Role of Oxidation in Arc Cathodes

We have recently made some observations which point to the importance of an oxide film on the cathode of arcs in the atmospheric pressure range. The experimental arrangement was similar to that used by Stolt,[1] except that the electrode and pole structure were enclosed so that gases other than air could be used. A typical observation with copper electrodes is the following: At a current of a few amperes and an electrode separation of 2 mm, and with a given magnetic field strength, the arc will rotate regularly in air or in nitrogen of 98 percent purity. If, however, oxygen-free dry hydrogen is used in the tube, an initial arc rotational velocity is found which is ten times as high as for the same current and magnetic field in impure nitrogen or air. In the course of a few minutes this high velocity decreases by a factor of about 100 times, however, coincident with the appearance of a bright "etched" condition of the electrode.

The arc, if it persists, follows the outer boundary of the clean (oxide-free?) electrode area, and when this becomes extensive, the arc changes to a striated glow discharge (glow II).[2] With pure hydrogen and with electrodes which have been cleaned in this way, it is then impossible to strike the arc form in this current range (1–10 amperes), the striated glow being the common and a self-sustaining form. If the current is increased in an attempt to find an arc in the 10–100 ampere range, an incipient discharge is produced which takes a long path to uncleaned portions of the electrode, or to the magnetic pole pieces which are well oxidized. If oxygen-free dry nitrogen is now used with electrodes which have been cleaned by hydrogen, it is found that the "arc" discharge is very unstable and prefers (1) to revert to a glow, or (2) to take a 20 mm path between the oxidized magnetic poles in preference to the 2 mm path between the cleaned electrodes.

Similar observations apply to silver electrodes, where it is impossible to produce anything but the glow form in the 1–10 ampere range in hydrogen. Arcs in these pure gases with a thermionic (C or W) cathode are, of course, quite stable.

We believe that these results point definitely to the importance of an oxide film in the case of cold cathode arcs. A likely interpretation is that with electrode materials like Ag and Cu (in this current range) the cathode cannot supply sufficient emission without an oxide mechanism, possibly identical with that studied by Güntherschulze and Fricke.[3] This result agrees with calculations (e.g., Lüdi's[4]) of field emission for cold cathode arcs which have always shown that the available field is too small.

Druyvesteyn[5] suggested the possibility of this mechanism in the arc cathode, but apparently his suggestion was not supported by experimental evidence.

Doan and Myer[6] and later Doan and Thorne[7] reported experiments in pure argon, helium, and neon, which showed that the normal stability of these arcs is destroyed by purifying the gas. They attributed the effect to "purity of the gas," but did not identify oxygen as the important agent. From studies of the electrical characteristics of arcs (with thermionic cathodes) in many of the common gases[8]

we know that argon in particular shows the greatest arc stability, e.g., lowest gradient, of all the common gases except mercury vapor. This is the "gas effect," and, in view of this and the present results, the experiments of Doan, et al., should be interpreted as an "electrode effect," probably an effect of oxide on the cathode.

It is a fact well known to welders and easy of verification that in air attempts to strike an arc between clean, bright iron welding rods and a clean, steel plate are unsuccessful until, by repeatedly restriking an incipient discharge, a visible oxide layer is formed on the cathode (the plate). This observation is also susceptible to the interpretation given above.

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March 23, 1938.

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[6] Doan and Myer, Phys. Rev. 40, 36 (1932).
[7] Doan and Thorne, Phys. Rev. 46, 49 (1934). See also experiments of Schrum and Wiest, Elec. Eng. 50, 827 (1931).
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Seasonal Variation in F_2 Ionization

Opportunity is taken to remark briefly on new data of variations in F_2 ionization in the light of the theory of a recent paper,[1] the data having become available after the paper was written. I refer to monthly average $f_{F_2}{}^x$ data through February, 1938, for Washington, D. C., U. S. A. (latitude 38° 50′ N) of the U. S. National Bureau of Standards,[2] and $f_{F_2}{}^0$ data through December, 1936, for Watheroo, Western Australia (latitude 30° 19′ S) of the Department of Terrestrial Magnetism,[3] Carnegie Institution. For comparison the average monthly noon data were converted to equivalent electron densities y_e by the usual formulae and are plotted in Fig. 1 with one point for each month; a scale of $f_{F_2}{}^x$ cycles sec.$^{-1}$ is appended.

Disregarding the general increase of y_e with increasing sunspots from 1934 to 1938 we note in Fig. 1 the summer minimum and winter maximum of the Washington curve, and the small dip in the summit of the maximum in December or January. The small dip marked "1" is
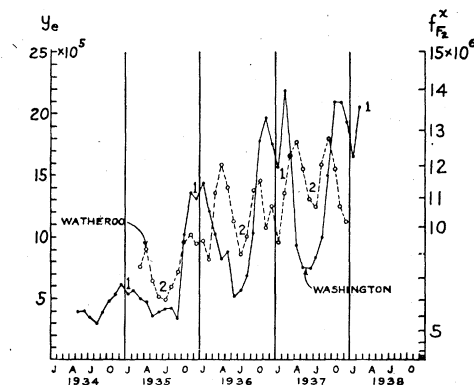

Fig. 1. Monthly average noon ionization of F_2 region.