

STREET ILLUMINATION AND UNITS OF LIGHT.

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PHOTOMETRY.

In order to make photometric comparisons of open and enclosed arcs, I have found it necessary to work as far as possible with fixed conditions such as current, voltage and position of arc. The widely different results of various investigators are in part due to insufficient attention to these essential points, particularly the latter. A photometer with a reasonably long bar is also indispensable. This should be provided with an adjustable revolving sector disk by which the light from the arc can be reduced so that all settings can be made in the most accurate part of the scale. This arrangement permits working with a single standard and with light of low intensity which decreases the error introduced by color difference. A rotating crane is required for elevating and depressing the lamps in order to measure the light from different angles in the vertical plane.

A Bunsen photometer as described can be operated by three observers, but I have found four more satisfactory; one devotes his time entirely to making settings of the screen, the second maintains the current and voltage at the proper values, the third notes the position of the arc, and the fourth records the readings taken when the fixed quantities are correct. After working together for a few days, such a complement can reproduce the average characteristics of light distribution of arc lamps to within 5 or 6 per cent. of the mean which, for arc lamp photometry, is considered very satisfactory.

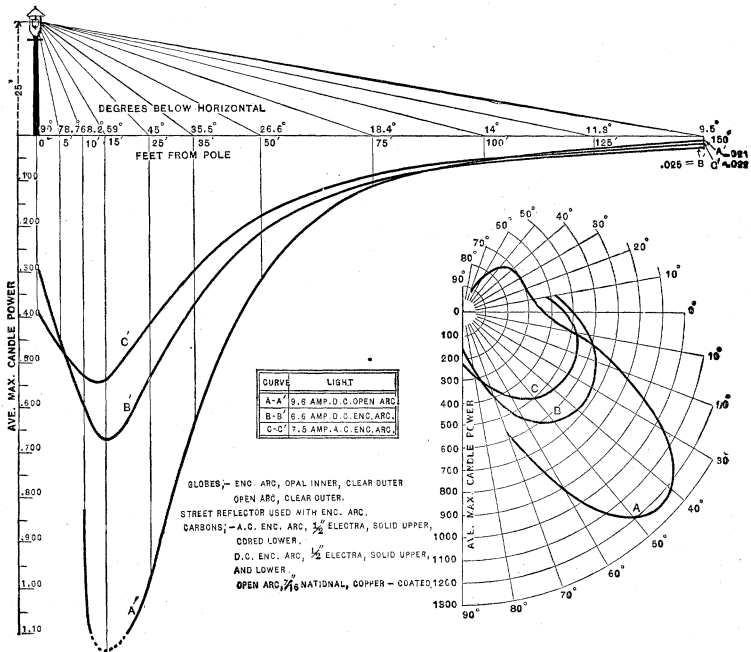
CANDLE POWER CURVES.

The curves in Fig. 1 were obtained by the method described.

To render the curves of commercial value the tests were carried on with lamps equipped as they ordinarily would be for street lighting, that is to say, the open arc lamp was trimmed with 7/16" National carbons and was provided with a clear globe.

The enclosed arc lamps were trimmed with high-grade carbons and were provided with opal enclosing and clear outer globes and street reflectors. All lamps were adjusted so as to consume approximately equal watts at the arc.

First confining our attention to the direct current lamps,



Street Illumination Curves.

Candle Power Curves.

FIG. 1

curves A and B, we will observe that the open arc lamp gives a greater maximum candle power (which, of course, is not by any means a measure of its usefulness). The enclosed arc lamp gives a stronger light through the most useful angles of from say 3° to 10° below the horizontal and from the shape of the curves it is self-evident that the distribution from the latter is more uniform.

ILLUMINATION CURVES.

We are not, however, particularly interested in the candle

power of the lamps. We desire principally an even illumination along the street surface, and we wish mainly to project the light as far from the source as possible.

To make this comparison, it is therefore necessary to convert the "candle power curves" into "illumination curves" giving the candle feet along the ground on surfaces normal to the rays of light.

The illumination curves in Fig. 2 are plotted for lamps 25 feet above the ground and at intervals of 300 feet. By introducing the element of distance we find that the strongest light received on the ground from the open arc is not projected at an angle of 45° as indicated by the candle power curves, but falls at an angle of about 60° below the horizontal, illuminating the ground brilliantly at a distance of about 15 feet from the pole, thus showing that in order to properly compare illumination of different lamps we must look to the surface illumination curves rather than the candle power curves, as previously stated.

