measure atomic radiation

Part II—Ion-chamber meters and a G-M counter you can build

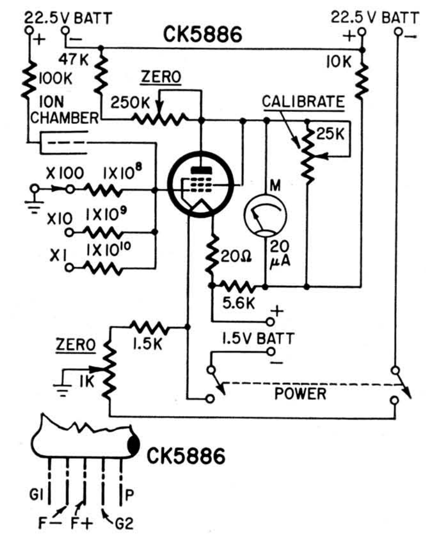


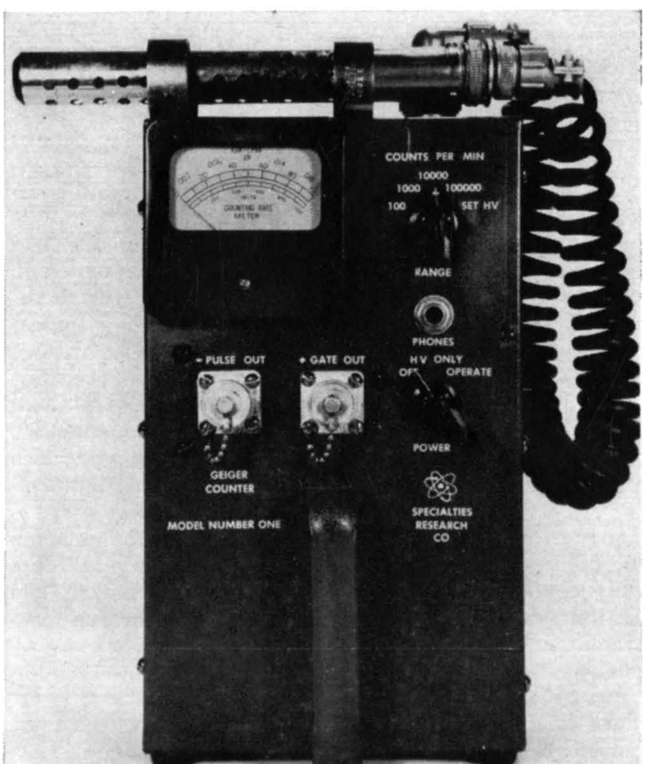
Fig. 5—Typical ion-chamber type radiation detector.

By CARL L. HENRY

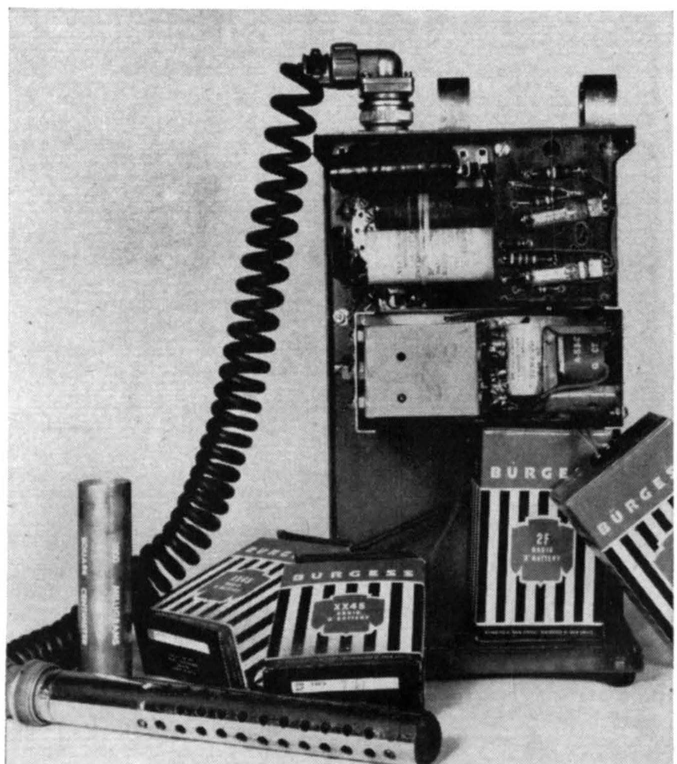
Last month we discussed devices that read the absorbed dose rate of nuclear radiation. Undoubtedly such equipment is very useful, since it tells you exactly how much radiation you have absorbed. But surveying an area for radiation is slow and difficult work with such equipment. A much better approach is an actual survey meter that uses an ion chamber as the basis of its indication. Such instruments that cover ranges of from 0.1 to 500 roentgens are available at a reasonable price. (Both Lafayette Radio and Radio Shack list one in their catalogs.)

