[illegible]

TOUR OF THE S[illegible] CALIBRATIONS LA[illegible]

Jack [illegible]

A[illegible]

This work was supported by the U.S. Nuclear Regulatory Commission under Interagency Agreement DOE 40-550-75 with the U.S. Department of Energy

LAWRENCE
LIVERMORE
LABORATORY
University of California | Livermore

Distribution Category
UC-23,37

LAWRENCE LIVERMORE LABORATORY
University of California/Livermore, California/94550

UCRL-52537

TOUR OF THE STANDARDS AND CALIBRATIONS LABORATORY

Jack H. Elliott

MS. date: August 7, 1978

CONTENTS

TOUR OF THE STANDARDS AND CALIBRATIONS LABORATORY

ABSTRACT

This tour of Lawrence Livermore Laboratory's Standards and Calibrations Laboratory is intended as a guide to the capabilities of and services offered by this unique laboratory. Described are the Laboratory's ability to provide radiation fields and measurements for dosimeters, survey instruments, spectrometers, and sources and its available equipment and facilities. The tour also includes a survey of some Health Physics and interdepartmental programs supported by the Standards and Calibrations Laboratory and a listing of applicable publications.

INTRODUCTION

The Standards and Calibrations Laboratory in Bldg. 255 is part of the Dosimetry Group of Hazards Control Department's Radiation Safety Group. Its purpose is to maintain radiation standards for Lawrence Livermore Laboratory (LLL) and to offer radioactive sources that provide gamma, neutron, beta, and x rays so all instruments at LLL may be standardized.

The Laboratory's responsibilities include using the accurate radiation fields of its low-scatter cell to calibrate instruments, to irradiate various materials for LLL researchers, and to perform routine calibrations for the Personnel Dosimetry Program. In addition, the Standards and Calibrations Laboratory is responsible for maintaining portable survey instruments and transfer standards to measure radioactivity and for evaluating state-of-the-art instruments designed by LLL employees and by commercial manufacturers. Its ^{60}Co irradiation pool also provides a high-intensity gamma field for radiation-damage studies and dosimetry-development programs.

EQUIPMENT AND FACILITIES

To fulfill its purpose and meet its responsibilities, the Standards and Calibrations Laboratory employs various equipment and facilities.

The low-scatter cell (see "Laboratory Description") houses a neutron generator, neutron and gamma sources, and a television monitor. The Laboratory also has two pneumatic source-transfer systems and a ^{60}Co irradiation pool.

Source calibrations of gamma are accomplished with ionization (Shonka) chambers calibrated by the National Bureau of Standards (NBS). Calibration of neutron sources is done by activation comparison with an NBS-calibrated plutonium-beryllium source. Other source calibrations are done in free-air ionization chambers.

In addition, the Standards and Calibrations Laboratory has x-ray generators, a beta-source range, and an instrument-calibration range. Descriptions of equipment and facilities can be found in the "Laboratory Description" section that follows.

LABORATORY DESCRIPTION

The Standards and Calibrations Laboratory is located at the east end of Bldg. 255. It consists of a control room with three associated irradiation cells (designated A, B, and C), a dosimetry laboratory, an instrument-calibration shop, and an office area (Figs. 1 and 2).

CONTROL ROOM

The control room (Fig. 3) houses consoles containing all the control and electronic readout equipment for the various systems in the Standards and Calibrations Laboratory. Included are pneumatic source-transfer systems and such safety features as interlock controls and remote-area monitors.

Pneumatic Source-Transfer Systems

There are two pneumatic source-transfer systems in the Laboratory—one for gamma sources, the other for neutron sources (Fig. 4). Both are capable of firing singly one of a choice of four encapsulated sources (Table 1) from their individual shielded storage casks in Cell C. A Geiger-Mueller detector is used to confirm the presence of the source capsule in the storage cask.

Controls for pneumatic transfer of high-dose-rate sources include source select, pressure test, and manual or automatic timing. Preset time can be set to one-thousandth of a minute. Timing begins when the source capsule interrupts a light beam to the photocell atop the source-irradiation head. At the end of the selected time interval, the source is automatically returned to its storage cask in Cell C.

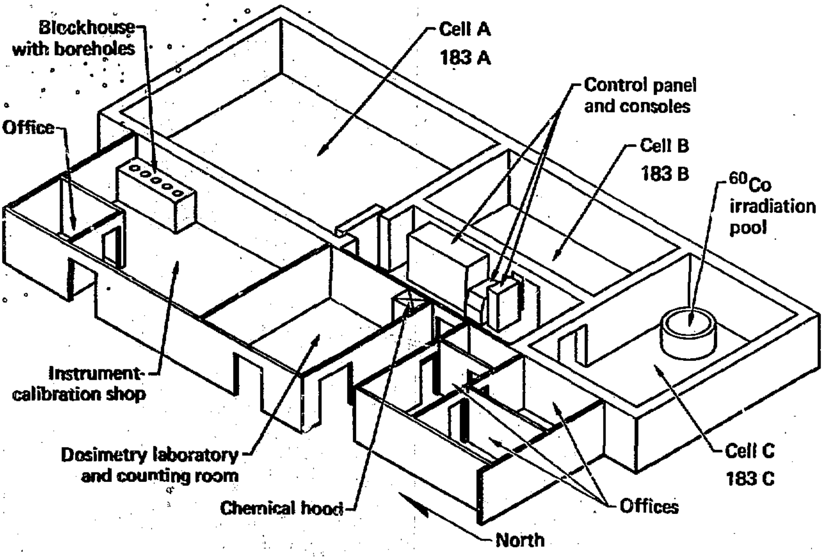

FIG. 1. Sketch of Hazards Control Standards and Calibration Laboratory in Bldg. 255 (not to scale).

