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EXTERNAL DOSIMETRY PROGRAM GUIDE

for Use with

Title 10, Code of Federal Regulations, Part 835, Occupational Radiation Protection

[This Guide describes suggested nonmandatory approaches for meeting requirements. Guides are not requirements documents and are not to be construed as requirements in any audit or appraisal for compliance with the parent Policy, Order, Notice, or Manual.]

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ACRONYMS

AEC	Atomic Energy Commission
ANSI	American National Standards Institute
BRH	Bureau of Radiological Health
CFR	Code of Federal Regulations
DOE	Department of Energy
DOELAP	Department of Energy Laboratory Accreditation Program
HPS	Health Physics Society
ICRP	International Commission on Radiological Protection
ICRU	International Commission on Radiation Units and Measurements
NCRP	National Council on Radiological Protection and Measurements
RCS	DOE-STD-1098-99, *Radiological Control*
RPP	radiation protection program
TLD	thermoluminescent dosimeter

EXTERNAL DOSIMETRY PROGRAM

1. PURPOSE AND APPLICABILITY

This Guide provides an acceptable methodology for establishing and operating an external dosimetry program that will comply with U.S. Department of Energy (DOE) requirements specified in Title 10 of the Code of Federal Regulations (CFR), Part 835, Occupational Radiation Protection (DOE 1998a), hereinafter referred to as 10 CFR 835. In particular, this Guide provides guidance for achieving compliance with subpart E of 10 CFR 835. For completeness, this Guide provides cross-references to detailed guidance provided in DOE-STD-1098-99, *Radiological Control* (DOE 1999a), hereinafter referred to as the RCS. This Guide also identifies applicable recommendations contained in secondary documents [American National Standards Institute (ANSI) standards, etc.].

The requirements of 10 CFR 835 are enforceable under the provisions of Sections 223(c) and 234A of the Atomic Energy Act of 1954, as amended (AEC 1954). The requirements and recommendations of other DOE documents are enforceable through contractual or administrative means.

This Guide also provides guidance for the structure, function, and operations of an external dosimetry program. The criteria for external dosimetry programs to serve epidemiology, risk assessment, and litigation are not within the scope of this Guide.

Except for requirements established by a regulation, a contract, or by administrative means, the provisions in this Guide are DOE's views on acceptable methods of program implementation and are not mandatory. Conformance with this Guide will, however, create an inference of compliance with the related regulatory requirements. Alternate methods that are demonstrated to provide an equivalent or better level of protection are acceptable. Where alternate methods are used, DOE expects these methods to be fully documented in the supporting technical basis document. DOE encourages its contractors to go beyond the minimum regulatory requirements and to pursue excellence in their programs.

The word "shall" is used in this Guide to designate requirements from 10 CFR 835. Compliance with 10 CFR 835 is mandatory except to the extent an exemption has been granted pursuant to 10 CFR 820, Procedural Rules for DOE Nuclear Activities (DOE 1997a). The words "should" and "may" are used to denote optional program recommendations and allowable alternatives, respectively.

This Guide is applicable to all DOE activities that are subject to the requirements of 10 CFR 835.

2. DEFINITIONS

Terms defined in 10 CFR 835 are used in this Guide consistent with their regulatory definitions.

DOELAP: The Department of Energy Laboratory Accreditation Program. This program defines a set of reference performance tests and provides a description of the minimum levels of acceptable performance for personnel dosimetry systems and radiobioassay programs under DOE-STD-1111-98*, Department Of Energy Laboratory Accreditation Program Administration* (DOE 1998b).

Exposure: The general condition of being subjected to ionizing radiation, such as by proximity to external sources of ionizing radiation or through intake of radioactive material into the body. In this document, exposure does not refer to the radiological physics concept of charge liberated per unit mass of air.

Uniform exposure: Hypothetical radiation field in which the fluence and its angular and energy distributions are the same throughout the volume of interest.

3. DISCUSSION

Due to the types of material handled or processed, low-level, chronic occupational exposures to external ionizing radiation are difficult to avoid, necessitating an external dosimetry program at most DOE and DOE-contractor facilities that use, handle, or store radioactive materials. An external dosimetry program generally consists of three elements:

- an area monitoring program, using an array of fixed and portable devices, as appropriate;
- an individual monitoring program, using personnel dosimeters; and
- a dose evaluation program that evaluates the data collected by the area and individual monitoring programs to determine the magnitude of individual doses.

4. IMPLEMENTATION GUIDANCE

This section provides guidance for establishing and conducting an external dosimetry program for individuals who are likely to be exposed to external sources of ionizing radiation. Conduct of an external dosimetry program involves determining area and individual monitoring methods and frequencies, distributing and controlling monitoring devices, and evaluating external doses. This section also addresses program organization, administration, staffing, and training.

