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UCRL-51049

THE HAZARDS CONTROL INSTRUMENT CALIBRATION FACILITY

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THE HAZARDS CONTROL INSTRUMENT CALIBRATION FACILITY

Abstract

Since the completion of the gamma and neutron calibration facility, calibration techniques for γ -ray and neutron health physics survey instruments have changed considerably. Previous routine calibrations on γ -ray survey meters were inconvenient, and the sources were of such a size that only the lower ranges of the instrument could be routinely

checked. With the addition of the new facility, these same survey meters can be calibrated in an exposure field of as much as 115 R/hr. This report describes the new facility and the type of calibrations for which it is used. Also included are descriptions of the other routine calibrations performed by the Hazards Control Instrumentation Group.

Introduction

The Instrumentation Group of the Hazards Control Department has the responsibility of performing maintenance on and calibrating all the portable radiation survey meters and fixed radiation monitors at the Laboratory. A wide range of different radiation fields exists around the Laboratory, resulting in the need for a great variety of radiation detection instruments for personnel protection. The service required for these instruments is provided by two experienced

Electronic Technicians and one Health and Safety Technician.

The bulk of this report will be devoted to a description of the gamma and neutron calibration facility and how it is used in relation to the routine maintenance effort. The remainder of the report will deal briefly with the other routine calibrations performed on the alpha survey meters, the low-range Geiger-Müller (G-M) counters, the remote area monitors (RAM), and the tritium gas detectors.

Gamma and Neutron Calibration Facility

SOURCES

Before the installation of this facility, routine calibrations on γ - and x-ray

monitoring instruments were made using low-activity sources. The higher ranges (> 50 mR/hr) of these instruments could not be checked since size of the

Fig. 1. General view of the calibration facility. (a) Neutron source console; (b) REMETER, (c) double-reflecting prism; (d) survey meter; (e) meter trolley; (f) absorbers; (g) absorber wheel; (h) well cover; (i) trolley stop selector lever; (j) gamma source console.

sources (necessarily small for personnel protection) precluded reaching these ranges. The lower ranges were adjusted properly, and it was assumed that the higher ranges would be reasonably accurate. On many instruments this is a valid assumption. (If conditions warranted it, the higher ranges could be checked at a temporary high-range calibration facility.)

The radioactive sources used in the present facility are of sufficient activity to indicate readings on all the ranges of the gamma survey meters.

Two γ -ray sources (^{137}Cs and ^{60}Co) and one neutron source (^{252}Cf) are used in the facility. The ^{137}Cs source (90 Ci) produces a maximum usable exposure rate of 115 R/hr. The ^{60}Co source (0.5 Ci) produces a maximum usable exposure rate of 1.3 R/hr. The ^{252}Cf source (32 μg) is used for calibrating the neutron survey meters (REMETERS¹) and produces a maximum intensity equal to 350 mrem/hr of absorbed dose equivalent.

DESIGN

The basic design of this facility is based partly upon a similar system used at the U. S. Army Metrology Laboratory in Sacramento, California.² The LRL design uses five wells 1 ft (30.5 cm) in diameter extending 11.5 ft (3.5 m) below floor level and 4 ft (1.2 m) above the floor through a concrete block 4 ft (1.2 m) wide and 11.5 ft (3.5 m) long (Fig. 1). The concrete block acts not only as a shield when the sources are up, but also serves as a convenient working space during calibrations. Wells 2, 4 and 5 (numbered from the operations console) contain the

^{137}Cs , ^{60}Co and ^{252}Cf sources, respectively. Wells 1 and 3 are used as storage wells.

The two gamma sources are located in lead collimator casks (flasks) which are raised and lowered by 1/12-hp electric motors operating through 180/1 gear reducers. A cross-section drawing depicting this elevator arrangement is shown in Fig. 2. Full travel for these flasks is 420 cm (13.8 ft) at a constant speed of 58 cm/min.

The neutron source is enclosed in a small polyethylene cylinder cantilevered out on an aluminum plate attached to an endless bicycle chain. Full travel for this elevator is 414 cm. The elevator is lifted by a variable-speed motor, with lifting speeds ranging from a low of 16.5 cm/min to a high of 199 cm/min.

Fitted into the tops of the two gamma source wells are lead aperture plates. These plates are 9.7 cm thick and provide an aperture diameter of 11.7 cm. In the fully-up position, the snout of the source flask fits into this opening. The aperture is used to reduce the beam size to a manageable 13-15 cm in diameter from an otherwise full beam of 30-40 cm in diameter. The smaller beam size reduces the amount of attenuator material necessary to vary the beam intensity, and also reduces the amount of scattered radiation around the calibration area. All our survey meters have a detection volume that can be accommodated by the reduced beam size. In addition to being a beam size reducer, the aperture also serves as a physical stop for the elevator in the event the upper-limit switch mechanism should fail.

