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**ENGINEER RESEARCH
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Report 1167

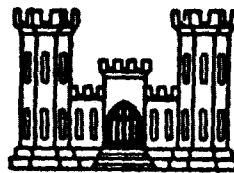
DISK TYPE NEGATIVE ELECTRODE

FOR CARBON ARC LAMPS

Project 8-18-00-001

2 May 1956

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CORPS OF ENGINEERS
ENGINEER RESEARCH
AND DEVELOPMENT LABORATORIES**

**THE ENGINEER CENTER
FORT BELVOIR, VIRGINIA**

ENGINEER RESEARCH AND DEVELOPMENT LABORATORIES

Report 1167

DISK TYPE NEGATIVE ELECTRODE
FOR CARBON ARC LAMPS

Project 8-18-06-001

2 May 1950

Submitted to

THE CHIEF OF ENGINEERS, U. S. Army

by

The Commanding Officer
Engineer Research and Development Laboratories

Prepared by

Louis R. Noffsinger
Radiation Branch
Engineer Research and Development Laboratories
Fort Belvoir, Virginia

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DISK TYPE NEGATIVE ELECTRODE
FOR CARBON ARC LAMPS

I. INTRODUCTION

1. Subject. This report describes a disk type negative electrode developed to achieve long uninterrupted burning life of the negative electrode in a super-high-intensity carbon arc lamp operating in the current range of 150 to 200 amperes.
2. Authority. The development of the disk type negative electrode was carried out in connection with Project 8-18-06-001, General Purpose Searchlight Equipment.
3. Persomnel. The Project Engineer in charge of the development was Louis R. Noffsinger, Chief, Illumination Laboratory, Radiation Branch. George W. Franks, Chief, Engineering Section, Radiation Branch, and Lt Claude H. Orr, Radiation Branch, assisted; Dr. Wolfgang Finkelburg acted as consultant.
4. Background. No known light source equals the carbon arc lamp in producing the high beam candlepower required for military searchlights. This type of lamp, however, has disadvantages, one of the most obvious being that the rapid consumption of the carbon electrodes makes stoppages necessary for their replenishment. This defect becomes even more of a problem when the modern, more efficient, super-high-intensity, small diameter, carbons are used because their consumption rate is considerably higher than that of the carbons currently used in the present military searchlight.

The general-purpose searchlight now being developed will be much smaller and lighter than present 60-inch searchlight equipment without sacrificing beam candlepower and lumens. It will therefore utilize the small, modern type of super-high-intensity carbon. The new searchlight must, however, operate for at least 90 minutes and preferably longer without stoppages. Hence, methods must be devised to achieve long uninterrupted burning life of both the negative and positive electrodes used in the lamp of this searchlight. As a solution to obtaining the desired characteristics in the negative electrode, the use of a carbon disk and suitable systems for its control were investigated.

II. INVESTIGATION

5. General. The disk type negative electrode is not new; it was used by the British during the last war in a very high

current (4000 ampere) arc lamp and by Dr. Gretener of Switzerland in a unique air-blown arc. The British arc is a sputtering unstable arc but useful for their application of the lamp; the Gretener arc is unique for its air blast stabilization augmented by a magnetic field. No record was found in the literature of a disk type negative electrode being used in conventional arc lamps which operate in the current range of 150 to 200 amperes. The problem was to determine if the disk electrode could be adapted to this type of lamp and, if so, what difficulties would arise.

6. Preliminary Investigation. It is obvious that a disk type negative electrode requires rotation to obtain use of the entire periphery. This rotation is analogous to the feeding of the conventional rod electrode. A conventional arc lamp was modified by removing the negative carbon feed assembly and replacing it with a device that would hold a 12-inch carbon disk as shown in Fig. 1 and which would allow the disk to be manually rotated. The arc gap or distance between the tip of the positive carbon and the edge of the negative disk was the same as that between the tips of the rod type electrodes normally used in the lamp. The arc with the negative disk was started in all of the tests with a hand-held third electrode which was momentarily held across the arc gap. The initial tests with this lamp operating in the range of 150 to 200 amperes indicated the following:

