PHYSICS

Simultaneous Application of Townsend and Streamer Theory

Recently conductivity current measurements up to the sparking potential have been carried out in hydrocarbon gases which can be interpreted if it is assumed that Townsend and streamer processes act simultaneously.

A sample measurement for *iso*pentane is shown in Fig. 1. At $E/p = 300$ V. cm.$^{-1}$/mm. mercury, $p = 3$ mm. mercury, the d.c. ionization current was measured, by successive reduction of i_0, over more than eight decades of amplification, without any sign of a deviation from the normal α slope, up to the sparking voltage of 990 V. which occurred at $d = 1{\cdot}1$ cm. The last slope was obtained with 10 electrons leaving the cathode per second and this type of measurement has often been repeated and confirmed.

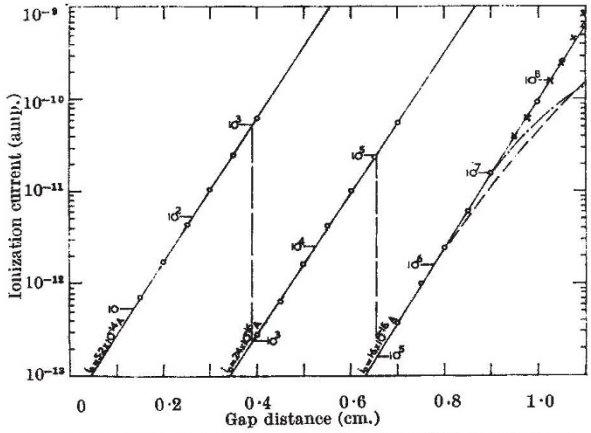

Fig. 1. Ionization current, i, as a function of gap distance, d, showing large multiplication possible in *iso*pentane without apparent deviation from a normal α slope. Spark occurred at 990 V., $d = 1{\cdot}1$ cm.; $E/p = 300$ V. cm.$^{-1}$ mm. Hg^{-1}, $p = 3$ mm. Hg, $\alpha = 17{\cdot}9$ cm.$^{-1}$. —O—O, Experimental curve; — — — estimated α curve, Richter (ref. 1); –.–.–., estimated α curve, Heylen; ×—×—×, calculated values according to equation (3)

By monitoring the pulse shape of the ionic component of individual avalanches, it has been observed[1] that the number of charge carriers (n) increases less than $\exp(\alpha x)$ if n surpasses $N = 10^6$. The space charge field of the positive ions is held responsible for the reduction of the ionization of the advancing electrons and is comparable to the applied field; we are thus entering the streamer regime. It was found (for ether, a gas exhibiting an extremely low γ coefficient) that for $n \geqslant N$, Townsend's α coefficient could be expressed as:

$$\alpha(n) = \alpha\,(1 - B \ln n/N) \qquad (1)$$

in which $B = 0{\cdot}065$. From this, the charge multiplication factor was evaluated as:

$$x - x_N = \frac{1}{\alpha}\left\{\frac{1}{1 - B \ln n/N} - \frac{1}{B}\ln(1 - B \ln n/N) - 1\right\} \qquad (2)$$

in which $N = \exp(\alpha x_N)$. The reduction from the normal α slope, according to equation (2), is shown in Fig. 1 (dashed line), and does not agree with the observed data. The discrepancy can be cleared up if it is assumed that Townsend's secondary mechanism is operating simultaneously with the streamer inducing space charge reduction of Townsend's primary process. This can be taken into account by using the generalized Townsend equation:

$$i_x = i_0 \frac{\exp\left(\int_0^x \alpha dx\right)}{1 - \gamma\left(\exp\left(\int_0^x \alpha dx\right) - 1\right)} \qquad (3)$$

in which $\exp\left(\int_0^x \alpha x d\right)$ can be found from Fig. 1 (dashed line). An estimate of γ can be obtained by making equation (3) fit the experimental curve. Thus, for $\gamma = 4{\cdot}3 \times 10^{-8}$, a normal α slope would be recorded up to $d = 0{\cdot}9$; for longer gaps, an upcurving would occur and the Townsend criterion for breakdown would be reached at $d = 0{\cdot}98$, which is not in agreement with experiment.

From previous work[2] it has been surmized that for normal hydrocarbons, little space charge distortion occurs until $n \geqslant N = 10^7$, and from Richter's data[1] an equally good fit to $\alpha(n)$ can be obtained for $B = 0{\cdot}2$. Substitution of this value into equation (2) yields the curve as shown in Fig. 1 (dot-dashed line). Combining this with equation (3) yields $\gamma = 10^{-8}$; the calculated values are shown (×). It is observed that no apparent deviation from a normal α slope occurs to within 5 per cent of the sparking distance, at which a faster than usual Townsend upcurving takes place.

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[2] Heylen, A. E. D., Proc. Fourth International Conference on Ionization Phenomena in Gases, Uppsala, **50**, 150 (North-Holland Pub. Co., Amsterdam, 1960).

The Nitrous Oxide Dosimeter

Nitrous oxide has been proposed[1] as a suitable material for the dosimetry of ionizing radiations over wide temperature- and pressure-ranges and with a wide variety of types of radiation. The basis for the yields quoted in ref. 1 was the measurement of radiation flux using ionization chambers or ferrous sulphate solutions. We have investigated the radiolysis of nitrous oxide and have compared the results of absolute measurements based on tritium as an internal source with measurements based on ferrous or ceric sulphate dosimetry, using cobalt-60 γ-rays or 4-MeV. X-rays as external sources.

It has been found that good agreement between the two methods is obtained provided the irradiations are done in vessels with internal diameters greater than about 15–20 mm. As the internal diameter decreases, the yields of all products, based on ferrous dosimetry, increase in a manner reminiscent of the increase in $G(Fe^{3+})$ from the ferrous sulphate dosimeter in vessels of a few millimetres diameter[2,3].