An external dosimetry program should include the following features:

- adequate staff provided with appropriate technical training;
- a technical basis document that explains each program element;
- procedures that address each step in the activities that determine external dose;
- criteria and methods for implementing the area monitoring program;
- criteria and methods for identifying individuals who require individual monitoring;
- appropriate personnel dosimeter measurement methods and frequencies;
- methods for control, accountability, and safe handling of dosimeters;
- appropriate dosimetric models and default parameters for evaluating external dose;
- timely analysis of personnel dosimeter measurements and transmission of results, dose evaluation, and recommendations to monitored individuals, management, and DOE, as appropriate;
- historical records of the external dosimetry program, procedures, and results; and
- a quality assurance (QA) program that covers all steps in the activities that determine individual external dose.

4.1 PROGRAM MANAGEMENT AND ADMINISTRATION

4.1.1 General Requirements

The external dosimetry program implemented to demonstrate compliance with 10 CFR 835.402(a) shall be adequate to demonstrate compliance with the dose limits established in Subpart C of 10 CFR 835 [10 CFR 835.402(b)] and shall be:

- accredited by the DOE Laboratory Accreditation Program (DOELAP); or
- excepted from DOELAP accreditation in accordance with the DOELAP standards; or
- determined by the Secretarial Officer responsible for environment, safety and health matters (currently the Assistant Secretary for Environment, Safety, and Health) to have performance substantially equivalent to that of programs accredited under the DOE Laboratory Accreditation Program for Personnel Dosimetry [10 CFR 835.402(b)].

Guidance for achieving accreditation or exception from accreditation under the DOELAP Program is provided in DOE-STD-1111-98. DOE will consider requests for other program approvals on a case-by-case basis.

The specification of accreditation requirements only for programs implemented to demonstrate compliance with 10 CFR 835.402(a) does not reflect an intent to provide a lesser degree of protection to individuals unlikely to receive doses exceeding the regulatory monitoring thresholds, nor does it reflect DOE's intent for its contractors to establish two separate individual monitoring programs (i.e., an accredited program for individuals likely to exceed the regulatory monitoring thresholds and a nonaccredited program for individuals who are unlikely to exceed these thresholds). Rather, those individuals who are unlikely to exceed the regulatory monitoring thresholds are provided an adequate degree of protection by the various engineering and administrative controls that limit their doses. Implementation of a comprehensive area monitoring program verifies the effectiveness of these controls. When an accredited dosimeter program already exists and management of any given facility chooses to provide monitoring for those individuals who are unlikely to exceed the regulatory monitoring threshold, consideration should be given to using the accredited program. This will obviate the need to implement two dosimeter programs, one accredited and the other not. In addition, it will avoid giving workers who are not required to be monitored the impression that they are being provided a lesser degree of protection. However, this does not imply that the monitoring program for those unlikely to exceed the monitoring threshold must be accredited.

Sections 401–403 of 10 CFR 835 establish specific monitoring requirements for areas and individuals. 10 CFR 835 also establishes requirements for preserving dosimetric records and reporting external radiation doses to individuals.

4.1.2 Organization, Staffing, and Facilities

4.1.2.1 Organization

The external dosimetry program should be administered by the radiological control organization under the leadership of the radiological control manager. When elements of the external dosimetry program are performed by a subcontractor, the radiological control organization should establish contractual standards and assessments that ensure the subcontractor meets all applicable requirements in 10 CFR 835, the documented radiation protection program (RPP), DOELAP standards, and the technical basis document.

4.1.2.2 Staffing

Management should maintain an adequate staff with the necessary expertise and skill to implement the external dosimetry program. For staff members responsible for evaluating external doses, management should establish minimum qualification standards that include both experience and education requirements. Additional guidance on education, skills, and training is provided in DOE G 441.1-1A, *Management and Administration of Radiation Protection Programs Guide* (DOE 1999b) and DOE STD-1107-97, *Knowledge, Skills, and Abilities for Key Radiation Protection Positions at DOE Facilities* (DOE 1997b). Personnel should be familiar, at a level commensurate with their assigned responsibilities, with relevant external dosimetry literature and related recommendations of national and international scientific organizations.

4.1.2.3 Facilities and Resources

Computational facilities and software tools used by external dosimetry personnel should be adequate for performing calculations required for dose evaluation. A library of handbooks, reference materials, scientific publications, applicable regulations, and guidance documents should be readily available.

4.1.3 Technical Basis Document

A technical basis document should be developed for the external dosimetry program to provide (or provide reference to) the regulatory, scientific, and technical foundation of the program. The technical basis document should include:

- the methods used for evaluating external doses from workplace and individual monitoring data and the technical basis for those methods;
- justification of categories selected for participation in and exception from DOELAP personnel dosimeter performance testing;
- QA procedures for dosimeters that are outside of the DOELAP testing protocol, as appropriate;

- the physical characteristics of external radiation to be monitored, methods for calculating external doses, methods for documenting calculations, dose evaluation quality assurance, and procedures for recording and reporting external dose results;
- the methodology used in determining the dose of record when multiple dosimeters are used and when dosimeters are relocated;
- individual monitoring methods, their lower limits of detectability, and monitoring intervals, along with a rationale or justification for the methods and intervals chosen;
- calibration models, parameters, assumptions, and default values used in dosimetric modeling and evaluation; and
- statistical methods for evaluating dosimeter data, using appropriate controls, identifying above-background values, and analyzing trends.