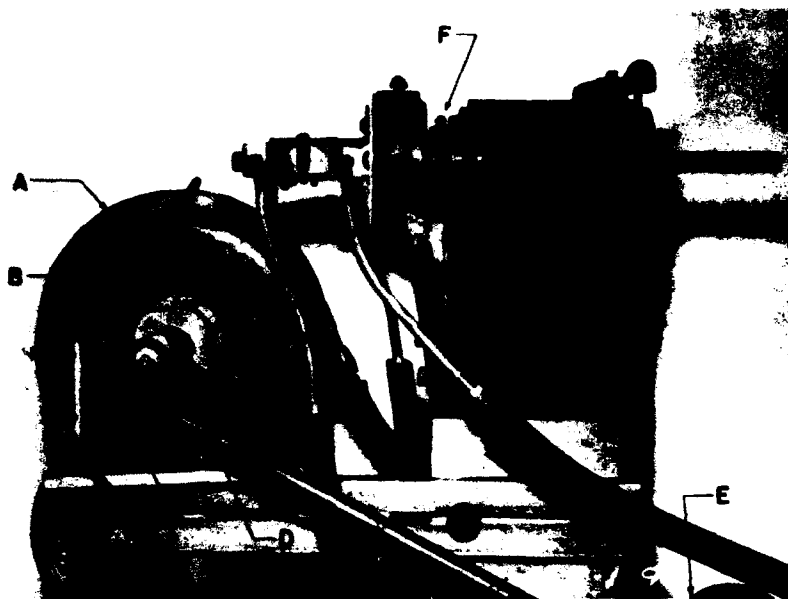
a. The base of the arc, the point at which the arc flame touches the edge of the disk, moves slowly but non-uniformly along the periphery of the disk away from the positive carbon (to the left in Fig. 1). This effect is caused by magnetic fields formed by the arc current. (For convenience, the base of the arc is called the footpoint in the remainder of this report.)

b. The arc operated best when the footpoint was on a line connecting the center of the carbon disk and the tip of the positive carbon. This condition could be maintained if the disk were rotated so that the edge of the disk moved at the same rate and in the direction opposite to the movement of the footpoint. This was difficult to do with a manually operated rotational device.

c. The arc had good stability and, if the footpoint was kept on a line connecting the center of the carbon disk and the tip of the positive carbon, operated as would an arc with the conventional rod type electrode.

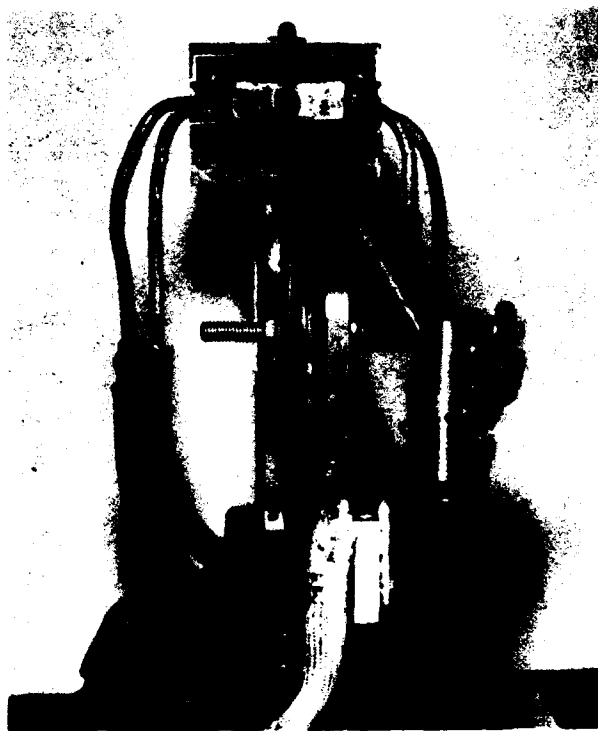
7. Design of Automatic Rotational Control Mechanism for the Disk Electrode. Two methods to accomplish automatically the rotation of the disk (subparagraph 6b) were considered:

a. To set up an optical system that would focus an image of the footpoint on a heat or light sensitive element which,



162-1-97

Fig. 1. Side of 12-inch disk electrode, showing (A) carbon disk, (B) conducting probe, (C) final gear reduction, (D) drive shaft, (E) motor, and (F) positive carbon feeding mechanism.



