civil defense Technical Bulletin

TB-11-20
SEPTEMBER 1955
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RADIOLOGICAL DEFENSE SERIES

A DIGEST OF TECHNICAL INFORMATION

RADIOLOGICAL INSTRUMENTS FOR CIVIL DEFENSE

This revision of TB-11-20 describes radiation survey meters and dosimeters developed for use in civil defense operations and training. It replaces information previously issued in the following FCDA (OCDM) technical bulletins, which are rescinded:

TB-11-2—Personal Dosimeters for Radiological Defense.
TB-11-3—The Most Promising Personal Dosimeters for Civil Defense Use.
TB-11-4—Development Status of Personal Dosimeters.
TB-11-15—Phosphate Glass Dosimetry.

This is one of a series of technical bulletins on civil defense against the radiological effects of nuclear weapons.

BACKGROUND

TB-11-22, *Radiation Physics and Bomb Phenomenology,* discusses how a nuclear (or atomic) explosion releases energy in several forms. One of these forms of energy is nuclear radiation—chiefly beta particles and gamma rays—emitted from radioactively contaminated material in the atomic cloud.

This radioactive material can "fall out" over an area of several thousands of square miles. The residual nuclear radioactivity from fallout persists for some time, and is the type that most concerns those who are to conduct radiological defense operations, as part of civil defense. Nuclear radiation can cause serious illness, genetic or other physical injury, and death—according to the dose rate of the radiation and length of exposure.

Although fallout can sometimes be detected by sight or touch, nuclear radiations from the fallout particles cannot be detected by the human senses. Therefore, for civil defense purposes, instruments for detecting and measuring nuclear radiation have been developed by the Office of Civil and Defense Mobilization (OCDM).

INSTRUMENT REQUIREMENTS AND CAPABILITY

There is no equivalent of combat experience upon which to base the requirements for civil defense radiological instruments. However, extensive tests of nuclear weapons under known conditions have indicated the kinds and extent of residual radiation that could result from their use; and the knowledge gained from other types of experiments makes it possible to relate this radiation to biological effects. The radiological instruments developed by OCDM can provide the measurements necessary for evaluating the hazard of this ionizing radiation.

Many variables, such as bomb size, place and height of detonation, type of bomb assembly, and meteorological conditions, influence the concentration and distribution of fallout contamination that might be encountered in civil defense operations. This being so, it is not possible to predict accurately the radiation levels that could result from fallout; and a wide capability is required for radiation measurements. No single instrument meets all of the operational requirements that might result from a nuclear attack. Therefore, OCDM has developed several instruments that together provide a wide capability for monitoring. These are discussed later, under the heading "Types of OCDM Radiological Instruments."

The instruments that have been developed are in two major groups: Survey meters and dosimeters.

SURVEY METERS AND DOSIMETERS

One group of instruments—survey meters—is designed to detect nuclear radiation and to measure the dose rate. Some of these meters measure gamma only, others are beta-gamma discriminating.

Instruments of the other group—dosimeters—detect and register total accumulated gamma dose.

Estimates of total exposure and related biological effects can be made on the basis of dose-rate measurement, decay rates, and probable exposure time; but these estimates should be used for planning purposes only. Tolerance to radiation depends on whether or not doses were acute. Therefore, in civil defense operations, determination of actual exposures must be based on both dose rate as read on survey meters and on total dose indicated by dosimeters.

The units of measurement used on radiological instruments to show cumulative dose and dose rate of gamma radiation are, respectively, the roentgen (r) and the roentgen per hour (r/hr). The roentgen, as defined, relates to the effect of radiation on air. However, it is a useful unit for measuring radiation damage to tissue because over a wide range of energies (wave lengths) there is a nearly constant relationship between the energy absorbed per gram of air and the energy absorbed per gram of tissue.

The scale calibrations of meters developed by OCDM are not related directly to dose or dose-rate values of beta radiation. *Meter indication of beta radiation can be interpreted only in a general way, and is useful in estimating the ratio of beta to gamma radiation.*

SURVEY METERS

Survey meters are basically reconnaissance instruments, and can be used to provide the information required for direction of radiological defense (RADEF) and other civil defense operations.

Survey meters useful for civil defense operations have direct-reading scales that show the gamma dose rate in roentgens per hour. In tests by OCDM, survey meters designed to give merely "go-no-go" indications, such as those with blinking lights or audible warnings, did not provide adequate information on dose rate. These models are no longer being considered for use.

