SOME INTERESTING PECULIARITIES OF THE ALTERNATING ARC LAMP.

BY THOMAS SPENCER.

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Although arc lighting by means of direct currents has been practised in this country for nearly fifteen years, it is only quite recently that an attempt has been made here to utilize the alternating current for that purpose, although it is a historical fact that the very first attempts made to introduce arc lighting for street illumination was by means of such a current. I refer to the Joblochhoff candle. Joblochhoff found that he had to use an alternating current to make his two carbon pencils, which composed his candle, burn away equally. Since Joblochhoff's time there has been a great deal of work done in Europe, and especially in Germany, where greater progress has been made in the electrical sciences than any other part of the eastern continent, towards utilizing the alternating current for arc lighting, and I have the pleasure of showing you one of the latest productions of that country (both as to lamp and carbon to be used with it) this evening. The lamp itself, though, being an American production, it being manufactured by the Helios Electrical Company, of Philadelphia, under patents of the German company of the same name. This lamp I will speak of later.

As I said before, it is only quite recently that alternating currents have been utilized for arc lighting. The first systematical attempt of the sort was, no doubt, that of the pioneers of alternating currents in this country, the Westinghouse Electrical Company, of Pittsburgh, Pa., when they put upon the market their well-known alternating series system. This was, no doubt, brought about by a circumstance, and that circumstance was the invention by Mr. William Stanley, who was then consulting electrician for

that company, of a wonderful constant current alternating current dynamo. This machine I look upon as one of the most beautiful in its performance of anything in the whole range of electro-dynamic machinery. It was my pleasure to be so situated as to have the handling of two of the first machines of this kind sent out by the company, the performance of these machines were simply wonderful. I have time and time again switched one of these machines from full load; that is, sixty arc lamps, each taking forty-five volts, to a dead short circuit, with only a variation of a half ampère in the current, and this without any mechanical regulation. I would say, in passing, that with this machine the only thing to be feared was an open circuit, and that the safe way to run the machine was dead short circuited.

The principle on which this machine worked was very vaguely understood for some time, the inventor himself having a very complicated explanation, based on armature reaction, but no doubt the correct explanation is this: The machine has an armature of the tooth form, on which there is wound quite a large amount of wire, and as a result the electro-motive force generated by the machine is quite large, but on account of the way the armature is constructed there is a large self-induction. These two factors being so great the actual resistance in the current becomes insensible in comparison with them, so the current is practically independent of the resistance in circuit; or, in other words, constant.

This can more clearly be seen from the following equation:

Where

c , is the current.

E , the electro-motive force.

R , the total resistance in the circuit, including the resistance of the arcs of the arc lamps.

L , the coefficient of self-induction.

$p = 2\pi n$, where n is the frequency.

$$c = \frac{E}{\sqrt{R^2 + L^2 p^2}}$$

Now, if E and L are very large in comparison to LR , we have

$$c = \frac{E}{Lp}$$

or the current is constant, no matter what the external resistance may be, providing it is not too large.

With such a machine the Westinghouse Company thought they had solved the problem of arc lighting by means of alternating currents, but in this they were mistaken; in fact, this was really the easiest end of the problem, and although this machine has now been known for over three years, this system has made little progress, due to

Fig. 1.

the fact that these lamps did not come up to the standard set by the direct system in common use.

The fact is, that here in this country an alternating current arc lamp has been studied entirely in those lines on which a direct current lamp was found to give the best results, while European practice shows plainly that a treatment entirely different should be followed.

Let us study the arcs formed by the two kinds of currents; first, as regards the distribution of their illuminating power.

Let *Fig. 1* represent the two carbon pencils in a direct arc lamp, where the upper pencil is supposed to be positive. Suppose we take a , the arc, as a centre of a circle,

and suppose we plot off on each radii the candle-power in the direction represented by it. Now, if we trace a curve through all the points thus found, we have a curve, as shown in *Fig. 1*, from which we see that nearly all the light is thrown down in the direction *a b*. This is due to the fact that nearly all the light from an arc lamp comes from the crater on the positive carbon.

Fig. 2 shows the curve for an alternating arc, which you see is altogether different from the first curve, there being four wings instead of two, as in the first curve, and these wings are shorter.