162-1-96

Fig. 2. Front of 12-inch disk electrode showing probe, or third electrode (top right of center), which controls rotation of disk.

in turn, would control the disk rotation so as to maintain the image in a fixed position with respect to the sensitive element.

b. To take advantage of the facts that a potential difference exists between the tip of the positive electrode and any part of the arc stream, and that current can be drawn from the arc by introducing a conducting probe into the arc flame. The use of a conducting probe method was tried first because of its apparent simplicity. Figs. 1 and 2 show the experimental carbon arc lamp with such a control device. Fig. 3 illustrates the details of the negative disk assembly. The position of the probe can be seen from these photographs. One side of the armature winding of a 1/50-hp, 65-volt, shunt wound, d-c electric motor was connected to the probe. The other armature terminal was connected to the positive terminal of the arc lamp. The field winding was connected to the arc lamp terminals. The motor was mechanically connected to the shaft on which the disk was mounted through two gear reductions with a combined ratio of 2610 to 1. Connections were made so that the top of the disk would rotate towards the positive carbon when an electrical circuit was completed between the probe and the negative power. The disk was mounted on a 3/8-inch brass shaft which turned in a brass sleeve bearing. In the initial tests the arc current was carried through the sleeve bearing surface. No difficulties were encountered with this; however, good practice dictated a slip ring or brush arrangement (Fig. 3). A flat spring washer maintains a firm contact between the large flat current carrying disks, which are made of brass.

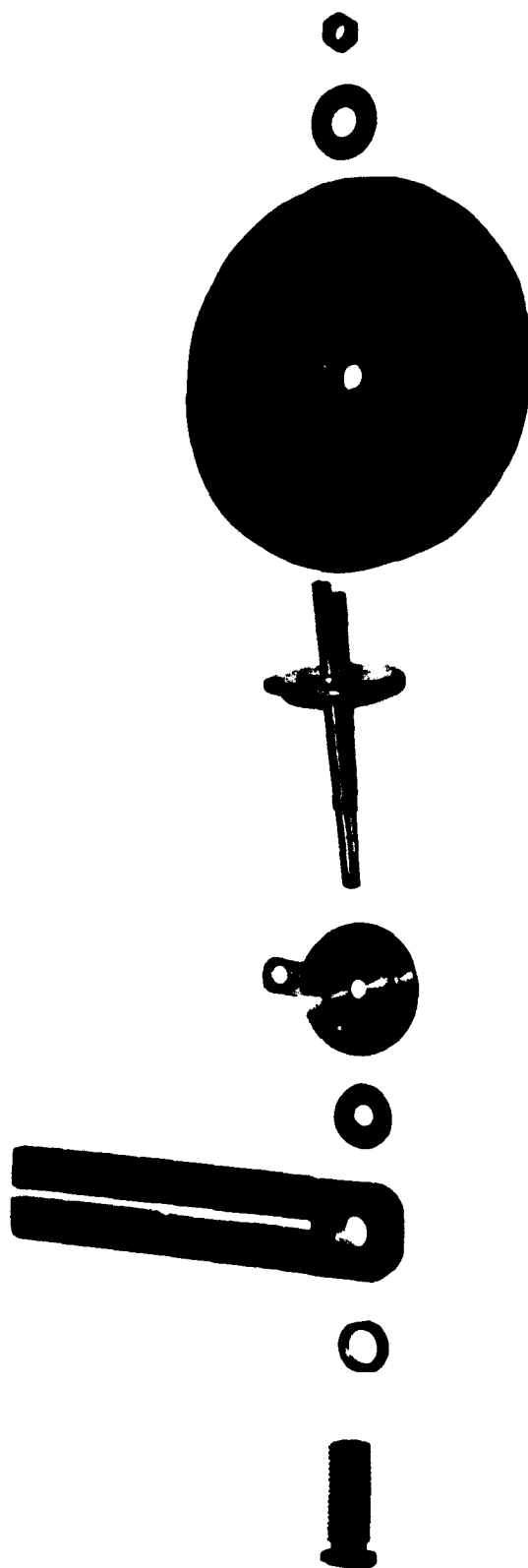
The positions of the arc flame and probe are shown in Fig. 4. The footpoint moves along the edge of the disk away from the positive carbon; when the probe is positioned as shown, such a movement will cause the arc flame to contact the probe, thereby establishing an electrical circuit between the probe and the negative power. This energizes the motor armature causing the motor to rotate the disk in the proper direction to carry the footpoint back to the position shown in Fig. 4. In actual operation the system establishes a balanced condition and the disk rotates at a fairly uniform rate.