The technical basis document should be reviewed periodically and updated as necessary to ensure that it remains appropriate for current conditions. The technical basis document should be handled as a controlled document and retained as an RPP record.

4.1.4 Procedures

10 CFR 835 requires that written procedures be developed and implemented as necessary to ensure compliance, commensurate with the radiological hazards created by the activity and consistent with the education, training, and skills of the individuals exposed to those hazards (10 CFR 835.104). All functions of the external dosimetry program should be specified in written procedures that provide for appropriate quality control and QA measures. The procedures should be consistent with 10 CFR 835, the DOELAP technical standards, and the technical basis document. In summary, the procedures should provide the following information:

- methods and requirements for measuring, evaluating, and recording external dose;
- methods for consistent collection of workplace and personnel monitoring data, its evaluation, documentation of results, and records maintenance;
- components and reporting structure of the external dosimetry program;
- responsibilities of line management and members of the dose evaluation group; and
- elements of the area monitoring program that are germane to external dose determination.

Additional guidance on written procedures is provided in DOE G 441.1-1A.

4.1.5 Quality Assurance

Internal audits shall be conducted such that all functional elements are reviewed no less frequently than every 36 months and shall include program content and implementation (10 CFR 835.102). External peer-review by qualified individuals, on a periodic basis, is also recommended. See DOE G 441.1-1A for further information on internal audits.

4.2 AREA MONITORING PROGRAM

The area monitoring program supplements the individual monitoring program by providing a prospective assessment of radiological conditions, thus facilitating decisions regarding postings, access controls, work authorizations, and individual monitoring, and providing backup data for use in individual dose evaluations. Because of the need to evaluate individual external doses (prospectively and retrospectively) from contained sources, airborne radioactive material, and surface contamination, the area monitoring program should include methods for assessing the degree of hazard arising from each of these hazards to which individuals may be exposed. Guidance for implementing surface contamination and airborne radioactivity monitoring programs is provided in DOE G 441.1-9, *Radioactive Contamination Control Guide* (DOE 1999c) and DOE G 441.1-8, *Air Monitoring Guide* (DOE 1999d), respectively. Guidance for implementing area monitoring for other external sources of radiation is provided below. For each element of the area monitoring program, additional guidance is provided in Chapter 5 of the RCS.

4.2.1 Monitoring Instruments and Devices

External radiation monitoring instruments and devices include both fixed and portable instruments that provide real-time indication of radiation levels [such as portable dose rate meters and electronic dosimeters which provide dose rate information] and passive monitoring devices [such as thermoluminescent dosimeters (TLDs) and radiosensitive film] that provide a retrospective indication of radiological conditions. Guidance on instrument selection, calibration, and operational checks is provided in DOE G 441.1-7, *Portable Monitoring Instrument Calibration Guide* (DOE 1999e).

Although fixed instruments provide the advantage of continuous operation with little or no attention, their application is limited by their lack of mobility. Fixed instruments should be used to monitor areas and installations:

- having a known and relatively predictable operation where little variation in the radiological hazards is expected;
- where monitoring of an access point (and possible provision of an alarm function) is desirable to warn individuals of hazards in the area;
- where it is desirable to continuously monitor an area to detect changes in radiological conditions, possibly as a result of an unplanned change in process functions;

- where continuous monitoring and alarm functions are necessary to prevent unplanned exposures; and

- as necessary to provide input into interlocks, control devices, and alarm systems that are dependent upon or that control the operation being monitored.

Portable instruments are most appropriate for use in performing prospective monitoring for the purposes of work planning, radiological condition verification, facility integrity verification, and operational assessments. The quality and utility of the data provided by portable instruments are highly dependent upon the knowledge and skills of the user. Because of these important applications and significant vulnerabilities, portable instruments should be used only by trained individuals (such as specifically-trained radiological workers and radiological control technicians). Refer to DOE G 441.1-7, *Portable Monitoring Instrument Calibration Guide*, for guidance on use of portable instruments, e.g., calibration, instrument check, sensitivity, etc.

Passive monitoring devices (e.g., area monitoring TLDs) should be placed in areas surrounding radiological areas to verify that doses in these areas do not exceed the individual monitoring threshold. Passive monitoring devices should be placed where they will be exposed to radiation fields similar to those affecting individuals frequenting the area, but should be protected from loss or vandalism. The use of passive monitoring devices to characterize radiation fields as a part of pre-job planning should also be considered.

