The U.S. Department of Energy Laboratory Accreditation Program for Testing the Performance of Extremity Dosimetry Systems: A Summary of the Program Status

F.M. Cummings, R.D. Carlson, T.F. Gesell, DOE/Idaho Falls
and
R.M. Loesch, DOE/Office of Health

Introduction

In 1986, The U.S. Department of Energy (DOE) implemented a program to test the performance of its personnel whole-body dosimetry systems. This program was the DOE Laboratory Accreditation Program (DOELAP). The program parallels the performance testing program specified in the American National Standard for Dosimetry - Personnel Dosimetry Performance - Criteria for Testing (ANSI N13.11-1983), but also addresses the additional dosimetry needs of DOE facilities. As an extension of the whole-body performance testing program, the DOE is now developing a program to test the performance of personnel extremity dosimetry systems. The draft DOE standard for testing extremity dosimetry systems is much less complex than the whole-body dosimetry standard and reflects the limitations imposed on extremity dosimetry by dosimeter design and irradiation geometry. A pilot performance test session has been conducted to evaluate the proposed performance testing standard.

DOE Laboratory Accreditation

The process for gaining accreditation of a dosimetry system follows. The laboratory seeking accreditation completes an application form that identifies the irradiation categories in which testing is required and that describes the dosimetry system being tested. This application is submitted through the local DOE Field Office to the Performance Evaluation Program Administrator. At the direction of the performance testing laboratory, the applicant sends an appropriate number of dosimeters for testing. The testing laboratory irradiates the dosimeters and returns them to the applicant. This process of sending, irradiating and returning the dosimeters is repeated two more times. The duration of the dosimeter testing phase is approximately five months. The applicant reports the dosimeter results to the testing laboratory where the results are evaluated using the performance criteria defined in the testing standard. If a dosimetry system does not meet the specified performance criteria, the applicant must repeat all or a portion of the performance test.

When the performance test criteria have been successfully met, the administrator assigns two assessors from other laboratories to evaluate the applicant's ability to conduct a credible personnel dosimetry program. The onsite assessment includes evaluation of quality assurance, documentation of the system, personnel training, personnel competency, facilities and equipment, equipment maintenance and calibration and recordkeeping. Using the results of the performance test and the onsite assessment, the administrator collects a file of supporting information which is used by the DOELAP Oversight Board for recommending accreditation actions to the DOELAP Program Administrator at DOE Headquarters. If the applicant feels an action is incorrect, the applicant and DOE Field Office may petition a

Board of Appeals.

To maintain accreditation, DOE laboratories must pass performance testing and onsite assessment every two years. A laboratory which does not pass all of the performance testing may be granted conditional accreditation for a subset of the testing requirements specified in the application. If a laboratory is not fully accredited it must submit and implement a remedial action plan to correct the deficiencies prior to achieving full accreditation.

Testing Categories

The draft extremity dosimetry standard applies to dosimetry performed for health protection under controlled (protection level) and uncontrolled (accident level) conditions. Tests for accident dosimetry are approximately represented by a high dose category. Performance studies for angular dependence and lower limit of detectability are required one time only for each dosimeter type submitted for evaluation.

The testing categories are summarized in Table 1. With the exception of the uranium slab source, all of the irradiation sources in the standard are consistent with specifications in ISO documents. With the exception of neutron irradiations, the reference depth for the specification of dose or dose equivalent to the extremities is 7 mg/cm^2. The testing criteria are:

$$|B| + S - |E| \leq L$$

where
- B is the average bias of dosimeters in a particular category or subcategory,
- S is the standard deviation of the measurements for a particular category or subcategory,
- E is the estimation of the fractional uncertainty in the delivered dose or dose equivalent rate and
- L is the tolerance level (L = 0.3 for category I and 0.5 for categories II through IV)

Performance tests for neutron dosimetry are included in the draft standard because neutron exposures are currently measured and reported by DOE and DOE contractor facilities where the extremities of workers are exposed to significant dose equivalents from neutron fields. It is recognized that numerous complexities exist in assigning a dose to the extremities from neutron radiation. For purposes of dosimeter performance evaluation, the testing standard uses the existing neutron fluence to dose equivalent conversion factors specified in International Standard ISO-8529 for the whole body. While there are significant technical inadequacies with this approach, including the depth for dose evaluation and the use of quality factors, the approach is consistent with practices used at this time to record dose equivalent. A study by DOE to determine more meaningful and technically based quantities for extremities is planned. As that information becomes available, the standard will be revised.

Categories comprised of mixtures of sources (e.g., low and high energy photons or beta particles and high energy photons) have not been included at this time. In general, the extremity dosimeters that are currently in

use cannot discriminate between radiation types and energies unless they are multi-element dosimeters. In addition, extremity dosimeters are typically used to monitor specific exposure situations where the source of exposure is known or the response of the dosimeter has been previously characterized.

