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Radioactivity Meter for Nuclear Research

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RADIOACTIVITY METER

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Electronic engineering makes another contribution to the development of atomic energy for constructive purposes

• With nuclear research and nuclear engineering programs rapidly being formulated by universities, hospitals and various industrial and government groups, the need for instrumentation in this comparatively new field has increased the importance of the Geiger counter and its associated equipment. The Geiger counter is used to detect and count the bursts of energy and the particles which are emitted from the nuclei of radioactive materials. Two familiar applications are the quantitative measurement of radioactive materials and cosmic ray research.

A most promising field is in conjunction with radioactive isotopes, since the advent of the cyclotron has made possible the production on a usable scale of several hundred such isotopes. The radioactivity of these isotopes provides a tracer, by means of which their course in chemical and physical processes can be followed with the counting-rate meter. The present applications of this technic include problems in medicine, chemistry, geology, meteorology and agriculture. In industry also this counter has been found useful—notably in petroleum prospecting.

The development of the counting rate meter described in this article was started before the war as a cooperative endeavor by interested groups at Massachusetts Institute of Technology and the General Radio Co. Several such instruments have seen service in various projects during the war and improved designs are now being produced on a commercial basis.

Fig. 1—Panel view of the type 1500-A meter with its associated pre-amplifier and probe assembly

Counter operation

If a low voltage is applied to two adjacent electrodes in an ionized gas, the positive ions will be attracted toward the negative electrode and the negative ions will migrate to the positive electrode. If the voltage is just sufficient to draw the ions out of the area, the device is called an ionization chamber and the current flow is a measure of the number of ions in the field. However, if the applied voltage is sufficiently increased, an ionizing particle or ray will initiate a continuous discharge which stops only due to a reduction of the interelectrode voltage. The device operating under these conditions is called a Geiger counter.

Fig. 2—Connecting a plug-in type beta ray counter to radioactivity meter pre-amplifier

If a large resistance is placed in series with the voltage source of the Geiger counter, the discharge will quench itself. This is because the electrons produced in the gas by ionization move with high velocity to the positive electrode, altering its potential and leaving a slowly moving positive ion sheath which then travels to the negative electrode. The high resistance prevents the potential of the positive electrode from recovering before all positive ions (which might start new discharges) have been neutralized. A similar quenching action may be obtained by means of vacuum tube circuits.

As a result of this quenching action, each discharge pulse is an indication that a charged particle has entered the counter. Furthermore, there is a regulatory action so that the counter may be operated over a voltage range where the current due to an ionization cycle will be fairly constant. The center of this current "plateau" is the usual operating point of the Geiger counter. Proper counter design is concerned with the resolving time or speed with which the quenching action takes place, its freedom from temperature and humidity effects, the broadness of the plateau, stability,

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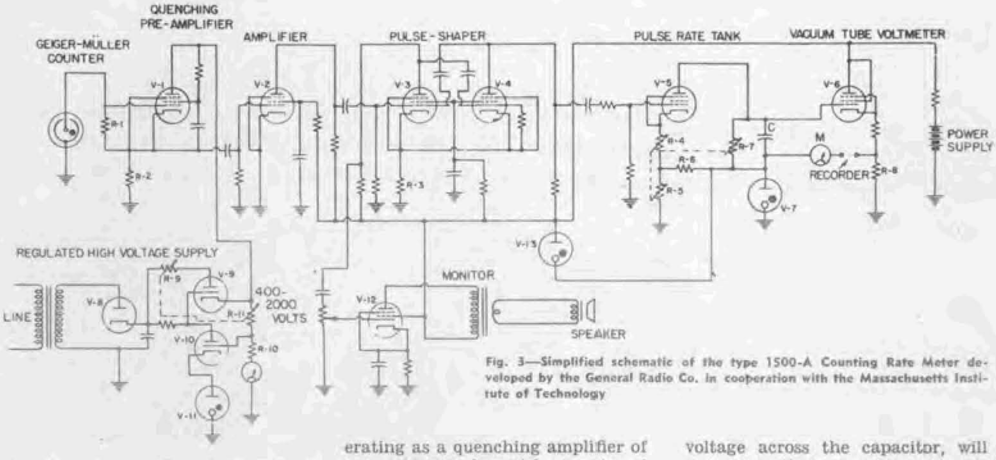

