Lawrence Radiation Laboratory
UNIVERSITY OF CALIFORNIA
LIVERMORE

UCRL-50007-70-1

HAZARDS CONTROL
PROGRESS REPORT No. 36
January Through May 1970

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84

Contents

Introduction	1
PROGRESS REPORTS	1
<u>Radiation Protection</u>	
LRL Low Activity-Level Environmental Survey (P. H. Gudiksen)	1
Measurement of FIDLER Response to Low Energy Environmental Background Radiation in the Livermore Valley (C. L. Lindeken and D. J. Hodgkins)	2
Environmental Radiation Dose Measurements with $\text{CaF}_2:\text{Dy}$ Detector (C. L. Lindeken, D. E. Jones, K. F. Petrock and R. E. McMillen)	2
Waste Drum Counter Field Evaluation (W. E. Silver and K. M. Scown)	3
Hand Dose Measurement at Tritium Glove Boxes (W. E. Silver, C. T. Prevo, A. M. Celoni and V. C. Santomassimo)	3
High Dose Measurement with TLD (D. E. Jones, K. F. Petrock and R. E. McMillen)	4
Calibration and Standards Facility Operational Status (J. V. Boggs)	5
Whole Body Counting Room (R. V. Griffith and A. L. Anderson)	5
<u>Industrial Hygiene</u>	
Testing Organic Vapor Respirator Cartridges for Useful Life (C. L. Lindeken, G. O. Nelson, W. E. Ruch and R. E. Johnsen)	6
Sodium Chloride Filter Test Apparatus (C. L. Lindeken, J. L. Murrow and V. C. Santomassimo)	6
<u>Instrumentation Development</u>	
Photoneutron Determination of Beryllium (J. F. Tinney and J. L. Cate)	7
Zinc Sulfide Detector for Atmospheric Diffusion Studies (J. F. Tinney, T. O. Hoeger and R. D. Taylor)	7
A Surface Contamination Monitor for Tritium (S. Block and D. J. Hodgkins)	8
Stack Effluent Monitor Status (W. E. Silver, N. A. Greenhouse and E. G. Shapiro)	8
Studies of Pulsed Neutron Effects on the Remeter Neutron Dosimeter (S. Block and V. C. Santomassimo)	9
<u>Education</u>	
New Course Offerings (D. L. Woods)	9
TECHNICAL NOTES	10
<u>Radiation Protection</u>	
Thermoluminescence Data Analysis by Computer (D. E. Jones, C. H. Moseley and R. S. Flint)	10

Fading and Second Reading of LiF and CaF ₂ :Dy TLD's (D. E. Jones and R. E. McMillen)	10
A Remotely Positioned Detector for Accelerator Output Measurements (N. A. Greenhouse)	11
<u>Industrial Hygiene</u>	
In-Place Testing of Air Sampling Systems (C. L. Lindeken and G. E. Costella)	11
<u>Fire Safety</u>	
New High-Heat Source for Smoke Chamber (J. R. Gaskill, D. J. Hodgkins and R. D. Taylor)	12
<u>Instrumentation Development</u>	
Improvements in TLD Reader Design (K. F. Petrock and D. E. Jones)	12
Plutonium Estimation in Critically-Safe Tanks (J. L. Cate, Jr.)	13
Equipment for Rapid Identification of Plutonium Isotopic Composition (T. O. Hoeger and J. F. Tinney)	14
Plutonium Wound Monitor (T. O. Hoeger and J. F. Tinney)	14
Fecal Sample Analysis for Plutonium with FIDLER (J. L. Cate, Jr.)	14
Sewer Monitor Grab Sampler (J. L. Cate, Jr. and T. O. Hoeger)	15
PUBLICATIONS	16
References	18

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Introduction

This issue of the Hazards Control Progress Report introduces a new format which we hope will be more illustrative of the wide range of activities in the Department. The Progress Reports section covers the status of activities undertaken or continuing during the period; additional reports or separate publications will cover the final results of these activities. The

Technical Notes section reports interesting activities of a more limited scope on which further reporting is not anticipated. A list of publications and papers by members of the Department follows in the Publications section. Those who are interested in more detail regarding any item may contact the authors of the reports who are listed in the Contents.

Progress Reports

RADIATION PROTECTION

LRL Low Activity-Level Environmental Survey

For several years the Hazards Control Department has conducted an environmental surveillance program to ensure that on-site contamination control efforts, which place maximum emphasis on controlling the effluent at the source, are indeed restricting the release of radioactivity from the Livermore Laboratory and Site 300 to concentrations below the permissible levels as set forth in AEC Manual 0524 or 10 CFR 20. This program has consisted of collecting air, water, soil, milk, vegetation, and sewage samples which were analyzed for gross alpha and beta activities (with a few samples being subjected to more thorough analysis). The results have shown that both on- and off-site environmental ac-

tivity levels have not even approached the current permissible levels.

