SOME OBSERVATIONS ON THE BEHAVIOUR OF BROMINE-QUENCHED GEIGER TUBES

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Summary

A number of Geiger tubes were constructed using 18 : 8 low-carbon stainless steel and 99·9+ per cent. aluminium cathodes with tungsten anodes.

Plateaux improved, but threshold voltages rose 2 V/°C with increase in temperature. Tubes with stainless steel cathodes operated at 100 °C for one week showed no deterioration.

A few tubes with bromine pressures approximately 0·01 cm Hg in a total filling of 20 cm Hg argon exhibited oscillations over an interval along the length of the plateau. During this interval the tubes were insensitive to external radiations. These tubes, as well as others with higher bromine pressures, also gave, at some defined overvoltage, Geiger pulses with extended tails, upon which 25 kc/s oscillations were superimposed.

I. INTRODUCTION

Halogen-quenched Geiger tubes have been investigated by numerous workers (Liebson and Friedman 1948; Le Croissette and Yarwood 1951; Loosemore and Sharpe 1951; van Zoonan and Prast 1952; and Ward and Krumbien 1955) but little information is available concerning their behaviour at elevated temperatures, except that recently reported by Clark (1955). Fujioka, Kita, and Minakawa (1951) have observed, as have Belin and Bainbridge (unpublished data), that alcohol-argon Geiger tubes, with suitable pretreatment, can be made to operate with negligible change in their characteristics to 200 °C. Halogen-quenched tubes in which the halogen does not react chemically at this temperature will probably behave likewise. Thus, since Geiger tubes of long life were required for use at elevated temperatures, an evaluation of the behaviour of halogen-quenched tubes with temperature seemed appropriate.

During the investigation of the effect of the variation of bromine partial pressure with noble gas pressure and of temperature on plateau characteristics some new observations were made, in particular oscillations of a different character from those already reported by Le Croissette and Yarwood (1951) and van Zoonan and Prast (1952).

II. GEIGER TUBE CONSTRUCTION

Geiger tubes of two sizes were constructed. Their anodes consisted of tungsten wire 0·004 and 0·006 in. in diameter, while the cathodes, which were $\frac{5}{8}$ and 1 in. in diameter, consisted of 18 : 8 low-carbon stainless steel and

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aluminium of 99·9+ per cent. purity respectively. Uhlig (1948) gives the former as moderately resistant and the latter as of good resistance to bromine at temperatures up to 100 °C. Thin nickel strip of 99·4 per cent. purity was used to join the cathode to the tungsten-to-glass seal. All tubes were sheathed in borosilicate glass and chemically cleaned internally, after construction.

The vacuum system and filling procedures followed a similar pattern to that described by Le Croissette and Yarwood (1951). Before filling, the tubes were left for 12 hr with an internal atmosphere of bromine at a pressure of 2 cm Hg. This conditioning vapour was then pumped out, through bromine traps, with a silicone oil diffusion pump and the tubes filled with the required mixture of argon (or neon) and bromine which for a normal tube was 20 and 0·02 cm Hg respectively. Fillings investigated ranged from 10 to 30 cm Hg of noble gas with from 0·05 to 5 per cent. of bromine.

III. Experimental

Pulses from the halogen-quenched tubes were usually examined by using a pre-amplifier with a 2 μμF input coupling condenser to the Geiger tube. The oscillations described below, on the tail of a pulse, were also examined by direct connection of the tube to the input of a cathode-ray oscilloscope.

IV. Results

(a) General Observations

The threshold voltage of tubes, sealed after filling, normally rose about 100–150 V after a period of approximately 2 weeks at room temperature. This process was always accompanied by an improvement in plateau slope and could be completed by heating the tube to 50 °C for 45 min.