4.2.2 Performance of Area Radiation Monitoring

10 CFR 835 defines radiation and high radiation areas in terms of the radiation levels at a distance of 30 centimeters from the source or from any surface penetrated by the radiation. Similarly, 10 CFR 835 defines very high radiation areas in terms of the radiation levels at a distance of 100 centimeters. Therefore, area radiation monitoring should be performed at these distances (consistent with facility hazards) to ensure compliance with the 10 CFR 835.603 area posting requirements. However, actual and likely exposure conditions should be considered when performing monitoring for task planning, hazard analysis, or dose assessment. If an individual is likely to linger at a distance of several feet from a shield wall, use an obvious travel path between stations, or work within a few inches of a radiation source, measurements should be made at those locations (and recorded as such) to provide representative information. Such monitoring should be performed as necessary to ensure compliance with 10 CFR 835.401(a). Methods used in performing area radiation monitoring should also be adequate to identify localized variations in radiation levels to facilitate dosimeter placement and individual exposure reduction actions.

Important variables that should be considered for inclusion in procedures and training include instrument selection, operation, functional testing, detector orientation, response time, operational limitations, source-to-detector distance considerations, and documentation requirements.

4.2.3 Allowance for Physical Characteristics

The physical characteristics of the radiation field present should be considered in the design of the monitoring program and in the evaluation of external dose equivalent. These characteristics include radiation quality, energy, fluence rate, and direction of incidence. If certain characteristics are not known, the assumed values used as the basis for the area monitoring program design should be documented in the technical basis document. For instance, if monitoring for beta particles is performed, but the energies are not known, the energy assumed and rationale used for calibration purposes should be recorded.

4.2.4 Recourse for Technology Shortfall

The technology may not be available to perform area monitoring for some types of radiation at levels indicative of the monitoring requirements. If the performance objectives cannot be achieved for this reason, the facility should (1) use the best practicable monitoring methods and (2) implement enhanced design, operational controls, personnel protection equipment, and procedures to control external exposures.

4.3 INDIVIDUAL MONITORING PROGRAM

This section discusses program features for individual monitoring, compensatory actions for lost, damaged, or contaminated dosimeters, nuclear accident dosimetry, and dosimetry for planned special exposures.

4.3.1 Establishing the Need for Individual Monitoring

It is usually not necessary for all individuals at a facility to wear dosimeters unless there is a documented technical basis. Unnecessary issuance of dosimeters should be avoided. If an individual does not enter areas where there is a likelihood of external exposure resulting in a dose near or in excess of the regulatory monitoring thresholds, issuance of a dosimeter to that individual is discouraged. For reasons of practicality and uniformity, decisions regarding those individuals to whom dosimeters are issued should be made on the basis of work group affiliation, type of work to be performed, and/or areas to be entered. There is generally no need to perform calculations regarding individual dose expectations to support decisions regarding the provision of individual dosimeters. The issuance of dosimeters to concerned individuals should not be a substitute for providing information, training, access controls, and a comprehensive area monitoring program. The criteria for the selection of individuals to be monitored should be documented in the technical basis document.

10 CFR 835 establishes individual monitoring requirements based on the likelihood of an individual receiving a dose in excess of a regulatory monitoring threshold. In determining the likelihood of potential exposures, the use of professional judgment is necessary. This judgment should include consideration of the following:

- areas to which the individual will have access;
- the individual's previous occupational dose during the current year;

- activities taking place in the areas to be entered;
- restrictions on areas entered or time in these areas;
- design basis radiological conditions in the areas to be entered;
- documentation of actual radiological conditions in the areas to be entered, obtained through prior individual and area monitoring; and
- potential for changes that may affect the radiological conditions.

Except for provisions for nuclear accident dosimetry, it is not necessary to include consideration of accidents or emergencies, because these events are not considered "likely."

4.3.2 Routine Monitoring of Individual External Doses

Individual monitoring shall be performed for those individuals likely to receive external doses exceeding the monitoring thresholds provided in 10 CFR 835 and for individuals entering high radiation or very high areas [10 CFR 835.402(a)]. The frequency of collecting and processing personnel dosimeters depends on the measurement method and associated lower limit of detectability. The collection/processing frequency should be chosen so that it is unlikely that an individual will receive a dose equivalent equal to or greater than the values listed in 10 CFR 835.402(a) from external radiation without detection and quantification.

The specific physical characteristics of the radiation field should be considered in choosing the measurement method. These characteristics include radiation type, quality, energy, fluence rate, and direction of incidence. If these characteristics are not quantified, conservative assumptions should be used until further information is available, and should be stated in the technical basis document.

4.3.2.1 Deep Dose Monitoring

10 CFR 835.402(a) requires monitoring for individuals likely to exceed the specified effective dose equivalent threshold as a result of exposure to external radiation sources. The deep dose equivalent from external exposures may be used as the effective dose equivalent to the whole body, which shall be evaluated at a tissue depth of 1 cm (1000 mg/cm^2) [10 CFR 835.2(b), deep dose equivalent and effective dose equivalent].

