is to say, the carbons that were recommended to go with the lamp and supplied with it.

MR. MARKS:—Probably "Electra" carbons.

MR. SPAULDING:—That would be so in the case of the Manhattan.

THE PRESIDENT:—I am glad that Mr. Marks was able to give us the benefit of his long experience in discussing this paper, because the paper was taken up from an entirely different standpoint. Absolutely disinterested parties simply took lamps as they found them, the standard lamps on the market, and gave them a pretty thorough, and certainly an impartial test, and it was not intended to go into the general theory of such lamps—the physics of it, you might say, but of the engineering problem to decide what these different lamps will do, and by parties who were not interested in any way in the different lamps. To give the actual names of the different lamps was not considered exactly proper, although it was stated that they were representative types. All the lamps were included, but individualizing was carefully avoided, and I think wisely under the circumstances. Any considerable variations in conditions were of course impossible, because the lamps were simply taken as they were found, and used as recommended by their manufacturers which would seem to be the ordinary condition of practice. There is very little information

on this subject available, particularly from disinterested parties, and it was thought that the same information that was useful to us would be useful to others, and I might add that the investigation was originally taken up with the idea of determining for Columbia University whether it would use these lamps, and if so, which ones.

MR. STEINMETZ:—I have been very much interested in this paper, and in the discussion by Mr. Marks. There is however one point which I believe needs some further elucidation, since it may lead to mistakes. That is on page 446. The light efficiency is given there, but it does not state whether the power consumed by the arc alone has been considered or the power consumed by the whole lamp including the rheostat; furthermore whether the lamp was tested when new or after running some time and with a deposit formed on the globe.

The values given there, half a watt per candle, appear at the first view abnormally low—far beyond anything reasonable. But the explanation is that these are not the spherical candle powers. In open arc lamps, it is frequently the custom to measure "hemispherical" candle powers, considering the light thrown upwards as wasted—as may be quite proper—perhaps, where the arc is used for street lighting. The enclosed arc however finds its most useful field in indoor lighting, in competition with the incandescent lamp, and in this case the light, which is thrown upwards, is not lost, but reflected by the ceiling and to a large extent even more useful than the direct light, by giving a diffused illumination which is more valuable than direct illumination. Consequently it would only be proper to measure the spherical candle power, and then with two clear glass globes you would get one watt per candle and with one opal and one clear globe, 1.12 to 1.20 watts, and with two opal globes 1.8 to 2 watts per candle, which means in such case an efficiency fairly close to that of the incandescent lamp. Hence the enclosed arc lamp takes an intermediate position between the open arc and the incandescent lamp in its efficiency. The efficiency is lower than that of the open lamp and higher than that of the incandescent lamp. It shares with the incandescent lamp many valuable features, as the long life, absence of danger from the arc, etc., but it shares the other feature that the light decreases with the time, by the blackening of the globe. It has however the advantage of the incandescent lamp in the latter respect that the quality of light does not change; it remains the same light in color, but decreases in brightness; while in the incandescent lamp the light is yellow and reddish.

I do not think the conclusions drawn in the paper are quite complete, but they are rather one-sided, only the advantages being given. The open arc lamp is undoubtedly a very valuable piece of apparatus. But it has disadvantages, too.

As a conclusion I may then add as disadvantages of the en-

closed arc lamp—lower efficiency compared with the open arc, and decrease of light with the time of running.

It would be interesting also to compare it with the incandescent lamp, with which it competes in indoor lighting, and we find then, that the enclosed arc lamp has over the incandescent lamp the advantage of greater efficiency and constancy of the quality of light, but the disadvantage of being a little more complicated in its operation and not quite as handy, and besides, not allowing such extended subdivision of light, having necessarily larger units of light.

MR. CHARLES T. RITTENHOUSE:—On page 432 the authors bring out the point that a saving of about 13 per cent was obtained when using 100 volts compared with 115 volts. Mr. Marks has pointed out that it is not necessary under good conditions to use any external resistance at all.

MR. MARKS:—No, excuse me. I did not say that. I said the voltage might be lower.

MR. RITTENHOUSE:—I understood that the external resistance was not absolutely necessary. Granting that external resistance is necessary, I should like to know, when two lamps are operated in series, whether the gain would be greater than indicated by these results. That is to say, would one lamp tend to regulate another lamp, or is it necessary to use about the same resistance in each of them?

MR. MARKS:—Do you mean when two lamps are operated in series and on a 220 volt circuit?

MR. RITTENHOUSE:—Yes.

MR. MARKS:—Yes, there is a slight gain there, inasmuch as it is possible to operate the lamps at a higher voltage at the arc. As the voltage of the mains goes up it is possible to operate lamps in series as high as 100 volts across the arc, so that there would be a gain in that case.

MR. RITTENHOUSE:—I should like to ask whether it is necessary to have as much external resistance in series as when one lamp is used alone. That is to say, would the resistance in series of the two lamps be double that used in the one lamp.

MR. MARKS:—No; that would not follow.

CLOSING SESSION. WEDNESDAY, JULY 28th.

THE PRESIDENT:—We have assembled this afternoon in special session to read one paper from this morning's list, and the one assigned for this evening in order to avoid the necessity of holding an evening session. The paper to be considered now is on "Armature Reactions in a Rotary Transformer", by Professor Robert B. Owens, of Lincoln, Nebraska.