Beta-Gamma Discrimination

Beta and gamma radioactivity from fallout persists for a long time. Gamma radiation is, in general, more dangerous to humans than beta radiation because it is highly penetrating and can damage cells deep inside the body. The danger from beta radiation is related to its energy level. Even at relatively high energies beta radiation will not penetrate beyond the surface layers of the skin. Because the biological effects of beta and gamma radiation differ, there should be radiological instruments to discriminate between them.

Measurement of beta radiation is complicated by the very wide range of energies of these particles. Most beta detection instruments will not respond to extremely low-energy beta particles. However, that portion of the beta radiation that can be measured should be, so that its proportion to the total radiation can be determined. This is necessary to estimate possible damage by each type of radiation.

Sensitivity Requirements

Radiation effects on people must be the major concern in radiological defense.

The sensitivity requirements of radiation instruments depend upon the tasks the instruments must perform. An instrument used to measure the contamination of personnel, food, water, equipment, and living quarters must indicate very small amounts of radiation above normal background. This type of instrument would have little use in areas of heavy contamination.

To provide adequate monitoring, civil defense portable radiological instruments should be capable of measuring gamma dose rates as high as 500 r/hr, and indicating when dose rates exceed this figure. Measurement above this amount is not necessary for portable survey instruments, because a higher level of radiation would preclude further surface operation.

Aerial survey meters must be extremely sensitive to give correct readings of radiation levels on the ground (surface), and may be calibrated to read surface radiation levels directly. Aerial survey meters are under development by OCDM.

Remote-reading instruments used to indicate radiation levels outside fallout shelters should indicate gamma dose rates up to 1,000 r/hr.

Within the entire group of radiological instruments developed by OCDM, the capability for measurement of ionizing radiation dose rates ranges from a minimum of natural background radiation on the CD V-700, to a maximum of 1,000 r/hr on the CD V-711. This wide range of measurement capability is considered adequate for nearly all civil defense operational needs.

DOSIMETERS

Radiation survey meters measure the rate of exposure, but do not show total accumulated dose. Dosimeters are used for this purpose.

Some dosimeters may read directly, with the increase in total dosage being indicated by color changes or progressively higher scale readings of the meter. Other types of dosimeters, such as film badges or packets, require rigidly controlled processing before they can be properly interpreted. Radiophotoluminescent (phosphate glass) dosimeters have long shelf-life and can be read at any time without destroying previous readings, but require the use of a complex instrument for reading. Both the photographic and phosphate glass dosimeters respond to several types of nuclear radiation. Because of this, it is difficult to relate the readings to tissue damage.

For civil defense operations, OCDM recommends the use of the self-indicating quartz-fiber electrostatic dosimeter, with a range of either 0 to 20 r or 0 to 200 r. The lower range dosimeter is used when the expectation is that total exposure will be small, or that quite small repeated doses will be received over a long period of time.

The higher range dosimeter is recommended for use where personnel could be accidentally exposed to large doses of radiation. It should be used when personnel are required to enter fields of high radiation or remain in lower fields for long periods during postattack survival and recovery missions. Without such information for mission planning, workers might be asked later to undertake duties involving radiation exposures that would be dangerous when added to previous unknown exposures.

TYPES OF OCDM RADIOLOGICAL INSTRUMENTS

To provide a capability for meeting the various requirements of civil defense operations and training, OCDM has developed the following types of radiological instruments:

A. A highly sensitive dose-rate survey instrument that can discriminate between beta and gamma radiation, for long-term cleanup and decontamination operations and for training programs, where low radiation dose rates will be encountered (CD V-700).

B. A medium-range gamma survey meter to meet the principal radiological monitoring requirements for civil defense operations following an attack (CD V-710).

C. A high-range survey meter to measure and discriminate between beta and gamma radiation in areas where high dose rates exist (CD V-720).

D. An extremely sensitive gamma radiation aerial survey instrument for rapidly surveying contaminated areas from aircraft (CD V-780). (Experimental; not a stock item.)

E. A fixed-station monitoring instrument for group shelters, fire stations, and other structures, to provide occupants with measurements of outside radiation (CD V-711). (Production prototype being modified; not a stock item.)

F. Dosimeters of three ranges that can be worn or carried by individuals to indicate total radiation exposure (CD V-138, CD V-730, and CD V-742). (The CD V-742 replaces the CD V-740.)

