THE PRODUCTION OF GEIGER-MULLER TUBES

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Geiger-Muller counting tubes are used so extensively today that everyone is more or less familiar with them. However, there have been so many differing points of view on the actual operation of a counter, that we will discuss the discharge mechanism with a view to determine what comprises a good counting tube. The bibliography for the various ideas presented here would be too lengthy and hence no reference will be given.

Although the counting and recording circuits and even scaling circuits, where high speed counting is employed, have been developed to an entirely satisfactory degree, there still remains much to be desired in improving the technique for the production of tubes with good characteristics, and it is just this very difficulty that has limited their use.

The things that are definitely known about the action of a Geiger-Muller tube are that when a ray produces at least one pair of ions inside of the tube, a discharge will take place, and this discharge must in turn be stopped. The time of this discharge, together with the time required for the tube to recover sufficiently to register the next ray should be as short as possible.

Let us try to analyze the action taking place while a count is being recorded. It is only necessary for the ray traversing the tube to produce a single ion pair. The electron from this first ionization comes into the region of the central wire, which is at a high potential with respect to the cylinder. When the electron reaches this strong field it produces both positive and negative ions by collision with the atoms of the gas. The electrons are quite certainly the chief ionizing agent since the field in the neighborhood of the central wire is sufficient for the electrons to ionize by collision. Due to the fact that the mobility of the positive ions is much less than that of the electrons, the positive ions do not play an important part in this process. Each new electron will in turn create new ion pairs, so that the region of the central wire will become heavily ionized.

If this heavy ionization actually takes place, it must be accompanied by the production of photons. This can be visually confirmed by the fact that if one observes the tube in a darkened room while it is operating, a flash of light covering the central wire will be seen every time a discharge takes place. These photons at the center of the counter may again eject photoelectrons by absorption in the gas or the cathode of the tube. Many have considered these ejected electrons to play a most important part in the characteristics of a counter, and so they have attempted to reduce the effect of these ejected electrons by increasing the work function of the cathode or by coating the cathode with a high resistance material.

It seems reasonable that since the positive ions are less mobile than the electrons, there will be an accumulation of positive charges around the central wire. This will reduce the potential gradient until no further ionization even by the electrons can take place. The positive cloud then moves outwardly and reaches the cathode in about 10^{-6} seconds. On reaching the cathode these positive ions may or may not produce new electrons.

It seems that the so-called "self quenching" counters are those in which no new electrons are produced. Tubes in this class are those containing vapors, and tubes that have special coatings on the cathode. If, on the other hand, new electrons were produced at the surface of the cylinder, the entire action might be repeated if the potential difference across the electrodes was at least equal to the threshhold voltage. The voltage across the tube will have been reduced by the migration of these ions by an amount depending on the quantity of charge transferred; the constants of the circuit; and on the amount of charge that leaked back to the electrode through the external high resistance. If the initial surge of ions reduces the voltage across the tube sufficiently then the discharge will be stopped even though new electrons be formed at the cathode. On the other hand, if this surge does not reduce the potential difference sufficiently a new surge of ions takes place, and each surge would reduce the potential difference and the action finally ceases when the difference of potential is reduced to a value below threshold voltage.

There have been many other ideas put forth concerning the discharge mechanism of a counter, but the ones which have been presented above seem to be the most reasonable ones. They also have been verified by experience to a large extent.

Thus to build a fast counter it is obvious that the whole discharge process should be completed with a single surge of the charges inside of the tube. This will be the case provided no electrons will be produced at the cathode when the positive ions strike the wall, as is the case in the "self quenching" type of counter. In this type of tube the vapor filled ones seem to be the most successful. The methods of filling these tubes are not critical, and it is possible to obtain practically one hundred per cent production efficiency. A good technique consists of evacuating the tubes with a force pump; filling them to a pressure of about a centimeter of mercury with some organic vapor, such as ethyl alcohol; adding about nine centimeters of mercury pressure of argon; and finally sealing them off. The way in which these vapor tubes are generally used is by connecting them to the source of potential difference through a resistance of the order of 10^5 ohms.

Another type of fast counter is one in which the potential difference would be reduced to a value below threshold voltage by a single surge of the ions. The technique that we have employed for a tube of this kind involves a thorough cleansing before assembling the parts of the tube. After the parts are assembled the tube is filled with cleaning solution for several hours, and then washed with distilled water. The tube is then pumped on a high vacuum system from ten to twenty hours at a temperature of over 500°C. This removes impurities especially from the surface of the glass. The copper cylinder is then oxidized and the oxide coat is removed with a dilute solution of nitric acid, in order to get the copper cylinder in as clean a condition as possible. After a thorough flushing with distilled water, the tubes are again put on the pumping system and baked for several hours. Commercial hydrogen is then admitted while the tube remains at the high temperature. This reduction is continued for about two hours, after which time they are evacuated and refilled with hydrogen through a palladium valve to about ten centimeters of mercury pressure. With this technique we have obtained tubes with plateaus of over a thousand volts having very good all-around performance. Due to the long plateau no stabilized source of high voltage is necessary. These tubes can be used at a very high over voltage, thus increasing the speed with which the ions multiply.

The tube is generally used with a Neher-Harper or a Neher-Pickering amplifying circuit which reduces the time required for recovery. We have found these hydrogen tubes to stay constant over indefinitely long periods of time. Some of our tubes, which were built five years ago, still function as well as when they were made. I do not know of any vapor tubes than can quite measure up to this performance. The chief drawback to this tedious technique for the hydrogen tubes is that the production mortality is very high.

There are other techniques used by investigators for building Geiger-Muller tubes, but in many cases these magic formulae seem to work only for the persons who devised them. The two techniques which have been considered in this paper are probably the most widely used.