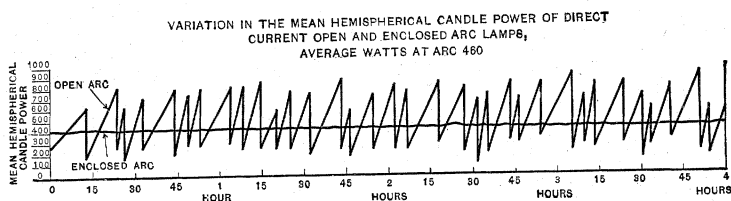


FIG. 2

Further analyzing the curves, it will be observed that the illumination of objects on the street surface from the open arc lamp is brighter up to a distance of about 100 feet from the source. Beyond this the light from the enclosed arc lamp is the strongest, and at 150 feet it exceeds the open arc by considerable, and this is made still more effective by the absence of strong light in the immediate vicinity of the lamp. This advantage is so obvious that further comment seems unnecessary.

Comparisons so far have been confined to fixed conditions with respect to current, voltage and the position of the arc.

We have next to consider the variations caused by the wandering of the arc, variations of potential between picking up and feeding points, fluctuations due to drafts of wind, non-homogeneity of carbons and other changes introduced by the inherent peculiarities of the different lamps.

VARYING ARC.

Open arc lamps ordinarily pick up at about 45 volts and feed normally at about 50. The light projected in any direction is approximately proportionate to the amount of crater area visible from any point in that direction, and the amount of crater area visible varies greatly with the small change in the length of the arc introduced by a difference of 5 volts.

Where lamps have been installed for a considerable period and have not received proper attention, the voltage variation may greatly exceed the normal limits. The lamp is then said to be working between a sluggish feed and the hissing point, and as

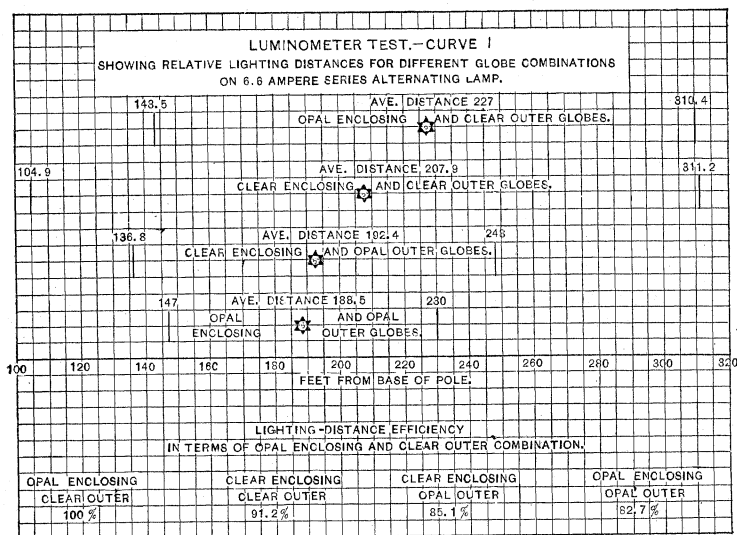


FIG. 3.

the arc feeds on an average cycle of about ten minutes, varying irregularly between 5 and 15 minutes, the candle power and illumination shown in Figs. 1 and 2 represents only instantaneous values which occur at very irregular intervals.

The enclosed arc lamp is particularly free from this variation. The arc is about $\frac{3}{8}$ " in length and the lamp feeds in about 4-hour cycles, varying irregularly between 3 and 5 hours, and the feed is an instantaneous drop and pick up to the original position. There is, however, a rise of voltage due to the heating of the shunt coils which may amount to 10 or 15 volts. This is a grad-

ual rise, taking place during two or three hours, and is not noticeable as a variation to the casual observer. It is objectionable, however, for other reasons. In some lamps this variation is con-

