

REPORT OF COMMITTEE ON ELECTRICAL DEVICES

MR. HARVEY M. WIBLE, *Chairman*
MR. MAX MAYER
MR. W. G. KUNZMANN
MR. H. A. CAMPE

INTRODUCTION

1. Advantages and disadvantages of alternating current ; How objections may be overcome.
 - (a) Advantages.
 - (b) Disadvantages.
2. Advantages and disadvantages of direct current ; How objections may be overcome.
 - (a) Advantages.
 - (b) Disadvantages.
3. Various methods of changing from alternating to direct current when alternating current is available and direct current is desired.
 - (a) Mercury Arc Rectifiers.
 - (b) Motor Generator.
 - (c) Rotary Converter.
 - (d) Mechanical Rectifier.
4. Various apparatus for obtaining proper arc voltage when alternating current is to be used.
 - (a) Choke Coil or Reactance.
 - (b) Auto Transformer.
 - (c) Rheostat.
5. Determination of proper arc voltage for both direct current and alternating current at various currents.
6. Relation to alternating current of frequency flicker and its synchronization with the shutter.
7. Nature, size and structure of carbons required for both alternating and direct currents for various currents.
8. Proper angle of carbons for alternating current and direct current.
9. Maximum density of current at carbon points in order to obtain maximum efficiency.

In the early days of the motion picture industry, the source of light was, in many instances, of the well known calcium type. Artificial gas, such as acetylene was also used, but as the public became interested in this new form of entertainment and education, the demand for a better form of illuminant necessitated discarding these sources of light. This was due to the increased size of the picture theatres and the demand for larger and better illuminated or more distinct pictures. It was for these reasons, primarily, that the electric arc was adopted for motion picture work.

The electric arc is particularly well adapted to this service as it is one of the most intensely brilliant artificial illuminants known to science. The major portion of the light produced, however, is not obtained directly from the arc, but from the incandescent tips of the carbon electrodes. The brilliant illumination of the film is secured by the condenser lenses which collect a portion of the light produced and converge it through the aperture plate, the illuminated area being generally known as the "spot." It is obvious, therefore, that if the spot is to be uniformly bright over its entire area the source of light must be concentrated in a fixed and as small a point as possible.

1. (a) The earliest current supply used for an electric arc for a light source for projection work was alternating, due to the fact that alternating current is more widely distributed and therefore, more readily available, and also because control apparatus for alternating current was simpler, more easily designed and less expensive. It is practically impossible to find direct current mains everywhere, except in the centers of some of the large cities, while alternating current is available at practically all places where there is a sufficient number of people to warrant the establishment of motion picture houses. The apparatus for the control of alternating current for an alternating current arc is simple, comparatively inexpensive, and on the market in a variety of forms readily available for practically any current throughout the range of application. The advantage of alternating current from a carbon standpoint lies only in the efficiency of the supply to the arc. By means of a transformer, reactance, etc., the line voltage can be very readily reduced to any value required by the arc with very little loss of power.

1. (b) That the arc produced by alternating current is not so satisfactory as the arc produced by direct current is quite generally recognized. This fact is due to a number of physical characteristics of the alternating current arc. (1) Both electrodes are heated almost uniformly, producing practically equal illumination. However, only the incandescent tip of one carbon can be located at the proper focal point for the condenser lenses. (2) The average temperature of the crater is comparatively low on account of the rapid transfer of this crater from one carbon end to the other. (3) If an improper revolving shutter is employed or if a satisfactory shutter is operated at other than correct speed, the pictures will have an undesirable flicker, due to the fact that the value of the alternating current is zero twice

each cycle of 120 times for a 60 cycle circuit. (4) The alternating current arc has a greater tendency to travel around the ends of the electrodes, which constantly shifts the incandescent area of the carbon tips, thus producing "ghosts" on the screen. (5) The light produced by alternating current has a preponderance of the violet end of the light spectrum, which is not so desirable as the yellow, from an optical point of view. (6) The cost of power for the alternating current arc is high, because the current required to produce a given illumination is about three times greater than the direct current required. From a carbon point, the disadvantage is chiefly in operation. The very highest grade, and therefore costly, carbons are required. The very short arc required for satisfactory operation means constant attention on the part of the operator. Further, the high currents necessary to get the degree of illumination now considered desirable, renders such an arc very noisy, which in itself is a hardship on the operator.