Table 1. Irradiation Categories

Test Category	Energy	Test Range
IA. Photons, Accident, General		0.1 to 5 Gy
NIST M150 X ray	70 kev (Average)	
^{137}Cs	662 keV	
IB. Photons, Accident, Special		
NIST M150 X ray	70 keV (Average)	
IC. Photons, Accident, Special		
^{137}Cs	662 keV	
IIA. Low Energy Photons		2.5 to 100 mSv
NIST M30 X ray	20 keV (Average)	
NIST M150 X ray	70 keV (Average)	
IIB. High Energy Photons		2.5 to 100 mSv
^{137}Cs	662 keV	
IIIA. Beta Particles, General (point geometry)		2.5 to 100 mSv
^{204}Tl	0.76 MeV (Maximum)	
$^{90}Sr/^{90}Y$	2.3 MeV (Maximum)	
IIIB. Beta Particles, Special (point geometry)		2.5 to 100 mSv
$^{90}Sr/^{90}Y$	2.3 MeV (Maximum)	
IIIC. Beta Particles, Special (point geometry)		2.5 to 100 mSv
^{204}Tl	0.76 MeV (Maximum)	
IIID. Beta Particles, Special (slab geometry)		2.5 to 100 mSv
Uranium	2.3 MeV (Maximum)	
IVA. Neutron, General		2.5 to 100 mSv
^{252}Cf (D_2O-moderated)		
^{252}Cf (unmoderated)		
IVB. Neutron, Special		2.5 to 100 mSv
^{252}Cf (D_2O-moderated)		
IVC. Neutron, Special		2.5 to 100 mSv
^{252}Cf (unmoderated)		

Dosimeter Phantoms

Five phantom designs shall be used for extremity dosimeter irradiations: one to represent a lower arm or leg to test wrist or ankle dosimeters for photon and point geometry beta exposures; a second similar phantom for neutron irradiations; a third to represent a finger to test ring or hand dosimeters; a fourth to represent a lower arm or leg to test wrist or ankle dosimeters for uranium slab exposures and a fifth to represent a finger to test ring or hand dosimeters for uranium slab exposures. Originally, the standard specified only three phantoms, but two additional phantoms were required to perform uranium slab irradiations. The arm/leg phantoms used

for photon and beta exposures are right circular cylinders of aluminum with a diameter of 60 mm nested inside a tube of polymethylmethacrylate (PMMA) with an inner diameter of 60 mm and an outer diameter of 73 mm. The length of the aluminum insert and the PMMA tube are both 300 mm. The arm/leg phantom used for neutron irradiations is a right circular cylinder of PMMA with a diameter of 73 mm and a length of 300 mm. The finger phantoms are right circular cylinders of PMMA with a diameter of 19 mm and a length of 300 mm.

The phantoms used for uranium slab exposures incorporate sections of phantoms as specified above, but allow all the dosimeters to be placed on the slab at once and float in such a manner to allow dosimeters of different thickness to be in contact with the slab source simultaneously without being tilted.

The factors for the photon fields which convert exposure to dose equivalent (Sv/R) at 7 mg/cm^2 have been measured by Roberson, et. al. and incorporate a quality factor of unity. The factors are:

	Arm/Leg Phantom	Finger Phantom
M30 X-Ray Technique	9.9	9.5
M150 X-Ray Technique	11.4	10.1
^{137}Cs Gamma-Ray Source	10.2	9.8

The neutron fluence to dose equivalent conversion factors are for the torso phantom and have been specified in International Standard ISO-8529. Those factors are 9.1×10^{-11} $Sv \cdot cm^2$ for the D_2O-moderated ^{252}Cf source and 3.33×10^{-10} $Sv \cdot cm^2$ for the unmoderated ^{252}Cf source. The factor for the moderated Cf source is further modified to account for the loss of thermal neutrons in the cadmium shield surrounding the D_2O.

Performance Testing Pilot Study

A pilot test session has been conducted to evaluate the proposed performance testing standard. Six DOE laboratories submitted a total of six ring dosimeters and two wrist dosimeters for testing. While not all test sub-categories were included in testing, all sources were included (e.g., testing occurred in category IA, Photons, Accident, General using M150 and ^{137}Cs, but not in the special categories IB and IC for which a single source is specified.)

Extremity DOELAP Status

The draft Standard and Handbook for the DOELAP for extremity dosimetry have been submitted to all DOE Field Offices for review and comment. The comments will be evaluated and included as appropriate into the final Standard and Handbook. The DOE Order 5480.15 which regulates the performance of personnel dosimeters will be modified during 1992 and submitted for comment. The DOE will begin a phase of voluntary testing starting January, 1993. When the DOE Order has been modified to include extremity dosimetry performance testing and published, performance testing for extremity dosimetry systems will be mandatory for all DOE laboratories.

References

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