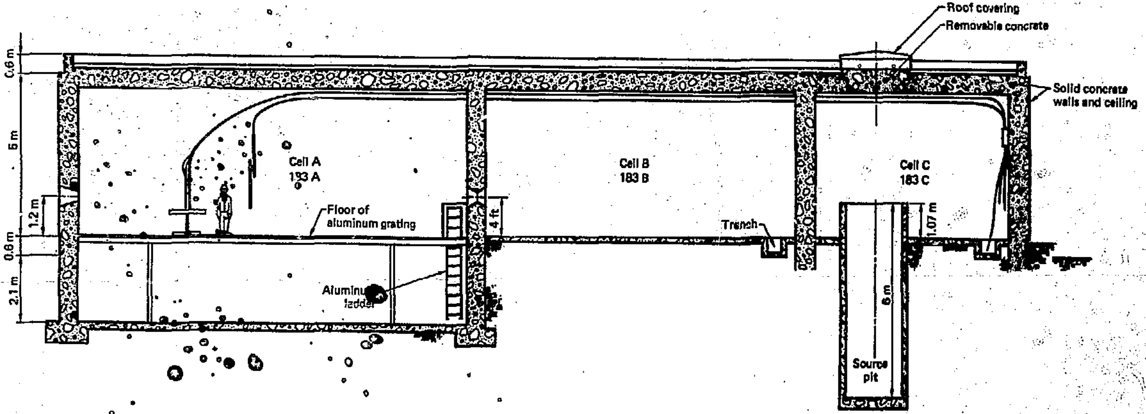

FIG. 2. Cross section of Cells A, B, and C.

FIG. 3. Control room and consoles in the Standards and Calibrations Laboratory.

Measuring Radiation Fields

Gamma fields from each pneumatically transferred source are measured with Shonka-type ionization chambers calibrated by the NBS. A ^{252}Cf neutron-emission rate of 1.3 × 10^9 was calibrated at the NBS, and an ANISN (or similar) code describes neutron intensities in the low-scatter cell (Cell A). The Laboratory also has a variety of Victoreen Radocon probes calibrated by Victoreen and traceable to the NBS for routine gamma-intensity measurements and for x rays and low and medium-energy free-air ionization chambers for basic measurements of roentgen.

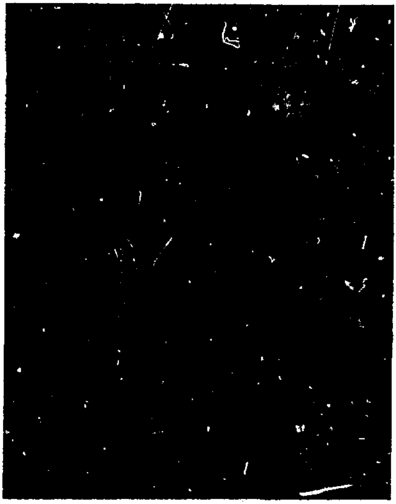

FIG. 4. Pneumatic source-transfer heads and neutron generator shown in place in Cell A.

Portable Sources

Table 2 is a listing of portable neutron sources available in the Standards and Calibrations Laboratory, together with their strengths, dates of calibration, and energies.

In addition, the Laboratory has a 14-Ci ^{241}Am photon source of 60 keV with an assortment of

TABLE 1. Available source choices in the gamma and neutron pneumatic source-transfer systems.

Gamma system			Neutron system		
Source[a]	Dose rate at 1 m (mR/min)[b]	Half life (yr)	Source	Dose rate at 1 m (n/s)	Half life (yr)
^{60}Cs	136	5.263	^{252}Cf	1.316 × 10^{9}[b]	2.646
^{60}Cs	29.2	5.263	^{238}PuBe	7.8 × 10^{7}[c]	86.4
^{137}Cs	406	30	^{238}PuBe	1.6 × 10^{8}	86.4
^{137}Cs	12.9	30	Photoneutron source storage		Short

[a] Isotopes.
[b] Dose rate as of 1 June 1978.
[c] Dose rate as of 28 February 1973.

TABLE 2. Portable neutron sources.

Neutron source	Strength (n/s)	Date Calibrated	$\bar{E}$ (MeV)
^{238}PuLi No. 300095	1.75×10^6 (±3%)	3/27/73	0.45
^{238}PuBe No. 300094[a]	4.01×10^6 (±1.7%)	4/30/71	4
^{238}PuBe No. 300101	1.29×10^7 (±3%)	12/13/75	4

[a] Calibrated by the NBS.

fluorescers for lower energy photons. For information on the development of the photon source, see J. V. Boggs, "A Portable Low-Energy Photon Calibration Source," *Health Physics* (Pergamon Press, Northern Ireland, 1971) vol. 2, pp. 631-635.

Safety Features

Cell safety features include run-safe switches (inside the cells) and doors that can only be opened by a key; the same key enables performance of all hazardous operations. For example, after closing the A-Cell door, one must insert the key into a control panel before the pneumatic sources can be transferred or the neutron generator can be used. If the door is opened, the key is removed, or the run-safe switch is returned to the safe position, the source would be automatically returned to its storage cask.

Cell A has an additional safety feature—a remote-area monitor for radiation that is set to alarm if any pneumatic sources are in the cell when the door is opened. Similar trip levels are set for sources in Cells B and C.