2. (a) The advantages of the direct current arc can be briefly stated as being converses of the disadvantages which have been cited for the alternating current arc. Careful experiments have demonstrated that the light resulting from a direct current arc is produced by the crater on the positive carbon, by the incandescent tip of the negative carbon, and by the arc stream proper, in the proportions of 85 per cent., 10 per cent. and 5 per cent., respectively. The crater is of comparatively small area and can therefore be located at the proper focal point of the condenser lenses. This explains the fundamental advantages of the direct current arc. The ease of operation, requiring little attention from the operator and the inherent stability and good operation of the direct current arc over wide range of arc voltages, makes this form of current ideal. Very high arc wattages can be made use of on direct current to obtain the illumination essential for very large pictures, but which would hardly be feasible to attempt with alternating current, so that in the field of projection in the large picture houses, direct current is supreme.

2. (b) The disadvantage of using direct current is primarily in the cost of converting appliances to change from alternating current to direct current, or if operating directly from 110 volts direct current, the entire line voltage enters into the cost consideration, since whatever energy is not used in the arc must be dissipated in resistance.

3. (a) If an alternating current supply system only is available and direct current is desired for the projecting machines, it is necessary to install equipment which will rectify or convert the alternating current to direct current. There are numerous types of equipment available for this service, such as Mercury Arc Rectifier, Motor Generator Sets (of which there are two classes, namely, constant potential and constant current), Rotary Converters and Mechanical Rectifiers. When any one of the various types of converting equipments is used, with the exception of the Mercury Arc Rectifier, it is advisable to provide for "break down" service, so

that if the auxiliary equipment is disabled, the projectors may be operated temporarily with alternating current.

4. When alternating current only is available, and is to be used, the apparatus for obtaining the proper arc voltage may consist of a choke coil, reactance, transformer or rheostat. The transformers ordinarily used are of the single winding or auto type designed with sufficient reactance to stabilize the arc. A standard double winding transformer having suitable voltage characteristics could be used, providing a suitable reactance coil is connected in series with the arc. Rheostats should not be considered on account of their extremely low efficiency.

5. On Alternating Current a very short arc must be maintained; we cannot deviate from this operating condition. The arc voltage is, therefore, settled for the operator and usually is between 33 and 39 arc volts; that is, at a very short arc just after feeding, the voltage may be 33 and as the arc length increased with the burning of the carbon, the arc voltage will increase to a value of about 39 volts, if the arc is permitted to get any longer we find an immediate irregularity and unsteadiness in the arc. It will be found in practice that an Alternating Current will require feeding every 75 seconds. On Direct Current we have an inherently steady arc; that is, inherently steady as compared with an Alternating Current. The range of arc length and arc voltage can be made whatever the operator desires within certain limits, but there is one fact to be borne in mind, and that is, that for each given current value there is a definite arc length and arc voltage at which we have the most efficient operation. This can be determined in the following manner: Set the Carbons for a constant current, then shorten the arc length gradually and you will finally produce an unstable, noisy arc. Just previous to that point is the minimum limiting arc length for that given current and given carbons. Likewise, take a given arc length and increase the current until a noisy and unstable arc forms, then decrease the current a trifle and you will have the condition of maximum efficiency for that arc length. Because of the fact that a given arc length can only accommodate a certain maximum amount of current, it can readily be seen that we must increase the arc length each time we increase the current. Arc length is of course synonymous with arc voltage, so wherever we have mentioned increasing arc length we can say increasing arc voltage. So making this change in nomenclature we can make the statement that increasing current values in an arc requires an increased arc length and voltage. In actual practice it is found that there is some variation in the arc voltage for a given current with the make of the carbons and the combinations used, so that the voltages which we have listed are averages which are built up on the principles given above.

