A WIDE-RANGE GAMMA-RAY DOSE-RATE METER

D. SRDOČ

Institute "Ruđer Bošković", Zagreb, P.O.B. 171, Yugoslavia

Abstract—Properties of gas-filled detectors have been discussed in connection with their use in portable dose-rate meters. It has been pointed out that the relatively long dead time of a G.M. counter causes a serious limitation to high dose-rate measurements. Since G.M. counters offer some advantages in comparison with ionization chambers (substantially higher current output per unit dose-rate) an attempt has been made to obtain a wide range dose-rate meter by using a newly developed G.M. counter tube. A substantially shorter dead time of the order of a microsecond has been obtained. The new counter tube does not saturate until 10^3 r/hr in the Geiger region. Several tubes have been tested up to 5×10^5 r/hr in the proportional region without observing saturation phenomena or radiation damage after prolonged exposure. Schematic diagrams of a portable dose-rate meter and a monitoring system for a kilocurie ^{60}Co source using the newly developed tubes have been presented.

INTRODUCTION

It is desirable to combine the wide measuring range and the spectral insensitivity of a properly designed ionization chamber with the fast response, acoustic indication and high sensitivity of a G.M. counter. An approach to such a device might be attained by using a halogen G.M. tube, measuring the pulse-rate at low dose-rates and the average current in the high dose-rate region. A G.M. tube has a current amplification of 10^4 to 10^6, which allows substantial simplification of the electronic circuitry. However, the phenomenon of high internal amplification of a G.M. tube is accompanied by a long "dead time" which causes saturation at a relatively moderate dose-rate, thus limiting the use of G.M. counters in dose-rate meters. A halogen counter, such as a Philips 18504 tube, covers about two decades before reaching saturation. There exists a possibility—at least in principle—of combining a set of counters, each of them being of a different size and having overlapping radiation vs. current characteristics. Such an arrangement has the serious drawback from the practical point of view that counters of different sizes usually have different working voltages, pulse amplitudes and dead times. This may lead to a cumbersome design of radiation detection instrument. An attempt has been made to overcome these difficulties by using a parallel plate halogen filled G.M. counter (1) which has some outstanding properties, such as fast response to ionizing particles, short dead time and high charge per pulse.

PARALLEL PLATE COUNTER

Several authors have pointed out (2, 3) that parallel plate geometry should give rise to a faster response to an ionization event. This is because in a cylindrical counter, electron multiplication only occurs in a small region of high potential gradient around the anode. Electrons produced outside this region are in an area of relatively low potential gradient through which they slowly drift without multiplication until they reach the area around the anode where multiplication can occur. In a parallel plate counter there is no time lag due to this electron transit before multiplication. If such a fast rise time is followed by a short recovery time then a substantial increase in counting rate may be achieved allowing the counter to be used at higher dose-rates. Earlier attempts (2, 3) were unsuccessful in obtaining the short recovery time; a very fast pulse rise time of the order of a few tens of nanoseconds was followed by a recovery time of a few milliseconds. However, our experiments with halogen quenching mixtures showed that the recovery time might be reduced to a fraction of a microsecond by proper counter design and by the use of an optimum gas mixture.

The counter geometry is very simple, consisting of two stainless steel plates, separated by a glass ring. Measurements of the counter characteristics showed an optimal gap around 0.3 cm at 100 mm of neon plus 1.0 mm of bromine. Departures from these values are permissible if a shorter operating range may be tolerated. The plate diameter is not critical up to several cm. However, further increase leads to a capacitance which may be large enough to affect the discharge mechanism, leading to a self-sustained streamer.

The mechanism responsible for discharge propagation in our counter is photoionization in the gas. This is a very fast process, requiring about 10^{-8} sec to complete the avalanche at a high overvoltage. At lower overvoltages near the Geiger threshold a very slow buildup of the pulse is observed indicating another mechanism, probably the production of metastable states and their slow diffusion and de-excitation. This region should be avoided, because the slow pulse build-up takes several micro-seconds. The time necessary for the completion of a discharge includes the time for the transit and neutralization of positive ions. Because of the high potential gradient extending across the whole counter, positive ions will cross a parallel plate counter faster than a cylindrical counter with its large region of relatively low electric field near the cathode. Thus a transit time of a fraction of a microsecond can be obtained. Taking the drift velocity of positive ions to be approximately 1–2 cm/μsec at the E/p value of $\approx$ 20 V/cm mm Hg (the exact values for gas mixtures under consideration are not known), the time necessary for an ion to cross the gap is $\approx$ 0.15—0.3 μsec. The oscilloscope measurement shown in Fig. 1 confirms these assumptions, giving for the discharge development a rise time of $\approx$ 20 nsec and an ion transit time of $\approx$ 150 nsec. Thus the discharge is completed