8. Tests of Arc Lamp with Automatically Controlled Rotating Disk Negative Electrode. The automatic rotational control mechanism for the disk negative electrode was installed on the test carbon arc lamp, and tests were made to determine:

The best position for the control probe.

A suitable material from which to make the control probe.

Ability of the control system to maintain a stable arc.



162-1-99
Fig. 3. Parts used to make up negative disk assembly. Left to right: sleeve bearing, lock nut, support, spring washer, current carrying slip ring, shaft, carbon disk, washer, and nut.

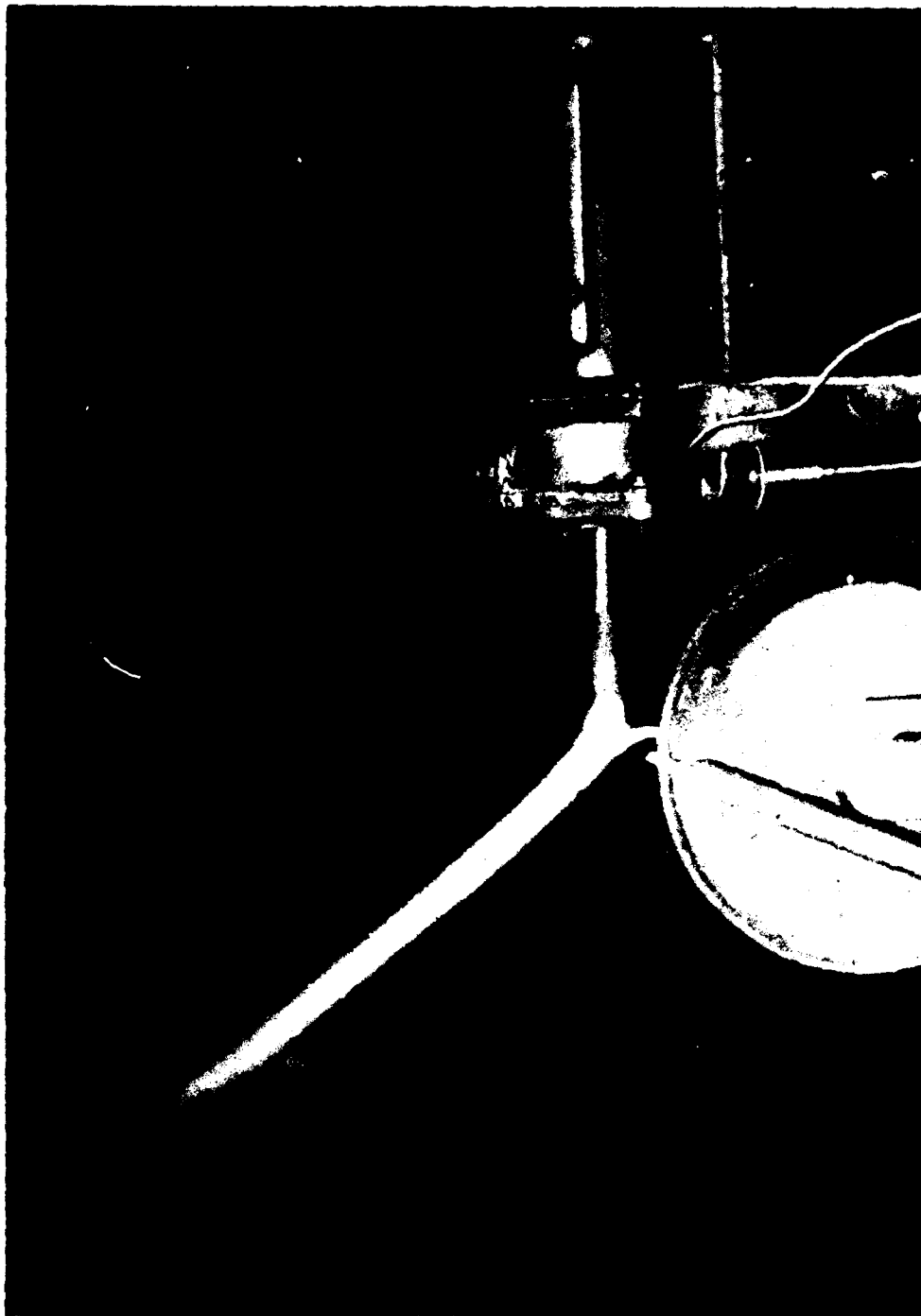
The life of the disk type electrode.