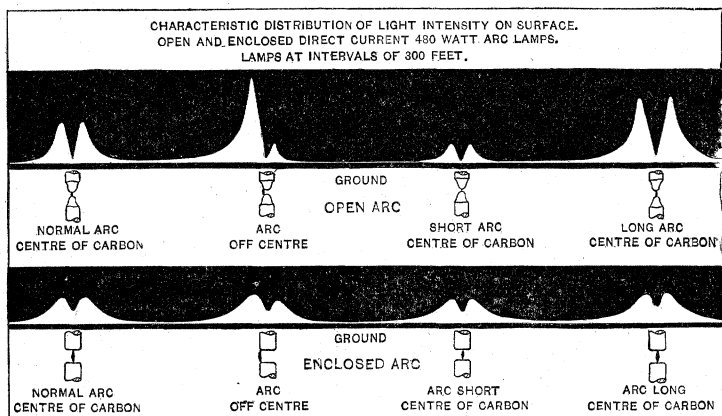


FIG. 4.

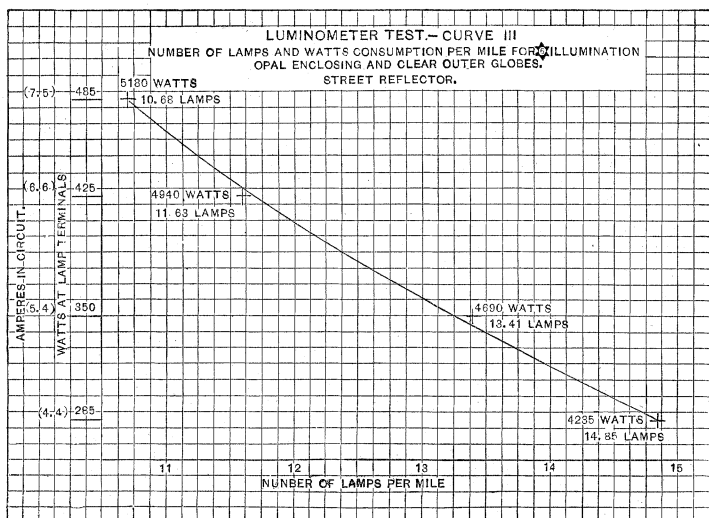


FIG. 5.

trolled by what is called a “compensating winding” which automatically adjusts the relation between the shunt and series coils as the lamp heats up.

For such lamps we may say that the mean hemispherical light is practically constant, as the voltage at the arc does not materially change. Thermostats have also been employed to accomplish the same result, but they have not proved entirely satisfactory, and in some localities they require a summer and a winter adjustment.

WANDERING ARC.

The second variation of importance in open arcs is caused by wandering of the arc, due primarily to the non-homogeneity of the cheap grade of solid carbons usually employed. When the

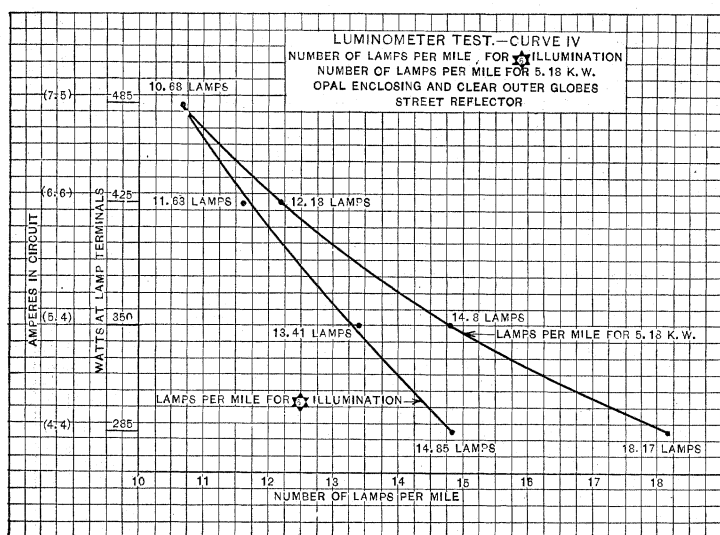


FIG. 6.

arc travels to the edge of the carbons we have a great volume of light from one side and very little from the opposite side.

Under such conditions the photometer would probably show a freak reading of 1,600 to 1,800 maximum candle power from a lamp which would give about 1,200 when the arc is co-axial with the carbons.