In view of the current national emphasis on environmental pollution control with the distinct possibility of the present protection guide values being revised downward, we are planning to improve our present environmental sampling program to be able to detect any increase in activity above background levels as a result of LRL operations. This program will include the collection of a limited number of environmental samples which will be analyzed for a variety of radionuclides by techniques which have sensitivity limits about three orders of magnitude lower than previously necessary. It will include the analysis of about 50 soil samples for ^{239}Pu and ^{90}Sr activities to differentiate between global plutonium fallout and plutonium which we may have released. These samples will

be collected within a 75-sq. mi. area surrounding the Laboratory, and at Site 300. Some of these samples will also be subjected to analyses for various radio-nuclides of uranium, californium, curium and americium. Other samples will be taken from our perimeter air samplers, local wells, and the Livermore Sewage Disposal Plant to be analyzed for plutonium, strontium and tritium content.

Collection of samples for this program will be done by LRL personnel, but the analyses will be performed by a contractor who is yet to be selected.

Measurement of FIDLER Response to Low-Energy Environmental Background Radiation in the Livermore Valley

We have been continuing monthly measurements of the counting response of the FIDLER detector to natural environmental background at 10 locations in the Livermore Valley as described in Hazards Control Progress Report No. 35 (UCRL 50007-69-3). These measurements were undertaken to determine geographic and seasonal variations in terrestrial background surrounding the Laboratory. The variations have been found to be small thus far. The seasonal variation has been about 20% with the lowest values in February when the moisture of the soil is greatest. The greatest geographical variation was about 30%. Backgrounds on the west side of the Valley have been somewhat higher than on the east side, with the lowest values being found in the center.

During the May survey, dose rate measurements were made at each station with a 3 X 3 in. NaI detector supplied by the Health Physics Department of LRL,

Berkeley.¹ This instrument is calibrated in $\mu\text{R/hr}$. Comparison of observed dose rates with FIDLER readings (in integral counts/min. from 10 to 100 keV) showed a good correlation: $1 \mu\text{R/hr} \approx 800 \text{ counts/min}$. Because the Berkeley instrument discrimination is set to accept energy above 100 keV, this correlation with the low-energy FIDLER detector reflects the uniformity of natural background spectral distribution (as found in previous FIDLER surveys) and that the spectral uniformity is also maintained at higher energies.

Environmental Radiation Dose Measurements with $\text{CaF}_2:\text{Dy}$ Detector

A program has been initiated to measure environmental radiation dose rates at selected stations in the Livermore Valley using TLD-200 ($\text{CaF}_2:\text{Dy}$).

Since anticipated dose rates will not be greater than about $10 \mu\text{R/hr}$, it becomes necessary to use an extremely low background area for storage of the control and calibrating dosimeters. We evaluated our underground whole body counting room as a storage area, but found that a 3-in. thick lead container with a cadmium-copper graded liner is about as good. Both enclosures have backgrounds of about $0.3 \mu\text{R/hr}$.

We selected 400 TLD-200 chips and 200 TLD-100(LiF) chips from our supply. The TLD-200 chips were irradiated to doses of 0.5 R; over 300 chips showed a deviation in response of less than $\pm 5\%$ from the mean and were retained for our study. The TLD-100 chips had previously been screened from an original lot of 1200 and were matched to within $\pm 2\%$.

As a preliminary test a background dose rate measurement was made inside

Laboratory property. Eighty TLD-200 and 40 TLD-100 chips were annealed at 400°C for 1-1/2 hr followed by a post-annealing at 80°C for 16 hr. The dosimeters were packaged in our personnel dosimeter holder with two CaF_2 and one LiF crystals in each holder. Ten of these holders were set out March 13, 1970.

The remaining dosimeters used for calibration curves and controls were divided equally and stored in the whole body counting room or the 3-in. lead container. Two weeks later dosimeters from both storage areas were exposed to 60-keV gammas from a ^{241}Am source.

All the dosimeters were read in our hot gas reader on April 12, 1970. The CaF_2 calibration curve showed a linear response down to 1 mR, whereas LiF indicated a pronounced departure from linearity below 10 mR. As a result, the CaF_2 to LiF ratio which has been used as a means for energy determination will probably not be useful in determining average environmental energy at low doses.

The 10 environmental dosimeters gave a CaF_2 reading of 7.4 ± 1.1 mrad for a month's exposure. The background readings of the dosimeters stored in the whole-body counting room were 11% lower than readings of the dosimeters which had been stored in the 3-in. lead container.

We currently have 10 dosimeter packages distributed in the Livermore Valley and 108 dosimeter packages in the homes of Hazards Control personnel. These dosimeters will be collected and read after a month's exposure.

Waste Drum Counter Field Evaluation

The waste drum counter described in the preceding progress report² was set up

for use in the field with the Metallurgical Chemistry Group during January 1970. Since then the waste-filled drums resulting from three month's routine operations have been counted. A comparison of the new counter readings with those from the previous neutron counter taken during February (see Table 1 below) shows a significant increase in accuracy with the new system. Since then we have requested that the neutron counter system be discontinued. The new counter appears to be an improved materials control tool, and we have been able to correlate the measured wastes with the point of origin in processing. We have placed a $\pm 26\%$ reliability factor on the monthly total mass reports and notify the Materials Management Group when any drum contains more than 10 g of plutonium. Considering geometry, counting statistics, and common waste shielding methods, we should be able to reliably see 100 mg of plutonium.