The current carrying ability of the disk.

a. Best Position for Control Probe. Experimentation showed that the best position for the tip of the control probe for a lamp made to operate between 150 and 230 amperes was found to be as shown in Figs. 2 and 3. The tip of the electrode is approximately $1/4$ inch above the edge of the disk, about $1/2$ inch from the footpoint (Fig. 4) and not more than $1/16$ inch to the side of the axis of the arc. The position, however, was not critical, the only requirement being that the arc stream would make good contact with the probe if the footpoint moved. Voltage measurements showed that the voltage applied to the motor armature varied between zero and 16 volts with a negative disk 12 inches in diameter when the arc was operating at 170 amperes. The rate of movement of the footpoint was found to be approximately 3.5 inches per minute at 160 to 170 amperes, regardless of the diameter of the disk.

b. Probe Material. The different types of probes used are shown in Fig. 5. A carbon electrode was first employed but was discarded because of very rapid deterioration. This probe did, however, control the rotation of the disk satisfactorily as long as the tip was in the proper position. A metal probe, made of a copper rod $5/8$ inch in diameter with a tungsten tip $3/16$ inch in diameter protruding $3/4$ inch from the end of the heavy copper rod, was tried next. This probe showed very little deterioration. One of these probes was used over 20 hours with no appreciable shortening of the tungsten tip. A third type of electrode, made of a $3/4$ -inch monel metal rod and shaped as shown in Fig. 5 with a tip $1/4$ -inch in diameter, was used for more than 6 hours without noticeable deterioration.

c. Arc Stability. The disk type negative introduces one new factor affecting arc stability, that being the requirement that the control mechanism should maintain proper arc alignment. Tests were conducted wherein the same positive carbon was operated at 170 amperes with a disk type negative and a rod type negative 9 mm in diameter. A barrier layer type photocell was placed in front of the arc, that is, viewing the arc crater, while a light baffle shielded the cell from all light emitted by the tail flame. Fig. 6 shows typical 1-minute records of the photocell current for each type of arc. The fluctuation in the photocell current represents fluctuation in the light emitted by the arc. A study of these two representative records shows that there is very little difference in the steadiness of the two types of arcs. The position of the footpoint was held to within $\pm 1/16$ inch by the control device when properly adjusted. Apparently this slight variation in the position of the footpoint introduces no abnormal variations in the arc.



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Fig. 4. Disk type negative electrode in operation on a test lamp showing relation-
ship of parts and characteristic flame.