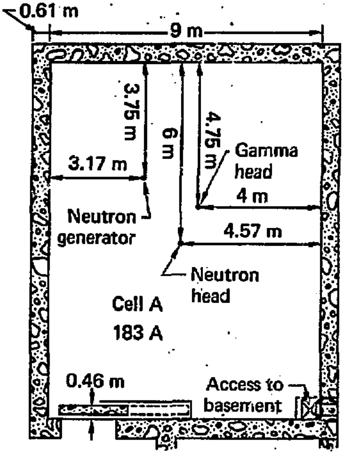

FIG. 5. Locations of pneumatic source-transfer heads and *neutron generator in* Cell A. *See the heads,* generator, and aluminum-grating floor in Fig. 4.

CELL A

Designed as a low-scatter room, Cell A (Fig. 5) has a false floor made of aluminum grating that is essentially transparent to neutrons. This floor lies 3 m above the solid concrete floor of the cell and 5 m below the solid concrete ceiling.

In the center of Cell A is a pneumatic source-transfer head for neutron sources; near it is a source-transfer head for gamma sources (Figs. 4 and 5). These heads are positioned vertically so that fired sources are 1 m above the aluminum-grating floor. The transfer heads are so positioned to keep neutron sources transferred into the cell as far from the ceiling and walls of the cell as possible to reduce the effects of scattering, which would alter the energy spectrum and irradiation field of the sources.

One pneumatic source-transfer system can accommodate four gamma sources—one at a time—that are to be transferred into the cell. The other system is capable of selecting one of a choice of four neutron sources (see Table 1) to be transferred into the cell. All the sources are stored in Cell C, which is furthest from Cell A, to minimize background interference with the selected source by the stored sources.

Neutron Generator

A Texas Nuclear Model 9400 neutron generator (Figs. 6 and 7) located in a quadrant of the low-scatter cell can produce 14.6-MeV neutrons through the T(d,n) ^{4}He reaction and 2.8-MeV neutrons through the D(d,n) ^{3}He reaction.

Operation of the neutron generator depends on the production, extraction, and acceleration of deuterium ions. After acceleration, the ions are allowed to strike a suitable target material to produce neutrons. These ions are generally accelerated to 150 kV, and the generator is designed to produce 10^{11} n/s at 14 MeV and 3×10^8 n/s at 2.8 MeV. More information on the neutron generator can be found in Ref. 1.

Portable Survey Instruments

Calibration of portable survey instruments having very high dose-rate ranges is accomplished by positioning them in the low-scatter cell to give the desired dose rate and by attaching a servo motor remote screwdriver to each instrument to correct the meter reading (Fig. 8). A closed-circuit television allows one to read the meter reading remotely after firing the source into the cell, and the servomotor controls permit one to adjust the instrument to give the correct reading.

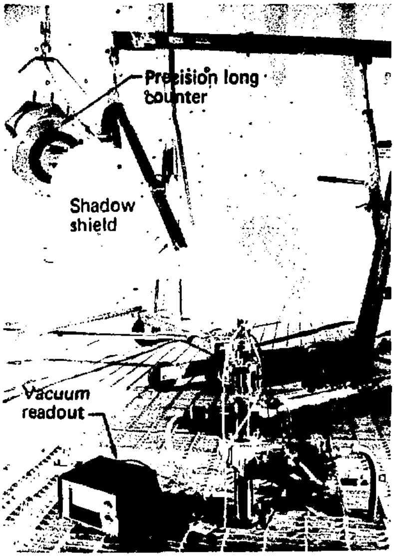

FIG. 6. Top target portion of neutron generator shown with de Pangher precision long counter and shadow shield.

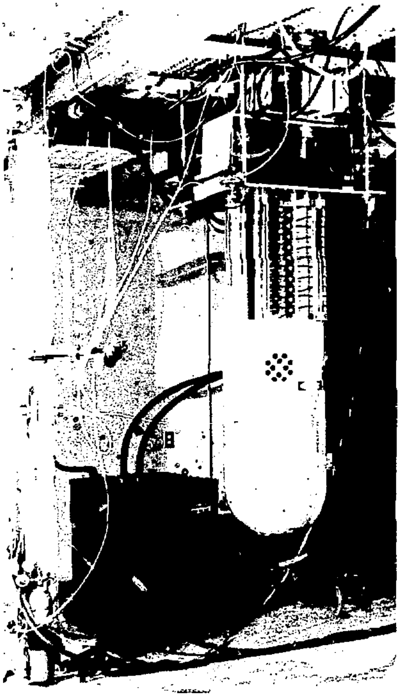

FIG. 7. Neutron-generator accelerator suspended below aluminum-grating floor of Cell A.

CELL B

Cell B contains two x-ray systems, a bath for neutron-source calibrations, and a beta-exposure range.