Table 1. Comparison of drum scanner with neutron counter for five waste drums.

Drum No.	Indicated plutonium (g)	
	Drum scanner	Neutron counter
1	9.6	24
2	13.8	4
3	1.9	0.0
4	1.4	1.4
5	1.3	3.0
Total	28 $\pm$ 6	

Hand Dose Measurement at Tritium Glove Boxes

Because previous reports estimated the average energy of tritium bremsstrahlung through neoprene gloves at 6 keV, the Hazards Control Calibration and Standards

Facility was asked to provide a TLD-100 calibration for that energy. This was done with the fluorescent x-rays from iron (approx. 6.5 keV).

The actual energy spectrum of the bremsstrahlung was determined for several different glove materials by spectrum analysis with a 10-mil beryllium window Reuter-Stokes proportional counter with a TMC 400 channel analyzer.* The peak for the three glove combination (27-mil Butysol, 1-3/4-mil polyethylene, 10-mil PVC) currently used was approximately 6.5 keV. We found, however, that through a 30-mil neoprene glove the spectrum had hardened somewhat and that there were now two peaks, one at 7.1 keV and one of about one-fourth the intensity at 12.0 keV, as shown in Fig. 1.

Exposures to one hand for one-week periods have varied from no detectable dose to 0.290 rem. Most of the operators' work was done under conditions which would represent maximum expected exposure.

As a result of this work, we now require that TLD-100 chips be worn by the operators whenever extensive handling of tritium is required in their operations.

High Dose Measurement with TLD

We are often called upon to use our experience with TLD materials to assist other groups in making special dosimetry measurements. This assistance often deals with doses that are outside the usual range of interest in personnel dosimetry

*Reference to a company or product name does not imply approval or recommendation of the product by the University of California or the U.S. Atomic Energy Commission to the exclusion of others that may be suitable.

Fig. 1. Bremsstrahlung energy spectra through three-glove combination and 30-mil thick neoprene.

situations. A recent effort involved the characterization of the mixed electron and gamma radiation for the Hermes II Marks generator. The important dosimetry information to be obtained from this series was the relative output for a group of related bursts and the variation of dose

with position. Both parameters were found to be extremely important, with the output showing a significant variation of over a factor of at least 5X in a somewhat regular pattern.

Commercial ^7LiF powder was used for the above measurements. For higher doses ($>10^4$ rads) we have experimented with a pure ^7LiF powder obtained from the Oak Ridge Pure Materials Research Group. This material has been used successfully for a variety of experiments in which the high temperature glow peaks (around 450°C) are integrated. One measurement in the LPTR reactor core, for which two ^{60}Co calibration sources were used, gave considerable evidence of poor behavior for some glow peaks, perhaps due to dose rate. We are investigating this material in considerable detail in order to establish its usefulness for physical dosimetry problems and to better understand TLD's in general. One project currently underway is to determine its response after exposure to a range of high doses. This is important since our supply is limited. No results are presently available.

Calibration and Standards Facility Operational Status

Activation of this facility is about 80% complete. Among the major tasks still to be accomplished are the following:

Completion and activation of the pneumatic transfer systems is expected in early June. These systems will transfer one of two gamma sources ($100\text{ Ci }^{137}\text{Cs}$ and $2\text{ Ci }^{60}\text{Co}$) and/or one of two neutron sources ($10^9\text{ n/sec }^{252}\text{Cf}$ and $10^8\text{ n/sec }^{238}\text{Pu Be}$) from their storage casks into irradiation positions for the desired time.

The $10^5\text{ Ci }^{60}\text{Co}$ source irradiation well hardware installation should also be completed by early June. This hardware will hold 72 source pencils at the bottom of a 20-ft well filled with water.

A small portable low-energy source using 4 g (14 Ci) of $^{241}\text{AmO}_2$ as the primary source and various targets for secondary x-ray production has been built and calibrated. This device can emit fairly intense beams* of mono-energetic k x-rays. Some neutrons are emitted as well, which could be important at irradiation positions very close to the holder. Work is continuing on this device and a complete report is forthcoming.

Whole Body Counting Room

The whole body counting facility was officially opened on April 16, 1970, and will be operated until the end of the summer with a single 8×4 in. sodium iodide detector. The system geometry normally consists of a horizontal bed which moves under a fixed $11\text{-}1/2 \times 4$ in. crystal mounted above the bed and a collimated 8×4 in. crystal located under the bed. In late January, the $11\text{-}1/2 \times 4$ in. and the 8×4 in. crystals were radiographed with 12-MeV gammas, and in so doing, became activated by the $^{127}\text{I}(\gamma, n)^{126}\text{I}$ reaction. These crystals, which showed initial count rates after activation of about 10^5 counts/min are now decaying out with the ^{126}I 13-day half life and will be suitable for use in mid August. At the present, there is no indication of the presence of a longer-lived contaminate. In the meantime, preliminary calibration and normal counting

* A few hundred mR/hr.

is being done with another 8 X 4 in. detector. This system will be used for the detection of gamma-emitting isotopes with gamma-ray energies in excess of 100 keV.

