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THE DEPARTMENT OF ENERGY LABORATORY ACCREDITATION PROGRAM IN PERSONNEL DOSIMETRY: RESULTS OF THE PILOT PERFORMANCE TEST

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Published October 1986

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SUMMARY

A complete pilot test of the Department of Energy Laboratory Accreditation Program (DOELAP) has been conducted. The three required rounds of test irradiations were conducted from February through May 1985. The results were communicated to the participants July 29, 1985. During the second part of the accreditation program, assessors, chosen for their expertise in personnel dosimetry, made on-site visits. These visits were conducted in October and November of 1985.

Six Department of Energy (DOE) and DOE contractor personnel dosimetry programs were involved in the pilot test. The six participants were chosen from eight applicants. They represented a cross section both of DOE and DOE contractor dosimetry programs and of personnel dosimeter types. Nine dosimeter types were tested, including three separate neutron dosimeters. Both film dosimeter and thermoluminescent dosimeter (TLD) types were represented for low-energy photon, high-energy photon, and beta categories. TLD-albedo and track-etch dosimeter types were represented for neutron categories.

This was a complete test of DOE's Radiological and Environmental Sciences Laboratory (RESL) capabilities of administering the performance testing portion of DOELAP. It also proved RESL and the Pacific Northwest Laboratory (PNL) capable of delivering the test irradiations. Together, RESL and PNL were able to handle the 315 participant dosimeters, plus 108 Quality Assurance (QA) dosimeters for each round. At the same time, these laboratories maintained the specified quality levels and met the designated schedule. Both have made a number of improvements in their calibration facilities as a result of the pilot test experience.

The pilot test was conducted in accordance with drafts of the *DOE Standard for the Performance Testing of Personnel Dosimetry Systems*[1] and the *Quality Assurance Manual for the DOE Laboratory Accreditation Program for Personnel Dosimetry Systems.*[2] It served as an official, albeit voluntary, performance test for the participants' dosimetry systems.

As a group, the participants met the test criteria in only 38% of the categories. The test data showed, however, that Participant F had a serious calibration problem that distorted the overall results. The other five participants met the test criteria in 48% of the categories. The performance test results are summarized as follows:

Participant	Number of Categories Tested	Number of Satisfactory Performances
A	10	9
B	9	5
C	9	4
D	12	4
E	10	2
F	13	0
	63	24

The most difficult categories appeared to be the low-energy photon accident category, the low-energy photon + beta mixture categories, and the neutron categories. Most participants had difficulty in any category that required a low-energy photon irradiation.

Participant A used a thin phosphor, four-element TL dosimeter and did very well in all but one category. Participant B used a film dosimeter supplied by a commercial vendor, and Participant C used a four-chip TLD card. These two participants met the test criteria in about one-half of the categories in which they were tested. Therefore, participants will probably be able to pass the test criteria of the DOE Standard with different types of dosimeters. They will need to make detailed studies of their dosimeter's responses to this wide range of radiation types and energies and design their dose calculation algorithms accordingly.

Many of the participants had problems with the neutron categories. Participant C, however, successfully passed all three neutron categories with a simple albedo dosimeter built into a TLD card. Participant C did this after having the dosimeter calibrated at the performance testing laboratory, using both the bare and D_2O-moderated Cf neutron spectra specified in the DOE Standard. This suggests that other participants should also be able to significantly improve their performance in neutron categories by taking advantage of this available option.

The significant difficulties which some of the participants experienced clearly indicate that the DOELAP is essential to ensure quality personnel dosimetry throughout the DOE.

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PNL: F.M. Cummings, C.D. Hooker, F.N. Eichner, R.A. Fox, R.T. Hogan, and P.L. Roberson.

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INTRODUCTION

The DOE Office of Nuclear Safety (Environment, Safety, and Health) has established DOELAP to ensure that DOE and DOE contractor facilities provide high-quality personnel dosimetry services to their employees. DOELAP satisfies a long-recognized need to establish performance criteria for personnel dosimetry programs and the testing procedures to ensure that those criteria are met. It culminates an effort begun in 1963 within DOE and its predecessor agencies, the Atomic Energy Commission (AEC) and the Energy Research and Development Agency (ERDA).

In the 1960s, the AEC participated in developing performance criteria for film dosimetry systems. In 1973, AEC and other state and federal agencies participated in a task force which the Conference of Radiation Control Program Directors commissioned to establish a testing program. The task force asked the Health Physics Society Standards Committee (HPSSC) to develop a new standard, establishing appropriate testing criteria for such a program. ERDA representatives participated in the working group which the HPSSC formed to write the new standard for the American National Standards Institute (ANSI). The resultant draft standard was distributed in 1976.

