AIM

Association for Information and Image Management

1100 Wayne Avenue, Suite 1100
Silver Spring, Maryland 20910
301/587-8202

Centimeter

Inches

MANUFACTURED TO AIM STANDARDS
BY APPLIED IMAGE, INC.

1 of 1

12
8-2-93 JS (1)

UCRL-ID-112675

Calibration of the Standards and Calibration Laboratory's Co⁶⁰ Radiation Pool

Richard H. White and G. Richard Wirtenson

January 1993

This is an informal report intended primarily for internal or limited external distribution. The opinions and conclusions stated are those of the author and may or may not be those of the Laboratory.

Work performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISCLAIMER

This document was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor the University of California nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately own rights. Reference herein to any specific commercial products, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or the University of California, and shall not be used for advertising or product endorsement purposes.

This report has been reproduced
directly from the best available copy.

Available to DOE and DOE contractors from the
Office of Scientific and Technical Information
P.O. Box 62, Oak Ridge, TN 37831
Prices available from (615) 576-8401, FTS 626-8401

Available to the public from the
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Rd.,
Springfield, VA 22161

Calibration of the Standards and Calibration Laboratory's Co⁶⁰ Radiation Pool

G. Richard Wirtenson and Richard H. White

University of California
Lawrence Livermore National Laboratory
P.O. Box 808, L-298
Livermore, CA 94551

ABSTRACT

We report measurements of dose rates at various locations in the LLNL Standards and Calibrations Laboratory's Co⁶⁰ Radiation Pool. Plots show the dependence of dose rate on radius near the bottom of the pool and the dependence of dose rate on height at a fixed distance from the pool center. The effect of varying sample location within the pool's dry-well was also investigated. Lead shielding was used to determine the magnitude of backscattering.

Motivation

It is known that optical glasses darken with exposure to ionizing radiation^{1,2} and that glasses can be modified to resist these changes but at the expense of short wavelength transmission.^{3,4} We have conducted a series of Co⁶⁰ radiation exposure studies on glasses used in a pair of Startracker lenses earmarked for the Brilliant Pebbles program. This study sought to determine the vulnerability of these glasses to radiation-induced darkening.

During the initial phase of the study, differences were seen between the reported transmission of two samples of the same glass ostensibly dosed to the same value. One of these was dosed in our study at LLNL, while the second was reported by JAYCOR from previous studies.

In trying to resolve this difference in glass transmission, we found that there were uncertainties in the dose rate reported at various locations in LLNL's Co⁶⁰ which is part of the Standards and Calibration Laboratory located in Building 255. The report "Tour of the Standards and Calibration Laboratory" includes information about this facility.⁵ The observed transmission differences, coupled with the uncertainties in the dose rate led to this effort to calibrate the Co⁶⁰ pool. We hope this report will be of some use to others who wish to use the Co⁶⁰ source to evaluate the effects of radiation on space based equipment or for other applications.

The Co^{60} source radiates γ -rays at 1.17 and 1.33 Mev with a half life of 5.263 years. (Other components have decayed to the point that they are negligible.) The measurements reported here were made on or about November 1, 1992.

The information presented here is confined to measurements made at positions away from the pool center. The dose rates at the center are so high that the central position cannot be used for lower-level radiation exposures. For example, at the center, a dose of 1 krad in optical glass is reached in about 4 seconds.

Dosimeters

The study used three types of dosimeters:

- 1) Ionization Chamber (IC) — Curtis Graham, from Hazards Control Department's Safety Services Division, supplied an ionization chamber dosimeter, 317RTG, manufactured by Far West Technology Inc., Goleta, CA. This 1 cm³ cavity unit is a Shonka A-150 type made from tissue equivalent plastic. It is calibrated at 7.55×10^{-14} Amperes per Roentgen per hour (A/R/hr) from a National Institute of Standards and Technology (NIST) traceable source. It was used in the Co^{60} pool dry-well to measure the dose rate as a function of position.
- 2) Opti-chromic (OC) — Tests were conducted using 70-40M, waveguide type, opti-chromic dosimeters with an absorbed dose range of 1 to 200 krad manufactured by Far West Technology, Inc., Goleta, CA and supplied to us by Curtis Graham. The dosimeters include a radiation sensitive solution contained in a fluorinated ethylene-propylene (FEP) tube, 3 mm diameter by 50 mm long, sealed with borosilicate beads. The photometric readout is accomplished with a Model 200 Opti-Chromic reader also made by Far West. These dosimeters are calibrated by Far West at wavelengths of 600 and 656 nm using known Co^{60} exposures.
- 3) Thermo-Luminescent Dosimeters (TLD) — These LiF crystals are used by LLNL in personnel dosimeters. The luminescent output is a function of the absorbed dose and is usually calibrated against similar crystals exposed to known doses in the Cs^{137} source which is also housed in LLNL's Standards and Calibration Laboratory. In this case we calibrated the TLD's against the opti-chromic dosimeters. The relative doses of the TLD's were measured by Don Jones and his coworkers in the Personnel Dosimetry Group of the Safety Services Division.