This distribution of light, of the alternating arc, has

Fig. 2.

always been looked upon as a failing, for the light represented by the two upper wings is usually thrown up and wasted, especially if the lamp is out of doors. This defect has been in a great measure remedied in the lamp before you, by making the lamp focusing; that is, making the arc remain always in the same place, and using a white reflecting plate close above the arc. This plate will reflect something like eighty per cent. of the light incidenced upon it. There is another point in which there is a great difference in the two currents, it is this: One of the first things noticed about the alternating current, was that there was very little arcing at switches where currents of large ampèrage were broken. This pecu-

liarity was looked upon as a particularly valuable feature for, in the construction switches, the arcing was the principal thing to be guarded against, especially where high voltages were to be broken. I think, with the general introduction of alternating current plants, this property is not appreciated. One has only to stand and watch the arc that follows a plug switch in a direct arc switch-board, where the voltage is not over 2,500 volts and ten ampères, and to imagine what the result would be if the alternating current should suddenly acquire the same property, on some of the beautiful switch-boards for incandescent lighting of about the same voltage and much larger ampèrage, when the switches began to be thrown. There has been a great many theories about this property of the alternating current, but it is about settled that it is due to the fact that at a certain instant there is no current flowing to keep up the temperature of the vapor through which the current is flowing, sufficient to maintain a strong, hardy arc, and as a result it is easily broken. Now, this property, although it is just the thing we want, as far as switches are concerned, is far from desirable when we come to use the alternating current for arc lighting. It is evident from what has been said that an alternating arc is much less hardy than that of a direct current, of the same current density. We see, therefore, that it is a mistake to follow the lines of the direct system in devising an alternating system. What is desired is to get as much heat generated as possible in the flame, so as to keep up the temperature of the vapor through the time when the generation of heat practically stops for the instant. This is best illustrated by *Fig. 3*, where *a a a* is the current curve and *f f f* the temperature curve of the flame for the same instants, and *c c c* the minimum temperatures, which the flame reaches. Now *c c c* will be larger the larger the current, and the arc will be more hardy.

So it would seem that the only way to produce a good alternating arc lamp, is to use a large current, but a large current means a large candle-power, unless we lower what is called the counter electro-motive force of the arc, or the

drop in electro-motive force which occurs at the crater itself. If we refer to *Fig. 4*, where *A* and *B* are the carbon points, the distance between them being exaggerated for convenience, and suppose the drop in potential plotted from one point to the other, assuming *A* the positive carbon, we find for the direct system, at the point *a*; that is, at the crater, that there is a sudden drop of the potential to a point marked *b*. This drop is what is known as the counter electro-motive force of the arc. For the remaining part of the distance the drop is more gradual, and varies as the current. This is the part due to the drop in the flame itself. So it is apparent that if we could reduce the counter electro-motive force, leaving as large a loss of energy in the flame as possible, we would get an arc which would be much less affected

Fig. 3.

than with a smaller current, at the same time without any larger output in watts for the lamp. This has been done in the lamp before you by the use of a special low voltage carbon, which allows this lamp to give an illuminating effect with twenty-eight volts and ten ampères, equal about that given by a forty-five volt seven ampère direct-current lamp. Referring again to the counter electro-motive force, I would say that there has been a great deal of controversy over whether such a thing really existed. I myself am one of the party who believe in its existence. In fact, there is a strong current setting in the direction of that belief. I myself have been convinced that there was a real electro-motive force in the arc by studying the alternating arc itself; in fact, there are reactions in the arc which could only be

explained by the existence of a counter electro-motive force. A gentleman in England, whose name I have forgotten, has recently tried an experiment of heating a carbon juncture in a hydroxygen flame, and was able by this carbon thermopile to get quite a difference of potential between the two carbons. He claims that his results were such as to account for the counter electro-motive force of the carbons had been raised to the temperature of the arc. Also quite recently Sylvanus Thompson has tried quite a number of experiments bearing on this subject, and has come to the conclusion that the electro-motive force is the result of the energy which disappears as latent heat in the volatilization of the carbon in the crater.

There is another peculiarity of the alternating arc which is the most serious objection to it, from a commercial stand-

point, and that is the noise made by the arc. Even this has been attacked, and so overcome that it is no longer the objection it was in the early forms of lamps using alternating currents. The cause of this noise is due to the constant variation of temperature of the flame, as I have described already, which produces an expansion and contraction in the surrounding air. The result is a musical note depending on the frequency of the current. That there is a real rise and fall, even in the light given out by the arc, can be shown by moving a white stick, or better a short piece of white wire moved back and forth rapidly near the lamp, when the white band, caused by the persistence of impression in the eye, will be observed to be broken up into bands, showing that the light is varying with the alternations.