They are sensitive to atmospheric moisture and shock, and in general have low-reliability circuits. However, to balance these drawbacks, they are accurate, highly portable and easy to use. Ion chambers measure the *exposure dose rate.* They are normally calibrated in roentgens per hour. In other words, if you walked into an area and the meter indicated 500 roentgens, you could walk out again and the absorbed dose you received would be on the order of 10 roentgens had you been in the field for approximately 1 minute.

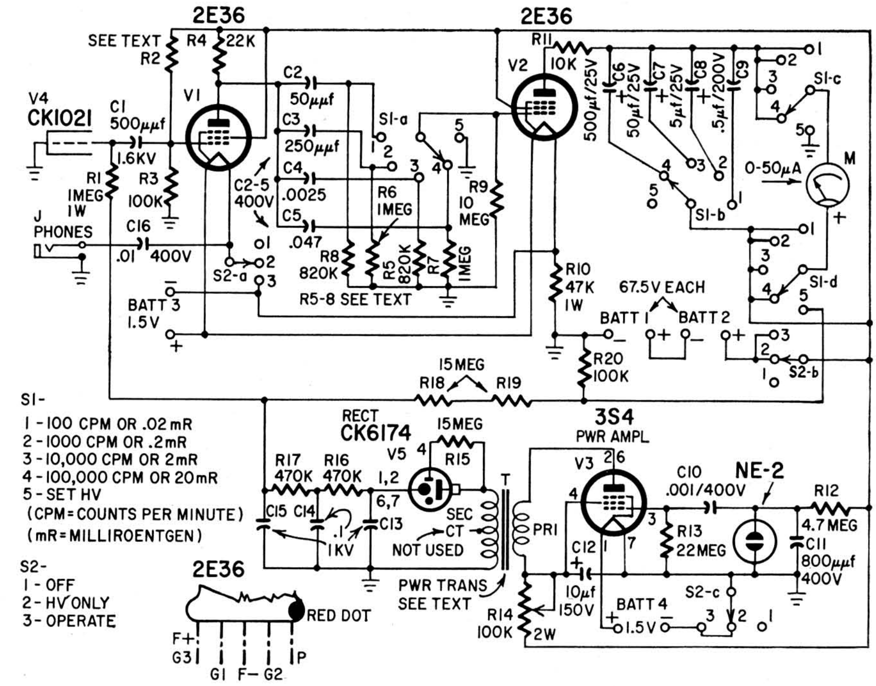
Fig. 5 is the schematic of a typical ion-chamber instrument. The measurement basis is a sealed chamber filled with gas or dry air. The chamber is "saturated" by a 22.5-volt battery, and any ions generated in the chamber are collected by the center electrode. The current from this chamber may be on the order of 10^{-10} to 10^{-14} amperes. Measuring such a small current accurately is a tough job. The 5886 electrometer tube is the only possible simple solution. The extremely high-impedance grid circuit accounts for the basic trouble with this type meter. Moisture has a great effect on the reading. The meter must be frequently balanced and corrected. In the past year I have repaired six of these instruments. In each case, the 5886 had to be replaced. This does not mean that the circuit is poorly designed—rather that the circuit is delicate, and when more reliability is designed in, cost increases appreciably.



Front-panel layout of precision Geiger counter.



Inside the Geiger counter.