This wandering also takes place in the enclosed arc lamp, but it is not due particularly to the non-homogeneity of the carbons, because a high grade of carbon is employed, but it is primarily caused by the carbons burning flat in a globe practically free from oxygen and the arc wanders of necessity. The variation in the light from this cause is not so great as in the open arc, but it is not altogether pleasant when clear globes are employed.

By using an opal-enclosing globe, the light is balanced and the variation is reduced to a satisfactory degree of steadiness and all shadows are obliterated (Fig. 3).

FLICKERING ARC.

A common complaint against the open arc is the flickering due in a measure to non-homogeneity of carbons, but mainly to the wind blowing the arc about. While the latter cause is not inherent in the arc, it is common practice in America to leave the arc exposed to the wind and as this condition exists it seems reasonable to include it in the comparison.

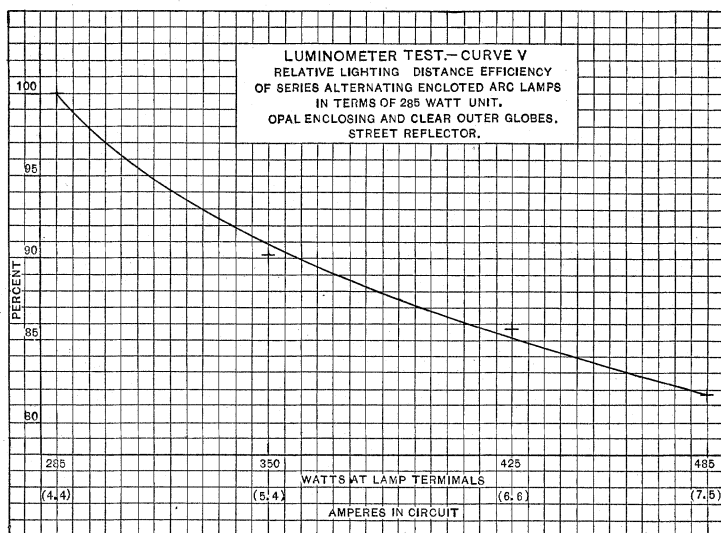


FIG. 7.

High grade carbons are employed in the enclosed arc lamp and the arc is thoroughly protected from the wind so that flickering from the above mentioned cause is entirely absent.

ALTERNATING VS. DIRECT CURRENT ARC.

We are all more or less familiar with the low light-giving efficiency of an alternating open arc lamp. By the introduction of the enclosed lamp with its long arc and opal globe, the difference in lighting efficiency between alternating and direct current has practically disappeared, so that the alternating enclosed arc has about the same illuminating value as a direct current enclosed arc of equal watts.

