ARC DISCHARGE NOT OBTAINED IN PURE ARGON GAS

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Abstract

Between very pure iron electrodes in an argon atmosphere of fairly good purity, the low-voltage arc was easily maintained. When the argon was rigorously purified the arc could not be struck even with moderate potentials. Although the present theories do not require it, the normal arc discharge does appear to depend upon the presence of chemically active atoms or molecules, either in the gas or on the electrodes. Various hypotheses are presented.

THE low voltage electrical discharge through gas or vapor has been explained by K. T. Compton[1] on the basis of thermionic emission from a hot cathode, and by I. Langmuir[2] from the accumulation opposite the cathode of a positive space charge which pulls electrons out of the cathode, whatever the cathode temperature. Most arcs can be successfully accounted for by one or the other theory.

Neither theory postulates the necessity for the presence of chemically active atoms or molecules in the arc environment. Previous experimenters have reported on arcs maintained without difficulty in inert gases, such as argon, helium and neon. However, the present experiments indicate that with potentials upwards to 120 volts between electrodes of very pure gas-free iron, in highly purified argon gas at atmospheric pressure, the arc discharge does not take place. Separating the electrodes following contact produces a spark which goes out instantly, with no manifestation of the arc discharge. The short circuit current is of the order of 5 amperes. The slightest trace of atmospheric contamination in the argon gas changes the results entirely and permits the normal arc to be struck and easily maintained. It appears that a slight contamination of the argon by chemically active molecules is a prerequisite for the arc discharge. Between pure iron electrodes, in pure argon at atmospheric pressure, the normal arc discharge is not obtained.

The iron electrodes used were of exceptional purity. Iron oxalate was repeatedly recrystallized from solution in distilled water. This oxalate was heated to the oxide, reduced by hydrogen to finely divided iron, sintered and swaged in a hydrogen furnace, and drawn into wire of 1/8 inch diameter. This wire was placed in a glass tube where it was heated in vacuo by induced currents for several hours, the glass tube being sealed at this temperature. Iron so prepared absorbs practically no gas[3] at normal temperatures. New

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[1] K. T. Compton, Phys. Rev. **21,** 266 (1923).

[2] I. Langmuir, Gen. Elec. Review **26,** 735 (1923); Science **58,** 290 (1923).

[3] S. Dushman, Jour. Frank. Inst., June, 1931; A. Sieverts, Zeits. f. Metallkunde **21,** 37 (1929).

electrodes were used for each test. They were carefully polished before use, and discarded thereafter.

The supply of argon gas was likewise quite pure (less than 30 parts in 1,000,000 total impurities—principally nitrogen and water vapor), but it was subjected to further purification within the arcing system by means of a misch metal arc. The arcing system (Fig. 1) of Pyrex glass was evacuated, scavenged with argon and again evacuated. The final argon gas was admitted at atmospheric pressure, and its complete purification was begun by circulating it through the misch metal arc. Here the misch metal, vaporized by the heat of a high voltage arc, combined chemically with the residual impurities of the system, leaving only the inert argon gas. In the purification process the heated

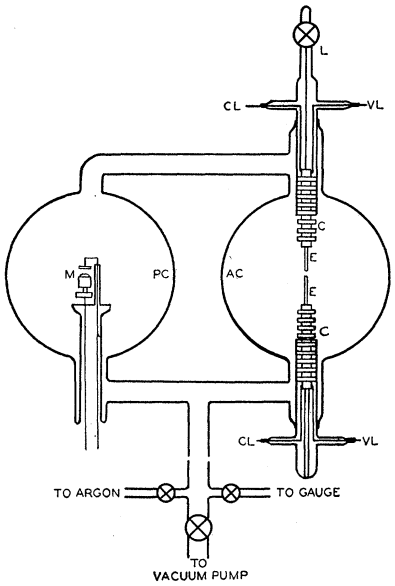

Fig. 1. Purification and arcing chambers used in these experiments. *AC*, Arcing chamber; *C*, Electrode holders of copper with cooling fins; *CL*, Current leads; *E*, Pure iron electrodes; *L*, Lug for moving upper electrode; *PC*, Purification chamber; *M*, Misch metal purification arc; *VL*, Voltmeter leads.

gas established convection through the connecting tubes to the arcing chamber proper, and thus all the gas is easily purified by 4 or 5 hours running of the misch metal arc.