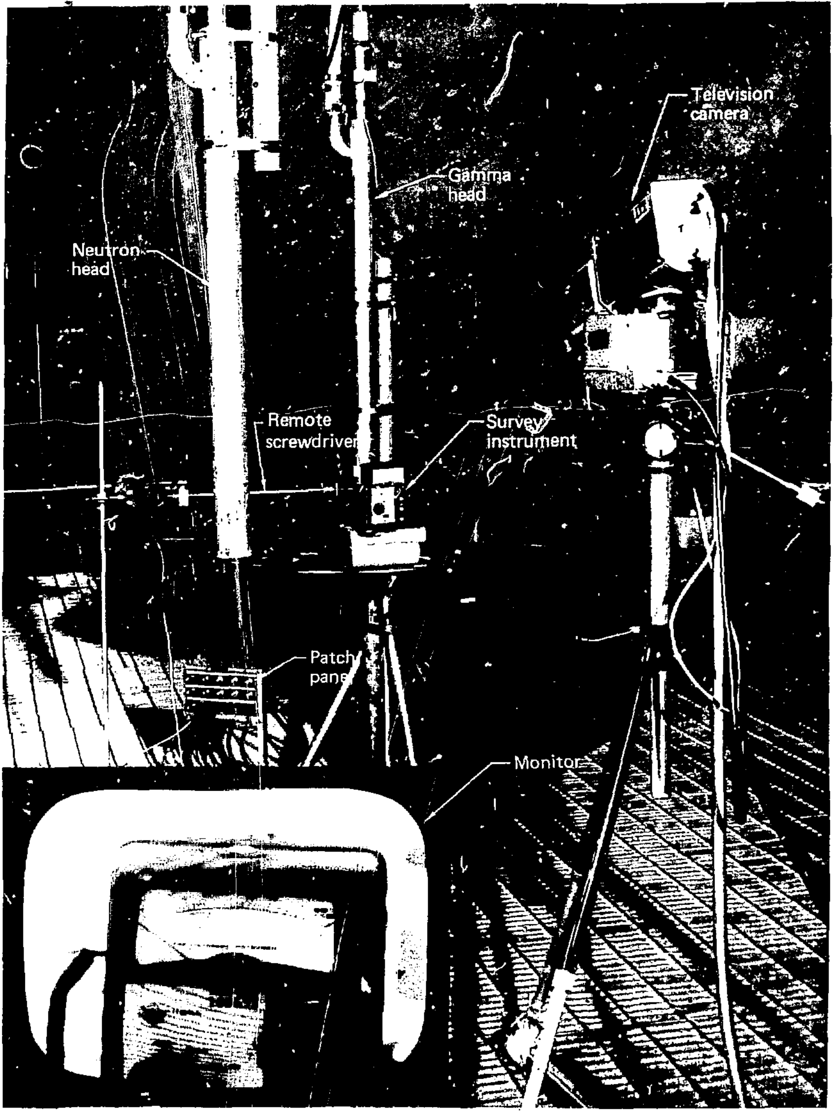

FIG. 8 The kiloroentgen/hour scales on portable survey instruments are calibrated with pneumatically transferred sources, a remote screwdriver, and a television monitor (inset).

X-ray Systems

One x-ray system, a high-voltage (150-kV, 10-mA) output tube that can be used directly or with fluorescers to give characteristic x rays of various materials, has been used for experiments with Borrmann transmission in very pure crystals.

The second x-ray system—TRAX—has three transmission anode x-ray tubes. In a transmission anode tube (developed at LLL), x rays characteristic of the anode emerge, giving a fairly discrete or narrow band of energy depending on the anode materials. The Laboratory presently has copper, silver, and neodymium anode tubes with principal energies of 8, 22, and 38 keV, respectively. For further information, see Ref. 2.

Neutron Sources

The Laboratory has a number of neutron sources. One primary source that has been calibrated by the NBS is used as a reference for calibrating other neutron-producing sources. Calibration is accomplished with a large manganese-sulfate bath that is, in cylindrical geometry, approximately 0.9 m in diameter and 1 m in height.

The manganese-sulfate-bath method involves activating the manganese to ^{56}Mn by placing a source in the center of the solution. The bath acts as an efficient moderator so very few neutrons escape. The solution is then activated for at least 16 h to approach a 99% saturation point. Then the source is removed, and activity is counted at various intervals so saturation activity can be calculated. After decay, a second source can be inserted and the process can be repeated. The induced activity of the two sources can then be compared to determine the activity of the unknown source. For further information, see Ref. 3.

Beta Sources

Three beta sources offering a wide choice of energies can be used in the beta range. These sources have intensities of about 200 mR/h at 250 mm. The three beta sources used in the Standards and Calibrations Laboratory are shown in Table 3.

CELL C

The source-storage cell, Cell C (Fig. 9), houses a number of gamma, beta, and neutron sources used by health physicists and scientists in Hazards Control Department and occasionally by other groups. An air sampler continually monitors air quality in the cell. The intense pneumatically-fired gamma sources are stored in large lead casks, and the neutron sources are stored behind plastic and water moderation. The most intense source is located at the bottom of the ^{60}Co pool in Cell C.

^{60}Co Pool

The ^{60}Co irradiation pool in Cell C (Fig. 10) is about 2 m in diameter and 6 m deep. The intense source that lies at the bottom of this pool consists of 72 pencil-shaped, encapsulated ^{60}Co rods arranged vertically in a wire-mesh basket so they form a circle of approximately 25 cm in diameter (Fig. 11). Each

TABLE 3. Beta-source choices in the Standards and Calibrations Laboratory beta-source range.

Isotope	$\overline{E}$ (keV)	E_{max} (keV)	$T_{1/2}$ (yr)	Calibration (mCi)	Date	Window	γ	Dose rate (R/h)[a]
^{147}Pm	70	224	2.62	0.33 ± 0.4/sr 4.9 ± 0.5	9/75	Aluminum	514 keV (0.4%)	0.075
^{85}Kr	249	672	1076	~13	9/75	0.002-in.-thick stainless steel	None, samarium x rays	2.2
^{90}Sr/^{90}Yt	200/931	545/2270	28	21 ± 10%	10/75	0.002-in.-thick titanium	Significant bremsstrahlung	18.2

[a] Dose rate of 25 February 1977, using JUNO at ~25 cm with all shields open.