From 1977 to 1982, the University of Michigan administered a pilot study consisting of three rounds of performance testing. A modified standard, based on the results of the pilot study, was adopted as the final ANSI Standard N13.11.[3] The National Voluntary Laboratory Accreditation Program (NVLAP) which services Nuclear Regulatory Commission (NRC) licensees currently uses this Standard.

An independent DOE study showed, however, that ANSI N13.11 was inadequate for evaluating dosimetry programs at DOE and DOE contractor facilities. Furthermore, DOE felt a performance testing program should encourage and interact with ongoing research and development efforts. Therefore, DOE decided in late 1983 that DOELAP should be put into place as soon as possible. Drafts of the DOE Standard and a DOELAP Handbook were prepared at PNL and circulated for review. The Radiological and Environmental Sciences Laboratory (RESL), located at the Idaho National Engineering Laboratory (INEL), was selected to administer DOELAP and to be the lead performance testing laboratory (PTL). PNL is assisting RESL by providing performance test irradiations for the low-energy photon and neutron categories. PNL also serves as the lead laboratory for DOE's dosimetry research program.

By the fall of 1984, initial reviews of draft versions of the DOE Standard and the DOELAP Handbook were completed. In October, DOE Headquarters (DOE/HQ) sent a letter to the field offices soliciting participants for a DOELAP pilot test session. The same month, RESL and PNL submitted a project plan for the pilot test to DOE/HQ. In November, a National Bureau of Standards (NBS) review team visited RESL and PNL to evaluate their facilities and preparations for the pilot study. In January 1985, a DOE *ad hoc* review committee visited the two facilities. Both teams reported their findings and recommendations to DOE, and the laboratories implemented the recommendations before starting the performance tests.

The applications to participate in the pilot study were received in late December of 1984 and early January 1985. On January 16, 1985, a letter was sent notifying six of the eight applicants that they had been selected. The three rounds of performance tests were conducted at RESL and PNL from February through May of 1985; the results of those tests were mailed to the participants on July 29, 1985. This report discusses the pilot study and the performance test results.

MATERIALS AND METHODS

Testing Process

When the applicants were notified of their acceptance in the pilot study, they were told how many of each type of dosimeter being tested to send for each testing round. The number included control and replacement dosimeters. The applicants were also told when these dosimeters were due at RESL. When RESL personnel received the dosimeters, they: (a) logged them in; (b) verified that the correct number were sent; (c) verified that each dosimeter had a unique participant ID number; (d) surveyed the dosimeters for contamination; and (e) attached a unique bar-coded DOELAP ID number (Figure 1) to each. RESL then randomly selected five dosimeters of each type for each irradiation category and linked the DOELAP IDs to the participant IDs in the computer data base. Later, RESL personnel reentered both numbers as before to verify that these IDs had been entered correctly.

Figure 1. Bar-coded DOELAP ID label.

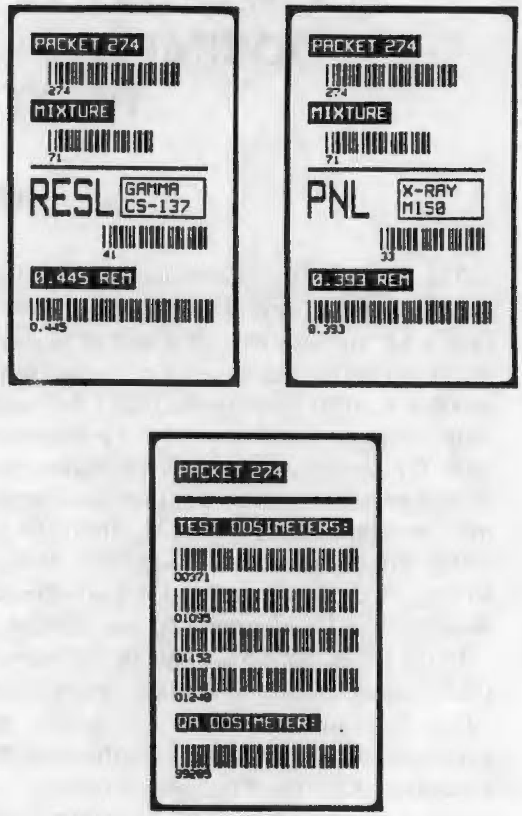

Figure 2. DOELAP Irradiation Packet Labels.

After RESL had entered all the dosimeter IDs into the data base and assigned the irradiation categories, they put the dosimeters into irradiation packets. Each packet contained as many as four dosimeters of different types and a DOELAP QA dosimeter. They printed labels and attached them to each packet (Figure 2). These labels identified the dosimeters inside, the types of irradiations, and the computer-assigned doses or dose equivalents they were to receive.