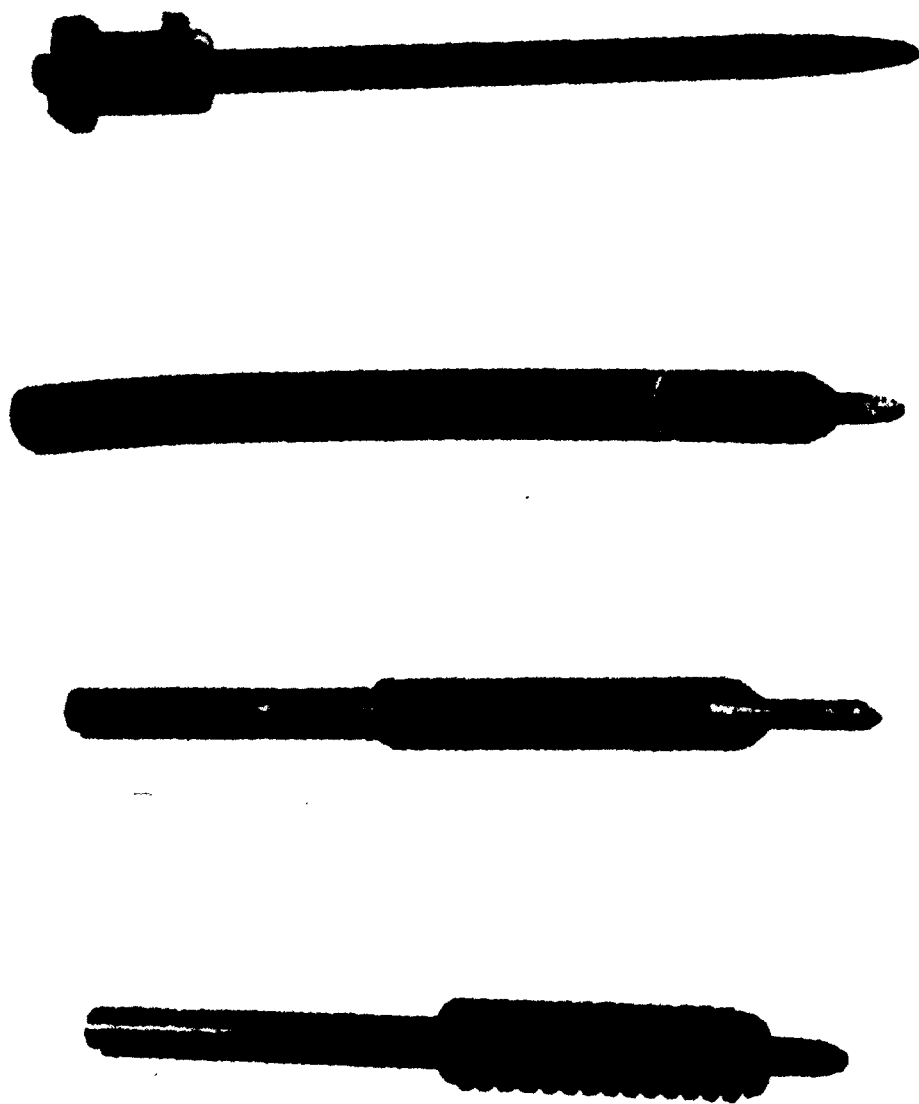
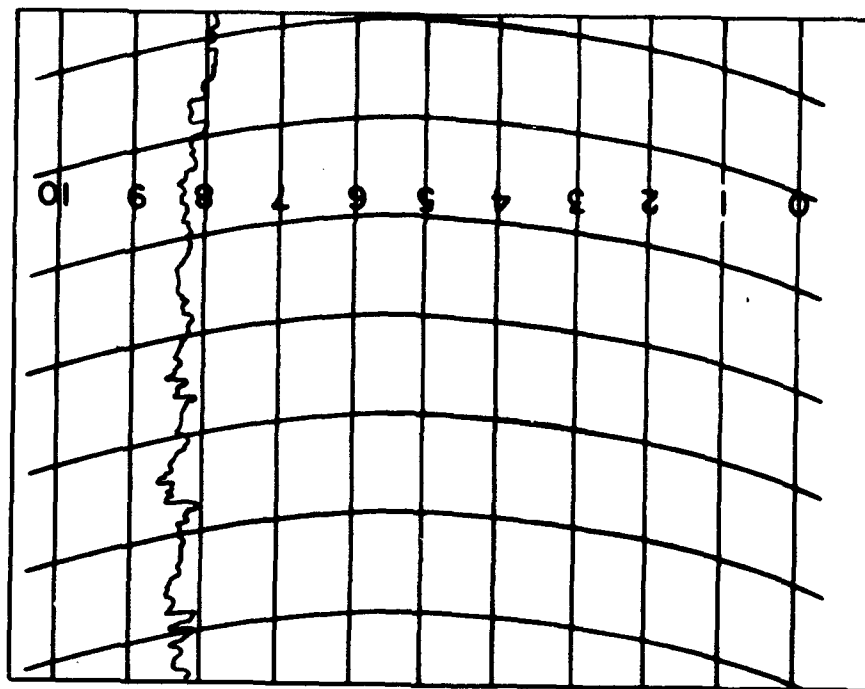
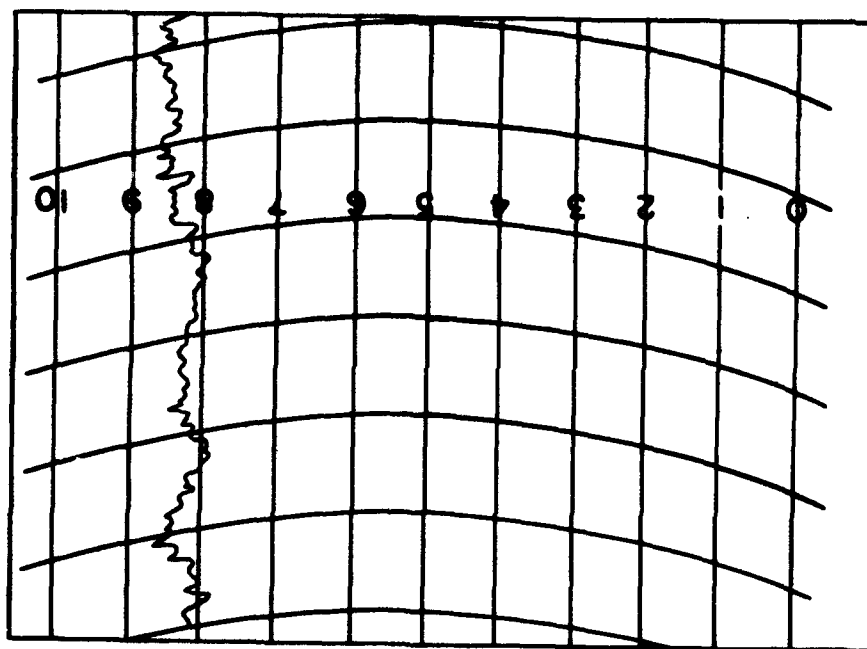


