APPLICATION OF SIMILITUDE RELATIONS TO IGNITION OF A GAS DISCHARGE IN HYDROGEN

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Additional verification is given for the deviations from the similitude relations found earlier in hydrogen for the left branch of the Paschen curve; these deviations are found with electrodes made of copper, stainless steel, and nickel. Deviations are also observed in deuterium.

EARLIER investigations [1] of ignition of a discharge in hydrogen in the region $pd < (pd)_{min}$ have shown considerable deviations from the similitude relations. The ignition potential U_S of a gap with a uniform electric field obeys the relation

$$U_s = \frac{4.6 \cdot 10^{-3}}{(pd^{0.58})^6},$$

where U_S is expressed in kV, the pressure p in mm Hg, and the length d in cm.* Thus, U_S varies differently as a function of p and d. In contrast McClure, [2] who investigated this phenomenon in hydrogen for two similar discharge gaps differing in linear dimensions by a factor of 2.5, found that the similitude relation is in fact obeyed with satisfactory accuracy.

McClure has suggested that the discrepancy between the results of the two papers is probably due to edge effects in the discharge gap used by the present authors. However, we have shown that edge effects are not present: [1] first, changing electrode polarity has no effect on U_S and second, the same deviations from the similitude relation are found in tubes in which the plane electrodes have differently shaped edges.

The experiments reported in [1] and [2] differ in the following ways.

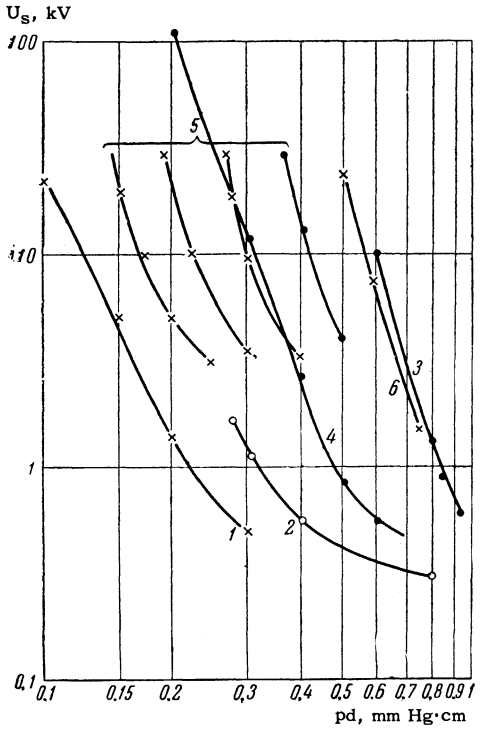
1. The cathode used in [1] was made of nickel while the cathode used in [2] was stainless steel.

2. In [1] the pressure was varied by changing the temperature of the hydrogen source, an ampoule containing titanium hydride heated by an electric current. The pressure was determined by measuring the voltage change across a heater which was calibrated for hydrogen pressure beforehand. In [2] a regulated continuous flow of hydrogen was admitted into the discharge space and the pressure was measured with a McLeod gauge.

3. In [1] all $U_S(p, d)$ curves were taken with the same tube and the same cathode. In [2] ignition curves were taken with two different tubes so that it was impossible to avoid effects due to differences of the surface states of the tube cathodes.

4. In [1] the investigation was carried out with a discharge gap with a uniform field between plane electrodes bounded by metal surfaces. In [2] the cathode was a plane disc while the anode was a cup with edges turned toward the cathode. Part of the discharge gap was bounded by the cup.

After becoming acquainted with the work of McClure [2] we carried out additional experiments



Ignition curves in hydrogen plotted from the following data: 1) d = 1.72 cm, Ni cathode; [3] 2) d = 0.2 and 1 cm, Ni and Fe cathodes; [4] 3) d = 4.3 and 10.8 cm, Fe cathode; [2] 4) d = 4.6 cm, Fe cathode; [5] 5) d = 0.4, 0.8, 1.6, and 2.8 cm, Ni cathode; [1] 6) data of the present work with an experimental tube similar to the tube used by McClure (d = 10.8 cm).

*In the earlier work, [1] because of an oversight of the authors, the decimal point was omitted in the numerator of the expression for U_S.

to see to what extent the differences in the experimental arrangements given in items 1 and 2 above could be responsible for the discrepancies between our results and those of McClure. These experiments showed the following:

a) The deviations from the similitude relation are the same whether the electrodes are made of nickel, stainless steel, or copper. Consequently the discrepancy between our data and McClure's is not due to the difference in electrode materials.

b) Changing the hydrogen pressure in the discharge gap by smashing glass ampoules filled with known amounts of hydrogen does not affect the observed deviations from the Paschen law.

The additional experiments give additional verification of the deviations from the similitude relation observed earlier although they do not furnish any explanation for the discrepancies between our results and those of McClure.

In analyzing the experimental differences noted in items 3 and 4 above one should note that we have used a more reliable means of evaluating the similitude relation since the measurements were carried out with the same cathode and in a discharge gap with no insulating walls, which could become charged to an unknown potential, possibly affecting the ignition of the discharge.

Indirect proof that the observed deviations from the similitude relation are real also follows from an analysis of the presently available data reported by various workers who have investigated ignition in hydrogen discharges with $pd < (pd)_{min}$. The $U_s(p,d)$ curves shown in the figure indicate a wide spread in the data obtained by various workers. Nevertheless, one can observe a clear tendency for a shift to the right for curves taken with greater distances between the plane electrodes, in accordance with the deviation from the similitude relation reported by us.

The ignition curves obtained by McClure are shown in the figure for comparison with results obtained by various workers who used uniform fields. This comparison can be made because it has been shown by Guseva [5] that for the diameter-to-height ratio of the cup-anode used by McClure the ignition curve is approximately the same as for a uniform field with d equal to the distance from the plane cathode to the bottom of the cup-anode.

Thus, additional experiments, as well as a comparison of the results of various workers who have investigated discharge ignition in hydrogen when $pd < (pd)_{min}$, verify the existence of appreciable deviations from the similitude relation in hydrogen. It might also be noted that we have observed these deviations from the similitude relation in the ignition of discharges in deuterium.

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