At this time, RESL mailed all irradiation packets requiring either low-energy photon or neutron irradiations, or both, to PNL by overnight U.S. Express Mail. The shipment included a magnetic tape listing and hard copy printout of the packet data. PNL initiated the low-energy photon and neutron irradiations as soon as these packets arrived. Concurrently, the RESL-only beta and high-energy photon irradiations were started at RESL. As soon as PNL completed their irradiations (generally within 5-8 days), they returned the dosimeters to RESL by U.S. Express Mail. PNL also included a magnetic tape listing and hard copy printout of all irradiation data. The final mixture irradiations were then completed at RESL.

Approximately three weeks were required to perform all the irradiations in each test round. As soon as the irradiations were completed, the packets were disassembled. The bar-coded DOELAP ID labels were removed and the dosimeters were sorted and boxed for return to the participants. A computer-generated report form was sent with the dosimeters to the participants. Five weeks were allowed for each round of testing. By the third round, the process could be completed in four weeks.

The participants were directed to record the measured doses or dose equivalents on the report forms and return them to RESL within one month. When the forms were returned, RESL hand-entered the data into a computer terminal. RESL used the computer-generated output data sheets to check for entry errors. After all the data were entered and checked, RESL printed a report for each participant showing their performance in each test category.

The test criterion for successful performance in a particular category was:

$$|B| + S \leq 0.30 \tag{1}$$

where the bias B is the average and S is the standard deviation of the performance quotients (P_i) of the dosimeters irradiated for that category. Here

$$P_i = \frac{[X_i(\text{reported}) - X_i(\text{delivered})]}{X_i(\text{delivered})} \tag{2}$$

where the deep or shallow dose or dose equivalent can be inserted for X. A modified test criterion was used for the low-energy beta performance (Tl-204):

$$|B| \leq 0.50 \tag{3}$$

Radiation Sources

RESL Irradiations. RESL performed the beta and high-energy photon irradiations. They used two Cs-137 sources for the high-energy photon irradiations and Sr-90/Y-90, Tl-204, and natural uranium slab sources for the beta irradiations. The Cs, Sr/Y and Tl sources are located in Room D of the RESL calibration facility, CF-638. This building is a hemi-cylindrical concrete building originally built as a munitions bunker. Room D is approximately 13 m x 8 m x 4 m at the center of the room. A MINC 23 data logger/microcomputer system, with two independent internal clocks, controls the sources. This system is located in a nearby room. Temperature- and pressure-measuring instruments interface directly to the computer. They provide data for automatically correcting in-phantom ionization chamber readings which verify that the correct doses have been delivered. A dose rate calibration at the surface of the phantom is used to determine the exposure times. The computer calculates the source decay and updates the dose rate. It uses the dose rate to calculate the necessary exposure time. One clock serves as a timer to operate the source, the second to check the exposure time. RESL performed the uranium slab irradiations in the beta laboratory at CF-690. They manually placed dosimeters on, or removed them from, one of two natural uranium slabs. Irradiation times were determined using a calibrated clock.

RESL Sources

1200-Ci Cs-137. The nominal 1200-Ci Cs-137 source is contained in a Picker Model V4M60 teletherapy irradiator. RESL uses a single, fixed source-to-phantom distance of 2.00 m. A calibrated rod sets the distance for all irradiations. A 3-cm^3 Victoreen Model 550 ionization chamber monitors the integrated dose. The chamber is embedded in the lower corner of a standard 30-cm x 30-cm x 15-cm methylmethacrylate phantom. To maintain NBS-traceable calibration, RESL uses an NBS-calibrated Victoreen Model 415 ionization chamber and periodically verifies calibration by participating in NBS-sponsored Measurement Quality Assurance (MQA) tests. In November 1984, MQA tests, using 3 NBS-owned ion chambers, showed agreement to 1% or better.

20-Ci Cs-137. The nominal 20-Ci Cs-137 source is mounted in a Shepherd Model 81-8B irradiator. A fixed-rail system positions the 30- cm x 30- cm x 15-cm phantom at either 1.00 m or 2.00 m from the source. Calibrated rods set these distances. The methylmethacrylate phantom has a 30-cm^3 Victoreen Model 550 ionization chamber embedded in the corner to monitor the delivered dose. RESL maintains NBS-traceable calibration exactly as described above for the 1200-Ci source. MQA tests in November 1984 showed agreement to 1.4% or better.