Results of Measurements

The IC was used to evaluate the dependence of dose rate in the Co^{60} pool on both radius and height. The Co^{60} pool is about 2 m in diameter and 6 m deep; it is water filled. A dry-well 15 cm in diameter, with a 0.26 cm thick stainless steel wall, extends to the bottom of the pool to permit irradiation without direct contact with the water. We used an "elevator" in the dry-well to lower and raise the dosimeters.

The dry-well was positioned at 4 different radial positions in the pool placing the exposed sample at distances of 30, 42.8, 53.5, and 65.5 cm from the center of the source. We call these positions "inner," "mid," "normal", and "outer", respectively. Figure 1 shows a schematic view of the Co^{60} pool from above.

Fig. 1: The Co^{60} Radiation Pool from Above (Schematic)

Usually items will be exposed to the radiation with the elevator resting on the bottom of the pool. In our calibrations, when the elevator rested at the bottom, the exposed item was approximately 10 cm above the bottom. Figure 2 shows a horizontal schematic view of the Co^{60} pool.

Fig. 2: Horizontal Schematic View of the Co^{60} Radiation Pool

In addition to calibration measurements taken at the bottom of the dry-well, measurements were done at other positions above the bottom. These off-bottom measurements were done only at the *normal* (53.5 cm) radial position. In this test, we measured the dose rate with the elevator in the *bottom* position and with the elevator raised 15 cm, 30 cm, 45 cm, and 60 cm above the *bottom* position. (The IC was, therefore, 10 , 25 , 40 , 55, and 70 cm above the bottom of the tank.)

Data collected from these radial and vertical locations are listed in Table 1. At two different radii in the *bottom* location, three measurements were taken. We report the average measured values and the mean standard deviation at these locations. Exposure rates are given both in Roentgens per hour and as dose rates in silicon: krad Si /hr. (*Silicon is chosen as the dosed substance both because dose rates in Si are often quoted in connection with exposures of electronic components and because dose rates in Si are practically the same as for the various glasses. To convert from kR to krad Si, multiply by 0.869. To convert krad H₂O to krad Si, multiply by 0.9*)

Table I
Variation of Dose Rate with Height and Radius
In the Standards & Calibration Laboratory Co⁶⁰ Pool
~November 1, 1992

Location		IC current (nA)	Dose Rate	
radius (cm)	height (cm)		kR / hr	krad (Si) / hr
varying radius				
30.0	0	1.99	26.3	22.9
42.8	0	0.71 ±.02	9.4 ±.2	8.2 ±.2
53.5	0	0.264±.002	3.49 ± .02	3.03 ±.02
65.5	0	0.126	1.67	1.45
varying height				
53.5	0	0.264 ±.002	3.49 ±.02	3.03 ±.02
53.5	15	0.244	3.21	2.81
53.5	30	0.174	2.30	2.00
53.5	45	0.089	1.18	1.02
53.5	60	0.024	0.32	0.28

In the *bottom normal* position the IC gave the dose rate 3.03 krad Si/hr. This is in good agreement with the OC detectors which gave 2.94 krad Si/hr, differing from the IC value by ~3%.

The dependence of dose rate on radial distance from the source center and on height is shown in Figs. 3 and 4. Small displacements in the dry-well's radial position can produce significant changes in the dose rate. At radii between 42.8 and 53.5 cm and height 0.0 (*bottom normal* position), a 1 cm radial displacement changes the dose rate by about 9%.

The dry-well is a 6 m long tube; radial positions are measured at the top of the well; the samples are usually at the well bottom. Therefore, an angular displacement of the tube from the vertical of just 0.1 degrees (due to flex in the tube or its mounting) will produce discrepancies of 1 cm between radii to the dry-well at the top and bottom of the pool. Therefore, the data presented here are intended mainly to get a rough estimate of dose rates at various locations so the dry-well can be properly positioned for any given experiment. Precise dose rate control requires that radiation detectors (IC, OC, or TLD) be used to calibrate each time the dry-well is moved.

Fig. 3: Variation of Dose Rate with Radius in Co⁶⁰ Pool.
(elevator in the *bottom* position, ~November 1, 1992)

Fig. 4: Variation of Dose Rate with Height in Co⁶⁰ Pool.
(dry-well in *normal* position, ~November 1, 1992)

The OC dosimeters were used in a series of tests to evaluate the dose rate across a chord of the dry-well, perpendicular to the source location, and to correlate the OC readings to the IC readings. The OC readings vary 5%. Their average value differs from the corresponding IC value by only 3%.

In two tests, TLD's were mounted in a plane perpendicular to the tank radius as shown in Fig. 5. In two other tests, the dosimeter mounting plane was parallel to the source. OC's were used only in the *normal* radial position

With the dosimeter plane perpendicular to the radius, the OC's showed a uniform dose rate ($\pm 2\%$) over the central 10.5 cm of the plane, while the extreme position (0.5 cm from the edge and 6.5 cm from the center) showed a slightly lower ($- 6\%$) dose rate. This is thought to occur because of the slightly longer γ -ray path length in water at the edge of the dry-well due both to the increased distance from the source (~ 0.4 cm) and the curved sides of the dry-well (Fig.5).