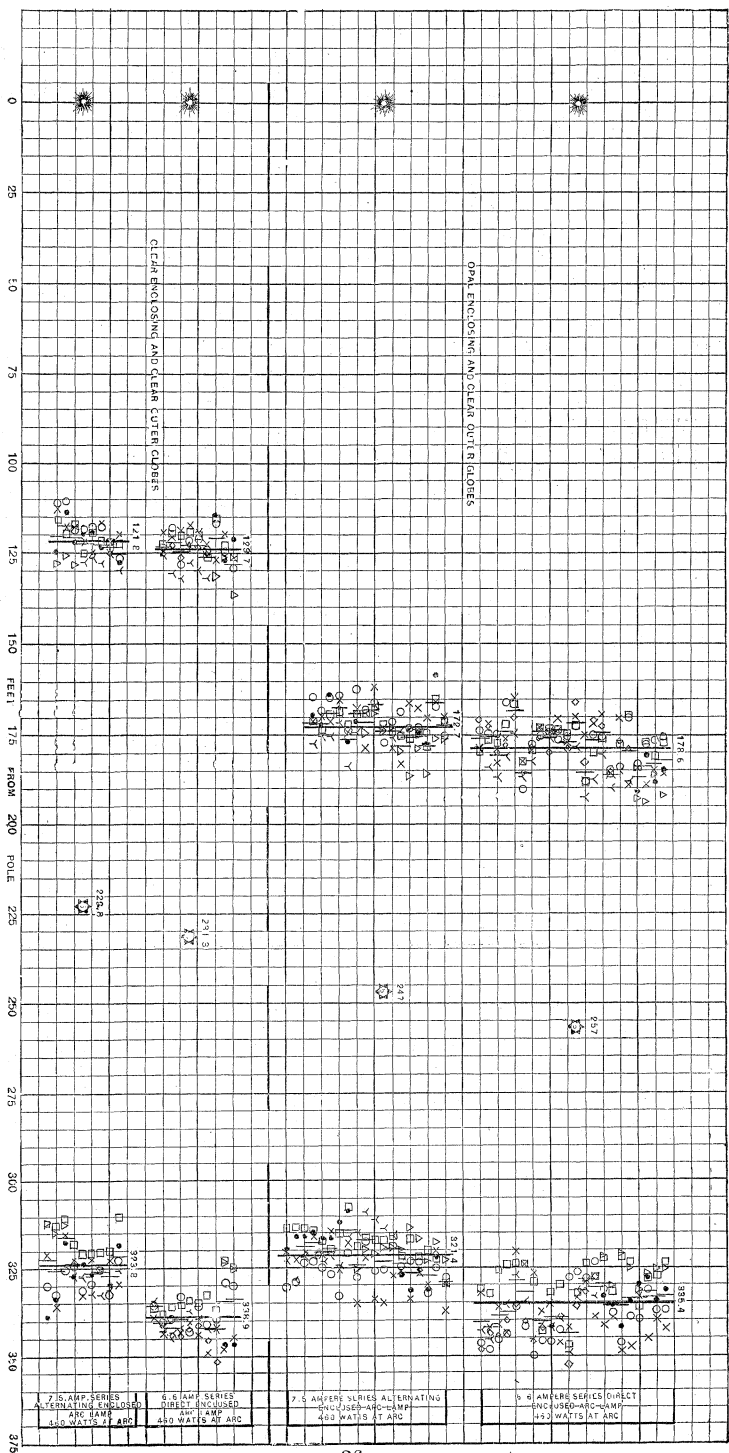
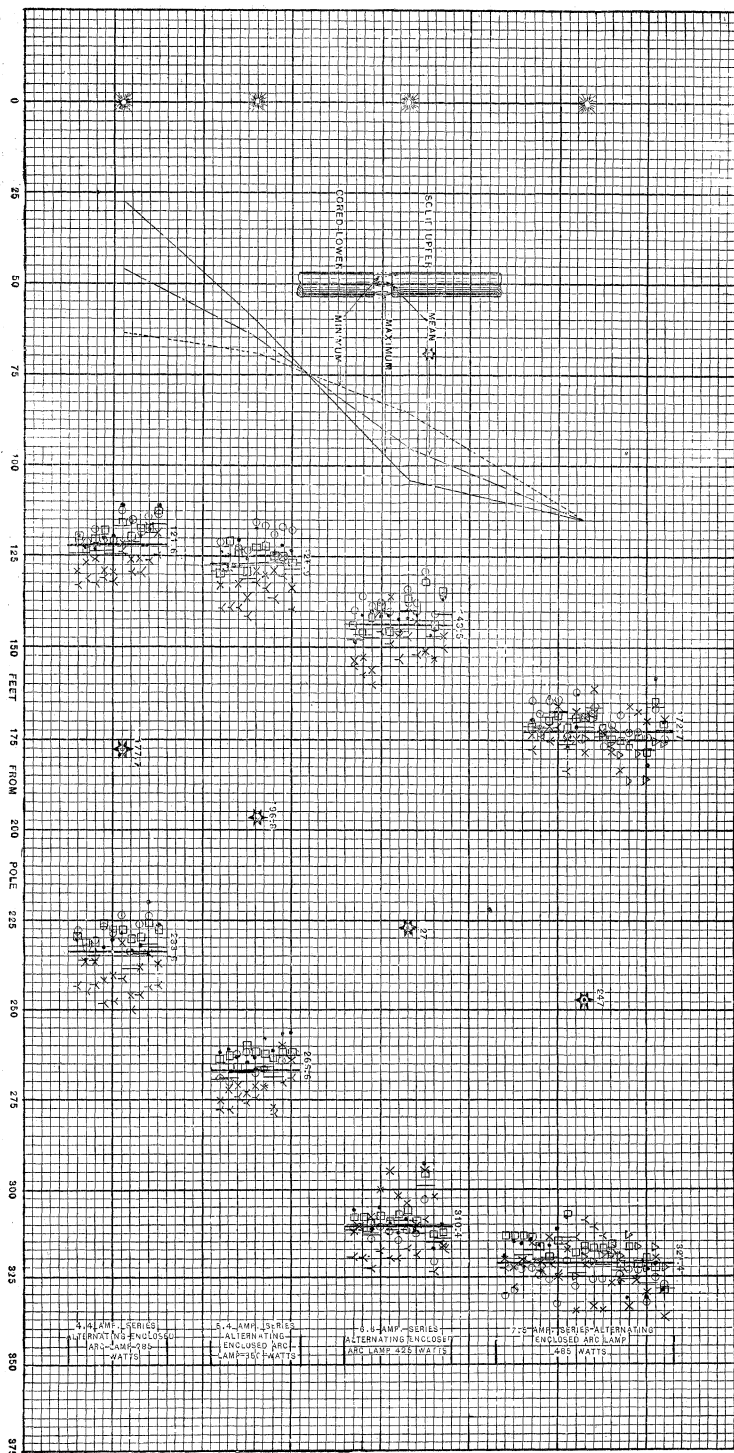