For direct current combinations using the ordinary positive carbons as indicated in the table and matching them up with plain negatives "Group A" we have a table of voltages as indicated in the following table marked "Group A" Negative Voltages :

	Group A Negatives	Group B Negatives
Amps.	Arc Voltage	Voltage
30	52	52
40	55	54
50	58	56
60	61	58
70	64	60
80	67	62
90	68	64
100	69	66

In the above table, the table of voltages given for the combinations in which the positives are matched up with small negatives of "Group B" it will be noticed that these voltages are somewhat less. It has been found in actual practice that a well shaped crater can be obtained at these lower voltages with negative carbons of diameters which are one-half that of the positive. The usual size negative is approximately two-thirds the diameter of the positive. These special small negatives are metal clad in order to give them carrying capacity and life since they are operated at current densities far beyond their possibilities were they not metal clad.

6. The electric arc when operating on Alternating Current is known to possess the peculiarity of varying in intensity to a marked degree with the peak and zero points of the alternations; being clearly visible to the eye on frequencies under 40 Cycles.

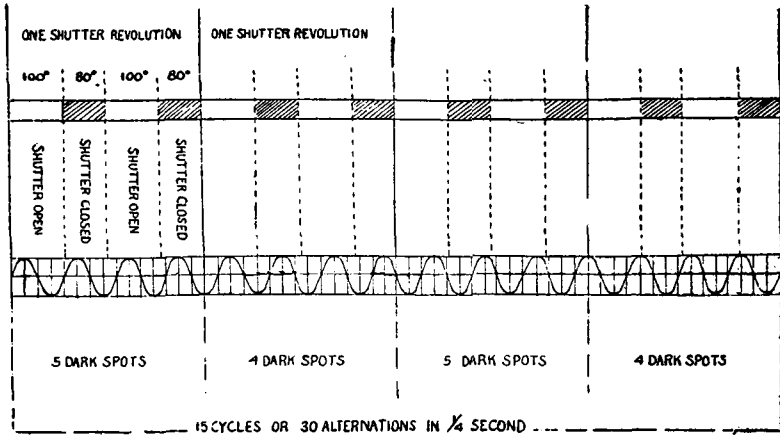
At commercial frequencies higher than 40 Cycles, this may be visibly demonstrated by moving under the arc a light colored pencil, or other object, against a dark background. When moved rapidly under direct sunlight or direct current arc, the pencil would naturally appear blurred, owing to the rapid change of position. Under the alternating current arc, the rapidly moving pencil would seem to be a number of pencils, each one clearly visible, with dark intermediate spaces. This is precisely the same effect as is obtained by moving the pencil in the light beam of a projector with the shutter revolving.

In reality, we are therefore dealing with two intermittent periods in the light source, when operating a film projector with an alternating current arc; namely, the light interruption of the shutter and the rise and fall of the light intensity of the arc. The former depends for its frequency upon the speed of rotation of the shutter and the number of wings therein; while the latter depends upon the frequency of the current.

In determining the relation between current frequency and shutter movement, we might for example imagine a shutter with three 60-degree openings and revolving at 40 revolutions per second.

This would give us 120 dark spots per second. An arc lamp on 60 cycle current would also have 120 dark spots per second. It is therefore evident that under these conditions, if the shutter opening occurred at the same instant at the zero point of the cycle, practically

no light would be obtainable on the screen; as the shutter wings would block out the light each time it occurred.



If now the shutter be moved 60 degrees on its shaft, the maximum light would be obtained, as then the shutter openings would register with the peaks of the current alternations. These conditions, of course, would prevail only if the shutter and current were perfectly synchronized. If the speed of the shutter were reduced to 20 revolutions per second, 4 peaks at each opening.

While the 60 cycle current prevails in practice the aforementioned speed and shutter openings do not; consequently, at the normal shutter speed of 16 revolutions per second, the shutter openings would be out of step with the current frequency, with the result that some of the shutter openings would receive one, some two and some three impulses of light, causing a visible variation of light on the screen.