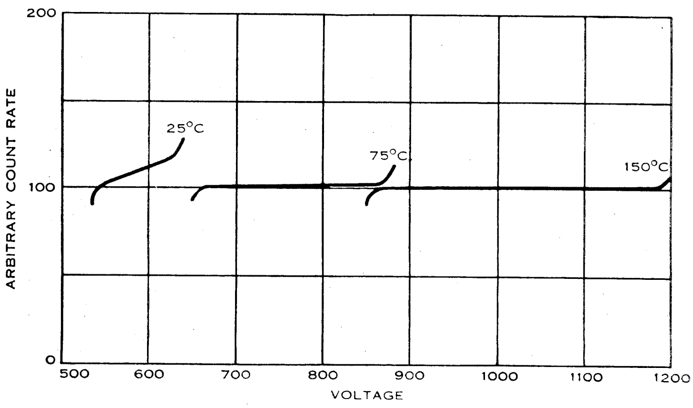

Fig. 1.—Threshold voltage and plateau of a bromine-argon counter at temperatures 25, 75, and 150 °C. A bad counter at 25° was chosen to accentuate the improvement with temperature.

Observations, at room temperature, made on tubes which had "aged" in this manner, showed that the relationships of the gaseous filling constituents with threshold voltage and plateau length agreed substantially with those of other workers (Le Croissette and Yarwood 1951; and Ward and Krumbien 1955).

In about 24 tubes investigated no negative plateau slopes, resulting from multiple pulses, were observed, as those reported by Le Croissette and Yarwood (1951) in neon-bromine tubes.

The effect of temperature on plateau length, threshold voltage, and slope of a particularly poor stainless steel cathode Geiger tube, already aged, is shown in Figure 1. This was characteristic of all tubes investigated. In general the threshold voltage had a positive temperature coefficient of approximately 2 V/°C. The tubes could be cycled between 20 and 100 °C with the threshold voltage rising and falling in unison and held at 100 °C for many days without appreciable deterioration.

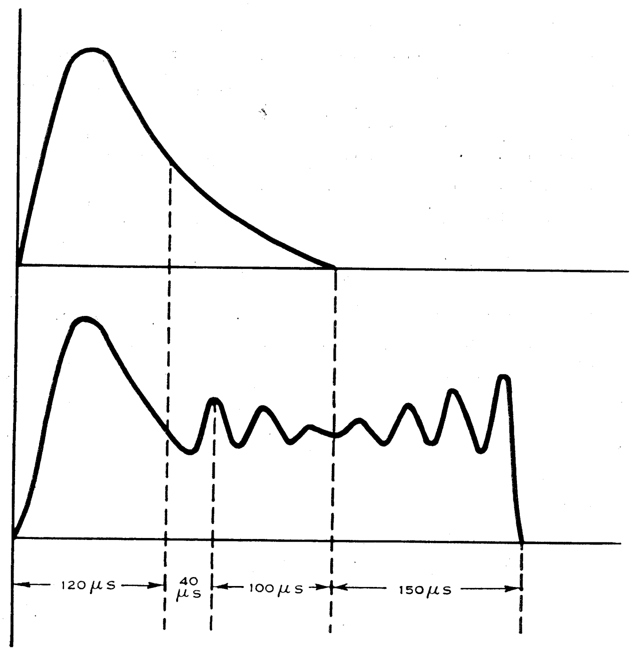

Fig. 2.—A normal Geiger pulse and one containing the observed oscillations.

In general Geiger tubes with aluminium cathodes behaved in a similar manner but showed some deterioration after operation at 100 °C for 8 days. A tube using commercial aluminium was soon rendered useless when subjected to the same treatment.

