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NATIONAL ACCELERATOR LABORATORY

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FOREWORD

The Department of Energy (DOE) has established regulatory requirements for occupational radiation protection in Title 10 of the *Code of Federal Regulations*, Part 835 (10 CFR 835), "Occupational Radiation Protection," amended in 1998 and again in 2007.[1] Failure to comply with these requirements may lead to appropriate enforcement actions as authorized under the Price-Anderson Act Amendments (PAAA).

The SLAC National Accelerator Laboratory (SLAC) has developed this *Radiological Control Manual* to assist line managers in meeting their responsibilities for implementing occupational radiological control programs.

This *Manual* restates, paraphrases, or cites many (but not all) of the requirements of 10 CFR 835 and related documents (e.g., occupational safety and health, hazardous materials transportation, and environmental protection standards).

SLAC has identified provisions of the DOE Radiological Control Standard[2] and the DOE Guide 441.1-1C series of Guides that support its efforts to implement an effective radiological control program and incorporated those provisions, as appropriate, into this site-specific SLAC *Radiological Control Manual*.

SLAC employees, users, visitors, and SLAC subcontractors shall comply with the requirements of 10 CFR 835 and the provisions of this *Manual*.

SLAC encourages the users of this *Manual* to submit comments regarding its content, accuracy, and utility to the Radiation Protection Department.

SLAC Radiation Protection Program Principles

ALARA
Personal radiation exposure shall be maintained As Low As Reasonably Achievable (ALARA).

Ownership
Each person involved in radiological work is expected to follow the guidelines in this Manual and the procedures developed to implement this Manual.

Excellence
Excellent performance is evident when radiation exposures are maintained well below regulatory limits, and radioactivity is well controlled.

1 Title 10, *Code of Federal Regulations,* "Energy," Chapter 3, "Department of Energy," Part 835, "Occupational Radiation Protection" (10 CFR 835)

2 Department of Energy Standard 1098-2017, "Radiological Control" (DOE-STD-1098-2017)

Following is a reprint of the Department of Energy Radiological Health and Safety Policy, which was originally published as DOE Policy 441.1 on April 26, 1996.[3]

DEPARTMENT OF ENERGY
Radiological Health and Safety Policy

It is the policy of DOE to conduct its radiological operations in a manner that ensures the health and safety of all its employees, contractors, and the general public. In achieving this objective, the Department shall ensure that radiation exposures to its workers and the public and releases of radioactivity to the environment are maintained below regulatory limits and deliberate efforts are taken to further reduce exposures and releases as low as reasonably achievable. The Department is fully committed to implementing a radiological control program of the highest quality that consistently reflects this policy. In meeting this policy, the Department shall:

A. **Establish and maintain a system of regulatory policy and guidance reflective of national and international radiation protection standards and recommendations.** The Assistant Secretary for Environment, Safety and Health has responsibility for promulgating and maintaining policies, standards, and guidance related to radiological protection. Departmental radiological protection requirements are, at a minimum, consistent with the presidentially approved "Radiation Protection Guidance to the Federal Agencies for Occupational Exposure" which was developed by the Environmental Protection Agency in accordance with its mandated Federal guidance responsibilities. Departmental requirements often are more stringent and reflect, as appropriate, recommendations and guidance from various national and international standards-setting and scientific organizations, including the International Commission on Radiological Protection, the National Council on Radiation Protection and Measurements, the American National Standards Institute, and others. Departmental requirements related to radiological protection will be set forth, as appropriate, in rules and Department of Energy Orders; and guidance documents will be issued on acceptable means to implement these requirements.

B. **Ensure personnel responsible for performing radiological work activities are appropriately trained.** Standards shall be established to ensure the technical competency of the Department's work force, as appropriate, through implementation of radiological training and professional development programs.

C. **Ensure the technical competence of personnel responsible for implementing and overseeing the radiological control program.** An appropriate level of technical competence gained through education, experience, and job-related technical and professional training is a critical component for achieving the goals of the Department's radiological control policy. Qualification requirements commensurate with this objective shall be established for technical and professional radiological control program positions and shall, at a minimum, be consistent with applicable industry standards and promote professional development and excellence in radiological performance as a goal.

D. **Establish and maintain, at all levels, line management involvement and accountability for departmental radiological performance.** The responsibility for compliance with Departmental radiological protection requirements, and for minimizing personnel radiation exposure, starts at the worker level and broadens as it progresses upward through the line organization. The Department's

3 Department of Energy Policy 441.1, "DOE Radiological Health and Safety Policy" (DOE P 441.1)

line managers are fully responsible for radiological performance within their programs and the field activities and sites assigned to them and shall take necessary actions to ensure requirements are implemented and performance is monitored and corrected as necessary.

E. **Ensure radiological measurements, analyses, worker monitoring results and estimates of public exposures are accurate and appropriately made.** The capability to accurately measure and analyze radioactive materials and workplace conditions, and determine personnel radiation exposure, is fundamental to the safe conduct of radiological operations. Policy, guidance, and quality control programs shall be directed towards ensuring such measurements are appropriate, accurate, and based upon sound technical practices.

F. **Conduct radiological operations in a manner that controls the spread of radioactive materials and reduces exposure to the workforce and the general public and that utilizes a process that seeks exposure levels as low as reasonably achievable.** Radiological operations and activities shall be preplanned to allow for the effective implementation of dose and contamination reduction and control measures. Operations and activities shall be performed in accordance with departmental conduct of operations requirements and shall include reasonable controls directed toward reducing exposure, preventing the spread of radiological contamination, and minimizing the generation of contaminated wastes and the release of effluents.

G. **Incorporate dose reduction, contamination reduction, and waste minimization features into the design of new facilities and significant modifications to existing facilities in the earliest planning stages.** Wherever possible, facility design features shall be directed toward controlling contamination at the source, eliminating airborne radioactivity, maintaining personnel exposure and effluent releases below regulatory limits and utilizing a process that seeks exposure levels and releases as low as reasonably achievable. Radiological design criteria shall reflect appropriate consensus recommendations of national and international standards setting groups.

H. **Conduct oversight to ensure departmental requirements are being complied with and appropriate radiological work practices are being implemented**. All departmental elements shall conduct their radiological operations in a manner consistent with the above policies and objectives.

CHAPTER 1 EXCELLENCE IN RADIOLOGICAL CONTROL

PART 1 Overview of Radiological Control at SLAC

111 Radiation Protection Program Policy

A key element of the Radiation Protection Guidance to the Federal Agencies for Occupational Exposure approved by President Reagan on January 20, 1987, and a fundamental principle underlying this Manual is:

> There should not be any occupational exposure of workers to ionizing radiation without the expectation of an overall benefit from the activity causing the exposure.

The SLAC National Accelerator Laboratory (SLAC) is firmly committed to having a radiation protection program of the highest quality based on the principles identified at the beginning of this Manual. This commitment has also been made by the Department of Energy (DOE), as reflected in the DOE Radiological Health and Safety Policy published at the beginning of this Manual. This applies to those SLAC activities that manage radiation and radioactive material that may potentially result in radiation exposure to workers, the public, and the environment. 835 **During routine operations, the combination of physical design features and administrative controls shall provide that: The ALARA process is utilized for personnel exposures to ionizing radiation.** [10 CFR 835.1003(b)][4]

As allowed by DOE guidelines, the specific application of the various practices of this Manual will be used as appropriate for operations at SLAC and as a means of implementing the requirements of Title 10, *Code of Federal Regulations,* Part 835, "Occupational Radiation Protection" (10 CFR 835).[1] Existing training programs and documents will be used until the new elements implementing the requirements of 10 CFR 835 have been incorporated into the SLAC Radiation Protection Program Implementation Plan (hereafter abbreviated as "RPP").[5]

The discussion in this Chapter summarizes the RPP elements and is intended to guide the actions of every person involved in radiological work at SLAC.

835 **No person or DOE personnel shall take or cause to be taken any action inconsistent with the requirements of: (1) this part' or (2) any program, plan, schedule, or other process established by this part.** [10 CFR 835.3(a)]

835 **With respect to a particular DOE activity, contractor management shall be responsible for compliance with the requirements of this part.** [10 CFR 835.3(b)]

835 **Nothing in this part shall be construed as limiting actions that may be necessary to protect health and safety.** [10 CFR 835.3(d)]

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4 Articles 115 and 116 of this *Manual* describe of the structure of the *Manual*, the meaning of Article Numbers, and the manner of display of 10 CFR 835 citations.

5 SLAC National Accelerator Laboratory Radiation Protection Program Plan for Implementing 10 CFR 835 (SLAC-I-720-1A05M-002)

835 **A DOE activity shall be conducted in compliance with a documented radiation protection program (RPP) as approved by the DOE.** [10 CFR 835.101(a)]

835 **The DOE may direct or make modifications to a RPP.** [10 CFR 835.101(b)]

835 **For those activities that are required by 10 CFR 835.102, 835.901(e), 835.1202(a), and 835.1202(b), the time interval to conduct these activities may be extended by a period not to exceed 30 days to accommodate scheduling needs.** [10 CFR 835:3(e)]

835 **Unless otherwise specified, the quantities used in the records required by this part shall be clearly indicated in special units of curie, roentgen, rad, or rem, including multiples and subdivisions of these units, or other conventional units, such as, dpm, dpm/100 cm^2 or mass units. The SI units, Becquerel (Bq), Gray (Gy), and Sievert (Sv), may be provided parenthetically for reference with scientific standards.** [10 CFR 835.4]

112 Manual Applicability and Control

This document is known as the SLAC *Radiological Control Manual*, henceforth referred to as the *RadCon Manual*, "the *Manual*" or "this *Manual*." The *RadCon Manual* establishes practices for the conduct of RPP activities at SLAC. The *Manual* states the positions of SLAC and views on the best courses of action currently available in the area of radiological controls. Accordingly, the provisions in the *Manual* are techniques, methods, or solutions for line management fulfilling their duties and responsibilities for development and implementation of radiological control practices. Requirements of 10 CFR 835 shall be used by DOE in evaluating the performance of SLAC in conducting radiological operations.

All definitions used throughout this *Manual* are meant to conform to their like-worded definitions in 10 CFR 835.2.

This *Manual* is not a substitute for regulations; it is intended to be consistent with all relevant statutory and regulatory requirements and it shall be revised whenever necessary to ensure such consistency. Some of the provisions of the *Manual*, however, challenge the user to go well beyond minimum requirements. Following the course of action delineated in the *Manual* will result in achieving and surpassing related statutory or regulatory requirements.

1. This *Manual* is a living document. SLAC intends to review and update provisions on an occasional basis to incorporate lessons learned and suggestions for improvement. The SLAC Radiological Control Manager (RCM) is responsible for this task. Recommendations to correct or improve this *Manual* are encouraged and should be sent to the RCM.
2. This *Manual* shall be kept current and entered into the SLAC document control system.
3. The provisions of this *Manual* do not apply to activities related to patients undergoing medical treatment at SLAC.

113 Compliance

1. This *Manual* sets forth the views of SLAC on the proper course of action in the area of radiological control within the scope of DOE-sponsored activities. If fully implemented, SLAC will have complied with, and most likely exceeded, any related statutory, regulatory, or contractual requirement.

2. The word "shall," as used in this *Manual*, identifies those elements and requirements that have been considered by SLAC management to be mandatory or that are required to comply with DOE requirements. Many of these requirements have a regulatory basis in 10 CFR 835, "Occupational Radiation Protection," as indicated by the bracketed references seen at several points in this *Manual*. If a manager wishes to implement an alternative approach to a "shall" statement, the manager shall submit the suggested alternative approach to the RCM for review. If it is agreed that the alternative is acceptable, it shall be transmitted by the RCM to the DOE. The submittal shall contain the description of the alternative approach, the technical rationale and basis, the suggested wording, and justification that the alternative will achieve equal or improved performance employing equal or better techniques, solutions, or methods.
3. The word "should," as used in this *Manual*, means that DOE has evaluated the provision and found that it is a proven practice or remedy that supports compliance with the basic requirements found in applicable regulations or DOE Orders or their underlying basis documents for occupational radiation protection. The responsible SLAC manager has the responsibility of following the provision. The use of "should" recognizes that there may be conditions that warrant special treatment and that literal compliance with the elements and requirements of the provision may not achieve the desired level of radiological control performance. An alternative solution demonstrating technical equivalency or demonstrating that implementation of the provision is not necessary due to the nature of the facility, material, or operations may be proposed to the RCM for review. The procedure may be followed if approved by the RCM.
4. Potential violations of the regulations or of the commitments made in the Radiation Protection Program shall be brought to the attention of the RCM in a timely manner. The RCM shall coordinate the assessment of such potential violations through the designated Price-Anderson Amendments Act (PAAA) Coordinator. All compliances will be reported in accordance with the requirements of 10 CFR 820 and applicable guidance.

114 Site-Specific Manual

1. This *Manual* has been drafted, where practicable, to be consistent with the provisions of the DOE Standard 1098-2017, "Radiological Control."[6] SLAC site specific additions, supplements, and clarifications which address unique operations or provide more detailed direction, have been included. This *Manual* does not require review or approval by DOE.
2. SLAC employees, users, visitors, and SLAC subcontractors shall comply with the requirements of 10 CFR 835 and the provisions of this *Manual*.
3. This *Manual* applies to all facilities and operations at SLAC.

115 Structure of This Manual and the Meaning of Its Article Numbers

This *Manual* is divided into seven Chapters. Each Chapter can have one or more Parts. Each Part is further subdivided into Articles.

6 Department of Energy Standard 1098-2017, "Radiological Control" (DOE-STD-1098-2017)

Articles are identified by the three-digit number preceding them. The first digit in an Article Number is the Chapter Number in which the Article appears. The second digit in an Article Number is the Part Number within that Chapter in which the Article is positioned. The third digit in an Article Number is the sequential order indicator of that particular Article with the other Articles within that same Chapter and Part.

Example:

> Using this particular Article (Article 115 'Structure of this *Manual* and the Meaning of its Article Numbers'), the first digit in the Article Number (e.g., "1") means that this Article is in Chapter 1. The second digit in the Article Number (e.g., "1") means that this Article is in Part 1. The third digit in the Article Number (e.g., "5") number means that this Article is the fifth one in numerical order in this particular Chapter and Part.

116 Citations in This Manual from 10 CFR 835, "Occupational Radiation Protection"

Regulatory citations taken either wholly or in part from 10 CFR 835 and inserted into this *Manual* are shown in emboldened text, with a small "835" preceding the text and the passage from 10 CFR 835 from which the citation is taken shown in brackets following cited passage.

Example:

> 835 **Optimization methods shall be used to assure that occupational exposure is maintained ALARA in developing and justifying facility design and physical controls.** [10 CFR 835.1002(a)]

The text of the cited passages can feature modifications from the verbatim regulation that is cited in order to render the cited passage more relevant to SLAC and useful to the SLAC reader. In such instances the added information is in parentheses and not bolded.

PART 2 Leadership in Radiological Control

121 Senior Management Commitment

1. The SLAC Director has established high standards for the performance of radiological control as noted in the *SLAC Environment, Safety, and Health Manual,* henceforth the *ESH Manual,* Chapter 1.[7] These standards and management expectations should be frequently communicated to the work force.
2. The SLAC Directorate has stated in writing its firm commitment to an RPP of the highest quality. Management commitment and support are demonstrated by allocating sufficient resources, including personnel, and providing training to ensure workers are qualified for their assigned duties.

7 *SLAC Environment, Safety, and Health Manual* (SLAC-I-720-0A29Z-001), Chapter 1, "General Policy and Responsibilities"

3. All laboratory managers, including department heads and group leaders, should ensure that orientation, training, and indoctrination reinforce rules and guidelines for each worker to optimize radiation exposure and control radioactivity.
4. Managers should hold workers and their supervisors accountable for radiological control performance. Relevant knowledge and performance should be assessed as a part of the Activity and Training Authorization (ATA) for each person.
5. The SLAC Directorate should solicit feedback from its radiological control professionals, line managers, and workers on radiological control performance.
6. The SLAC Directorate should adopt and promote a positive attitude toward radiological control. This attitude will encourage initiatives to recognize problems or potential problems at an early stage, implement timely controls both to minimize problems and make them more easily correctable, and promote doing the job correctly the first time.
7. The authority and responsibility to establish a comprehensive and effective radiological control training program should be assigned to line managers and their subordinates. Training, in most cases, should be provided by a dedicated ESH Division training organization, but the responsibility for quality and effectiveness rests with line management and each individual laboratory employee.
8. The SLAC Directorate shall be alert to opportunities for minimizing the generation of radioactive waste and discharges to the environment, controlling contamination at its source, and reducing radiation exposure to workers and to the public.
9. Reporting a problem to a superior (SLAC or DOE manager) does not absolve the manager from promptly fixing or mitigating a situation.

122 Worker Attitude

Optimization of worker radiation exposure can be achieved only if all persons involved in radiological activities have an understanding of radiation and the consequences of poor radiological control practices.

1. All workers should understand that proper radiological control is an integral part of their daily duties.
2. Improving the attitude of the work force should be supported by the training program. To achieve this, training personnel need to be knowledgeable about the SLAC work environment and those aspects of radiological control that are important for developing a better worker attitude and perspective.
3. The attitude that radiation exposures should be optimized needs to be developed at all levels of management and in the work force. It is expected that there will be cooperation between the work force and the Radiation Protection (RP) Department. Workers should not look upon radiological controls as hurdles or restrictions to be bypassed.
4. RP Department personnel should be helpful in showing workers how to follow the rules. A spirit of cooperation is expected without subverting the control functions of RP Department Health Physics Technicians. A situation in which radiological controls are left solely to the RP Department is unacceptable.

123 Worker Responsibilities

Trained personnel should recognize that their actions directly affect contamination control, the overall personnel radiation exposure, and the radiological environment associated with their work.

124 Radiation and Risk Communications

1. It is not sufficient to rely solely on regulatory limits for establishing or defining acceptable work practices and work environments. Managers and first-line supervisors shall ensure that their workers are given the opportunity to understand the fundamentals of radiation, its risks, and their role in optimizing exposure. Workers who are concerned about their exposure and its potential consequences shall be referred to appropriately trained staff.
2. Radiological Control and Medical Personnel should be trained to deal with workers who have anxiety about radiation. This function will normally be carried out by the SLAC Occupational Health Center. This training should include the following:
   A. Guidance on handling such personnel interactions
   B. Emphasis on being factual
   C. Fundamentals of communicating risks
   D. Importance of keeping management informed

125 Conduct of Radiological Operations

1. Managers at all levels are expected to be involved in the planning, scheduling, and conduct of radiological work. Assurance of adequate radiological safety should not be compromised to achieve SLAC research objectives.
2. Supervisors should be technically knowledgeable and inquisitive and should ask questions of the work force concerning radiological work details to assure and demonstrate worker understanding and comprehension.
3. Line managers should routinely visit work areas to observe personnel at work and to identify radiological deficiencies and concerns. Inspections and walk-throughs, including off-hours and weekends (where appropriate), are essential to reinforce management expectations to the work force.
4. Managers, supervisors, and workers should be involved in the development of accurate and clear written procedures for performing radiological work. If during the use of procedures a written requirement cannot be responsibly followed, the work should be stopped and guidance obtained. 835 **Written procedures shall be developed and implemented as necessary to ensure compliance with this part, 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]
5. Supervisors and managers should encourage the work force to identify radiological control deficiencies and concerns. Prompt action should be taken to address and eliminate identified issues and prevent recurrence.

6. Managers and supervisors should establish working conditions that encourage improved radiological control. This includes temperature and lighting as well as the more difficult considerations of accessibility. Work conditions should be considered in planning work.
7. Cleanliness and good housekeeping are essential. A good radiological control program cannot exist in a sloppy, dirty workplace. Cleaning up after operations should be automatic for each person. It is not reasonable to expect radiological control to be separated from the work environment; they go together.
8. Subcontractors and subcontracted employees should be treated the same as facility staff in the area of radiological matters; they should have comparable training and should meet the same requirements and expectations.
9. Conditions that could cause or promote the spread of contamination, such as a leaking roof or piping, should be identified and corrected on a priority basis.

126 Improving Worker Awareness of Radiological Conditions

Workers who are assigned duties within Radiological Areas shall be familiar with the area radiological conditions and be aware of the possibility that changes may occur due to unforeseen reasons. Some surveys and monitoring can be done by workers who are not Health Physics Technicians. This practice can reduce the number of individuals who might be exposed and thus reduce the collective dose, as well as improve contamination control.

Specific examples of surveys that may be effectively performed by workers include self-monitoring of dose rates during High Radiation Area entries and surveys of work areas during short-term entries into the accelerator housing. The performance of legal record surveys, such as release surveys for material containing radioactivity due to activation from exposure to accelerator beams, and surveys to determine the appropriate placement of required dosimetry, remain the responsibility of qualified RP personnel.

127 Critiques

It is the SLAC desire and expectation, based on concern for the safety and well-being of workers and the general public, that radiological work practices be continually scrutinized and questioned so that opportunities for improvement can be identified, assessed, and applied.

The RP Department has implemented a procedure to address the process to initiate, issue, track and trend radiological issues. The Radiological Issue Report (RIR) is used to identify and document potential radiological issues, and to identify improvement opportunities that involve radiation protection. This process complements DOE Order 232.2, "Occurrence Reporting and Processing of Operations Information."[8]

128 Facility Modifications and Radiological Design Considerations

1. 835 **Optimization methods shall be used to assure that occupational exposure is maintained ALARA in developing and justifying facility design and physical**

8 Site Compliance Plan for Department of Energy Order 232.2A, Change 1, "Occurrence Reporting and Processing of Operations Information" (DOE O 232.2A, Chg. 1 [MinChg] SCP)

controls. [10 CFR 835.1002(a)] See the Glossary for the definition of optimization as intended for SLAC operations. 835 **During routine operations, the combination of physical design features and administrative control shall provide that the ALARA process is utilized to help minimize personnel exposures to ionizing radiation.** [10 CFR 835.1003 (b)]

2. 835 **The design objective for controlling personnel exposure from external sources of radiation in areas of continuous occupancy (2,000 hours per year) shall be to maintain exposure levels below an average of 0.5 millirem (5 µSv) per hour and as far below this average as is reasonably achievable. The design objective for exposure rates for potential exposure to a radiological worker where the occupancy or duration of the exposure differs from the above shall be ALARA and shall not exceed 20 percent of the applicable standards given in 10 CFR 835.202** (See Table 2-1, "Summary of Occupational Dose Limits"). [10 CFR 835.1002(b)]

3. At SLAC, radiological control performance is primarily affected by engineered design features and secondarily by human performance. This *Manual* primarily addresses the way people operate and use existing facilities and sites. General design criteria for new facilities and major modifications to existing facilities are contained in 10 CFR 835 (as referenced in this Article) and the contract between the DOE and Stanford University for operation of SLAC [9] Designs for new facilities and major modifications to existing facilities should be based on the following additional radiological control design criteria:

   A. Individual worker doses should be maintained to be ALARA.

   B. Efficiency of maintenance and operations as well as decontamination and decommissioning should be maximized.

   C. In the design phases, components should be selected to minimize the buildup of radioactivity.

4. Facilities currently under construction should be evaluated and the above criteria applied where practicable.

5. Placement of office space and lunchrooms or eating areas within Radiologically Controlled Areas should be minimized.

6. 835 **During the design of new facilities or modification of existing facilities, the following objectives shall be adopted:** [10 CFR 835.1002]

   A. 835 **Regarding the control of airborne radioactive material, the design objective shall be, under normal conditions, to avoid releases to the workplace atmosphere and in any situation, to control the inhalation of such material by workers to levels that are ALARA; confinement and ventilation shall normally be used.** [10 CFR 835.1002(c)]

   B. 835 **The design or modification of a facility and the selection of materials shall include features that facilitate operations, maintenance, decontamination, and decommissioning.** [10 CFR 835.1002(d)]

9 Department of Energy Contract DE-AC02-76SF00515 (DE-AC02-76SF00515)

PART 3 Improving Radiological Performance

131 Line Management Responsibility

1. Line management is responsible for understanding and implementing the radiological safety requirements at SLAC as stated in this *Manual* and in procedures developed for implementing this *Manual* and 10 CFR 835. This includes ensuring that their employees receive the required training and follow these requirements.
2. Line management shall be held accountable for implementation of the Radiation Protection Program. Actions should include:
   A. Direct line supervision in the workspace
   B. Appropriate worker training
   C. Planning work and work schedules
   D. Use of appropriate radiological control personnel
3. When Radiation Protection Program performance is less than adequate, performance shall be improved. Consideration should be given to strengthening line management and the radiological control organization in order to provide adequate radiological control.

132 Radiation Protection Program Performance Goals

ALARA

Since its inception, SLAC has had a process of planning and maintaining radiation exposures to workers and the general public to be "as low as is reasonably achievable" (ALARA).

SLAC strives to ensure that facility operation and shielding are designed in accordance with the ALARA process objectives in Article 128.2. Accordingly, SLAC supports a design policy of limiting the annual dose outside shielded areas to one (1) rem per year. Actual measured doses have been even smaller. The action levels for operational exposure control are given in this *Manual* in Article 211 and Article 312.3 and are established on the basis of the potential for radiation exposure. Beyond these prescribed numbers, however, SLAC policy is to maintain doses at or below the administrative action levels.

In keeping with the ALARA process, if employees are aware of areas where radiation exposures may be unnecessarily high, even though they may be within legal limits, they should contact the Radiological Control Manager (RCM).

Performance Goals

1. Individual doses will be controlled so as to optimize the doses against the useful work that results while avoiding any doses that exceed regulatory or administrative limits.
2. Contamination Areas within buildings (square feet): Operating with a smaller contaminated area results in less radioactive waste, fewer personnel contaminations, and improved productivity. The reduction of existing contaminated areas needs to be balanced by the recognition that this generates radioactive waste. Goals for both should be correlated.

3. SLAC radiological activities, including remedial actions, must be conducted so that exposures of members of the public to ionizing radiation will:

   A. Not cause a total effective dose (TED) exceeding 100 mrem in a year, an equivalent dose to the lens of the eye exceeding 1500 mrem in a year, or an equivalent dose to the skin or extremities exceeding 5000 mrem in a year, from all sources of ionizing radiation and exposure pathways that could contribute significantly to the total dose per DOE Order 458.1, "Radiation Protection of the Public and the Environment."[10]

   B. The public dose limit applies to members of the public located off DOE sites and DOE sites outside controlled areas, and to those exposed to residual radioactive material subsequent to any remedial action or clearance of property.

133 Management of Radiological Performance Goals

The RCM or designee should provide a summary report of the radiation worker population exposures to the SLAC senior managers at the end of each quarter. The ALARA Committee will review personnel dosimeter results quarterly and compare them with the performance goals.

1. The SLAC Directorate is encouraged to recommend radiological performance goals.
2. Radiological performance goals should be reviewed annually and be revised as appropriate.
3. The performance indicator report shall be distributed to key managers on site. Radiation Protection Program performance indicators shall be incorporated into the appropriate DOE performance indicator report as needed.

134 Performance Reports and Other Communication Expectations of the RCM and SLAC Supervisors

1. The RCM shall provide a periodic report that summarizes the performance of the Radiation Protection Program to the SLAC laboratory management and the SLAC Directorate on at least a quarterly basis. This Report can take the form of the ES&H Division Quarterly Report or the ALARA Committee Meeting Minutes.[11]
2. The RCM should provide radiation exposure information, such as dosimeter readings to appropriate supervisors and managers on a sufficiently frequent basis to promote priority management of exposure control. The frequency should be consistent with the nature of the workload and the radiation exposure potential, but will be no less frequent than quarterly, as required by the DOE performance indicator program.

10 Site Compliance Plan for Department of Energy Order 458.1, Change 4, "Radiation Protection of the Public and the Environment" (DOE O 458.1, Chg 4 [LtdChg] SCP)

11 As Low As Reasonably Achievable (ALARA) Committee

135 Quality Assurance and Assessments

Assessment, as used in this *Manual*, is the process of providing independent feedback to senior line managers to indicate the adequacy of the RPP.

1. Inspections, audits, reviews, investigations, and self-assessments are part of the numerous checks and balances needed in a good radiological protection program.

   835 **Internal audits of the radiation protection program, including examination of program content and implementation, shall be conducted through a process that ensures all functional elements are reviewed no less frequently than every 36 months.** [10 CFR 835.102] These functions should be performed by the RP Department and other applicable SLAC and ESH Division elements.

2. Identification of the functional elements of the program depends upon many site or facility specific factors. Based upon the contents of 10 CFR 835 and the RPP, the following functional elements should be considered for inclusion in the assessment program:

   - Personnel dosimetry and dose assessment
   - Portable and fixed instrumentation
   - Contamination control
   - Radiological monitoring (area and item monitoring)
   - ALARA program
   - Accident and emergency dose controls
   - Radioactive material control, including sealed radioactive source control and material release
   - Entry controls
   - Training
   - Posting and labeling
   - Records and reports
   - Radiological design and administrative controls

3. Managers, supervisors, and workers should look upon assessments as helpful. It is desirable to approach assessments with nothing to hide and with the Radiation Protection Program as an open book. Results of assessments should be incorporated into the ongoing process of improving radiological control.

4. Managers should encourage the positive view that identifying even minor deficiencies represents an opportunity for further improvement. The numbers of deficiencies do not in themselves measure the overall quality of the Radiological Control Program. A prioritization system to implement actions for resolving the deficiencies should be implemented.

5. In developing corrective action plans for assessment activities, managers should address basic underlying reasons for the identified deficiencies or concerns, not only the specific symptoms identified by the reviewer.
6. Feedback on findings from assessments, root-cause analyses, status of corrective actions, and adherence to action plan schedules should be frequently provided to management in accordance with the SLAC self-assessment plan.[12]

136 Workplace Awareness

The RP Department has developed and implemented a procedure to address the process to initiate, issue, track and trend radiological issues. The Radiological Issue Report (RIR) is used to identify and document potential radiological issues, and to identify improvement opportunities that involve radiation protection. The RIR Coordinator provides input (tracking, trending, lessons learned) to the quarterly ALARA Committee Meeting.

137 Internal Exposures

In order to minimize internal exposures, all SLAC managers should take deliberate actions to control contamination at the source and reduce Airborne Radioactivity Areas, Contamination Areas, and High Contamination Areas. Control and prevention of internal exposure, particularly from any long-lived radionuclides in the workplace, warrant particular attention. Factors to consider for recognition and evaluation of the potential for intakes of radioactivity, and design of controls to minimize the potential intakes, include:

- Workers may be exposed to unanticipated levels of elevated airborne radioactivity. The time required to collect representative airborne radioactivity samples and to determine the airborne concentration of radionuclides may contribute to worker intakes of radioactivity.
- If controls fail, internal depositions of radionuclides can occur in a short period of time.
- The continued exposure of workers to airborne radioactivity over extended periods of time can create worker concerns.
- Doses from some radionuclides taken into the body can be difficult to determine, particularly for some long-lived radionuclides, like the isotopes of plutonium.
- Medical intervention to mitigate internal deposition, such as by the administration of blocking and chelating agents, can add risks by introducing additional chemicals into the body.
- Sampling of body excretions and whole-body or organ counting techniques encourage worker perceptions of internal exposure significance.
- Administration of internal dose assessment can be costly in dollars and worker time. Control and analysis of samples are also more complicated and time consuming than the elements of external dosimetry.
- Use of respiratory protection devices imposes additional physical stresses upon participating

12 Institutional Assessment Program (CACM-2018-017)

workers.

The hierarchy of controls required to minimize internal exposures is provided in Article 316.

138 Neutron Exposures

Typically, neutron radiation contributes only a small fraction of the total radiation dose at SLAC. Moreover, SLAC history shows that the most likely source of measurable neutron doses results from handling sealed neutron sources. Nonetheless, care is taken to measure the neutron radiation field in occupied areas and the exposure to individuals who handle neutron sources.

PART 4 SLAC Radiological Control Organization

141 Radiological Control Organization

The Radiation Protection Department is the radiological control organization at SLAC. The Radiation Protection Department, hereafter also known as either the "RP Department" or "RP," is responsible for establishment and administration of the radiation protection program and provides radiation protection expertise and support to SLAC workers and line management. The RP Department is part of the SLAC ESH Division.

1. The head of the RP Department at SLAC is the Radiological Control Manager (RCM). The RCM is responsible for and should establish a high-quality radiological control program. The RCM also is the SLAC Radiation Safety Officer (RSO).
2. The RCM (RSO) reports to the SLAC Chief Safety Officer (CSO). The RCM / RSO shall have access to the SLAC leadership to provide advice on radiation safety matters.
3. Responsibilities of the RCM (RSO) are:
    - Advise the CSO on radiation safety policy and requirements
    - Approve minor changes to the Radiation Safety System (Shielding, Personnel Protection System and Beam Containment System)
    - Ensure the Radiation Safety Committee (RSC) reviews major changes to the Radiation Safety System and provides the RSO advice and counsel before the RSO approves such work
    - Approve significant and major new activities by signifying that an activity's proponent has completed an adequate radiation hazards analysis and has developed plans for sufficient mitigation measures (controls) and that the activity will conform to ESH policy and requirements.
    - Stop any activity on-site that presents an imminent radiation hazard to workers, the public, the environment, or property. Stop any activity in which radiation safety program requirements are not met, even if hazards are not imminent, where the RSO believes continuation of the non-compliant activity will: 1) Prompt a notification to the DOE SLAC Site Office or the Office of Science per Occurrence Reporting and Processing Systems (ORPS) reporting requirements. 2) Put SLAC at risk for Price-Anderson Act Amendments compliance actions.

3) Create long-term environmental liabilities such as tritium contamination.
4) Create community relation challenges.

- In other cases of non-compliance not meeting criteria in situations 1) or 2), the RSO may allow continuation of operations but will consult the appropriate managers to ensure they are aware of the deficiency and to be satisfied that corrective actions are planned or will soon be planned.
- In all such stop unsafe activity decisions, the RSO can be overruled only by the SLAC Director or CSO. Deficiencies prompting any of these three actions must be recorded in SLAC's Action Tracking System (ATS).
- Recommend internal radiation safety policies and requirements at SLAC. Proposed policies and requirements are submitted for review and approval by the SLAC Chief Safety Officer.
- Ensure radiation safety requirements are updated as needed.
- Serve as an ex officio member of the Radiation Safety Committee and ALARA Committee.
- Stay current on DOE Orders and federal regulations relating to radiation safety.
- Review draft DOE Orders and federal regulations and prepare comments on such drafts for submission to DOE.
- Revise the SLAC *RadCon Manual* and other radiation safety related documents to meet regulatory requirements.
- Establish radiation safety requirements and procedures.
- Approve additions, modifications, and/or deletions to the radiological training program to ensure accuracy and effectiveness.
- Coordinate all radiological safety related audits, operational awareness, and compliance matters with DOE and other external regulatory bodies when appropriate.

142 Radiological Control Manager Qualifications

The SLAC RCM serves as the SLAC Radiation Safety Officer (RSO) and RP Department Head.

1. The RSO must be an experienced professional proficient in the radiological considerations of high-energy electron accelerator and synchrotron radiation facilities, particularly shielding design and safety systems (Personnel Protection and Beam Containment Systems) and be familiar with the design features and operations of the facility that affect the potential for exposures of persons to radiation.
2. The RSO must have the technical competence and experience to establish radiation protection programs and the supervisory capability to direct the implementation and maintenance of radiation protection programs. In addition, the RSO must have technical competence and experience in the identification of radiological hazards, and the implementation of mitigation measures, radiation shielding design, and assessment of safety systems.

3. The RSO should have a minimum of a master's degree or equivalent in a radiological science or in science or engineering. Certification by the American Board of Health Physics (ABHP) is required. At least five years of professional experience should be in applied radiological control work, program design and/or management, and regulatory compliance. The RSO's professional experience should include shielding design and the assessment of safety systems.

143 Radiological Control Organization Functions and Staffing

The RPP is implemented via the services and efforts of the RP Department. These services and efforts include:

- Radiological engineering. This service controls matters involving specification of radiation safety systems, shielding design calculations, and related radiological safety considerations.
- Together with the associated SLAC safety office and line managers, RP issues Beam Authorization Sheets (BAS), Beam Line Authorizations (BLA), or other documents which specify required conditions that shall be in place prior to beam operations. RP also conducts initial shielding verification tests under various beam loss scenarios.
- Radiological operations. This service controls matters including program and project radiation safety planning, training, workplace surveys, radiological measurements, postings, radioactive material inventory control, radioactive waste management, contamination control, instrumentation calibrations, radioanalysis, dosimetry, Radiological Calibration Facility (RCF) operations, environmental monitoring, other aspects of applied radiation safety, and
- All related documentation and record generation of same.
- The senior staff of the radiological control organization should include health physicists and other professionals. Training and education provisions for these individuals are established in Article 654.
- Radiological support personnel provide health physics and radiological engineering, dosimetry, bioassay, training, independent oversight, instrumentation, and calibration functions.

144 Relationship between Health Physics Technicians and Workers

Health Physics Technicians (HPTs) and their supervisors perform the functions of assisting and guiding workers in the radiological aspects of the job. Qualifications and training requirements for HPTs are defined in Chapter 6 of this *Manual*.

1. Workers should be sufficiently trained to recognize questionable or deteriorating radiological conditions and seek advice from HPTs and their supervisors.
2. HPTs and their supervisors have the responsibility and authority to stop work or mitigate the effect of an activity in accordance with Article 345.
3. The actions or presence of radiological control personnel does not absolve workers of their responsibility for properly conducting the radiological aspects of the job.

Radiological control personnel are not present to compensate for poor management of the work force and should not be required to do so.

145 ALARA Committee

The ALARA Committee provides expertise in ionizing radiation doses and releases from radioactive source material, radiation-generating devices, and engineering controls of radiation hazards. The ALARA Committee evaluates program and project plans for effective dose-control planning per its Charter as appropriate.[13]

The Charter features threshold dose criteria that are to be used for minimizing individual and collective doses to the extent feasible in the spirit of ALARA.[13] The Committee reviews the radiation dose records for various groups at SLAC, procedures for work in Radiological Areas, and proposes changes in operating procedures or equipment design with the objective of optimizing radiation doses.

146 Radiation Safety Committee

The Radiation Safety Committee (RSC) evaluates the hazards analysis, adequacy of planned hazard controls, and conformance to SLAC ESH policy and requirements for major and significant new activities (such as experiments, projects, test beams, construction, facility modifications), recommends changes in existing radiation safety policy and recommends new policies, and reviews accelerator facility procedures.[14]

PART 5 DOE Compliance

151 DOE Employees at SLAC

DOE employees at the SLAC site are subject to and shall adhere to the provisions of this *Manual*.

13 As Low As Reasonably Achievable (ALARA) Committee

14 Radiation Safety Committee

CHAPTER 2 RADIOLOGICAL STANDARDS

PART 1 Administrative Control Levels and Dose Limits

A major SLAC priority is to maintain personnel radiation exposure well below regulatory limits. To help uphold this priority, SLAC has established numerical Administrative Control Levels below the regulatory limits to administratively control and help optimize individual and collective radiation doses.

Unless otherwise indicated, administrative and special control levels and dose limits are stated in terms of the sum of the doses received from internal and external sources.

211 Administrative Control Level

1. SLAC has adopted an annual facility Administrative Control Level of 500 mrem total effective dose (TED) per year.
2. No person shall be allowed to go above the Administrative Control Level of 500 mrem TED per year without the prior approval of the SLAC Director or designee
3. 835 **During routine operations, the combination of engineered and administrative control shall provide that the anticipated occupational dose to general employees shall not exceed the limits established at 10 CFR 835.202.** [10 CFR 835.1003(a)] (see Table 2-1, "Summary of Occupational Dose Limits")

212 ALARA Level

Each individual radiological worker should have a dose-management "ALARA Level" of a maximum of 360 mrem TED per year above natural background levels of radiation.

1. Each Directorate should adopt or set a lower value than this value of 360 mrem TED per year as appropriate.
2. No radiological worker should exceed the ALARA Level without the prior approval of the RP Department Head (DH), Associate Laboratory Director, and the Radiological Control Manager (RCM).
3. The responsibility lies with the supervisor of each radiological worker to exercise timely planning and review of their subordinates' radiological work and tasks and anticipated doses to ensure that this level is not exceeded.