Fig. 5. Probes (third electrodes) used during tests. Left to right: monel, copper
162-1-100
body tungsten tipped, copper body tungsten tipped, carbon.



(B) Rod negative



(A) Disk negative

Fig. 6. Records of arc steadiness.

Visual observation of the two arcs revealed no apparent difference in the steadiness of the two.

d. Life of the Disk Type Negative Electrode. The life of the disk type electrode at a given arc current depends upon its maximum and minimum operating diameters, the thickness of the disk and the consumption rate, that is, grams of carbon consumed per minute. The maximum and minimum diameters of the disk are a function of the lamp design. The largest diameter used in the test was $12\frac{1}{4}$ inches. The smallest diameter used was less than 5 inches. No difference in arc performance was noted as the diameter of the disk was reduced. The thicker the disk the longer the life of the electrode; however, tests indicated that at 160 to 170 amperes the arc tended to wander laterally across the edge of the disk when a disk thicker than $1/4$ inch was used. The consumption rate of the $1/4$ -inch thick disk at 160 amperes was approximately 0.15 gram per minute or 9 grams per hour. At this consumption rate a 12-inch disk, $1/4$ inch thick, would be reduced to a 5-inch disk in 69 hours. No disk was actually operated for that long a period; however, one was operated for 10 hours at between 160 and 170 amperes. The diameter of this disk was reduced by $25/32$ inch in that time. Even though the arc length and probe position were not adjusted to compensate for this reduction in disk diameter the arc operation was good throughout the 10-hour period.

e. Current Carrying Ability. The disk electrode because of its relatively large current carrying cross-section was free from overheating when the high arc currents are used. No temperature measurements were made; however, it was noted that at no time did the electrode become incandescent except in the very small area called the footpoint.

III. DISCUSSION

9. Applications. These tests indicate that the disk type negative electrode has definite possibilities as a solution for a long life negative electrode. The only apparent limitation on life is the maximum size of the disk permissible. This long life can be obtained without changing the performance of the arc and without the complication of a magazine feed for the negative electrode. In addition to offering a method of obtaining long uninterrupted periods of operation with a carbon arc lamp, this electrode is remarkably free from overheating when high arc currents are employed. For these reasons, this type of electrode should be considered whenever an arc lamp is to operate for long uninterrupted periods of time; whenever a high current arc is being considered; or whenever both high current and long electrode life are desired.

10. Shadow Effects. Any arc mechanism will necessarily shadow the light coming from the arc toward the reflector and will also shadow the light reflected by the reflector into the beam. A well-designed lamp should cause minimum shadow effects in order to obtain maximum effective reflector area and maximum candlepower. The disk negative casts slightly more shadow on the reflector than the rod negative; however, losses from the two types of negatives are largely the same because the lamp supports intercept light reflected from the zone of the mirror shadowed by the disk negative electrode. Therefore, it is considered that the shadow losses from a disk electrode arc mechanism should be very little greater, if any, than the shadow losses from a conventional rod negative arc mechanism. However, no quantitative measurements of comparative shadow losses have been made.

11. Further Investigations. Although sufficient information is now available to design an arc lamp that will operate properly with the disk type negative, further investigation of the effects of extremely high current might prove valuable. Arc lamps operating at more than 400 amperes tend to become unstable because of a winding or spiral effect of the arc stream.¹ A study of the cause of this winding effect indicates that the disk shaped electrode with its rotation may prevent the undesirable spiraling in the arc stream. Further investigation should be made to determine the minimum disk thickness permissible consistent with good operation at various currents since a thin disk will reduce the shadow effect and possibly increase stability. Another problem, the solution of which would directly benefit the general-purpose search-light program, would be to devise a way of substituting a controllable clutch for the electric motor now used to drive the negative disk. Such a clutch (perhaps a magnetic clutch) would be controlled by the position of the footpoint, possibly by the control probe voltage and would transmit power to the disk from the motor normally used to drive the positive electrode feed mechanism. This device would eliminate one motor but would prove valuable only if it were cheaper, simpler, and more dependable than the motor it would replace.