For individuals who require individual monitoring, external dose should be determined using such devices as TLDs, track-etch dosimeters, or radiation-sensitive film. The dosimeter should be worn to provide a measurement of the maximum dose received at any location on the whole body. When the whole body is exposed fairly uniformly, the location should be on the front of the torso between the neck and waist. For nonuniform irradiation, multiple dosimeters should be used or the primary dosimeter should be relocated to the area receiving the highest dose.

Guidance on the use of multiple dosimeters and dosimeter relocation is provided later in this section.

4.3.2.2 Lens of the Eye Monitoring

The lens of the eye dose equivalent shall be evaluated at a tissue depth of 0.3 cm (300 mg/cm^2) [10 CFR 835.2(b), lens of the eye dose equivalent.

For uniform exposures, a measurement taken in the torso region is sufficient. For nonuniform exposures that would result in an individual receiving a significantly higher dose to the lens of the eye than to the whole body, such as access to or near reactor beams, X-ray machines, sources of beta radiation, and shield penetrations, the dose equivalent should be measured near the eye, such as with a dosimeter worn on the side of the head or forehead.

For beta particles with maximum energies less than about 3.5 MeV, the dose limit to the skin is more restrictive than that for the lens of the eye. At higher energies, the lens of the eye dose limit dominates. Therefore, at beta energies below 3.5 MeV, if it can be shown that skin monitoring is not required, then it follows that lens of the eye monitoring is also not required [See International Commission on Radiation Units and Measurements (ICRU) Report No. 43, *Determination of Dose Equivalents from External Sources—Part 2* (ICRU 1988)]. Protective eyewear using 1/10-inch of acrylic plastic will completely attenuate beta particles with maximum energies < 800 KeV. This covers most beta-emitting isotopes with the exception of P-32, Y-90, and Pa-234. See the *Radiological Health Handbook* (BRH 1970).

4.3.2.3 Skin and Extremity Monitoring

Exposure to the extremities and skin from external radiation (except for nonuniform exposure of the skin as discussed in Section 4.4.2 of this Guide) shall be evaluated using the shallow dose equivalent as evaluated at a tissue depth of 0.007 cm (7 mg/cm^2) [10 CFR 835.2(b), shallow dose equivalent].

Monitoring for skin exposure is usually performed in conjunction with that for the effective dose equivalent using a single whole body dosimeter. This method is adequate for uniform or nearly uniform fields. Guidance on the use of extremity dosimeters is provided later in this section.

When monitoring the extremities, if the most exposed location is not directly monitored, a field correction factor may be applied based the gradient between the location monitored and the most exposed location (or the dose equivalent at contact if there is direct source-to-skin or -extremity contact).

Because of difficulties associated with inducing an albedo effect necessary for proper function of commonly available neutron dosimeters, monitoring for neutron dose to the extremities can present special challenges to the external dosimetry program. Neutron dose to the extremities may be determined by one of three methods:

- direct measurement by neutron sensitive dosimeters, when available;
- application of a gamma dose to neutron dose correction factor determined through the measurement of the gamma and neutron dose rates incident to the affected extremities; or
- application of a whole body dose to extremity dose correction factor determined through measurements of the neutron dose rates incident to both the whole body and the affected extremities.

Justification for the choice of dosimeter and placement of dosimeter and results of field gradient measurements should be provided in the technical basis document.

4.3.2.4 Embryo/Fetal Monitoring

Following the pregnancy declaration, a declared pregnant worker should continue to wear her dosimeter in the normal manner if she will be entering areas or performing work for which individual monitoring is required. If she is in an area where the dose is likely to approach 50 millirem in a month, a supplemental dosimeter should be worn to obtain a monthly estimate of the dose. If she is exposed to localized sources of radiation, the supplemental dosimeter should be worn on or near the abdomen.

Guidance for determining the dose to the embryo/fetus is provided in DOE G 441.1-6, *Evaluation and Control of Radiation Dose to the Embryo/Fetus Guide* (DOE 1999f).