Sr-90/Y-90. The nominal 50-mCi source is part of a set of secondary standard beta sources obtained from Amersham Buchler. The source is encapsulated in a threaded holder that screws into an aluminum irradiation fixture. The 30- cm x 30- cm x 5-cm methylmethacrylate phantom is attached to a support. The phantom support moves between irradiation positions along a rail system. A spring-loaded peg is inserted into a hole at fixed irradiation distances. The 50.0-cm irradiation distance is used for the Sr-90/Y-90 source. The MINC computer remotely operates the shutter. RESL monitors the delivered dose at the phantom surface using a Far West Technology thin-walled extrapolation chamber embedded in the corner of the phantom. Dosimeters are positioned only within that portion of the 15- cm x 15- cm irradiation area of the phantom where the dose equivalent rate is within 3% of the mean. The Physikalisch-Technische Bundesanstalt (PTB) in Germany initially calibrated this source. MQA tests at RESL with RESL and NBS instruments agreed within the precision of the measurements.

Tl-204. RESL obtained the nominal 5-mCi source from the University of Lowell, MA. The source is mounted in a threaded holder for use in the rail system described above. The methylmethacrylate phantom is moved to the 30.0-cm position, and a beam flattening filter is used. As with the Sr-90/Y-90 source, dosimeters are positioned only within that portion of the 15- cm x 15- cm irradiation area where the dose equivalent rate is within 3% of the mean. During their visit in November 1984, the NBS staff calibrated the source at RESL. MQA tests using RESL and NBS instruments were in agreement to 1.2%.

Natural Uranium Slabs. RESL uses two 51-cm x 8-cm x 0.5-cm natural uranium slabs for contact irradiations. The slabs are covered with 6.5 mg/sq cm of Mylar to protect both the slabs and the badges. Using a PTW extrapolation chamber, RESL determined the dose rates at 7 mg/sq cm to be 213 mrad/hr for both slabs. This agrees with the published values.

PNL Irradiations. PNL performed low-energy photon and neutron irradiations using two x-ray generators for the NBS filtered techniques and the K-fluorescence irradiations. PNL uses a Picker TFI 320 kVcp x-ray machine for the S60, M150, H150 techniques and for the nearly monoenergetic 16-keV and 59-keV K-fluorescence techniques. PNL uses a 160-kVcp Phillips unit for the M30 technique. These x-ray generators are located side-by-side in a room about 10 m x 18 m x 3 m high. The control console and the HP-85 data logger/microcomputer, used to control the irradiations and record the data, are located in an adjacent room. They use a Cf-252 source, unmoderated or moderated by 15 cm of heavy water (NUREG/CR-1024),[4] for the neutron irradiations. A pneumatic source transfer system directs the source to the irradiation position at the center of a 10- m x 16- m x 9-m-high low-scatter concrete-surfaced room. The pneumatic system timer controls the neutron irradiation times. PNL has ordered a process control computer.

Low-Energy Photons. For the NBS techniques, PNL directs the beams horizontally through filters, collimators, and a transmission ionization chamber. To generate K-fluorescence x-rays, they direct the primary beam downward onto a target mounted at 45 degrees relative to the beam axis. They use a zirconium target for the 16-keV x-rays and a tungsten target for the 59-keV x-rays. These characteristic x-rays are then filtered and collimated in the horizontal direction, and the beam passes through a transmission chamber. A rail system allows the horizontal beam from either unit to be aligned with a 30- cm x 30- cm x 15-cm methylmethacrylate phantom. To position the phantom, PNL uses a perpendicular laser beam previously set using a calibrated measuring rod. Source-to-phantom distances are 2.00 m for the NBS techniques and 0.50 m for the K-fluorescence techniques. Based on the output from the transmission ionization chambers, the computer controls exposures. A Radocon Model 550-4 ionization chamber embedded in the phantom also monitors the irradiations. Because measurements with both film and TLDs have shown the beams are not sufficiently uniform over the 15- cm x 15-cm irradiation area of the phantom for all techniques, PNL uses individual dose rates for each dosimeter position when appropriate. To maintain NBS-traceable calibration, PNL uses a Capintec Model PM-30 chamber or a Victoreen Model 415-A chamber depending on the photon energies. To verify it periodically, PNL participates in NBS-sponsored MQA tests.

Neutrons. PNL uses a nominal 800 μg Cf-252 source for both the unmoderated and heavy-water moderated neutron spectra. NBS calibrated the source emission rate. The free-field dose equivalent rate at 50 cm is calculated according to NBS recommendations (NBS Special Publication 633).[5] Room return measurements performed with albedo neutron dosimeters showed that the scatter contributions were 6% (unmoderated) or 2% (moderated) of the total free-field dose equivalent at 0.50 m. These contributions are not included in the final reported dose equivalents. The participants are responsible for correcting their dosimeter responses for facility scatter or for requesting field calibration irradiations. PNL uses a tissue-equivalent ionization chamber to verify that the correct dose is delivered. They use inverse-square corrections to correct for dose rate differences between the different dosimeter positions. As measured, the ratios of the response of a boron trifluoride detector in a 9-in. diameter sphere to that in a 3-in. diameter sphere were 2.70 for the unmoderated spectrum and 0.31 for the moderated spectrum. These data are provided to the participants, and the dosimeters irradiated with each spectrum are identified. The high-energy photon components of the two spectra were determined to be 7% (unmoderated) and 18% (moderated). This is included in the reported total delivered deep dose equivalent for the neutron mixture categories.