213 Occupational Exposure Limits (including Planned Special Exposures)

1. The dose limits for general employees are provided in Table 2-1 of this *Manual* and shall not be exceeded. A reasonable attempt should be made to determine occupational exposure received by SLAC employees at other sites. 835 **All occupational doses received during the current year, except doses resulting from Planned Special Exposures conducted in compliance with 10 CFR 835.204 and emergency exposures authorized in accordance with 10 CFR 835.1302, shall be included when demonstrating compliance with 10 CFR 835.202(a) and 835.207.** **[10 CFR 835.202(b)]** **The total effective**

dose during a year shall be determined by summing the effective dose from external exposures and the committed effective dose from intakes during the year [10 CFR 835.203(a)]

2. Workers from other DOE or DOE contractor facilities may receive occupational exposure as a worker if they:

   A. Provide record of current training equivalent to that required for SLAC employees.

   B. Receive SLAC site-specific Radiological Worker Training (RWT) I or II.

   C. Provide written estimates for the current year if feasible. 835 **Documentation of all occupational doses received during the current year, except for doses resulting from Planned Special Exposures conducted in compliance with 10 CFR 835.204 and emergency exposures authorized in accordance with 10 CFR 835.1302(d), shall be obtained when demonstrating compliance with 10 CFR 835.202(a). If complete records documenting previous occupational dose during the year cannot be obtained, a written estimate signed by the individual may be accepted to demonstrate compliance.** [10 CFR 835.702(d)]

3. 835 **A Planned Special Exposure may be authorized for a radiological worker to receive doses in addition to and accounted for separately from the doses received under the limits specified in 10 CFR 835.202(a), provided that each of the following conditions is satisfied:** [10 CFR 835.204(a)]

   A. 835 **The Planned Special Exposure is considered only in an exceptional situation when alternatives that might prevent a radiological worker from exceeding the limit in 10 CFR 835.202(a) are unavailable or impractical.** [10 CFR 835.204(a)(1)]

   B. 835 **The contractor management (and employer, if the employer is not the contractor) specifically requests the Planned Special Exposure, in writing.** [10 CFR 835.204(a)(2)](For purposes of compliance with this regulatory passage, SLAC considers "the contractor" to be SLAC and "the contractor management "to be SLAC management.) The proposed activity shall be reviewed by the RCM and submitted by the SLAC Director to the DOE SLAC Site Office for approval.

   C. 835 **Joint written approval from the appropriate DOE Headquarters program office and the Secretarial Officer responsible for environment, safety and health matters.** [10 CFR 835.204(a)(3)]

   D. 835 **Prior to requesting an individual to participate in an authorized Planned Special Exposure, the dose received by the individual from all previous Planned Special Exposures and all doses in excess of the occupational dose limits shall be determined.** [10 CFR 835.204(b)]

   E. 835 **An individual shall not receive a Planned Special Exposure that, in addition to the doses determined in 10 CFR 835.204(b), would result in a Planned Special Exposure dose exceeding the following:** [10 CFR 835.204(c)]

      1) 835 **In a year, the numerical values of the dose limits established at 10 CFR 835.202(a); and** [10 CFR 835.204(c)(1)]

      2) 835 **Over the individual's lifetime, five times the numerical values of the dose limits established at 10 CFR 835.202(a)** [10 CFR 835.204(c)(2)]

F. 835 **Prior to a Planned Special Exposure, written consent shall be obtained from each individual involved. Each such written consent shall include** [10 CFR 835.204(d)]

1) 835 **The purpose of the planned operations and procedures to be used** [10 CFR 835.204(d)(1)]

2) 835 **The estimated doses and associated potential risks and specific radiological conditions and other hazards which might be involved in performing the task; and** [10 CFR 835.204(d)(2)]

3) 835 **Instructions on the measures to be taken to keep the dose ALARA considering other risks that may be present.** [10 CFR 835.204(d)(3)]

G. 835 **Records of the conduct of a Planned Special Exposure shall be maintained and a written report submitted within 30 days after the Planned Special Exposure to the approving organizations identified in 10 CFR 835.204(a)(3).** [10 CFR 835.204(e)]

H. 835 **The dose from Planned Special Exposures is not to be considered in controlling future occupational dose of the individual under 10 CFR 835.202(a), but is to be included in records and reports required under 10 CFR 835.** [10 CFR 835.204(f)]

All Planned Special Exposures shall require a Job-Type Radiological Work Permit (RWP) per Articles 321 and 322 of this *Manual*.

4. Emergency exposure limits are not Planned Special Exposure limits. SLAC Guidelines for emergency exposures are provided in Appendix 2A of this *Manual*. 835**A general employee whose occupational dose has exceeded the numerical value of any of the limits specified in 10 CFR 835.202 as a result of an authorized emergency exposure may be permitted to return to work in radiological areas during the current year, provided that all of the following conditions are met:** [10 CFR 835.1301(a)]

Note: Table 2-1 of this *Manual* corresponds to the limits specified in 10 CFR 835.202.

A. **Approval is first obtained from the contract management and the Head of the responsible DOE field organization;** [10 CFR 835.1301(a)(1)]

Note: for purposes of this *Manual*, the SLAC Director is the 'contract management' at SLAC, and the Site Manager of the DOE SLAC Site Office is the Head of the responsible DOE field organization.

B. **The individual receives counseling from radiological protection and medical personnel regarding the consequences of receiving additional occupational exposure during the year.** [10 CFR 835. 1301(a)(2)]

C. **The affected individual agrees to return to radiological work.** [10 CFR 835.1301(a)(3)]

5. The general employee dose limits provided in Table 2-1 of this *Manual* apply to all employees. However, general employees who have not completed RWT I or II are not permitted unescorted access to any Radiological Areas.

6. 835 **All doses exceeding the limits specified in 10 CFR 835.202 shall be recorded in the affected individual's occupational dose record.** [10 CFR 835.1301(b)]

214 Member of the Public Dose Limit

835 **The total effective dose limit for members of the public exposed to radiation and/or radioactive material during access to a controlled area is 0.1 rem (0.001 Sv) in a year.** [10 CFR 835.208]

215 Dose Limits for Minors at SLAC

835 **The dose limits for minors occupationally exposed to radiation and/or radioactive materials at a DOE activity (e.g., SLAC) are 0.1 rem (0.001 Sv) total effective dose in a year and 10 percent of the occupational dose limits specified at 10 CFR 835.202(a)(3) and (a)(4).**[10 CFR 835.207] A minor is defined as a person under 18 years of age.

Table 2-1 Summary of Occupational Dose Limits

835 Type of Exposure	Limit
General Employee : Whole Body (internal and external); Total effective dose, or TED	**5 rem/year**
General Employee : Lens of eye (external)	**15 rem/year**
General Employee : Skin and extremities (external shallow dose plus internal dose resulting in dose to the skin)	**50 rem/year**
General Employee : Any organ or tissue (other than lens of eye) (internal plus internal)	**50 rem/year**
Declared Pregnant Worker: Embryo/Fetus (internal plus external)	**0.5 rem per gestation period**
Minors: Whole Body (internal plus external) (TED)	**0.1 rem/year**
Minors: Lens of the eye, skin, and extremities)	**10% of General Employee limits**

Comments:

- **For members of the public, the Whole Body (internal and external) TED limit is 0.1 rem /year.**

- **Also, for purpose of 10 CFR 835 only, in Table 2-1 a Radiological Worker means the same as General Employee.**

Notes:

1. The tissue weighting factors in Appendix 2B of this *Manual* shall be used in converting organ equivalent dose to effective dose for the whole body dose [see 10 CFR 835.203(b)].
2. The annual limit of dose to "any organ or tissue" is based on the committed equivalent dose to that organ or tissue resulting from internally deposited radionuclides over a 50-year period after intake plus any equivalent dose to that organ from external exposures during the year [see 10CFR835.202(a)(2)].
3. Exposures due to background radiation, as a patient undergoing therapeutic and diagnostic medical procedures, and participation as a subject in medical research programs shall not be included in either personnel radiation dose records or assessment of dose against the limits in this Table [see 10CFR 835.202(c)].
4. See Appendix 2C for guidance on non-uniform exposure of the skin.
5. Whole body dose (total effective dose [TED]) = effective dose from external exposures + committed effective dose from internal exposures [see 10 CFR 835.2(a)].
6. Lens of the eye equivalent dose = equivalent dose from external exposure determined at a tissue depth of 0.3 cm [see 10 CFR 835.2(a)].
7. Equivalent dose from external exposure determined at a tissue depth of 0.007 cm [see 10 CFR 835.2(a)].
8. The SLAC Administrative Control Levels for limiting exposure are described in Article 211.
9. The total effective dose during a year shall be determined by summing the effective dose from external exposures and the committed effective dose from intakes during the year [10 CFR 835.203(a)].
10. Determinations of the effective dose shall be made using the radiation and tissue weighting factor values provided in Appendix 2B of this *Manual* [10 CFR 835.203 (a)].
11. Definitions for the Types of Dose in Table 2-1 are provided in the Glossary of this *Manual*.

216 Embryo/Fetus Dose Controls

After a worker voluntarily notifies the SLAC Occupational Health Center in writing that she is pregnant, she is considered a declared pregnant worker for the purposes of fetal/embryo dose protection. This declaration may be revoked, in writing, at any time by the declared pregnant worker.

1. SLAC should provide the option of a mutually agreeable assignment of work tasks, without loss of pay or promotional opportunity, such that further occupational radiation exposure during the remainder of the gestation period is unlikely.
2. For a declared pregnant worker who chooses to continue work involving occupational exposure:
   A. 835 **The equivalent dose limit for the embryo/fetus from the period of conception to birth (entire gestation period) as a result of occupational exposure of a declared pregnant worker, is 500 mrem (0.005 Sv).** [10 CFR 835.206 (a)]
   B. 835 **Substantial variation above a uniform exposure rate that would satisfy the limits provided in 10 CFR 835.206(a) shall be avoided.** [10 CFR 835.206(b)] Efforts should be made to avoid exceeding 50 mrem per month to the declared pregnant worker.
3. 835 **If the equivalent dose to the embryo/fetus is determined to have already exceeded 500 mrem by the time a worker declares her pregnancy, the declared pregnant worker shall not be assigned to tasks where additional occupational radiation exposure is likely during the remaining gestation period.** [10 CFR 835.206(c)]
4. Although the DOE and the National Council on Radiation Protection and Measurements (NCRP) guidelines suggest prenatal occupational radiation dose limits, it is the sole and fundamental responsibility of the pregnant worker to decide whether she formally declares her pregnancy in writing and consequently becomes subject to dose limits and restrictions.
5. If you are a pregnant worker at SLAC, you have three options regarding prenatal occupational radiation exposure and its monitoring:
   A. You can formally declare your pregnancy by submitting a Declaration of Pregnancy Form. You then obtain mutually agreeable work re-assignment to ensure further occupational radiation exposure is unlikely.
   B. You can formally declare your pregnancy (or your intention to get pregnant) by submitting a Declaration of Pregnancy Form.[15]

      You then continue to work at your current job, agreeing to the following additional precautions:

      - Wear additional dosimeters and be monitored on a timely basis for prenatal occupational radiation exposure.
      - Accept work restrictions to keep total prenatal occupational radiation exposure below 500 mrem TED. If the RP dosimetry program staff

15 Radiological Safety: Declaration of Pregnancy Form (SLAC-I-760-0A02J-001)

determines the equivalent dose to the fetus has already exceeded 500 mrem TED by the time you declare your pregnancy, you will not be assigned to tasks where additional occupational radiation exposure is likely during the remainder of the pregnancy.

- Attempt to keep your occupational radiation exposure below 50 mrem TED per month until your pregnancy is over.

The RP dosimetry program staff will send you current occupational radiation exposure reports at a frequency determined by your occupational radiological conditions. The original Declaration of Pregnancy Form will be filed in your medical record.

C. You can choose not to formally declare your pregnancy (or your intention to become pregnant) and continue to work without dose or work restrictions or additional dosimeters.

6. If you choose to declare your pregnancy, you can withdraw it in writing by submitting a Withdrawal of Pregnancy Form.[16]

A. Upon submitting the Withdrawal of Pregnancy Form, you agree to lifting all additional dosage and work restrictions, and to removing all additional dosimeters.

B. Your benefits, seniority, or potential for promotion will not be affected by the choice you make regarding a declaration of your pregnancy. To obtain forms, or for more information or counseling about these options, contact the SLAC Occupational Health Center.

217 Special Considerations for Individuals Receiving Medical Radiation Doses

A supervisor should be attentive to special circumstances of employees, such as those undergoing radiation therapy or nuclear medicine procedures. Each such employee and their supervisor should contact the RP Department Dosimetry Program Manager to develop any additional dose controls deemed appropriate.

PART 2 Contamination Control and Control Levels

Control of radioactive contamination is achieved by using engineering controls and worker performance to contain contamination at the source, reducing existing areas of contamination, and promptly decontaminating areas that become contaminated.

221 Personnel Contamination Control

1. Article 339 establishes contamination monitoring requirements for personnel exiting Contamination Areas, High Contamination Areas, or Airborne Radioactivity Areas established for contamination control. These requirements do not apply to personnel exiting areas containing only radionuclides, such as tritium, that cannot be detected using hand-held or automatic frisking equipment.

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2. Monitoring for contamination should be performed using frisking equipment that under laboratory conditions can detect total contamination at or below the values specified in Table 2-2 of this *Manual*. Use of automatic monitoring units that meet the above requirements is encouraged.

3. Personnel found with detectable contamination on their skin or personal clothing, other than radon daughter products or other natural background radioactivity, should be promptly decontaminated as described in Article 541.

222 Contamination Control Levels

1. A surface is considered contaminated if either the removable or total radioactivity is detected above the levels in Table 2-2 of this *Manual*. 835 **Any area in which contamination levels exceed the values specified in appendix D of this part shall be controlled in a manner commensurate with the physical and chemical characteristics of the contaminant, the radionuclides present, and the fixed and removable surface contamination levels.** [10 CFR 835.1102 (b)] **(**Note: Table 2-2 of this *Manual* corresponds to "appendix D of this part" in this regulatory passage.)

   Appropriate postings and controls are established in Chapters 2, 3, and 4 of this *Manual*.

2. Surfaces exceeding the values of Table 2-2 of this *Manual* for total contamination may be covered with a fixative coating to prevent the spread of contamination. However, reasonable efforts should be made to decontaminate an area before a coating is applied. A fixative coating should not be applied without the approval of the RCM or designee.

   835 **The data presented in appendix D are to be used in identifying and posting contamination and high contamination areas in accordance with 10 CFR 835.603(e) and (f) and the need for surface contamination monitoring and control in accordance with 10 CFR 835.1101 and 1102.** [10 CFR 835.1 Appendix D.I1] **(**Note: Table 2-2 of this *Manual* corresponds to "appendix D of this part" in this regulatory passage)

3. Appropriate controls for areas of fixed contamination are provided in Article 224.

4. For areas with contaminated soil that is not releasable in accordance with DOE's environmental protection standards, a Soil Contamination Area should be established that:

   - Is posted as specified in Article 238.
   - Meets the requirements of Articles 231.1 through 231.8.

5. Soil Contamination Areas may be located outside Radiological Buffer Areas.

223 Airborne Radioactivity Control Levels

1. Use of engineering and administrative controls are used at SLAC to reduce the potential for internal exposures before allowing personnel, with or without respiratory protection, to enter areas with airborne radioactivity. RP may require a waiting period after beam shutoff before personnel entry is permitted into areas with high beam loss.

2. Posting requirements for occupied areas with airborne radioactivity are specified in Article 235.

Table 2-2 Summary of Surface Contamination Values

Radionuclide (See Table Note 1)	Removable (dpm/100 cm^2) (See Table Notes 2 & 4)	Total (fixed + removable) (dpm/100 cm^2) (See Notes 2 & 3)
U-natural, U-235, U-238 and associated decay products	[7]1,000 alpha	[7]5,000 alpha
Transuranics, Ra-226, Ra-228, Th-230, Th-228, Pa-231, Ac-227, I-125, I-129	20	500
Th-nat, Th-232, Sr-90, Ra-223, Ra-224, U-232, I-126, I-131, I-133	200	1,000
Beta-gamma emitters (nuclides with decay modes other than alpha emission or spontaneous fission) except Sr-90 and others noted above (See Note 5)	1,000 beta-gamma	5,000 beta-gamma
Tritium and special tritium compounds (STCs)[6]	10,000	See Note 6

Notes

1. The values in this Table with the exception noted in Note 6 below, apply to radioactive contamination deposited on, but not incorporated into the interior of, the contaminated item. Where contamination by both alpha- and beta-gamma emitting nuclides exists, the limits established for the alpha, beta, and gamma-emitting nuclides apply independently.
2. As used in this table, dpm (disintegrations per minute) means the rate of emission by radioactive material as determined by correcting the counts per minute observed by an appropriate detector for background, efficiency, and geometric factors associated with the instrumentation.
3. The levels may be averaged over one square meter provided the maximum surface activity in any area of 100 cm^2 is less than three times the value specified For purposes of averaging, any square meter of surface shall be considered to be above the surface contamination value if: (1) from measurements of a representative number of sections it is determined that the average contamination level exceeds the applicable value; or for purposes of averaging, any square meter of surface shall be considered to be above the surface contamination value if: (2) it is determined that the sum of the activity of all isolated spots or particles in any 100 cm^2 area exceeds three times the applicable value.
4. The amount of removable radioactive material per 100 cm^2 of surface area should be determined by swiping the area with dry filter or soft absorbent paper while applying moderate pressure and then assessing the amount of radioactive material on the swipe with an appropriate instrument of known efficiency. (Note – The use of dry material may not be appropriate for tritium.) With removable contamination on objects with a surface area less than 100 cm^2, the activity per unit area shall be based on the actual area and the entire surface shall be swiped. It is not necessary to use swiping techniques to measure removable contamination levels if direct scan surveys indicate that the total residual surface contamination levels are within the limits for removable contamination.
5. This category of radionuclides includes mixed fission products, including Sr-90 which is present in them. It does not apply to Sr-90 that has been separated from the other fission products or mixtures where the Sr-90 has been enriched.
6. Tritium contamination including special tritium compound (STCs) may diffuse into the volume or matrix of materials. Evaluation of surface contamination shall consider the extent to which such contamination may migrate to the surface in order to ensure the surface contamination value provided in this appendix is not exceeded. Once this contamination migrates to the surface, it may be removable, not fixed; therefore, a "total" value does not apply. In certain cases, a "Total" value of 10,000 dpm/100 cm^2 may be applicable either to metals of the types from which insoluble special tritium compounds are formed, that have been exposed to tritium, or to bulk materials to which insoluble special tritium compound particles are fixed to a surface.

7 These limits apply only to the alpha emitters within the respective decay series. [10 CFR 835 Appendix D]

224 Fixed Contamination Areas

A Fixed Contamination Area contains radioactive material that has been deposited onto a surface and cannot be readily removed by non-destructive means.

835 **Areas accessible to individuals where the measured total surface contamination levels exceed, but the removable surface contamination levels are less than, corresponding surface contamination values specified in appendix D of 10 CFR 835 of this part, shall be controlled as follows when located outside of Radiological Areas:** [10 CFR 835.1102(c)]

For purposes of this *Manual*, Table 2-2 of this *Manual* corresponds to appendix D of 10 CFR 835.

1. 835 **The area shall be conspicuously marked to warn individuals of the contaminated status;** [10 CFR 835.1102(c)(2)]

2. 835 **The area shall be routinely monitored to ensure the removable surface contamination level remains below the removable surface contamination values specified in appendix D of 10 CFR 835.** [10 CFR 835.1102(c)(1)]

   The conditions for establishing and maintaining Fixed Contamination Areas include all of the following:

   A. Markings shall be kept legible.

   B. Fixed contamination should be covered with two layers of fixative coatings having different colors.

   C. Markings should include the standard radiation symbol, be clearly visible from all directions, and contrast with the colors of the surface coatings.

   D. Additional coatings should be applied when the bottom color appears.

   E. Appropriate administrative procedures are established and exercised to maintain control of these areas.

3. A Fixed Contamination Area shall also be posted in accordance with 10 CFR 835.603, depending on the dose rate.

4. A Fixed Contamination Area is exempt from the general posting requirements of Articles 232-238 and the entry and exit requirements of Chapter 3 of this *Manual*.

PART 3 Posting

231 Posting Requirements

1. 835 **Signs required by this subpart shall be clear and conspicuously posted and may include radiological protection instructions.** [10 CFR 835.601(b)]

   Radiological posting shall be used to alert personnel to the presence of radiation and radioactive materials and to aid them in minimizing exposures and preventing the spread of contamination.

   835 **Postings and labels required by this subpart shall include the standard radiation warning trefoil in black or magenta imposed upon a yellow background.**
   [10 CFR 835.601(a)]

Radiological postings used at SLAC are identified and described in the *ESH Manual*, Chapter 9, "Radiological Safety," Radiological Safety: Radiological Work and Area Entry Requirements.[17]

3. Radiological postings should be displayed only to signify actual or potential radiological conditions. Signs used for training should be clearly marked, such as "For Training Purposes Only."
4. Posted areas should be as small as practicable for efficiency.
5. Postings should be maintained in a legible condition and updated using the results of the most recent surveys.
6. If more than one radiological condition (such as contamination and high radiation) exists in the same area, each condition shall be identified.
7. In areas of ongoing work activities, the dose rate or range should be included on, or in conjunction with, each posting, as applicable.
8. Postings at entrance points to areas of ongoing work activities controlled for radiological purposes should state basic entry requirements, such as dosimetry, Radiological Work Permit (RWP), and respiratory protection requirements, where appropriate.
9. Rope, tape, chain, and similar barriers used to designate the boundaries of posted areas should be yellow and magenta in color.
10. Physical barriers should be placed so that they are clearly visible from all directions and at various elevations. They should not be easily walked over or under, except at identified access points. These barriers shall be set up such that they do not impede the intended use of emergency exits or evacuation routes.
11. Posting of doors should be such that the postings remain visible when doors are open or closed.
12. A radiological posting that signifies the presence of an intermittent radiological condition should include a statement specifying when the radiation is present, such as "CAUTION: RADIATION AREA WHEN RED LIGHT IS ON." A variety of other signs are used to control access to the accelerator housing. These are discussed in Article 235.

232 Posting Accelerator Area and Controlled Areas

1 The Accelerator Area at SLAC is defined by the physical fence around the SLAC main accelerator complex where access is controlled by SLAC Site Security. Non-radiological hazards may exist there due to normal industrial or other activities. Radiological hazards exist within the Controlled Areas (CAs), which are posted.

2. 835 **A Controlled Area means any area to which access is managed by or for DOE to protect individuals from exposure to radiation and/or radioactive material.**
   [10 CFR 835.2(a)]
3. 835 **Each access point to a Controlled Area** (as defined in 10 CFR 835.2, above) **shall be posted whenever radiological areas or radioactive material areas exist in the area.**

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Individuals who enter only controlled areas without entering radiological areas or radioactive material areas are not expected to receive a total effective dose of more than 0.1 rem in a year. [10 CFR 835.602(a)]

Signs used for this purpose may be selected (by SLAC) **to avoid conflict with local security requirements.** [10 CFR 835.602(b)]

4. If a Controlled Area shares a common boundary with a Radioactive Material Area, the two conditions may be combined onto one sign, or separately posted. If a Controlled Area shares a common boundary with a Radiological Area, the two conditions may be posted on separate signs or posted only for the Radiological Area.

233 Posting Radiologically Controlled Areas

At SLAC, a Radiologically Controlled Area (RCA) is a Controlled Area that requires dosimetry for entry. The radiation level in certain localized areas within an RCA may vary, requiring limited occupancy. Individuals who enter only RCAs without entering Radiological Areas are not expected to receive a total effective dose (TED) of more than 0.1 rem in a year.

1. RCAs can be designated for purposes of access control even if no radiological condition otherwise warrants. However, certain types of radiological conditions shall require establishment of an RCA.
2. Each RCA shall be posted with the appropriate signs.
3. If an RCA shares a common boundary with a Radioactive Material Area the two conditions may be combined onto one sign or separately posted. If an RCA shares a common boundary with a Radiological Area, the two conditions may be posted on separate signs or posted only for the Radiological Area.

234 Posting Radiological Buffer Areas (RBAs)

At SLAC, Radiological Buffer Areas can be posted at the entrance of Contamination Areas to provide additional control of contamination. Minimum requirements for entry into RBAs include Radiological Worker Training (RWT) I and personnel dosimetry.

235 Posting Radiation Areas, High Radiation Areas, Very High Radiation Areas, Radioactive Material Management Areas, and Hot Spots

1. 835 **Each access point to radiological areas (as defined in 10 CFR 835.2) shall be posted with conspicuous signs bearing the wording provided in this section.** **[10 CFR 835.603 (a)(b)(c)]. Areas may be excepted from posting requirements of 10 CFR 835.603 for periods of less than 8 continuous hours when placed under continuous observation and control of an individual knowledgeable of, and empowered to implement, required access and exposure control measures.** [10 CFR 835.604 (a)]
2. Criteria for posting Radiation Areas, High Radiation Areas, Very High Radiation Areas, Radioactive Material Management Areas, and Hot Spots are provided in Table 2-3. Dose rate measurements used for posting of Radiation and High Radiation Areas should be made at a distance of 30 centimeters from the radiation source or from any surface

through which the radiation penetrates. For Very High Radiation Areas, the measurement should be made at 100 cm.

3. Contact readings should be used to determine the need for posting hot spots. Measures taken to identify sources of elevated general area radiation levels while conducting routine radiation surveys are sufficient to identify hot spot locations. Special surveys for the sole purpose of identifying hot spots are not required.

4. A label marking the location of the hot spot should be placed on or as near the spot as practical. The provisions of Articles 231.7 through 231.11 do not apply to the labeling of hot spots. Labeling of hot spots is not required in High Radiation Areas with general area dose rates greater than one rem/h or in Very High Radiation Areas.

5. The requirement for a Radiological Work Permit (RWP) should be included on Radiation and High Radiation Area postings.

6. Dose received in an hour may be used as the criterion for posting; see column headed "Posting" in Table 2-3. In this Table, the unit "rad" is associated with absorbed dose rates that pose an immediate danger.

7. A current list of Radiation Areas, High Radiation Areas, Very High Radiation Areas (if any), and Radioactive Material Management Areas (if any), is available from the RP Department.

236 Posting Contamination Areas, High Contamination Areas, and Airborne Radioactivity Areas

1. 835 **Areas shall be conspicuously marked to warn individuals of the contaminated status.** [10 CFR 835.1102(c)(2)] **Each access point to radiological areas and radioactive material areas (as defined at 10 CFR 835.2) shall be posted with conspicuous signs bearing the wording in this section.** [10 CFR 835.603]

   For purposes of this *Manual*, "bearing the wording in this section" in the previous sentence means bearing the wording in 10 CFR 835.603(d), (e), or (f), and Article 231 of this *Manual*.

2. 835 **Areas may be excepted from posting requirements of 10 CFR 835.603 for periods of less than 8 continuous hours when placed under continuous observation and control of an individual knowledgeable of, and empowered to implement, required access and exposure control measures.** [10 CFR 835.604 (a)]

3. The requirement for an RWP should be included on each posting, as applicable.

4. Derived Air Concentration (DAC) values listed in Appendices 2D and 2E shall be used in posting Airborne Radioactivity Areas in accordance with Table 2-4.

5. Areas meeting the criteria for Fixed Contamination Areas specified in Table 2-4 and Article 222.3 do not have to be posted as Contamination Areas or High Contamination Areas.

6. For a current list of Contamination Areas, High Contamination Areas (if any), and Airborne Radioactivity Areas (if any) contact the RP Department.

Table 2-3 Criteria for Posting Locations as Radiation Areas, High Radiation Areas, Very High Radiation Areas, Radioactive Material Management Areas, and Hot Spots

Area Type	Dose Rate Criteria	Posting (See Table Notes 1 and 3)
Radiation Area	**> 0.005 rem/h and ≤ 0.1 rem/h at 30 cm**	**"CAUTION, RADIATION AREA" "Personnel Dosimeter and RWP Required for Entry"**
High Radiation Area	**> 0.1 rem/h at 30 cm and ≤ 500 rad/h at 100 cm**	**"Caution, High Radiation Area" or "DANGER, HIGH RADIATION AREA" "Personnel Dosimeter, Supplemental Dosimeter, and RWP Required for Entry"**
Very High Radiation Area	**> 500 rad/h at 100 cm**	**"GRAVE DANGER, VERY HIGH RADIATION AREA" "SPECIAL CONTROLS REQUIRED FOR ENTRY"**
Radioactive Material Management Area (RMMA)	Area where the potential exists for radioactive contamination due to unencapsulated or unconfined radioactive material, or an area with material exposed to accelerator beams capable of causing radioactivation.	"All potentially Radioactive Materials (RAM) must be surveyed prior to removal"
Hot Spot (See Table Note 2)	> 5 times general area dose rate and > 0.1 rem/h(penetrating radiation) on contact	"CAUTION, HOT SPOT"

[10 CFR 835.603(a), 603(b), and 603(c)]

Table 2-3 notes:

1 In most locations within the accelerator housing, as well as with most machine-generated sources in use at SLAC, the posting needs are greatly reduced when the machine is not energized. Only in certain areas of the accelerator where residual radioactivity remains at levels high enough and in the storage and use of certain commercially procured sealed radioactive sources at SLAC of sufficient strength are the posting requirements in this Table routinely needed.

2. The term and use of hot spot is used for guidance from DOE-STD-1098-2017[6] at SLAC. 10 CFR 835 neither defines hot spot nor requires posting for a hot spot.

3. For examples, see Radiological Safety: Radiological Work and Area Entry Requirements.

Table 2-4 Criteria for Posting Contamination, High Contamination, and Airborne Radioactivity Areas

Area	Criteria	Posting*
Contamination Area	Removable contamination levels (dpm/100 cm^2) > Table 2-2 values(1) but ≤ 100 times Table 2-2 values	"CAUTION, CONTAMINATION AREA" "RWP Required for Entry"
High Contamination Area	Removable contamination levels (dpm/100 cm^2) > 100 times Table 2-2 values[1]	"CAUTION, HIGH CONTAMINATION AREA" or "DANGER, HIGH CONTAMINATION AREA" "RWP Required for Entry"
Fixed Contamination Area	Removable contamination levels < Table 2-2 removable values and total contamination levels > Table 2-2 total values	"CAUTION, FIXED CONTAMINATION"
Soil Contamination	Contaminated soil not releasable in accordance with DOE Order 458.1	"CAUTION, SOIL CONTAMINATION AREA"
Airborne Radioactivity Area	Airborne concentrations (µCi/ml) above background: 1) are > the applicable DAC values[1]; or 2) could result in an individual (w/o respirator) receiving an intake > 12 DAC-hrs in a week	"CAUTION, AIRBORNE RADIOACTIVITY AREA" or "DANGER, AIRBORNE RADIOACTIVITY AREA" "RWP Required for Entry"

[1] Levels exceed or are likely to exceed the listed values
Source: 10 CFR 835.603(d), 603(e), and 603(f)

Table Notes:
dpm = disintegrations per minute, a measure of radioactivity
DAC = derived air concentration

* For examples, see Radiological Safety: Radiological Work and Area Entry Requirements

237 Posting Radioactive Material Areas

1. Each access point to Radioactive Material Areas shall be posted with conspicuous signs bearing the wording "Caution, Radioactive Material(s)," per 10 CFR 835.603(g). The posting shall meet the requirements in Article 231.
2. Radioactive Material Areas shall be located within Controlled Areas (CAs), but may have the same boundaries.
3. Areas may be excepted from the Radioactive Material Area posting requirements of 10 CFR 835.603(g) when:
   A. Posted in accordance with 10 CFR 835.603 (a) through (f) (see Tables 2-3 and 2-4 in this *Manual*);
   B. or Each item or container of radioactive material is labeled in accordance with 10 CFR 835 Subpart G such that individuals entering the area are made aware of the hazard; or
   C. 835 **The radioactive material of concern consists solely of structures or installed components which have been activated (i.e. such as by being exposed to neutron radiation or particles produced in an accelerator).** [10 CFR 835.604(b)(3)]
   D. 835 **Areas containing only packages received from radioactive material transportation labeled and in non-degraded condition need not be posted in accordance with 10 CFR 835.603 until the packages are monitored in accordance with 10 CFR 835.405.** [10 CFR 835.604(c)]
4. The definition of radioactive material and the requirements for labeling radioactive material are provided in Chapter 4 of this *Manual*.

238 Posting Underground Radioactive Material Areas

1. Underground Radioactive Material Areas should be established to indicate the presence of underground items that contain radioactive material such as pipelines; radioactive cribs; covered ponds; covered ditches; catch tanks; inactive burial grounds; and sites of known, covered, unplanned releases (spills). Underground Radioactive Material Areas need not be posted if physical or administrative controls are implemented to ensure appropriate radiological controls are established prior to excavating, penetrating, or otherwise disturbing underground radioactive material.
2. Underground Radioactive Material Areas should be posted "UNDERGROUND RADIOACTIVE MATERIAL." Posting should include instructions or special warnings to workers such as "Consult with RP Department Before Digging" or "Subsurface Contamination Exists." The posting shall meet the applicable requirements of Article 231.
3. Underground Radioactive Material Areas may be located outside Controlled Areas unless access is likely to result in individual doses greater than 100 mrem in a year from underground radioactive material.
4. Underground Radioactive Material Areas are exempt from the entry and exit requirements of Chapter 3 of this *Manual* when access is not likely to result in individual doses greater than 100 mrem in a year. When access is likely to result in individual doses greater than 100 mrem in a year, entry requirements in Article 332 should be implemented.

239 Posting Soil Contamination Areas

1. For areas with contaminated soil that is not releasable in accordance with DOE's environmental protection standards, a Soil Contamination Area should be established that is posted in accordance with the requirements in Articles 231.1 through 231.8. Posting should include the words "Caution, Soil Contamination Area" and instructions or special warnings to workers, such as "Consult with RP Department before Digging" or "Subsurface Contamination Exists."
2. Soil Contamination Areas may be located outside Controlled Areas if exposure to the material in the area is not likely to cause any individual to receive a total effective dose in excess of 100 mrem in a year.

Appendix 2A Guidelines for Control of Emergency Exposures

In extremely rare cases, emergency exposure to radiation may be necessary to rescue personnel or to protect major property. Emergency exposures may be authorized in accordance with the provisions contained in 10 CFR 835.1302(a)(b)(c)(d). These doses are in addition to and accounted for separately from the doses received under the limits in Table 2-1.

835 **The risk of injury to those individuals involved in rescue and recovery operations shall be minimized.** [10 CFR 835.1302(a)] **Operating management shall weigh actual and potential risks against the benefits to be gained.** [10 CFR 835.1302(b)] **No individual shall be required to perform rescue action that might involve substantial personal risk** [10 CFR 835.1302(c)] **Each individual authorized to perform emergency actions likely to result in occupational doses exceeding the values of the limits provided at 10 CFR 835.202 (a) shall be trained in accordance with 10 CFR 835.901(b) and briefed beforehand on the known or anticipated hazards to which the individual will be subjected.** [10 CFR 835.1302(d)]

Table 2-5 is used as guidance at SLAC for potential authorized emergency exposure for rescue action.

Table 2-5 Guidance for Potential Authorized Emergency Doses for Rescue Action

Dose Limit (Whole Body*)	Activity Performed	Conditions
5 rem	All	
Up to 25 rem	Lifesaving, or protection of large populations.	Only on a voluntary basis where lower dose limit not practicable
>25 rem	Lifesaving or protection of large populations	Only on a voluntary basis by personnel fully aware of the risks involved

Notes*
1. The dose limit to the lens of the eye should be three times the listed value.
2. The dose limit to the skin of the whole body and the extremities is ten time the listed values.

835 **When the conditions under which a dose was received in excess of the limits specified in 10 CFR 835.202, except those doses received in accordance with 10 CFR 835.204, have been eliminated, operating management shall notify the Head of the responsible DOE field organization.** [10 CFR 835.1301(c)] **Operations which have been suspended as a result of a dose after a dose was received in excess of the limits specified in 10 CFR 835.202, except those received in accordance with 10 CFR 835.204, may be resumed only with the approval of the DOE.** [10 CFR 835.1301(d)]

Appendix 2B Radiation and Tissue Weighting Factors

Radiation and Tissue Weighting factors per [10 CFR 835.203 (b)] follow.

Table 2B-1 Radiation Weighting Factors, w_R

Type and energy range	Radiation weighting factor
Photons, electrons and muons, all energies	1
Neutrons, energy < 10 keV[2, 3]	5
Neutrons, energy 10 keV to 100 keV[2, 3]	10
Neutrons, energy > 100 keV to 2 MeV[2, 3]	20
Neutrons, energy > 2 MeV to 20 MeV[2, 3]	10
Neutrons, energy > 20 MeV[2, 3]	5
Protons, other than recoil protons, energy > 2 MeV	5
Alpha particles, fission fragments, heavy nuclei	20

Table 2B-1 Notes

1. All values relate to the radiation incident on the body or, for internal sources, emitted from the source.
2. When spectral data are insufficient to identify the energy of the neutrons, a radiation weighting factor of 20 shall be used.
3. When spectral data are sufficient to identify the energy of the neutrons, the following equation may be used to determine a neutron radiation weighting factor value:

$$w_R = 5 + 17 \exp\left[\frac{-(\ln(2E_n))^2}{6}\right]$$ Where E_n is the neutron energy in MeV.

Table 2B-2 Tissue Weighting Factors for Various Organs and Tissues, W_T

Organs or tissues, T	Tissue weighting factor, w_T
Gonads	0.20
Red bone marrow	0.12
Colon	0.12
Lungs	0.12
Stomach	0.12
Bladder	0.05
Breast	0.05
Liver	0.05
Esophagus	0.05
Thyroid	0.05
Skin	0.01
Bone surfaces	0.01
Remainder[1]	0.05
Whole body[2]	1.00

Table 2B-2 Notes

[1] "Remainder" means the following additional tissues and organs and their masses, in grams, following parenthetically: adrenals (14), brain (1400), extrathoracic airways (15), small intestine (640), kidneys (310), muscle (28,000), pancreas (100), spleen (180), thymus (20), and uterus (80). The equivalent dose to the remainder tissues ($H_{remainder}$), is normally calculated as the mass-weighted mean dose to the preceding ten organs and tissues. In those cases in which the most highly irradiated remainder tissue or organ receives the highest equivalent dose of all the organs, a tissue weighting factor of 0.025 (half of remainder) is applied to that tissue or organ and 0.025 (half of remainder) to the mass-weighted equivalent dose in the rest of the remainder tissues and organs to give the remainder equivalent dose.

[2] For the case of uniform external irradiation of the whole body, a tissue weighting factor (w_T) equal to 1 may be used in determination of the effective dose.

835 Tissue weighting factor (w_T) means the fraction of the overall health risk, resulting from uniform, whole body irradiation, attributable to specific tissue (T). The equivalent dose to tissue, (H_T), is multiplied by the appropriate tissue weighting factor to obtain the effective dose (E) contribution from that tissue. **[10 CFR 835.2]**

For example, a 5 rem dose to the thyroid gland would be multiplied by the tissue weighting factor 0.05 to yield 0.25 rem TED.

Appendix 2C Non-Uniform Exposure of the Skin

Table 2C-6 Non-Uniform Exposure of the Skin

Non-uniform exposures of the skin from X-rays, beta radiation, and radioactive materials on the skin, including hot particles, shall be assessed and recorded as specified in the table below [see 835.205(b)].

Area of Skin Irradiated	Method of Averaging, Adding to Other Doses Received, and Recording Non-uniform Skin Dose
≥ 100 cm^2 [see 835.205(b)(1)]	**Averaged over the 100 cm^2 of skin receiving the maximum dose** **Added to any uniform equivalent dose also received by the skin** **Recorded as the equivalent dose (H) to any extremity or skin for the year**
≥ 10 cm^2 and < 100 cm^2 [see 835.205(b)(2)]	**Averaged over the 1 cm^2 of skin receiving the maximum absorbed dose (D), reduced by the fraction (f) which is the irradiated area in cm^2 divided by 100 cm^2 (i.e. H = fD)** **Added to any uniform equivalent dose also received by the skin** **Recorded as the annual extremity or skin equivalent dose[1]**
< 10 cm^2 [see 835.205(b)(3)]	**Averaged over the 1 cm^2 of skin receiving the maximum dose** **Not added to any other equivalent dose, extremity or skin equivalent dose recorded for the annual equivalent dose** **Recorded in the individual's radiation dose record as a special entry[1]**

Table 2-6 Notes

1 Recording of the non -uniform equivalent dose to the skin is not required if the dose is less than 2 % of the limit specified for the skin at 10 CFR 835.202(a)(4).