For the detection of heavy elements, such as ^{239}Pu , which characteristically emit x-rays in the 17-keV region, a new twin-crystal system is being assembled. This system will use thin x-ray detectors of sodium iodide backed by thicker cesium iodide for background suppression. With pulse-shape discrimination techniques, we expect to achieve a factor-of-30 reduction in background as compared with our previous system, thus permitting detection and measurement of fractional body-burdens of plutonium in the lungs and other parts of the body.

An Alderson calibration phantom will be used for much of the heavy element calibration, and a number of sets of lung fillers using various concentrations and distributions of ^{239}Pu as well as other heavy elements, will be made up and used with this phantom. The Canadian bottle phantom is currently being used to make calibrations for whole-body measurements of ^{137}Cs and ^{40}K .

An ultrasonic diagnostic unit has been ordered and will be used for the measurement of chest wall thickness to assist in our heavy element calibration program.

INDUSTRIAL HYGINE

Testing Organic Vapor Respirator Cartridges for Useful Life

To test the useful life of respirators, we have built a breathing machine with motor-driven pistons designed to simulate human respiration. Breathing patterns reflecting a range of work loads are sim-

ulated by interchangeable cams. The patterns corresponding to inhalation and exhalation are recorded from the output of a strain gage transducer that senses the pressure drop across a fine screen placed in the breather line. Performance of our machine with respect to amplitude (maximum flow rate), period and volume per minute, compares favorably with available data obtained with human test subjects. The respirators to be tested will be fitted to the inlet of the machine, and an organic vapor will be supplied at a given concentration from a generator to be described in a separate report.

Respirator life will be determined from break-through curves, the break-through period being the time required for saturation of the cartridge. Saturation is indicated when the vapor concentration penetrating the cartridge is equal to that fed to it. Using a concentration of 10 TLV the test would be run to break-through. From the break-through curve, the time required for the respirator cartridge to pass 1 TLV could be determined. This would be the useful life of the respirator for the organic vapor used in the test. Respirator life will be determined for a series of vapors under several simulated work loads, with humidity, temperature and concentration as parameters.

Sodium Chloride Filter Test Apparatus

At the request of the AEC Division of Operational Safety we have constructed a HEPA filter test unit to evaluate the use of an aerosol of NaCl as the test medium. Hitherto, American practice has been to use dioctyl phthalate (DOP) aerosols, while the British have used the NaCl aerosols. It was desired to gain some

experience with the British practice and to perform comparative tests with the two aerosols.

Check out of the equipment is now completed. Previously reported overheating of the photomultiplier tube was traced to excessive hydrogen flow rates to the burner of the flame photometer. With the recommended flow rate dark current is within specifications and clean flame readings are stable. Mass concentration measurements show aerosol concentration of approximately 10 mg/m^3 at an air flow of 1000 cfm. Electron microscope samples indicate a particle size range of from 4 microns down to a few hundredths of a micron. Both mass concentration and particle size range are in good agreement with British data.

Direct reading of the upstream (unfiltered) aerosol cannot be made without light-shocking and photomultiplier tube, therefore a successive dilution system is used for upstream readings. However, we have had difficulty in reproducing these dilutions. The British have substituted optical filters to effect simulation of a 10^4 dilution. We have ordered these filters and when they are received we plan to test a number of filters that have previously been DOP tested and compare the penetration data.

INSTRUMENTATION DEVELOPMENT

Photoneutron Determination of Beryllium

The photoneutron method of beryllium determination, based on the $^9\text{Be}(\gamma, n)^8\text{Be}$ reaction is nondestructive, rapid, reliable, and relatively simple compared to fluorometric methods of analysis. However, previously reported (γ, n) detection sys-

tems^{3,4} using small ^{124}Sb sources ($< 0.5 \text{ Ci}$) could only assay samples containing at least $10 \mu\text{g}$ of beryllium. Recent theoretical calculations and preliminary experiments indicate that samples containing less than $1 \mu\text{g}$ of beryllium can be analyzed by this technique. A sensitive photoneutron detection system is therefore being developed to assay 8×10 in. filter papers and environmental soil samples for beryllium.

To achieve the desired detection sensitivity, the source/sample/detector geometry has been optimized for a $5 \text{ Ci } ^{124}\text{Sb}$ source. The source and sample are placed in the center of a 9-in. diam lead cylinder which is surrounded by a 4-in. thick polyethylene moderator. Thirteen 2-in. diam by 12-in. active-length boron trioxide neutron counters are located in the moderator. The entire assembly will be housed in a neutron-gamma shield to minimize the influence of natural background neutrons and to further shield the ^{124}Sb source.

Fabrication of the system is proceeding on schedule and 8×10 in. filter papers containing known amounts of beryllium have been prepared for calibration.

Zinc Sulfide Detector for Atmospheric Diffusion Studies

Zinc sulfide aerosol particles in the 1-5 micron size range are frequently used as tracers for atmospheric diffusion studies. For studies now in progress at LRL, these particles are collected on H-shaped collector rods which rotate at 2400 rpm to provide an air sampling rate of 41 liters/min. The number of particles collected on each rod is then determined by visual counting under a microscope with ultraviolet illumination. Unfortunately, this

simple readout method is very time consuming and impractical when a large number of collector rods must be counted. A specialized reader is therefore being developed for this purpose.