Exposure QA/QC

The DOELAP pilot study followed the QA procedures specified in the Quality Assurance Manual. As the Manual required, each facility kept an extensive QA manual detailing such things as source and instrument calibration traceability data, personnel training information, and irradiation procedures. The following subsections discuss quality assurance (QA) and quality control (QC) procedures employed during the DOELAP pilot performance testing to ensure that dosimeters were correctly irradiated.

Bar Coding. Figure 1 shows an example of the bar-coded DOELAP ID label that was attached to each dosimeter. Figure 2 shows examples of the bar-coded labels attached to the packets to which all dosimeters were assigned. These packet labels indicated the assigned dose or dose equivalent, the irradiation category(s), and the DOELAP IDs of the enclosed dosimeters. Bar-coding ensured correct data entry into both the RESL VAX data base and the facility process control computers because it eliminated manually entering these data. In addition, wanding the bar-coded DOELAP IDs on the individual dosimeters and on the packets made it easy to verify that the correct dosimeters were in the packet. RESL used bar code readers for all three rounds, and PNL used them for their second and third rounds. A data logger/microcomputer used the bar-coded packet label information to control all irradiations except the uranium slab beta irradiations at RESL and the neutron irradiations at PNL.

QA Dosimeters. Thin phosphor, four-element TL dosimeters, included in every packet, were irradiated with the dosimeters in that packet. These had previously been calibrated for each radiation source used in the performance testing. The measured element responses were then compared to the expected element responses calculated using the element response factors and the delivered doses for each irradiation. Because the relative responses of the four elements vary for the different types of irradiations, the element ratios were also used to evaluate whether or not the correct radiation source was used.

Dosimeter Assignments. Irradiation packets contained dosimeters from more than one participant in all but one of eighteen categories. In that category, only one dosimeter type remained after a second was terminated at the end of the first round. If there were enough participants in a particular test category, RESL included as many as four different types of dosimeters in the same packet, in addition to the QA dosimeter, and irradiated them together. When a question arises about a particular irradiation, RESL can compare the reported results for the different dosimeters in the irradiation packet.

Ionization Chambers. Ionization chambers, embedded in the phantoms, monitored the high-energy photon, low-energy photon, and general beta category irradiations. The data from these chambers were fed directly into the computer and compared with the expected value. In addition, in-beam transmission chambers used in the low-energy photon beams controlled the exposure time. A tissue-equivalent ionization chamber located near the Cf-252 source monitored neutron irradiations.

Clocks. The MINC process control computer at RESL has two independent internal clocks. The first served as a timer to operate the source; the second verified the exposure time.

Dosimeter Storage Procedures. RESL and PNL stored all irradiation packets in low-background storage and handling rooms until the day they irradiated them. They then removed and stored the packets in a storage cask at the irradiation laboratory. The packets were removed only during the actual irradiations. All dosimeters were returned to the storage and handling room by the end of the day. Both facilities use TL dosimeters to monitor the background levels. They process these dosimeters every month to ensure that background levels are less than 30 μR/hr.

Uncertainties

We estimated the total uncertainty in the dose delivered to the sensitive element of the test dosimeters. When we combined uncertainties as explained in this subsection, the total was less than 5% in all cases.

We estimated the total as the arithmetic sum of the total random and the total systematic uncertainties. To calculate both the total random and systematic uncertainties, we combined the individual random or the individual systematic uncertainties in quadrature. The estimates of the individual random uncertainties were made at the one sigma level.

We estimated individual uncertainties for all but two factors contributing to the assigned dose—the C_x factors for photons and the flux-to-dose equivalent conversion factors for neutrons. The DOE Standard specifically excludes the C_x factors.

We considered the exposure rate to have only systematic uncertainty, and the exposure time, distance from the phantom to the source, and the background dose as having only random uncertainty. We considered the distance from the sensitive element to the phantom and the factor relating the dose rate at the dosimeter position to the dose rate at the center of the phantom to have both systematic and random components.

For the x-ray machines, we used the random uncertainty of the transmission chamber instead of the random uncertainty of the timer, since we determined exposure by the transmission chamber in this case. We incorporated an additional setup uncertainty to account for slight changes as the x-ray machine was configured from bremsstrahlung to fluorescence x-rays and back. The uncertainty for neutron exposures also includes the uncertainty in the scattered radiation.