Since each projected image is illuminated for a time period equal to the sum of all the shutter openings during one revolution, the light impinged on each image would be the same if the light source were constant. With the alternating current arc, the light would vary with the number of peaks to each respective image, the variation and resulting flicker depending upon actual difference in frequency of shutter flicker, or in other words, depending on how much they are out of step.

The following diagrams show these variations under the normal conditions of a projection speed of 16 images per second, with a 60 cycle arc, and using a commercial shutter of two 80-degree wings with two 100-degree openings.

It is obvious from the above that a current flicker can be avoided in alternating arc projection, only by occasional accidental synchronizing for short periods of time, or by a carefully planned synchronization, together with special shutter design.

It is evident that current flicker is an inherent objection to alternating current arc projection. There are other faults better known, such as the bluish color of the light, the poor concentration of light at the light source focus of condenser, and the noisy hum of the arc.

Without entering into details of these other objections, which are apart from the subject matter of this paper, the mention of them seems permissible, as it completes the evidence against alternating current projection, and proves its use poor practice.

Since the direct current arc possesses none of these objections and since a large variety of thoroughly satisfactory and practical apparatus is on the market for converting alternating current to direct current, there seems to be no excuse for faulty projection, resulting from the use of alternating current.

For alternating current, cored carbons in both upper and lower are always used and these are the same size. This is essential, of course, since the rate of consumption is practically the same for both the upper and lower carbon. On direct current some operators use cored carbons, both upper and lower, and also use the same size carbon for the positive as well as the negative.

While it is sometimes desirable to use cored carbons, both positive and negative, it is the wrong principle to use the same size—the negative carbon should always be smaller than the positive.

For all around service the most advisable ratios will be such that the cross section of the positive carbon would be twice that of the negative carbon, but in actual practice we find that a negative carbon would not have the carrying capacity for the current required for the positive, if the latter were operated at maximum current density. Therefore, the following combinations are a compromise which have been standardized for various current densities. These are as follows:

MAXIMUM CURRENT.

Size	Alternating Current	Direct Current	Plain Direct Current	Negatives	Metal Coated Neg. Dir. Cur.
1"	100	85-100	3/4 Cored or sol.	3/8 sol. spec. coated	
7/8"	90	65-85	3/4 " " "	3/8 " reg. "	
3/4"	75	50-65	5/8 " " "	11/32 " " "	
5/8"	60	50	1/2 " " "	5/16 " " "	
9/16"	50	40			
1/2"	40	35			
7/16"	25	25			
3/8"	15	15			
5/16"	10	10			
7 mm	8	8			
6 mm	6	6			

In the table of direct current capacities, from the 5/8" size up, the next smallest sized solid carbon is used as the negative.

Cored negative carbons give steadiness at the cost of the candle power of the arc. Under certain conditions it is possible to operate carbons at somewhat higher current densities than here given and still obtain satisfactory service. It is, however, essential, in order to

operate at these higher current densities, that special small diameter metal coated negative carbons be used, the reason being as already mentioned that such combinations can be operated at high current densities, with short and steady arcs free from noise, whereas for the same current density and the use of ordinary negatives, the arcs would be unsteady.

8. Since the light from the direct current arc is emitted from the crater of the positive carbon, it is desirable that the carbon be tilted at such an angle as to point the crater directly at the lens, and still prevent the lower carbon from cutting off the light. An angle of about 25 degrees has become standard for this service. With an alternating current arc the light is given by both carbons, which means that it is desirable to use the carbons more nearly vertical. A slight angle is, however, necessary in order to make draft conditions correct.

9. With Alternating current the carrying capacity is limited by the ability of the carbon to carry the current, whereas on direct current, it is limited by the ability of the crater to stand up under high current densities; that is, the 5/8" carbon can carry 60 amperes alternating current without undue heating, but on direct current 50 amperes would be the limit, since a higher current value would tend to break down the crater formation with subsequent unsteady operation.