Appendix 2D Derived Air Concentrations (DACs) for Air Monitoring

835 **The data presented in appendix A are to be used for controlling individual internal doses in accordance with 10 CFR 835.209, identifying the need for air monitoring in accordance with 10 CFR 835.403, and identifying and posting Airborne Radioactivity Areas in accordance with 10 CFR 835.603(d).** [10 CFR 835 Appendix A]

For purposes of this *Manual*, "Appendix A" in this regulatory citation corresponds to Appendix 2D in this *Manual*.

835 **The DAC values are given for individual radionuclides. For known mixtures of radionuclides determine the sum of the ratio of the observed concentration of a particular radionuclide and its corresponding DAC for all radionuclides in the mixture. If the sum exceeds unity (1), then the DAC has been exceeded. For unknown radionuclides, the most restrictive DAC (lowest value) for those isotopes not known to be absent shall be used. For any single radionuclide not listed in appendix A with decay mode other than alpha emission or spontaneous fission and with radioactive half-life greater than two hours, the DAC value shall be 4 E−11 µCi/mL (1 Bq/m3). For any single radionuclide not listed in appendix A that decays by alpha emission or spontaneous fission the DAC value shall be 2 E−13 µCi/mL (8 E−03 Bq/m^3).** [10 CFR 835 Appendix A]

For purposes of this *Manual*, "Appendix A" in this regulatory citation corresponds to Appendix 2D in this *Manual*.

835 **The DACs for limiting radiation exposures through inhalation of radionuclides by workers are listed in this appendix.** [10 CFR 835 Appendix A] For purposes of this *Manual*, "appendix" in this regulatory citation corresponds to Appendix 2D in this *Manual*. **The values are based on either a stochastic (committed effective dose) dose limit of 5 rem (0.05 Sv) or a deterministic (organ or tissue) dose limit of 5 rem (0.05 Sv) per year, whichever is more limiting.**
10 CFR 835 Appendix A]

Note: The 15 rem [0.15 Sv] dose limit for the lens of the eye does not appear as a critical organ dose limit.

The columns in this appendix contain the following information:

(1) Radionuclide;

(2) inhaled air DAC for type F (fast), type M (moderate), and type S (slow) materials in units of µCi/mL;

(3) inhaled air DAC for type F (fast), type M (moderate), and type S (slow) materials in units of Bq/m3;

(4) an indication of whether or not the DAC for each class is controlled by the stochastic (effective dose) or deterministic (organ or tissue) dose.

The absorption types (F, M, and S) have been established to describe the absorption type of the materials from the respiratory tract into the blood. The range of half-times for the absorption types correspond to: Type F, 100% at 10 minutes; Type M, 10% at 10 minutes and 90% at 140 days; and Type S 0.1% at 10 minutes and 99.9% at 7000 days. The DACs are listed by radionuclide, in order of increasing atomic mass, and are based on the assumption that the particle size distribution of 5 micrometers Activity Median Aerodynamic Diameter (AMAD) is used. For situations where the particle size distribution

is known to differ significantly from 5 micrometers AMAD, appropriate corrections may be made to both the estimated dose to workers and the DACs. [10 CFR 835 Appendix A]

Radionuclide	Absorption Type[3] µCi/mL			Absorption Type[3] Bq/m^3			Stochastic or organ or tissue[1]
	F	M	S	F	M	S	(F/ M/ S)
H-3 (Water)[2]	2 E−05	2 E−05	2 E−05	7 E+05	7 E+05	7 E+05	St/St/St
H-3 (Elemental)[2]	2 E−01	2 E−01	2 E−01	9 E+9	9 E+9	9 E+9	St/St/St
STC (Insoluble)[4]	1 E−05	6 E−06	2 E−06	3 E+05	2 E+05	8 E+04	St/St/St
STC (Soluble)	1 E−05	1 E−05	1 E−05	5 E+05	5 E+05	5 E+05	St/St/St
Be-7	-	1 E−05	1 E−05	-	4 E+05	4 E+05	/St/St
Be-10	-	8 E−08	2 E−08	-	3 E+03	1 E+03	/St/St
C-11(Vapor)[2]	-	1 E−04	-	-	6 E+06	-	/St/
C-11 (CO)[2]	4 E−04	4 E−04	4 E−04	1 E+07	1 E+07	1 E+07	St/St/St
C-11 (CO_2)[2]	2 E−04	2 E−04	2 E−04	9 E+06	9 E+06	9 E+06	St/St/St
C-14(Vapor)[2]	-	9 E−07	-	-	3 E+04	-	/St/
C-14 (CO)[2]	7 E−04	7 E−04	7 E−04	2 E+07	2 E+07	2 E+07	St/St/St
C-14 (CO_2)[2]	8 E−05	8 E−05	8 E−05	3 E+06	3 E+06	3 E+06	St/St/St
F-18	4 E−06	3 E−06	3 E−06	1 E+05	1 E+05	1 E+05	ET/ET/ET
Na-22	2 E−07	-	-	1 E+04	-	-	E/ /
Na-24	4 E−07	-	-	1 E+04	-	-	ET/ /
Mg-28	3 E−07	3 E−07	-	1 E+04	1 E+04	-	ET/St/
Al-26	4 E−08	4 E−08	-	1 E+03	1 E+03	-	St/St/
Si-31	9 E−06	5 E−06	5 E−06	3 E+05	1 E+05	1 E+05	ET/St/St
Si-32	1 E−07	5 E−08	1 E−08	5 E+03	2 E+03	3 E+02	St/St/St
P-32	5 E−07	1 E−07	-	1 E+04	7 E+03	-	St/St/
P-33	4 E−06	4 E−07	-	1 E+05	1 E+04	-	St/St/
S-35 (Vapor)	-	4 E−06	-	-	1 E+05	-	/St/
S-35	7 E−06	5 E−07	-	2 E+05	1 E+04	-	St/St/
Cl-36	1 E−06	1 E−07	-	4 E+04	4 E+03	-	St/St/
Cl-38	7 E−06	5 E−06	-	2 E+05	2 E+05	-	ET/ET/
Cl-39	2 E−06	4 E−06	-	1 E+05	1 E+05	-	ET/ET/
K-40	1 E−07	-	-	6 E+03	-	-	St/ /

Radionuclide	Absorption Type[3] µCi/mL			Absorption Type[3] Bq/m^3			Stochastic or organ or tissue[1]
	F	M	S	F	M	S	(F/ M/ S)
K-42	2 E−06	-	-	1 E+05	-	-	E/ /
K-43	9 E−07	-	-	3 E+04	-	-	ET/ /
K-44	8 E−06	-	-	2 E+05	-	-	ET/ /
K-45	9 E−06	-	-	3 E+05	-	-	ET/ /
Ca-41	-	2 E−06	-	-	8 E+04	-	/BS/
Ca-45	-	2 E−07	-	-	9 E+03	-	/St/
Ca-47	-	2 E−07	-	-	9 E+03	-	/St/
Sc-43	-	-	2 E−06	-	-	7 E+04	/ /ET
Sc-44m	-	-	2 E−07	-	-	1 E+04	/ /St
Sc-44	-	-	1 E−06	-	-	4 E+04	/ /ET
Sc-46	-	-	1 E−07	-	-	4 E+03	/ /St
Sc-47	-	-	7 E−07	-	-	2 E+04	/ /St
Sc-48	-	-	2 E−07	-	-	1 E+04	/ /ET
Sc-49	-	-	8 E−06	-	-	3 E+05	/ /ET
Ti-44	7 E−09	2 E−08	9 E−09	2 E+02	7 E+02	3 E+02	St/St/St
Ti-45	3 E−06	2 E−06	2 E−06	1 E+05	1 E+05	1 E+05	ET/ET/ET
V-47	8 E−06	6 E−06	-	3 E+05	2 E+05	-	ET/ET/
V-48	2 E−07	2 E−07	-	9 E+03	7 E+03	-	ET/St/
V-49	1 E−05	2 E−05	-	7 E+05	9 E+05	-	BS/St/
Cr-48	2 E−06	2 E−06	2 E−06	8 E+04	8 E+04	8 E+04	ET/ET/ET
Cr-49	7 E−06	5 E−06	5 E−06	2 E+05	2 E+05	2 E+05	ET/ET/ET
Cr-51	1 E−05	1 E−05	1 E−05	6 E+05	6 E+05	5 E+05	St/St/St
Mn-51	7 E−06	5 E−06	-	2 E+05	2 E+05	-	ET/ET/
Mn-52m	7 E−06	5 E−06	-	2 E+05	2 E+05	-	ET/ET/
Mn-52	2 E−07	2 E−07	-	8 E+03	8 E+03	-	ET/ET/
Mn-53	5 E−06	1 E−05	-	2 E+05	5 E+05	-	BS/St/
Mn-54	5 E−07	4 E−07	-	1 E+04	1 E+04	-	St/St/
Mn-56	2 E−06	2 E−06	-	9 E+04	8 E+04	-	ET/ET/

Radionuclide	Absorption Type[3] µCi/mL			Absorption Type[3] Bq/m^3			Stochastic or organ or tissue[1]
	F	M	S	F	M	S	(F/ M/ S)
Fe–52	6 E−07	5 E−07	-	2 E+04	2 E+04	-	ET/E/
Fe-55	6 E−07	1 E−06	-	2 E+04	6 E+04	-	St/St/
Fe-59	1 E−07	1 E−07	-	6 E+03	6 E+03	-	St/St/
Fe-60	1 E−09	4 E−09	-	6 E+01	1 E+02	-	St/St/
Co-55	-	5 E−07	5 E−07	-	2 E+04	2 E+04	/ET/ET
Co-56	-	1 E−07	1 E−07	-	5 E+03	4 E+03	/St/St
Co-57	-	1 E−06	9 E−07	-	5 E+04	3 E+04	/St/St
Co-58m	-	3 E−05	3 E−05	-	1 E+06	1 E+06	/St/St
Co-58	-	4 E−07	3 E−07	-	1 E+04	1 E+04	/St/St
Co-60m	-	4 E−04	4 E−04	-	1 E+07	1 E+07	/St/St
Co-60	-	7 E−08	3 E−08	-	2 E+03	1 E+03	/St/St
Co-61	-	6 E−06	6 E−06	-	2 E+05	2 E+05	/ET/ET
Co-62m	-	7 E−06	6 E−06	-	2 E+05	2 E+05	/ET/ET
Ni-56 (Inorg)	4 E−07	4 E−07	-	1 E+04	1 E+04	-	ET/ET/
Ni-56 (Carbonyl)	-	4 E−07	-	-	1 E+04	-	/St/
Ni-57 (Inorg)	5 E−07	5 E−07	-	2 E+04	2 E+04	-	ET/ET/
Ni-57 (Carbonyl)	-	7 E−07	-	-	2 E+04	-	/ET/
Ni-59 (Inorg)	2 E−06	5 E−06	-	9 E+04	2 E+05	-	St/St/
Ni-59 (Carbonyl)	-	6 E−07	-	-	2 E+04	-	/St/
Ni-63 (Inorg)	1 E−06	1 E−06	-	4 E+04	6 E+04	-	St/St/
Ni-63 (Carbonyl)	-	2 E−07	-	-	1 E+04	-	/St/
Ni-65 (Inorg)	5 E−06	4 E−06	-	1 E+05	1 E+05	-	ET/ET/
Ni-65 (Carbonyl)	-	8 E−07	-	-	3 E+04	-	/ET/
Ni-66 (Inorg)	7 E−07	2 E−07	-	2 E+04	1 E+04	-	St/St/
Ni-66 (Carbonyl)	-	2 E−07	-	-	1 E+04	-	/ET/
Cu-60	5 E−06	4 E−06	4 E−06	1 E+05	1 E+05	1 E+05	ET/ET/ET
Cu-61	3 E−06	3 E−06	3 E−06	1 E+05	1 E+05	1 E+05	ET/ET/ET
Cu-64	4 E−06	3 E−06	3 E−06	1 E+05	1 E+05	1 E+05	ET/E/E

Radionuclide	Absorption Type[3] µCi/mL			Absorption Type[3] Bq/m^3			Stochastic or organ or tissue[1]
	F	M	S	F	M	S	(F/ M/ S)
Cu-67	2 E−06	1 E−06	9 E−07	8 E+04	3 E+04	3 E+04	ET/St/St
Zn-62	-	-	8 E−07	-	-	3 E+04	/ /St
Zn-63	-	-	5 E−06	-	-	2 E+05	/ /ET
Zn-65	-	-	2 E−07	-	-	7 E+03	/ /St
Zn-69m	-	-	1 E−06	-	-	6 E+04	/ /St
Zn-69	-	-	7 E−06	-	-	2 E+05	/ /ET
Zn-71m	-	-	1 E−06	-	-	5 E+04	/ /ET
Zn-72	-	-	3 E−07	-	-	1 E+04	/ /St
Ga-65	1 E−05	9 E−06	-	4 E+05	3 E+05	-	ET/ET/
Ga-66	8 E−07	7 E−07	-	3 E+04	2 E+04	-	ET/St/
Ga-67	3 E−06	2 E−06	-	1 E+05	7 E+04	-	ET/St/
Ga-68	6 E−06	4 E−06	-	2 E+05	1 E+05	-	ET/ET/
Ga-70	1 E−05	1 E−05	-	6 E+05	4 E+05	-	ET/ET/
Ga-72	5 E−07	5 E−07	-	2 E+04	2 E+04	-	ET/ET/
Ga-73	4 E−06	2 E−06	-	1 E+05	1 E+05	-	ET/St/
Ge-66	2 E−06	2 E−06	-	9 E+04	9 E+04	-	ET/ET/
Ge-67	1 E−05	7 E−06	-	3 E+05	2 E+05	-	ET/ET/
Ge-68	6 E−07	7 E−08	-	2 E+04	2 E+03	-	ET/St/
Ge-69	1 E−06	1 E−06	-	3 E+04	3 E+04	-	ET/ET/
Ge-71	5 E−05	5 E−05	-	2 E+06	1 E+06	-	ET/E/
Ge-75	1 E−05	7 E−06	-	4 E+05	2 E+05	-	ET/ET/
Ge-77	1 E−06	1 E−06	-	4 E+04	4 E+04	-	ET/ET/
Ge-78	3 E−06	3 E−06	-	1 E+05	1 E+05	-	ET/ET/
As-69	-	9 E−06	-	-	3 E+05	-	/ET/
As-70	-	2 E−06	-	-	8 E+04	-	/ET/
As-71	-	1 E−06	-	-	4 E+04	-	/St/
As-72	-	4 E−07	-	-	1 E+04	-	/St/
As-73	-	8 E−07	-	-	3 E+04	-	/St/

Radionuclide	Absorption Type[3] µCi/mL			Absorption Type[3] Bq/m^3			Stochastic or organ or tissue[1]
	F	M	S	F	M	S	(F/ M/ S)
As-74	-	3 E−07	-	-	1 E+04	-	/St/
As-76	-	6 E−07	-	-	2 E+04	-	/St/
As-77	-	1 E−06	-	-	4 E+04	-	/St/
As-78	-	3 E−06	-	-	1 E+05	-	/ET/
Se-70	2 E−06	2 E−06	-	1 E+05	9 E+04	-	ET/ET/
Se-73m	1 E−05	1 E−05	-	5 E+05	4 E+05	-	ET/ET/
Se-73	1 E−06	1 E−06	-	6 E+04	5 E+04	-	ET/ET/
Se-75	4 E−07	3 E−07	-	1 E+04	1 E+04	-	St/St/
Se-79	3 E−07	1 E−07	-	1 E+04	6 E+03	-	K/St/
Se-81m	1 E−05	6 E−06	-	3 E+05	2 E+05	-	ET/ET/
Se-81	1 E−05	1 E−05	-	6 E+05	4 E+05	-	ET/ET/
Se-83	6 E−06	5 E−06	-	2 E+05	1 E+05	-	ET/ET/
Br-74m	3 E−06	2 E−06	-	1 E+05	1 E+05	-	ET/ET/
Br-74	4 E−06	4 E−06	-	1 E+05	1 E+05	-	ET/ET/
Br-75	4 E−06	3 E−06	-	1 E+05	1 E+05	-	ET/ET/
Br-76	5 E−07	5 E−07	-	2 E+04	2 E+04	-	ET/ET/
Br-77	2 E−06	2 E−06	-	7 E+04	7 E+04	-	ET/ET/
Br-80m	6 E−06	5 E−06	-	2 E+05	2 E+05	-	ET/St/
Br-80	3 E−05	2 E−05	-	1 E+06	7 E+05	-	ET/ET/
Br-82	3 E−07	3 E−07	-	1 E+04	1 E+04	-	ET/ET/
Br-83	9 E−06	6 E−06	-	3 E+05	2 E+05	-	ET/ET/
Br-84	7 E−06	5 E−06	-	2 E+05	2 E+05	-	ET/ET/
Rb-79	8 E−06	-	-	2 E+05	-	-	ET/ /
Rb-81m	1 E−05	-	-	6 E+05	-	-	ET/ /
Rb-81	2 E−06	-	-	1 E+05	-	-	ET/ /
Rb-82m	8 E−07	-	-	3 E+04	-	-	ET/ /
Rb-83	5 E−07	-	-	2 E+04	-	-	St/ /
Rb-84	3 E−07	-	-	1 E+04	-	-	St/ /

Radionuclide	Absorption Type[3] µCi/mL			Absorption Type[3] Bq/m^3			Stochastic or organ or tissue[1]
	F	M	S	F	M	S	(F/ M/ S)
Rb-86	4 E−07	-	-	1 E+04	-	-	St/ /
Rb-87	7 E−07	-	-	2 E+04	-	-	St/ /
Rb-88	1 E−05	-	-	5 E+05	-	-	ET/ /
Rb-89	1 E−05	-	-	3 E+05	-	-	ET/ /
Sr-80	3 E−06	-	2 E−06	1 E+05	-	9 E+04	ET/ /St
Sr-81	7 E−06	-	5 E−06	2 E+05	-	2 E+05	ET/ /ET
Sr-82	1 E−07	-	7 E−08	6 E+03	-	2 E+03	St/ /St
Sr-83	1 E−06	-	9 E−07	3 E+04	-	3 E+04	ET/ /ET
Sr-85m	4 E−05	-	3 E−05	1 E+06	-	1 E+06	ET/ /ET
Sr-85	1 E−06	-	8 E−07	3 E+04	-	3 E+04	St/ /St
Sr-87m	1 E−05	-	9 E−06	4 E+05	-	3 E+05	ET/ /ET
Sr-89	4 E−07	-	1 E−07	1 E+04	-	3 E+03	St/ /St
Sr-90	1 E−08	-	7 E−09	4 E+02	-	2 E+02	BS/ /St
Sr-91	1 E−06	-	9 E−07	5 E+04	-	3 E+04	ET/ /St
Sr-92	2 E−06	-	1 E−06	8 E+04	-	6 E+04	ET/ /St
Y-86m	-	7 E−06	6 E−06	-	2 E+05	2 E+05	/ET/ET
Y-86	-	4 E−07	4 E−07	-	1 E+04	1 E+04	/ET/ET
Y-87	-	9 E−07	8 E−07	-	3 E+04	3 E+04	/ET/ET
Y-88	-	1 E−07	1 E−07	-	6 E+03	6 E+03	/St/St
Y-90m	-	4 E−06	4 E−06	-	1 E+05	1 E+05	/St/St
Y-90	-	3 E−07	3 E−07	-	1 E+04	1 E+04	/St/St
Y-91m	-	2 E−05	2 E−05	-	7 E+05	7 E+05	/ET/ET
Y-91	-	1 E−07	9 E−08	-	4 E+03	3 E+03	/St/St
Y-92	-	2 E−06	2 E−06	-	7 E+04	7 E+04	/St/St
Y-93	-	9 E−07	9 E−07	-	3 E+04	3 E+04	/St/St
Y-94	-	8 E−06	8 E−06	-	3 E+05	3 E+05	/ET/ET
Y-95	-	1 E−05	1 E−05	-	4 E+05	4 E+05	/ET/ET
Zr-86	5 E−07	5 E−07	5 E−07	2 E+04	2 E+04	2 E+04	ET/ET/ET

Radionuclide	Absorption Type[3] µCi/mL			Absorption Type[3] Bq/m[3]			Stochastic or organ or tissue[1]
	F	M	S	F	M	S	(F/ M/ S)
Zr-88	1 E−07	3 E−07	3 E−07	5 E+03	1 E+04	1 E+04	St/St/St
Zr-89	6 E−07	6 E−07	6 E−07	2 E+04	2 E+04	2 E+04	ET/ET/ET
Zr-93	3 E−09	1 E−08	1 E−07	1 E+02	6 E+02	5 E+03	BS/BS/BS
Zr-95	9 E−08	1 E−07	1 E−07	3 E+03	5 E+03	4 E+03	BS/St/St
Zr-97	7 E−07	4 E−07	4 E−07	2 E+04	1 E+04	1 E+04	ET/St/St
Nb-88	-	5 E−06	5 E−06	-	1 E+05	1 E+05	/ET/ET
Nb-89 (66 min)	-	3 E−06	3 E−06	-	1 E+05	1 E+05	/ET/ET
Nb-89 (122 min)	-	2 E−06	2 E−06	-	1 E+05	1 E+05	/ET/ET
Nb-90	-	3 E−07	3 E−07	-	1 E+04	1 E+04	/ET/ET
Nb-93m	-	1 E−06	6 E−07	-	7 E+04	2 E+04	/St/St
Nb-94	-	7 E−08	2 E−08	-	2 E+03	8 E+02	/St/St
Nb-95m	-	7 E−07	6 E−07	-	2 E+04	2 E+04	/St/St
Nb-95	-	4 E−07	4 E−07	-	1 E+04	1 E+04	/St/St
Nb-96	-	4 E−07	4 E−07	-	1 E+04	1 E+04	/ET/ET
Nb-97	-	5 E−06	5 E−06	-	1 E+05	1 E+05	/ET/ET
Nb-98	-	3 E−06	3 E−06	-	1 E+05	1 E+05	/ET/ET
Mo-90	8 E−07	-	7 E−07	3 E+04	-	2 E+04	ET/ /ET
Mo-93m	1 E−06	-	1 E−06	3 E+04	-	3 E+04	ET/ /ET
Mo-93	2 E−07	-	4 E−07	7 E+03	-	1 E+04	BS/ /St
Mo-99	1 E−06	-	5 E−07	5 E+04	-	1 E+04	E/ /St
Mo-101	8 E−06	-	6 E−06	3 E+05	-	2 E+05	ET/ /ET
Tc-93m	8 E−06	7 E−06	-	3 E+05	2 E+05	-	ET/ET/
Tc-93	3 E−06	3 E−06	-	1 E+05	1 E+05	-	ET/ET/
Tc-94m	5 E−06	4 E−06	-	1 E+05	1 E+05	-	ET/ET/
Tc-94	1 E−06	1 E−06	-	4 E+04	3 E+04	-	ET/ET/
Tc-95m	8 E−07	6 E−07	-	3 E+04	2 E+04	-	ET/St/
Tc-95	1 E−06	1 E−06	-	5 E+04	5 E+04	-	ET/ET/
Tc-96m	2 E−05	2 E−05	-	1 E+06	1 E+06	-	ET/ET/

Radionuclide	Absorption Type[3] µCi/mL			Absorption Type[3] Bq/m^3			Stochastic or organ or tissue[1]
	F	M	S	F	M	S	(F/ M/ S)
Tc-96	3 E−07	3 E−07	-	1 E+04	1 E+04	-	ET/ET/
Tc-97m	1 E−06	2 E−07	-	5 E+04	7 E+03	-	St/St/
Tc-97	4 E−06	3 E−06	-	1 E+05	1 E+05	-	ET/St/
Tc-98	3 E−07	9 E−08	-	1 E+04	3 E+03	-	St/St/
Tc-99m	1 E−05	1 E−05	-	5 E+05	4 E+05	-	ET/ET/
Tc-99	1 E−06	1 E−07	-	5 E+04	6 E+03	-	St/St/
Tc-101	1 E−05	1 E−05	-	6 E+05	4 E+05	-	ET/ET/
Tc-104	9 E−06	7 E−06	-	3 E+05	2 E+05	-	ET/ET/
Ru-94	5 E−06	5 E−06	5 E−06	2 E+05	1 E+05	1 E+05	ET/ET/ET
Ru-97	2 E−06	2 E−06	2 E−06	8 E+04	8 E+04	8 E+04	ET/ET/ET
Ru-103	8 E−07	2 E−07	2 E−07	3 E+04	1 E+04	9 E+03	St/St/St
Ru-105	2 E−06	2 E−06	2 E−06	9 E+04	8 E+04	8 E+04	ET/ET/ET
Ru-106	5 E−08	3 E−08	1 E−08	2 E+03	1 E+03	5 E+02	St/St/St
Rh-99m	3 E−06	3 E−06	3 E−06	1 E+05	1 E+05	1 E+05	ET/ET/ET
Rh-99	8 E−07	6 E−07	6 E−07	3 E+04	2 E+04	2 E+04	ET/St/St
Rh-100	5 E−07	5 E−07	5 E−07	1 E+04	1 E+04	1 E+04	ET/ET/ET
Rh-101m	1 E−06	1 E−06	1 E−06	6 E+04	6 E+04	6 E+04	ET/ET/ET
Rh-101	3 E−07	3 E−07	1 E−07	1 E+04	1 E+04	6 E+03	St/St/St
Rh-102m	2 E−07	2 E−07	1 E−07	1 E+04	7 E+03	4 E+03	St/St/St
Rh-102	6 E−08	1 E−07	6 E−08	2 E+03	4 E+03	2 E+03	St/St/St
Rh-103m	4 E−04	2 E−04	2 E−04	1 E+07	8 E+06	8 E+06	St/St/St
Rh-105	3 E−06	1 E−06	1 E−06	1 E+05	5 E+04	4 E+04	ET/St/St
Rh-106m	1 E−06	1 E−06	1 E−06	6 E+04	5 E+04	5 E+04	ET/ET/ET
Rh-107	1 E−05	9 E−06	9 E−06	5 E+05	3 E+05	3 E+05	ET/ET/ET
Pd-100	5 E−07	5 E−07	5 E−07	2 E+04	2 E+04	2 E+04	ET/ET/ET
Pd-101	3 E−06	3 E−06	3 E−06	1 E+05	1 E+05	1 E+05	ET/ET/ET
Pd-103	4 E−06	1 E−06	1 E−06	1 E+05	6 E+04	7 E+04	E/St/St
Pd-107	1 E−05	1 E−05	1 E−06	5 E+05	4 E+05	7 E+04	K/St/St

Radionuclide	Absorption Type[3] µCi/mL			Absorption Type[3] Bq/m^3			Stochastic or organ or tissue[1]
	F	M	S	F	M	S	(F/ M/ S)
Pd-109	2 E−06	1 E−06	1 E−06	9 E+04	4 E+04	4 E+04	St/St/St
Ag-102	9 E−06	7 E−06	7 E−06	3 E+05	2 E+05	2 E+05	ET/ET/ET
Ag-103	8 E−06	7 E−06	7 E−06	3 E+05	2 E+05	2 E+05	ET/ET/ET
Ag-104m	8 E−06	6 E−06	6 E−06	2 E+05	2 E+05	2 E+05	ET/ET/ET
Ag-104	3 E−06	3 E−06	3 E−06	1 E+05	1 E+05	1 E+05	ET/ET/ET
Ag-105	7 E−07	8 E−07	7 E−07	2 E+04	2 E+04	2 E+04	St/St/St
Ag-106m	2 E−07	2 E−07	2 E−07	9 E+03	9 E+03	9 E+03	ET/ET/ET
Ag-106	1 E−05	1 E−05	1 E−05	5 E+05	4 E+05	4 E+05	ET/ET/ET
Ag-108m	7 E−08	1 E−07	2 E−08	2 E+03	4 E+03	1 E+03	St/St/St
Ag-110m	8 E−08	9 E−08	7 E−08	3 E+03	3 E+03	2 E+03	St/St/St
Ag-111	9 E−07	3 E−07	3 E−07	3 E+04	1 E+04	1 E+04	St/St/St
Ag-112	4 E−06	2 E−06	2 E−06	1 E+05	8 E+04	8 E+04	E/St/St
Ag-115	1 E−05	8 E−06	8 E−06	4 E+05	3 E+05	3 E+05	ET/ET/ET
Cd-104	4 E−06	4 E−06	4 E−06	1 E+05	1 E+05	1 E+05	ET/ET/ET
Cd-107	5 E−06	5 E−06	4 E−06	2 E+05	1 E+05	1 E+05	ET/ET/ET
Cd-109	2 E−08	9 E−08	1 E−07	9 E+02	3 E+03	4 E+03	K/K/St
Cd-113m	1 E−09	6 E−09	1 E−08	6 E+01	2 E+02	6 E+02	K/K/K
Cd-113	1 E−09	5 E−09	1 E−08	5 E+01	2 E+02	5 E+02	K/K/K
Cd-115m	3 E−08	1 E−07	1 E−07	1 E+03	3 E+03	3 E+03	K/St/St
Cd-115	9 E−07	4 E−07	4 E−07	3 E+04	1 E+04	1 E+04	K/St/St
Cd-117m	1 E−06	1 E−06	1 E−06	4 E+04	4 E+04	4 E+04	ET/ET/ET
Cd-117	2 E−06	2 E−06	2 E−06	8 E+04	7 E+04	7 E+04	ET/ET/ET
In-109	4 E−06	4 E−06	-	1 E+05	1 E+05	-	ET/ET/
In-110 (69 min)	5 E−06	4 E−06	-	1 E+05	1 E+05	-	ET/ET/
In-110 (5 h)	9 E−07	9 E−07	-	3 E+04	3 E+04	-	ET/ET/
In-111	1 E−06	1 E−06	-	5 E+04	5 E+04	-	ET/ET/
In-112	2 E−05	1 E−05	-	9 E+05	6 E+05	-	ET/ET/
In-113m	1 E−05	1 E−05	-	4 E+05	3 E+05	-	ET/ET/

Radionuclide	Absorption Type[3] µCi/mL			Absorption Type[3] Bq/m^3			Stochastic or organ or tissue[1]
	F	M	S	F	M	S	(F/ M/ S)
In-114m	5 E−08	9 E−08	-	1 E+03	3 E+03	-	St/St/
In-115m	6 E−06	5 E−06	-	2 E+05	2 E+05	-	ET/ET/
In-115	1 E−09	5 E−09	-	4 E+01	1 E+02	-	St/St/
In-116m	4 E−06	3 E−06	-	1 E+05	1 E+05	-	ET/ET/
In-117m	5 E−06	4 E−06	-	2 E+05	1 E+05	-	ET/ET/
In-117	7 E−06	5 E−06	-	2 E+05	2 E+05	-	ET/ET/
In-119m	1 E−05	1 E−05	-	6 E+05	4 E+05	-	ET/ET/
Sn-110	1 E−06	1 E−06	-	6 E+04	6 E+04	-	ET/ET/
Sn-111	1 E−05	1 E−05	-	6 E+05	5 E+05	-	ET/ET/
Sn-113	7 E−07	2 E−07	-	2 E+04	1 E+04	-	St/St/
Sn-117m	8 E−07	2 E−07	-	3 E+04	9 E+03	-	BS/St/
Sn-119m	1 E−06	3 E−07	-	5 E+04	1 E+04	-	St/St/
Sn-121m	5 E−07	1 E−07	-	2 E+04	6 E+03	-	St/St/
Sn-121	4 E−06	2 E−06	-	1 E+05	7 E+04	-	ET/St/
Sn-123m	1 E−05	7 E−06	-	4 E+05	2 E+05	-	ET/ET/
Sn-123	3 E−07	1 E−07	-	1 E+04	3 E+03	-	St/St/
Sn-125	4 E−07	2 E−07	-	1 E+04	7 E+03	-	St/St/
Sn-126	4 E−08	3 E−08	-	1 E+03	1 E+03	-	St/St/
Sn-127	2 E−06	2 E−06	-	9 E+04	7 E+04	-	ET/ET/
Sn-128	2 E−06	2 E−06	-	1 E+05	8 E+04	-	ET/ET/
Sb-115	1 E−05	1 E−05	-	5 E+05	4 E+05	-	ET/ET/
Sb-116m	3 E−06	2 E−06	-	1 E+05	1 E+05	-	ET/ET/
Sb-116	1 E−05	1 E−05	-	4 E+05	3 E+05	-	ET/ET/
Sb-117	1 E−05	1 E−05	-	4 E+05	3 E+05	-	ET/ET/
Sb-118m	1 E−06	1 E−06	-	4 E+04	4 E+04	-	ET/ET/
Sb-119	6 E−06	6 E−06	-	2 E+05	2 E+05	-	ET/ET/
Sb-120 (16 min)	2 E−05	2 E−05	-	1 E+06	7 E+05	-	ET/ET/
Sb-120 (6 d)	3 E−07	3 E−07	-	1 E+04	1 E+04	-	ET/ET/

Radionuclide	Absorption Type[3] µCi/mL			Absorption Type[3] Bq/m^3			Stochastic or organ or tissue[1]
	F	M	S	F	M	S	(F/ M/ S)
Sb-122	8 E−07	4 E−07	-	3 E+04	1 E+04	-	St/St/
Sb-124m	4 E−05	3 E−05	-	1 E+06	1 E+06	-	ET/ET/
Sb-124	2 E−07	1 E−07	-	1 E+04	4 E+03	-	St/St/
Sb-125	2 E−07	1 E−07	-	7 E+03	6 E+03	-	BS/St/
Sb-126m	1 E−05	7 E−06	-	3 E+05	2 E+05	-	ET/ET/
Sb-126	2 E−07	1 E−07	-	9 E+03	6 E+03	-	ET/St/
Sb-127	7 E−07	3 E−07	-	2 E+04	1 E+04	-	E/St/
Sb-128 (9 h)	5 E−07	5 E−07	-	2 E+04	2 E+04	-	ET/ET/
Sb-128 (10 min)	1 E−05	9 E−06	-	4 E+05	3 E+05	-	ET/ET/
Sb-129	1 E−06	1 E−06	-	6 E+04	5 E+04	-	ET/ET/
Sb-130	3 E−06	2 E−06	-	1 E+05	1 E+05	-	ET/ET/
Sb-131	6 E−06	4 E−06	-	2 E+05	1 E+05	-	ET/ET/
Te-116 (Vapor)	-	6 E−06	-	-	2 E+05	-	/St /
Te-116	2 E−06	2 E−06	-	8 E+04	7 E+04	-	ET/ET/
Te-121m (Vapor)	-	4 E−08	-	-	1 E+03	-	/BS/
Te-121m	1 E−07	1 E−07	-	4 E+03	5 E+03	-	BS/St/
Te-121 (Vapor)	-	1 E−06	-	-	4 E+04	-	/St /
Te-121	1 E−06	1 E−06	-	3 E+04	3 E+04	-	ET/ET/
Te-123m (Vapor)	-	5 E−08	-	-	2 E+03	-	/BS/
Te-123m	1 E−07	1 E−07	-	4 E+03	6 E+03	-	BS/St/
Te-123 (Vapor)	-	1 E−08	-	-	4 E+02	-	/BS/
Te-123	2 E−08	5 E−08	-	1 E+03	1 E+03	-	BS/BS/
Te-125m (Vapor)	-	1 E−07	-	-	3 E+03	-	/BS/
Te-125m	2 E−07	1 E−07	-	9 E+03	7 E+03	-	BS/St/
Te-127m (Vapor)	-	6 E−08	-	-	2 E+03	-	/BS/
Te-127m	1 E−07	9 E−08	-	5 E+03	3 E+03	-	BS/St/
Te-127 (Vapor)	-	7 E−06	-	-	2 E+05	-	/St/
Te-127	5 E−06	3 E−06	-	2 E+05	1 E+05	-	ET/St/

Radionuclide	Absorption Type[3] µCi/mL			Absorption Type[3] Bq/m^3			Stochastic or organ or tissue[1]
	F	M	S	F	M	S	(F/ M/ S)
Te-129m (Vapor)	-	1 E−07	-	-	5 E+03	-	/St/
Te-129m	3 E−07	1 E−07	-	1 E+04	3 E+03	-	St/St/
Te-129 (Vapor)	-	1 E−05	-	-	5 E+05	-	/St/
Te-129	1 E−05	7 E−06	-	4 E+05	2 E+05	-	ET/ET/
Te-131m (Vapor)	-	1 E−07	-	-	5 E+03	-	/T/
Te-131m	3 E−07	3 E−07	-	1 E+04	1 E+04	-	T/St/
Te-131 (Vapor)	-	6 E−06	-	-	2 E+05	-	/T/
Te-131	1 E−05	7 E−06	-	4 E+05	2 E+05	-	ET/ET/
Te-132 (Vapor)	-	7 E−08	-	-	2 E+03	-	/T/
Te-132	1 E−07	1 E−07	-	6 E+03	6 E+03	-	T/St/
Te-133m (Vapor)	-	1 E−06	-	-	6 E+04	-	/T/
Te-133m	3 E−06	2 E−06	-	1 E+05	1 E+05	-	T/ET/
Te-133 (Vapor)	-	7 E−06	-	-	2 E+05	-	/T/
Te-133	1 E−05	9 E−06	-	4 E+05	3 E+05	-	ET/ET/
Te-134 (Vapor)	-	6 E−06	-	-	2 E+05	-	/St/
Te-134	3 E−06	2 E−06	-	1 E+05	1 E+05	-	ET/ET/
I-120m (Methyl)	4 E−06	-	-	1 E+05	-	-	T/ /
I-120m (Vapor)	-	3 E−06	-	-	1 E+05	-	/St /
I-120m	2 E−06	-	-	8 E+04	-	-	ET/ /
I-120 (Methyl)	1 E−06	-	-	6 E+04	-	-	T/ /
I-120 (Vapor)	-	1 E−06	-	-	5 E+04	-	/T/
I-120	2 E−06	-	-	1 E+05	-	-	E/ /
I-121 (Methyl)	5 E−06	-	-	2 E+05	-	-	T/ /
I-121 (Vapor)	-	4 E−06	-	-	1 E+05	-	/T/
I-121	8 E−06	-	-	3 E+05	-	-	T/ /
I-123 (Methyl)	1 E−06	-	-	7 E+04	-	-	T/ /
I-123 (Vapor)	-	1 E−06	-	-	5 E+04	-	/T/
I-123	2 E−06	-	-	1 E+05	-	-	T/ /

Radionuclide	Absorption Type[3] µCi/mL			Absorption Type[3] Bq/m^3			Stochastic or organ or tissue[1]
	F	M	S	F	M	S	(F/ M/ S)
I-124 (Methyl)	3 E−08	-	-	1 E+03	-	-	T/ /
I-124 (Vapor)	-	2 E−08	-	-	9 E+02	-	/T/
I-124	4 E−08	-	-	1 E+03	-	-	T/ /
I-125 (Methyl)	2 E−08	-	-	9 E+02	-	-	T/ /
I-125 (Vapor)	-	2 E−08	-	-	7 E+02	-	/T/
I-125	3 E−08	-	-	1 E+03	-	-	T/ /
I-126 (Methyl)	1 E−08	-	-	5 E+02	-	-	T/ /
I-126 (Vapor)	-	1 E−08	-	-	4 E+02	-	/T/
I-126	2 E−08	-	-	7 E+02	-	-	T/ /
I-128 (Methyl)	3 E−05	-	-	1 E+06	-	-	T/ /
I-128 (Vapor)	-	8 E−06	-	-	3 E+05	-	/St/
I-128	1 E−05	-	-	6 E+05	-	-	ET/ /
I-129 (Methyl)	3 E−09	-	-	1 E+02	-	-	T/ /
I-129 (Vapor)	-	2 E−09	-	-	1 E+02	-	/T/
I-129	5 E−09	-	-	2 E+02	-	-	T/ /
I-130 (Methyl)	2 E−07	-	-	7 E+03	-	-	T/ /
I-130 (Vapor)	-	1 E−07	-	-	6 E+03	-	/T/
I-130	3 E−07	-	-	1 E+04	-	-	T/ /
I-131 (Methyl)	1 E−08	-	-	6 E+02	-	-	T/ /
I-131 (Vapor)	-	1 E−08	-	-	5 E+02	-	/T/
I-131	2 E−08	-	-	9 E+02	-	-	T/ /
I-132m (Methyl)	1 E−06	-	-	7 E+04	-	-	T/ /
I-132m (Vapor)	-	1 E−06	-	-	6 E+04	-	/T/
I-132m	3 E−06	-	-	1 E+05	-	-	T/ /
I-132 (Methyl)	1 E−06	-	-	6 E+04	-	-	T/ /
I-132 (Vapor)	-	1 E−06	-	-	5 E+04	-	/T/
I-132	2 E−06	-	-	7 E+04	-	-	T/ /
I-133 (Methyl)	9 E−08	-	-	3 E+03	-	-	T/ /