The upper electrode (anode) was movable by means of a ground glass lug in the top of the arcing chamber proper. When contact and separation was made with the stationary electrode in an attempt to strike the arc in the highly purified argon system, a momentary spark resulted, accompanied by a faint glow at the gap which moved rapidly downward over the negative electrode to the copper holder, and went out, the entire process occupying less than a second. If the attempt were repeated, the same occurrence took place—the weak sparking, followed by the faint glow on the cathode and its rapid extinction.

If the purification of the system was less rigorously carried out, these results were not obtained. For instance, if the electrode holders of copper were not degassified, the cathode glow discharge about 1.5 inches long played on the holder for a minute or more (effectively an iron anode and impure copper cathode), and then removed upward to the tip of the iron electrode and behaved subsequently as a normal arc. The establishment of an arc under these less pure conditions was apparently due to volatilization of gas from the copper holders for after the copper holders were removed and treated in a hydrogen furnace, it was no longer possible to establish the arc in the manner described.

If the final purification of argon were omitted, the arc could be struck readily between the iron electrodes. In this case the arc was supported by the residual impurity of the argon gas. This impurity is chiefly nitrogen and water vapor, as previously mentioned.

To discover approximately how much oxygen or oxide was present in the contaminated condition which supported the arc discharge, the argon was evacuated. Fabry and Buisson[4] and also Child[5] have reported that the low-current arcs cannot be operated in vacuum without the presence of oxides. In each instance of the present investigation, the arc could not be struck after evacuation of the argon. This suggests that even under the contaminated conditions in which an arc can be maintained, the amount of active material is very small. Spectroscopic observations are of little avail in detecting the role of oxygen in the arc, as the band spectra contain such an abundance of lines as to obscure the oxygen lines (if present) in the visible region. No observations were taken in the ultraviolet, which would possibly be a better region in which to work.

The inability to obtain the normal arc discharge was experienced only after a scrupulous purification of the system. Four complete glass systems were built up and each purified and tested several times with the same result. The consistent inability to obtain the arc discharge between the iron electrodes was quite surprising since it was not previously understood that the arc discharge depends upon the presence of chemically active atoms or molecules.

In commenting on the inability to obtain the normal arc under these conditions, K. T. Compton[6] suggests that possibly an oxide layer on the cathode is a prerequisite in maintaining the proper cathode temperature (in accordance with the thermionic emission theory of the arc). Such an oxide layer might raise the cathode temperature either by virtue of its electrical resistance, or its thermal insulating properties. Compton further suggests that the elastic electron impacts with argon molecules might so scatter the current over the cathode as to make the establishment of a cathode spot impossible.

S. Dushman,[7] also considering the arc in terms of thermionic emission,

[4] Fabry and Buisson, C. R. **150,** 1674 (1910).
[5] C. D. Child, Phys. Rev. **20,** 364 (1905).
[6] K. T. Compton, Private communication.
[7] S. Dushman, Private communication.

remarks that a thin film of iron on an oxide surface of the metal has a far greater thermionic emission than the uncontaminated metal surface itself. He is undertaking new experiments in a study of such effects.

J. Slepian[8] has discussed the subject in the light of Langmuir's space-charge theory. For low current arcs, such as used in these experiments, the positive space charge just outside the cathode is very small. Consequently, the lines of force of such a charge are widely spread out, so that the electric field is materially weakened between the space charge and the cathode. If the field strength drops below a certain value, it is impossible for electrons to be "pulled out" of the cathode, and hence the discharge can not be supported.

At present, it can not be said which of these suggestions is the most reasonable in accounting for the inability to obtain the arc discharge in pure argon gas. The investigation is being continued in an attempt to determine the important factors involved.

[8] J. Slepian, Discussion, Winter Convention A.I.E.E. New York, January 29, 1932.