PRESSURE AND HIGH VELOCITY VAPOUR JETS AT CATHODES OF A MERCURY VACUUM ARC

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Abstract

The amount of vaporization of copper from the cathode of a copper arc measured by Tanberg as well as the velocity of this vapour calculated from the force of reaction on the cathode, agree closely with the values obtained by another method from the cathode of a mercury arc. With a mercury arc and fixed cathode spot the mercury vaporization is 0.017×10^{-3} gr/amp. sec. and the vapour velocity 16 to 43×10^{5} cm/sec.

Introduction

During attempts to fix the rapidly moving cathode spot of the mercury arc in a conical tungsten insertion-piece, it was observed that when the entire surface of the mercury was covered by the cathode spot the force exerted on the mercury was considerable. The following experimental tests were carried out during the first six months of 1929 with the object of measuring this force. In the meantime, Mr. Tanberg[1] had published a description of a quantitative investigation of the force exerted on the cathode of a copper arc, and although the methods of measurement and the cathode materials are very different, the results agree very closely.

Description of Experiments

Fig. 1 shows diagrammatically the 3-anode rectifier with which the tests were carried out. G is a glass container of about 5·5 litres capacity, in the floor of which is the cathode K, and in the cover the three iron anodes A, equally spaced in the form of a triangle. The cathode is shown in section in Fig. 2. The conical and cylindrical-shaped tungsten insertion-piece W is extended in an upward direction by a quartz cone Q, so that the arc may be ignited in it by touching the mercury with the ignition anode Z. After ignition, the mercury is lowered into the cylindrical part of the tungsten insertion-piece by rotating the screw S. When increasing the cathode current, the mercury pressure must be adjusted at the same time by means of the screw S, so that the surface of the mercury, which is entirely covered by the cathode spot, neither rises nor sinks. The pressure can then be read on the slanting capillary glass tube O. In order to determine the amount of mercury vapour, the decrease in the mercury level in the tungsten insertion-piece and the corresponding ampère-seconds were determined at a constant temperature of the container and with the mercury feed pipe closed. It is well known that the vaporization of mercury at the cathode of a mercury arc with a free moving cathode spot has already often been established.[2] When the cathode spot

[1] R. Tanberg, Phys. Rev. **35**, 1080 (1929).

[2] Zeits. f. Physik **2**, 74–87 (1922); Phys. Zeits. **29**, 857 (1928); Phys. Zeits. **30**, 233 (1929).

is moving freely, the surface of the mercury is much larger than the area of the spot, and in this case the vaporization is greatly dependent upon the mean temperature of the surface of the mercury. When the cathode spot is fixed and covers the entire surface of the mercury, the amount of vaporization remains at a certain value which is no longer greatly dependent upon

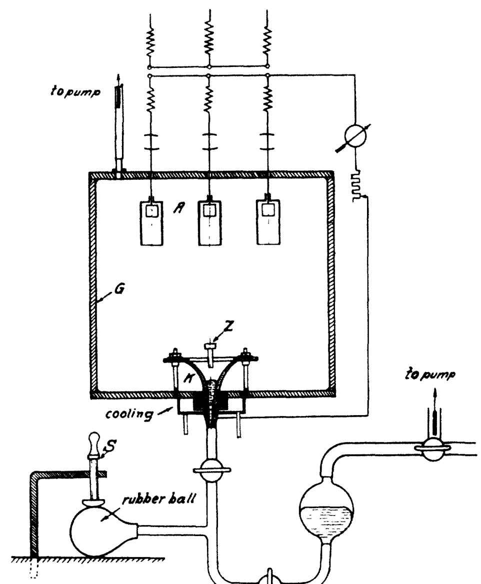

Fig. 1. Diagram of 3-anode rectifier.

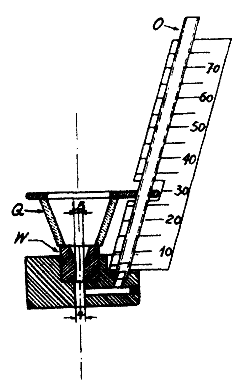

Fig. 2. Cross section of cathode.

the cooling of the cathode. This is also the case with a strongly-cooled copper-mercury cathode. The copper disk used as a cathode contained holes of about 2 mm diameter filled with mercury. A cooling liquid with a temperature of $-10°C$ was circulated round a channel in the disk during the test. The arc only burned until all the holes covered by the cathode spot were used up. A subsequent examination of the copper disk showed that it had been scarcely burned by the arc, since an arc current of only 14 amp. was used.

Results

The amount of mercury vapour at an average current of 35 amp. and with the cathode spot fixed in the tungsten insertion-piece was 0.017×10^{-3} gr/amp. sec.

The gas pressure in the container, arc current, force on the cathode spot and vapour velocity are given in Table I. The vapour velocity was calculated from formula (9) in Mr. Tanberg's article. No corrections for electrostatic and electrodynamic forces were made because they are of so little influence (less than 5 percent) that they do not effect the comparison of results which are already approximate.

Table I.

1	2	3	4	5	6
Arc current amp.	Current density in cathode spot amp./cm²	Gas pressure mm Hg $\times10^{-3}$	Height of mercury in glass tube cm	Force in dynes	$(C^2)1/2$ vapour velocity in cm/sec.
30	1700	1	6.5	1470	42×10^5
37	2090	0.5	3.0	687	16
35	1980	1.5	6.5	1470	36
32	1810	0.5	7.0	1700	43

The figures in column 3 give only the gas pressure in the container, and not the mercury vapour pressure.

These values do not vary more than those of Mr. Tanberg. In the case of the above-described tests, the variation arises from the difficulty of adjusting the counter pressure of the cathode mercury. The close agreement of the results is of special interest considering the difference between the two methods of measurement. These results show that it is not possible to calculate the vapour velocity with a moving cathode spot; this velocity would be smaller but very variable. The well-known zig-zag movement of the cathode spot with mercury arcs is certainly due to the fact that the mercury transmits the pressure of the vapour to the sides of the vessel if the cathode spot is not held stationary.

Mr. Tanberg also calculates the absolute temperature of the cathode spot from the vapour velocity, and obtains a temperature of the order of 5 to 7×10^{5}°K. Mr. Compton[3] has since given us a new reason for the high vapour react. force, so that it is useless to calculate the temperatures from the velocities given here. On the other hand, the question arises why the amount of mercury vapour per amp. sec. in a mercury arc is the same as the amount of copper vapour in a copper arc. There appears to be some close relationship between the amount of cathode voltage drop and the thermal properties of the cathode material-specific heat, heat of fusion, heat of vaporization and heat-conductivity.

[3] K. T. Compton, Phys. Rev. **36**, 706 (1930).