Fig. 2. Cross section of well No. 2.

Attenuators

A four-position absorber wheel is located over the ^{137}Cs source well (Figs. 1 and 3). This allows a choice of four beam intensity attenuations: 0, 0.1, 0.01, and 0.001. Without moving the source position, four meter ranges can be rapidly checked. Problems arise, however, in the calibration of the beam with heavy attenuation.

(This will be discussed later.) The proper tenth-value thicknesses were established empirically, with lead discs used for coarse attenuation and copper discs for fine adjustment. Since the majority of the calibrations are made with the higher intensity ^{137}Cs source, it was not economically desirable to outfit the ^{60}Co source well with an absorber wheel.

Fig. 3. Closeup of absorber wheel

Meter Carriage Mechanism

The γ -ray survey meter to be calibrated is placed on an aluminum holder attached to a four-wheeled carriage (Figs. 1 and 4). The carriage runs along a steel track with knife edges on each side to accept the carriage wheels. An overhead double-reflecting prism is attached to the meter holder so that the meter can be observed directly from the front, as shown in Fig. 4a. For convenience in travel, the mass of the meter plus prism is counterbalanced by a lead weight. The entire trolley can be positioned anywhere along the track by a stainless steel cable running over a pulley crank located by the control console

(Fig. 4b). The trolley can be positioned directly over any of the five wells by means of physical stops located on a rod under the track. The proper stop can be dialed into position from the trolley operating end. This dial lever can be seen in Fig. 4b. When high-range G-M detectors are calibrated, a yoke to hold the probe can be inserted into the holder so that the probe is properly positioned at the calibration point, as shown in Fig. 4c.

The neutron detector holder is simply an aluminum plate fixed to the concrete block over the 12-in. well. Four indentations were drilled into the plate to accept the REMETER feet to insure that each

Fig. 4a. View of meter trolley with instrument, showing face in prism.

instrument is centered over the source in a reproducible manner.

Control Consoles

The control console for the gamma sources is shown in Fig. 5. Although that portion of the console operating the ^{60}Co source contains controls for an attenuation (absorber) wheel, they are not used and are for contingency only.

The elevator can be operated in two modes. In the automatic mode, a preset height in centimeters is selected and the

mode switch is placed in the automatic position to start driving. The preset register (5a) will begin counting down until it reaches zero, at which time the elevator will be stopped and an audible signal will be sounded. Because of the slow speed of the elevator, considerable time can be expended in getting to a selected height. During this time the operator can be attending to other duties in the immediate area, knowing that the signal will mean the source is ready for calibration. To reset the signal, the mode switch is reset to the manual position and the drive direction indication will automatically be changed to the down position, meaning that any unplanned movement of the elevator will be downward, and thus away from the operator.

The preset height (5a) and actual height (5b) registers are revolution counters coupled to the elevator motor by a speedometer cable. The ratios are adjusted such that one register unit is equivalent to one centimeter of travel. Since the preset height register only counts in one direction, for any elevator adjustment other than the initial adjustment off the bottom the change in height whether up or down is punched into the preset height register.

For operation in the manual mode two buttons are provided, one "Up" and the other "Down." The selected button is pressed and held until the desired height adjustment is made. This mode of operation is used for very small adjustments in the position of the elevator.

Limit switches are placed at both ends of the wells to immediately stop elevator movement when actuated. The lower-limit portion of the limit switch must be

Fig. 4b. End view of trolley and track from operating area.

reset before the elevator can be raised. When the elevator reaches the upper limit of travel, an audible signal is sounded and the switch must be reset to turn off this signal.

The attenuation wheel is controlled by the four Absorber buttons numbered 1 through 4 (5c). Position 1 offers the most attenuation over the source of three tenth-value layers (0.001); position 2, two tenth-value layers (0.01); position 3, one tenth-value layer (0.1); position 4, no attenuation, i.e., an open beam. When the facility is turned off or when the elevator is moving upward, the well is covered by the most attenuation. In these two conditions other positions can be

selected, but the wheel will just rotate through them all until position 1 is again achieved. When the facility is on with the source moving down or the elevator stationary, any position can be selected and achieved.

Both building main power and standby power are provided to the console so that in the event of a power failure of the removal of the operating key, the elevators will automatically drive down to the lower limit and the attenuation wheel will rotate to position 1. Two lights for each section are provided for information only. One is a light indicating the direction of travel of the elevator (5d) and the other indicating whether the

Fig. 4c. View of trolley with G-M probe.

elevator (hoist) or the attenuation wheel (table) is in operation (5e).