Fig. 8.—Luminometer diagram indicating that alternating and direct current arcs of equal energy will illuminate practically the same distance (Advantage of opal Enclosing globe).



It will be observed from the curves that the alternating arc does not give so high a candle power in any direction as the direct arc, but the distribution is slightly better and the effective illuminating value of the two lights at a point midway between lamps is about equal.

SMALL VS. LARGE UNITS.

In lighting a street we strive to light it uniformly so as to approach a moonlight effect. The employment of small units towards this end forms the basis of a most interesting investigation.

A photometer cannot be relied upon to give sufficiently accurate results for such comparisons, but I have found a small instrument called a "luminometer" very satisfactory. This instrument, while not a scientific piece of apparatus, is of considerable practical value, and it is used to determine the maximum distance a lamp will project a given illumination. A standard illumination of .006 of a candle foot was adopted throughout the tests. For convenience this was designated "star six illumination," and this convention is employed in all the diagrams. Tests taken on different nights and with different observers checked within 2 or 3 per cent. of the mean, and the results can be relied upon as being sufficiently accurate for all practical purposes.

It is quite impossible to lay down a fixed rule for the number of lamps which should be installed per mile, as the location is determined largely by the distance between cross streets, the amount of light required and other local conditions.

Nevertheless, data on the relative lighting distance of various units can be used to advantage.

The accompanying diagrams show the relative lighting distances of 285, 350, 425 and 485-watt alternating enclosed arc lamps. The lighting distance efficiency of these lamps in terms of the smallest unit is respectively 100, 90.2, 85.7 and 81.7 per cent.

For "star six illumination" midway between lamps, we would install 10.7—485 watt units or 14.9—285 watt units per mile.

The former would consume a terminal wattage of 5,180 and the latter 4,235, resulting in a saving of nearly 1,000 watts per mile with the advantage of four more brilliantly illuminated areas in the interval. Further, for 5,180 watts per mile we could install 18.2—285-watt units which would give us relatively eight