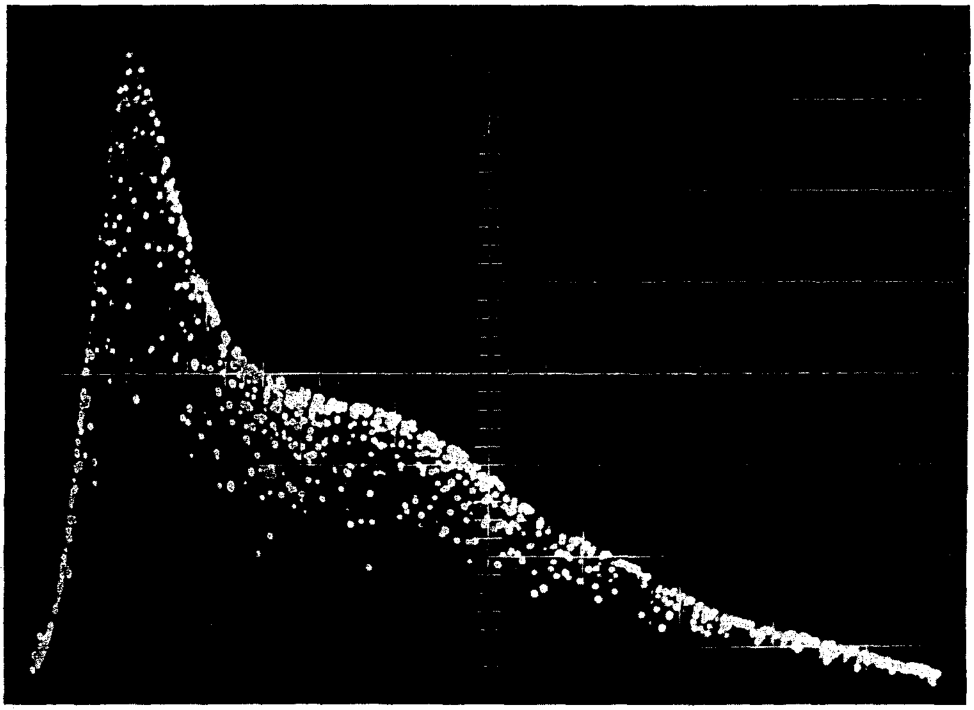


FIG. 1. Parallel plate counter pulse. Time: 20 nsec per larger division. Vertical scale: 4.6 mA per larger division.

in less than 200 nsec, which is shorter than typical values for conventional G.M. counters by several orders of magnitude. In order to exploit fully the very short dead time of a parallel plate counter it should be emphasized that the RC constant (R = series resistance, C = total capacitance of the electrode system) should be kept reasonably low. This is not always possible, because too low a series resistance causes poor counter characteristics. A simple transistorized circuit is under development by means of which it will be possible to take full advantage of the fast completion of the discharge.

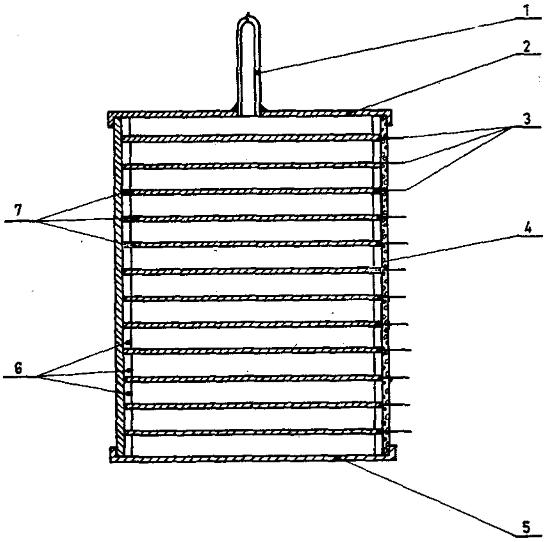


FIG. 2. Multiple counter. Schematic diagram and exploded view. 1, filling tube; 2, 5, top and bottom caps, glass matching alloy; 3, leads; 4, powdered glass seal; 6, glass or ceramic spacers; 7, stainless steel discs.