4.3.2.5 Nonuniform Radiation Fields

When individuals will be exposed to radiation in a manner that will result in significantly nonuniform doses to various areas of the whole body, multiple dosimeters should be issued or the primary dosimeter should be relocated to the area of the whole body likely to receive the highest dose. Such a situation may result from an irregular distribution of radiation sources in the area, a continued positioning of the individual that causes an irregular radiation exposure to the body, or the effects of personal protective equipment (e.g., lead aprons) or other shielding devices that do not protect all portions of the whole body in a uniformly effective manner. Multiple dosimeters should be used to assess whole-body dose when radiation fields vary by > 50% over the whole body and the anticipated dose to the maximally-exposed area is > 100 millirem (1 mSv) (deep dose equivalent) or 1 rem (shallow dose equivalent) during the dosimeter issue period. The technical basis document should provide details regarding the basis for dosimeter location(s) under nonuniform exposure conditions. Preliminary judgments on the need for multiple dosimeters and placement of multiple dosimeters should be made from direct exposure rate surveys with portable monitoring instruments or monitoring with dosimeters placed on phantoms. Multiple dosimeters may be used at any time to provide more detailed information for estimates of whole body dose. Additional guidance on the use of multiple dosimeters is provided in ANSI/HPS N13.41, *Criteria for Performing Multiple Dosimetry* (ANSI 1997). Guidance on the evaluation of individual dose from multiple dosimeter results is provided later in this section.

When the radiation field is well characterized and the individual's orientation is known, relocation of the primary dosimeter may be preferable to issuance of multiple dosimeters. If dosimeter relocation is desirable, the individual's dosimeter should be relocated to the portion of the whole body likely to receive the highest dose. Dosimeter relocation should be conducted in conformance with management-approved procedures or work authorizations, such as radiological work permits. Dosimeter relocation should not be performed by individuals without written authorization.

Multiple dosimeters should be placed at locations on the body likely to receive the highest dose equivalent. Common locations for multiple dosimeter placement include the head, chest, back, gonads, upper arms, and upper legs. If multiple dosimeters are used, the routine whole body dosimeter should be replaced with the set of multiple dosimeters during the multibadging activity. This keeps the normal dosimetry on its regular processing cycle and eliminates the possibility of "double counting" dosimetry results.

Note that this guidance is for whole body dosimeters only and does not apply to extremity dosimeters, which are treated separately in this Guide.

4.3.2.6 Supplemental Dosimeters

Supplemental dosimeters include, but are not limited to, electronic dosimeters, pocket dosimeters, and other self-reading, alarming dosimeters. Any individual entering a high radiation area or very high radiation area shall wear a supplemental dosimeter or be monitored by another means capable of providing an immediate estimate of that individual's integrated deep dose equivalent during the entry (e.g., stay time tracking) [10 CFR 835.502(a)].

Supplemental dosimeters should be read periodically while in use. The range and energy dependence of supplemental dosimeters, particularly to low-energy beta and X-ray radiation, should be considered in determining their applicability. Supplemental dosimeters with a limited range should be selected with the lowest range applicable for the anticipated exposure. Chapters 3 and 5 of the RCS provide additional guidance on the use of supplemental dosimeters.

4.3.3 Lost, Damaged, or Contaminated Dosimeters

An individual whose dosimeter is lost, damaged, or contaminated should place work in a safe condition, immediately exit the area, and report the occurrence to the radiological control organization.

Reentry of the individual into radiological areas should not be made until a review has been conducted, the individual has been issued a new dosimeter, and management has approved reentry. The review may be as simple as a documented survey showing the dosimeter not to be contaminated, in which case the worker may go back to work immediately. Otherwise, a review should include a dose evaluation to replace the results of the lost, damaged, or contaminated personnel dosimeter and should determine if work can continue while an investigation is in progress.

4.3.4 Nuclear Accident Dosimetry

Nuclear accident dosimetry shall be provided to individuals in installations possessing sufficient quantities of fissile material to potentially constitute a critical mass, such that the excessive exposure of individuals to radiation from a nuclear accident is possible [10 CFR 835.1304(a)]. Nuclear accident dosimetry shall include:

- a method to conduct initial screening of individuals involved in a nuclear accident;
- methods and equipment for analysis of biological materials;
- a system of fixed nuclear accident dosimeter units; and
- personal nuclear accident dosimeters [10 CFR 835.1304(b)].

Initial screening methods should include measurements of activation products in and on the bodies of exposed individuals (e.g., sodium-24 in the body, activation of jewelry) and/or evaluation of individual locations during the accident, as appropriate. Methods and equipment for analysis of biological materials should include appropriate counting systems maintained in operable condition and sample collection and preparation processes. Acceptable methods for implementing a nuclear accident dosimetry program are described in ANSI N 13.3, *Dosimetry for Criticality Accidents* (ANSI 1981). Additional guidance is provided in Chapter 5 of the RCS.

Placement of fixed nuclear accident dosimeter units should consider the nature of the operations, structural design characteristics, accessibility of areas to personnel, and recovery of units after a criticality accident. The number of fixed nuclear accident dosimeter units, their locations, the effect of intervening shielding, and an analysis demonstrating the above performance criteria should be documented in the technical basis document.

4.3.5 Planned Special Exposures

Planned special exposures are included in an individual's occupational dose record, but shall not be considered when determining compliance with the occupational dose limits [10 CFR 835.1(b)]. In order to maintain separate records of doses resulting from planned special exposures and routine occupational exposures, dosimeters adequate to measure the potential doses and appropriate for the work to be performed and specific radiological circumstances should be provided for the planned special exposure.