The console controlling the neutron source (Fig. 6) is very simple, consisting of only two controls: one determining the direction of travel, and the other the speed of travel. Upper and lower limit switches are provided which will stop source travel at either end of the well. The calibration for the position register is 3.7 units/cm of travel, ranging from 1553 at the bottom to 20 at the upper limit. Power is obtained from the gamma-source console, so the neutron source operation is also

key-operated. Source operation is entirely manual, although the two controls can be left in any position and the elevator will run until one of the limits is reached.

CALIBRATION

The calibration point was chosen at 3.5 cm above the meter holder. This coincides with the midpoint of the detection chamber of the most frequently calibrated instrument when it is resting in position on the holder.

The gamma-source calibration curves shown in Fig. 7 were determined by

Fig. 5. Gamma source console. (a) Preset register; (b) actual height register; (c) absorber buttons; (d) direction-of-travel light; (e) operate signal.

placing a well-calibrated ionization chamber at the calibration point and recording the output of the chamber with the source situated at various positions within the wells. The intensity versus position relation follows the inverse square law at least within practical limits even with the proximity of structural material that will cause scattering. This law doesn't necessarily hold when the beam is highly attenuated, however.

The ionization chamber was used to empirically determine the amount of absorber material necessary to achieve the

proper attenuation. The source was positioned within 50 cm of the top as this is the most convenient area for calibrating the instruments. The lead and copper discs are 20.3 cm in diameter, 1.85 cm and 0.159 cm thick, respectively (except for a 0.63-cm lead disc and a 0.081-cm copper disc used in the 0.001 absorber stack). The lead discs were placed on the wheel first and then the copper discs used for the fine adjustment were placed atop the lead. The final configuration is shown in Fig. 3 and the total amount of material used is listed in the following table.

Fig. 6. Neutron source console.

Fig. 7. Gamma source calibration curves.

Position	Attenuation	Absorber thickness (cm)	
		Lead	Copper
1	0.001	5.885	0.875
2	0.01	3.50	1.430
3	0.1	1.75	0.635
4	0	0	0

The attenuation values for positions 1 and 2 are not valid for source positions less than 3 meters above the bottom of the well because of spectrum softening caused by some scatter. Gamma pulse height spectra indicate that the average beam energy with the source at the bottom is between 400 and 500 keV. When the source is in the upper part of the well, the average energy is between 500 and 600 keV. There appears to be no significant change in average energy with the addition of absorbers over the source.

Placing a neutron source in one of the calibration wells naturally results in a tremendous amount of neutron scatter and energy spectra strongly dependent on source position within the well. However, since the REMETER will be the only instrument calibrated over this well and since its response is directly proportional to dose equivalent, the energies of the neutrons interacting with the counter are of little concern. The calibration of the well was accomplished by initially calibrating a good REMETER using a ^{252}Cf source in a low scatter area.³ All ranges were properly adjusted, with good calibration data in the low scatter area. The instrument was then placed over the well and the instrument response versus source position was noted with the results shown in Fig. 8. The well was then ready for routine calibration of other REMETERS. Because of the relatively

Fig. 8. Neutron source calibration curve.

short half-life (2.6 yr) of ^{252}Cf this calibration curve will have to be revised periodically, at least semiannually.

SAFETY

The safety of the operator has been considered throughout the design and construction of this facility. Operating power can only be obtained through a key-operated switch (key permissive), at which time a flashing magenta light is actuated. When the key is removed following an operation the gamma source elevators are automatically driven down, and the highest amount of attenuation is automatically rotated into position. When the facility is not being used, the key is itself secured in a locked container.

Various safety features are evident during normal operation of the gamma sources. When the ^{137}Cs source is being raised by the elevator, the greatest attenuation is present over the well. Immediately after an elevator movement

has ceased, the relay controlling the direction of movement is automatically set in the downward direction, and must then be intentionally overridden for an upward travel. An upper limit switch prevents elevator travel more than 420 cm from the bottom position.

Several safety features have been physically built into the system. The lead aperture plate reduces radiation exposure by decreasing the emergent beam diameter to the smallest practical size. It also serves as a physical stop in case the upper limit switch fails to stop the rising elevator. The instrument trolley allows the instrument to be positioned accurately on the holder away from the beam, and the double reflecting prism allows an unobstructed view of the meter face without the necessity of viewing the meter directly and risking possible exposure as well as an inaccurate calibration. All motors, gears, chains, and cables are covered to permit close-in operations. Finally, the sheer size of the block prevents inadvertent exposure in the primary beam.