The reader is similar in principle to the scintillation detector described by Nickola⁵ for fluorescent pigments collected on filter paper. However, substantial changes have been made to improve the detection efficiency for H-shaped collector rods. With the reader now being fabricated one leg of the collector rod is exposed to a 1-mCi ²³⁸Pu alpha source in a light-tight enclosure. Light emitted by the zinc sulfide is transmitted through a lucite light pipe to a 5-in. diam photo-multiplier tube. Pulses from the photo-multiplier tube are fed to a single channel analyzer and scaler to determine the scintillation rate which can be related to the amount of zinc sulfide present. This procedure is then repeated for the other leg of the collector rod.

Calibration of the reader will be achieved by comparing the scintillation counting rate with the visually determined particle number over a wide range of mass loadings.

A Surface Contamination Monitor for Tritium

A large-area thin-window proportional counter has been developed for use as a monitor for tritium in air.⁶ After this instrument was field tested, it became apparent that with some minor modifications and the use of commercially available electronics the detector could be applied as a surface contamination monitor for tritium. To this end, we mounted an aluminum plate on one side of the detector probe and

attached an Eberline electrical connector and cable assembly to it as shown in Fig. 2. The detector is thus compatible with an Eberline PAC-4G alpha survey meter for contamination readout, after adjustment of the operating voltage to ~2400 V and setting the discriminator to provide the maximum S^2/B ratio. The propane counting gas flow is set at a flow rate of about 30 cm³/min so that a bottle containing 3 ft³ would operate the system for about 46 hours.

Calibration of the system will be performed with tritium-labeled Formvar on a glass substrate.

Fig. 2. Tritium surface contamination monitor.

Stack Effluent Monitor Status

Field evaluation over a three-month period has shown this instrument system, described previously,⁷ to perform reliably and well. As a result, the present plan is to install it on both stacks of a gas chemistry building (Building 331). Use of this system will obviate the previous practice for estimating total monthly tritium release by manually integrating the area

under traces in a series of chart recordings. In addition to maintaining a cumulative total, the system will also give an immediate indication of the amount of tritium released in any 10-min period.

Studies of Pulsed Neutron Effects on the Remeter Neutron Dosimeter

A Kaman Nuclear Model A 810, 14-MeV neutron generator has been set up in our Calibration Facility. The neutron source produces a pulse rate frequency that can be varied from 1 to 10 pulses/sec. Its reported neutron emission is about 10^7 n/pulse. Pulse width (beam on-time) is about 5 μ sec. Under optimum conditions the calculated dose rate of the generator should be about 800 mrem/hr at 50 cm. The system will be calibrated by active and passive dosimeter techniques that will be described in the next report. After calibration, the neutron source will be used to evaluate the response of our port-

able fast neutron remeter dosimeter under various pulsed field conditions. Faster electronics will be designed, as required, to provide improved dosimeter capability.

We wish to thank Paul Meyers of A-Division for his great expenditure of time and effort in setting up the generator.

EDUCATION

New Course Offerings

An 8-hour course (HS-614) in accelerator safety has been prepared which covers operational safety controls, surveillance instrumentation, high-energy Bremsstrahlung and neutron shielding requirements, and the nature and consequences of radiation exposure.

The latest change (change 2) to the Health and Safety Manual includes an updated listing of health and safety courses presently offered by the Hazards Control Department.

Technical Notes

RADIATION PROTECTION

Thermoluminescence Data Analysis by Computer

In our thermoluminescence research the amount of data to be analyzed has grown significantly. To aid in this analysis and ensure that it is sufficiently complete we are developing a series of computer programs. During this reporting period we have developed a simple linear interpolation dose assignment program and adapted a general least-squares fitting program for dose assignment. Experience with the latter program will allow us to aid others in Hazards Control to solve a variety of curve fitting problems. We can currently apply 10 standard functional forms for fitting $y = f(x)$, $\ln y = f(x)$, or $\ln y = f(\ln x)$. The latter form has been incorporated as most effective for the usual thermoluminescence calibration data near the ends of the response range.

In studying TLD phosphors, or measuring mixed or poorly known radiations, it is often helpful to evaluate the glow curve structure. In the past we have done this by using a multichannel analyzer to multi-scale the phototube current thru a current-to-frequency converter. The major difficulty with this technique is that for an experiment of significant extent, the process becomes unwieldy. We have just completed a program to transfer the punched tape output of the analyzer to computer cards, and are currently working on programs for glow curve analysis, plotting and comparison.

We wish to thank Fred Fritsch of Computations Division for his assistance

in modifying the least squares fitting program and Ray DeSaussure for his help in adapting the PDP-1 computer to process our multichannel analyzer data.

Fading and Second Reading of LiF and $\text{CaF}_2\text{:Dy}$ TLD's

In order to better characterize TLD materials that we use for personnel monitoring, a series of measurements are being performed. During this reporting period our efforts have been directed to short term fading effects (approximately two months) and a study of rereading TLD's for higher temperature glow peaks. The fading study is important in relation to the longer accumulation period, currently three months for most employees. In the case of longer dosimetry periods that are being considered for the future, such information will be needed. Preliminary results indicate 30% and 7% decay for CaF_2 and LiF respectively, when compared to readings within 1/2-hr after exposure and 22% and 4% when compared to readings one day after exposure. These results have not included any post-irradiation annealing. The TLD's are now being recycled for a long term (1 year) fading study.