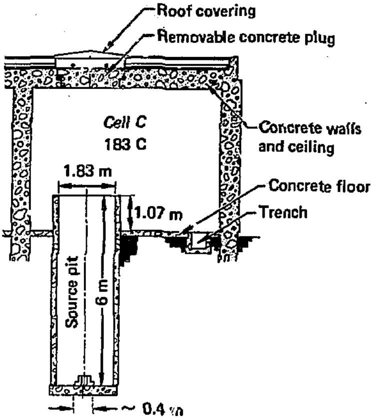

FIG. 9. Cell C (Room 183C, Bldg. 255) is the designated source-storage cell.

rod is sealed in 9-mm-diam by 229-mm-long tubing of stainless steel. The ends of the tubes are sealed so activity extends over the central 190 mm of the circle.

A ring with nine source positions encircles the basket. Each position on the ring can be used to place sources at a repeatable distance.

A 73-mm-i.d. bucket of stainless steel can be used to lower samples into the center of the source basket. A pneumatic (rabbit) system for sample transfer is also available for use in the pool, and samples can be shot into the center source position for short irradiation times.

Samples placed in the center of the 25-cm-diam circle and equidistant from both ends of each tube (about 100 mm from the bottom of the basket as shown in position A of Fig. 11) receive the most intense dose rate (Table 4). Those samples transported to position B by the rabbit transfer system receive below maximum intensity dose rates; very short exposures can be made on samples less than 12 mm in diameter and 48 mm in length. The outer ring bucket positioner can position (C) as many as nine samples in a field that is 0.183 of the dose at position B (based on ratios obtained with nylon film measurements on 12 November 1976).

Water attenuates the activity of the source at the bottom center of the pool. The pool is filled with water to within 1 m of the top of the pool walls, and the blue glow easily visible when looking down on the source ring is produced by the high-intensity gamma rays causing Cerenkov radiation (Fig. 10). The pool water is kept pure by continuous recirculation and by running through a resin deionizer and filters. These filters are monitored continuously for radioactivity in the event one of the source capsules should be damaged and radiation leak out. Although this has not happened and is not expected to happen, the system provides an effective safeguard.

DOSIMETRY LABORATORY

The dosimetry laboratory and counting room are remote from the control room and cells. Electronic signal cables can be patched into the laboratory, however, and can be fed to a computer-based pulse-height analyzer when data such as neutron spectrometer development or basic studies on x-ray transmission through nearly perfect crystals (Borrmann transmission) are needed.

A chemical hood is present in the dosimetry laboratory for use in venting tritium when portable tritium monitors are calibrated. Measurements of airflow for calibration of air monitors and preparation of chemical dosimeters are also among this laboratory's activities.

INSTRUMENT-CALIBRATION SHOP

The instrument-calibration and maintenance shop contains a large source-storage blockhouse of

TABLE 4. Sample dose rates at three ^{60}Co source positions as of 1 June, 1978.

Position	Dose rate (rads/s)
A Center	2200 ± 220
B Pneumatic	1884 ± 188
C Outer ring	358 ± 50