(b) *Oscillatory Behaviour of Bromine-quenched Geiger Tubes*

Geiger tubes with either argon or neon and with a bromine partial pressure not greater than 0·05 per cent. of the total filling pressure exhibited unusual effects. For example, one stainless steel cathode tube with approximately 0·01 cm Hg of bromine in a total filling pressure of 20 cm Hg of argon and with a threshold voltage of 330 V exhibited a plateau of 60 V ; that was followed by a gap of 15 V in which the tube did not respond to ionizing radiations. This gap was characterized by a continuous oscillation of approximately 25 kc/s and an amplitude of a few volts. After this gap the tube plateau reappeared for about 100 V before the tube went into continuous discharge. This 100 V plateau region was characterized by the appearance of oscillations on the tails of some Geiger pulses. Tubes with a higher percentage of quenching agent also showed similar Geiger pulses, as shown in Figure 2, when the overvoltage was increased sufficiently. A typical example is that of one tube with a filling of 20 cm Hg of argon and 0·2 mm Hg of bromine with a threshold of 460 V which showed tail oscillations at 190 V overvoltage. The dead time and recovery time at this operating voltage were measured as 120 and 140 μsec respectively. The oscillations started approximately 20 μsec after the dead time, reached their minimum amplitude at the end of the normal recovery time, and then continued with increasing amplitude for another 150 μsec before suddenly dropping to zero. Their average period was found to be approximately 40 μsec.

Another effect observed in these tubes with low bromine fillings was that the threshold showed, after a high count rate, a distinct downward shift which in one case was as high as 80 V. If the tube was left disconnected for about half an hour the threshold returned to its normal value.

V. Discussion

Desorption of bromine from the inner Geiger tube walls readily explains the permanent threshold voltage increase observed at room temperature, if it is remembered that the tubes adsorbed bromine heavily during the prefilling period. Desorption and adsorption of bromine also explain the variation of plateau length and threshold voltage with changes in temperature. Within the filling pressure range investigated, plateau length increases and threshold voltage rises with increase of bromine partial pressure.

The lowering of the threshold voltage as a result of a high counting rate is observed only in tubes with a low bromine content, which suggests a depletion of quencher near the anode. Calculation shows that this threshold depression cannot be explained merely by a decrease in the partial pressure of bromine near the anode (say within a distance of 0·1 cm), as a result of bromine ion movement to the cathode under normal Geiger operation. However, if there is accumulation of bromine due to some physical reaction at the cathode the partial pressure will decrease and lower the threshold. The effect is negligible in tubes of normal bromine content.

Oscillations on the tail of a Geiger pulse have been reported previously by Le Croissette and Yarwood (1951) and van Zoonan and Prast (1952). These oscillations were different from those observed by the author in that they appeared just after the dead time and died away to zero as the tail of the Geiger pulse approached the end of the normal recovery time. The oscillations recorded by these workers do not appreciably raise the average level of the Geiger tail shown in Figure 2.

Since the periods of the two observed types of oscillations are the same, they are probably related. It is also significant to note that, with these tubes, oscillations on the tails were not observed below the oscillatory region but appeared randomly above this region, i.e. when the tube had regained sensitivity to ionizing radiations. Also with tubes of higher bromine pressures, in which continuous oscillations were absent, the oscillations on the tail of a pulse appeared only at a certain overvoltage. These observations suggest an association with field strength.

The oscillations on the tail of a pulse begin only at the end of the dead time, which suggests that they are probably spurious pulses. They decrease in amplitude with increasing number of ion sheaths and reach a minimum at or near the time when the cathode collects the original ion sheath. After this the pulse amplitude again increases until a stage is reached beyond which the mechanism required to maintain the process becomes inoperative. This condition presumably prevails at the end of the oscillatory period, i.e. the amplitude of the pulses rises beyond the stage required to sustain conditions for their generation.

Evidence that the oscillations are small spurious pulses is available from the oscillatory region in the plateau of the tube. There appears to be no sensitivity to external radiation over this region. This suggests that ion sheaths, which result from pulse formation, are created by small self-maintained spurious pulses. These sheaths keep the field strength near the anode too low to produce pulses of greater amplitude.

VI. Conclusions

By raising the temperature of a bromine-argon (or neon) gas Geiger tube, desorption of bromine from the glass and metal surfaces raises the threshold voltage and increases the plateau length.

There is some evidence which suggests that the continuous oscillations appearing within an interval along the length of a plateau and those oscillations on the tails of Geiger pulses are self-sustained spurious pulses.

VII. References

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