The rereading study is of interest in case a significant exposure reading were to occur but was later questioned. Since the hot nitrogen heating technique and the automatic cycling limit the maximum read-out temperature and define a precise thermal history, any remaining thermoluminescence glow peaks can be used for a second reading. Preliminary results indicate that CaF_2 can be reread for

~300 mR doses and LiF for ~10 R doses, providing the TLD's are annealed at a temperature of 450°C to erase the TL due to previous exposures. These results were obtained in our research reader with linear heating and could undoubtedly be improved by special design emphasis.

A Remotely Positioned Detector for Accelerator Output Measurements

Health Physics personnel have frequently been called upon to make relative intensity measurements for beam alignment on radiographic linear accelerators. The usual method of placing radiographic film or arrays of personnel dosimeters in the beam have been time consuming to process and analyze. The use of a small silicon PIN junction detector and the remote positioning device overcomes these problems.

An apparatus used in recent measurements on a 10-MeV linac consisted of a remotely operated X-Y translator and a 1-cm diam $\times$ 0.1-cm thick Si detector with amplifier and power supply. The detector and amplifier were enclosed in a 2-cm diam $\times$ 8-cm long light-tight cylinder which was attached to the translator to scan a 10 $\times$ 10-cm area in the beam. For a constant accelerator pulse shape and repetition rate, the detector produces output pulses whose height, observed on an oscilloscope, is proportional to the relative bremsstrahlung intensity. In fields of the order of 10^3 R/min these pulses measured about 100 mV. Intensity variations of a few percent across the beam were detected with this apparatus, which allowed reasonably precise location of the

beam centerline for radiographic purposes. A small He-Ne laser, attached to the linac as an alignment aide, was then centered on the detector at the position of maximum output.

INDUSTRIAL HYGIENE

In-Place Testing of Air Sampling Systems

We have set up a prototype aerosol chamber in order to measure collection efficiencies of LRL particulate air sampling systems under typical field flow rates. Using the air mover, filter holder and filter medium common to a given operation, we can check the system's overall performance. This may prove to be a more realistic test than a measurement of collection efficiency of the filter medium, particularly for filter media with velocity-dependent collection characteristics, since we do not routinely operate at optimum-collection flow rates. More importantly, we can detect leakage around the filter with this technique.

The present chamber accommodates filter heads as large as the 8 $\times$ 10-in. environmental Hi-Vol. We are using a poly-dispersed DOP test aerosol which is mixed with air flowing through the chamber at rates up to 50 cfm. During a test, the filter holder is fitted with the medium used in regular service and is placed in the chamber. It is connected to its air mover with the normal tubing. The sampling rate is adjusted to that routinely employed. DOP concentrations in the chamber are compared with concentrations downstream from the filter holder using a forward light scattering photometer.

FIRE SAFETY

New High-Heat Source for Smoke Chamber

Studies of the characteristics of smoke from smoldering and flaming polymeric building materials are being continued with our smoke chamber. Since our previous report we have constructed a large heat source in order to increase the scope of our tests. This heat source consists of four iodine-vapor, quartz-envelope, tungsten filament, 650 W lamps mounted in a gold-plated, aluminum block with a water cooled backing plate. The lamps are connected in series-pairs through a variable transformer to a 208 V, 1- ϕ , 60-Hz power source.

For calibration one of our regular 3 X 3 in. sample holders was modified by installing sheet metal rings at each corner and in the center in which a water-cooled Gardon-foil type radiometer can be placed in turn to measure the heat flux at these locations. A given voltage was applied to the heater and the radiometer readings at each location were taken. The heater was thus calibrated for each of several voltages between 50 and 200 V. The results showed almost identical heat flux patterns across the face of the sample holder regardless of the applied voltage. The average heat flux across the sample face was found to be 80% of the flux measured by the radiometer in the central position.

INSTRUMENTATION DEVELOPMENT

Improvements in TLD Reader Design

The hot nitrogen TLD reader designed in 1966 and previously described,^{8,9} has

been in routine use for the last four years. Although approximately 10^5 readings have been made with no major problems during that time, significant improvements have recently been made in the reader.

A complex glass readout chamber⁸ has been replaced by a solid block of aluminum, as seen in Fig. 3, which simplifies disassembly and cleaning. A smaller 50-W nitrogen heater fits within this block, requiring less total heat while concentrating it directly on the TLD. The block also contains passages for cooling water and supports the elevator mechanism that carries the TLD up into the heated gas. The TLD pick-up tube is rotated at 120 rpm by a motor-driven bevel gear which engages only when the TLD is being read.

Fig. 3. View of interior of TLD reader. TLD crystals are carried in holes on circumference of aluminum wheel.