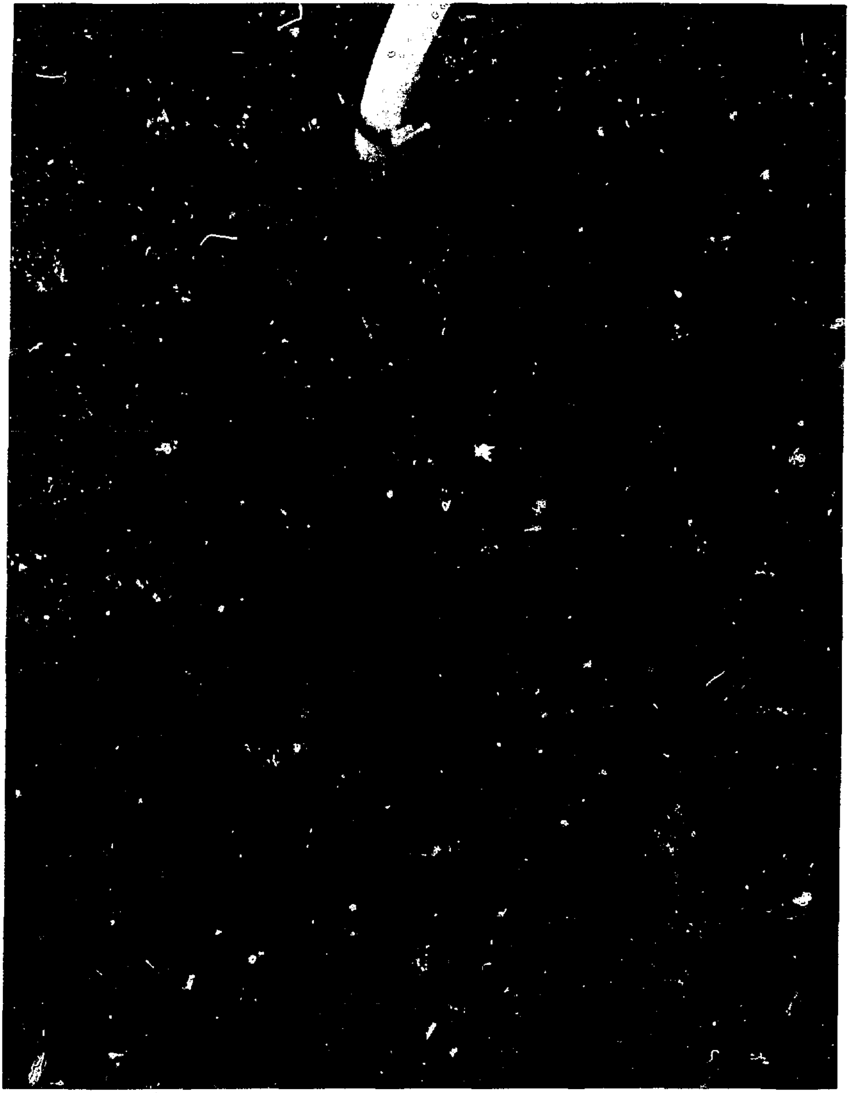

FIG. 10. A pneumatic sample capsule transfers samples to the source at the bottom of the 6-m-deep ^{60}Co irradiation pool in Cell C. The blue glow is produced by high-intensity gamma rays causing Cerenkov radiation.

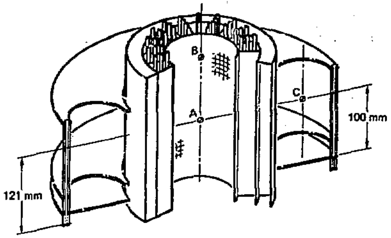

FIG. 11. Cutaway view of the source, showing part of the 72 ^{60}Co rods in place in the wire-mesh basket and the outer ring positioner. The (A) center, (B) pneumatic, and (C) outer ring positions for samples are also indicated.

concrete (Fig. 12) that houses three vertical boreholes. Each borehole contains a source mounted on an elevator. The top of the blockhouse is 1-1/4 m above floor level, making it difficult to expose one's body to direct radiation from the sources. An absorber wheel is positioned over one source so several decades of intensities can be obtained through the combination of absorber and source positioning.

At least twice each year, electronics personnel from this shop calibrate and service approximately 900 instruments. They also service and maintain hand-and-foot monitors and continuous-air monitors in the field.

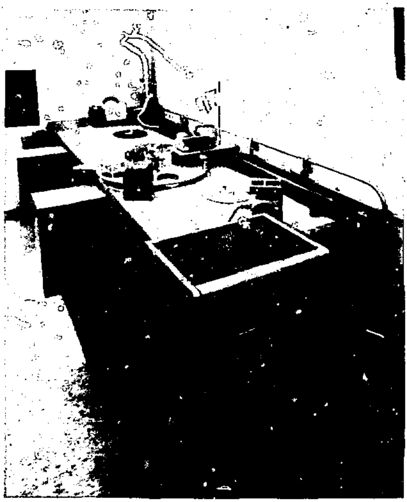

FIG. 12. Radioactive-source blockhouse for calibrating portable survey instruments. Sources are *stored at the bottom of vertical holes 4 m below the* top surface.

ACTIVITIES

The Standards and Calibrations Laboratory is used by personnel in Hazards Control and by persons from various LLL divisions and outside agencies.

Hazards Control activities in the Standards and Calibrations Laboratory include monthly calibration of the personnel thermoluminescent dosimeter (TLD) reader (Fig. 13); reader calibrations for environmental monitoring programs and special investigations; albedo-neutron and neutron-spectrometer development (Fig. 14); and fission-track and chemical high-dose-rate dosimeter research. Hazards Control personnel have also conducted Borrmann crystal studies with x rays.

Activities by researchers from other LLL divisions and outside agencies include:

- Biomed studies on damage to female germ cells in mice exposed to ^{60}Co (Fig. 15).
- An Earth Sciences Department study on high-resolution neutron analysis for carbon abundance down well boreholes (Fig. 16).
- LBL-LLL neutron damage studies on high-purity germanium, semiconductor particle detectors (Fig. 17).
- Sandia Laboratories radiation-damage studies on light pipes, quartz, and gases in the ^{60}Co irradiation pool.

Figures 18 and 19 show the equipment setup for an LET (linear energy transfer) chamber

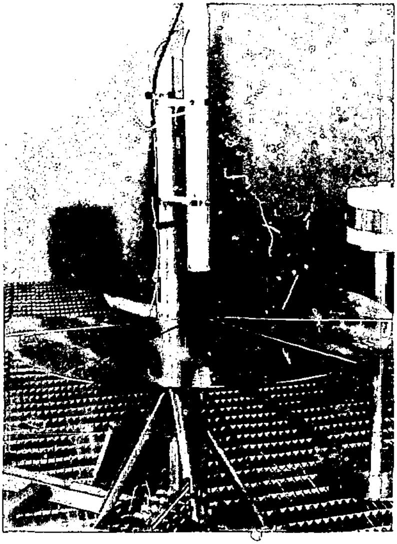

FIG. 13. TLD-reader calibrations are made on chest phantoms.

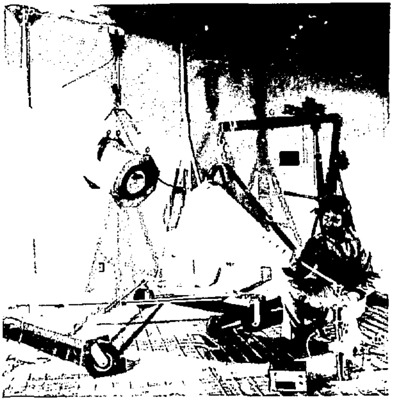

FIG. 14. In conjunction with neutron spectrometer development, a Hazards Control researcher prepares to measure the amount of neutron scatter in Cell A.