RESULTS AND DISCUSSION

Six DOE and DOE contractor dosimetry programs participated in the pilot performance testing session. Initially these programs presented ten dosimeter types for testing, including three separate neutron dosimeters. The pilot study tested a total of nine of these dosimeter types. It discontinued testing the tenth type after the first round of tests because the participant sent the dosimeters in the wrong holders. For each round after that first round, RESL assigned a total of 335 participant dosimeters and 108 QA dosimeters to 108 barcoded irradiation packets. RESL and PNL delivered 153 irradiations per round—73 at PNL and 80 at RESL. Table 1 summarizes the performance results for each participant.

Participant A was the most successful one in the pilot. This participant uses a thin phosphor, four-element dosimeter which successfully met the test criteria in nine of the ten categories. A low-energy photon + beta mixture category was the only category where this participant was not successful.

Participant B has a commercial processor provide dosimetry services. This participant uses a combination all-purpose film-track etch dosimeter and is currently considering using an albedo-track etch neutron dosimeter. Both dosimeter types were tested. They satisfactorily met the test criteria in five of the nine categories tested. Of the four others, their worst performance corresponded to a test statistic $|B| + S$ of 0.502.

Participant C designed the four-chip TLD dosimeter used at their facility. This dosimeter satisfactorily met the test criteria in four of the nine categories attempted. In each of the other five categories the test statistic was between 0.30 and 0.40. Four of those five categories were low-energy photon or low-energy photon mixture categories. The test statistic was greater than 0.30 in the fifth category because of a large performance quotient of 0.64 for one dosimeter. This irradition was at the extreme low end of the test range. A dose equivalent of 0.054 rem was reported when 0.033 rem was delivered. Participant C met the test criteria in all three neutron categories, after having the dosimeter calibrated in the bare and D_2O moderated Cf-252 neutron fields at PNL.

Participant D entered a film dosimeter and a separate albedo neutron dosimeter in the performance tests. It was clear that this participant had significant difficulties with some of the test categories. They successfully met the test criteria in only four of twelve categories attempted. An outlier in the general low-energy photon category accounted for the very large test statistic for that category. However, without it, they still would not have met the criterion.

Participant E tested a thin phosphor, four-element dosimeter and an albedo neutron dosimeter. A third type of dosimeter was to have been tested, but it was withdrawn after the dosimeters were sent in the wrong badge holders for round 1. Participant E successfully met the test criteria in two of ten categories attempted. They were not successful in one category because they entered a wrong number into the computer during the dose evaluation.

Participant F tested a six-chip TLD dosimeter of their own design. They did not meet the test criteria in any of the thirteen categories attempted. It is clear that Participant F had a very serious calibration problem. Even the high-energy photon categories showed a very large bias.

In summary, the participants met the DOELAP test criteria in 24 of the 63 categories they entered. Excluding Participant F from the evaluation, this becomes 24 of 50 categories (48%). In 15 other categories (30%), these five other participants had test statistics between 0.30 and 0.50.

Table 1. Performance results of pilot test program[a]

Category Description	Depth	Participant A			Participant B			Participant C			Participant D			Participant E			Participant F		
		B	S	|B| + S	B	S	|B| + S	B	S	|B| + S	B	S	|B| + S	B	S	|B| + S	B	S	|B| + S
I. High Dose Low-energy photons M150	Deep							0.233	0.095	0.328	-0.228	0.238	0.466				3.738	6.724	10.462
II. High Dose High-energy Photons Cs-137	Deep	-0.037	0.034	0.071				0.172	0.073	0.244	-0.124	0.125	0.249	-0.189	0.220	0.408	1.043	0.213	1.255
III.A. General Low-energy	Shal.	-0.043	0.109	0.152	-0.299	0.181	0.480	0.306	0.067	0.373	3.135	10.825	13.960				0.807	0.464	1.271
Photons H150	Deep	-0.129	0.082	0.210	-0.305	0.185	0.491	0.257	0.058	0.315	3.287	11.292	14.579				0.692	0.572	1.264
III.B. Pu Envr Low-energy	Shal.							0.251	0.129	0.381				-0.350	0.043	0.393	1.108	0.392	1.500
Photons 59 KeV	Deep							0.104	0.072	0.176				-0.383	0.044	0.427	0.904	0.466	1.370
IV. High-energy	Shal.	0.004	0.031	0.036	0.045	0.076	0.121	0.247	0.117	0.364	0.025	0.089	0.114	-0.091	0.099	0.190	0.939	0.548	1.486
Photons Cs-137	Deep	-0.016	0.029	0.045	0.023	0.071	0.094	0.159	0.042	0.201	0.003	0.087	0.090	-0.111	0.094	0.205	0.535	0.469	1.004
V.A. General Beta Particles T1-204	Shal.	-0.028	0.375								-0.029	0.157					-0.758	0.469	
V.B. Beta Particles Nat. U	Shal.	0.190	0.075	0.265							0.243	0.684	0.927	-0.034	0.107	0.141	0.377	0.201	0.578
VI. Neutron Moderated					-0.191	0.296	0.487												
Cf-252	Deep				-0.143	0.138	0.282	-0.055	0.052	0.107	1.083	0.183	1.266	0.961	0.524	1.485	1.298	1.151	2.450
VII. Mixture M150 Photon +	Shal.	0.041	0.066	0.107	0.040	0.097	0.137				0.036	0.240	0.276				0.945	0.514	1.459
Cs-137 Photon	Deep	-0.071	0.065	0.136	0.002	0.090	0.092				0.037	0.237	0.274				0.837	0.546	1.383
VII. Mixture 59 KeV. Photon +	Shal.							0.278	0.085	0.362				-0.202	0.113	0.315			
Cs-137 Photon	Deep							0.144	0.060	0.204				-0.239	0.094	0.333			