Radionuclide	Absorption Type[3] µCi/mL			Absorption Type[3] Bq/m^3			Stochastic or organ or tissue[1]
	F	M	S	F	M	S	(F/ M/ S)
I-133 (Vapor)	-	7 E−08	-	-	2 E+03	-	/T/
I-133	1 E−07	-	-	5 E+03	-	-	T/ /
I-134 (Methyl)	8 E−06	-	-	2 E+05	-	-	T/ /
I-134 (Vapor)	-	3 E−06	-	-	1 E+05	-	/St/
I-134	3 E−06	-	-	1 E+05	-	-	ET/ /
I-135 (Methyl)	4 E−07	-	-	1 E+04	-	-	T/ /
I-135 (Vapor)	-	3 E−07	-	-	1 E+04	-	/T/
I-135	6 E−07	-	-	2 E+04	-	-	T/ /
Cs-125	1 E−05	-	-	4 E+05	-	-	ET/ /
Cs-127	4 E−06	-	-	1 E+05	-	-	ET/ /
Cs-129	2 E−06	-	-	9 E+04	-	-	ET/ /
Cs-130	1 E−05	-	-	6 E+05	-	-	ET/ /
Cs-131	7 E−06	-	-	2 E+05	-	-	ET/ /
Cs-132	9 E−07	-	-	3 E+04	-	-	ET/ /
Cs-134m	8 E−06	-	-	2 E+05	-	-	ET/ /
Cs-134	5 E−08	-	-	2 E+03	-	-	St/ /
Cs-135m	8 E−06	-	-	2 E+05	-	-	ET/ /
Cs-135	5 E−07	-	-	2 E+04	-	-	St/ /
Cs-136	2 E−07	-	-	1 E+04	-	-	E/ /
Cs-137	8 E−08	-	-	3 E+03	-	-	St/ /
Cs-138	5 E−06	-	-	2 E+05	-	-	ET/ /
Ba-126	4 E−06	-	-	1 E+05	-	-	ET/ /
Ba-128	4 E−07	-	-	1 E+04	-	-	St/ /
Ba-131m	4 E−05	-	-	1 E+06	-	-	ET/ /
Ba-131	1 E−06	-	-	4 E+04	-	-	ET/ /
Ba-133m	2 E−06	-	-	7 E+04	-	-	St/ /
Ba-133	3 E−07	-	-	1 E+04	-	-	St/ /
Ba-135m	2 E−06	-	-	9 E+04	--	-	St/ /

Radionuclide	Absorption Type[3] µCi/mL			Absorption Type[3] Bq/m^3			Stochastic or organ or tissue[1]
	F	M	S	F	M	S	(F/ M/ S)
Ba-139	1 E−05	-	-	3 E+05	-	-	St/ /
Ba-140	3 E−07	-	-	1 E+04	-	-	St/ /
Ba-141	1 E−05	-	-	4 E+05	-	-	ET/ /
Ba-142	9 E−06	-	-	3 E+05	-	-	ET/ /
La-131	1 E−05	8 E−06	-	4 E+05	3 E+05	-	ET/ET/
La-132	1 E−06	1 E−06	-	5 E+04	5 E+04	-	ET/ET/
La-135	1 E−05	1 E−05	-	4 E+05	4 E+05	-	ET/ET/
La-137	4 E−08	2 E−07	-	1 E+03	8 E+03	-	L/L/
La-138	3 E−09	1 E−08	-	1 E+02	4 E+02	-	St/St/
La-140	4 E−07	3 E−07	-	1 E+04	1 E+04	-	ET/St/
La-141	5 E−06	2 E−06	-	1 E+05	9 E+04	-	St/St/
La-142	2 E−06	2 E−06	-	9 E+04	8 E+04	-	ET/ET/
La-143	1 E−05	1 E−05	-	6 E+05	4 E+05	-	ET/ET/
Ce-134	-	3 E−07	3 E−07	-	1 E+04	1 E+04	/St/St
Ce-135	-	5 E−07	5 E−07	-	2 E+04	2 E+04	/ET/ET
Ce-137m	-	1 E−06	9 E−07	-	3 E+04	3 E+04	/St/St
Ce-137	-	1 E−05	1 E−05	-	7 E+05	7 E+05	/ET/ET
Ce-139	-	4 E−07	4 E−07	-	1 E+04	1 E+04	/St/St
Ce-141	-	2 E−07	1 E−07	-	7 E+03	6 E+03	/St/St
Ce-143	-	5 E−07	5 E−07	-	2 E+04	2 E+04	/St/St
Ce-144	-	2 E−08	1 E−08	-	9 E+02	7 E+02	/St/St
Pr-136	-	1 E−05	1 E−05	-	3 E+05	3 E+05	/ET/ET
Pr-137	-	9 E−06	9 E−06	-	3 E+05	3 E+05	/ET/ET
Pr-138m	-	2 E−06	2 E−06	-	7 E+04	7 E+04	/ET/ET
Pr-139	-	1 E−05	1 E−05	-	5 E+05	5 E+05	/ET/ET
Pr-142m	-	6 E−05	5 E−05	-	2 E+06	2 E+06	/St/St
Pr-142	-	8 E−07	7 E−07	-	2 E+04	2 E+04	/St/St
Pr-143	-	2 E−07	2 E−07	-	1 E+04	9 E+03	/St/St

Radionuclide	Absorption Type[3] µCi/mL			Absorption Type[3] Bq/m[3]			Stochastic or organ or tissue[1]
	F	M	S	F	M	S	(F/ M/ S)
Pr-144	-	1 E−05	1 E−05	-	4 E+05	4 E+05	/ET/ET
Pr-145	-	2 E−06	2 E−06	-	8 E+04	8 E+04	/St/St
Pr-147	-	9 E−06	9 E−06	-	3 E+05	3 E+05	/ET/ET
Nd-136	-	4 E−06	4 E−06	-	1 E+05	1 E+05	/ET/ET
Nd-138	-	1 E−06	1 E−06	-	5 E+04	5 E+04	/St/St
Nd-139m	-	1 E−06	1 E−06	-	5 E+04	5 E+04	/ET/ET
Nd-139	-	1 E−05	1 E−05	-	6 E+05	6 E+05	/ET/ET
Nd-141	-	3 E−05	3 E−05	-	1 E+06	1 E+06	/ET/ET
Nd-147	-	2 E−07	2 E−07	-	1 E+04	9 E+03	/St/St
Nd-149	-	4 E−06	4 E−06	-	1 E+05	1 E+05	/ET/ET
Nd-151	-	9 E−06	9 E−06	-	3 E+05	3 E+05	/ET/ET
Pm-141	-	1 E−05	1E−05	-	4 E+05	4 E+05	/ET/ET
Pm-143	-	5 E−07	6 E−07	-	2 E+04	2 E+04	/St/St
Pm-144	-	1 E−07	1 E−07	-	3 E+03	5 E+03	/St/St
Pm-145	-	1 E−07	4 E−07	-	5 E+03	1 E+04	/BS/St
Pm-146	-	4 E−08	6 E−08	-	1 E+03	2 E+03	/St/St
Pm-147	-	1 E−07	1 E−07	-	4 E+03	6 E+03	/BS/St
Pm-148m	-	1 E−07	1 E−07	-	5 E+03	4 E+03	/St/St
Pm-148	-	2 E−07	2 E−07	-	9 E+03	9 E+03	/St/St
Pm-149	-	7 E−07	6 E−07	-	2 E+04	2 E+04	/St/St
Pm-150	-	2 E−06	2 E−06	-	8 E+04	8 E+04	/ET/ET
Pm-151	-	9 E−07	8 E−07	-	3 E+04	3 E+04	/St/St
Sm-141m	-	5 E−06	-	-	2 E+05	-	/ET/
Sm-141	-	1 E−05	-	-	4 E+05	-	/ET/
Sm-142	-	4 E−06	-	-	1 E+05	-	/ET/
Sm-145	-	4 E−07	-	-	1 E+04	-	/BS/
Sm-146	-	2 E−11	-	-	1 E+00	-	/BS/
Sm-147	-	2 E−11	-	-	1 E+00	-	/BS/

Radionuclide	Absorption Type[3] µCi/mL			Absorption Type[3] Bq/m^3			Stochastic or organ or tissue[1]
	F	M	S	F	M	S	(F/ M/ S)
Sm-151	-	7 E−08	-	-	2 E+03	-	/BS/
Sm-153	-	8 E−07	-	-	3 E+04	-	/St/
Sm-155	-	1 E−05	-	-	3 E+05	-	/ET/
Sm-156	-	2 E−06	-	-	7 E+04	-	/St/
Eu-145	-	5 E−07	-	-	2 E+04	-	/ET/
Eu-146	-	3 E−07	-	-	1 E+04	-	/ET/
Eu-147	-	5 E−07	-	-	2 E+04	-	/St/
Eu-148	-	2 E−07	-	-	9 E+03	-	/St/
Eu-149	-	2 E−06	-	-	9 E+04	-	/St/
Eu-150 (12 h)	-	2 E−06	-	-	7 E+04	-	/St/
Eu-150 (34 yr)	-	1 E−08	-	-	6 E+02	-	/St/
Eu-152m	-	1 E−06	-	-	6 E+04	-	/St/
Eu-152	-	2 E−08	-	-	7 E+02	-	/St/
Eu-154	-	1 E−08	-	-	5 E+02	-	/St/
Eu-155	-	7 E−08	-	-	2 E+03	-	/BS/
Eu-156	-	1 E−07	-	-	6 E+03	-	/St/
Eu-157	-	1 E−06	-	-	4 E+04	-	/St/
Eu-158	-	5 E−6	-	-	1 E+05	-	/ET/
Gd-145	9 E−06	7 E−06	-	3 E+05	2 E+05	-	ET/ET/
Gd-146	1 E−07	1 E−07	-	4 E+03	4 E+03	-	St/St/
Gd-147	7 E−07	6 E−07	-	2 E+04	2 E+04	-	ET/ET/
Gd-148	5 E−12	2 E−11	-	2 E−01	9 E−01	-	BS/BS/
Gd-149	1 E−06	7 E−07	-	4 E+04	2 E+04	-	ET/ET/
Gd-151	2 E−07	8 E−07	-	9 E+03	3 E+04	-	BS/St/
Gd-152	7 E−12	3 E−11	-	2 E−01	1 E+00	-	BS/BS/
Gd-153	9 E−08	4 E−07	-	3 E+03	1 E+04	-	BS/St/
Gd-159	3 E−06	1 E−06	-	1 E+05	5 E+04	-	St/St/
Tb-147	-	2 E−06	-	-	1 E+05	-	/ET/

Radionuclide	Absorption Type[3] µCi/mL			Absorption Type[3] Bq/m^3			Stochastic or organ or tissue[1]
	F	M	S	F	M	S	(F/ M/ S)
Tb-149	-	1 E−07	-	-	6 E+03	-	/St/
Tb-150	-	2 E−06	-	-	8 E+04	-	/ET/
Tb-151	-	1 E−06	-	-	4 E+04	-	/ET/
Tb-153	-	2 E−06	-	-	8 E+04	-	/St/
Tb-154	-	5 E−07	-	-	2 E+04	-	/ET/
Tb-155	-	2 E−06	-	-	8 E+04	-	/St/
Tb-156m (24 h)	-	2 E−06	-	-	9 E+04	-	/St/
Tb-156m (5 h)	-	4 E−06	-	-	1 E+05	-	/St/
Tb-156	-	4 E−07	-	-	1 E+04	-	/E/
Tb-157	-	2 E−07	-	-	8 E+03	-	/BS/
Tb-158	-	1 E−08	-	-	6 E+02	-	/BS/
Tb-160	-	1 E−07	-	-	3 E+03	-	/St/
Tb-161	-	4 E−07	-	-	1 E+04	-	/St/
Dy-155	-	2 E−06	-	-	1 E+05	-	/ET/
Dy-157	-	5 E−06	-	-	1 E+05	-	/ET/
Dy-159	-	2 E−06	-	-	8 E+04	-	/BS/
Dy-165	-	6 E−06	-	-	2 E+05	-	/ET/
Dy-166	-	3 E−07	-	-	1 E+04	-	/St/
Ho-155	-	1 E−05	-	-	4 E+05	-	/ET/
Ho-157	-	2 E−05	-	-	1 E+06	-	/ET/
Ho-159	-	2 E−05	-	-	9 E+05	-	/ET/
Ho-161	-	3 E−05	-	-	1 E+06	-	/ET/
Ho-162m	-	9 E−06	-	-	3 E+05	-	/ET/
Ho-162	-	5 E−05	-	-	2 E+06	-	/ET/
Ho-164m	-	3 E−05	-	-	1 E+06	-	/St/
Ho-164	-	2 E−05	-	-	8 E+05	-	/ET/
Ho-166m	-	7 E−09	-	-	2 E+02	-	/St/
Ho-166	-	6 E−07	-	-	2 E+04	-	/St/

Radionuclide	Absorption Type[3] µCi/mL			Absorption Type[3] Bq/m^3			Stochastic or organ or tissue[1]
	F	M	S	F	M	S	(F/ M/ S)
Ho-167	-	4 E−06	-	-	1 E+05	-	/ET/
Er-161	-	3 E−06	-	-	1 E+05	-	/ET/
Er-165	-	2 E−05	-	-	1 E+06	-	/ET/
Er-169	-	6 E−07	-	-	2 E+04	-	/St/
Er-171	-	1 E−06	-	-	6 E+04	-	/St/
Er-172	-	4 E−07	-	-	1 E+04	-	/St/
Tm-162	-	9 E−06	-	-	3E+05	-	/ET/
Tm-166	-	1 E−06	-	-	4 E+04	-	/ET/
Tm-167	-	5 E−07	-	-	2 E+04	-	/St/
Tm-170	-	1 E−07	-	-	4 E+03	-	/St/
Tm-171	-	2 E−07	-	-	9 E+03	-	/BS/
Tm-172	-	4 E−07	-	-	1 E+04	-	/St/
Tm-173	-	2 E−06	-	-	8 E+04	-	/St/
Tm-175	-	8 E−06	-	-	2 E+05	-	/ET/
Yb-162	-	1 E−05	1 E−05	-	5 E+05	5 E+05	/ET/ET
Yb-166	-	6 E−07	5 E−07	-	2 E+04	2 E+04	/St/St
Yb-167	-	3 E−05	3 E−05	-	1 E+06	1 E+06	/ET/ET
Yb-169	-	2 E−07	2 E−07	-	9 E+03	8 E+03	/St/St
Yb-175	-	8 E−07	8 E−07	-	3 E+04	2 E+04	/St/St
Yb-177	-	6 E−06	5 E−06	-	2 E+05	2 E+05	/ET/ET
Yb-178	-	5 E−06	5 E−06	-	1 E+05	1 E+05	/ET/E
Lu-169	-	9 E−07	9 E−07	-	3 E+04	3 E+04	/ET/ET
Lu-170	-	4 E−07	4 E−07	-	1 E+04	1 E+04	/ET/ET
Lu-171	-	6 E−07	6 E−07	-	2 E+04	2 E+04	/St/St
Lu-172	-	3 E−07	3 E−07	-	1 E+04	1 E+04	/St/St
Lu-173	-	2 E−07	4 E−07	-	8 E+03	1 E+04	/BS/St
Lu-174m	-	2 E−07	2 E−07	-	7 E+03	8 E+03	/BS/St
Lu-174	-	9 E−08	2 E−07	-	3 E+03	8 E+03	/BS/St

Radionuclide	Absorption Type[3] µCi/mL			Absorption Type[3] Bq/m^3			Stochastic or organ or tissue[1]
	F	M	S	F	M	S	(F/ M/ S)
Lu-176m	-	3 E−06	3 E−06	-	1 E+05	1 E+05	/St/St
Lu-176	-	3 E−09	1 E−08	-	1 E+02	6 E+02	/BS/St
Lu-177m	-	5 E−08	4 E−08	-	2 E+03	1 E+03	/St/St
Lu-177	-	5 E−07	5 E−07	-	2 E+04	1 E+04	/St/St
Lu-178m	-	4 E−06	4 E−06	-	1 E+05	1 E+05	/ET/ET
Lu-178	-	8 E−06	8 E−06	-	3 E+05	3 E+05	/ET/ET
Lu-179	-	3 E−06	3 E−06	-	1 E+05	1 E+05	/St/St
Hf-170	1 E−06	1 E−06	-	4 E+04	4 E+04	-	ET/ET/
Hf-172	6 E−09	3 E−08	-	2 E+02	1 E+03	-	BS/BS/
Hf-173	2 E−06	2 E−06	-	9 E+04	8 E+04	-	ET/ET/
Hf-175	5 E−07	6 E−07	-	2 E+04	2 E+04	-	BS/St/
Hf-177m	2 E−06	1 E−06	-	9 E+04	6 E+04	-	ET/ET/
Hf-178m	8 E−10	4 E−09	-	3 E+01	1 E+02	-	BS/BS/
Hf-179m	2 E−07	1 E−07	-	8 E+03	6 E+03	-	BS/St/
Hf-180m	2 E−06	1 E−06	-	7 E+04	6 E+04	-	ET/ET/
Hf-181	1 E−07	1 E−07	-	4 E+03	5 E+03	-	BS/St/
Hf-182m	5 E−06	4 E−06	-	2 E+05	1 E+05	-	ET/ET/
Hf-182	5 E−10	2 E−09	-	2 E+01	9 E+01	-	BS/BS/
Hf-183	6 E−06	4 E−06	-	2 E+05	1 E+05	-	ET/ET/
Hf-184	1 E−06	1 E−06	-	5 E+04	4 E+04	-	ET/St/
Ta-172	-	5 E−06	5 E−06	-	1 E+05	1 E+05	/ET/ET
Ta-173	-	3 E−06	3 E−06	-	1 E+05	1 E+05	/E/E
Ta-174	-	5 E−06	5 E−06	-	2 E+05	2 E+05	/ET/ET
Ta-175	-	1 E−06	1 E−06	-	6 E+04	6 E+04	/ET/ET
Ta-176	-	1 E−06	1 E−06	-	3 E+04	3 E+04	/ET/ET
Ta-177	-	4 E−06	4 E−06	-	1 E+05	1 E+05	/St/St
Ta-178	-	3 E−06	3 E−06	-	1 E+05	1 E+05	/ET/ET
Ta-179	-	4 E−06	1 E−06	-	1 E+05	7 E+04	/St/St

Radionuclide	Absorption Type[3] µCi/mL			Absorption Type[3] Bq/m^3			Stochastic or organ or tissue[1]
	F	M	S	F	M	S	(F/ M/ S)
Ta-180m	-	9 E−06	9 E−06	-	3 E+05	3 E+05	/St/St
Ta-180	-	1 E−07	4 E−08	-	4 E+03	1 E+03	/St/St
Ta-182m	-	6 E−06	6 E−06	-	2 E+05	2 E+05	/ET/ET
Ta-182	-	9 E−08	7 E−08	-	3 E+03	2 E+03	/St/St
Ta-183	-	3 E−07	2 E−07	-	1 E+04	1 E+04	/St/St
Ta-184	-	8 E−07	8 E−07	-	3 E+04	3 E+04	/ET/ET
Ta-185	-	5 E−06	5 E−06	-	2 E+05	1 E+05	/ET/ET
Ta-186	-	7 E−06	7 E−06	-	2 E+05	2 E+05	/ET/ET
W-176	3 E−06	-	-	1 E+05	-	-	ET/ /
W-177	5 E−06	-	-	2 E+05	-	-	ET/ /
W-178	3 E−06	-	-	1 E+05	-	-	ET/ /
W-179	1 E−04	-	-	5 E+06	-	-	ET/ /
W-181	1 E−05	-	-	4 E+05	-	-	ET/ /
W-185	2 E−06	-	-	9 E+04	-	-	St/ /
W-187	1 E−06	-	-	5 E+04	-	-	ET/ /
W-188	6 E−07	-	-	2 E+04	-	-	St/ /
Re-177	1 E−05	1 E−05	-	6 E+05	4 E+05	-	ET/ET/
Re-178	1 E−05	1 E−05	-	5 E+05	3 E+05	-	ET/ET/
Re-181	1 E−06	1 E−06	-	5 E+04	4 E+04	-	ET/ET/
Re-182 (64 h)	4 E−07	3 E−07	-	1 E+04	1 E+04	-	ET/St/
Re-182 (12 h)	1 E−06	1 E−06	-	4 E+04	4 E+04	-	ET/ET/
Re-184m	6 E−07	1 E−07	-	2 E+04	4 E+03	-	St/St/
Re-184	7 E−07	3 E−07	-	2 E+04	1 E+04	-	ET/St/
Re-186m	4 E−7	7 E−08	-	1 E+04	2 E+03	-	St/St/
Re-186	7 E−07	4 E−07	-	2 E+04	1 E+04	-	St/St/
Re-187	2 E−04	1 E−04	-	8 E+06	4 E+06	-	St/St/
Re-188m	3 E−05	2 E−05	-	1 E+06	1 E+06	-	St/St/
Re-188	8 E−07	7 E−07	-	3 E+04	2 E+04	-	St/St/

Radionuclide	Absorption Type[3] µCi/mL			Absorption Type[3] Bq/m^3			Stochastic or organ or tissue[1]
	F	M	S	F	M	S	(F/ M/ S)
Re-189	1 E−06	9 E−07	-	4 E+04	3 E+04	-	St/St/
Os-180	1 E−05	1 E−05	1 E−05	5 E+05	3 E+05	3 E+05	ET/ET/ET
Os-181	3 E−06	3 E−06	3 E−06	1 E+05	1 E+05	1 E+05	ET/ET/ET
Os-182	1 E−06	9 E−07	9 E−07	3 E+04	3 E+04	3 E+04	ET/ET/ET
Os-185	4 E−07	5 E−07	5 E−07	1 E+04	2 E+04	1 E+04	St/St/St
Os-189m	1 E−04	7 E−05	7 E−05	4 E+06	2 E+06	2 E+06	St/St/St
Os-191m	1 E−05	4 E−06	4 E−06	5 E+05	1 E+05	1 E+05	St/St/St
Os-191	1 E−06	4 E−07	3 E−07	5 E+04	1 E+04	1 E+04	St/St/St
Os-193	2 E−06	8 E−07	8 E−07	7 E+04	3 E+04	3 E+04	St/St/St
Os-194	4 E−08	4 E−08	1 E−08	1 E+03	1 E+03	4 E+02	St/St/St
Ir-182	9 E−06	7 E−06	7 E−06	3 E+05	2 E+05	2 E+05	ET/ET/ET
Ir-184	1 E−06	1 E−06	1 E−06	7 E+04	6 E+04	7 E+04	ET/ET/ET
Ir-185	2 E−06	1 E−06	1 E−06	7 E+04	7 E+04	7 E+04	ET/ET/ET
Ir-186 (16 h)	8 E−07	7 E−07	7 E−07	2 E+04	2 E+04	2 E+04	ET/ET/ET
Ir-186 (2 h)	5 E−06	4 E−06	4 E−06	1 E+05	1 E+05	1 E+05	ET/ET/ET
Ir-187	4 E−06	3 E−06	3 E−06	1 E+05	1 E+05	1 E+05	ET/ET/ET
Ir-188	6 E−07	6 E−07	6 E−07	2 E+04	2 E+04	2 E+04	ET/ET/ET
Ir-189	3 E−06	1 E−06	1 E−06	1 E+05	5 E+04	4 E+04	St/St/St
Ir-190m (3 h)	2 E−06	2 E−06	2 E−06	8 E+04	8 E+04	7 E+04	ET/ET/ET
Ir-190m (1 h)	9 E−05	5 E−05	5 E−05	3 E+06	2 E+06	1 E+06	ET/St/St
Ir-190	4 E−07	2 E−07	2 E−07	1 E+04	9 E+03	8 E+03	ET/St/St
Ir-192m	1 E−07	1 E−07	2 E−08	3 E+03	6 E+03	1 E+03	St/St/St
Ir-192	2 E−07	1 E−07	1 E−07	9 E+03	5 E+03	4 E+03	St/St/St
Ir-194m	8 E−08	8 E−08	6 E−08	3 E+03	3 E+03	2 E+03	St/St/St
Ir-194	1 E−06	7 E−07	7 E−07	5 E+04	2 E+04	2 E+04	St/St/St
Ir-195m	2 E−06	2 E−06	2 E−06	9 E+04	7 E+04	7 E+04	ET/ET/ET
Ir-195	7 E−06	5 E−06	4 E−06	2 E+05	1 E+05	1 E+05	ET/ET/ET
Pt-186	3 E−06	-	-	1 E+05	-	-	ET/ /

Radionuclide	Absorption Type[3] µCi/mL			Absorption Type[3] Bq/m^3			Stochastic or organ or tissue[1]
	F	M	S	F	M	S	(F/ M/ S)
Pt-188	8 E−07	-	-	3 E+04	-	-	E/ /
Pt-189	3 E−06	-	-	1 E+05	-	-	ET/ /
Pt-191	1 E−06	-	-	7 E+04	-	-	ET/ /
Pt-193m	2 E−06	-	-	8 E+04	-	-	ET/ /
Pt-193	2 E−05	-	-	7 E+05	-	-	ET/ /
Pt-195m	1 E−06	-	-	5 E+04	-	-	ET/ /
Pt-197m	7 E−06	-	-	2 E+05	-	-	ET/ /
Pt-197	3 E−06	-	-	1 E+05	-	-	ET/ /
Pt-199	1 E−05	-	-	4 E+05	-	-	ET/ /
Pt-200	1 E−06	-	-	5 E+04	-	-	St/ /
Au-193	4 E−06	3 E−06	3 E−06	1 E+05	1 E+05	1 E+05	ET/E/St
Au-194	9 E−07	9 E−07	9 E−07	3 E+04	3 E+04	3 E+04	ET/ET/ET
Au-195	3 E−06	7 E−07	4 E−07	1 E+05	2 E+04	1 E+04	ET/St/St
Au-198m	6 E−07	2 E−07	2 E−07	2 E+04	1 E+04	1 E+04	ET/St/St
Au-198	1 E−06	5 E−07	5 E−07	4 E+04	2 E+04	1 E+04	ET/St/St
Au-199	2 E−06	8 E−07	7 E−07	7 E+04	3 E+04	2 E+04	ET/St/St
Au-200m	5 E−07	4 E−07	4 E−07	1 E+04	1 E+04	1 E+04	ET/ET/ET
Au-200	1 E−05	7E−06	7 E−06	4 E+05	2 E+05	2 E+05	ET/ET/ET
Au-201	1 E−05	1 E−05	9 E−06	5 E+05	3 E+05	3 E+05	ET/ET/ET
Hg-193m (Org)	1 E−06	-	-	4 E+04	-	-	ET/ /
Hg-193m	1 E−06	1 E−06	-	4 E+04	4 E+04	-	ET/ET/
Hg-193m (Vapor)	-	1 E−07	-	-	6 E+03	-	/St/
Hg-193 (Org)	5 E−06	-	-	1 E+05	-	-	ET/ /
Hg-193	5 E−06	4 E−06	-	1 E+05	1 E+05	-	ET/ET/
Hg-193 (Vapor)	-	5 E−07	-	-	1 E+04	-	/St/
Hg-194 (Org)	2 E−08	-	-	1 E+03	-	-	St/ /
Hg-194	3 E−08	1 E−07	-	1 E+03	3 E+03	-	St/St/
Hg-194 (Vapor)	-	1 E−08	-	-	5 E+02	-	/St/

Radionuclide	Absorption Type[3] µCi/mL			Absorption Type[3] Bq/m^3			Stochastic or organ or tissue[1]
	F	M	S	F	M	S	(F/ M/ S)
Hg-195m (Org)	1 E−06	-	-	5 E+04	-	-	ET/ /
Hg-195m	1 E−06	8 E−07	-	5 E+04	3 E+04	-	ET/St/
Hg-195m (Vapor)	-	6 E−08	-	-	2 E+03	-	/St/
Hg-195 (Org)	6 E−06	-	-	2 E+05	-	-	ET/ /
Hg-195	6 E−06	6 E−06	-	2 E+05	2 E+05	-	ET/ET/
Hg-195 (Vapor)	-	4 E−07	-	-	1 E+04	-	/St/
Hg-197m (Org)	1 E−06	-	-	5 E+04	-	-	ET/ /
Hg-197m	1 E−06	8 E−07	-	5 E+04	3 E+04	-	ET/St/
Hg-197m (Vapor)	-	9 E−08	-	-	3 E+03	-	/St/
Hg-197 (Org)	4 E−06	-	-	1 E+05	-	-	ET/ /
Hg-197	4 E−06	2 E−06	-	1 E+05	7 E+04	-	ET/St/
Hg-197 (Vapor)	-	1 E−07	-	-	4 E+03	-	/St/
Hg-199m (Org)	8 E−06	-	-	3 E+05	-	-	ET/ /
Hg-199m	8 E−06	5 E−06	-	3 E+05	1 E+05	-	ET/ET/
Hg-199m (Vapor)	-	3 E−06	-	-	1 E+05	-	/St/
Hg-203 (Org)	7 E−07	-	-	2 E+04	-	-	St/ /
Hg-203	9 E−07	2 E−07	-	3 E+04	1 E+04	-	St/St/
Hg-203 (Vapor)	-	8 E−08	-	-	2 E+03	-	/St/
Tl-194m	5 E−06	-	-	2 E+05	-	-	ET/ /
Tl-194	2 E−05	-	-	8 E+05	-	-	ET/ /
Tl-195	6 E−06	-	-	2 E+05	-	-	ET/ /
Tl-197	8 E−06	-	-	2 E+05	-	-	ET/ /
Tl-198m	2 E−06	-	-	9 E+04	-	-	ET/ /
Tl-198	1 E−06	-	-	5 E+04	-	-	ET/ /
Tl-199	5 E−06	-	-	2 E+05	-	-	ET/ /
Tl-200	8 E−07	-	-	3 E+04	-	-	ET/ /
Tl-201	4 E−06	-	-	1 E+05	-	-	ET/ /
Tl-202	1 E−06	-	-	5 E+04	-	-	ET/ /

Radionuclide	Absorption Type[3] µCi/mL			Absorption Type[3] Bq/m^3			Stochastic or organ or tissue[1]
	F	M	S	F	M	S	(F/ M/ S)
Tl-204	9 E−07	-	-	3 E+04	-	-	St/ /
Pb-195m	7 E−06	-	-	2 E+05	-	-	ET/ /
Pb-198	2 E−06	-	-	9 E+04	-	-	ET/ /
Pb-199	4 E−06	-	-	1 E+05	-	-	ET/ /
Pb-200	1 E−06	-	-	4 E+04	-	-	ET/ /
Pb-201	2 E−06	-	-	7 E+04	-	-	ET/ /
Pb-202m	1 E−06	-	-	6 E+04	-	-	ET/ /
Pb-202	4 E−08	-	-	1 E+03	-	-	St/ /
Pb-203	2 E−06	-	-	7 E+04	-	-	ET/ /
Pb-205	9 E−07	-	-	3 E+04	-	-	BS/ /
Pb-209	9 E−06	-	-	3 E+05	-	-	ET/ /
Pb-210	1 E−10	-	-	5 E+00	-	-	BS/ /
Pb-211	4 E−08	-	-	1 E+03	-	-	ET/ /
Pb-212	5 E−09	-	-	2 E+02	-	-	ET/ /
Pb-214	4 E−08	-	-	1 E+03	-	-	ET/ /
Bi-200	5 E−06	4 E−06	-	2 E+05	1 E+05	-	ET/ET/
Bi-201	3 E−06	2 E−06	-	1 E+05	1 E+05	-	ET/ET/
Bi-202	2 E−06	2 E−06	-	9 E+04	9 E+04	-	ET/ET/
Bi-203	7 E−07	7 E−07	-	2 E+04	2 E+04	-	ET/ET/
Bi-205	4 E−07	4 E−07	-	1 E+04	1 E+04	-	ET/ET/
Bi-206	2 E−07	2 E−07	-	9 E+03	8 E+03	-	ET/ET/
Bi-207	4 E−07	1 E−07	-	1 E+04	6 E+03	-	ET/St/
Bi-210m	3 E−09	2 E−10	-	1 E+02	9 E+00	-	K/St/
Bi-210	1 E−07	9 E−09	-	6 E+03	3 E+02	-	K/St/
Bi-212	1 E−08	8 E−09	-	4 E+02	3 E+02	-	ET/ET/
Bi-213	1 E−08	7 E−09	-	4 E+02	2 E+02	-	ET/ET/
Bi-214	1 E−08	1 E−08	-	6 E+02	4 E+02	-	ET/ET/
Po-203	5 E−06	4 E−06	-	1 E+05	1 E+05	-	ET/ET/

Radionuclide	Absorption Type[3] µCi/mL			Absorption Type[3] Bq/m^3			Stochastic or organ or tissue[1]
	F	M	S	F	M	S	(F/ M/ S)
Po-205	4 E−06	3 E−06	-	1 E+05	1 E+05	-	ET/ET/
Po-207	1 E−06	1 E−06	-	7 E+04	6 E+04	-	ET/ET/
Po-210	7 E−10	2 E−10	-	2 E+01	9 E+00	-	K/St/
At-207	1 E−06	2 E−07	-	4 E+04	1 E+04	-	St/St/
At-211	7 E−09	5 E−09	-	2 E+02	1 E+02	-	ET/St/
Rn-220[5]	1 E−08	-	-	6 E+02	-	-	-
Rn-222[5]	8 E−08	-	-	3 E+03	-	-	-
Fr-222	1 E−08	-	-	3 E+02	-	-	ET/ /
Fr-223	4 E−07	-	-	1 E+04	-	-	St/ /
Ra-223	-	9 E−11	-	-	3 E+00	-	/St/
Ra-224	-	2 E−10	-	-	8 E+00	-	/St/
Ra-225	-	1 E−10	-	-	4 E+00	-	/St/
Ra-226	-	2 E−10	-	-	9 E+00	-	/St/
Ra-227	-	8 E−07	-	-	3 E+04	-	/BS/
Ra-228	-	1 E−10	-	-	5 E+00	-	/BS/
Ac-224	1 E−08	6 E−09	5 E−09	6 E+02	2 E+02	2 E+02	BS/St/St
Ac-225	2 E−10	9 E−11	8 E−11	7 E+00	3 E+00	3 E+00	BS/St/St
Ac-226	1 E−09	6 E−10	5 E−10	4 E+01	2 E+01	2 E+01	ET/St/St
Ac-227	2 E−13	1 E−12	1 E−11	1 E−02	5 E−02	4 E−01	BS/BS/St
Ac-228	6 E−09	3 E−08	4 E−08	2 E+02	1 E+03	1 E+03	BS/BS/St
Th-226	-	4 E−09	4 E−09	-	1 E+02	1 E+02	/ET/ET
Th-227	-	9 E−11	7 E−11	-	3 E+00	2 E+00	/St/St
Th-228	-	2 E−11	2 E−11	-	7 E−01	8 E−01	/BS/St
Th-229	-	2 E−12	1 E−11	-	7 E−02	4 E−01	/BS/St
Th-230	-	3 E−12	4 E−11	-	1 E−01	1 E+00	/BS/BS
Th-231	-	1 E−06	1 E−06	-	5 E+04	5 E+04	/St/St
Th-232	-	3 E−12	4 E−11	-	1 E−01	1 E+00	/BS/BS
Th-234	-	1 E−07	9 E−08	-	3 E+03	3 E+03	/St/St

Radionuclide	Absorption Type[3] µCi/mL			Absorption Type[3] Bq/m[3]			Stochastic or organ or tissue[1]
	F	M	S	F	M	S	(F/ M/ S)
Pa-227	-	4 E−09	4 E−09	-	1 E+02	1 E+02	/ET/ET
Pa-228	-	1 E−08	1 E−08	-	3 E+02	4 E+02	/BS/St
Pa-230	-	1 E−09	9 E−10	-	4 E+01	3 E+01	/St/St
Pa-231	-	1 E−12	1 E−11	-	4 E−02	4 E−01	/BS/BS
Pa-232	-	1 E−08	1 E−07	-	6 E+02	7 E+03	/BS/BS
Pa-233	-	2 E−07	1 E−07	-	7 E+03	6 E+03	/St/St
Pa-234	-	7 E−07	7 E−07	-	2 E+04	2 E+04	/ET/ET
U-230	6 E−10	5 E−11	4 E−11	2 E+01	2 E+00	1 E+00	K/St/St
U-231	2 E−06	1 E−06	1 E−06	8 E+04	4 E+04	4 E+04	ET/St/St
U-232	5 E−11	1 E−10	2 E−11	2 E+00	4 E+00	7 E−01	BS/St/ET
U-233	4 E−10	2 E−10	7 E−11	1 E+01	9 E+00	2 E+00	BS/St/ET
U-234	5 E−10	2 E−10	7 E−11	1 E+01	9 E+00	2 E+00	BS/St/ET
U-235	5 E−10	3 E−10	8 E−11	1 E+01	1 E+01	3 E+00	BS/St/ET
U-236	5 E−10	2 E−10	7 E−11	1 E+01	1 E+01	2 E+00	BS/St/ET
U-237	1 E−06	3 E−07	3 E−07	4 E+04	1 E+04	1 E+04	ET/St/St
U-238	5 E−10	3 E−10	8 E−11	2 E+01	1 E+01	3 E+00	BS/St/ET
U-239	1 E−05	9 E−06	9 E−06	5 E+05	3 E+05	3 E+05	ET/ET/ET
U-240	1 E−06	7 E−07	6 E−07	5 E+04	2 E+04	2 E+04	ET/St/St
Np-232	-	3 E−06	-	-	1 E+05	-	/BS/
Np-233	-	7 E−05	-	-	2 E+06	-	/ET/
Np-234	-	5 E−07	-	-	2 E+04	-	/ET/
Np-235	-	1 E−06	-	-	4 E+04	-	/BS/
Np-236 (1 E+05 yr)	-	4 E−11	-	-	1 E+00	-	/BS/
Np-236 (22 h)	-	5 E−08	-	-	1 E+03	-	/BS/
Np-237	-	8 E−12	-	-	3 E−01	-	/BS/
Np-238	-	1 E−07	-	-	4 E+03	-	/BS/
Np-239	-	5 E−07	-	-	1 E+04	-	/St/
Np-240	-	2 E−06	-	-	8 E+04	-	/ET/

Radionuclide	Absorption Type[3] µCi/mL			Absorption Type[3] Bq/m^3			Stochastic or organ or tissue[1]
	F	M	S	F	M	S	(F/ M/ S)
Pu-234	-	3 E−08	3 E−08	-	1 E+03	1 E+03	/St/St
Pu-235	-	9 E−05	8 E−05	-	3 E+06	3 E+06	/ET/ET
Pu-236	-	1 E−11	7 E−11	-	6 E−01	2 E+00	/BS/St
Pu-237	-	1 E−06	1 E−06	-	7 E+04	6 E+04	/St/St
Pu-238	-	6 E−12	5 E−11	-	2 E−01	1 E+00	/BS/St
Pu-239	-	5 E−12	6 E−11	-	2 E−01	2 E+00	/BS/BS
Pu-240	-	5 E−12	6 E−11	-	2 E−01	2 E+00	/BS/BS
Pu-241	-	2 E−10	2 E−09	-	1 E+01	1 E+02	/BS/BS
Pu-242	-	5 E−12	6 E−11	-	2 E−01	2 E+00	/BS/BS
Pu-243	-	5 E−06	5 E−06	-	1 E+05	1 E+05	/E/E
Pu-244	-	5 E−12	6 E−11	-	2 E−01	2 E+00	/BS/BS
Pu-245	-	9 E−07	8 E−07	-	3 E+04	3 E+04	/St/St
Pu-246	-	8 E−08	8 E−08	-	3 E+03	2 E+03	/St/St
Am-237	-	8 E−06	-	-	3 E+05	-	/ET/
Am-238	-	2 E−06	-	-	9 E+04	-	/BS/
Am-239	-	1 E−06	-	-	6 E+04	-	/ET/
Am-240	-	7 E−07	-	-	2 E+04	-	/ET/
Am-241	-	5 E−12	-	-	1 E−01	-	/BS/
Am-242m	-	5 E−12	-	-	1 E−01	-	/BS/
Am-242	-	4 E−08	-	-	1 E+03	-	/St/
Am-243	-	5 E−12	-	-	1 E−01	-	/BS/
Am-244m	-	3 E−06	-	-	1 E+05	-	/BS/
Am-244	-	1 E−07	-	-	5 E+03	-	/BS/
Am-245	-	5 E−06	-	-	2 E+05	-	/ET/
Am-246m	-	6 E−06	-	-	2 E+05	-	/ET/
Am-246	-	2 E−06	-	-	9 E+04	-	/ET/
Cm-238	-	1 E−07	-	-	4 E+03	-	/St/
Cm-240	-	2 E−10	-	-	7 E+00	-	/St/

Radionuclide	Absorption Type[3] µCi/mL			Absorption Type[3] Bq/m^3			Stochastic or organ or tissue[1]
	F	M	S	F	M	S	(F/ M/ S)
Cm-241	-	2 E−08	-	-	8 E+02	-	/St/
Cm-242	-	1 E−10	-	-	5 E+00	-	/St/
Cm-243	-	7 E−12	-	-	2 E−01	-	/BS/
Cm-244	-	9 E−12	-	-	3 E−01	-	/BS/
Cm-245	-	5 E−12	-	-	1 E−01	-	/BS/
Cm-246	-	5 E−12	-	-	1 E−01	-	/BS/
Cm-247	-	5 E−12	-	-	2 E−01	-	/BS/
Cm-248	-	1 E−12	-	-	5 E−02	-	/BS/
Cm-249	-	8 E−06	-	-	3 E+05	-	/ET/
Cm-250	-	2 E−13	-	-	8 E−03	-	/BS/
Bk-245	-	3 E−07	-	-	1 E+04	-	/St/
Bk-246	-	8 E−07	-	-	3 E+04	-	/ET/
Bk-247	-	3 E−12	-	-	1 E−01	-	/BS/
Bk-249	-	1 E−09	-	-	5 E+01	-	/BS/
Bk-250	-	2 E−07	-	-	9 E+03	-	/BS/
Cf-244	-	1 E−08	-	-	5 E+02	-	/ET/
Cf-246	-	1 E−09	-	-	5 E+01	-	/St/
Cf-248	-	5 E−11	-	-	2 E+00	-	/BS/
Cf-249	-	3 E−12	-	-	1 E−01	-	/BS/
Cf-250	-	7 E−12	-	-	2 E−01	-	/BS/
Cf-251	-	3 E−12	-	-	1 E−01	-	/BS/
Cf-252	-	1 E−11	-	-	6 E−01	-	/BS/
Cf-253	-	5 E−10	-	-	2 E+01	-	/St/
Cf-254	-	2 E−11	-	-	8 E−01	-	/BS/
Es-250	-	4 E−07	-	-	1 E+04	-	/BS/
Es-251	-	3 E−07	-	-	1 E+04	-	/St/
Es-253	-	2 E−10	-	-	9 E+00	-	/St/
Es-254m	-	1 E−09	-	-	5 E+01	-	/St/

Radionuclide	Absorption Type[3] µCi/mL			Absorption Type[3] Bq/m³			Stochastic or organ or tissue[1]
	F	M	S	F	M	S	(F/ M/ S)
Es-254	-	6 E−11	-	-	2 E+00	-	/BS/
Fm-252	-	2 E−09	-	-	8 E+01	-	/St/
Fm-253	-	1 E−09	-	-	6 E+01	-	/St/
Fm-254	-	6 E−09	-	-	2 E+02	-	/ET/
Fm-255	-	2 E−09	-	-	8 E+01	-	/St/
Fm-257	-	1 E−10	-	-	4 E+00	-	/St/
Md-257	-	2 E−08	-	-	1 E+03	-	/St/
Md-258	-	1 E−10	-	-	4 E+00	-	/St/

[10 CFR 835 Appendix A]

835 **Footnotes for Appendix A (for purposes of this Manual, 10 CFR 835 "Appendix A" corresponds to Appendix 2D of this Manual)**

[1] A determination of whether the DACs are controlled by stochastic (St) or deterministic (organ or tissue) dose, or if they both give the same result (E), for each absorption type, is given in this column. The key to the organ notation for deterministic dose is: BS = Bone surface, ET = Extra thoracic, K = Kidney, L = Liver, and T = Thyroid. A blank indicates that no calculations were performed for the absorption type shown.