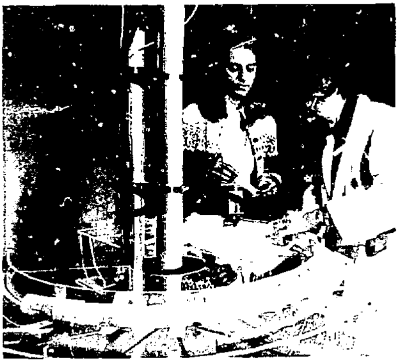

FIG. 15. Biomed experiment on damage to female germ cells in mice exposed to ^{60}Co.

research study conducted by a summer employee and his co-worker from Kansas University. A list of publications covering all activities in the Standards and Calibrations Laboratory appears in the appendix.

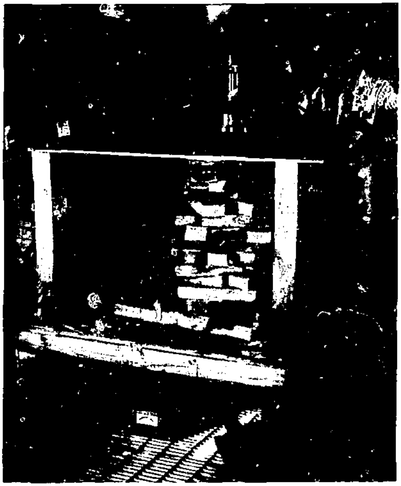

FIG. 16. Earth Sciences project to improve carbon determination by neutron-scattering analysis for use in well-borehole measurement.

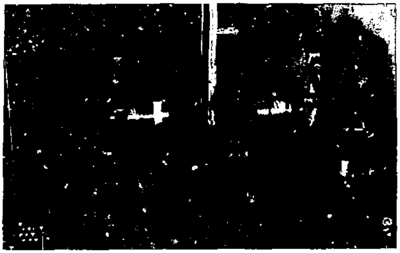

FIG. 17. Germanium nuclear detectors used for an LBL-LLL study of radiation-damage resistance. Detectors made with different materials and techniques were compared.

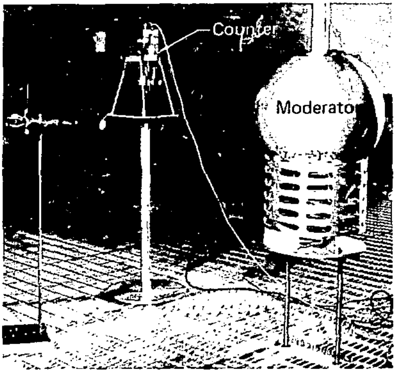

FIG. 18. Experimental setup for measuring the neutron-dose equivalent at locations in the low-scatter cell, using a tissue-equivalent LET proportional counter. A solid aluminum moderator is shown in position around the source head.

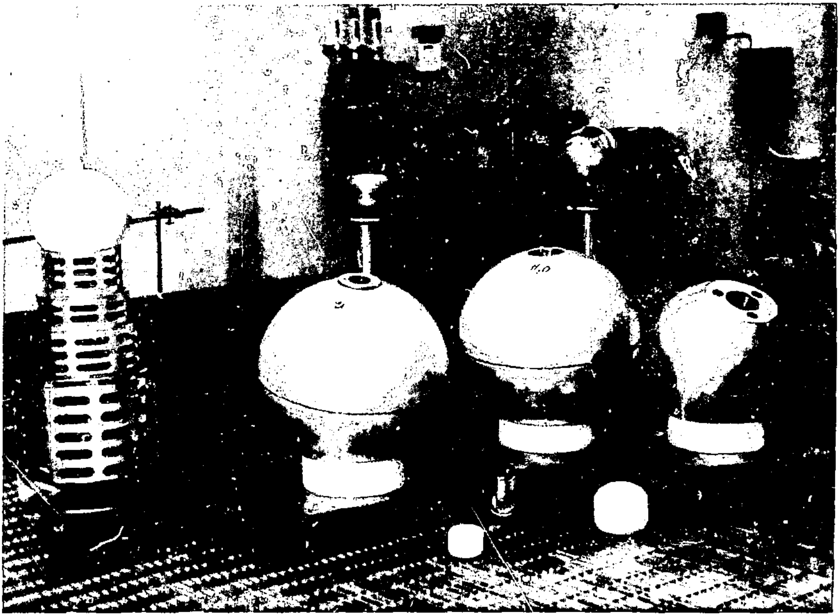

FIG. 19. The Standards and Calibrations Laboratory has a variety of neutron-source moderators to simulate the spectra to which worker might be exposed. Available moderator materials include polyethylene, water, D_2O, and solid aluminum. A hydraulic jack positions the spheres around the source head.

SUMMARY

This tour of the Standards of Calibrations Laboratory has attempted to provide the reader with a somewhat general overview of Laboratory work and available equipment and facilities. More information on specific items and projects can be obtained from the publications listed in the references and in the appendix

REFERENCES

1. J. H. Elliott, *Operation of the Hazards Control Calibration Facility Neutron Generator*, Lawrence Livermore Laboratory, Rept. UCID-17215 (1976).
2. J. L. Cate, Jr., "Transmission Anode X-ray Tube Development," *Hazards Control Progress Report No. 53*, Lawrence Livermore Laboratory, Rept. UCRL-50007-76-2 (1976).
3. J. H. Elliott, *Neutron Source Calibration Procedure by Activation Comparison*, Lawrence Livermore Laboratory, Rept. UCID-17216 (1976).