R1—1 megohm, 1 watt, deposited carbon
R2—see text
R3—100,000 ohms
R4—22,000 ohms
R5, R8—820,000 ohms
R6, R7—1 megohm
R9—10 megohms
R10—47,000 ohms, 1 watt
R11—10,000 ohms
R12—4.7 megohms
R13—22 megohms
R14—pot, 100,000 ohms, 2 watts, linear taper
R15—15 megohms
R16, R17—470,000 ohms
R18, R19—15 megohms
R20—100,000 ohms
All resistors 1/2-watt 10% unless noted
C1—500 μμf, 1,600 volts, ceramic
C2—50 μμf, 400 volts, ceramic
C3—250 μμf, 400 volts, ceramic
C4—.0025 μf, 400 volts, ceramic
C5—.047 μf, 400 volts, paper
C6—500 μf, 25 volts, electrolytic
C7—50 μf, 25 volts, electrolytic
C8—5 μf, 25 volts, electrolytic
C9—0.5 μf, 200 volts, paper
C10—.001 μf, 400 volts, ceramic
C11—800 μμf, 400 volts, ceramic
C12—10 μf, 150 volts, electrolytic
C13, C14, C15—0.1 μf, 1,000 volts, paper
C16—.01 μf, 400 volts, ceramic
BATT 1, BATT 2—67.5 volts (NEDA 200)
BATT 3, BATT 4—1.5 volts (NEDA 11)
J—phone jack
M—microammeter, 0-50, (Lafayette TM-70 or equivalent)
S1—rotary switch, ceramic, 2-gang 4-pole 5-position
S2—rotary switch, 3-pole 3 position
T—any plate to push-pull grid audio interstage transformer
V1, V2—2E36
V3—3S4
V4—CK1021
V5—CK6174
Neon lamp, NE-2
Case, to suit
Miscellaneous hardware

Fig. 6—An accurate, battery-powered Geiger counter.

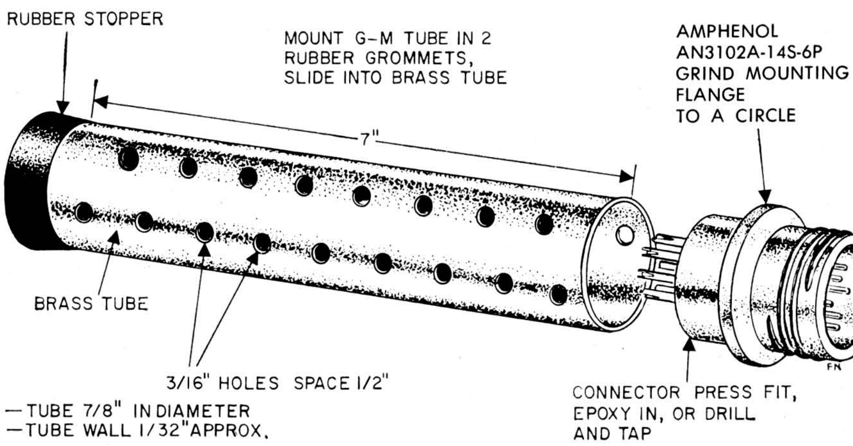


Fig. 7—Details of G-M tube housing.

Notwithstanding all these arguments, the ion chamber is the best high-level radiation surveying instrument now available. Servicing this type instrument is a problem. You *cannot* check the 5886 except by replacing it with a known good tube. You can make a careful check of batteries and circuit to discover any obvious defects. Be extremely careful when checking the meter, since it is usually very sensitive. One manufacturer markets an instrument with a 5-μa meter as the indicator. If there is no apparent trouble and the chamber appears sealed, your best bet is to substitute a good 5886.

At present, ion-chamber instruments are available that measure radiation from .01 milliroentgen to 10,000 Roentgen per hour. Although the present concern over fallout has served to drop prices on these instruments, they are still overpriced for the average person.

Pulse counting

So far in this article we have discussed methods of measuring the absorbed dose and the exposure dose rate, both methods being based directly on the ionization produced by the radiation being measured. Now we are going to discuss the third method of measuring radiation, pulse counting. All of us are familiar with Geiger-Muller counters. They work because gamma radiation excites the walls of the G-M tube, causing the gas within to be ionized by particles given out by the tube walls. Theoretically only 1% to 10% of the gamma radiation present is actually measured by a conventional G-M tube. Also, since the G-M tube measures particles or events, and the definition of a roentgen refers to the amount of ionization in a given volume of gas, the G-M tube cannot measure roentgens.