[2] The ICRP identifies these materials as soluble or reactive gases and vapors or highly soluble or reactive gases and vapors. For tritiated water, the inhalation DAC values allow for an additional 50% absorption through the skin, as described in ICRP Publication No. 68, Dose Coefficients for Intakes of Radionuclides by Workers. For elemental tritium, the DAC values include a factor that irradiation from gas within the lungs might increase the dose by 20%.

[3] A dash indicates no values given for this data category.

[4] DAC values derived using hafnium tritide particle and are based on "observed activity" (i.e., only radiation emitted from the particle is considered). DAC values derived using methodology found in Radiological Control Programs for Special Tritium Compounds, DOE-HDBK-1184-2004.[18]

[5] These values are appropriate for protection from radon combined with its short-lived decay products and are based on information given in ICRP Publication 65: Protection Against Radon-222 at Home and at Work and in DOE-STD-1121-98: Internal Dosimetry. The values given are for 100% equilibrium concentration conditions of the short-lived radon decay products with the parent. To allow for an actual measured equilibrium concentration or a demonstrated equilibrium concentration, the values given in this table should be multiplied by the ratio (100%/actual %) or (100%/demonstrated %), respectively. Alternatively, the DAC values for Rn-220 and Rn-222 may be replaced by 2.5 working level (WL) and 0.83 WL, respectively, for appropriate limiting of decay product concentrations. A WL is any combination of short-lived radon decay products, in one liter of air without regard to the degree of equilibrium, that will result in the ultimate emission of 1.3 E+05 MeV of alpha energy. [10 CFR 835 Appendix A]

18 Department of Energy Handbook 1184-2004, Change Notice 1, "Radiological Control Programs for Special Tritium Compounds" (DOE-HDBK-1184-2004, Change Notice 1)

Appendix 2E Derived Air Concentrations (DACs) For Workers from External Exposure During Immersion in a Cloud of an Airborne Radioactive Material

a. 835 **The data presented in appendix C are to be used for controlling occupational exposures in accordance with 10 CFR 835.209, identifying the need for air monitoring in accordance with 10 CFR 835.403, and identifying and posting airborne radioactivity areas in accordance with 10 CFR 835.603(d).** For purposes of this *Manual*, "appendix C" in this regulatory citation corresponds to Appendix 2E of this *Manual*.

b. The air immersion DAC values shown in this appendix are based on a stochastic dose limit of 5 rems (0.05 Sv) per year. Four columns of information are presented: (1) radionuclide; (2) half-life in units of seconds (s), minutes (min), hours (h), days (d), or years (yr); (3) air immersion DAC units of µCi/ml; and (4) air immersion DAC units of Bq/m^3. The data are listed by radionuclide in order of increasing atomic mass. The air immersion DACs were calculated for a continuous, non-shielded exposure via immersion in a semi-infinite cloud of airborne radioactive material. The DACs listed in this appendix may be modified to allow for submersion in a cloud of finite dimensions. For purposes of this *Manual*, "appendix" in this regulatory citation corresponds to Appendix 2E of this *Manual*.

The DAC values are given for individual radionuclides. For known mixtures of radionuclides, determine the sum of the ratio of the observed concentration of a particular radionuclide and its corresponding DAC for all radionuclides in the mixture. If this sum exceeds unity, then the DAC has been exceeded. For unknown radionuclides, the most restrictive DAC (lowest value) for those isotopes not known to be absent shall be used.

Air Immersion DAC			
Radionuclide	**Half-Life**	**(µCi/mL)**	**(Bq/m^3)**
Ar-37	35.02 d	3E + 00	1E + 11
Ar-39	269 yr	1E-03	5E + 07
Ar-41	1.827 h	3E-06	1E + 05
Kr-74	11.5 min	3E-06	1E + 05
Kr-76	14.8 h	1E-05	3E + 05
Kr-77	74.7 h	4E-06	1E + 05
Kr-79	35.04 h	1E-05	6E + 05
Kr-81	2.1E+05 yr	7E-04	2E + 07
Kr-83m	1.83 h	7E-02	2E + 09
Kr-85	10.72 yr	7E-04	2E + 07
Kr-85m	4.48 h	2E-05	1E + 06
Kr-87	76.3 min	4E-06	1E + 05
Kr-88	2.84 h	1E-06	7E + 04
Xe-120	40.0 min	1E-05	4E + 05
Xe-121	40.1 min	2E-06	8E + 04
Xe-122	20.1 h	8E-05	3E + 06
Xe-123	2.14 h	6E-06	2E + 05
Xe-125	16.8 h	1E-05	6E + 05
Xe-127	36.406 d	1E-05	6E + 05
Xe-129m	8.89 d	2E-04	7E + 06
Xe-131m	11.84 d	5E-04	1E + 07
Xe-133	5.245 d	1E-04	5E + 06
Xe-133m	2.19 d	1E-04	5E + 06
Xe-135	9.11 h	1E-05	6E + 05
Xe-135m	15.36 min	1E-05	3E + 05
Xe-138	14.13 min	3E-06	1E+05

For any single radionuclide not listed above with decay mode other than alpha emission or spontaneous fission and with radioactive half-life less than two hours, the DAC value shall be 1 E−06 µCi/mL (7E+04 Bq/m^3).

CHAPTER 3 CONDUCT OF RADIOLOGICAL WORK

PART 1 Planning Radiological Work

311 Requirements

1. 835 **Measures shall be taken to maintain radiation exposure ALARA through physical facility and equipment design features and administrative control. The primary methods used shall be physical design features (e.g., confinement, ventilation, remote handling, and shielding). Administrative controls shall only be employed as supplemental methods to control radiation exposure.** [10 CFR 835.1001(a)]

2. 835 **For specific activities where the use of physical design features is demonstrated to be impractical, administrative controls shall be used to maintain radiation exposures ALARA.** [10 CFR 835.1001(b)]

3. Work in Radiological Areas, including construction, modifications, operations, maintenance, and decommissioning, should incorporate radiological safety criteria to help ensure safety and maintain radiation exposures ALARA. To accomplish this, the design and planning processes should incorporate radiological considerations in the early planning stages. The checklist in Appendix 3A is helpful in reducing occupational radiation exposure.

4. DOE regulations for occupational radiation protection require written authorizations to control access to and work in Radiological Areas. The level of detail included in such authorizations is dependent upon facility hazards and the nature of the work force. Technical requirements for the conduct of work, including construction, modifications, operations, maintenance, and decommissioning, should incorporate radiological criteria to ensure safety and maintain radiation exposures ALARA. In general, efforts to reduce individual dose should not be allowed to cause a concurrent increase in collective dose.

5. Work planning and control (WPC) is the use of formalized, standardized, and documented methods and processes for considering and mitigating risks when planning, authorizing, releasing, and accomplishing work. Using the principles of integrated safety and environmental management systems (ISEMS), WPC emphasizes using a graded approach in the mitigation of hazards to personnel, environment, and equipment that varies the requirements by type of work. To ensure adequate protection of the work force, planning for radiological work should also include consideration of all other workplace hazards (*e.g.,* industrial hygiene and safety, fire safety, electrical safety), consistent with the principles of ISEMS.

312 Planning for Maintenance, Operations, and Modifications

1. Maintenance, modifications, and operations that involve the accelerator Personnel Protection Systems (PPS), Beam Containment System (BCS) or shielding, Beam Shut-Off Ion Chamber (BSOIC) system, experimental beam lines, or work in High Radiation Areas, or radiological work in Radiation Areas shall be reviewed to identify and incorporate radiological protection requirements, such as engineering controls and dose and

contamination reduction considerations. These reviews shall be controlled and documented through the following processes, with support and concurrence from the RP Department:

A. Modifications of the accelerator radiation safety systems: internal review by the Radiation Safety Officer (RSO), and Radiation Safety Work Control Form. (See *Conduct of Accelerator Facility Operations*.[19])

B. Initial construction or modifications of experimental beamlines: review by the SLAC Radiation Safety Committee per its Charter.[20]

C. Operations of beam lines and beams to experimental areas: as outlined in approval of Beam Authorization Sheet [BAS] (See *Conduct of Accelerator Facility Operations*.[19])

D. For other work requiring an RWP, contact the RP Field Office.

2. For the radiological conditions and trigger levels listed below, RWPs and/or written procedures should be used for planning maintenance operations and modifications. For more specific information, contact the RP Field Office.

   A. Estimated individual doses greater than 50 mrem TED per day (generally associated with entries into posted High Radiation Areas all of which require RWPs),

   B. Estimated individual doses greater than 100 mrem TED per week,

   C. Collective dose greater than 200 person-mrem TED for the planned activity,

   D. Entry into Radiological Areas,

   E. Machining of radioactive materials, including grinding wheels and welding rods containing thorium.

3. Non-routine or complex work activities shall be checked beforehand against the radiological action levels in the ALARA Committee Charter.[21]

4. Non-routine tasks with the potential to exceed the above trigger levels (Article 312.2.A, B, and C) shall undergo a formal, documented radiological or ALARA review. At a minimum, this review should consider the following:

   A. Inclusion of Radiological Control Hold Points in the technical work documents.

   B. Specification of special radiological training or monitoring requirements.

   C. Use of mock-ups for high exposure or complex tasks.

   D. Engineering, design, and use of temporary shielding to reduce radiation levels.

   E. Walk-down or dry-run of the activity using applicable procedures.

   F. Staging and preparation of necessary materials and special tools.

19 Conduct of Accelerator Facility Operations (CACM-2019-059)

20 SLAC Radiation Safety Committee Charter

21 As Low As Reasonably Achievable (ALARA) Committee

G. Maximization of prefabrication and shop work.

H. Review of abnormal and emergency procedures and plans.

I. Identification of points where signatures and second party or independent verifications are required.

J. Establishment of success or completion criteria, with contingency plans to anticipate difficulties.

K. Development of a pre-job estimate of collective exposure to be incurred for the job.

L. Provisions for waste minimization and disposal.

M. Elimination or reduction of radioactivity through line flushing and decontamination.

N. Use of work processes and special tooling to reduce time in the work area.

O. Use of engineering controls to minimize the spread of contamination and generation of airborne radioactivity.

5. Radiological requirements identified as part of the above radiological review should be documented in the job plans, procedures, or work packages.

6. Radiological tasks anticipated to exceed individual or collective dose criteria established in the ALARA Committee Charter shall be reviewed and approved in advance by the ALARA Committee.

7. The design of major modifications to experimental beam lines may include a detailed and documented review and approval by the RSO.

313 Infrequent or First-Time Activities

Infrequent maintenance that involves radiological activities should be conducted in accordance with the policy stated in Article 312. Planning for first-time activities such as the activation of new beam lines and the initiation of activities that involve sources of radiation shall include as appropriate:

1. Controls established by the RSO, Radiation Protection (RP) Department and appropriate safety officer, or by Beam Authorization Sheet (BAS), RWP, or other similar document.

2. Senior management review directed toward anticipation of concerns with emphasis on and specification of protective measures.

3. Review by the Radiation Safety Committee and/or the ALARA Committee, the latter of which can be called upon to conduct optimization reviews as deemed appropriate.

4. Enhanced line and RP Department management oversight during the initiation and conduct of the work.

314 Temporary Shielding

1. The installation, use, and removal of temporary shielding should be approved by RP Department personnel.

2. The effects of the additional weight of temporary shielding on systems and components should be evaluated and established to be within the design basis prior to installation.
3. Installed temporary shielding should be periodically inspected and surveyed to verify effectiveness and integrity.
4. Radiation surveys should be performed during the alteration or removal of installed temporary shielding.
5. Installed temporary shielding should be periodically evaluated to assess the need for its removal or replacement with permanent shielding.
6. Site procedures may identify specific shielding applications, such as the shielding of low activity sources or samples that fall outside the recommendations of this Article.

315 Technical Work Documents

1. Technical work documents, such as procedures, work packages, or job or research plans, should be used to control hands-on work with radioactive material. Technical work documents are not required for incidental or routine work activities that involve a low potential of worker exposure or workplace contamination unless work is in a High Radiation Area or a High Contamination Area.
2. Technical work documents used to control radiological work activities should be developed by line management and reviewed and approved by the RP Department.
3. Radiological Control Hold Points should be incorporated into technical work documents and Radiological Work Permits (RWPs) to help indicate the steps that require action by the RP Department in order to prevent radiation doses in excess of Administrative Control Levels, the production of high airborne radioactivity concentrations, the spread of contamination, or the release of radioactivity to the environment.
4. Each Radiological Control Hold Point should include the criteria that must be met or action that must be taken to satisfy the Hold Point prior to continuing with subsequent steps in the planned activity.
5. The radiological control hold point should include the criteria that must be met or action that must be taken to satisfy the hold point prior to continuing with subsequent steps in the planned activity. Radiological control limiting conditions typically provide conditions which, if encountered, require some action, such as stopping work. Examples of radiological control limiting conditions would be encountering unanticipated levels for; dose, dose rate, removable surface contamination, airborne radioactivity concentrations, etc.

316 Minimization of Internal Exposure

Historically, there rarely has been a need to monitor for internally-deposited radionuclides from normal SLAC operations.

The containment of source material, operations involving radiological low conductivity water (LCW) systems, and activities involving volume-activated material should be controlled such that internal exposure to radioactive material is minimized or prevented.

The minimization and control of internal exposure as discussed in Article 137 should be conducted in accordance with the following hierarchy of controls:

1. Engineering controls, including containment of radioactive material at the source wherever practicable, should be the primary method of minimizing airborne radioactivity and internal exposure to workers.
2. Administrative controls, including access restrictions and the use of specific work practices designed to minimize airborne radioactivity, should be used as the secondary method to minimize worker internal exposure.
3. When engineering and administrative controls have been applied and the potential for airborne radioactivity still exists, respiratory protection should be used to limit internal exposures. Use of respiratory protection should be considered under the following conditions:
    A. Entry into Airborne Radioactivity Areas.
    B. Work in areas or on equipment with removable contamination levels greater than 100 times the values in Table 2-2 in this *Manual* and also where airborne radioactivity is likely.
    C. During work on contaminated or activated surfaces that have the potential to generate airborne radioactivity.
    D. During breach of contaminated systems or components.
4. The selection of respiratory protection equipment should include consideration of worker safety, comfort, and efficiency. The use of positive pressure respiratory protection devices is recommended wherever practicable to alleviate fatigue and increase comfort.
5. In specific situations, the use of respiratory protection may be contraindicated due to physical limitations, the potential for significantly increased external exposure, or other safety combinations. In such situations, a formal ALARA review should be conducted in accordance with Article 312 to ensure measures are implemented to assess available options, monitor and minimize worker exposure, and provide for follow-up monitoring, as required. Specific justification of the need to accept the exposure, including a description of measures taken to mitigate the airborne radioactivity, should be documented as part of the review process.
6. The following controls are applicable for activities authorized in accordance with the above:
    A. Stay time controls to limit intake should be established for the entry.
    B. Evaluation of workplace airborne radioactivity levels should be provided through the use of continuous air monitors or air samplers with expedited assessment and analysis of results.

PART 2 Work Preparation

321 Radiological Work Permits

1. The RWP is an administrative mechanism used to establish radiological controls for intended work activities and to provide written authorization for entry into and work within Radiological Areas. The RWP informs workers of area radiological conditions and entry requirements and provides a mechanism to relate worker exposure to specific work activities. The RWP should include the following information:
   A. Description of work
   B. Work area radiological conditions
   C. Dosimetry requirements
   D. Pre-job briefing requirements, as applicable
   E. Training requirements for entry
   F. Protective clothing and respiratory protection requirements
   G. Radiological Control coverage requirements and stay time controls, as applicable
   H. Limiting radiological conditions that may void the RWP
   I. Special dose or contamination reduction considerations
   J. Special personnel frisking considerations
   K. Technical work document number, as applicable
   L. Unique identifying number
   M. Date of issue and expiration
   N. Authorizing signatures
2. The RWP should be integrated with other work authorizations that address safety and health issues, such as those for industrial safety and hygiene, welding, or confined space entry.

322 Use of Radiological Work Permits

835 **Written Authorizations shall be required to control entry into and perform work within Radiological Areas. These authorizations shall specify radiation protection measures commensurate with existing and potential hazards.** [10 CFR 835.501 (d)]

There are three types of Radiological Work Permits at SLAC:

- Routine Area RWP – for entering Radiological Areas
- Routine Task RWP – for reoccurring jobs for which RWPs are required
- Job-Type RWP – for specific non-routine or non-repetitive jobs with the potential for changing radiological conditions

The RP Department Field Operations Group Leader, or a designated representative, may determine on a case-by-case basis whether a Job-Type RWP provides adequate control for work conducted within a Radiological Area. This determination may be appropriate when:

A. The work activity itself results in the creation of the Radiological Area.

B. Only workers covered under the Job-Type RWP will enter and perform radiological work within the Radiological Area.

Discussion of these types of RWPs and their applicability follows:

1. An "equivalent formal authorization" can be used in lieu of an RWP with RP Department approval. An equivalent formal authorization can take the form of a written procedure or an experiment authorization, which serves as the administrative control over the particular radiological work activity. If an equivalent formal authorization is used instead of an RWP, it should meet the requirements of this Article and of Article 321 and Article 323 of this *Manual*. An RWP or equivalent formal authorization shall be used to control the following activities:

   A. All entries into all Radiological Areas (e.g., Radiation Areas, High Radiation Areas, Very High Radiation Areas, Contamination Areas, High Contamination Areas, Airborne Radioactivity Areas, etc.).

   B. Handling of material with removable contamination that exceeds the values in Table 2-2.

   C. Work in localized benchtop areas, laboratory fume hoods, sample sinks, and containment devices that has the potential to generate contamination in areas that are otherwise free of contamination.

   D. Machining of radioactive and/or activated material.

   E. Work that disturbs the soil in soil contamination areas

   F. Work that involves digging in underground radioactive material areas

2. Radiological Work versus Non-Radiological Work

   The type of RWP depends in part on the type of work to be performed. There are two classifications of work for radiological protection planning purposes defined below:

   A. "Radiological Work" is work involving any use of tools on beamlines or beamline components or beamline safety items such as shielding, PPS components, BCS components where radiological hazards may be affected, or any work on radiation Hot Spots. "Radiological Work" also is any work on radioactive low conductivity water (LCW) systems; that is, any LCW system with tritium in the water at a concentration greater than 2E4 pCi/liter.

   B. "Non-Radiological Work" is work that does not involve breaching a known radioactive water system (a radioactive water system is one in which tritium is present in the water at a concentration greater than 2E04 pCi/liter), does not involve handling radioactive contaminated components, or work where dose rates or accumulated doses are not expected to exceed 50 mrem TED per day or 100 rem TED per week or collective dose of 200 person-mrem TED for a job or task. Examples of Non-Radiological Work can include tours, observations, PPS

searches, radiological surveys, and any entry made into a Radiological Area only for collection or recording of data.

3. Routine Area RWPs are used for general access into Radiological Areas (Radiation, High Radiation, Contamination, and High Contamination Areas). Routine Area RWPs may also be used for non-radiological work in Radiation and Contamination Areas. Radiological work in any area requires a Job-Type or Routine Task RWP. A Job-Type RWP is required for any work (radiological or non-radiological) in High Radiation and High Contamination Areas.
4. Routine Task RWPs may be used to control routine or repetitive activities, such as inspections or minor work activities, in areas with well-characterized and stable radiological conditions. Routine Task RWPs should not be approved for periods longer than one year and typically are changed every calendar quarter.
5. Job-Type RWPs shall be used to control non-routine operations or work in areas with a potential for changing radiological conditions that could increase radiation exposure or generate radioactive contamination, and for conducting Work in High Radiation Areas and High Contamination Areas. The Job-Type RWP shall remain in effect only for the duration of the job.
6. Radiological surveys shall be routinely reviewed to evaluate the adequacy of RWP requirements. RWPs shall be updated if radiological conditions change to the extent that protective requirements need modification.
7. RWPs should be posted at the access point to the applicable radiological work area.
8. Workers shall acknowledge by signature or through electronic means that they have read, understood, and will comply with the RWP prior to initial entry to the area and after any revisions to the RWP. When a Job-Type RWP or Routine Task RWP is used in addition to a Routine Area RWP, both should be reviewed and signed. The supplemental dosimeter readings, if used, are recorded on the Job-Type RWP or Routine Task RWP.
9. Electronic dosimeter readings should be recorded in a format that identifies and provides linkage to the applicable RWP.
10. See the RP Department *Radiological Work Permits Procedure*[22] for more specific criteria and directions.

323 Radiological Work Permit Preparation

1. The responsibility for ensuring adequate planning and control of work activities resides with line management. The lead work group responsible for the planned activity involving Job-Type or Routine Task RWPs should initiate the preparation of the Technical Work Document for the job or task.
2. The RWP shall be based on current radiological surveys and anticipated radiological conditions.

22 Radiological Work Permits Procedure (SLAC-I-760-0A05B-002, FO 005)

3. The RWP, including any revisions or extensions, shall be approved by the supervisor responsible for the work or work area, the RP Department Field Operations Group Leader and/or the Radioactive Waste Group Leader or Radiological Control Manager designee.

324 Pre-Job Briefings

1. At a minimum, pre-job briefings should be held prior to the conduct of work anticipated to exceed the trigger levels identified in Article 312.2.
2. At a minimum, the pre-job briefing should include:
   A. Scope of work to be performed.
   B. Radiological conditions of the workplace.
   C. Procedural and RWP requirements.
   D. Special radiological control requirements.
   E. Radiologically limiting conditions, such as contamination or radiation levels that may void the RWP.
   F. Radiological Control Hold Points.
   G. Communications and coordination with other groups.
   H. Provisions for housekeeping and final cleanup.
   I. Emergency response provisions.
3. Pre-job briefings should be conducted by the cognizant work supervisor.
4. Workers and supervisors directly participating in the job, cognizant radiological control personnel, and representatives from involved support organizations should attend the briefing.
5. A summary of topics discussed and attendance at the pre-job briefing should be documented. This documentation should be maintained with the technical work document.

325 Personal Protective Equipment and Protective Clothing

1. Personnel shall wear protective clothing during the following activities:
   A. Handling of contaminated material that has removable contamination in excess of the levels in Table 2-2 of this *Manual*
   B. Working in Contamination, High Contamination, and Airborne Radioactivity Areas
   C. Working or other activities as directed by the RP Department or as required by the RWP
2. Protective clothing and shoes designated for radiological control should be worn only in Radiological Areas.
3. Protective clothing dress-out areas will be specified in the RWP. Whenever possible, protective clothing dress-out areas should be established directly adjacent to the work

area. Workers should go directly to the radiological work area after donning personal protective equipment (PPE) and protective clothing.

4. General guidelines for protective clothing selection and use are provided in Table 3-1 and the Addendum to Table 3-1 in Appendix 3C.
5. The use of lab coats as radiological protective clothing is appropriate for limited applications, where the potential for personal contamination is limited to the hands, arms, and upper front portion of the body. Lab coats should not be used as protective clothing for performing physical work activities in Contamination, High Contamination, or Airborne Radioactivity Areas.
6. Instructions for donning and removing protective clothing should be posted at the dress-out and step-off pad areas.
7. The use of PPE and protective clothing (including respiratory protection) beyond that authorized by the RP Department detracts from work performance and is contrary to ALARA principles and waste minimization practices. Such use should not be authorized.
8. SLAC-issued clothing not intended for contamination control, such as work coveralls and shoes, should be considered the same as personal clothing. Such clothing should not be used for radiological control purposes.

PART 3 Entry and Exit Requirements

835 **Personnel entry control shall be maintained for each radiological area. The degree of control shall be commensurate with existing and potential radiological hazards within the area.**

One or more of the following methods shall be used to ensure control:

1. **Signs and barricades;**
2. **Control devices on entrances;**
3. **Conspicuous visual and/or audible alarms;**
4. **Locked entrance ways; or**
5. **Administrative controls.**

Written authorizations shall be required to control entry into and perform work within radiological areas. These authorizations shall specify radiation protection measures commensurate with the existing and potential hazards. No controls shall be installed at any radiological area exit that would prevent rapid evacuation of personnel under emergency conditions. [10 CFR 835. 501(a) through (e)]

331 Controlled Areas

835 **A Controlled Area means any area to which access is managed by or for DOE to protect individuals from exposure to radiation and/or radioactive material.** [10 CFR 835.2]

Individuals who enter only controlled areas without entering radiological areas or radioactive material areas are not expected to receive a total effective dose of more than 0.1 rem in a year. [10 CFR 835.602 (a)]

Controlled Areas are established and posted to alert individuals that they are entering locations in which Radiologically Controlled Areas, Radioactive Material Areas, and/or Radiological Areas may exist. All Radiologically Controlled Areas, Radioactive Material Areas, and Radiological Areas lie within the boundaries of Controlled Areas (although the boundaries may be contiguous).

1. DOE regulations for occupational radiation protection require that individuals complete radiation safety training commensurate with the hazards and required controls:
   A. Prior to unescorted access to Controlled Areas [see 10 CFR 835.901(a)]; and
   B. Prior to receiving occupational dose during access to Controlled Areas (whether escorted or not) [see 10 CFR 835.901(a)].
2. General Employee Radiological Training (GERT) training is required for unescorted entry into Controlled Areas. Article 622 establishes training provisions that should be met prior to permitting members of the public in Controlled Areas.

332 Radiologically Controlled Areas

At SLAC, a Radiologically Controlled Area (RCA) is a Controlled Area that requires dosimetry for entry. The radiation level in certain localized areas within the RCA may vary, requiring limited occupancy. Individuals who enter only RCAs without entering Radiological Areas are not expected to receive a total effective dose (TED) of more than 0.1 rem in a year.

Minimum requirements for unescorted entry into an RCA are:

1. Successful completion of GERT
2. Personnel dosimetry

Article 622 establishes requirements for escorting members of the public in RCAs. A current list of RCAs is available from the RP Department.

333 Radiological Buffer Areas (RBAs)

At SLAC, Radiological Buffer Areas may be used at the entrance of Contamination Areas to provide additional control of contamination. Minimum requirements for entry into RBAs include Radiological Worker Training (RWT) I and personnel dosimetry.

334 Radioactive Material Areas and Radioactive Management Material Areas

For unescorted entry into Radioactive Material Areas and Radioactive Material Management Areas, an individual should be at least GERT trained if the annual TED is likely to be less than 100 mrem and RWT if the annual dose is expected to exceed that. If individual doses are likely to exceed the applicable monitoring thresholds, individual monitoring shall be conducted in accordance with Article 511 and Article 521 [see 10 CFR 835.402(a) and (c)].

335 Radiation Areas, High Radiation Areas, and Very High Radiation Areas

See Table 2-3 of this *Manual* for definitions of each of these types of Radiological Areas. In general, most Radiological Areas at SLAC occur only as the result of accelerator operations.

835 **Personnel entry control shall be maintained for each radiological area.** [10 CFR 835. 501 (a)]

1. Minimum requirements for unescorted entry into Radiation Areas shall include the following:
   A. RWT I
   B. Signature of the worker on the RWP, as required
   C. Personnel dosimetry
2. Physical controls to prevent inadvertent or unauthorized access to High and Very High Radiation Areas are established in Appendix 3B.
3. Minimum requirements for unescorted entry into High Radiation Areas shall include the following:
   A. RWT I with High/Very High Radiation Area access training (as defined for SLAC in Article 632) and training in the use of a survey meter (or dose-rate indicating device), as described in Article 126.
   B. Signature of the worker on the RWP.
   C. A personnel dosimeter**.**
   D**.** An electronic dosimeter serving as **835 a supplemental dosimetry device or other means capable of providing an immediate estimate of the individual's integrated equivalent dose to the whole body during the entry. [10 CFR 835. 502(a)(2)].**
   E. **835 The area shall be monitored as necessary during access to determine the exposure rates to which the individuals are exposed. [10 CFR 835.502(a)(1)]**
4. Minimum requirements for unescorted entry into High Radiation Areas where dose rates exist such that a worker could exceed an equivalent dose to the whole-body dose of one (1) rem in one hour at 30 cm shall [835.502(b)] include those items listed in Article 335.1 and the following:
   A. Prior to initial entry a determination of the current dose of the worker based upon the primary dosimeter reading. Supplementary dosimeter readings should be used to estimate the dose if the primary dosimeter has been lost or damaged and for exposures that occurred since the most recent primary dosimeter change.
   B. Pre-job briefing, as applicable.
   C. Review and determination by the RP Department regarding the required level of radiological coverage.
5. At SLAC, High Radiation Areas with levels exceeding 5 rem/h may exist in the linear accelerators' housings, the Stanford Synchrotron Radiation Lightsource (SSRL) booster synchrotron housing, the beam switchyard, damping rings' housings, and certain experimental areas when the linear accelerators and/or synchrotrons are in operation.

Workers are prevented from entering these areas by an engineered access control system. Following shutdown of the accelerator, a survey is performed to identify and post Radiation Areas or High Radiation Areas that result from residual radioactivity before access is permitted in the specified location.

6. Accelerator operations personnel shall notify personnel of operational or system changes made by accelerator operators which could result in significantly increased area dose rates.

7. Approved Accelerator operations personnel shall strictly control the number, issue, and use of keys where locked entryways are used to control access to Accelerator, High and Very High Radiation Areas.

8. The RP Department should maintain an inventory of High and Very High Radiation Areas.

9. Inspections of the physical access controls to High and Very High Radiation Areas should be made to verify controls are adequate to prevent unauthorized entry. Inspections and tests of the basic interlocks such as door switches and emergency OFF buttons are conducted as part of the operator search of the area.

10. Administrative procedures shall be developed as necessary to implement area access controls. These procedures shall address measures implemented to help ensure the effectiveness and operability of entry control devices, such as barricades, alarms, and locks. The RP Department maintains these procedures under separate cover; contact the RP Department for current information about these procedures.

11. Personnel Exclusion Areas are locations secured by some physical manner other than by means of the Personnel Protection System to keep personnel from accessing those areas during accelerator beam operations due to the potential for abnormal ionizing radiation dose rates. Personnel shall not enter any posted areas within a Personnel Exclusion Area unless the operation requiring the Personnel Exclusion Area posting is halted or as specifically approved by the RP Department.

336 Contamination, High Contamination, and Airborne Radioactivity Areas

835 **Appropriate controls shall be maintained and verified which prevent the inadvertent transfer of removable contamination to locations outside of radiological areas under normal operating conditions.** [10 CFR 835.1102(a)]

1. Minimum requirements for unescorted entry into Contamination Areas shall include the following:

   A. Radiological Worker II training (site-specific Contamination Control Module)

   B. Signature of the worker on the RWP as required.

   C. Protective clothing, as required

   D. Personnel dosimeter, as required.

2. Minimum requirements for unescorted entry into High Contamination Areas or Airborne Radioactivity Areas shall include the following:

   A. Radiological Worker II training (site-specific Contamination Control Module)

B. Signature of the worker on the RWP

C. Protective clothing and respiratory protection as specified by the RWP

D. Pre-job briefing for High Contamination Area or Airborne Radioactivity Areas, as applicable

E. Personnel dosimeter, as appropriate

3. Personnel exiting Contamination Areas, High Contamination Areas, or Airborne Radioactivity Areas shall:

A. Remove protective clothing as specified in Appendix 3C of this *Manual*.

B. 835 **Individuals exiting contamination, high contamination, or airborne radioactivity areas shall be monitored, as appropriate, for the presence of surface contamination.** [10 CFR 835.1102(d)] Individuals should perform a whole body frisk immediately upon entry into an uncontaminated area after exiting a Contamination, High Contamination, or Airborne Radioactivity Areas in accordance with Article 339.

4. Exit points from Contamination Areas, High Contamination Areas, or Airborne Radioactivity Areas should include the following:

A. Protective clothing removal instructions

B. Designated containers inside the area boundary for the collection of protective clothing and equipment

C. Contamination monitoring equipment located as close to the contamination boundary as background radiation levels permit

5. Protective clothing and monitoring requirements specific to benchtop work, laboratory fume hoods, sample stations, and gloveboxes are identified in Article 347.

6. Tools or equipment being removed from areas posted for removable surface or airborne radioactivity control shall be monitored for release in accordance with Article 421. RP Department personnel should survey materials removed from Controlled Areas if such materials are not adequately contained upon removal.

337 Visitor Entry Requirements

1. When an escort is used in lieu of training in accordance with 10 CFR 835.901 (a) and (b), the SLAC escort shall have completed the required training, examinations, and performance demonstrations required for entry to the area and shall be approved to escort visitors (note the definition of "visitors" in the Glossary) within a Radiologically Controlled Area (RCA) [10 CFR 835.901(d)(1)]. The escort shall observe the following precautions:

A. Visitors who are escorted in an RCA are not required to wear a dosimeter. The escort is required to wear a tour dosimeter in addition of their own dosimeter.

B. When inside a Controlled Area, visitors shall be accompanied by a trained SLAC escort at all times.

3. Visitors shall be prevented from entering Radiation, High Radiation, Very High Radiation, Contamination, High Contamination, and Airborne Radioactivity Areas.
4. Training requirements for visitors are identified in Articles 622 and Article 657.

338 Controlling the Spread of Contamination

The following measures should be used to prevent the spread of contamination across the boundaries of Contamination, High Contamination, and Airborne Radioactivity Areas:

1. Use solid barriers to enclose areas wherever practicable.
2. Mark and secure items that cross the boundary, such as hoses and cords, to prevent safety hazards or the spread of contamination.
3. Control and direct airflow from areas of lesser to greater removable contamination or airborne radioactivity.
4. Use engineering controls and containment devices such as glovebags, gloveboxes, and tents.

339 Monitoring for Personnel Contamination

1. Personnel shall perform a whole-body frisk under the following conditions:
   A. Immediately upon entry into an uncontaminated area after exiting Contamination Areas, High Contamination Areas, or Airborne Radioactivity Areas
   B. As directed by the RWP or the RP Department
2. Where frisking cannot be performed at the exit from Contamination Area, High Contamination Area, or Airborne Radioactivity Areas due to high background radiation levels, personnel shall:
   A. Remove all protective equipment and clothing at the exit
   B. Proceed directly to the nearest designated monitoring station
   C. Conduct a whole-body frisk
3. Personnel frisking should be performed after removal of protective clothing and prior to washing or showering.
4. Guidelines for personnel frisking are provided in Appendix 3D.
5. Personal items, such as notebooks, papers, and flashlights, should be subject to the same frisking requirements as the person carrying them.
6. Instructions for personnel frisking should be posted adjacent to personnel frisking instruments or monitors.
7. The personnel frisking requirements contained in this Article are not applicable for those areas on site that contain only radionuclides, such as tritium, that cannot be detected by currently available hand-held or automated frisking instrumentation. At such locations, where the potential exists for exceeding 10% of a Derived Air Concentration (DAC), additional emphasis should be placed on worker bioassay programs and routine area contamination monitoring and air sampling programs.

PART 4 Radiological Work Controls

341 Requirements

1. Radiological work activities shall be conducted as specified by the controlling technical work document and RWP.
2. Before work is initiated, prerequisite conditions (such as tag-outs and system isolation) should be verified in accordance with the technical work documents.