JAC/kt

APPENDIX
STANDARDS AND CALIBRATIONS LABORATORY PUBLICATIONS

J. V. Boggs, *The Hazards Control Instrument Calibration Facility,* Lawrence Livermore Laboratory, Rept. UCRL-51049 (1971).

J. V. Boggs, "Neutron Scattering in the Hazards Control Low-Scatter Cell," *Hazards Control Progress Report No. 34,* Lawrence Livermore Laboratory, Rept. UCRL-50007-69-2 (1969).

T. R. Crites, *An Experimental Study of the Spectral Dependence of an Albedo-Type Neutron Dosimeter,* Lawrence Livermore Laboratory, Rept. UCRL-77028 (1975).

R. L. Dobson et al., "Vulnerability of Female Germ Cells in Developing Mice and Monkeys to Tritium, Gamma Rays, and Polycyclic Aromatic Hydrocarbons," in *Proc. Hanford Biol. Symp., 17th, 1977* (Hanford Research Institute, Richland, Washington, 1977).

C. L. Graham and S. G. Homann, "Gamma-Ray Dosimetry Errors with TLDs," in *IAEA Symp. Nat. and Int. Stand. Rad. Dosim., 1977* (International Atomic Energy Agency, Atlanta, Georgia, 1977).

R. V. Griffith, "Personnel Monitoring Measurements," in *Measurements for the Safe Use of Radiation,* U.S. Department of Commerce/National Bureau of Standards, Rept. NBS SP456 (1976).

R. V. Griffith et al., "LLL Development of a Combined Etch Track-Albedo Dosimetry," in *Proc. 6th ERDA Workshop Pers. Neut. Dosim., 1977* (Energy Research and Development Administration, Oak Ridge, Tennessee, 1977).

R. V. Griffith et al., "LLL Special Projects Division Research in Neutron Measurement Techniques," in *Proc. 5th ERDA Workshop Pers. Neut. Dosim., 1975* (Battelle Northwest, Washington, D.C., 1975).

R. V. Griffith et al., "Multi-Technique Characterization of Neutron Fields From Moderated ^{252}Cf and ^{238}PuBe Sources," in *IAEA Symp. Nat. and Int. Rad. Dosim., 1977* (International Atomic Energy Agency, Atlanta, Georgia, 1977).

R. B. Griffith and J. C. Fisher, "Light Particle Track Registration for Fast Neutron Personnel Dosimetry," in *Proc. 21st Annual Mtg. Health Phys. Soc., 1976* (Health Physics Society, San Francisco, California, 1976).

D. E. Hankins, "A Modified A-B Remmeter with Improved Directional Dependence and Thermal Neutron Sensitivity," *Health Phys.* **34**, 249-254 (1978).

D. E. Hankins, "Neutron Dosimetry Studies at the Lawrence Livermore Laboratory," in *Proc. 6th ERDA Workshop Pers. Neut. Dosim., 1977* (Energy Research and Development Administration, Oak Ridge, Tennessee, 1977).

C. M. Hartwig, "Radiation-Induced Formation of Hydrogen and Deuterium Compounds in Silica as Observed by Raman Scattering," *J. Chem. Phys.* **66** (1), 227-238 (1977).

J. R. Hearst, *Laboratory Studies of an Improved Carbon/Oxygen Log,* Lawrence Livermore Laboratory, Rept. UCRL-81650 (1978). (Submitted to *Log Analyst.*).

R. H. Pehl et al., *Radiation Damage Resistance of Reverse Electrode Ge Coaxial Detectors,* Lawrence Berkeley Laboratory, Rept. LBL-8307 (1978). (Submitted to 1978 Nuclear Science Symposium for publication in *IEEE Trans. Nucl. Sci.* **26** (1) (1979).)

C. T. Prevo, "Use of the Borrmann Effect to Produce Nearly Monoenergetic X Rays," in *Proc. Nucl. Sci. Symp., 1976* (Nuclear Science, New Orleans, Louisiana, 1976).

C. T. Prevo, *The Use of the Borrmann Effect to Produce Monoenergetic X Rays* (prepared for PhD thesis) Lawrence Livermore Laboratory, Rept. UCRL-52286 (1977).

J. E. Shelby, "Effect of Gamma Irradiation on the Physical Properties of Glass," in *Proc. Amer. Ceramic Soc. Ann. Mtg., 1978* (American Ceramic Society, Detroit, Michigan, 1978).

J. E. Shelby, "Radiation Composition of Glass," in *Proc. Amer. Ceramic Soc. Glass Div. Mtg., 1977* (American Ceramic Society, Glass Division, Bedford Springs, Pennsylvania, 1977).

J. E. Shelby, "Radiation Effects in Hydrogen-Impregnated Vitreous Silica," Sandia Laboratories, Livermore (1978). (Prepared for publication in *J. Appl. Phys.*)

J. E. Shelby and P. L. Mattern, "Hydrogen Reactions with Vitreous Silica," in *Proc. Gordon Conf. Glass, 1975.*

D. R. Slaughter and D. W. Rueppel, *Calibration of a dePangher Long Counter from 2 keV to 19 MeV,* Lawrence Livermore Laboratory, Rept. UCRL-79206 (1977). (Prepared for submittal to *Nucl. Instr. Meth.*)

J. H. White et al., "An Analysis of Error in Measuring the Environmental Radiation Background Using Thermoluminescent Dosimetry," in *Proc. Nat. Rad. Env. III, 1978* (International Association of Environmental Analysts, Houston, Texas, 1978).

☆ U.S. GOVERNMENT PRINTING OFFICE: 1979 — 680-049/25