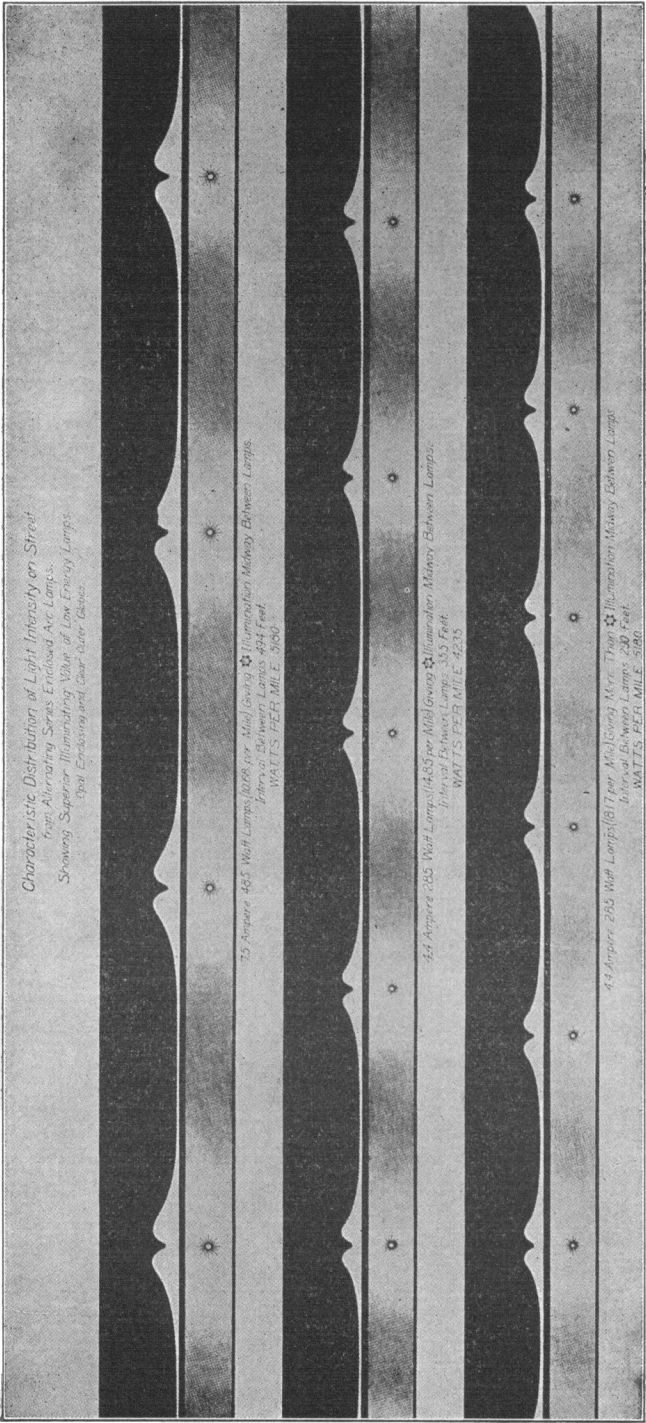


FIG. 10.

more brilliantly illuminated areas in the interval, for the same expenditure of energy and with more than six illumination midway between lamps, therefore, from a light distribution point of view, the advantage of the small unit is established.

While I am not prepared to state that a 285-watt lamp is the lowest practical arc unit, still I believe that this is about as small as can be satisfactorily operated for street lighting. I can say, however, that the argument for small units does not apply to incandescent lamps, because one of the essential requirements for good lighting is the illumination of buildings and other objects on the street to a considerable height above the ground. This requirement is fulfilled by arc lights which flood the buildings with light and thus produce a general diffusion, giving the street an illuminated appearance impossible to obtain with incandescent lamps, even when placed very high, and at such short intervals as to make their use prohibitive from a point of economy. Moreover, the light from incandescent lamps in common with all comparatively low temperature sources lacks the luminosity or brilliancy obtainable from the electric arc, and it therefore cannot encroach upon the arc where a considerable volume of light is required, although it fulfills in a very satisfactory manner a street lighting field essentially its own.

From the foregoing we draw the following conclusions:

- First:—Open arcs give a higher maximum candle power than enclosed arcs of corresponding wattage, but the maximum candle power is in an undesirable direction, and the light fluctuates through wide limits. Enclosed arcs give a higher candle power through the most useful angle, from say 3 to 10° below the horizontal. The light from the enclosed arc is more uniform and steadier and generally superior from an illuminating point of view to open arcs.
- Second:—Direct current enclosed arcs produce slightly higher candle power than alternating enclosed arcs of corresponding wattage, but so far as the illuminating value is concerned, the two lamps are on a fair basis of equality, both being superior to the direct current open arc.
- Third:—Small unit arcs will illuminate proportionately greater distances than large units for a given expenditure of energy.
- Fourth:—Incandescent lamps do not illuminate brilliantly to a sufficient height above the street surface to produce the effect of good lighting, and are therefore not comparable with arc lights.

In justice to the open arc, I wish to state that if we follow European practice, as carried out in large cities, of installing lamps at short intervals, say 80 to 175 feet apart and use more

complicated lamps which work within closer limits when carefully attended to, burn high grade carbons, protect the arc from the wind and use opal globes, the advantage of the enclosed arcs over open, from a light distribution point of view, will somewhat disappear.

Aside from the mere question of light however, there are other arguments for the enclosed arc, particularly with reference to maintenance, convenience and cost of operating, which would throw the balance in its favor even if the open arc were raised to an equal illuminating plane.