342 Work Conduct and Practices

1. 835**Appropriate controls shall be maintained and verified which prevent the inadvertent transfer of removable contamination to locations outside of radiological areas under normal operating conditions.** [10 CFR 835. 1102 (a)] Contamination levels caused by ongoing work shall be monitored and controlled in accordance with the ALARA principle. Decontamination should be performed at pre-established levels, taking into account worker exposure.
2. Tools and equipment should be inspected to verify operability before being brought into Contamination Areas, High Contamination Areas, or Airborne Radioactivity Areas.
3. The use of radiologically clean tools or equipment in Contamination Areas, High Contamination Areas, or Airborne Radioactivity Areas should be minimized by the implementation of a contaminated tool crib. When such use is necessary, tools or equipment with complex or inaccessible areas should be wrapped or sleeved to minimize contamination.
4. Engineering controls such as containment devices, portable or auxiliary ventilation, and temporary shielding should be installed and inspected prior to use in accordance with the technical work documents.
5. The identity of components and systems should be verified prior to work.
6. Work activities and shift changes should be scheduled to prevent idle time in Radiation Areas.
7. Where practicable, parts and components should be removed to areas with low dose rates to perform work.
8. Upon identification of radiological concerns, such as inappropriate work controls or procedural deficiencies, workers should immediately report the concern to line supervision or the RP Department.
9. Requirements for area cleanup should be included in the technical work documents. Work activities should not be considered complete until support material and equipment have been removed and the area has been returned to at least pre-work status.
10. Eating, drinking, and chewing policy in radiologically posted locations at SLAC.
    A. Eating, chewing, or smoking shall not be permitted in any Radiological Areas, Radioactive Material Area, or Accelerator Housing. This restriction is intended to minimize potential for intakes of radioactivity.

B. Drinking is not allowed in Contamination Areas, High Contamination Area, and Airborne Radioactivity Area.

C. Restricted drinking (from a closed container, such as water bottle) is allowed during the course of work in

- Radiation Areas,
- High Radiation Areas,
- Radioactive Material Areas, and
- Accelerator Housing

D. The Radiological Control Manager can impose additional radioactive material intake monitoring and/or bioassay requirements beyond any that are specified in the involved RWP or other involved work authorization.

343 Logs and Communications

1. RP Department personnel should maintain logs to document radiological occurrences, such as an exposure greater than expected for a particular job, the status of work activities, and other relevant information, as appropriate.
2. Communication systems required by the RWP or technical work document should be checked for operability before being brought into the work area and periodically during work.
3. Workers should keep RP Department personnel informed of the status of work activities that affect radiological conditions.

344 Review of Work in Progress

1. As part of their normal work review, supervisors should periodically review ongoing jobs to ensure prescribed radiological controls are being implemented.
2. RP Department personnel should conduct frequent tours of the workplace to review the adequacy of radiological work practices, posting, and area controls.
3. During the performance of jobs for which a pre-job dose estimate was made, the RP Department, in cooperation with line management, should periodically monitor collective dose accumulation and compare it with the pre-job dose estimate. Differences should be reviewed to identify causes and assess the need for corrective actions.

345 Stop Radiological Activity Authority

1. RP Department Health Physics Technicians and their supervisors, line supervision, and workers (through their supervisor) have the authority and responsibility (refer to the *ESH Manual*, Chapter 2, "Work Planning and Control"[23]) to stop radiological work activities for any of the following reasons:

23 *SLAC Environment, Safety, and Health Manual* (SLAC-I-720-0A29Z-001), Chapter 2, "Work Planning and Control"

A. Inadequate radiological controls

B. Radiological controls not being implemented

C. Radiological Control Hold Point not being satisfied

2. Any stopping of radiological work activity shall be exercised in a justifiable and responsible manner and immediately brought to the attention of the Radiological Control Manager (RCM) and the line manager responsible for the work.

3. Once radiological work activity has been stopped, it shall not be resumed until proper radiological control has been reestablished.

4. Resumption of radiological work activity requires the approval of the RCM or designee and the line manager responsible for the work.

346 Response to Abnormal Situations

1. This *Manual* establishes requirements for alarm response procedures. Alarm response procedures should address the general actions in all the Items in this Article.

2. Response to increasing or unanticipated radiation levels, as identified by a supplemental dosimeter, Area Radiation Monitor alarm, or a Continuous Air Monitor (CAM) alarm (for specific CAM alarm actions, see RP Department specific work documents), should include the following actions:

A. Stop work activities in the area

B. Alert others

C. Affected personnel immediately exit the area

D. Notify supervisor, place a call to ext. 5555, and notify RP Department at ext. 4299.

3. Although not applicable at SLAC, should response to a criticality alarm situation be created in the conduct of an experimental program not at SLAC, your response should include the following actions:

A. Immediately evacuate the area, without stopping to remove protective clothing or performing exit monitoring

B. Report to designated assembly area

4. Although not applicable at SLAC, response to a personnel contamination monitor alarm should include the following actions:

A. Remain in the immediate area.

B. Notify RP Department personnel.

C. Take actions that may be available to minimize cross-contamination, such as putting a glove on a contaminated hand.

D. Take follow-up actions in accordance with Article 541.

5. Response to a spill of radioactive material should include the following actions:

A. Stop or secure the operation causing the spill. (For spills involving highly toxic chemicals, workers should immediately exit the area without attempting to stop or secure the spill. They should then call 911 if the spill is an emergency)

B. Warn others in the area.

C. Isolate the spill area if possible.

D. Minimize individual exposure and contamination.

E. Secure unfiltered ventilation.

F. Notify supervisor, place a call to ext. 5555, and notify RP Department at ext. 4299.

347 Controls for Shop, Glovebox, Ventilated Hood, and Sample Stations Work

The following requirements are applicable to radiological work in localized shop areas that are otherwise contamination-free:

1. An RWP should be issued to control radiological work in localized shop areas.
2. Areas shall be posted in accordance with 10 CFR 835.602 and 603.
3. The following controls apply to localized shop work:
   A. Appropriate shop clothing will be worn.
   B. Precautions shall be taken to avoid floor contamination.
   C. Workers should monitor the area after work is completed to ensure that no contamination (i.e., radioactive filings, turnings, or grindings) remains, cutting solutions have been appropriately contained, and no other radioactive materials or items remain outside of proper containers.
   D. Upon completion of work or prior to leaving the area, workers shall monitor those areas of their body that are potentially contaminated. At a minimum, the areas include hands, arms, face, and front portions of the body including the face, nose, and mouth.
4. The following controls apply to localized benchtop and laboratory fume hood operations:
   A. Protective clothing shall, at a minimum, include lab coats and gloves. Gloves should be secured at the wrist as necessary.
   B. Shoecovers should be considered based on the potential for floor contamination.
   C. Workers should periodically monitor their hands during work.
   D. Upon completion of work or prior to leaving the area, workers shall monitor those areas of their body that are potentially contaminated. At a minimum, this includes hands, arms, and front portions of the body. Workers should perform a whole-body frisk.
5. The following controls apply to sample station operations:
   A. Protective clothing shall, at a minimum, include lab coats and gloves. Gloves should be secured at the wrist as necessary.
   B. Shoecovers should be considered based on the potential for floor contamination.

C. If there is a potential for splashing or airborne radioactivity, such as when taking pressurized samples, additional controls such as rubber aprons, face shields, full protective clothing (PCs), or respiratory protection should be instituted.

D. Workers should periodically monitor their hands during work.

E. Upon completion of work or prior to leaving the area, workers shall monitor those areas of their body that are potentially contaminated. At a minimum, this includes hands, arms, and front portions of the body. Workers should perform a whole-body frisk.

6. The following controls apply to glovebox operations:

A. Gloveboxes should be inspected for integrity and operability prior to use.

B. Gloveboxes should be marked or survey measurements should be posted to identify whole body and extremity dose rates.

C. Protective clothing shall, at a minimum, include lab coats and gloves. Gloves should be secured at the wrist as necessary.

D. Shoecovers should be considered based on the potential for floor contamination.

E. Workers should periodically monitor their hands during work.

F. Upon completion of work or prior to leaving the area, workers shall monitor those areas of their body that are potentially contaminated. At a minimum, this includes hands, arms, and feet. Workers should perform a whole-body frisk.

348 Controls for Hot Particles

Hot particles are small, discrete, highly radioactive particles capable of causing extremely high doses to a localized area in a short period of time. Hot particle contamination may be present or be generated when contaminated systems are opened or when operations such as machining, cutting, or grinding are performed on highly radioactive material. Volume activation at SLAC normally does not lead to material of high enough specific activity for concern as hot particles; however, should such material be handled at SLAC, the following controls will be used:

1. Hot particles are defined for SLAC purposes as those particles capable of producing an equivalent dose to the skin greater than 100 mrem in 1 hour.

2. Measures for controlling hot particles, as identified in Items 3 through 7 of this Article, should be implemented under the following conditions:

A. Upon identification of hot particles

B. During new or non-routine operations with a high potential for hot particles, based on previous history

C. Upon direction of the RP Department

3. Survey requirements for areas or operations with the potential for hot particle contamination are established in Article 554.8.

4. Contamination Area postings should be annotated to specifically identify the known presence of hot particles.

5. Access to hot particle areas should be controlled by a Job-Type RWP. The following controls should be considered for inclusion on the RWP:
   A. Periodic personnel monitoring during the work activity, at a frequency based on the potential magnitude of personnel exposure
   B. Additional PPE and protective clothing
   C. Direct Radiological Control coverage during work or assistance during removal of protective clothing
   D. Use of sticky pads or multiple step-off pads
6. PPE and protective clothing used in hot particle areas should be segregated from other radiological protective equipment and clothing during laundering and surveyed prior to reuse.
7. Response to hot particle skin or clothing contamination should include the following:
   A. Immediate removal and retention of the hot particle for subsequent analysis
   B. Analysis of the particle
   C. Assessment of worker dose
   D. Evaluation of work control adequacy

PART 5 Evaluation of Performance

During the conduct of radiological work, the handling of radioactive material, or during routine accelerator operations, abnormal events may occur which could indicate a weakness or area of programmatic breakdown of radiological controls. Prompt, consistent gathering of facts related to such events is required to satisfy reporting and investigation requirements and to formulate corrective actions to prevent recurrence. In addition, successful performance or completion of unique activities should be evaluated to identify and incorporate appropriate lessons learned.

Analysis of the facts should reveal areas where improvements can be made or methods identified to prevent the recurrence of undesired results.

351 Conduct of Formal Critiques and Investigations

Critiques are meetings among personnel knowledgeable about an event, whether it was a successful event (for example, completion of a job without exceeding the expected collective dose limits) or an abnormal event, in order to document a chronological listing of the facts. The purpose of the critique is not to assign blame, but to establish and record the facts.

1. Critiques should be conducted for successes and abnormal events, as determined by line management.
2. Critique leaders should be trained in the required elements of the critique process and the appropriate methods of conducting and controlling the critique.
3. Critique meetings should be conducted as soon as practicable after the event or situation is stabilized, or after a successful evolution is completed. Critiques of abnormal events should preferably be conducted before involved personnel leave for the day.

4. At a minimum, the general critique process should include the following elements:
   A. Formal meetings, chaired by a critique leader
   B. Attendance by all members of the work force who can contribute
   C. Personal statement forms completed by selected personnel before the meeting
   D. Attendance records
   E. Minutes, recorded and signed by the critique leader and all contributors
   F. Personal statements signed and attached to the meeting minutes
   G. A listing of the facts in chronological order
   H. Supporting material, including documents, records, photographs, parts, and logs, maintained by the critique leader
5. Evaluation of complex evolutions or events may require multiple critiques.

352 Post-Job Reviews

1. Performance should be reviewed after completion of non-routine radiological work (Job-Type RWPs). Requirements for post-job reviews should be consistent with SLAC normal work review practices, with the RWP requirements, and degree of compliance in doses received, in addition to the normal tracking of the effectiveness of the work done.
2. As appropriate to the work in question, post-job reviews should include reviews of:
   A. The total and individual doses compared to the pre-job estimates
   B. The efficacy of the radiological controls implemented for the work
   C. Any adverse events occurring during the work, such as skin contaminations, unexpectedly high individual exposures, or problems resulting from unnecessarily burdensome control requirements
   D. Conflicts between radiological safety requirements and other safety requirements
   E. Opportunities to improve performance or efficiency during repeated or similar work
   F. Significant differences between expected and actual radiological conditions or other issues affecting the work
   G. Worker input regarding possible improvements in radiological safety practices for repeated or similar work

353 Lessons Learned

Lessons learned are available from post-job reviews and reports of past radiological events on-site and at other facilities. The RP Department, in conjunction with line management, should evaluate lessons learned, provide prompt distribution, and incorporate the lessons into the SLAC Radiological Control Program, the SLAC Radiological Training Program, and related operations.

PART 6 Special Applications

This part provides supplemental information to augment the basic requirements of this *Manual*.

361 Plutonium Operations

There is the perception that exposure to small quantities of plutonium presents greater risk than exposure to other radionuclides. Low levels of plutonium in the body are difficult to measure and biological removal processes for plutonium can be slow. For these reasons:

1. Primary emphasis should be placed on engineered features to contain plutonium and to prevent airborne and surface contamination.
2. In addition to the provisions of this *Manual*, guidance contained in Department of Energy Standard DOE-STD-1128-2013, "Good Practices for Occupational Radiological Protection in Plutonium Facilities,"[24] should be considered for plutonium operations on site. This reference provides specific guidance related to dosimetry, radiological monitoring, instrumentation, contamination control, and applicable radiological control procedures.
3. Although SLAC does not conduct operations involving quantities of plutonium requiring the special plutonium facilities, individual experiments with measurable quantities may be conducted on occasion. Portions of the radiological controls identified in Article 361.2 above will be used where appropriate at SLAC.

362 Uranium Operations

Natural, depleted, and low-enriched uranium are unusual in that their chemical toxicity is more limiting in the human body than their radioactivity. Also, processed uranium sometimes contains transuranic and other radionuclides from recycled materials. For these reasons, in addition to the provisions of this *Manual*:

1. The guidance contained in the DOE Standard 1136-2009, "Guide of Good Practices for Occupational Radiological Protection in Uranium Facilities," should be considered for uranium operations.[25] This reference provides specific guidance related to management controls, radiological monitoring, contamination control, and internal and external exposure controls.
2. SLAC does not conduct operations involving milling, machining, or otherwise processing large quantities of uranium requiring the special uranium facilities that are the main intent of DOE for this Article, but SLAC will apply those radiological control measures in Article 362.1 above as appropriate for a particular application.

24 Department of Energy Standard 1128-2013, "Good Practices for Occupational Radiological Protection in Plutonium Facilities," (DOE-STD-1128-2013)

25 Department of Energy Standard 1136-2017, "Guide of Good Practices for Occupational Radiological Protection in Uranium Facilities" (DOE-STD-1136-2017)

363 Tritium Operations

The following characteristics of tritium require consideration in the implementation of the Radiological Control Program at tritium facilities, which do not presently exist at SLAC, but could in the future be established on a temporary basis as a part of the experimental program:

1. Tritium emits low-energy beta particles that cannot be monitored using external dosimeters, consequently requiring the use of bioassay measurements to evaluate worker dose.
2. Worker exposure to tritium as water vapor causes a much greater dose than exposure to elemental tritium gas.
3. Normal personnel frisking techniques are ineffective for tritium. Consequently, a high reliance is placed on worker bioassay and routine contamination and air monitoring programs.
4. Due to its high ability to permeate substances with which it comes in contact, tritium is difficult to contain. Special attention should be directed to the selection of PPE and protective clothing.

For the above reasons, guidance contained in the document DOE Handbook 1129-2008, "Tritium Handling and Safe Storage"[26] should be considered in preparing controls for specific experiments that use large quantities of tritium. It provides specific guidance related to internal dosimetry, contamination and air monitoring, tritium containment practices and techniques, and PPE and protective clothing selection.

364 Operation of the Accelerators

Special considerations associated with accelerator facilities include the presence of extremely high dose rates, high energy and heavy particles, the generation of activation products, and detection and monitoring difficulties associated with pulsed or high-energy radiation.

- In preparing this *Manual*, consideration was given to the information provided in DOE Order 420.2D, "Safety of Accelerator Facilities."[27]
- The *Conduct of Accelerator Facility Operations* above and the *Radiation Safety Systems*[28] document should be consulted for details on accelerator operations and safety systems.

1. Operation of the Accelerators

   The Beam Authorization Sheet (BAS), Beam Line Authorization (BLA), or other approved document govern the radiologically safe beam operation of the accelerators and beam lines at SLAC.

2. Beam Authorization Sheet and Beam Line Authorization

26 Department of Energy Handbook 1129-2015, "Tritium Handling and Safe Storage" (DOE-HDBK-1129-2015)

27 Site Compliance Plan for Department of Energy Order 420.2D, "Safety of Accelerator Facilities" (DOE O 420.2D SCP)

28 Radiation Safety Systems (SLAC-I-720-0A05Z-002)

The BAS and BLA is jointly prepared and is issued and approved by the responsible Radiation Physicist, the appropriate Safety Officer, and the operations line manager. It specifies the required conditions for safe radiological beam operations.

If changes or additions are needed, the RP Department and the appropriate Safety Officer shall agree on the change. This agreement may be reached in person, by e-mail or phone. The change shall be entered in the BAS or BLA and signed by the appropriate operator. See *Conduct of Accelerator Facility Operations* for more details.[29]

3. Shielding

Radiation shielding and other physical barriers such as fences are engineered safeguards designed to attenuate radiation or otherwise reduce the prompt dose rate to acceptable levels. Such passive engineering controls are preferred to active engineering controls such as Beam Containment System (BCS), and administrative controls, such as ropes and signs. Administrative controls may be used to supplement the engineering controls and should be used only if adding shielding or other barriers is not practicable. All primary beams (original accelerator beams) and synchrotron radiation beams must be fully enclosed by shielding and barriers that cannot be circumvented in an unauthorized manner.

During normal operations, all beam lines and experimental facilities must be shielded to control exposures from external radiation to less than 1,000 mrem per year and be kept ALARA. Shielding must also be designed to protect individuals under abnormal operating conditions (mis-steering and system-failure cases).

The RSO approves shielding design specifications. The Radiation Physics Group (RPG) within the RP Department is responsible for determining the shielding required for a facility and must be consulted prior to the design of a new facility or the modification of an existing facility. To obtain approval of a shielding design from the RSO, it is the responsibility of the line manager (or designee) to provide information in writing and work with a radiation physicist within the RPG who is tasked with oversight of facility construction or modification where shielding is required. The radiation physicist will then propose a shielding design and seek concurrence from the RSO on the design.

Any facility that requires radiation shielding shall have an appropriate configuration control program to ensure the shielding is properly in place before and during accelerator operation. Both moveable and permanent shielding shall not be moved unless permission is given by the responsible radiation physicist and the appropriate safety office or the assigned Safety Officer. Shielding is controlled through Beam Authorization Sheets (BAS), Radiation Safety Work Control Forms, and Safety Checklists. See *Conduct of Accelerator Facility Operations* for more details.[29] The configuration control program also applies to all radiation safety-significant systems such as the Beam Containment and the Personnel Protection Systems.

4. Beam Containment

A. Radiation safety policy at SLAC requires that beams be transported within their designated channels to the designed termination point, such as a detector, beam

29 Conduct of Accelerator Facility Operations (CACM-2019-059)

dump, or injection into a storage ring. If beams diverge from their proper channels, high radiation levels can occur in unprotected areas.

B. The Beam Containment System (BCS) prevents beams from diverging from the designated channel and detects excessive beam power or beam losses that could cause radiation levels exceeding established radiation limits.

C. Containment of beams is usually accomplished by a combination of passive devices, such as collimators, that are designed to absorb errant beams, and active devices, such as electronic monitors, that shut off beams when out-of-tolerance conditions are detected.

D. Beam parameters such as energy and current and/or beam losses in an area may need to be monitored and limited by BCS devices to prevent excessive radiation levels outside the shielding enclosure. BCS devices are also used to turn off the beam if the beam power striking a device designated to contain it exceeds the power safety limit of that device.

E. The details of BCS design guidelines are described in the *Radiation Safety Systems*[30] technical basis document.

5. Personnel Protection System (PPS)

At SLAC, the interlocked access control system is called the PPS. It protects personnel from exposure to prompt ionizing radiation from beams and interlocked electrical hazards in the accelerator housing. A PPS consists of access interlock logic, display of access states, key controls, and other controls. The interlocked access control system that protects personnel from exposure to prompt ionizing radiation in synchrotron radiation beam line hutches is called the hutch protection system (HPS). The general design requirements, review, and approval of the HPS are similar to those described for the PPS. New and modified PPSs, as well as PPS bypasses, must be approved by the RSO prior to implementation.

A. Accessible beam lines must have a PPS to protect personnel from prompt radiation. The PPS prevents exposure through the use of beam stoppers (or beam inhibiting devices). The PPS also prevents entry to beam enclosures when beams are operating and turns off beams when a security violation is detected.

B. The PPS will be established and maintained to be fail-safe. To meet this goal, the PPS is scrutinized continuously via configuration control, periodic certification, and testing of its physical and electrical components.

C. Before a new PPS is used for routine operation, it will be reviewed and documented by means of drawings and a written function description. PPS modification must also be documented, reviewed, and approved.

D. In the case of an access violation, the PPS will automatically terminate the radiation hazard by removing or redirecting the beam and/or inserting metal plugs into the beam line path.

30 Radiation Safety Systems (SLAC-I-720-0A05Z-002)

E. Large, illuminated signs are generally located adjacent to each major beam line housing entrance. The signs display access-state information (such as "No Access," "Restricted Access," or "Controlled Access") that alert personnel to possible hazardous conditions in the beam line housing.

F. Key controls at access doors are used to account for personnel in accelerator and beam line housings when access states are in the controlled access configuration (that is, each person has a key). Qualified operators (such as PEP-II and Linac Accelerator Systems Department operations staff for main SLAC accelerators) enforce these key controls as personnel enter and exit accelerator housings. When keys are removed, the system provides a safety interlock to ensure a beam cannot be directed into areas occupied by personnel.

6. Venting

The primary function of the vent fans is to exhaust "stale" air and vent, for example ozone, before personnel access is required in certain areas such as the Damping Rings or Positron Target Vault and the Beam Switch Yard. Vent fans should be turned off when running the primary electron beam.

7. Accelerator Area Fence

A fence shall surround the two-mile long accelerator and research area. The entire area within this fence is the Accelerator Area and there are specific training and personal identification requirements for access to this Area.

8. Radiation Warning Signs

Radiation warning signs shall be used to mark Radiological Areas. Areas where the continuous radiation level exceeds 5 mrem/hour (0.05 mSv/hour) at 30 cm shall be posted using a sign "CAUTION, RADIATION AREA." Radiation tapes or ropes may be used to define the area. The entry to areas in which the radiation levels can exceed 5 mrem in one hour because of an intermittent source (for example, when a beam is on) should be equipped with a device that indicates when the radiation is present. The sign should include a statement that indicates how to determine when the radiation is present (for example, "CAUTION, RADIATION AREA WHEN LIGHT IS FLASHING").

If the radiation equivalent dose to the whole body can exceed 100 mrem in an hour (1 mSv/h) at 30 cm, the sign shall state "CAUTION," or "DANGER, HIGH RADIATION AREA" (refer to Table 2-3).

If the radiation absorbed dose can exceed 500 rad in an hour (5 Gy/h) at 100 cm, the sign should state "GRAVE DANGER, VERY HIGH RADIATION AREA" (refer to Table 2-3).

9. Start-up Warning

An audio and visual warning is provided inside the housing upon start of the accelerators.

10. Warning Lights

There shall be status indicating lights at all entrances to Accelerator Areas. Continuous magenta will indicate there is the potential for a beam in the accelerator. Flashing magenta will indicate that there is an actual beam present. Yellow will indicate that there may possibly be residual radioactivity in the area.

365 Radiation Generating Devices

A *radiation generating device (RGD)* is a collective term for devices which produce ionizing radiation, including certain sealed radioactive sources, small particle accelerators used for single purpose applications which produce ionizing radiation (e.g., radiography), and electron generating devices that produce x-rays incidentally.

Special considerations associated with the use of radiation generating devices include the presence of extremely high dose rates and the potential for uncontrolled exposures. Operation of these devices requires stringent physical and administrative controls to prevent overexposure to operating and support personnel and those in adjacent work areas.

1. Acquisition and Use of Nonmedical X-ray Generators and Sealed Gamma-Ray Sources

   A. [Reserved]

   B. Each RGD shall be registered with the RP Department. Each RGD shall have an authorized custodian (responsible person) appointed by their supervisor and the RGD's location and use shall be approved by the RP Department. Interlocks and radiation warning signs shall be provided as specified by the RP Department.

   C. Each RGD shall have a radiation RGD authorization sheet (RGDAS) posted in a conspicuous location. It must list the custodian, operators, users, and approved operating mode(s).

   D. Each potential custodian of radiation generating devices shall notify the RP Department directly or via the directorate ESH Safety Coordinator prior to purchase or transfer from another site to SLAC. Each potential custodian shall declare the radiation generating device via the SLAC Purchasing Department's standard purchase requisition form,

   E. If the RGD is built in-house, the potential custodian shall notify the RP Department before construction so that appropriate safety interlocks and visual warnings can be incorporated in the design. Radiation safety requirements are detailed in *Radiation Generating Devices Program Manual*.[31]

   F. SLAC shall use to the extent appropriate ANSI/ HPS N43.3, "General Radiation Safety-Installations Using Non-Medical X-Ray and Sealed Gamma-Ray Sources, Energies up to 10 MeV,"[32] for operations involving the irradiation of materials. See the *Bldg. 24 Radiological Calibration Facility Use Procedures*.[33]

2. Fluorescence Analyzers/X-ray Crystallography Devices

   ANSI/HPS N43.2, "Radiation Safety for X-Ray Diffraction and Fluorescence Analysis Equipment,"[34] shall be adhered to for operations involving the following devices:

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31 Radiation Generating Devices Program Manual (SLAC-I-760-2A30C-015, FO 035)

32 American National Standards Institute (ANSI)/Health Physics Society (HPS) N43.3, "General Radiation Safety-Installations Using Non-Medical X-Ray and Sealed Gamma-Ray Sources, Energies up to 10 MeV" (ANSI/HPS N43.3)

33 Bldg 24 Radiological Calibration Facility Use Procedures (SLAC-I-760-1A03C-001, FO 015)

34 American National Standards Institute (ANSI)/Health Physics Society (HPS) N43.2, "Radiation Safety for X-Ray Diffraction and Fluorescence Analysis Equipment," (ANSI/HPS N43.2)

A. Analytical diffraction and fluorescence spectrometers

B. Sealed source irradiators used for diffraction studies

3. Line management, in conjunction with the RP Department, shall establish the radiological control requirements for all RGDs.

4. Devices for medical use shall be registered with the appropriate regulatory agency.

5. Control requirements for radiographic devices include the following:

A. On-site operations with devices containing sealed sources should be conducted in accordance with the requirements contained in 10 CFR 34.[35]

B. ANSI/HPS N43.3 should be used to guide on-site radiographic devices.

C. On-site operations conducted by off-site contractors shall be approved by line management in coordination with the RP Department. This process shall ensure the contractor has a valid Nuclear Regulatory Commission or Agreement State license and that the operational and emergency procedures are current and available.

6. Safety devices and interlocks at fixed installations shall be operational prior to and during generation of a radiation field. Operational status shall be verified by testing. Safety devices and interlocks should be fail-safe.

PART 7 Construction and Restoration Projects

Construction and restoration projects, including decontamination and decommissioning (D&D), remedial action, or other actions involving material that contains low levels of radioactivity, may present special problems and require site-specific or program-specific control methods. Health and Safety Plans are normally developed to specify controls for all types of restoration programs.

371 Requirements

Radiological operations and work activities at construction and environmental restoration projects shall be conducted in accordance with 10 CFR 835. In light of the special nature of these activities, which typically involve low levels of radioactivity and the use of heavy construction or earth-moving equipment, these projects require some radiological considerations different from other activities governed by this *Manual*.

For the following specific subject areas, the radiological requirements of this *Manual* may be modified by the limited application of the provisions of Article 113.2. The RCM is authorized to change mandatory "shall" requirements to "should" to facilitate implementation of radiological controls in the following specific subject areas.

1. Performance goals and indicators appropriate to remedial activities.

2. PPE requirements and practices to accommodate other hazards on the site.

35 Title 10, *Code of Federal Regulations*, "Energy," Chapter 1, "Nuclear Regulatory Commission," Part 34, "Licenses for Radiography and Radiation Safety Requirements for Radiographic Operations" (10 CFR 34)

3. Use of respiratory protection as normal conduct of operation due to lack of engineering controls and temporary nature of the work.
4. Use of contamination reduction corridors to accommodate movement of personnel and heavy equipment through a variety of decontamination stations.
5. Methods to obtain representative samples for release of equipment and material from the work areas.
6. Surveying of materials released from Soil Contamination Areas that exhibit significant contamination transfer properties.
7. Precedence of state and federally mandated soil cleanup criteria over surface contamination criteria that otherwise apply.
8. Monitoring and survey frequency for inactive facilities or large areas that are infrequently occupied.
9. Outdoor storage of uncontained, bulk radioactive material such as contaminated soil.
10. Postings of privately owned and adjacent property.
11. Evaluation of outdoor air monitoring methodologies that take into account dust loading, environmental factors, and supplemental breathing zone sampling.
12. Criteria for suspension of operations under inclement conditions, such as wind or rain.

Note SLAC should document the technical equivalency of alternative solutions and shall ensure compliance with the applicable requirements of 10 CFR 835.

372 Environmental Conditions

Inclement weather or other environmental conditions may disrupt radiological controls. If that occurs, the following actions should be considered:

1. The use of covers, wind screens, and runoff collection basins to preclude the inadvertent spread of radioactive material
2. Provisions for worksite personnel to assemble and be monitored prior to release or re-establishment of work
3. Evaluation of work area to determine if a need exists for modified work controls or decontamination
4. If any work will involve excavation of any radioactive soil or removal of any radioactive water from the ground, contact the SLAC Environmental Protection Department to ensure that any National Environmental Protection Act prerequisites are identified and completed prior to start of such work.

373 Other Workplace Hazards

Radiological controls should be implemented in a balanced way to ensure that protection from all workplace hazards can be implemented. Other hazards to consider include the following:

1. General construction hazards
2. Confined spaces

3. Flammable materials
4. Reactive chemicals
5. Heat stress
6. Chemical exposures
7. Energized electrical equipment
8. Biological hazards
9. Rotating equipment
10. Noise and vibration
11. Excavations
12. Non-ionizing radiation
13. Magnetic fields

Appendix 3A Checklist for Reducing Occupational Radiation Exposure

The following checklists and topics should be considered in the preparation for radiological work at SLAC.

Preliminary Planning and Scheduling

- Plan in advance.
- Delete unnecessary work.
- Determine expected radiation levels.
- Estimate person-rem (collective dose).
- Sequence jobs.
- Schedule work.
- Select a trained and experienced work force.
- Identify and coordinate resource requirements.

Preparation of Technical Work Documents

- Include special radiological control requirements in technical work documents.
- Perform ALARA pre-job review.
- Plan access to and exit from the work area.
- Provide for service lines (air, welding, ventilation).
- Provide communication (sometimes includes closed-circuit television).
- Remove or shield sources of radiation.
- Plan for installation of temporary shielding.
- Decontaminate if appropriate.
- Work in lowest radiation levels.
- Perform as much work as practicable outside Radiation Areas.
- State requirements for standard tools.
- Consider special tools, including robots.
- State staging requirements for materials, parts, and tools.
- Incorporate Radiological Control Hold Points.
- Minimize discomfort of workers.
- Revise estimates of collective dose (person-rem).
- Prepare Radiological Work Permits (RWPs).

Temporary Shielding

- Design shielding to include stress considerations.
- Control installation and removal by written procedure.
- Inspect after installation.
- Conduct periodic radiation surveys.
- Prevent damage caused by heavy lead temporary shielding.
- Balance radiation exposure received in installation against exposure saved by installation.
- Shield travel routes.
- Shield components with abnormally high radiation levels early in the maintenance period.
- Shield position occupied by worker.
- Perform directional surveys to improve design of shielding by locating source of radiation.
- Use mock-ups to plan temporary shielding design and installation.
- Consider use of water-filled shielding.

Rehearsing and Briefing

- Rehearse.
- Use mock-ups duplicating working conditions.
- Use photographs and videotapes.
- Supervisors conduct briefings of workers.

Performing Work

- Comply with technical work documents and RWPs.
- Post radiation levels.
- Keep excess personnel out of Radiation Areas.
- Minimize radiation exposure.
- Supervisors and workers keep track of radiation exposure.
- Workers assist in radiation and radioactivity measurements.
- Delegate radiological control monitoring responsibilities.
- Evaluate use of fewer workers.
- Re-evaluate reducing radiation exposures.
- Compare actual collective dose against pre-job estimate.
- Review work practices to see if changes will reduce dose.
- Coordinate personnel at the job site to reduce nonproductive time.

Appendix 3B Physical Access Controls for High Radiation Areas and Very High Radiation Areas

1. 835 **One or more of the following features shall be used for each entrance or access point to a high radiation area where radiation levels exist such that an individual could exceed an equivalent dose to the whole body of 1 rem (0.01 Sv) in any 1 hour at 30 centimeters from the source or from any surface that the radiation penetrates:**

   A. A control device that prevents entry to the area when high radiation levels exist or upon entry causes the radiation level to be reduced below that level defining a high radiation area;

   B. A device that functions automatically to prevent use or operation of the radiation source or field while individuals are in the area;

   C. A control device that energizes a conspicuous visible or audible alarm signal so that the individual entering the high radiation area and the supervisor of the activity are made aware of the entry;

   D. Entryways that are locked. During periods when access to the area is required, positive control over each entry is maintained;

   E. Continuous direct or electronic surveillance that is capable of preventing unauthorized entry;

   F. A control device that will automatically generate audible and visual alarm signals to alert personnel in the area before use or operation of the radiation source and in sufficient time to permit evacuation of the area or activation of a secondary control device that will prevent use or operation of the source.
   [10 CFR 835.502(b)]

2. 835 **In addition to the above measures, additional measures shall be implemented to ensure individuals are not able to gain unauthorized or inadvertent access to very high radiation areas.** [10 CFR 835:502(c)] Such additional measures shall be implemented when dose rates are in excess of the posting requirements of Table 2-3. See *Conduct of Accelerator Facility Operations* for further information.[36]

3. 835 **No control(s) shall be established in a high or very high radiation area that would prevent rapid evacuation of personnel.** [10 CFR 835. 502(d)] See *Conduct of Accelerator Facility Operations* for further information.[36]

36 Conduct of Accelerator Facility Operations (CACM-2019-059)

Appendix 3C Contamination Control Practices

Selection of Protective Clothing

1. Workers should inspect protective clothing (PC) prior to use for tears, holes, or split seams that would diminish protection. Any defective items should be replaced with intact PC.
2. PC, as prescribed by the Radiological Work Permit (RWP), should be selected based on the contamination level in the work area, the anticipated work activity, worker health considerations, and regard for non-radiological hazards that may be present. Table 3-1 provides general guidelines for selection. A full set and double set of PC typically includes the items referenced in Table 3-2, "Typical Full or Double Set of PC."

Table 3-1 Guidelines for Selecting Protective Clothing

WORK ACTIVITY	REMOVABLE CONTAMINATION LEVELS		
	LOW (1 to 10 times Table 2-2 values)	**MODERATE** (10 to 100 times Table 2-2 values)	**HIGH** (> 100 times Table 2-2 values)
Routine	Full set of PCs or the combination of shoe covers and lightweight gloves.	Full set of PCs	Full set of PCs, double gloves, double shoe covers
Heavy work	Full set of PCs, work gloves	Double set of PCs, work gloves	Double set of PCs, work gloves
Work with pressurized or large volume liquids, closed system breach	Full set of non-permeable PCs	Double set of PCs (outer set non-permeable), rubber boots	Double set of PCs and non-permeable outer clothing, rubber boots

Table 3-2 Typical Full or Double Set of PC

Full Set of PCs	Double Set of PCs
Coveralls	Two pairs of coveralls
Cotton glove liners	Cotton glove liners
Gloves	Two pairs of gloves
Shoe plastic booties	Two pairs of plastic booties
Rubber shoe covers	Rubber shoe covers
Hood	Hood

3. Cotton glove liners may be worn inside standard gloves for comfort but should not be worn alone or considered as a layer of protection.
4. Shoe covers and gloves should be sufficiently durable for the intended use. Leather or canvas work gloves should be worn in lieu of, or in addition to, standard gloves for work activities requiring additional strength or abrasion resistance.
5. Use of industrial safety equipment, such as hard hats, in Contamination, High Contamination, and Airborne Radioactivity Areas should be controlled by the RWP. Reusable industrial safety equipment designated for use in such areas should be distinctly colored or marked.
6. Shoe covers and gloves should be secured or taped at the coverall legs and sleeves when necessary to prevent worker contamination. Tape should be tabbed to permit easy removal.
7. Supplemental pocket or electronic dosimeters should be worn outside the PC, in a manner accessible to the worker. Workers should protect such dosimeters from contamination by placing them in an outer coverall pocket or in plastic bags or pouches.
8. Outer personal clothing should not be worn under protective clothing for entry to High Contamination Areas or during work conditions requiring a double set of PCs.

Removal of Protective Clothing

Potentially contaminated PC should be removed without spreading contamination, and, in particular, without contaminating the skin. Workers should be instructed not to touch the skin or place anything in the mouth during PC removal. Instructions for PC removal comparable to the sequence presented below should be posted adjacent to the step-off pad, in accordance with Article 325.6.

Recommended Sequence for Removing a Full Set of Protective Clothing

Before stepping out of the Contamination Area or Airborne Radioactivity Area, the worker should:

1. Remove exposed tape.
2. Remove rubber shoe covers.
3. Remove gloves.
4. Remove hood from front to rear.
5. Remove respiratory protection, as applicable.
6. Remove coveralls, inside out, touching inside only.
7. Take down barrier closure, as applicable.
8. Remove tape or fastener from inner shoe cover.
9. Remove each bootie, placing shoe onto clean area.
10. Remove cloth glove liners.
11. Replace barrier closure, as applicable.
12. Commence whole-body frisking.

13. Monitor badge and dosimeter.

The sequence for the removal of primary and supplemental dosimetry is dependent upon where the dosimetry was worn and the potential for contamination.

Recommended Sequence for Removing a Double Set of Protective Clothing Using Sequentially Cleaner Zones

Before stepping to the inner clean zone, the worker should:

1. Remove exposed tape.
2. Remove rubber shoe covers.
3. Remove outer gloves.
4. Remove hood from front to rear.
5. Remove respiratory protection, as applicable.
6. Remove outer coverall, inside out, touching inside only.
7. Remove tape from inner coverall and sleeves.
8. Remove each outer shoe cover, stepping in the inner clean zone as each is removed.

Before stepping to the outer clean zone, the worker should:

1. Remove inner rubber gloves.
2. Remove inner coveralls, inside out, touching inside only.
3. Take down barrier closure, as applicable.
4. Remove tape or fastener from inner shoe cover.
5. Remove each inner shoe cover, placing shoe on clean outer clean zone.
6. Remove cotton glove liners.
7. Replace barrier closure, as applicable.
8. Commence whole-body frisking.
9. Monitor badge and dosimeter.

The sequence for the removal of primary and supplemental dosimetry is dependent upon where the dosimetry was worn and the potential for contamination.

Use of Multiple Clean Zones

1. Multiple clean zones should be used to control exit from High Contamination Areas. These zones define interim control measures within the posted area to limit the spread of contamination. The following controls apply:
   A. The inner zone should be located immediately outside the highly contaminated work area, but still within the posted area.
   B. The worker should remove highly contaminated outer clothing prior to stepping in the inner zone.

C. Additional secondary clean zones, still within the posted area, may be utilized as necessary to restrict the spread of contamination out of the immediate area.

D. The final or outer clean zone should be located immediately outside the Contamination Area.

Appendix 3D Guidelines for Personnel Contamination Monitoring with Hand-Held Survey Instruments

General Requirements

1. Verify that the instrument is in service, set to the proper scale, and that the audio output can be heard during frisking.
2. Hold the probe less than 1/2 inch from surface being surveyed for beta and gamma contamination, approximately 1/4 inch for alpha contamination.
3. Move probe slowly over surface, approximately 2 inches per second.
4. If the count rate increases during frisking, pause for 5 to 10 seconds over the area to provide adequate time for instrument response.
5. If the count rate increases to a value greater than a pre-established contamination limit or the instrument alarms, remain in the area and follow the non-life-threatening incident notification process by notifying the supervisor, place a call to ext. 5555, and notify the RP Department at ext. 4299.
6. The whole-body frisk should take at least two to three minutes.