There is a way around this problem. If we pick a monochromatic radiation source (a source that radiates gamma radiation on one frequency) such as cobalt (60) or radium, and adjust the G-M counter to read correctly the proper roentgen value of the radiation, it will be correct on any other monochromatic source of similar strength. It will be accurate enough on other sources to give an approximate indication within 20% to 30%. Further inaccuracies are caused by particles that leave the source at different velocities (measured in electron volts, ev, or million electron volts, mev). The accuracy of a G-M counter is usually good enough for survey work, however.

In dealing with high-level radiation, such as in a radiography laboratory or with fallout from an atomic bomb blast, the G-M counter has a further big disadvantage. All G-M tubes have a dead time of from 80 to 300 microseconds. This "dead time" means that, as in all gas tubes, a certain length of time is required for the gas to deionize before it can begin another ionization period. With a dead time of 100 microseconds, any pulses occurring quicker than 100 microseconds apart will be lost. This limits the counting rate to 10,000 pulses per second, which roughly corresponds to 50 milliroentgens per hour. The bad thing about a G-M counter is that when the radiation field exceeds the maximum value, the G-M tube is continuously ionized, and the counter will go dead. There are several ways around this problem as we shall see shortly.

Home-built counter

Fig. 6 shows a precision home-built counter that is very accurate and stable. Fig. 7 shows details of the G-M tube mounting. The tube and instrument are connected with a 3-foot length of shielded two-conductor coil cord terminated in an Amphenol AN3106A-14S-6S connector. A matching connector is on the probe. The counter is rather elaborate. However, it has two advantages. The circuit is very reliable and basically very accurate. It *is* large and heavy, making it difficult to carry and use for any length of time.

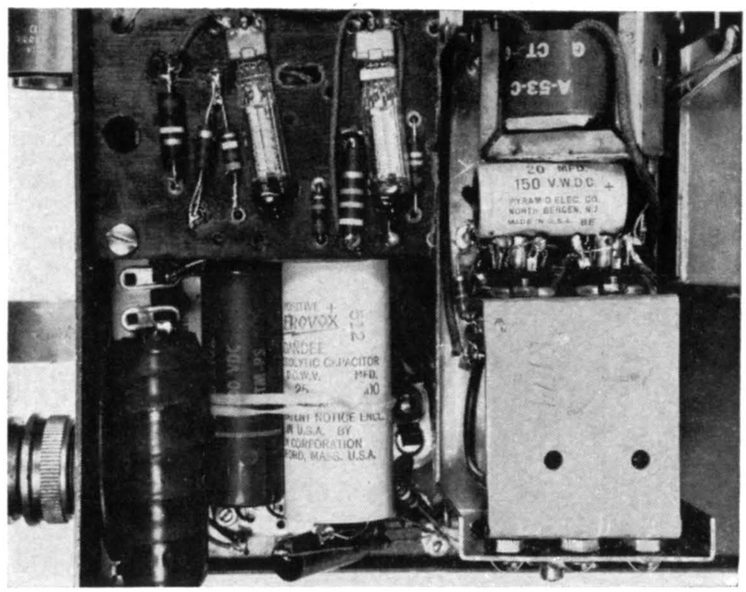
The instrument is built in two sections. The first is the high-voltage supply and the Geiger tube circuit. The high-voltage section is built in a separate small box between the counting-rate meter and the battery space. It consists of a neon-bulb oscillator that feeds a power amplifier. The amplifier output is stepped up by a plate-to-grid audio interstage transformer, and rectified by a cold-cathode rectifier tube. After filtering, the high voltage (variable from 600 to 1,100 volts) is applied through a limiting resistor to the Geiger tube. Pulses in the neighborhood of 1 volt peak to peak are obtained from the Geiger tube in normal operation.