IV. CONCLUSIONS

12. Conclusions. It is concluded that:

a. The disk type negative electrode provides the following advantages over the rod type negative electrode:

1. Wolfgang Finkelburg, Field Information Agency Technical Final Report 1052, Office of Military Govt for Germany (U. S.), The High Current Carbon Arc, page 127.

(1) Long, uninterrupted burning time without the use of a complicated magazine feed mechanism.

(2) Ability to carry very high currents without overheating.

b. Stability of the arc is not adversely affected by use of a disk type negative.

c. Losses in light output of searchlights caused by the shadowing effects of the two types of electrodes and associated supports and mechanisms depend on lamp design, and should be approximately equal.

Submitted by:

Louis R. Noffsinger

LOUIS R. NOFFSINGER
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Forwarded by:

Fred W. Paul

FRED W. PAUL
Chief, Radiation Branch

Approved 2 May 1950 by:

Oscar P. Cleaver

OSCAR P. CLEAVER
Chief, Mechanical and Electrical
Engineering Department

APPROVAL OF

Report 1167

DISK TYPE NEGATIVE ELECTRODE

FOR CARBON ARC LAMPS

2 May 1950

and

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FORT BELVOIR, VA.

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FORT BELVOIR, VA.

26 MAY 1950

IN REPLY
REFER TO: **TECHD ASI**
400.1 (8-18-06-001)

SUBJECT: Transmittal of Report 1167, Disk Type Negative Electrode for Carbon Arc Lamps

THRU: Commanding General
The Engineer Center and Fort Belvoir
Fort Belvoir, Virginia

TO: Chief of Engineers
Department of the Army
Washington 25, D. C.
ATTENTION: Chief, Engineer Research and Development Division

1. Transmitted herewith is Report 1167, "Disk Type Negative Electrode for Carbon Arc Lamps," dated 2 May 1950, which was prepared by the Technical Staff of the Engineer Research and Development Laboratories. This report describes a disk type negative electrode developed to achieve long uninterrupted burning life of the negative electrode in a super-high-intensity carbon arc lamp operating in the current range of 150 to 200 amperes.

2. The report concludes that:

a. The disk type negative electrode provides the following advantages over the red type negative electrode:

- (1) Long, uninterrupted burning time without the use of a complicated magazine feed mechanism.
- (2) Ability to carry very high currents without overheating.

b. Stability of the arc is not adversely affected by use of a disk type negative.

c. Losses in light output of searchlights caused by the shadowing effects of the two types of electrodes and associated supports and mechanisms depend on lamp design, and should be approximately equal.

TECHD ASI

400.1 (8-18-06-001)

Subject: Transmittal of Report 1167, Disk Type Negative Electrode for
Carbon Arc Lamps

3. The report and its conclusions are approved.

O. B. Beasley
O. B. BEASLEY
Colonel, CE
Commanding

2 Incls

1. Proposed distr list
(in quint)
2. Rpt 1167 (in quad)

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Hq, The Engr Cen & Ft Belvoir, Ft Belvoir, Va. 26 MAY 1950

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SUBJECT: Transmittal of Report 1167, Disk Type Negative Electrode for
Carbon Arc Lamps

ENGMA(26 May 50)

2nd Ind.

Office of the Chief of Engineers, Washington 25, D. C.

5 June 1950

TO: The Commanding General, The Engineer Center, Fort Belvoir, Virginia

Report 1167, "Disk Type Negative Electrode for Carbon Arc Lamps"
and proposed distribution of the report are approved.

BY ORDER OF THE CHIEF OF ENGINEERS:

1 Incl.

1. n/s (4 cys w/d)

2. w/d

D. G. Hammond
D. G. HAMMOND

Lt. Colonel, Corps of Engineers
Chief, Engr. Research & Develop. Div.
Military Operations

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Hq, The Engr Cen & Ft Belvoir, Ft Belvoir, Va.

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