A radiation survey was made to determine the exposure rate at the operator's position in front of the block with the ^{137}Cs source at the upper limit. A meter was placed in position over the beam to induce normal scattering, and readings were taken at chest height for all four attenuation positions. The measurements were 0.1, 2, 50, and 200 mR/hr for positions 1, 2, 3, and 4, respectively. The 200-mR/hr field is admittedly too high to work in for prolonged periods of time, but this type of configuration would be rare in routine calibrations because for this to occur the instrument would

have to be in an intense field greater than 100 R/hr, and this is beyond the range of most of our instruments. As there is no beam catcher over this well, the beam can be measured on the roof of the building and a 100 R/hr field would result in a reading of 1.25 R/hr with the source at the upper limit and with no attenuation. Appropriate warning signs are posted in the area and at the roof access points.

With the large amount of "tweeking" (fine screwdriver adjustments) necessary on some instruments, a significant hand exposure will result if many such instruments are calibrated. For this reason a light, 3-ft-long right-angle screwdriver with a high turn ratio of 16/1 is used to adjust the instrument, thus precluding exposure of the operator's hand.

Calibration of Other Instruments

Many radiation detection instruments other than gamma and neutron detectors are calibrated at this facility. These require special procedures not applicable to the facility just described. These instruments include alpha-particle detectors, low-range G-M counters (too low for the gamma facility), remote area monitors (RAM) which are calibrated in the field, and tritium gas detectors.

The alpha-particle survey meters use air proportional probes, and are calibrated on a commercially available tray of four ^{239}Pu sources as shown in Fig. 9. Metal screens are available to be placed over the sources to obtain a count rate approximately 2.5 times less than the uncovered count rate. This allows eight possible count rates, ranging from 1.13×10^6 cpm to 350 cpm.

Low-range G-M counters can be calibrated quickly by inserting the probes into one of two holes drilled into a lucite block as shown in Fig. 10. These holes are lined with depleted uranium plates, and produce readings of 16.5 and 2 mR/hr.

High-range, beta-gamma ionization chambers can be checked in the field by

Fig. 9. Alpha detector calibration tray.

placing them on a four-position check source set as shown in Fig. 11. Twenty-four of these sets are available in the field for a rapid check of the Juno survey

Fig. 10. Low-range G-M calibrating block.

meters.⁴ A rotating plastic disc underneath the instrument holder holds either three or four ^{90}Sr disc sources ranging in activity from 10 μCi to 3 mCi and yielding meter readings of from about 30 mR/hr to 40 R/hr. Each source set is individually calibrated before being turned out for field use. These sets are used between more accurate semiannual calibrations on the gamma calibration facility.

The RAM's are calibrated in the field by a unique device using 0.6 Ci of ^{137}Cs . This source, shown in operation in Fig. 12, is housed in a lead cylinder such that the operator is shadow-shielded by

Fig. 11. High-range beta check source set.

Fig. 12. RAM calibration source.

the cylinder and can operate the device with no appreciable exposure. Available exposure rates range from 100 mR/hr to 10 R/hr (1 R/hr for large detectors). For transporting, the source is placed in a specially constructed lead pig and locked onto a two-wheel hand cart.

The tritium gas detectors are calibrated by known amounts of tritiated methane gas.⁵ A small amount of gas

is released into an evacuated ion chamber and the activity in the chamber is determined from the resultant current. After this determination, the gas is released into and circulated through a plastic box into which the detector has previously been placed. The volume of the box is 0.125 m³, and the concentration can be determined by knowing the activity of the amount of gas in the chamber.

Acknowledgments

The author gratefully acknowledges the efforts of A. Millman, R. Taylor, H. Schultz, and J. Cormier in the design and construction of the facility; B. Barlow and R. Hugenberger in the design of the electronic components, and R. Banneck, W. Hilgesen, and J. Hajny in the measurement and operation of the facility.

References

1. Hazards Control Progress Report No. 18, Lawrence Radiation Laboratory, Livermore, Rept. UCRL-12167, p. 17 (1964).
2. G. S. Higgins and C. R. Wallace, "Radiation Survey Meter Calibrator," Health Phys. 12, 1526 (1966).
3. Hazards Control Progress Report No. 34, Lawrence Radiation Laboratory, Livermore, Rept. UCRL-50007-69-2, p. 47 (1969).
4. Hazards Control Progress Report No. 14, Lawrence Radiation Laboratory, Rept. UCRL-7571, p. 43 (1963).
5. S. Block, Lawrence Radiation Laboratory, Livermore, private communication (March 17, 1971).

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Printed in USA. Available from the National Technical
Information Center, National Bureau of Standards,
U. S. Department of Commerce, Springfield, Virginia 22151
Price: Printed Copy \$3.00; Microfiche \$0.65.