For practical purposes it is convenient to use a stack of parallel plate counters, thus increasing the pulse rate or the average current for a given radiation intensity. Figure 2 shows an assembly of parallel plate counters. The construction and preparation of a counter is relatively simple, using prefabricated parts. Every cell consists of two metal discs separated by a glass ring. The thermal coefficient of linear expansion of glass and metal should match closely in order to avoid stresses. A glass to metal vacuum-tight seal is obtained using low melting point powdered glass, the whole assembly being heated up to the melting point of the powdered glass in an inert gas atmosphere.

The properties of a parallel plate counter are compared with those of a conventional G.M. counter of the same dimensions in Fig. 3. For the parallel plate counter the average current for a given radiation intensity is 5–10 times larger, depending on the radiation intensity; furthermore, the conventional G.M. tube saturates at 10^2 mr/hr, while the parallel plate counter only reaches 90% of its saturation current at 10^5 mr/hr.

A further extension of the counting range towards high dose-rates is observed when the tube operates at a few volts below the Geiger threshold. No saturation phenomenon occurs at 10^6 r/hr, the maximum dose-rate available is our experimental set-up. The pulse amplitude spectra observed on the oscilloscope show that the detector is working as a typical proportional counter. The amplification factor is estimated to be 10^4. No radiation damage is observed after $\approx$ 1 Mrad, the estimated absorbed dose during experiments.

DOSE-RATE METER AND MONITORING SYSTEM

The use of a parallel plate counter in portable dose-rate meters makes a substantial simplification of the electronic circuitry possible. The block diagram of a portable dose-rate meter is shown in Fig. 4. The main parts consist of a stabilized high voltage supply, a linear D.C. amplifier and a 50 μA meter. The instrument is provided with a ^{90}Sr calibration source. The calibration is performed by opening the ^{90}Sr source and adjusting the EHT voltage until the counter current reaches a defined value.

Fig. 5 shows a detailed electronic circuit diagram, and Fig. 6 is a photograph of the portable survey meter using the newly developed tube.

A high current output, ranging about 50 μA, and excellent resistance to radiation damage make the parallel plate counter suitable for monitoring the area close to radiation sources and for positioning them. A schematic diagram in Fig. 7 shows such an arrangement applied