More detailed descriptions of these six types of radiological instruments follow:

Survey Meters

CD V-700

The CD V-700 radiation survey meter (fig. 1) is a highly sensitive low-range instrument that can measure and discriminate between beta and gamma radiation. OCDM recommends its use for measurement of radioactivity in food and water during emergency operations, and for use in long-term cleanup and decontamination operations. The instrument can also be used in training programs, where low radia-

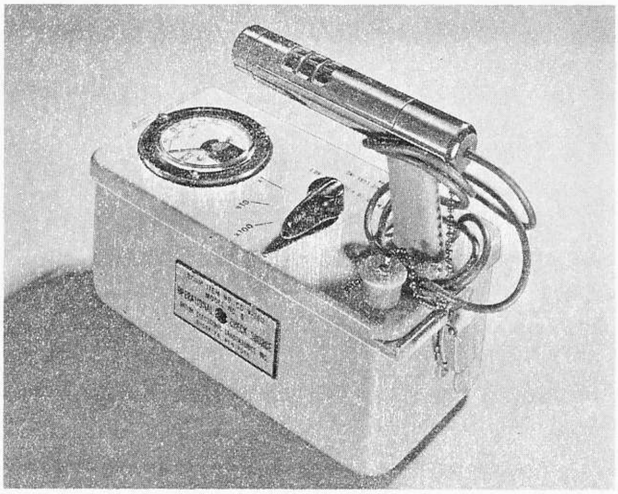

FIGURE 1.—CD V-700, low-range beta-gamma survey meter.

tion dose rates will be encountered. The ranges of this instrument are 0-0.5, 0-5, and 0-50 mr/hr to within 15 percent accuracy of true dose rate when calibrated against gamma rays from cobalt 60 or cesium 137.

The detecting element of the CD V-700 is a Geiger tube, shielded so that only gamma dose rate is measured, or beta and gamma can be indicated together with the shield open. A headphone for audible indication is supplied with this instrument; and a loudspeaker attachment is under development as optional equipment for training use. This instrument is designed for sensitive measurements, and has limited usefulness in areas of high contamination. In radiological defense operations, during the survival and recovery periods, the instrument would have to be used in locations well shielded from fallout radiation—where food, water, and personnel could be checked for contamination.

CD V-710

The CD V-710 (fig. 2) is a medium-range gamma survey meter for general postattack operational use. The ranges of this instrument are 0-0.5, 0-5, and

FIGURE 2.—CD V-710, medium-range gamma survey meter.

0-50 r/hr, to within 20 percent accuracy of true dose rate. (The CD V-715, now under development, will have an additional range of 0-500 r/hr, and will replace the CD V-710.)

The detecting element of the CD V-710 is an ionization chamber. This instrument was designed for ground survey work, but may be used in aerial surveys. In flight, the instrument readings should be doubled for each 200 feet of altitude to approximate the ground dose rate. (For example: a reading of 10 r/hr at an altitude of 600 feet would be multiplied by 2 times 2 times 2. This would give 80 r/hr, the estimated dose rate on the ground).

CD V-720

The CD V-720 (figure 3) is a high-range beta-gamma survey meter designed for special postattack

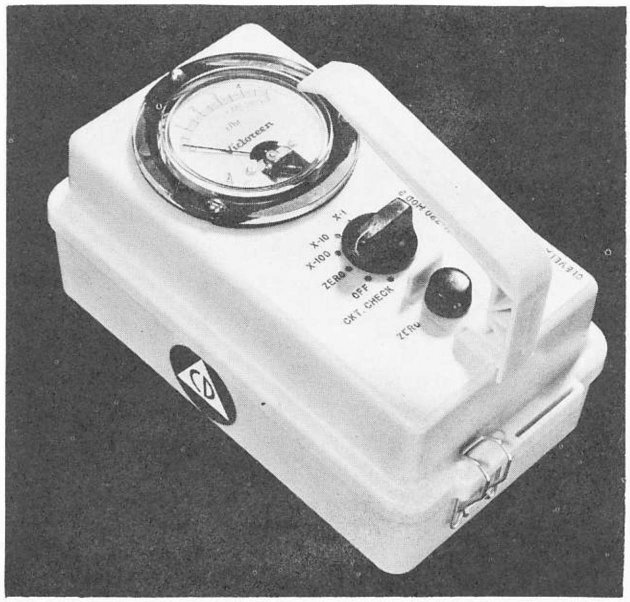

FIGURE 3.—CD V-720, high-range beta-gamma survey meter.

use by qualified monitors. The ranges of this instrument for gamma radiation are 0-5, 0-50, and 0-500 r/hr, to within 15 percent accuracy of the true dose rate, when calibrated against cobalt 60.

