JOURNAL OF
THE
INDIAN INSTITUTE OF SCIENCE
SECTION B

VOLUME 40 OCTOBER 1958 NUMBER 4

DEPRESSION OF MAGNETICALLY FIXED EMISSION ZONE IN LOW PRESSURE MERCURY ARCS

By A. I. Vishnievsky
Unesco Expert (USSR)
and
Joseph Vithayathil
(Electrical Engineering Section, Indian Institute of Science, Bangalore-3)

Received on May, 26, 1958

Abstract

A transverse magnetic field was used to fix the cathode spot of a low pressure mercury arc with liquid cathode. It was noticed that such fixation causes considerable depression of the emission zone below the mercury level. This depression varies with the arc current and the magnetic field and is associated with an increase in the arc voltage drop. It indicates appreciable pressure in the emission zone.

The phenomenon of retrograde motion of the cathode spot of a vacuum arc discharge is well known. If the liquid cathode of a mercury arc tube is confined to the annular region between two concentric glass tubes, it is possible to get regular motion of the arc cathode spot by subjecting the spot to a radial magnetic field.[1] The direction of motion is contrary to that given by the 'left hand rule' of force on a current carrying conductor. Different explanations have been advanced to explain this anomalous behaviour.[2, 3]

Utilizing this phenomenon one of the authors (J. Vithayathil) devised experimental arc tubes in which it was possible to work with fixed cathode spots without metallic anchor. In the experimental tubes constructed by him a glass obstruction was placed in the annular region containing the cathode so as to prevent complete revolutions of the cathode spot under the action of the radial horizontal magnetic field (Fig. I). The cathode spot had, consequently, only two operating positions one on either side of the obstruction in the annular region depending on the polarity of the radial field. It was decided to study certain properties of cathode spots fixed magnetically in this way and the present paper describes the results of experiments conducted by the authors for this purpose.

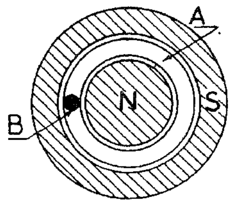

FIG. I
A. Annular Region Containing Hg Cathode. B. Glass Rod Obstructing Motion of Cathode Spot. N. S. Poles of Electromagnet.

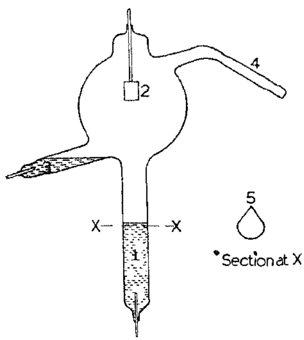

FIG II
1. Hg Cathode. 2. Graphite Anode. 3. Starting Electrode.
4. Vacuum Connection. 5. Region of Spot Fixation.

Fig. II shows the arc tube of simplified design used for the purpose. The use of two concentric glass tubes was avoided. The bottom tube containing the mercury cathode instead of having a circular cross section throughout, was made to have a sharp vertical corner parallel to the axis of the tube over some distance (Fig. III). By placing this region between suitably shaped poles of an electromagnet the arc cathode spot could be driven to this edge by having the required polarity for the electromagnet. For starting the arc a separate electrode was sealed into a side tube containing mercury. The arc is initiated by braking a temporary connection between the mercury in the side tube and the cathode pool made by tilting the arc tube. A search coil of 100 turns attached to the discharge tube on the outside in the region of the cathode spot was used for measurements of magnetic field strength using a flux meter. This however measured the field in the direction normal to the glass wall near the region of the fixed spot. Besides, due to the appreciable area of the search coil and the non-uniformity of field distribution due to the shape of the poles the field measurements can be considered approximate only. The arc tube was continuously evacuated during the experiments using a mercury diffusion pump and associated equipment. A cooling fan was mounted below the tube for air cooling.