Performance of Monitoring

1. Frisk the hands before picking up the probe.
2. Perform the frisk in the following order:
   A. Head (pause at mouth and nose for approximately five seconds)
   B. Neck and shoulders
   C. Arms (pause at each elbow for approximately five seconds)
   D. Chest and abdomen
   E. Back, hips, and seat of pants
   F. Legs (pause at each knee for approximately five seconds)
   G. Shoe tops
   H. Shoe bottoms (pause at sole and heel for approximately five seconds)
   I. Personnel and supplemental dosimeters
3. Return the probe to its holder and leave the area. The probe should be placed on the side or face up to allow the next person to monitor their hands before handling the probe.

CHAPTER 4 RADIOACTIVE MATERIALS

PART 1 Radioactive Material Identification, Storage, and Control

For the purposes of this *Manual*, radioactive material is any material, equipment, or system component determined by using sensitive instrumentation to be activated, contaminated, or suspected of being activated and/or contaminated. All material located in accelerator housings, Contamination, High Contamination, or Airborne Radioactivity Areas and having the potential to become contaminated are considered radioactive material. Radioactive material includes activated material, sealed and unsealed sources, and other material that emits radiation. Controls for sealed sources are described in Article 431.

RP Department approval is required prior to bringing onsite any radioactive material, including any device containing one or more sealed sources or a holder with radioactive material to be used at experimental beam lines.

411 Requirements

1. All material used in Radioactive Material Management Areas (RMMAs) or Radioactive Material Areas (RMAs) in a manner which might contaminate or activate them shall be considered radioactive material until surveyed and released. Material in Contamination, High Contamination, or Airborne Radioactivity Areas shall be considered contaminated until surveyed and released. Any equipment or system component removed from a process which may have had contact with radioactive material shall be considered contaminated until shown to be free of contamination by survey. The item may require disassembly to the extent required to perform an adequate survey. These survey and release requirements do not apply to Airborne Radioactivity Areas where only gaseous, short-lived (half-life of one hour or less) radionuclides are present.

2. 835 **Items and containers may be excepted from the radioactive material labeling requirements of § 835.605 when: (1) Used, handled, or stored in areas posted and controlled in accordance with this subpart and sufficient information is provided to permit individuals to take precautions to avoid or control exposures; or (2) The quantity of radioactive material is less than one tenth of the values specified in appendix E** (which corresponds to Appendix 4A of this *Manual*) **of this part and less than 0.1 Ci; or (3) Packaged, labeled, and marked in accordance with the regulations of the Department of Transportation or DOE Orders governing radioactive material transportation; or (4) Inaccessible, or accessible only to individuals authorized to handle or use them, or to work in the vicinity; or (5) Installed in manufacturing, process, or other equipment, such as reactor components, piping, and tanks; or (6) The radioactive material consists solely of nuclear weapons or their components.**[10 CFR 835 606(a)]**.**

3. In event of a loss of known or suspected radioactive material, the Radiation Protection (RP) Department shall be notified. RP shall respond to such notification by launching a search for the missing material, investigating the cause, and documenting the outcome. For sealed source management, see Article 431 of this *Manual*.

412 Radioactive Material Labeling

1. 835 **Except as provided in 10 CFR 835.606** (see Article 411.2)**, each item or container of radioactive materials shall bear a durable, clearly visible label bearing the standard radiation warning trefoil and the words "Caution, Radioactive Material" or "Danger, Radioactive Material." The label shall also provide sufficient information to permit individuals handling, using, or working in the vicinity of the items or containers, to take precautions to avoid or control exposure.** [10 CFR 835.605]

2. Postings and access control requirements for Contamination, High Contamination, and Airborne Radioactivity Areas provide sufficient personnel protection to negate the need for individual container or item labeling. Radioactive material outside RMMAs shall be labeled in accordance with Table 4-1 of this *Manual*, "Labeling Requirements for Radioactive Material."

Table 4-1 Labeling Requirements for Radioactive Material

Item/Material	Required Labeling*	Supplemental Labeling
Equipment, components, and other items that are radioactive, potentially radioactive, or have been exposed to radioactive contamination or activation sources	Standard radiation warning trefoil, and "CAUTION" or "DANGER" and "RADIOACTIVE MATERIAL" [see 10 CFR 835.605]	"CONTAMINATED" or "POTENTIALLY CONTAMINATED"
Sealed and unsealed radioactive sources or associated storage containers		
Equipment, components, and other items with actual or potential internal contamination		"INTERNAL CONTAMINATION" or " POTENTIAL INTERNAL CONTAMINATION"
Components, equipment, or other items with fixed contamination		"FIXED CONTAMINATION"

* Labeling required on item or container meets the criteria established in 10 CFR 835.605.

3. Labels shall include contact radiation levels, removable surface contamination levels (specified as alpha or beta-gamma as appropriate), estimated quantity of radioactivity, dates surveyed, surveyor's name, and description of items. Items which are too small to be labeled with all of the stated information shall be labeled, at a minimum, with the words "CAUTION, RADIOACTIVE MATERIAL" and the standard radiation symbol.

4. The label on packaged radioactive material shall be visible through the package or affixed to the exterior of the package.

5. The following may be exempted from labeling requirements:

   A. Materials and items surveyed and determined to be free of radioactivity using SLAC procedure, *Protocols for Defining and Monitoring for Radioactive*

Material[37] and to have contamination levels lower than values in Table 2-2, "Summary of Surface Contamination Values" (in this *Manual*).

B. PPE and protective clothing

C. 835 **Inaccessible, or accessible only to individuals authorized to handle or use them, or to work in the vicinity.** [10 CFR 835.606(a)(4)] Radiological control samples such as air, process and soil samples, or swipes that are in the custody of RP Department personnel or personnel properly trained in the handling, packaging, and transport of these samples

D. Equipment or installed system components as defined in this Part of this *Manual* (*e.g.* Chapter 4, Part 2) undergoing maintenance covered by a Radiological Work Permit (RWP).

E. Activated or contaminated portable tools and equipment with fixed contamination permanently marked with yellow or magenta and maintained in an RMMA, RMA, a contaminated tool crib, or storage and distribution area.

F. Installed system components as defined in this Part of this *Manual* located within an area, the entrance to which is posted in accordance with Table 2-3 of this *Manual*.

G. Historical items, such as large items used in demonstration projects, located within an RMMA or RMA. Such items shall be properly labeled when they are removed from an RMMA or RMA. Large items can have the word "RAM" painted in yellow.

H. Short-lived (half-life of one hour or less) radioactive material generated during an irradiation and immediately used (such as research samples generated while an experiment is being conducted).

I. Items containing radioactive material when 835 **installed in manufacturing, process, or other equipment, such as reactor components, piping, and tanks.** [10 CFR 835.606(a)(5)] At SLAC, the items captured by this requirement include counters, accelerator components, piping, and tanks.

413 Radioactive Material Packaging

The requirements for packaging radioactive material are given in the SLAC procedure, *Shipping and Receiving of Radioactive Material Procedure*.[38]

1. Radioactive material that is outside Contamination Areas, High Contamination Areas, or Airborne Radioactivity Areas and is confirmed or suspected of having removable radioactive contamination levels greater than values in Table 2-2, "Summary of Surface Contamination Values." shall be securely wrapped in plastic or placed in a closed container and labeled.

37 Protocols for Defining and Monitoring for Radioactive Material (SLAC-I-760-0A30C-006, FO 018)

38 Shipping and Receiving of Radioactive Materials Procedure (SLAC-I-760-0A30C-002, FO 010)

2. Radioactive material with sharp edges or projections should be taped or additionally protected to ensure package integrity.
3. Radioactive material with removable or potentially removable contamination levels in excess of 100 times of its corresponding Table 2-2 values should have additional packaging controls, such as double-wrapping or the use of plastic bags inside containers.
4. Transparent plastic wrapping material or clear plastic bags properly marked should be used for packaging radioactive material having loose contamination and/or if the radioactive material consists of one or more items that are sufficiently small to fit easily inside the wrapping material. Radioactive waste shall be packaged so that the waste is readily visible through the bags. To facilitate ease of viewing their contents, only clear bags are permitted to be used for radioactive waste.
5. The amount of combustible material used in packaging should be minimized.

414 Radioactive Material Storage

1. Radioactive material in quantities exceeding the value specified in Appendix 4A of this *Manual* shall be stored in an RMA or other area posted in accordance with Article 235 or 236.
2. Long-term (more than 60 days) storage of radioactive material should be in a specially designated RMA.
3. Decontamination, disposal, or recycling of radioactive material are the preferred alternatives to storage. Temporary storage areas can be established on a case-by-case basis with prior approval by the RP Department.
4. Each RMA should be approved by the Radiological Control Manager (RCM) or designee.
5. Line managers should assign a custodian for each of their RMAs. A custodian may have responsibility for more than one RMA.
6. The custodian should conduct visual walkthrough surveys of RMAs to check the integrity of containers and wrapping material.
7. The custodian should conduct annual or more frequent reviews of each RMA, with emphasis on decontamination, movement of material to long-term storage locations, and disposal of unneeded material.
8. Storage of non-radioactive material in an RMA is discouraged.
9. In cases where outdoor storage is necessary, the integrity of containers or wrapping material or the items themselves, such as difficult-to-containerize-or-wrap, large concrete blocks, shall be ensured to prevent degradation from weathering and subsequent release of radioactive material. The custodian periodically should check container or wrapping material integrity and legibility of labels at each outdoor RMA.
10. Radioactive material should be stored in a manner that reduces combustible loading. The use of cardboard containers and wooden pallets for storage is discouraged.
11. Flammable or combustible materials should not be stored adjacent to RMAs.

12. Fire protection measures such as smoke detectors, water sprinklers, and fire extinguishers shall be incorporated when establishing an RMA that is located inside a building.

415 Use of Radioactive Consumer Products Exempted by the NRC

If radioactive consumer products (such as thoriated welding rods and thoriated grinding wheels) are used inappropriately, contamination or dose consequences may result.

1. Whenever such products are considered for use at SLAC, the user is required to notify the RP Department to justify its use, obtain approval, and apply specified engineering controls.
2. For thoriated tungsten welding rods or grinding wheels, this *Manual* has been amended to invoke a Radiological Work Permit or Written Procedure (Article 312) for this process. Engineering controls are required as appropriate (Article 453) to control the airborne activity and the surface contamination.

PART 2 Release and Transportation of Radioactive Material

421 Release to Controlled Areas

1. Material and equipment in RMAs, RMMAs, Contamination Areas, High Contamination Areas, or Airborne Radioactivity Areas shall be surveyed prior to release from radiological controls. Unpackaged radioactive material and/or contaminated equipment to be released to Controlled Areas shall be demonstrated to have contamination levels less than the limits in Table 2-2 of this *Manual*. Radioactive material and/or contaminated equipment to be released to uncontrolled areas shall be surveyed in accordance with Article 422.
2. 835 **Material and equipment with fixed contamination levels that exceed the total surface contamination limits specified in appendix D of this part may be released for use in controlled areas outside of radiological areas, but only under the following conditions** (Note: Table 2-2 of this *Manual* corresponds to "appendix D of this part" in this regulatory passage. Also, this *Manual* considers "SLAC Controlled Areas and SLAC Radiologically Controlled Areas outside of SLAC Radiological Areas" as equivalent to "controlled areas outside of radiological areas" in this regulatory passage.)
    - **Removable surface contamination levels are below the removable surface contamination levels in appendix D of this part, and**
    - **The material or equipment is routinely monitored and clearly marked or labeled to alert personnel of the contaminated status.** [10 CFR 835.1101(c)]
3. Items with removable contamination levels greater than the values in Table 2-2 shall be packaged prior to release to Controlled Areas. These items shall be clearly labeled in accordance with Article 422 and 10 CFR 835.605 and routinely monitored and controlled in accordance with administrative procedures.
4. Radioactive material not immediately released after survey must be controlled to prevent unauthorized use while awaiting release.

5. Material not immediately removed from Contamination Areas, High Contamination Areas, or Airborne Radioactivity Areas after the survey shall be controlled to prevent contamination while awaiting release.

6. Records for release of surveyed materials shall describe the property, date of last survey, identity of the person who performed the survey, type and identification number of the survey instruments used, and survey results.

7. Material released to Controlled Areas shall be labeled in accordance with Article 412.

8. 835 **Except as provided in paragraphs (b) and (c) of this section** (Note: in this *Manual*, Articles 431.2 and 431.10 correspond to "paragraphs (b) and (c) of this section" in this regulatory passage)**, material and equipment in Contamination Areas, High Contamination Areas, and Airborne Radioactivity Areas shall not be released to any** "Non-radiologically Controlled Area" portion of a **Controlled Area if:**

   - **Removable surface contamination levels on accessible surfaces exceed the removable surface contamination values specified in appendix D of this part , or**
   - **Prior use suggests that the removable surface contamination levels on inaccessible surfaces are likely to exceed the values specified in appendix D of this part.** [10 CFR 835.1101(a)(1)(2)]

9. 835 **Material and equipment exceeding the total or removable contamination levels specified in appendix D of this part may be conditionally released for movement on-site from one Radiological Area for immediate placement in another Radiological Area only if appropriate monitoring and control procedures are established and exercised.** [10 CFR 835.1101(b)]

422 Release to Uncontrolled Areas

1. Material in Controlled Areas documented to have been released from Contamination, High Contamination, or Airborne Radioactivity Areas shall be surveyed prior to release to uncontrolled areas.

2. The criteria stated in DOE Order 458.1[39] will be used for releasing material to uncontrolled areas. Material being released shall also be evaluated for internal contamination and for contamination under any coatings, where appropriate.

3. Surveyed radioactive material will be controlled until it is released to prevent unnecessary movement on site.

4. Radiological labels shall be removed or defaced prior to release of material for unrestricted use.

39 Site Compliance Plan for Department of Energy Order 458.1, Change 4, "Radiation Protection of the Public and the Environment" (DOE O 458.1, Chg 4 [LtdChg] SCP)

423 Transportation of Radioactive Material

1. 49 CFR 171 through 49 CFR 177[40]establish the requirements for inspecting and surveying packages, containers, and transport conveyances prior to off-site transport. 49 CFR 173 contamination values apply to off-site shipments transported by non-DOE conveyances. These limits also apply to onsite transfers of shipments by non-DOE conveyances received from or destined for offsite locations.

2. The removable contamination values in Table 2-2, "Summary of Surface Contamination Values," shall be used as controlling limits for onsite and offsite transportation when using a DOE conveyance. When a shipment is received from an offsite destination, in or on a non-DOE conveyance, the 49 CFR 173 contamination limit values shall be used. When transfers are made in a DOE conveyance from the onsite receiving location to the ultimate on-site destination after a shipment is received from an offsite destination, in or on a non-DOE conveyance, the 49 CFR 173 contamination limit values shall be used.

3. Off-site shipments of radioactive material, including subcontractors' handling of off-site shipments, and shipments to Stanford campus, shall be controlled and conducted in accordance with applicable federal, state, and local and international regulations. Use 49 CFR 173 for domestic off-site shipments and International Civil Aviation Organization (ICAO) radiological safety standards for air shipments.

4. Further instructions for offsite shipments of radioactive material and radioactive waste are contained in *Shipping and Receiving of Radioactive Materials Procedure*[41] and the *Radioactive Waste Manual*.[42]

5. When transporting radioactive materials onsite at SLAC over nonpublic thoroughfares:

   A. Transport of radioactive materials shall only be conducted using DOE or SLAC equipment (for example: government vehicles, forklifts and cranes). Use of personal vehicles to transport radioactive material is prohibited.

   B. Prior to transport, the radioactive material owner and the RP Department are responsible for surveying material and ensuring materials are properly packaged, identified and labeled in accordance with this Chapter and, as applicable, the *Radioactive Waste Manual*.[42]

   C. Before shipment, and upon receipt of a radioactive shipment, a visual inspection of packages shall be performed to ensure that packages are not damaged. The inspection should identify dents, flaking paint, torn bags, debris, holes, cracks, bulges, significant corrosion or package orientation that could compromise package integrity and/or result in leakage and/or the unintended release of radioactive material.

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40 Title 49, *Code of Federal Regulations*, "Transportation," Subtitle B, "Other Regulations Relating to Transportation," Chapter 1, "Pipeline and Hazardous Materials Safety Administration, Department of Transportation," Subchapter C, "Hazardous Materials Regulations" (49 CFR Chapter 1, Subchapter C)

41 Shipping and Receiving of Radioactive Materials Procedure (SLAC-I-760-0A30C-002, FO 010)

42 Radioactive Waste Manual (SLAC-I-760-02A08Z-001)

D. Secure containers to prevent sliding or shifting during transport. If necessary, use cinch straps or securing bars to keep containers upright. Ensure drum bungs are tight, bags are cushioned, and container lids are installed correctly and secured.

E. Transporters of radioactive materials shall ensure that the destination of the radioactive material is properly prepared for the receipt of the radioactive material, in particular the correct radiological posting. At minimum, the destination receiving area shall be posted as a Controlled Area, Radiologically Controlled Area, or Radioactive Material Area. If the material exceeds 5 mR/h at 30 centimeters (cm), the destination shall be posted as a Radiation Area. If the material exceeds 100 mR/h at 30 cm, then any destination area onsite at SLAC shall be posted as a High Radiation Area and the proper administrative and access controls shall be established.

F. Radioactive material should be located as far from the driver as practicable to help minimize the radiation dose during transport.

G. At minimum, a person transporting the radioactive material shall be either GERT or RWT-qualified and wearing his or her personal dosimeter.

H. On-site transfers over nonpublic thoroughfares or between facilities on the same site should be performed in accordance with written procedures. The procedures should include requirements to ensure appropriate monitoring and control of the radioactive material and be approved by the RP Department. Table 2-2 of this *Manual* states the removable contamination limits that shall be used as outer-packaging thresholds below which only onsite transfers and receipts of radioactivity can be allowed to proceed.

6. Before shipment, and upon receipt of a radioactive shipment, a comparison of package contents to the shipping manifest should be made to ensure accountability.

7. Transport conveyances should be visually inspected prior to loading.

8. Transport conveyances should be radiologically surveyed before loading, especially when using commercial carriers specializing in radioactive transport.

9. Transport of large volumes of radioactive material by non-DOE motor vehicles should be "Exclusive Use" to prevent commingling of DOE and other commercial shipments.

10. The site emergency plan describes appropriate responses for potential onsite radioactive material transportation accidents.

11. 10 CFR 71[43] describes requirements for inspecting and surveying packages, containers, and transport conveyances prior to off-site transport. The 10 CFR 71 contamination values apply to off-site shipments transported by non-DOE conveyances. These limits also apply to on-site transfers of shipments by non-DOE conveyances received from or destined to off-site locations.

43 Title 10, *Code of Federal Regulations*, "Energy," Chapter 1, "Nuclear Regulatory Commission," Part 71, "Packaging and Transportation of Radioactive Material" (10 CFR 71)

12. Off-site shipments of radioactive material, including subcontractors' handling of offsite shipments, shall be controlled and conducted in accordance with applicable federal, state, and local regulations.

13. Before shipment, and upon receipt of a radioactive shipment, a visual inspection of packages shall be performed to ensure that packages are not damaged. The inspection should identify dents, flaking paint, debris, package orientation, and any indication of leakage.

14. Drivers of DOE and non-DOE motor vehicles should have a copy of their emergency response plan, or the emergency response information required by 10 CFR 71, during transport on-site or during off-site transportation.

424 Transportation, Receipt of Packages Containing Radioactive Material

The following provisions apply to the receipt of packages containing radioactive material, including sealed sources at SLAC.

1. 835 **If packages containing quantities of radioactive material in excess of a Type A quantity (as defined at 10 CFR 71.4) are expected to be received from radioactive material transportation arrangements shall be made to either:**

   A. **Take possession of the package when the carrier offers it for delivery**4, **or**

   B. **Receive notification as soon as practicable after arrival of the package at the carrier's terminal and to take possession of the package expeditiously after receiving such notification.** [10 CFR 835.405(a)(1) and (2)]

   At SLAC, the Shipping and Receiving Department shall be the receiving portal for such types and quantities of radioactive material. The Shipping and Receiving Department shall notify the RP Department when it takes possession of any radioactive material.

   The RP Department shall monitor each received package of radioactive material in accordance with Articles 424.2 through 424.7 below.

2. 835 **Upon receipt from radioactive material transportation, external surfaces of the package shall be monitored if the package:** [10 CFR 835.405(b)]

   835 **Is labeled with a Radioactive White I, Yellow II, or Yellow III label (as specified at 49 CFR 172.403 and 172.436-440);** [10 CFR 835.405(b)(1)] or

   835 **Has been transported as low specific activity (LSA) material (as defined at 10 CFR 71.4) on an 'Exclusive Use' vehicle (as defined at 10 CFR 71.4);** [10 CFR 835.405(b)(2)] or

   835 **Has evidence of degradation, such as packages that are crushed, wet, or damaged.** [10 CFR 835.405(b)(3)]

3. 835 **The monitoring required by paragraph (b) of this section shall include:** (Note: Article 424.2 of this *Manual* corresponds to "paragraph (b) of this section" in this regulatory passage**)**

   Measurements of removable contamination levels, unless the package contains only special form (as defined at 10 CFR 71.4) or gaseous radioactive material; [10 CFR 835.405(c)(1)] **and**

Measurements of the radiation levels, if the package contains a Type B quantity (as defined at 10 CFR 71.4) of radioactive material. [10 CFR 835.405(c)(2)]

4. 835 **The monitoring required by paragraph (b) of this section shall be completed as soon as practicable following receipt of the package, but not later than 8 hours after the beginning of the working day following receipt of the package.** [10 CFR 835.405(d)] (Note: Article 424.2 of this *Manual* corresponds to "paragraph (b) of this section" in this regulatory passage**)**

5. If the package is labeled with a Yellow III or arrives as an "Exclusive Use" shipment, the RP Department should take immediate possession of the package, conduct a radiological survey of the package described in Articles 424.2 and 424.3, and store the package in an appropriate location.

6. For additional details on the protocol of receiving packages containing radioactive material at SLAC refer to *Shipping and Receiving Radioactive Material Procedure*.[41]

7. Monitoring pursuant to Article 424.2 is not required for packages transported on a DOE site which have remained under the continuous observation and control of a DOE employee or DOE contractor employee who is knowledgeable of and implements required exposure control measures.

PART 3 Radioactive Source Controls

431 Radioactive Source Controls

835 **Sealed radioactive sources shall be used, handled, and stored in a manner commensurate with the hazards associated with operations involving the sources.** [10 CFR 835.1201] Sealed radioactive sources will be identified and tracked via an inventory database including location of each source.

Radiological safety aspects must be reviewed and approved by RP Department prior to the bringing onsite of any radioactive material (examples include sealed sources, radioactive sealed samples, devices containing one or more sealed sources, or a holder with radioactive material to be used at experimental beam lines).

Included as sealed sources at SLAC are generally licensed radioactive devices as defined in Title 17, Section 30191 of the *California Code of Regulations*.[44] Generally licensed devices are to be treated at SLAC as non-accountable sealed sources.

Excepted from any and all requirements of this Article is any exempt radioactive product as defined in Title 17, Section 30180 of the *California Code of Regulations*.[45]

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44 Title 17, *California Code of Regulations*, "Public Health," Division 1, "State Department of Health Services," Chapter 5, "Sanitation (Environmental)," Subchapter 4, "Radiation," Group 2, "Licensing of Radioactive Materials," Article 4, "Licenses," Section 30191, "General Licenses – Source Material" (17 CCR 30191)

45 Title 17, *California Code of Regulations*, "Public Health," Division 1, "State Department of Health Services," Chapter 5, "Sanitation (Environmental)," Subchapter 4, "Radiation," Group 2, "Licensing of Radioactive Materials," Article 3, "Exemptions," Section 30180, "Carriers, Federal Licensees and Prime Contractors" (17 CCR 30180)

The inventory will be verified on at least a calendar year basis. However, only accountable sealed radioactive sources shall be subject to the following provisions and controls. Accountable sealed radioactive sources are sources having activities equal to or exceeding the values specified in Appendix 4A [10 CFR 835 appendix E].

1. Written procedures shall be established and implemented to control "accountable" sealed radioactive sources. These procedures should establish requirements for source acquisition, receipt, storage, transfer, inventory, leak testing, and usage.

2. Accountable sealed sources, or their storage containers, shall be labeled with the radiation symbol and "CAUTION" or "DANGER RADIOACTIVE MATERIAL." The label should also provide sufficient information to minimize exposures, such as the radionuclide, the quantity of radioactive material, and the date of quantity estimate, date of assay, source model, and serial number. 835 **However, radioactive material labels applied to sealed radioactive sources may be excepted from the color specifications of 10 CFR 835.601(a).** [10 CFR 835.606 (b)] (These color specifications normally are magenta or black on yellow) If the size or configuration of the source precludes application of a suitable label, the label should be attached to the source container or mechanism.

3. 835 **Each accountable sealed radioactive source shall be inventoried at intervals not to exceed six months. This inventory shall** [10 CFR 835.1202(a)]**:**

   A. 835 **Establish the physical location of each accountable sealed radioactive source;** [10 CFR 835.1202(a)(1)]

   B. 835 **Verify the presence and adequacy of associated postings and labels;** [10 CFR 835.1202(a)(2)] **and**

   C. 835 **Establish the adequacy of storage locations, containers, and devices.** [10 CFR 835.1202(a)(3)]

4. 835 **Except for accountable sealed radioactive sources consisting solely of gaseous radioactive material or tritium, each accountable sealed radioactive source shall be subject to a source leak test upon receipt, when damage is suspected and at intervals not to exceed six months.** [10 CFR 835.1202(b)]

5. 835 **Source leak tests shall be capable of detecting radioactive material leakage equal to or exceeding 0.005 µCi.** [10 CFR 835.1202(b)]

6. 835 **Notwithstanding the requirements of paragraph (b) of this section, an accountable sealed radioactive source is not subject to periodic source leak testing if that source has been removed from service. Such sources shall be stored in a controlled location and subject to periodic inventory in accordance with paragraph (a) of this section and subject to source leak testing prior to being returned to service.** [10 CFR 835.1202(c)] (Note: Articles 431.4 and 431.5 of this *Manual* corresponds to "paragraph (b) of this section" in this regulatory passage. Also, Article 431.3 of this *Manual* corresponds to "paragraph (a) of this section" in this regulatory passage.**)**

7. 835 **Notwithstanding the requirements of paragraphs (a) and (b) of this section, an accountable sealed radioactive source is not subject to periodic inventory and source leak testing if that source is located in an area that is unsafe for human entry (such as due to operational or environmental constraints) or otherwise inaccessible.**

[10 CFR 835.1202(d)] (Note: Articles 431.3, 431.4, and 431.5 of this *Manual* corresponds to "paragraphs (a) and (b) of this section" in this regulatory passage.)

8. When the conditions that restrict access to the area have been terminated, the inventory and leak test should be performed before allowing uncontrolled access to the area.

9. 835 **An accountable sealed radioactive source found to be leaking radioactive material shall be controlled in a manner that minimizes the spread of radioactive contamination.** [10 CFR 835.1202(e)]

10. Individual and group source custodians shall be appointed by line managers to maintain accountable radioactive source controls. The RP Department shall maintain records of these appointments. Source custodians shall obtain training specific for sealed source control.

11. Source custodians shall notify the RP Department of changes in use, storage, transfer, disposal, or loss of any sealed sources.

12. Procurement of radioactive sources or any device containing radioactive material shall be coordinated with the RP Department.

13. Sources, including radiography sources and density gauges, shall not be brought on site by external organizations without the prior written approval of the RP Department.

PART 4 Solid Radioactive Waste Management

441 Requirements

1. The *Radioactive Waste Manual*[42] per DOE Order 435.1, "Radioactive Waste Management"[46] shall be used for guidance on how solid radioactive waste is processed, packaged, stored, transported, and disposed.

2. Radiological operations generating radioactive waste should be designed and developed to promote waste minimization, segregation, monitoring, treatment, storage, and disposal.

3. Radioactive waste minimization goals and practices have been developed and implemented.

442 Waste Minimization

A radioactive waste minimization program shall be in effect to reduce the generation of radioactive waste and the spread of contamination from Contamination Areas, High Contamination Areas, or Airborne Radioactivity Areas. The following practices shall be integrated to support waste minimization. See the *Radioactive Waste Manual.*[42]

1. Restrict material entering Radiological Areas to those needed for performance of work.

46 Department of Energy Order 435.1, Change 2, "Radioactive Waste Management" (DOE O 435.1, Chg 2 [AdminChg])

2. Restrict quantities of hazardous material (such as paints, solvents, chemicals, cleaners, and fuels) entering Radiological Areas and take measures to prevent inadvertent radioactive contamination of such material.
3. Substitute recyclable items for disposable ones and reuse equipment when practical.
4. Select material, such as protective coverings and clothing, which are compatible with waste-processing systems, volume reduction, and waste form acceptance criteria.
5. Reserve an assortment of tools primarily for use in RMMAs, RMAs, Contamination, High Contamination, or Airborne Radioactivity Areas. Tools should be maintained in a designated storage or distribution area or a contaminated tool crib. Controls should be established for tool issuance and use.
6. Survey potentially contaminated material from Radiological Areas to separate uncontaminated from contaminated material.
7. Segregate known, non-activated and/or uncontaminated waste from potentially activated and/or contaminated waste.
8. Segregate reusable items, such as protective clothing, respirators, and tools, at the clean zone.
9. Minimize the number and size of RMAs.
10. Emphasize training in waste reduction philosophies, techniques, and improved methods.

443 Mixed Waste

Requirements specified in the Resource Conservation and Recovery Act and Toxic Substances Control Act apply to waste that contains both radioactive and hazardous material. See the *Radioactive Waste Manual.*[42]

1. The *Radioactive Waste Manual*[42] will be used as guidance to control mixed waste.
2. The *Radioactive Waste Manual* and Article 442 will be used as guidance for how mixed waste generation should be minimized.
3. Established technical and administrative controls are used to minimize the volume of mixed waste generated and the amount of radioactivity in such waste. Volume reduction methods include process optimization, material substitution, and new technology development.
4. Material suspected of being mixed waste shall be identified and segregated as soon as practical in the generating process to avoid combining mixed waste with other waste forms.
5. The most stringent regulatory requirements for the types of waste present should be applied to waste classification and disposal.

PART 5 Control of Radioactive Liquids and Airborne Radioactivity

451 Minimization and Control of Radioactive Liquid Wastes

1. The *Radioactive Waste Manual*[42] provides criteria for minimizing the generation of radioactive liquid waste. Minimization should include evaluating operational requirements to reduce liquid usage and maximize recycling activities.
2. A water management program shall be implemented to identify, trend, and minimize unnecessary sources of radioactive liquid waste and liquid mixed waste. This program should include aggressive measures to identify and repair leaks.
3. Activities that produce radioactive liquid waste shall be suspended unless sufficient processing, collecting, and storing capacity is available to accommodate the waste.
4. DOE Order 435.1[47] provides criteria for minimizing the generation of radioactive liquid waste.
5. Radioactive liquid waste discharges shall be controlled on a batch basis to enhance monitoring capability and to reduce the potential for inadvertent release. Since the only significant discharge of radioactive liquids at SLAC involves low conductivity water (LCW) from systems exposed to accelerator beams, which can lead to the production of low levels of tritium, LCW shall be collected in hold-up tanks, and radioanalysis performed for any LCW discharge to the sanitary sewer system.

   The RP Department maintains a list of systems and collection locations where samples and health physics technician (HPT) coverage is required. Contact the RP Department for the current list.
6. Radioactive liquid waste discharges shall be analyzed in association with each release to the sanitary sewer system. No release to the sanitary sewer system that would exceed predetermined limits shall be made.
7. Radioactive liquid waste that is not permissible to be discharged to the sanitary sewer shall be solidified or absorbed and disposed of as solid radioactive waste. The SLAC Environmental Protection Department should be consulted on choices of solidification and/or absorbent agents to be used.

452 Control of Radioactive Drains

Although there are no radioactive drains in the SLAC physical plant, (that is, a nuclear-facility-type radioactive liquid waste system [RLWS]), there are collection sumps at various points within the accelerator housing that are used to collect leaks from LCW cooling systems. The cooling systems and collection sumps in accelerator facilities are not radioactive drains by the industry standard definition.

47 Department of Energy Order 435.1, Change 2, "Radioactive Waste Management" (DOE O 435.1, Chg 2 [AdminChg])

453 Control of Airborne Radioactivity

1. Processes and activities with the potential for producing airborne radioactivity, such as a) the generation of short-lived radioactive gases during accelerator operations, b) machining/welding/torchcutting on surfaces of radioactive material, and c) grinding thoriated welding rods shall include engineering controls to limit releases and spread of contamination, whenever appropriate. The requirements of 40 CFR 61[48] shall be included in the evaluation.

2. 835 **Regarding the control of airborne radioactive material, the design objective shall be, under normal conditions, to avoid releases to the workplace atmosphere and in any situation, to control the inhalation of such material by workers to levels that are ALARA; confinement and ventilation shall normally be used.** [10 CFR 835.1002 (c)]

3. The RP Department shall be notified when engineering controls that prevent worker exposure to airborne radioactivity (such as access controls, barriers, gloveboxes, and glove bags) are compromised. An evaluation should be made of continuing operations with compromised engineering controls. The use of respiratory protection to continue activities under these conditions is discouraged. Implementation of short-term engineering modifications that provide a commensurate level of worker protection is the preferred alternative.

4. Preventive maintenance and surveillance procedures should be established to ensure equipment controls are maintained in an operable condition for ensuring adequate venting of accelerator housing and measurement of any radioactivity content of the vented air.

454 Excavation of Soil with Potential Radiological Hazard

Proper use of the excavation clearance process reduces worker exposure to hazards associated with excavation work at SLAC, including accidental contact with potential radiological hazards on and below the ground. The excavation clearance process also provides for proper management of excavated materials.

An excavation permit form[49] must be completed prior to the start of any work involving potentially radioactive soil, including any covering over of such soil with concrete or asphalt.

Once the reviews have been completed and approval granted, the excavation can proceed. Contact the SLAC Environmental Protection (EP) Department for further guidance. For more information, refer to the *ESH Manual,* Chapter 11, "Excavation Safety."[50]

48 Title 40, *Code of Federal Regulations*, "Protection of Environment," Chapter 1, "Environmental Protection Agency," Subchapter C, "Air Programs," Part 61, "National Emission Standards for Hazardous Air Pollutants" (40 CFR 61)

49 Excavation Safety: Excavation Permit Form (SLAC-I-730-0A23J-006)

50 *SLAC Environment, Safety, and Health Manual* (SLAC-I-720-0A29Z-001), Chapter 11, "Excavation Safety"

PART 6 Support Activities

461 Controls and Monitoring Personal Protective Equipment and Clothing

1. Except for disposable single use items, protective clothing designated for radiological control use should be specifically identified by color, symbol, or appropriate labeling.
2. Personal Protective Equipment (PPE) and protective clothing should not be stored with personal street clothing.
3. Cleaned PPE (such as face shields and respirators) that comes into contact with the wearer's face and SLAC-issued non-personal protective clothing shall be surveyed. Contamination levels should be below the contamination limits in Table 2-2, "Summary of Surface Contamination Values," prior to reuse. The use of statistically representative sampling is acceptable.
4. Sites and facilities are encouraged to continue efforts to reduce contamination levels on reusable PPE and clothing.

462 Laundry

SLAC does not operate a contaminated material laundry on site. SLAC utilizes one or more commercial radiological laundry services to clean radiological PPE that are radioactively contaminated. PPE that cannot be readily cleaned to background levels of radioactivity typically should be discarded as radioactive waste.

1. The provider will ensure that its operations are consistent with SLAC policies prior to transport when appropriate.
2. Clothing and equipment should be screened before they are laundered to segregate those that are damaged, present special handling problems, or require disposal.
3. Cleaned PPE and laundered PC shall be inspected prior to use. Clothing should be free of tears, separated seams, deterioration and damage, or it should be repaired in a manner that provides the original level of protection.
4. SLAC requires its commercial radiological laundry service provider(s) to clean SLAC's PPE to insignificant levels or radioactivity.

463 Decontamination

1. RWPs or technical work documents shall include provisions to control contamination at the source in order to minimize the amount of decontamination needed.
2. Work preplanning should include consideration of the handling, temporary storage, and decontamination of material, tools, and equipment.
3. If a situation arises where removable radioactivity exists, decontamination activities should be conducted in such a manner as to prevent the spread of contamination.
835 **Appropriate controls shall be maintained and verified which prevent the inadvertent transfer of removable contamination to locations outside of radiological areas under normal operating conditions.** [10 CFR 835.1102(a)]

4. Water is the preferred decontamination agent. Other cleaning agents and shop cutting solutions should be selected based upon their effectiveness, amount of waste generated, and ease of disposal. Hazardous chemicals for decontamination shall be avoided. If any mixed waste might be generated as a result of decontamination, prior approval must be obtained from the ESH Division Director.
5. SLAC line management should be responsible for directing decontamination efforts.

464 Vacuum Cleaners and Portable Air-Handling Equipment

Improper use of vacuum cleaners and portable air-handling equipment may result in the generation of airborne radioactivity, removable contamination, or high dose rates.

1. Vacuum cleaners and portable air-handling equipment used in areas established to control removable surface contamination or airborne radioactivity (except areas where only tritium is present) shall be equipped with high-efficiency particulate air (HEPA) filters. If the material to be vacuumed is wet enough to preclude resuspension, then HEPA filters are not necessary.
2. HEPA filters used in vacuum cleaners and portable/installed air-handling equipment shall meet the efficiency and construction requirements for HEPA filters in MIL-F-51068. The maximum flow rate of the device shall not exceed the flow rate at which the HEPA filter was efficiency tested. In addition, the device shall be leak tested prior to initial use, when units have been opened, and annually. Leak tests are conducted by injecting dioctyl phthalate (DOP) or equivalent aerosols into the inlet of the device and measuring the concentration at the inlet and outlet of the device.
3. Vacuum cleaners used for radiological work shall be:
    A. Marked and labeled in accordance with Article 412
    B. Controlled to prevent unauthorized use
    C. Designed to ensure HEPA filter integrity under conditions of use
    D. Constructed and controlled to prevent unauthorized or accidental access to the inner surfaces of the vacuum
4. Radiation and contamination surveys shall be performed periodically for vacuum cleaners in use and labels on these units shall be updated. The frequency of radiation surveys should depend on the specific use of the vacuum cleaner.
5. Airborne radioactivity levels shall be monitored when a vacuum cleaner is used in a High Contamination Area.
6. A nuclear safety review shall be performed and documented prior to the use of a vacuum cleaner for fissile material, should such an application ever occur at SLAC.

PART 7 Policy on Radioactive Materials at SLAC

SLAC is a "Radiological Facility," as defined in the DOE Standard 1027-2018, "Hazard Categorization of DOE Nuclear Facilities."[51] This classification restricts the quantity of radioactive material that may be:

- Stored in non-certified containers, and/or
- Present at any SLAC facility in non-certified containers.

Radioactive material (RAM) means any radioactivity detectable using sensitive instrumentation. RAM can be a solid, liquid, or gas. In solid form, it can be of a well-defined, stable form such as for example a beamline component, structural item, tools, or clothing, or it can be of a finely-divided form such as soil, dust, powdered concrete, or otherwise particulate material. SLAC both surveys and defines RAM via SLAC procedure, *Protocols for Defining and Monitoring for Radioactive Material.*[52]

These restrictions are imposed by the Category 3 threshold quantities that are specified in Attachment 1 of DOE-STD-1027-2018.

It is SLAC policy that radionuclides in non-certified containers be restricted to the lowest quantity that is consistent with operational or experimental requirements. The total amount of any radionuclide in a non-certified container at each of SLAC facilities must not exceed one half of the Category 3 threshold quantity for that radionuclide.

When more than one radionuclide is at a facility, the quantities of each shall be limited so that the sum of the fractions of the material will not exceed one half. The fraction is defined as the mass of each radionuclide divided by its Category 3 threshold quantity. See the example below.