The noise is, I find, a function of the form of the current curve. This came under my notice in trying to substitute a choking coil in place of a resistance to absorb the excess electro-motive force above what was wanted at the arc. I noticed that the noise was considerably increased by the coil over the resistance. You can see that this is the case by the experiment I have arranged before you, which is so wired that either the resistance or coil can be used. You will observe that when the lamp is burning on the coil, there is considerable more noise than when the resistance is in circuit. The reason why this is the case will be explained by referring to *Fig. 5*, where let *a a a* be a simple curve of sines, which is very near the case, with a well-designed alternating dynamo. Let this curve be deformed

Fig. 5.

by the current represented by it, passing through a choking coil with iron. The deformed curve will be something like the curve *b b b*, due to the lack of constancy of the permeability, and to hysteresis in the iron. If we look at this curve we will notice an abrupt rise in it, which means a sudden rise of temperature in the flame; or, in other words, we would have a sort of explosion, and as a result this form of current curve would be more noisy. There is no doubt but the form of the current curve, which would be the best as far as sound is concerned, is that of the simple sine curve, for in this curve the current rises gradually, and sinks away gradually.

One thing which puzzled me for some time was that I found that a choking coil, which contained no iron, even

made more noise than when a resistance was used. As there was no changing permeability or hysteresis, in the arc, the cause for this increased noise was not quite so apparent. The explanation, no doubt, lies in the fact that no machine gives a true sine curve, but in most cases the curve is symmetrical as regards the rise, and fall, as will be seen by the curve *a a a*, *Fig. 6*, which is supposed to be the form of curve given by the dynamo. Now, a choking coil without iron would deform this curve to the form shown in the curve *b b b*, on account of the change of phases which it would bring about in the different harmonics which make up the compound wave coming from the dynamo.

It is found that when the frequency is reduced the noise is greatly decreased; for instance, lamps burned by means

of the current supplied by some dynamos recently turned out by the Westinghouse Electric Company, which have a frequency of 7,200, practically made no noise. On the other hand, Mr. Tesla, by going the other way; that is, by raising the frequency above the audible point, made a perfectly quiet arc, but as high frequency introduced so many other objectionable features, I hardly expect to see this method very extensively introduced.

There is what you might call, still, a mechanical way by means of which the noise can, in a measure, be reduced, and that is by running with a short arc. The reason for this is self-evident, for by so doing you keep the flame well inside the hot walls of the carbon, which do not fluctuate as much in temperature as does the flame; as a consequence

the surrounding air is not so much affected, and the result less noise.

I will say in closing that an alternating arc lamp is something very much to be desired, as it forms one of the links in a chain towards which all electrical engineering is now drifting. I refer to the designing of a central station so that all kinds of electrical work can be done by one kind of current, which can be supplied by one kind of machinery at the central station. Not as now by several different kinds, as I saw to-day, a station using at least five different kinds of dynamos. That the alternating current is to be the current settled upon no one will deny, on account of its great flexibility. Therefore, I believe the alternating arc lamp has a great future before it, even greater than the series arc has had in the past. It, therefore, gives me pleasure to exhibit to you to-night a lamp, which I believe, embodies in its construction the most advanced idea in alternating arc light engineering.

BOOK NOTICES.

Electricity and Magnetism. Being a series of advanced primers of electricity. By Edwin J. Houston, A.M. New York: W. J. Johnston Company, 1893. 12°.

Electrical Measurements, and other advanced primers of electricity. By Edwin J. Houston, A.M. New York: W. J. Johnston Company. 1893. 12°.

The name of Professor Houston, recently elected President of the American Institute of Electrical Engineers, the highest honor within the gift of American electricians, is so widely known, not only as an eminent authority on electrical subjects but also as a scholar and author, that the intrinsic goodness of the above recently-published works might almost be assumed without investigation.

The two works noted above form part of a series of text-books which Professor Houston has in hand, and which are designed to simply and clearly elucidate the fundamental laws of electricity and the principal facts connected with its distribution and measurement. The first-named work is intended to bring out *principles* and *fundamental* facts rather than to have to do with *applications* of principles. Beginning with a brief historical retrospect the main phenomena of static electricity, the nature of insulators and conductors, the phenomena of electric discharges, the various dynamic, thermal and voltaic sources of electricity, are entertainingly and instructively dealt with; following these chapters are others devoted briefly to electro-