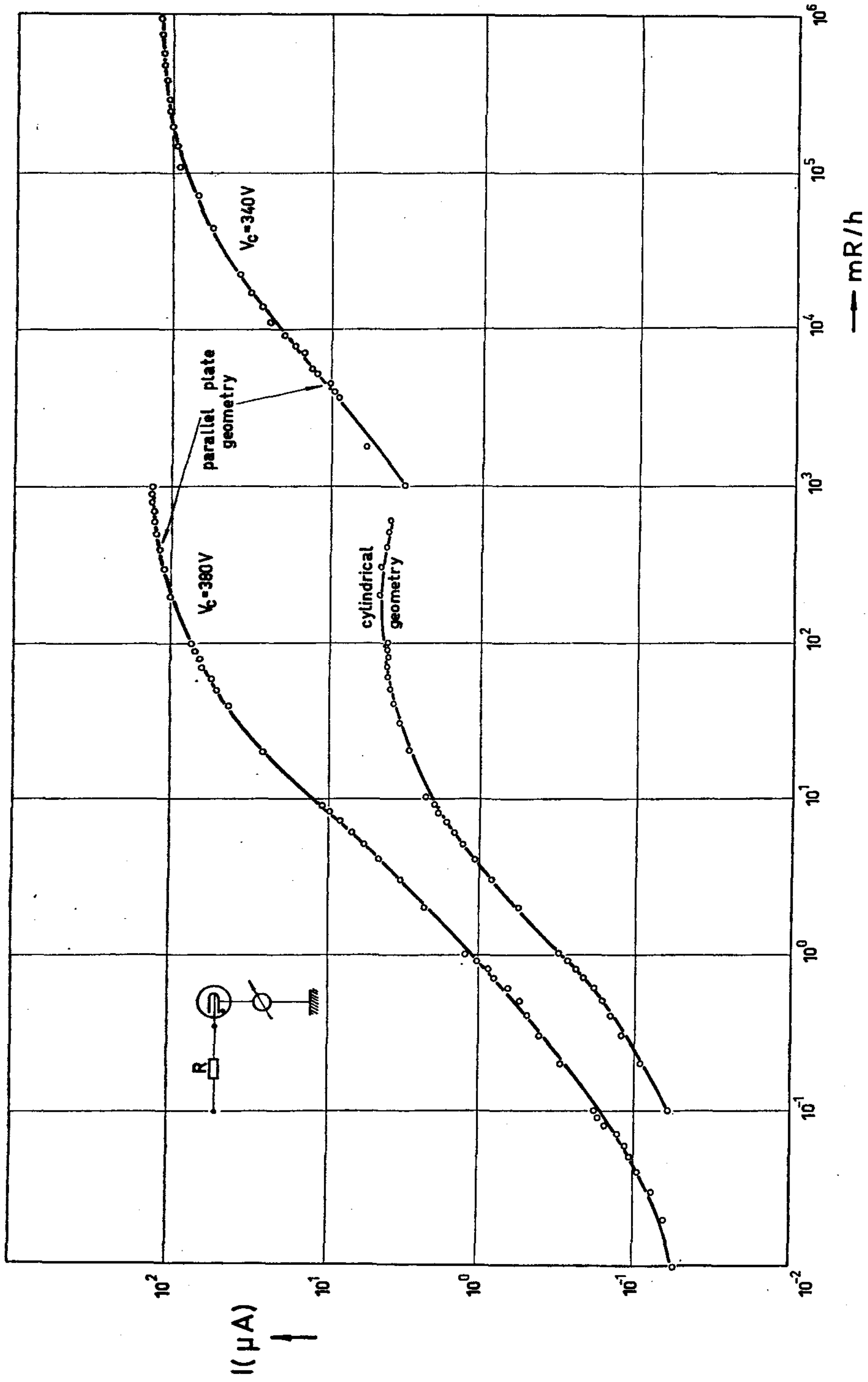


FIG. 3. Counter current vs. dose-rate plot. Comparison between the parallel plate and the cylindric counters.

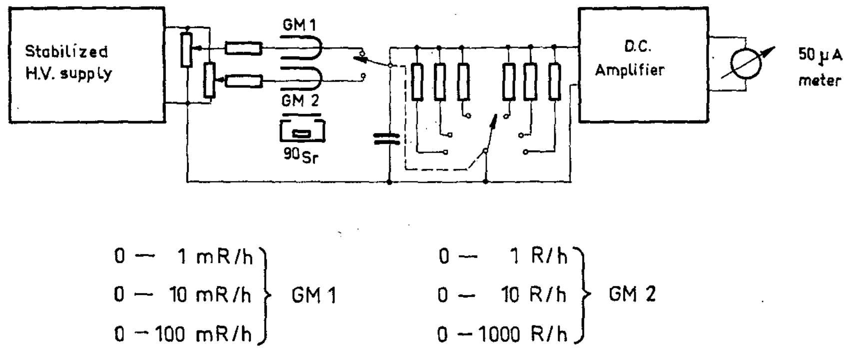
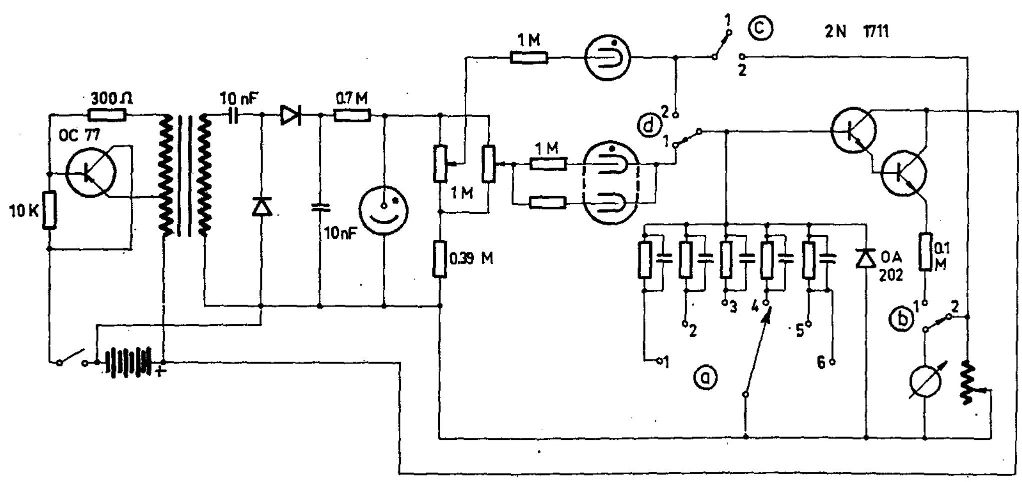


Fig. 4. Block diagram of a portable dose-rate meter based on the parallel plate counter.