Fig. 3—Simplified schematic of the type 1500-A Counting Rate Meter developed by the General Radio Co. in cooperation with the Massachusetts Institute of Technology

aging characteristics, efficiency and life.[1]

In the counting-rate meter to be described, the discharge pulses produce a voltage which indicates at any moment the rate per minute of the incoming pulses. With a volt-[illegible]er actuating a pen-and-ink re-[illegible]der, a running record is obtained, showing the past and present history of the radioactive emissions.

This meter is shown in Fig. 1 and a close-up of a beta-ray counter with its preamplifier is shown in Fig. 2. The plug-in type counter and its preamplifier are housed in a separate small compartment at the end of a cable to provide greater flexibility of operation.

Circuit description

In the circuit of Fig. 3 the Geiger counter is placed in series with R-1 and V-1, the anode of V-1 being connected to an electronically regulated voltage supply consisting of V-9, V-10 and V-11. In the absence of radiation, little or no current flows in R-1, leaving the grid essentially at zero bias with a consequent low voltage drop across the anode circuit and a relatively high voltage across the Geiger tube.

When gas in the Geiger tube becomes ionized as the result of bombardment by nuclear particles, a current flow takes place that can be stopped, or "quenched," only by reducing the applied voltage. This reduction is performed by V-1, operating as a quenching amplifier of a modified Neher-Pickering type.[1] Any current flow through R-1 will increase the grid bias of V-1, thereby reducing the anode current and lowering the voltage drop across the Geiger tube below the critical value required for continuous discharge. This restores the circuit to its quiescent state to await the next impulse. The speed at which V-1 is able to perform its quenching and voltage restoring function safely exceeds the transit time characteristics of the best available Geiger counters.

The output at the cathode of V-1 consists of a sharp negative pulse which is amplified by V-2 and shaped by V-3 and V-4, appearing at the output of V-4 as a greatly amplified positive pulse. Since from this point there is regenerative feedback to the grid of V-3, the output pulses will depend only in their time distribution on the input pulses, but will all be identical in shape and magnitude.

The integrator tube, V-5, is biased beyond cutoff. Each positive pulse appearing at its grid causes a definite amount of current to flow in the anode circuit; hence, the capacitor C in the anode circuit will absorb a definite quantity of charge for each incoming pulse—an intergrating process. The resistor R-7, however, introduces a differentiating factor, since it allows the impounded charge to leak out of the capacitor at a given rate dependent on the RC time constant. The residual charge, as indicated by the voltage across the capacitor, will depend entirely on the rate at which charging pulses have been coming in, since these pulses are all of equal amplitude and duration.

The pulse rate, in counts per minute, is indicated by a vacuum tube voltmeter[2] connected across capacitor C. This capacitor has been specially wound with polystyrene tape to reduce to a negligible value the effect of its dielectric absorption on the accuracy of differentiation.

The full scale meter current is 5 ma., suitable for operation of most ink recorders, and the range of pulse rates is extended by using different values of bleeder or differentiating resistors at R-7 and by varying the amount of degeneration caused by R-4 in the integrator tube. Full scale ranges of 200, 600, 2000, 6000 and 20,000 counts per minute are thereby obtained. A monitoring loud speaker, shown schematically in Fig. 3, is provided for convenient estimation of the counting rates.

The voltage supply to the counter may be adjusted to any value between 400 and 2000 volts and is electronically regulated to maintain the operating voltage of the Geiger counter at a fixed point near the center of the useful portion of its characteristic plateau.

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[1] "Electron and Nuclear Counters—Theory and Use," Korff, D. Van Nostrand Co., Inc.
[2] U.S. Patent No. 2,374,248.
See also "Design and Operation of an Improved Counting Rate Meter"—A. Kip, A. G. Bousquet, R. D. Evans and W. N. Tuttle, Review of Scientific Instruments, Vol. 17, No. 8 (August, 1946).