A first-surface, spherical mirror is mounted behind the readout chamber and positioned to focus the light on the photomultiplier tube. A 0.010-in. diam hole through the mirror in combination with a ^{14}C activated light mounted behind the mirror provides a standard illumination that can be turned on or off manually. The mirror assembly can be slipped out for cleaning. A fail-safe shutter prevents accidental exposure of the PM tube to room light. In addition, the shutter holder contains two neutral density filters which can be externally selected either separately or in combination to provide extended high dose capability. Several interlocks are built in to protect the reader; for example, the nitrogen gas heater will not operate without a flow of cooling water and/or nitrogen. If either of these fail while in operation the reader will complete only the immediate reading and then stop.

The reader uses the LRL designed current-to-frequency converter¹⁰ which is mounted within the thermoelectric photomultiplier tube cooler for temperature stability. The total variation of the reader including PM tube, high voltage supply, converter and light standard is less than $\pm 4\%$ in 24 hr. Several long term reproducibility tests are being carried out with a well-matched ($\pm 2\%$ total variation) set of TLD's.

Plutonium Estimation in Critically-Safe Tanks

In the process of machining metallic plutonium, the coolant may become loaded with fine particles of Pu. Typically, the coolant liquid is recirculated through a

filter, and a critically safe reservoir. After a period of use, replacement of the coolant becomes necessary, due to loss of lubricity or other properties. It is convenient to drain the coolant into non-critically safe containers. In order to do this safely, one must know that the Pu content of the coolant does not constitute a criticality hazard. We have devised a method and calibrated a standard portable survey instrument to make this measurement.

The method used is the detection of the complex of gamma rays around 380 keV which accompany the alpha decay of ^{239}Pu and the various other isotopes which normally accompany it. The yield of these gammas per alpha disintegration is low, but in the quantities associated with criticality hazards, they are abundant. Our instrument consists of an Eberline PRM-5 portable count rate meter/single channel analyzer, with a 2 X 2-in. NaI(Tl) detector. The analyzer window is set to cover about 350 to 410 keV (by peaking on a ^{133}Ba check source).

Calibration was accomplished empirically with a small ^{239}Pu source, and a length of 3-1/2 in. o.d. X 1/4 in. wall steel pipe (similar to the reservoir). For a uniformly distributed source of semi-infinite length (>1 m), the sensitivity is approximately 1.3×10^5 counts/min/g/cm (in horizontal geometry). For a point source lying on the bottom of the reservoir with the detector directly below, the sensitivity is about 4×10^4 counts/min/g. Since background count rate has typically been around 1 to 2×10^4 counts/min even in rooms where Pu is machined, this sensitivity is quite adequate.

Equipment for Rapid Identification of Plutonium Isotopic Composition

Health physics measurements of plutonium are frequently based on the detection of low energy x- and gamma rays. At LRL, for example, such measurements include plutonium contamination surveys, wound counting, lung counting, fecal sample assay, and sewer effluent monitoring. In each of these determinations the alpha activity is of primary concern from a radiological health standpoint. The (x/α) or (γ/α) ratio of the material involved must therefore be known for proper interpretation of the counting results. An instrument for measuring these ratios¹¹ has been fabricated, calibrated, and submitted to the Hazards Control counting group for further evaluation. Alpha particles are detected with a gas flow proportional counter and a thin NaI(Tl) scintillator, operating in coincidence, detects the photons. The results of these measurements can be combined with those obtained by high resolution alpha counting to estimate approximate isotopic composition.

Plutonium Wound Monitor

To upgrade the accident response capability of LRL's Hot Spot Team, a plutonium wound monitor has been calibrated and installed in Trailer 88. The detector is a 1.0-in. diam, 0.063-in. thick NaI(Tl) crystal with a 0.005-in. thick beryllium window. This crystal thickness was selected to have good detection efficiency for the 17-keV x-ray band as well as the 60-keV gamma rays that accompany the alpha decay of ²⁴¹Am. Interchangeable lead collimators delineate the distribution of the contaminant by restricting the

photon entrance aperture. The probe assembly is mounted on a flexible support for easy positioning and a multichannel analyzer is used for data accumulation.

Calibration of the counter was accomplished with small ²⁴¹Am and ²³⁹Pu sources imbedded in tissue-equivalent plastic. Since ²⁴¹Am is normally present in a mixture of plutonium isotopes from the beta decay of ²⁴¹Pu, the depth of the contaminant can be estimated from the x-ray to gamma ray intensity ratio. Calibration curves have therefore been established which relate the x-ray to gamma ray count rate ratio to tissue depth as a function of ²⁴¹Am content.

The detection sensitivity of the counter for surface contamination is 34 counts/min/nCi ²³⁹Pu (17-keV x-ray band) and the background count rate is about 5 counts/min. Thus, for a 10-min counting time, the minimum detectable surface contamination is less than 0.1 nCi ²³⁹Pu.

A second wound counter has been installed in the new whole body counter facility which will subsequently be calibrated for other heavy elements that emit low energy x-rays and gamma rays.

Fecal Sample Analysis for Plutonium with FIDLER

The FIDLER has been used to analyze several fecal samples from persons suspected of accidental exposure to airborne plutonium. The technique consists of collecting the sample in a thin plastic bag, sealing the bag and placing it in a thin-walled plastic cup which has a convex bottom as seen from the inside. The cup is placed directly against the detector's face, as shown in Fig. 4, and counts in the

Fig. 4. Geometry of sample cup with convex bottom as placed on FIDLER detector head.