Table 1. (continued)

Category Description	Depth	Participant A B	Participant A S	Participant A |B|+S	Participant B B	Participant B S	Participant B |B|+S	Participant C B	Participant C S	Participant C |B|+S	Participant D B	Participant D S	Participant D |B|+S	Participant E B	Participant E S	Participant E |B|+S	Participant F B	Participant F S	Participant F |B|+S
VII. Mixture M150 Photon + Sr-90/Y-90 Beta	Shal.	0.259	0.263	0.522													0.531	0.162	0.693
	Deep	0.384	0.448	0.833													1.357	0.543	1.900
VII. Mixture H150 Photon + Nat. U Beta	Shal.	-0.201	0.060	0.261							-0.187	0.125	0.312						
	Deep	-0.138	0.072	0.209							0.517	0.359	0.876						
VII. Mixture 16 KeV. Photon + Nat. U Beta	Shal.													0.070	0.122	0.192			
	Deep													0.555	0.186	0.741			
VII. Mixture Cs-137 Photon + Sr-90/Y-90 Beta	Shal.	0.183	0.082	0.265							-0.320	0.167	0.487						
	Deep	0.021	0.028	0.050							-0.011	0.106	0.118						
VII. Mixture Cs-137 Photon + Nat. U Beta	Shal.	0.169	0.059	0.227										-0.160	0.161	0.321	0.276	0.360	0.635
	Deep	0.036	0.030	0.067										0.024	0.104	0.128	0.799	0.494	1.293
VII. Mixture M30 Photon + Mod. Neutron					-0.239	0.118	0.357												
	Deep				-0.200	0.069	0.268	-0.160	0.097	0.257	0.576	0.349	0.925						
VII. Mixture 59 KeV Photon + Unmod. Neutron	Deep													-0.438	0.111	0.549	5.818	7.669	13.487
VII. Mixture Cs-137 Photons + Unmod. Neutron					-0.027	0.178	0.206												
	Deep				0.155	0.347	0.502	0.030	0.039	0.069	0.553	0.876	1.429	-0.263	0.091	0.344	5.231	7.879	13.110

a. Performance Criteria:
General Beta (TL-204): $|B| \leq 0.50$
All Other Categories: $|B| + S \leq 0.30$

PROBLEMS IDENTIFIED

This section discusses problems encountered during the pilot and makes recommendations based on the experience gained administering it.

During the pilot test, it was often difficult to get applicants, and then participants, to meet deadlines. Had we not frequently telephoned the applicants to remind them, few of them would have submitted applications by the appropriate date. Furthermore, without our frequent reminders, we would have received only a few dosimeter shipments in time for the start of the first round of test irradiations. Although the problem with shipments improved for later rounds, we then had difficulties getting some of the participants to report the data in a timely fashion. In the future, the lead performance testing laboratory should emphasize before testing begins that deadlines must be met. Participants must do this to avoid creating serious problems when DOELAP is conducting three complete test sessions each year.

The time that processors are given for submitting their results after their dosimeters are returned should be reevaluated. The draft DOE Standard allowed 60 days for this. Since this would make it easy to process dosimeters irradiated in more than one round together, we chose to ask for results within 30 days.

One participant chose not to participate in beta categories because they did not have any thallium betas and because the DOE Standard did not allow them to choose only the Sr-90/Y-90 source. In such a case, the participant could successfully complete the performance test portion of DOELAP but fail to gain accreditation. During the required on-site visit, the assessors could insist that the participant be tested in the beta and beta mixture categories. The final version of the DOE Standard should establish a mechanism to ensure that all appropriate testing categories are selected by the applicant. The possibility of modifying the DOE Standard to allow for the use of only low-energy betas (Tl-204) or high-energy betas (Sr-90/Y-90), where appropriate to test a particular facility, should be considered.