Positions	a	b	c	d
0 – 1 mR/h	1	2	3	4
0–10mR/h	2	1	1	1
0 100mR/h	3	1	1	1
0 – 1 R/h	4	1	1	2
0–10 R/h	5	1	1	2
0 1000 R/h	6	2	2	2

Fig. 5. Circuit diagram of a portable dose-rate meter based on the parallel plate counter.

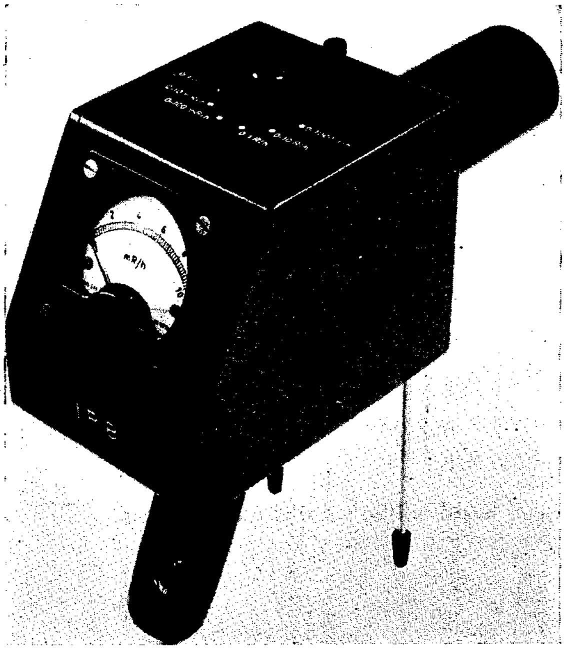


FIG. 6. Portable wide-range dose-rate meter.

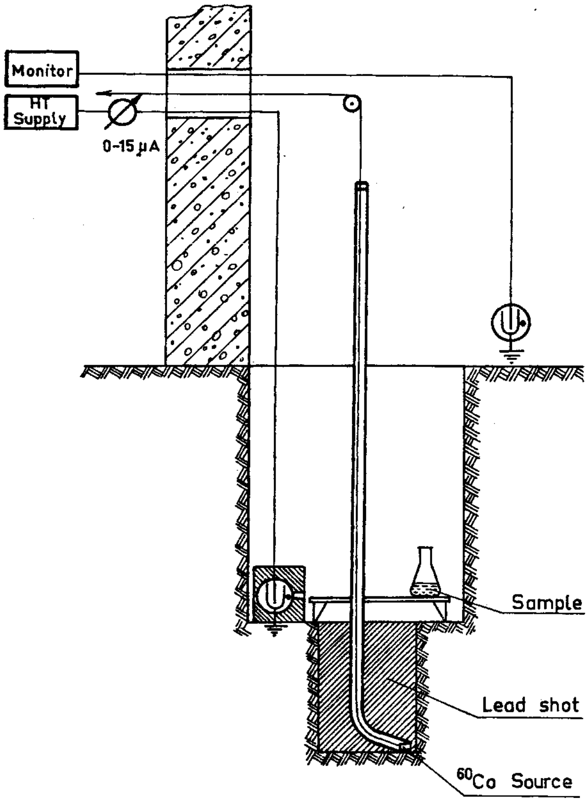


FIG. 7. Schematic diagram of a monitoring and positioning system using a parallel plate counter.

to a ^{60}Co gamma irradiation unit. During operation of the system it was observed that the electrical cables suffered from radiation damage, the leakage current through the cable insulation amounting to several microamperes when irradiated. Using teflon instead of polyethylene insulated cables reduced the leakage current below values which would affect the monitoring system.

CONCLUSIONS

The properties of the parallel plate counter offer the possibility of widening the dose rate range and of substantial simplification of dose-rate meter design.

The use of tissue-equivalent materials for counter walls is not possible because of the present technology of halogen counter production. Therefore, correction of the spectral sensitivity of the multiple counter could only be achieved by using filters. Another feature of this instrument is its directional sensitivity. This depends on the plate material, thickness, and diameter, so there is a possibility of minimizing the errors due to counter orientation. In the case of the multiple counter shown in Fig. 2, when the incident radiation was parallel with the counter axis the output current was 12% higher than for a beam perpendicular to the axis.

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