The detecting element of the CD V-720 is an ionization chamber, shielded so that gamma radiation only can be measured, or beta and gamma can be monitored together with the shield open.

CD V-780

The CD V-780 is an extremely sensitive gamma survey meter, now under development by OCDM, for use in measuring radiation dose rates on the ground by ground survey teams or in flight. The range of this instrument has been tentatively set at 0.01 to 400 r/hr. Readings of many times the high limit may be extrapolated, according to the altitude at which readings are taken.

The detecting element of the CD V-780 is a scintillator and photomultiplier tube. The CD V-780 is to be used for measurement of ground dose rates too high to be monitored from the ground, and for quick surveys of large areas. Until this instrument is available, the CD V-710 is recommended for aerial survey work.

CD V-711

The CD V-711 (fig. 4) is a remote-reading, fixed-station, wide-range gamma survey meter now under

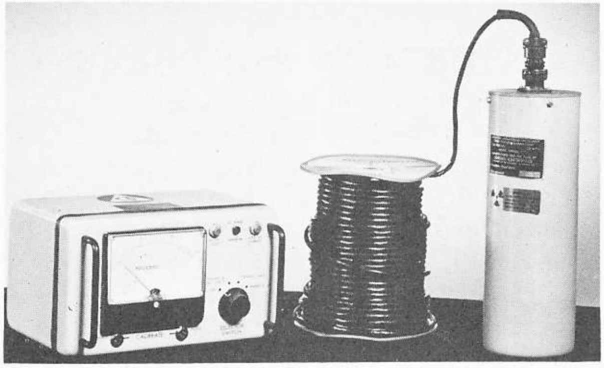

FIGURE 4.—CD V-711, fixed-station, wide-range gamma survey meter.

development by OCDM, but not yet available for distribution. It is designed to provide measurement of outside radiation dose rates to the occupants of public shelters, control points, and other types of well-shielded structures. The ranges of this instrument provide measurement from 1 to 1000 mr/hr, and 1 to 1000 r/hr, to within 20 percent accuracy of the true dose rate, when calibrated against cobalt 60.

The detecting element of the CD V-711 is a pressurized ionization chamber. A 200-ft. cable attached to the instrument permits remote readings. The CD V-711 has a built-in calibration device, and is operated from a 12-volt storage battery. For extended use, the battery charge is maintained by connecting the instrument to 110-volt alternating current.

Dosimeters

As mentioned earlier, OCDM recommends the use of self-indicating quartz-fiber electrostatic dosimeters in civil defense operations. (See fig. 5.)

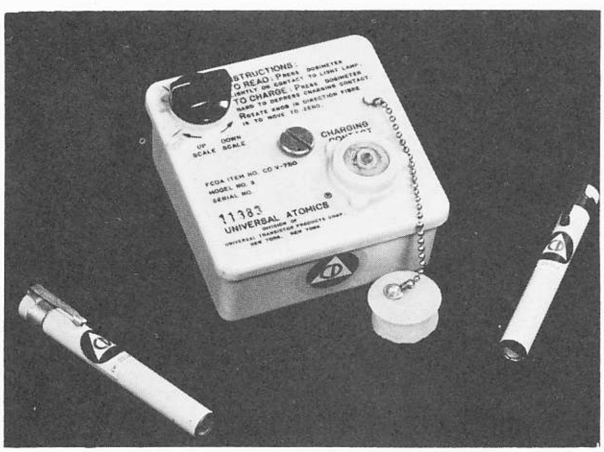

FIGURE 5.—CD V-750, dosimeter charger; and dosimeters.

CD V-730 and CD V-742 (for operational use)

The two models of dosimeters recommended for operational use are the CD V-730, with a range for ionizing radiations of 0-20 r, and the CD V-742, with a range of 0-200 r.

CD V-138 (for training)

For training purposes, model CD V-138, with a range of 0-200 milliroentgens, is recommended. Cobalt 60 sources of low activity can be used to provide readings for this instrument.