4.3.6 Personal Protective Equipment

Use of personal protective equipment (such as shielded aprons or other clothing items) may present special challenges in the placement of personnel dosimeters and the determination of the dose equivalent. Use of such items may create nonuniform radiation field conditions similar to those discussed in Section 4.3.2 of this Guide. If so, the placement of dosimeters and determination of the individual dose equivalent should be conducted consistent with that guidance. If the effect of personal protective equipment is not significant enough to create a nonuniform radiation field as described in the technical basis document, then the dosimeter should be placed on the area of the body likely to receive the highest dose equivalent. The effect

of the personal protective equipment on albedo effects that are critical for the proper function of neutron dosimeters should also be considered.

4.4 EXTERNAL DOSE EVALUATION

Radiation protection requirements are expressed in terms of limiting values of dose equivalent to individuals. The limiting values for dose equivalent in 10 CFR 835 are specified as total effective dose equivalent to the whole body and dose equivalent for other organs and tissues.

Methods for evaluating the various doses from external exposures should be based on recommendations given in International Commission on Radiological Protection (ICRP) Publication 26, *Recommendations of the International Commission on Radiation Protection* (ICRP 1977), NCRP Report No. 91, *Recommendations on Limits for Exposure to Ionizing Radiation* (NCRP 1987), and other reports of the ICRP and NCRP that address improvements and updates of the science of external dosimetry. Other methods may be used provided they are documented and justified in the procedures and/or technical basis document. The dose calculation methodology shall use the quality factors and tissue or organ weighting factors in 10 CFR 835.2(b) [10 CFR 835.203(b)].

4.4.1 Required Dose Calculations

Records shall be maintained to document the doses received by all individuals monitored in accordance with 10 CFR 835.402 and to document doses received as a result of planned special exposures, accident exposures, and emergency exposures [10 CFR 835.702(a)]. The following quantities shall be recorded for external dose received during the year:

- effective dose equivalent from external sources (deep dose equivalent may be used) [10 CFR 835.702(c)(3)(I)];
- lens of the eye dose equivalent [10 CFR 835.702(c)(3)(ii)];
- shallow dose equivalent to the skin [10 CFR 835.702(c)(3)(iii)]; and
- shallow dose equivalent to the extremities [10 CFR 835.702(c)(3)(iv)].

For airborne radionuclides that pose an external exposure hazard, the derived air concentration (DAC) values in Appendix C of 10 CFR 835 shall be used to control exposure to airborne radionuclides [10 CFR 835.209(a)]. The technical basis document should note which radionuclides could be present and whether the individual dosimeter responds correctly to the quality of the radiation or whether immersion exposures should be calculated separately and added to dosimeter results. When it is necessary to apply airborne radioactivity monitoring results to individual external dose assessment, such applications should include consideration of the concentration of the contaminant in the workplace and the duration of the exposure (i.e., maintenance of records of DAC-hours of exposure). The air immersion DAC values in 10 CFR 835 Appendix C were calculated for a continuous (2,000 hours per year), unshielded exposure via immersion in a semi-infinite atmospheric cloud. 10 CFR 835 allows modification of the

DAC values contained in Appendix C to allow for submersion in a cloud of finite dimensions. The method for making this room size modification should be based on recommendations given in ICRP Publication 30, *Limits for Intakes of Radionuclides by Workers* (ICRP 1979).

Personnel dosimeters should be calibrated to monitor for dose equivalent directly or indirectly through the use of a calibration factor. Dosimetry services that process dosimeters typically report personnel doses in units or subunits of rem and no further calculations need be performed unless modifying factors are applied.

When neutron monitoring is performed, the neutron dose equivalent is added to the other than neutron deep dose equivalent to determine the total whole body deep dose equivalent, and added, as applicable, to the extremity dose equivalent, and/or the lens of the eye dose equivalent. Varying neutron energy spectra are encountered at field locations, depending on the original energy of the neutrons and the degree of moderation and attenuation. These neutron energy spectra may not be representative of the energy spectra used in DOELAP. If this situation exists, specific field correction factors should be developed and used to adequately assess the neutron dose equivalent. The development and use of the field correction factors should be reflected in the technical basis document. Examples of methods for developing field correction factors can be found in *Personnel Neutron Dose Assessment Upgrade* (PNL 1988) and in *Neutron Dose and Energy Spectra Measurements at Savannah River Plant* (PNL 1987).

4.4.2 Special Considerations

Personnel dosimeter measurements are the preferred source of data for evaluating the external dose of individuals likely to exceed the monitoring thresholds. Area monitoring data and other personnel monitoring data should be used to evaluate external dose if personnel dosimeter measurements are not feasible or are not available. When personnel dosimeter measurements are not available, a dose evaluation should be performed for that period. The dose evaluation should be based on personnel dosimeter results from other individuals in the same area, on previously recorded doses (provided no significant changes in exposure rates would be anticipated), or on area monitoring results of the ambient radiation levels. These estimated or assigned doses shall be clearly recorded and maintained as such [10 CFR 835.702(a) and (g)]. When area monitoring results are used to estimate individual dose, the results of surveys, measurements and calculations used to determine individual occupational exposure from external sources shall be recorded [10 CFR 835.703(b)].