Fig. 5: The path in water from the source to B is longer than from the source to A. Two tests were done with the dosimeter plane (A-B) perpendicular to the source as shown here; two tests were done with the dosimeter plane rotated 90° to be parallel to the radius.

The following observations apply to measurements made, using OC dosimeters, within the elevator when it was stationed at the *bottom normal* location:

- 1) Within the range of height positions from -4 to +9 cm, dose rate does not depend on vertical location.
- 2) Lateral displacements on the order of 5 cm to either side of the center line produce no appreciable variation in the dose rates.
- 3) Shielding of the OC dosimeters with 0.8 mm of Al produced no change from the unshielded reading.
- 4) Doses measured by the OC dosimeters at the same location but during different "runs" varied by less than 5%.

Our original plan was to use a lead enclosure to minimize the effect of γ radiation during the lowering and raising of the elevator. The measurements of the variation of dose rate with height, made with the IC (Table I) proved this to be unnecessary. These IC measurements showed that in less than one second, samples could be lowered from (or raised to) regions where the dose rate was $< 10\%$ of the rate in the *bottom* position. Therefore exposure can be initiated and terminated promptly enough that virtually all exposure occurs in the *bottom* position.

TLD's were eventually used to obtain more general information about the pool. They were exposed in groups of 3 in thin plastic sleeves. These in turn were enclosed in blocks of Lexan which had been drilled to accept the sleeves.

We used 2 different types of elevators: 1) the "lantern" , a frame that carried both the ionization chamber and 3 sleeves, and 2) the "piglet" , a box with a 1 inch thick lead sliding door and 1 inch thick lead walls, which held sleeves inside its body. The piglet also had sleeves mounted outside its body. TLD's were located at various positions in both the lantern and piglet to explore the variation of dose rate with position inside the dry-well. Also, the piglet was exposed with its door facing the source and facing 90 degrees to the source to explore the amount of scatter from the water in the pool.

In the 90 degree position, no radiation could reach the TLD's inside the piglet body without either passing through the lead walls or scattering from the water. In this 90 degree position, some TLD's were notably in the shadow of the piglet walls and so they subtended a smaller volume of water than others. These received significantly less radiation than those that subtended the larger volume and yet more radiation than they should have received had the radiation been coming through the lead. All these observations emphasize that scattered radiation is an important component of the pool's radiation environment.

The following conclusions were drawn from the TLD measurements:

- 1) Variation of dose rate with radial position within the dry-well agreed with that obtained using the OC's.
- 2) Significant scatter of γ 's is observed; it is not correct to assume all the radiation comes directly from the source.

Summary and Recommendations

Slight changes in the position of the dry-well (3 to 5 cm) relative to the pool center can cause variations in the dose rate of 20 to 50%. Because of the difficulty in measuring the exact location of the bottom of the dry-well, we suggest, for precise work, that the dose rate be measured using calibrated OC detectors placed at the planned sample site after the dry well is positioned. The measurements using the OC detectors have been shown to correspond to measurements using the IC, our primary calibration standard, to within ~3%. The irradiated OC's are measured in the Standards and Calibration Laboratory in a room adjacent to the cell containing the Co⁶⁰ pool. This proximity makes them easier to use than the TLD's which must be taken off-site for analysis. Calibration of the dry-well in the position planned for sample exposure, at the time of testing, will eliminate any question or uncertainty in the results although the IC results presented in this report will provide some sense of the dose rate profiles in the pool.

In Summary: If your experiment requires accurate dose information, do not depend upon previous calibrations of the pool. Dose rate measurements should be part of the experimental plan and are most conveniently and reliably done using an IC or OC's. It is important that these calibrating dosimeters be placed at or in close proximity to the position to be occupied by the samples.

Acknowledgments

The authors thank Curtis Graham and Don Jones for their technical contributions to this study and especially, Marcia Kellam for performing the measurements.

This work was performed under the auspices of the U.S. Department of Energy by the University of California, Lawrence Livermore National Laboratory under Contract W-7405

References

- ¹ G. S. Monk, "Coloration of Optical Materials by High Energy Irradiations," Argonne National Laboratory Report, ANL-4536, July 31, 1950.
- ² M. J. Weber, ed., "Handbook of Laser Science and Technology," Vol. III, Part 1, Section 2: Radiation Damage, (R. T. Williams and E. J. Friebele), CRC Press, Boca Raton, FL 33431, 1986.
- ³ N. J. Kreidl and J. R. Hensler, "Formation of Color Centers in Glasses Exposed to Gamma Radiation," Journal of the American Ceramic Society, Vol. 38, No. 12, December 1, 1955.
- ⁴ N. J. Kreidl and J. R. Hensler, "Gamma Radiation Insensitive Optical Glasses," Journal of the Optical Society of America, Vol. 47, No. 1, January 1957.
- ⁵ J.H. Elliot, "Tour of the Standards and Calibrations Laboratory", Lawrence Livermore National Laboratory, UCRL-53537, April 7, 1978

**DATE
FILMED**

9/21/93

END