The counting-rate meter comprises the second section of the circuit. Referring to Fig. 6, you can see that the counting-rate meter uses two tubes. The first is normally conducting and, due to common-cathode resistor R10, keeps the second tube, V2, biased off. When a pulse from the Geiger tube arrives at V1's grid, it cuts off this tube, V2 conducts and the meter indicates a count. Values for C6, C7, C8 and C9 are chosen to damp the meter properly by lengthening the pulse. Resistors R5, R6, R7, and R8 serve to calibrate each range of the meter. The counting-rate circuit can be calibrated with a pulse generator if you have one available. Using the values shown, your accuracy should be within 20%.

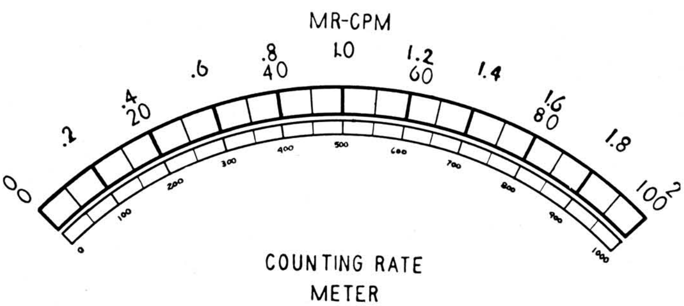
R2 determines the height of the negative pulse required to cut off V1. Normally, after construction is completed, you would turn on the instrument and have a potentiometer in place of R2. Vary the potentiometer until the meter reads background (about 40 to 60 counts per minute). Too much resistance here will cause V2 to draw a steady current and pin the meter. Too little resistance will prevent the radiation pulses from the G-M tube from cutting off V1. After determining the proper value for your meter, remove the potentiometer and replace it with a 5% fixed resistor.

Headphones or a small loudspeaker (with a matching transformer) can be plugged into J to give an audible indication of an increase in radiation.

If we keep in mind the limitations of the Geiger counter, it is very valuable in radiation survey work. It indicates beta as well as gamma radiation. It would be valuable inside a fallout shelter for checking radiation in food



A closer view of the inside of the Geiger counter.



Meter scale for the 0-to 50-μa meter used in the counter.

and water. Also the level of radiation outside the shelter could be approximated from inside. Most high-level survey instruments will not respond to low electron-volt or "soft" radiation. This radiation is lethal, and the G-M counter is the ideal instrument with which to measure it. Although the instrument cannot be calibrated in roentgens, an approximate calibration on cobalt 60 can be made.

The counter can also be used to check a projection TV set for soft radiation.

As I said before, a G-M counter is usually limited to 50 milliroentgens before it goes dead. There are two ways of extending the range of these counters, however. The first is by operating the Geiger tube in its *proportional range*. On the home-built instrument described here, the usable proportional range is between 750 and 800 volts. The Geiger range starts at 850 volts. In the Geiger range, the radiation pulses are amplified by gas action in the tube itself. In the proportional range, this amplification does not exist. The pulses from the tube must be amplified about 100 times in proportional operation before they are large enough to operate the counting rate meter. By using such an amplifier, a high range of 500 milliroentgens can be established on the counter. The equivalent counts per minute would be approximately 2.5 million. Both C2 and C9 would have to be reduced.

The second method of extending the range is by shielding the G-M tube with lead sheeting. The drawback in this is that different isotopes radiate particles and gamma rays at different strengths. An isotope of iridium, for instance, radiates on many wavelengths at several strengths. Lead shielding will apparently reduce the G-M counter reading since much of this radiation is stopped by the lead. A tube of lead ⅛ inch thick will reduce the reading by a factor of 20. When cobalt (60) is used in the same manner, the reading is reduced only by a factor of 0.9. Thus, two inches of lead would be required to reduce the reading by a factor of 100. In general, Geiger counters must be considered of little use in radiation areas above 50 milliroentgens. They are, however, ideal for low-level surveying.

A person working with radiation or concerned about possible fallout detection would have a good combination of detecting instruments in a dosimeter and a Geiger counter—the dosimeter to read the high-level radiation of absorbed dose, and the G-M counter to survey low-level areas or possible food contamination. Home-built ion-chamber instruments are not generally considered practical, since from the average person's standpoint, they cannot be calibrated and are useless. END