When an individual is provided multiple dosimeters, the dose measured by the highest responding dosimeter on the whole body should be assigned as the whole body dose of record. When multiple dosimeters are employed more than once during the year, dosimeter results may be summed by location and the highest total assigned as the whole body dose of record. However, sufficient records should exist to demonstrate that the dose to portions of the whole body between the monitoring locations did not exceed that recorded for the monitoring location. For example, if both the left and right upper arms were monitored, adequate records should be maintained to demonstrate that the dose to the head and torso, which may have been exposed as a result of exposure to both arms, did not exceed the dose to either upper arm.

If weighting factors are used to calculate effective dose equivalent from external radiation fields, the weighting factors in 10 CFR 835.2 shall be used [10 CFR 835.203(b)]. If necessary, a compartmentalization methodology, such as that recommended in ANSI/HPS N13.41 (ANSI 1997), may be applied to the multiple dosimeter results. A calculation of this type provides a better representation of the risk to the monitored individual and is consistent with the recommendations of ICRP Publication 26. Whatever methodology is selected, all multiple dosimeter results shall be recorded [10 CFR 835.702(a) and (g)].

When supplemental dosimeters are used, the results should be compared to the results from the primary dosimeter issued to the same individual (if the issue periods for the primary and supplemental dosimeters are the same). If the dose results differ by >50% from the primary dosimeter and the dose from the primary dosimeter is >100 millirem (1 mSv), an investigation should be initiated to explain the difference.

10 CFR 835.205 places additional requirements on evaluating and recording doses from nonuniform exposures of the skin from X-rays, beta radiation, and/or radioactive materials on the skin, including hot particles. The technical basis document should provide the basis for the action level used to identify the need for such evaluations. Decisions regarding the appropriate action levels should be based upon such factors as the likely magnitude of events resulting in nonuniform exposure of the skin, the likelihood of repeated events, and potential resulting doses (total of all events). An action level of 100 millirem (1 mSv) for the evaluation of skin dose for general employees is recommended. Further information regarding hot particles can be found in NCRP Report No. 106, *Limit for Exposure to "Hot Particles" on the Skin* (NCRP 1989).

For nonuniform exposures of the skin, the assessment of the exposed area should be recorded with the shallow dose equivalent. Nonuniform exposures of the skin of the extremities from X-rays, beta radiation, and radioactive materials on the skin, including hot particles, should be assigned to the extremity, not the skin. If the nonuniform shallow dose equivalent to the skin does not exceed 1 rem (0.01 Sv), then recording of the dose is not required [10 CFR 835.702(b)].

When an individual has been monitored for extremity exposure at some time during the calendar year, but is not monitored for the entire year, the shallow dose equivalent from the whole body dosimeter should be used as the extremity dose of record for periods when extremity dosimeters are not worn.

If it is necessary to determine a lens of the eye dose equivalent in the absence of reliable monitoring data (i.e., in the absence of properly calibrated lens of the eye dosimeters), the shallow dose equivalent should be used as an approximation of the lens of the eye dose or appropriate dose conversion factors should be used to convert the dosimeter reading to the lens of the eye dose. Appropriate dose conversion factors may be found in ICRP Publication 74, *Conversion Coefficients for Use in Radiological Protection Against External Radiation* (ICRP 1996), or peer-reviewed journals or may be determined locally through performance of a series of tests using dosimeters with different filters.

In the case of a large dose, actual or suspected, quick initial estimates should be made based on stay time and exposure rate. These estimates should be used to limit further external dose until dosimeter and bioassay results are available.

4.5 RECORD KEEPING AND REPORTING

10 CFR 835 requires that records be maintained to document certain aspects of the external dosimetry program. These records include radiation dose records, instrument and equipment calibration records, monitoring procedures, and area monitoring results. 10 CFR 835 also requires that certain reports be provided to individuals on their exposure received while performing their duties. DOE G 441.1-11, *Occupational Radiation Protection Record-Keeping and Reporting Guide* (DOE 1999g), provides detailed guidance on the records necessary to document the external dosimetry program and the reports to individuals required by 10 CFR 835. Chapter 7 of the RCS provides additional guidance.

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Request for Changes to
EXTERNAL DOSIMETRY PROGRAM GUIDE

(Use Multiple Pages as Necessary)

Page No. _____

Section No. _____

Paragraph No. _____

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Facility Requesting Change

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Contact Person

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Telephone Number - Fax Number

Description of Change Request:

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Suggested Specific Word Changes:

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