17-keV and 60-keV bands are collected on a multichannel analyzer.

After this nondestructive measurement, the samples were sent through the normal wet ashing alpha counting procedure. Using the calibration data presented in Ref. 12, the results of the two methods agreed within the limits of experimental error.

The system has been turned over to the Hazards Control counting group for routine use.

Sewer Monitor Grab Sampler

As an adjunct to the LRL sewer monitoring system previously described,¹³ we have designed a device which extracts a sample from the sewage stream at the time an alarm sounds. This sample of the sewage which caused the alarm is then available for laboratory analysis.

The sampler is activated by any of three alarm conditions (excess high or low energy radiation, or extremes in pH). When an alarm occurs, a control circuit energizes a small solenoid valve which admits tap water at 60 psi to a hydraulic cylinder which in turn opens a 1-in.-bore ball valve. This valve allows a fraction of the main sample stream to flow into a 5-gal carboy. After a preset time interval (adjustable to vary sample size), a second solenoid valve reverses the hydraulic cylinder, closing the ball valve, which terminates the sample. To prevent cross contamination of samples, the control box must be manually reset before another sample can be collected.

Publications

P. H. Gudiksen, Mass Concentrations and Particle Size Distributions as a Function of Time within a Nuclear Cratering Cloud (OUC), Lawrence Radiation Laboratory, Livermore, Rept. UCRL-50844 (1970).

This report describes a detailed study of how particle size distributions and mass concentrations of material contained within a large atmospheric dust cloud, generated by a nuclear cratering experiment, varies with time during the first hour after formation.

A mathematical model was developed for predictive purposes to account for the observed rate of change of these parameters during the period of interest. The model, which uses the measured twelve-minute mass concentrations and particle size distributions as input data, incorporates the effects of atmospheric diffusion in three dimensions, gravitational settling of particles within discrete size groups, distortion of the cloud due to the vertical profile of the horizontal winds as well as the deposition of the particles on the earth's surface.

The results of the calculation show excellent agreement between the calculated mass concentrations and particle size distributions and those measured up to four hours after cloud formation; indicating the model closely approximates the transport properties of the real atmosphere.

P. R. Zurakowski, Accelerator Pulsed Field Dosimetry, Lawrence Radiation Laboratory, Livermore, Rept. UCRL-71731 (1969).

Presented at the Second International Conference on Accelerator Dosimetry and Experience, SLAC, Palo Alto, California, November 5-7, 1969.

The current trend in particle accelerators is toward low and medium energy machines that produce high intensity radiation. These accelerators are finding wide application in medical therapy and research, activation analysis, cross-linking of polymers, physics, radiography and isotope production. Many users do not employ a qualified health physicist and there is, therefore, a general deficiency in the health physics practices employed. In addition to these poor health physics practices, there are serious gaps in our fundamental knowledge of medium energy accelerator health physics and pulsed field dosimetry.

The author has attempted to fill in some of the gaps in knowledge with the following series of measurements: Bremsstrahlung and neutron measurements were made with an LRL-developed calorimeter and pulsed neutron detector in pulsed fields varying in energy from 2 to 15 MeV. Accelerators that were used in the study were 4, 12, 13, and 5-15 MeV linacs, and the LRL 14 MeV 10^{12} n/sec neutron generator. The x-ray measurements, made under electronic equilibrium conditions, were compared with those

made with TLD 700 powder and extruded ribbon, a SLAC type RAMS, Victoreen thimble chambers and portable survey equipment with particular emphasis on energy and dose rate dependence. Calorimeter and TLD agreement was excellent. The ionization chambers showed varying degrees of dose rate and energy dependence. The effects of neutrons and beam electrons were also studied.

Neutron flux, dose and average energy measurements were in excellent agreement with those found in the literature. An Andersson-Braun type portable neutron instrument was compared with the pulsed neutron detector and found to be somewhat dose rate dependent.

Skyshine calculations and measurements are shown for a 13-MeV linac. The calculations agreed with the measurements to within a factor of 2.

K. J. Eger, K. R. Kase and B. L. Rich, Advanced Radiation Course for Monitors, Lawrence Radiation Laboratory, Livermore, Rept. UCRL-50789.

This training program is planned to fit the special needs of the Hazards Control Department of Lawrence Radiation Laboratory, Livermore. It deals with the principles which affect the wide range of radiation safety problems inherent in a large facility with diverse activities. The program is self-study by nature, but it incorporates a seminar approach for review of and expansion on important topics. It is designed at a lower undergraduate level, and does not require knowledge of calculus.

J. R. Gaskill, Smoke Development in Polymers During Pyrolysis or Combustion, Lawrence Radiation Laboratory, Livermore, Rept. UCRL-71687 Rev. 1 (1970).

An updated report on studies previously reported in the opacity and toxicity of smokes resulting from the pyrolysis or combustion of polymeric building materials under conditions of low radiant heat, with and without flame and with variations in ventilation.

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