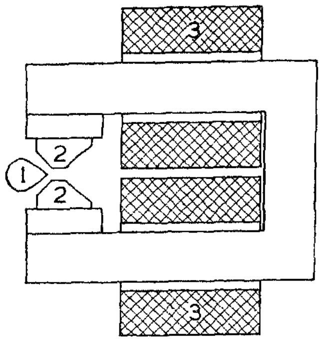

FIG. III
1. Surface of Hg Cathode. 2, 2. Poles of Electromagnet
3, 3. Windings of Electromagnet

Observations of the lowest arc current at which the arc was extinguished were made both under conditions of free spot emission (without fixing the emission zone) and with the fixed spot. It was found that there is no appreciable difference in this current due to magnetic anchoring.

The interesting phenomenon noticed was that the magnetically fixed spot did not stay on the surface of the mercury. The region of electron emission was considerably depressed below the mercury level in the region between the glass wall and the mercury. It was characterised by an intensely bright region, the depth of which below the surface of mercury was under some circumstances as much as 18 mm. or even more at times. The region of electron emission must have been in this region.

It was noticed that this phenomenon of spot depression was associated with an increase in the total arc voltage which presumably was the voltage drop across this depressed region. It was also observed that the depth below the mercury surface depended on both the strength of the magnetic field used for anchoring the emission region, as well as the magnitude of the arc current. Observations of the depression and voltage increase were made with different arc currents varying from a maximum of 5 amperes to the lowest possible value. This was repeated for different magnetic flux densities up to a maximum of approximately 1900 gauss.

Some of the results obtained are tabulated in Tables I and II. In Table I are given the readings corresponding to a field strength of 1070 gauss. In Table II the readings for a current of 3 amps at various magnetic field strengths are tabulated.

TABLE I

Observed values of arc voltage and depression for magnetic field strength of 1070 gauss.

Arc Current Amps.	2	3	4	5
Voltage drop across arc with free spot .	16	16	16	16.5
Voltage drop across arc with fixed spot .	25.5	22.5	23.5	23
Depression of arc, mm. . . .	9	9	11	15

TABLE II

Observed values of arc voltage and depression for arc current of 3 amps.

Magnetic field (Gauss) . .	210	430	715	1070	1430	1930
Voltage drop across arc with free spot	19	17	16	16	16	18
Voltage drop across arc with fixed spot	21	21	21.5	22.5	28	31
Depression of arc in mm. . .	5	7	8.5	9	15	14

It must be pointed out that the temperature of the arc tube was not maintained constant during the tests. The arc drop with fixed spot, was in most cases fluctuating. The magnitude of spot depression also was not quite steady. The results are therefore not precise enough to obtain quantitative relationships, but indicate the general characteristics of the phenomenon. The effect of the surface curvature of the mercury surface at the fixing edge has also not been considered.

The results, however, indicate the following general features. The magnitude of spot depression depends on the magnetic field strength and increases with it. It also depends on the magnitude of the arc current and increases with it for the same magnetic field intensity. The increase in arc voltage due to spot depression in general increases with the magnetic field for the same value of arc current.

The fact that free cathode spots occasionally plunge below the mercury level has been noticed before. H. v. Bertele[4] has shown the effect of such depression of the spot on a metallic surface 5 mm. below the mercury surface. The experiments indicate that at the region of electron emission there is appreciable static pressure. Such pressures have been measured before by Kobel[5] in the absence of any external magnetic field. Direct measurements of the static pressure made by Kobel have given values in the neighbourhood of 70 mm. of Hg for arc currents about 30 amps for spots confined to a restricted region. It is also obvious that the pressure immediately above the emission zone is appreciably high as otherwise it would be impossible to maintain the portion of the arc column at considerable level below the mercury surface. An acceptable explanation of the phenomenon of spot depression will necessarily be connected with a better understanding of the exact nature of the electron emission process at the cathode spot of the mercury arc.

The authors are grateful for the facilities of the Electrical Engineering Section, Indian Institute of Science, where the experiments were conducted.

References

1. Gallagher, C. J. ... *J. Appl. Phys.*, 1950, **21**, 768.
2. St. John, R. M. and Winans, J. W. ... *Phys. Rev.*, 1954, **94**, 1097.
3. Robson, A. E. and Engel, A. von ... *Phys. Rev.*, 1954, **93**, 1121.
4. Bertele, H. v. ... *Acta Phys. Austriaca*, 1955, **9**, 124.
5. Kobel, E. ... *Phys. Rev.*, 1930, **36**, 1636.