Two of the participants in the personnel-level general low-energy photon category did not participate in the accident-level (high dose) low-energy photon category. The DOE Standard indicates that they should have done so. We should have brought this to their attention, but we did not.

The DOE Standard suggests that participants should submit neutron dosimeters to the PTL beforehand to obtain field calibrations in the DOELAP neutron fields. Alternatively, they should make corrections for air scatter, room return, and source scatter, as described in Schwartz and Eisenhauer, 1982.[5] The latter procedure requires that dosimeters be submitted to the PTL for irradiations at different distances from the source. The participants obviously did not understand that these options were available. Only one requested field calibrations, and then only after the first round of tests had begun. These options should be emphasized and clarified in the final version of the Standard. It would be unfortunate if participants did not successfully complete neutron performance tests because they did not understand, and take advantage of, the available opportunities to characterize the neutron fields.

Both the uranium slab beta category and the K-fluorescence low-energy photon category can require very long exposure times. A 10- rem irradiation with a natural uranium slab takes almost 47 h. A reduction of the maximum dose equivalent to 5 rem in these categories should be considered.

Participants used various formats to identify their dosimeters. They should be directed to use a standard ID format in the future.

We had to interpret the DOE Standard before assigning participants to certain mixture categories. Appendix A is a list of our interpretations.

In some cases, the actual dose equivalent which a dosimeter received slightly exceeded the range specified in the Standard. This happened because the dose equivalent rate to the different quadrants varied, and because the dosimeter elements were closer to the source than the phantom surface was. The dose assignment algorithm should be modified slightly to eliminate this problem.

ANTICIPATED IMPROVEMENTS

RESL has most of the software it will use and the equipment for the high-energy photon and beta irradiations in place. New equipment to automate the uranium slab beta irradiations is being constructed. Plans are also underway to obtain the equipment and make the facility modifications which are needed to perform the low-energy photon and neutron tests at RESL as soon as possible.

In the meantime, PNL obtained a new data logger/microcomputer for use at the neutron irradiation facility. When the equipment is in operation, PNL will be able to use it to control all neutron irradiations. It will eliminate a significant potential source of error—manually entering the neutron irradiation data into the data base.

CONCLUSIONS

The performance test portion of the DOELAP pilot study demonstrated that RESL can administer a high-quality performance test program. Furthermore, RESL and PNL can deliver test irradiations accurately and on time. Both laboratories have successfully met the ambitious milestones for the pilot session without finding serious inadequacies in procedures or equipment.

For various reasons, participants in the DOELAP pilot study had more difficulty with some of the performance test categories than we expected. One had a serious calibration problem. Some chose to participate in unnecessary categories just to evaluate their systems. Most treated the pilot as a practice run and made little effort to evaluate and prepare their systems beforehand. Participant A's overall performance, and Participant C's performance in the neutron categories following dosimeter calibrations at PNL, suggest that the testing requirements are not too strict, however. The performances of these two, as well as the overall performance of participants B and C, show that existing dosimetry systems can achieve desired performance with some effort. Dosimetry programs should carefully evaluate calibration methods, dose calculation algorithms, and dosimeter processing procedures to accomplish this result. The fact that actual performances often fell short of the goal emphasizes the need for DOELAP to encourage and require DOE and DOE contractor dosimetry systems to achieve the appropriate level of performance.

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APPENDIX A

INTERPRETATIONS OF THE DRAFT DOELAP STANDARD

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1. Facilities participating in two categories having a mixture category for the combination will automatically participate in that mixture category.

2. Facilities participating in both x-ray subcategories (IIIA and IIIB) and/or both beta subcategories (VA and VB) *not intending to use different algorithms for these subcategories* need send only five dosimeters for mixtures involving those categories. The PTL shall make a random selection of spectra for those mixtures.

3. Facilities participating in both x-ray subcategories (IIIA and IIIB) and/or both beta subcategories (VA and VB) and *intending to use different algorithms for each subcategory* must send ten dosimeters (five for each subcategory) for each mixture involving x-ray and/or beta irradiation. In such cases, the PTL shall identify all dosimeters exposed to plutonium environment x-rays or uranium slab betas so that the correct algorithms can be used. The PTL will not further identify any other irradiations which these dosimeters may have received. The x-ray and beta mixture category will consist of a IIIA + VB mixture and a IIIB + VA mixture for facilities participating in all four of the above subcategories and using a different algorithm for each.

4. Facilities participating in neutron tests cannot tell the PTL which of the two Cf-neutron spectra to use. In either case, the PTL will tell the participants which spectrum was used. The PTL will provide the participants with a 9- to 3-in. ratio for that spectrum. Pretest calibration exposures for each spectrum can be requested.

5. The maximum dose equivalents which the PTL can assign for mixture category irradiations are 5.00 rem each for the two irradiation types.

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