Operation

Quartz-fiber electrostatic dosimeters contain two electrically conducting components: a coated quartz filament and a metal mounting ring. To prepare the instrument for operation, these two electrodes are charged, using a battery-operated charger, CD V-750 (see fig. 5).

Radiation passing through the dosimeter loses energy by ionization. As the ions are drawn to the electrodes, there is a reduction in the charge, and the quartz filament moves. Through a built-in optical system, the user of the dosimeter can read the position of the filament image on a graduated scale.

Electrostatic dosimeters are accurate to within 10 percent of true dose, when calibrated against cobalt 60. The accumulated dose can be read directly at any time. By recharging, these dosimeters can be used again and again. Electrostatic dosimeters may be more expensive than some other types. A disadvantage is that they can give erroneous readings if roughly handled, or because of electrical leakage over a very long period.

RADIOCHEMICAL LABORATORY EQUIPMENT

Radiological defense capability can be increased by the use of radiochemical laboratory instruments to (1) make more refined analyses of decay rates, (2) identify specific elements in radioactively contaminated materials, and (3) analyze samples of food and water.

OCDM has not sponsored the design or development of this type of equipment, but has encouraged State and local governments to plan for use, in civil defense operations, of university, governmental, or industrial isotope laboratories within their jurisdiction. These laboratories have the equipment and trained personnel required for the job. Some States have acquired specialized laboratory equipment and/or mobile laboratories for this work. (Acquisition in many cases was through use of Federal matching funds. See FCDA (OCDM) *Federal Contributions* Manual, AM25-1.)

Portable equipment, such as the CD V-700 low-range beta-gamma radiation survey meter or an electrometer analysis unit is suitable for field measurement of the radioactive contamination levels of food and water. Rough determinations of decay rates can be made with the CD V-710 gamma survey meter, or the CD V-720, high-range beta-gamma survey meter—or if the radiation levels are low enough, with the CD V-700 low-range beta-gamma survey meter.

INSTRUMENT CALIBRATION

Most radiological survey instruments must be calibrated frequently. Strong radiation sources are desirable for use in calibrating the CD V-710, CD V-715, and CD V-720. OCDM expects to make a limited number of such sources and associated calibration equipment available to the States for calibration of the high-range instruments by the end of 1960. Sources will be distributed to the States on a loan basis. Persons who wish to use these sources must obtain a license from the Atomic Energy Commission. Detailed byproduct material license requirements and application procedures will be announced as equipment becomes available.

As an interim procedure, some States and localities have made arrangements to calibrate high-range instruments at the laboratories of colleges and universities that have suitable high-activity sources.

INSTRUMENT PROCUREMENT

Federal matching funds are available to States and their political subdivisions for purchase of radiological instruments for civil defense operational and training purposes. (See FCDA (OCDM) *Federal Contributions* Manual, AM25-1.) The Federal Government will assume half the cost, subject to appropriation limitations and provided that certain criteria are met. In some instances, States will match expenditures of their political subdivisions. There are three ways in which radiological instruments may be procured: (1) Purchase through OCDM, (2) direct purchase, and (3) grant or loan from OCDM.

Standard OCDM radiological equipment for operational purposes, and for training purposes, is available from OCDM to other Federal Agencies, and to States and their political subdivisions. OCDM Advisory Bulletin 193, Revised May 14, 1959, *Availability to the States of Radiological Instrument and Detection Devices for Training Purposes,* tells how to request this equipment.

RESCISSION AND SUPERSESSION

The following FCDA (OCDM) technical bulletins are rescinded and superseded by this revision of TB-11-20:

TB-11-2—*Personal Dosimeters for Radiological Defense.*

TB-11-3—*The Most Promising Personal Dosimeters for Civil Defense Use.*

TB-11-4—*Development Status of Personal Dosimeters.*

TB-11-15—*Phosphate Glass Dosimetry.*

REFERENCES

The following OCDM publications can be obtained through your local civil defense director, or from the Publications Office, OCDM Operational Headquarters, Battle Creek, Mich.

OCDM Publications

Availability to the States of Radiological Instruments and Detection Devices for Training Purposes, AB-193, Revised May 14, 1959.

Federal Contributions for Civil Defense Equipment, AM25-1.

Interim Procedures for Maintenance of Radiological Instruments, AB-229, Jan. 8, 1959, and supps.

Radiation Physics and Bomb Phenomenology, TB-11-22, Revised June 1956.

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