

FORMS OF DISCHARGE IN MICRO-GAPS

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The potential required to produce a disruptive discharge between two electrodes immersed in a gas has been studied by a large number of workers. At gas pressures of 150 cm and less the breakdown potential follows Paschen's Law, that is $V_b = f(p \times d)$. The curve of breakdown potential versus electrode separation in this pressure range is characterized by a pronounced minimum potential, below which it is impossible to obtain a spark breakdown.

Hobbs¹ and others have shown that at atmospheric pressure there is a significant departure from Paschen's Law, in that the breakdown characteristic does not exhibit a minimum value. Instead, the potential at very small gaps decreases linearly to zero, which suggests a field dependent discharge. All the fields reported in the literature are of the order of 10^6 volts per cm. Although this is the order of field strength within which field currents have been obtained in vacuum, it was not until a recent paper by Pearson² that any measurements of field currents at atmospheric pressure were reported.

The discharge or breakdown at gaps of the order of 10^{-4} cm takes several different forms. At gaps somewhat smaller than this value, it has been generally observed that the breakdown results in cohesion or short circuit of the contacts. This cohesion has been shown to consist of a bridge of electrode metal. At gaps somewhat greater than 10^{-4} cm, it is found that breakdown results in a more or less stable discharge of the nature of an arc. It should be pointed out that the breakdown described above may occur at potentials less than the minimum sparking potential as given by the Paschen curve. Eskin³ previously suggested that this type of breakdown might well explain the reignition of AC arcs.

The authors, working with polished silver electrodes, have observed that the breakdown potential for these micro-gaps is dependent upon their history. This is perhaps best seen by reference to table I, which shows the manner in which the

breakdown voltage changes with the magnitude of the initial applied potential. In the case of electrodes 1 to 4 the initially applied potential of 10 volts was increased in steps of 10 volts, each step being held for 5 seconds, until breakdown occurred at the voltage indicated. For electrodes 5 to 12, in all except one case,

TABLE I.—EFFECT OF INITIAL VOLTAGE ON BREAKDOWN

Electrode number	Initial voltage	Breakdown voltage	Gap (Cm)
1.....	10	320	.000052
2.....	10	320	"
3.....	10	290	"
4.....	10	260	"
5.....	120	120	"
6.....	120	...	"
7.....	120	120	"
8.....	120	120	"
9.....	130	130	"
10.....	130	130	"
11.....	130	130	"
12.....	130	130	"

breakdown was observed at the initial potential.

Previous observations of the breakdown of these micro-gaps were made with the use of a voltmeter connected across the electrodes. Series resistance was used with the contacts, and the decrease in potential across the electrodes was taken as indication of a discharge. In the present study it has been found that transient discharges occur between polished silver electrodes before a breakdown (either cohesion or a stable discharge) takes place. These discharges are faintly audible, and luminous when observed in a darkened room, although it was found impossible to detect them on a voltmeter connected across the contacts. These discharges were characterized, however, by a variety of markings left upon the electrode surfaces. These markings are entirely different from those observed following a complete breakdown.

The markings observed were of two

¹ G. M. Hobbs, *Phil. Mag.* (6) 10, 617, 1905.

² G. L. Pearson, *Phys. Rev.* 56, 471, 1939.

³ S. G. Eskin, *J. App. Phys.* 10, 631, 1939.

distinct varieties. In fig. 1 is shown a so-called "bird shot" pattern. The markings were somewhat less than 1 mm in diameter, and the cathode marking was always found to be more extensive than the one on the anode. In general, this type of marking occurred with a low series resistance (76 ohms) and at a voltage of less than about 250 volts.

Fig. 2 shows a ring pattern, which consists of a number of concentric colored rings. This type of marking was observed in general with relatively high series resistance (1000 ohms) and at potentials above 270 volts. In some instances the rings completely filled the area, leaving no clear central region as shown in fig. 2. In other cases, a bird shot pattern has been observed within

the central area of a ring pattern.

Using an extremely high series resistance (10^{10} ohms) and a galvanometer in series with the electrodes, current pulses were observed within this range of gaps and voltages. At a given gap setting, these current pulses appear quite at random for voltages below 320 volts, but above this value, however, the pulses appear at more or less regular intervals until at 350 volts or so, the pulses are quite regularly spaced, having frequencies of the order of 30 per minute. A further increase in voltage greatly increases the frequency, until finally cohesion results. Each pulse is accompanied by a luminous discharge in the gap, but no markings such as described above have been observed on the electrodes.

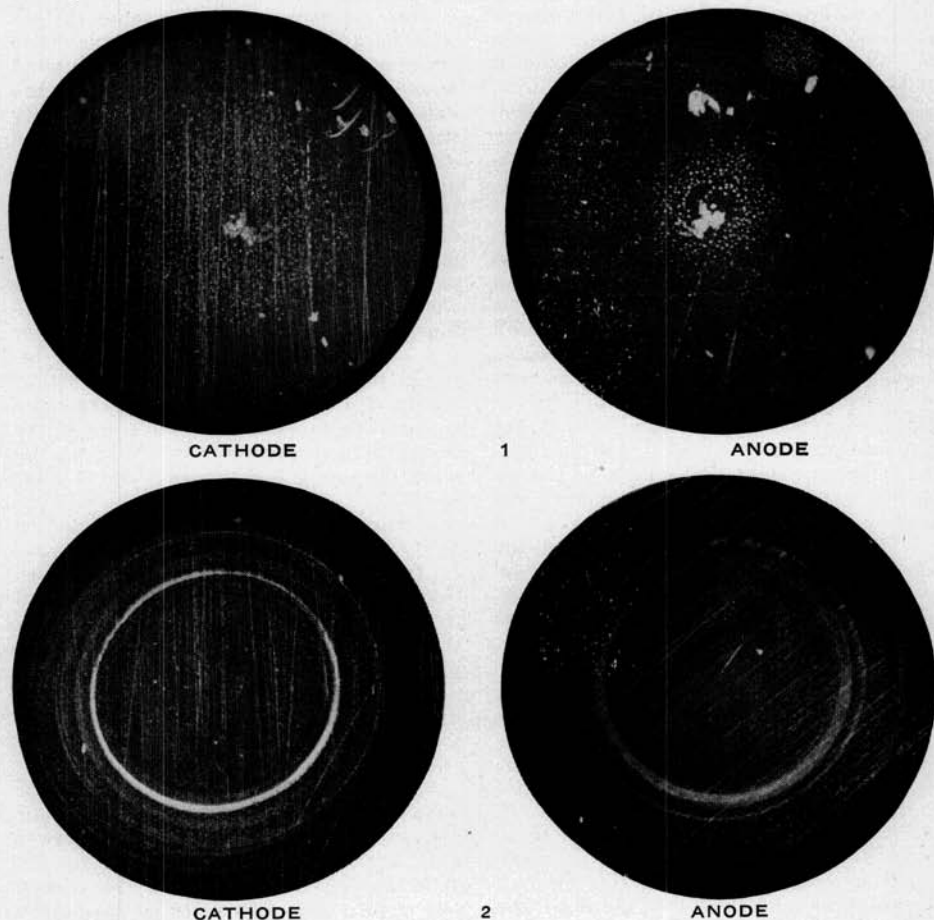


Plate I.—Electrode surface markings following a transient discharge. 1. Shows "bird-shot" 2. Shows ring pattern.