51 Department of Energy Standard 1027-2018, Change Notice 1, "Hazard Categorization of DOE Nuclear Facilities" (DOE-STD-1027-2018, Chg Notice 1)

52 Protocols for Defining and Monitoring for Radioactive Material (SLAC-I-760-0A30C-006, FO 018)

Example

Radionuclide	Mass for Use (Express in Grams)	Category 3 Threshold (expressed in Grams)	Fraction
Am-241	0.20	0.835	0.24
U-233	400	1330	0.30
Np-237	1097	7550	0.15
Th-230	75	138	0.54

1 Single Radionuclide Use

Any one of the above radionuclides whose fraction is < 0.5 is allowed. Th-230 would not be allowed at any single facility in the quantity shown in the Table above because its fraction is > 0.5.

2. Multiple Radionuclide Use

When using more than one radionuclide, add the fractions of those radionuclides to determine the sum. If the sum of the total combined fractions is < 0.5, they are allowed at a facility. However, if the sum of the total combined fractions is > 0.5, they will not be allowed at any single facility.

In this example:
Am-241 and Np-237 would be allowed because 0.24 + 0.15 is < 0.5.
Am-241 and U-233 would not be allowed because 0.24 + 0.30 is > 0.5.

Appendix 4A Values for Establishing Sealed Radioactive Source Accountability and Radioactive Material Posting and Labeling Requirements

The data presented in this Appendix are to be used for identifying accountable sealed radioactive sources as defined at 10 CFR 835.2(a), establishing the need for radioactive material area posting in accordance with 10 CFR 835.603(g), and establishing the need for radioactive material labeling in accordance with 10 CFR 835.605.

Nuclide	Activity (µCi)
H-3	1.5E+08
Be-7	3.1E+03
Be-10	1.4E+05
C-14	4.6E+06
Na-22	1.9E+01
Al-26	1.5E+01
Si-32	4.9E+04
S-35	2.4E+06
Cl-36	5.2E+05
K-40	2.7E+02
Ca-41	9.3E+06
Ca-45	1.1E+06
Sc-46	6.2E+01
Ti-44	1.5E+02
V-49	1.0E+08
Mn-53	7.5E+07
Mn-54	6.5E+01
Fe-55	2.9E+06
Fe-59	1.9E+02
Fe-60	8.1E+03
Co-56	3.9E+01
Co-57	2.3E+02
Co-58	1.3E+02
Co-60	1.7E+01
Ni-59	3.2E+06
Ni-63	1.3E+06
Zn-65	1.1E+02
Ge-68	5.6E+02
As-73	5.3E+02
Se-75	6.3E+01
Se-79	8.7E+05
Rb-83	9.1E+01
Rb-84	2.0E+02
Sr-85	1.2E+02
Sr-89	4.8E+05
Sr-90	3.5E+04
Y-88	3.3E+01
Y-91	5.0E+04
Zr-88	1.1E+02
Zr-93	9.3E+04
Zr-95	1.9E+02
Nb-91	6.9E+01

Nuclide	Activity (µCi)
Nb-91m	3.6E+02
Nb-92	1.8E+01
Nb-93m	4.4E+02
Nb-94	2.3E+01
Nb-95	3.4E+02
Mo-93	7.7E+01
Tc-95m	1.3E+02
Tc-97	8.1E+01
Tc-97m	3.5E+02
Tc-98	2.5E+01
Tc-99	8.4E+05
Ru-103	4.4E+02
Ru-106	2.5E+02
Rh-101	8.7E+05
Rh-102	6.4E+05
Rh-102m	3.0E+05
Pd-107	9.3E+06
Ag-105	3.3E+06
Ag-108m	1.8E+01
Ag-110m	2.2E+01
Cd-109	1.6E+02
Cd-113m	2.0E+04
Cd-115m	1.0E+04
In-114m	7.7E+02
Sn-113	3.1E+02
Sn-119m	3.3E+02
Sn-121m	8.1E+05
Sn-123	1.3E+04
Sn-126	1.8E+02
Sb-124	9.1E+01
Sb-125	6.7E+01
Te-121m	1.8E+02
Te-123m	2.8E+02
Te-125m	4.4E+02
Te-127m	8.0E+02
Te-129m	2.3E+03
I-125	3.5E+02
I-129	1.8E+02
Cs-134	2.6E+01
Cs-135	1.3E+06
Cs-137	6.0E+01
Ba-133	5.1E+01
La-137	2.7E+05
Ce-139	2.4E+02
Ce-141	2.4E+03
Ce-144	1.4E+03
Pm-143	1.3E+02
Pm-144	2.9E+01
Pm-145	2.6E+02
Pm-146	4.4E+01
Pm-147	7.7E+05
Pm-148m	1.0E+02

Nuclide	Activity (µCi)
Sm-145	2.4E+06
Sm-146	4.0E+02
Sm-151	2.5E+05
Eu-148	1.1E+06
Eu-149	1.1E+07
Eu-152	3.1E+01
Eu-154	3.1E+01
Eu-155	3.6E+02
Gd-146	5.1E+05
Gd-148	9.0E+01
Gd-151	2.9E+06
Gd-153	2.1E+02
Tb-157	2.5E+03
Tb-158	9.0E+04
Tb-160	1.2E+02
Dy-159	1.0E+07
Ho-166m	2.1E+01
Tm-170	8.4E+03
Tm-171	2.8E+04
Yb-169	5.5E+02
Lu-173	1.8E+06
Lu-174	9.3E+05
Lu-174m	1.0E+06
Lu-177m	5.8E+01
Hf-172	7.3E+04
Hf-175	3.0E+06
Hf-178m	8.7E+03
Hf-181	3.4E+02
Hf-182	7.5E+03
Ta-179	9.3E+06
Ta-182	7.3E+01
W-181	1.0E+03
W-185	3.9E+06
W-188	6.3E+04
Re-183	5.3E+02
Re-184	2.6E+02
Re-184m	1.5E+02
Re-186m	3.4E+05
Os-185	1.3E+02
Os-194	6.4E+04
Ir-192	1.3E+02
Ir-192m	1.4E+05
Ir-194m	2.7E+01
Pt-193	8.7E+07
Au-195	4.8E+02
Hg-194	5.2E+04
Hg-203	4.9E+02
Tl-204	2.2E+04
Pb-202	1.9E+05
Pb-205	9.0E+01
Pb-210	9.2E+01
Bi-207	1.7E+01

Nuclide	Activity (µCi)
Bi-208	1.5E+01
Bi-210m	1.2E+03
Po-209	6.3E+03
Po-210	1.2E+03
Ra-226	2.2E+02
Ra-228	1.5E+03
Ac-227	4.2E+00
Th-228	8.4E+01
Th-229	3.1E+01
Th-230	5.4E+00
Th-232	9.3E+01
Pa-231	3.0E+01
U-232	1.0E+02
U-233	3.9E+02
U-234	2.9E+02
U-235	6.7E+01
U-236	3.1E+02
U-238	3.5E+02
Np-235	1.1E+02
Np-236	2.1E+01
Np-237	4.9E+01
Pu-236	2.0E+02
Pu-237	3.3E+02
Pu-238	9.0E+01
Pu-239	8.4E+01
Pu-240	8.4E+01
Pu-241	4.6E+03
Pu-242	8.7E+01
Pu-244	9.0E+01
Am-241	7.2E+01
Am-242m	1.1E+02
Am-243	7.3E+01
Cm-241	1.0E+05
Cm-242	6.2E+02
Cm-243	4.8E+01
Cm-244	1.5E+02
Cm-245	5.0E+01
Cm-246	1.0E+02
Cm-247	8.5E+01
Cm-248	2.8E+01
Cm-250	5.4E+00
Bk-247	6.0E+01
Bk-249	2.7E+04
Cf-248	4.4E+02
Cf-249	5.5E+01
Cf-250	1.2E+02
Cf-251	5.3E+01
Cf-252	5.2E+00
Cf-254	1.2E+02
Es-254	6.3E+01
Es-255	8.8E+03
Fm-257	5.1E+02

Nuclide	Activity (µCi)
Md-258	6.1E+02

Any alpha emitting radionuclide not listed in Appendix 4A and mixtures of alpha emitters of unknown composition have a value of 10 µCi.

With the exception that any type of STC has a value of 10 Ci, any radionuclide other than alpha emitting radionuclides not listed in Appendix 4A of this *Manual* and mixtures of beta emitters of unknown composition have a value of 100 µCi.

Note: Where there is a combination of radionuclides in known amounts, derive the value for the combination as follows: determine, for each radionuclide in the combination, the ratio between the quantity present in the combination and the value otherwise established for the specific radionuclide when not in combination. If the sum of such ratios for all radionuclides in the combination exceeds unity (1), then the accountability criterion has been exceeded.
[10 CFR 835 Appendix E]

CHAPTER 5 RADIOLOGICAL HEALTH SUPPORT OPERATIONS

PART 1 External Dosimetry

511 Regulatory Requirements

835 **Monitoring of individuals and areas shall be performed to demonstrate compliance with 10 CFR 835; to document radiological conditions; to detect changes in radiological conditions; to detect the gradual buildup of radioactive material; to verify the effectiveness of engineered administrative controls in containing radioactive material and reducing radiation exposure; and identify and control potential sources of individual exposure to radiation and/or radioactive material.** [10 CFR 835.401(a)(1) through (a)(6)]

1. 835 **For the purpose of monitoring individual exposures to external radiation, personnel dosimeters shall be provided to and used by:** [10 CFR 835.402(a)]

   A. 835 **Radiological workers who, under typical conditions, are likely to receive one or more of the following:**

      (i) An effective dose of 0.1 rem (0.001 Sv) or more in a year; [10 CFR 835.402(a)(1)(i)]
      (ii) An equivalent dose to the skin or to any extremity of 5 rems (0.05 Sv) or more in a year; [10 CFR 835.402(a)(1)(ii)]
      (iii) An equivalent dose to the lens of the eye of 1.5 rems (0.015 Sv) or more in a year; [10 CFR 835.402(a)(1)(iii)]

   B. 835 **Declared pregnant workers who are likely to receive from external sources an equivalent dose to the embryo/fetus in excess of 10 percent of the applicable limit at 10 CFR 835.206(a);** [10 CFR 835.402(a)(2)]

   C. 835 **Occupationally exposed minors likely to receive a dose in excess of 50 percent of the applicable limits at 10 CFR 835.207 in a year** (50 mrem whole body, 750 mrem to the lens of the eye or 2.5 rem to the skin or any extremity) **from external sources.** [10 CFR 835.402(a)(3)]

   D. 835 **Members of the public entering a controlled area likely to receive in excess of 50 percent of the limit at 10 CFR 835.208 in a year from external sources.** [10 CFR 835.402(a)(4)]

      Fifty (50) percent of the dose limit in 10 CFR 835.208 corresponds to 50 mrem total effective dose, or TED.

   E. 835 **Individuals entering a high or very high radiation area** [10 CFR 835.402(a)(5)]

512 Personnel Dosimeters

1. A primary personnel dosimeter shall be issued to anyone entering Radiologically Controlled Areas (RCAs) for work purposes and shall be worn only by the individual to whom the dosimeter is issued.
2. [reserved]
3. Visitors/Tours (see Article 337.C)

4. Personnel should return dosimeters for processing as scheduled or upon request. Line managers are responsible for ensuring the prompt return of dosimeters to the RP Department. A primary dosimeter may also be issued to any employee who requests one.
5. Personnel should wear their primary dosimeters on the chest area, on or between the waist and the neck, in the manner prescribed by RP Department dosimetry services personnel.
6. Primary dosimeters issued by SLAC should not be worn at any other facility, and dosimeters issued at any other facility should not be worn at SLAC.
7. Personnel should not expose their dosimeters to security x-ray devices, excessive heat, or medical and dental sources of radiation.
8. A person whose dosimeter is lost, damaged, or contaminated should follow the procedures for obtaining a temporary replacement dosimeter. In no case shall a worker be allowed to re-enter the RCA without a replacement dosimeter in accordance with these procedures.
9. A dose reconstruction shall be performed for each instance of a lost, damaged, or contaminated personal dosimeter. The procedures in the *SLAC External Dosimetry Program Manual*[53] will be used.

513 Technical Requirements for External Dosimetry

1. 835 **External dose monitoring programs 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 this part and shall be: accredited, or excepted from accreditation, in accordance with the DOE Laboratory Accreditation Program for Personnel Dosimetry.** [10 CFR 835.402(b)(1)]

   (Note: Table 2-1 of this *Manual* corresponds to "subpart C of this part" in this regulatory passage**)**

   Appropriate documentation to justify the selection of the dosimeters and the conduct of the dosimetry program should be maintained by the RP Department.
2. Documentation should also address dosimeters monitoring radiation outside the scope of DOELAP, such as dosimetry associated with high-energy accelerators and extremity dosimeters.
3. 835 **The records required by this section shall: (1) Be sufficient to evaluate the compliance with subpart C of this part; (2) Be sufficient to provide dose information necessary to complete reports required by subpart I of this part; (3) Include the results of monitoring used to assess the following quantities for external dose received during the year:**

   (i) The effective dose from external sources of radiation (equivalent dose to the whole body may be used as effective dose for external exposure);
   (ii) The equivalent dose to the lens of the eye;
   (iii) The equivalent dose to the skin; and
   (iv) The equivalent dose to the extremities.

53 SLAC External Dosimetry Program Manual (SLAC-I-760-2A07F-001, DG 101)

[10 CFR 835.702(c)(3)(i) through (iv)]

4. Multiple personal primary dosimeters may be issued to personnel to assess whole-body exposure in non-uniform radiation fields or as required on Radiological Work Permits (RWPs). Non-uniform radiation fields exist when the dose to a portion of the whole body will exceed the dose to the primary dosimeter by more than 50 percent and the anticipated whole-body dose is greater than 100 mrem total effective dose (TED). When the radiation field is well characterized and the orientation of the worker to the radiation field is known, relocation of the primary personnel dosimeter is permitted in lieu of issuance of multiple dosimeters. SLAC dosimetry program documentation should describe the methodology used in determining the dose of record when multiple dosimeters are used.

5. A neutron dosimeter shall be provided by the RP Department when a person is likely to exceed 100 mrem effective dose annually from neutrons. RWT personnel are assigned quarterly personal dosimeters equipped with neutron dose measurement capability.

514 Supplemental Dosimeters and Electronic Dosimeters

Electronic dosimeters are supplemental dosimeters that provide real-time indication of exposure to radiation and assist in maintaining personnel doses less than Administrative Control Levels.

1. 835 **The following measures shall be implemented for each entry into a high radiation area: each individual shall be monitored by a supplemental dosimeter or other means capable of providing an immediate estimate of the individual's integrated equivalent dose to the whole body during the entry.** [10 CFR 835.502(a)(2)]

2. Supplemental dosimeters shall be worn on the upper torso between the neck and waist, unless otherwise directed by the RP Department.

3. Supplemental dosimeters should be read periodically while in use.

4. Routine work on a RWP shall be stopped if supplemental dosimeter readings indicate total exposure or rate of exposure equal to or greater than planned. The RP Department shall be consulted prior to continuation of work.

5. The energy dependence of supplemental dosimeters (particularly to low-energy beta radiation) should be considered in determining their applicability.

6. When dose results from electronic dosimeters differ by more than 50 percent from the primary dosimeter result and the primary dosimeter result is greater than 100 mrem, an investigation should be initiated to determine the validity of dose measurements.

515 Passive Area Monitoring Dosimeters

SLAC uses a passive area monitoring program to help demonstrate compliance with regulations in 10 CFR 835; document radiological conditions; detect changes in radiological conditions; detect the gradual buildup of radioactive material; verify the effectiveness of engineering and process controls in containing radioactive material and reducing radiation exposure; and identify and control potential sources of individual exposure to radiation and/or radioactive material. Establishment and maintenance of a comprehensive passive area monitoring program can minimize the number of areas requiring the issuance of personnel dosimeters and can help demonstrate that doses outside Radiological Areas are negligible. Minimizing the number of

personnel dosimeters issued reduces dosimetry program operating costs, as well as costs associated with maintaining personnel with enhanced training and qualifications.

1. Passive area monitoring dosimeters should be used to record and document radiation levels in routinely occupied areas adjacent to areas where radiation or operations with radiation exist. This monitoring requirement does not apply when the radiation arises solely from low-energy beta sources (such as carbon-14 or tritium).
2. Passive area monitoring dosimeter results should be used to support dosimetry investigations when personnel express concerns about their work environments and their exposure to ionizing radiation.
3. Passive area monitoring dosimeters should be used to supplement existing monitoring programs and to provide data in the event of an emergency.

For more information, refer to SLAC *Passive Area Monitoring Program Manual*.[54]

516 Nuclear Accident Dosimeters

Nuclear Accident Dosimeters are not applicable at SLAC, as stated in the approved *SLAC National Accelerator Laboratory Radiation Protection Program Implementation Plan* (RPP).[55]

PART 2 Internal Dosimetry

521 Requirements

1. Historically, no SLAC employees have routinely been exposed to unsealed sources of radionuclides of sufficient magnitude to require the establishment of a routine bioassay program. However, should conditions develop in any activity at SLAC that meet the listed criteria below, personnel involved in the activity shall participate in a bioassay program.
   835 **Internal dose monitoring programs implemented** (at SLAC) **to demonstrate compliance with 10 CFR 835.402(c) shall be adequate to demonstrate compliance with the dose limits established in subpart C of this part.** [10 CFR 835.402(d)]

   Internal dose monitoring programs implemented at SLAC shall comply with 10 CFR 835.402(c) and subpart C of 10 CFR 835.

   835 **For the purpose of monitoring individual exposures to internal radiation, internal dosimetry programs (including routine bioassay programs) shall be conducted for:** [10 CFR 835.402 (c)]

   A. 835 Radiological workers who, under typical conditions, are likely to receive a committed effective dose (CED) of 0.1 rem (0.001 Sv) or more from all occupational radionuclide intakes in a year.

54 Passive Area Monitoring Program Manual (SLAC-I-760-0A00Z-001, DG 401)

55 SLAC National Accelerator Laboratory Radiation Protection Program Plan for Implementing 10 CFR 835 (SLAC-I-720-1A05M-002)

2. 835 **The estimation of internal dose shall be based on bioassay data rather than air concentration values, unless bioassay data are:**

   A. unavailable;

   B. inadequate; or

   C. internal dose estimates based on air concentration values are demonstrated to be as or more accurate. [10 CFR 835.209(b)(1)(2)(3)]

3. Personnel shall participate in follow-up bioassay monitoring when their bioassay results indicate an occupational intake in the current year with a CED of 100 mrem or more.

4. Personnel who have or are suspected to have received an intake of radioactivity should have a bioassay measurement as soon as possible after the actual or suspected intake and again 24 hours after occurrence of the actual or suspected intake.

5. Personnel shall submit bioassay samples, such as urine or fecal samples, and participate in bioassay monitoring, such as whole-body or lung counting, at any appropriate frequency required by the bioassay program and/or if requested of a specific individual or individuals by the Radiological Control Manager (RCM).

6. Personnel shall be notified promptly of positive bioassay results and the results of dose assessments and subsequent refinements. Dose assessment results should be provided in terms of rem or mrem.

522 Technical Requirements for Internal Dosimetry

SLAC has elected not to accredit its internal dosimetry program (IDP) under DOE Laboratory Accreditation Program (DOELAP). DOE has given formal concurrence to SLAC not to accredit its IDP.[56] Unless and until SLAC accredits its internal dosimetry program with DOELAP, this *Manual* provides the technical guidance to implement an IDP.

1. SLAC's technical basis document (TBD) for its internal dosimetry program (IDP) is titled *Technical Basis Regarding Routine Bioassay Measurements at SLAC.*[57] This TBD describes the extent of the SLAC IDP and methods to address emergency or situational exposures that may occur outside the realm of routine activities on site.

   A. Because of the nature of the radiological environment at SLAC, any internal exposure at SLAC is considered to be unlikely.

   B. No SLAC employee is likely to exceed 100 mrem CED per year from internal dose.

   C. Baseline, periodic, and termination bioassays will be conducted only on an as-deemed-appropriate basis at SLAC.

56 Letter from John S. Muhlestein, Director of DOE Stanford Site Office to Dr. Kenneth R. Kase, Associate Director, SLAC ESH Division, dated 02/23/2001

57 Technical Basis Regarding Routine Bioassay Measurements at SLAC (SLAC-I-760-2A02C-xxx, DG-501)

D. Event-specific, or in the event a specific project may dictate a routine program, bioassays will be conducted by SLAC, or by another organization if so arranged by SLAC.

2. Baseline bioassay monitoring of personnel who are likely to receive intakes resulting in a CED greater than 100 mrem in a calendar year should be conducted before personnel begin work that may expose them to internal radiation exposure.

3. Routine bioassay monitoring methods and frequencies shall be established in each calendar year for those personnel who are likely to receive intakes resulting in a CED greater than 100 mrem in a calendar year. The technical basis for the methods and frequency of bioassay monitoring should be documented.

4. Management should require termination bioassay monitoring when a person who participated in the bioassay program terminates employment or concludes work involving the potential for internal exposure. The number of persons failing to achieve this monitoring should be reviewed periodically and should be used to determine whether further efforts to get cooperation are warranted.

5. Bioassay analyses shall also be performed when any of the following occurs:

   A. Detection of facial or nasal contamination that indicates a potential for internal contamination exceeding any monitoring threshold established in Article 521.1.

   B. Airborne monitoring indicates the potential for intakes that would result in an individual exceeding 100 mrem CED.

   C. Upon direction of the RP Department when an intake is suspected.

6. Levels of intakes that exceed five (5) times the Annual Limit on Intake (ALI) should warrant involvement of the SLAC Occupational Health Center. Possible side effects should be considered before use of medical intervention. The effectiveness of medical intervention, such as blocking or chelating agents, shall be documented using bioassay results.

7. A preliminary dose assessment by the RP Department from any intakes detected should be conducted prior to permitting an employee to return to radiological work.

8. IDP personnel should use radionuclide standards from, or traceable to, the National Institute of Standards and Technology (NIST). The degree of traceability required can be used to help determine which of the following levels of bioassay will apply:

   A. Screening bioassays may be conducted by SLAC to determine the need for a diagnostic bioassay. NIST traceability is not necessary for screening bioassays where the action levels are set sufficiently low to ensure that measurement uncertainty will not result in failure to meet the monitoring requirements (refer to Article 521).

   B. Diagnostic bioassays, where monitoring is required by the levels stated in Article 521, will not be conducted by SLAC. If event and/or screening bioassay data indicate that diagnostic bioassay is appropriate, SLAC will arrange for such bioassay to be evaluated by an off-site program that is capable of meeting DOE's accreditation requirements for IDPs.

9. IDP personnel should participate in the conduct of intercomparison studies and should use the "DOE Phantom Library." An off-site laboratory will most likely perform such studies.

523 Technical Requirements for Dose Assessment

Interpretations of bioassay results and subsequent dose assessments should include the following:

1. Characteristics of the radionuclide, such as chemical and physical forms
2. Bioassay results
3. Previous dose history of the individual
4. Exposure information, such as route of intake, time, and duration of exposure
5. Biological models used for dosimetry of radionuclides
6. Models to estimate intake or deposition and to assess dose
7. Intradepartmental coordination between the RP Department and the medical organization for doses that may require medical intervention

PART 3 Respiratory Protection Program

Respiratory protection equipment includes respirators with particulate or gas filtering cartridges, supplied air respirators, self-contained breathing apparatus, and airline-supplied air suits and hoods. Refer to the *ESH Manual,* Chapter 29, "Respiratory Protection," for details regarding the policy for respiratory protection on site.[58]

531 General Considerations and Requirements

1. Use of respiratory protection should be reduced to the minimum practicable by implementing engineering controls and work practices to contain radioactivity at the source.
2. 29 CFR 1910.134 establishes requirements for respiratory protection program that are applicable to most DOE facilities. ANSI Z88.2, "American National Standard for Respiratory Protection,"[59] provides acceptable detailed guidance for implementation of the respiratory protection program and associated training of personnel.
3. For the purpose of radiological control, respirators shall be issued only to personnel who have the need, are authorized by the RP Department, are trained, fitted, and medically qualified to wear the specific type of respirator. Training and qualification testing shall be performed annually, if necessary, in accordance with the policies specified in the *ESH Manual,* Chapter 29, "Respiratory Protection."[58]

58 *SLAC Environment, Safety, and Health Manual* (SLAC-I-720-0A29Z-001), Chapter 29, "Respiratory Protection"

59 American National Standards Institute (ANSI) Z88.2, "American National Standard for Respiratory Protection" (ANSI Z88.2)

4. Positive controls should be maintained for the issue, use, and return of respirators to ensure that only qualified personnel wear respirators.
5. Facility safety analyses should not take credit for the use of respiratory protection for routine work involving potential exposure to airborne radioactive material. Engineering controls should be designed to control radioactive material at the source, so that respiratory protection can be reduced.

532 Medical Assessment

Each prospective respirator wearer shall have a medical assessment prior to being fit-tested. The medical assessment shall determine if an employee's medical condition precludes the use of respirators. The ability of an employee to accommodate the additional stress placed on the body when working with a respirator is part of this assessment.

533 Use of Respiratory Protection

Personnel using respiratory protection shall be issued respirators only upon verification of medical approval, training, and fit testing by an industrial hygienist.

Personnel using respiratory protection should:

1. Perform fit checks of their respirators to ensure a proper seal before entering areas requiring respirator use.
2. Be clean-shaven in the area of fit.
3. Use corrective lenses, if needed, which are approved for respirators.
4. Be trained to avoid life-threatening situations when experiencing respirator failure by:
    - Leaving the work area
    - Removing their respirators

534 Heat Stress

Heat stress may result from working in areas of high heat, humidity, and radiant heat; working in protective clothing; and using respirators, particularly where other protective equipment is required. Heat stress has occurred at ambient temperatures less than 70°F when multiple sets of anti-contamination clothing or plastic suits were in use or strenuous work was required.

1. The planning stages for work in hot environments should address heat stress controls.
2. Recommended work time limits and use of body cooling devices should be considered to reduce heat stress. Job supervisors should inform their personnel of heat stress precautions prior to work on job assignments in hot environments.
3. If a person begins to feel symptoms of heat illness, the person should immediately notify the nearest co-worker, exit the area, remove PPE, notify the supervisor, and rest in a cool area. In such cases, medical assistance should be provided.

535 Half-Face Respirators

1. Half-face respirators have limited applications because of the design of the facial seal area. As a result, their permitted protection factor is low. Full-face respirators are generally preferred over half-face respirators because of the significant increase in protection offered with minimal loss of worker comfort.
2. The use of half-face respirators may be permitted in situations where intakes of radioactive material will be low, such as those resulting in a few mrem, and where industrial and safety considerations warrant, such as during the operation of heavy equipment.
3. The practice of using half-face respirators for emergency evacuation purposes at SLAC is discouraged.

PART 4 Handling Radiologically Contaminated Personnel

Although these types of problems are not routinely seen at SLAC, there are situations where some of the following actions might have to be taken on site.

541 Skin Contamination

1. When a person detects skin contamination, they shall notify the RP Department.
2. The extent of skin contamination should be determined prior to initiating decontamination procedures.
3. Intrusive decontamination methods, such as tissue removal, require medical assistance. Initially, RP Department personnel employ masking tape or waterless hand cleaner. All materials used for decontamination are to be saved for later analysis.
4. Personnel with skin contamination that triggers the need for dose assessment should be informed of the initial dose estimate to their skin as soon as practicable, preferably prior to the end of their work day.
5. Personnel with skin contamination who have not had a dose assessment performed should be informed of the nature of the contamination and be given an upper estimate on the potential skin dose (such as less than 10 mrem), as soon as practicable, preferably prior to the end of their work day.
6. An assessment of skin exposure requires time to conduct a detailed evaluation. Requirements for assessments are provided in Appendix 2C, “Non-Uniform Exposure of the Skin.” Promptly after completion, the results should be explained to the person(s) affected.
7. In any event, skin contamination incurred at SLAC greater than 10,000 counts per minute as measured by a G-M-type frisker should trigger the performance of a skin dose assessment.

542 Contaminated Wounds

1. Emergency medical care should be administered immediately for injuries involving radioactive material, in accordance with the National Council on Radiation Protection and Measurements Report Number 65. Medical treatment of injuries takes precedence over radiological control considerations.
2. The treatment of contaminated injuries should include the following:
   A. Treatment of contaminated wounds by medically qualified personnel
   B. Monitoring of wounds and associated bandages for contamination, including alpha emitters, if applicable
   C. Identification of the radionuclides involved
   D. Medical determination of the need for therapeutic intervention, such as blocking or chelating agents
   E. Initiation of appropriate bioassay monitoring
   F. Determination of need for work restrictions
3. An injured person should be counseled promptly on the medical and radiological implications resulting from contaminated wounds that result in internal doses greater than two percent of limits in Table 2-1, "Summary of Occupational Dose Limits." Senior radiological control and medical professionals should perform the counseling.

543 Handling Individuals Exposed to Airborne Radioactivity

Potential intakes of radioactive material are indicated when personnel without respiratory protection are exposed to airborne radioactivity, or when respiratory protection has been compromised. If intakes of radioactive material could result in an individual receiving a CED greater than 100 mrem or an exposure of 40 DAC-hours or more in a year, the following actions should be taken by the RP Department:

1. Identify personnel potentially exposed to airborne radioactivity
2. Obtain nasal smears for qualitative indication of intakes, where appropriate
3. Analyze air samples to determine airborne concentrations, where appropriate
4. Determine duration of potential exposure to airborne radioactivity
5. Perform bioassay appropriate for the type and quantity of radionuclides involved
6. Evaluate dose prior to permitting the worker to return to radiological work

PART 5 Radiological Monitoring and Surveys

551 Requirements

Workplace surveys provide a basis for posting and labeling, development of work permits and authorizations, implementation of ALARA measures, issuance of individual monitoring devices, and verification of the efficiency of design measures and engineering controls. Development of a

work place survey program should include consideration of the following factors to ensure adequacy of the program.

1. Radiological monitoring of radiation exposure levels, contamination, and airborne radioactivity shall be conducted to

   A Characterize workplace conditions and detect changes in those conditions [see 10 CFR 835.401(a)(2) and (3)]

   B. Verify the effectiveness of engineering and administrative controls in containing radioactive material and reducing radiation exposure [see 10 CFR 835.401(a)(5)]

   C. Demonstrate regulatory compliance [see 10 CFR 835.401(a)(1)]

   D. Detect the gradual buildup of radioactive material in the workplace [see 10 CFR 835.401(a)(4)]

   E. Identify and control potential sources of individual exposure to radiation and/or radioactive material [see 10 CFR 835.401(a)(6)]

   F. Determine exposure rates during each entry to a High Radiation Area or Very High Radiation Area [see 10 CFR 835.502(a)(1)]

2. Monitoring shall be performed only by trained and qualified personnel using instruments that are properly calibrated and routinely tested for operability. Personnel shall only use those monitoring instruments that they have been trained and qualified to use.

3. Surveys for radiation, contamination and airborne radioactive materials shall be performed as specified in Radiological Work Permits.

4. The RP Department or Committee designated by the RCM, such as the ALARA Committee, should perform and document a review of the adequacy of sampling and monitoring systems as part of any facility or operational changes affecting radiological control. In the absence of such changes, a review should be conducted on an annual basis**.**

5. Instruments used to perform radiation monitoring should be performance-checked daily or, if not checked within the past 24 hours, prior to operation. Response checks with radioactive sources shall be performed at least weekly when in use or prior to placing in use after calibrations or repairs. When responses are not within ±20 percent of the expected value, the instrument should be taken out of service. When response checks are not feasible, such as with instruments used to measure neutrons or tritium, compensatory actions should be established to ensure proper instrument performance.

6. Monitoring of radiological conditions should include a sufficient number of survey points to characterize the radiation present and to verify boundaries.

7. Monitoring should be performed before, during, and at the completion of work that has the potential for causing changes in levels of radiation and radioactivity.

8. Monitoring frequencies should be established based on potential radiological conditions, probability of change in conditions, and area occupancy factors.

9. The cognizant radiological supervisor should review monitoring results. The review should ensure that all required surveys have been performed and that the documentation is accurate and complete.

10. Results of current surveys or survey maps should be conspicuously posted for each High Radiation Area. Results of current surveys or survey maps can be provided either by
    - Posting hard copies of the surveys at each such location, or
    - Via the SLAC Web.
11. Monitoring results should be made available to line management and used in support of pre-job and post-job evaluations, ALARA preplanning, contamination control, and management of radiological control operations.
12. Monitoring data in each building or area should be compiled and reviewed yearly or when changes are made in the operation that may affect radiation exposures in a building or area. Changes or trends should be noted and corrective actions assigned.
13. 835 **Instruments and equipment used for monitoring shall be: (2) Appropriate for the type(s), levels, and energies of the radiation(s) encountered; (3) Appropriate for existing environmental conditions.** [10 CFR 835.401(b)(2)(3)]

552 Radiation Exposure Survey

1. In addition to the requirements of Article 551, routine radiation monitoring programs should be established to ensure that radiation exposure surveys are performed. The frequency of surveys is determined based on approved RP procedures that are consistent with the existing and potential hazards and activities planned in the area. The following are examples of radiation exposure surveys conducted by RP
    A. In office spaces located in Radiologically Controlled Areas.
    B. In routinely occupied Radiation Areas
    C. Upon initial entry and when accessible as appropriate, and when levels are expected to change, in High Radiation Areas
    D. For operating High-Efficiency Particulate Air (HEPA) filtered ventilation units
    E. For temporary Radiation and High Radiation Area boundaries to ensure that Radiation Areas do not extend beyond posted boundaries
    F. For Radioactive Material Areas (RMAs), or more frequently for any particular RMA as deemed appropriate by the RP Department
    G. For potentially contaminated ducts, piping, and hoses in use outside radiological facilities
    H. At radiation-generating devices as appropriate
2. Performance of radiation surveys should include dose rate measurements of the general area, dose rates at a distance of 30 centimeters (cm) from a source or surface of interest to evaluate potential whole body exposures, and dose rates on contact with potential sources of radiation where there is a potential for hands-on work.
3. Surveys should be conducted whenever operations are being performed that might result in personnel being exposed to small intense beams of radiation, such as those generated by shielded x-ray devices or due to removal or alteration of shielding.

4. Radiation monitoring instruments shall be capable of measuring ambient radiation dose rates for the purpose of controlling radiation exposures.

553 Area Radiation Monitors

1. In addition to the requirements of Article 551, area radiation monitors (not to include area monitoring dosimeters discussed in Article 515) should be installed in frequently occupied locations with the potential for unexpected increases in dose rates and in remote locations where there is a need for local indication of dose rates prior to personnel entry.
2. Area radiation monitors are not a substitute for radiation exposure surveys in characterizing a workplace.
3. The need for and placement of area radiation monitors should be documented and assessed when changes to facilities, systems, or equipment occur.
4. In addition to the requirements of Article 562, area radiation monitors should be tested on an established frequency to verify audible alarm system operability and audibility under ambient working conditions and operability of visual alarms when so equipped, if applicable.
5. If installed instrumentation is removed from service for maintenance or calibration, a radiation monitoring program providing at least equal detection capability should be maintained, consistent with the potential for unexpected increases in radiation dose rates.
6. Where an area radiation monitor is incorporated into a safety interlock system, the circuitry shall be such that a failure of the monitor shall either prevent entry into the area or prevent operation of the radiation-producing device.

554 Contamination Surveys

1. In addition to the requirements of Article 551, contamination surveys should be conducted in Radiological Areas established for the control of contamination and other areas with the potential for spread of contamination as follows:
   A. Prior to transfer of equipment and material from one Radiological Area to another except for material coming from a Radiation Area
   B. Prior to transfer of equipment and material from High Contamination Areas unless precautions such as bagging or wrapping are taken prior to transfer
   C. Daily, when in use, at Contamination Area control points, change areas, or step-off pads or per shift in high-use situations
   D. Daily, in office spaces located in Contamination Areas
   E. In lunchrooms or eating areas near Radiological Areas as deemed appropriate by the RP Department Field Operations Group
   F. Bi-weekly, in routinely occupied Contamination Areas
   G. Bi-weekly, or upon entry if entries are less frequent, in areas where radioactive material is handled or stored where contamination is likely.

H. Bi-weekly, or upon entry if entries are less frequent, where contamination boundaries or postings are located

I. During initial entry into a known or suspected Contamination Area, periodically during work, at completion of job, or as specified in an RWP

J. After a leak or spill of radioactive material

2. Articles 421 and 422 establish requirements for material release surveys.

3. Contamination surveys should incorporate techniques to detect both removable and fixed contamination when appropriate.

4. All items with inaccessible surfaces that fall under the following criteria shall be treated as potentially contaminated and shall be subject to administrative controls, unless the items are dismantled and monitored, or special survey techniques are used to survey all surfaces.

- Items located in known or suspected contamination locations
- Items contaminated with radioactivity, or having the potential to become contaminated, at levels likely to exceed removable contamination limits in Table 2-2 of this *Manual*, "Summary of Surface Contamination Limits"
- All beam line components in High Radiation Areas with inaccessible surfaces shall be considered potentially contaminated until surveyed by the RP Department.

5. Swipe surveys for removable contamination should be recorded in units of disintegrations per minute per 100 cm^2 (dpm/100 cm^2). For swipe surveys of small items covering less than 100 cm^2, the results should be reported in units of dpm per area swiped.

6. Large area wipes are encouraged and should be used to supplement standard swipe techniques in areas generally assumed not to be contaminated, such as entrances to Contamination Areas. If an evaluation indicates that a wiped area is contaminated, a thorough contamination swipe survey should be performed.

7. Areas identified as either contaminated, or having the potential for being contaminated, with highly radioactive particles ("hot particles") should be surveyed weekly. These areas should be surveyed at least daily during periods of work that may result in the generation of hot particles. Special swipe techniques to collect hot particles, such as tape and large area wipes, should be used. Counts from radon daughter product activity in the resulting sample can be identified and discounted by holding the sample for sufficient time to allow radon daughter products to decay away and thereby reveal the amount of their presence in the original count rate.

555 Airborne Radioactivity Monitoring

1. In addition to the requirements of Article 551, air monitoring equipment should be used in situations where airborne radioactivity levels can fluctuate and early detection of airborne radioactivity could prevent or minimize inhalation of radioactivity by personnel.
835 **Monitoring of airborne radioactivity shall be performed: (2) As necessary to characterize the airborne radioactivity hazard where respiratory protective devices for protection against airborne radionuclides have been prescribed.** [10 CFR 835.403(a)(2)] Selection of air monitoring equipment should be based on the specific job being

monitored. Air monitoring equipment includes portable and fixed air sampling equipment and continuous air monitors.

2. Any accessible area that meets either or both of the following conditions shall be posted as "Caution, Airborne Radioactivity Area," and shall be controlled and monitored as an Airborne Radioactivity Area until both of the following conditions no longer exist: 835 **(1) the concentration of airborne radioactivity, above natural background, exceeds or is likely to exceed the derived air concentration (DAC) values listed in appendix A or appendix C of this part, or (2) an individual present in the area without respiratory protection could receive an intake exceeding 12 DAC-hours in a week.**

   [10 CFR 835.2 definition for Airborne Radioactivity Area]

3. 835 **Monitoring of airborne radioactivity shall be performed: (1) Where an individual is likely to receive an exposure of 40 or more DAC-hours in a year; or (2) As necessary to characterize the airborne radioactivity hazard where respiratory protective devices for protection against airborne radionuclides have been prescribed.** [10 CFR 835.403(a)(1)(2)]

4. Air sampling equipment should be positioned to measure air concentrations to which persons are exposed. If adequate positioning cannot be achieved, a program of personal breathing-zone air sampling should be initiated.

5. 835 **Instruments and equipment used for monitoring shall be: (1) Periodically maintained and calibrated on an established frequency.** [10 CFR 835.401(b)(1)] The frequency shall be at least once per year. Continuous air monitors should be capable of measuring one DAC when averaged over eight hours (*i.e.,* eight DAC-hours) under laboratory conditions.

6. Continuous air monitoring equipment required by Article 555.3 shall have alarm capability and sufficient sensitivity to alert personnel that immediate action is necessary in order to minimize or terminate inhalation exposures.

7. A technical basis document should be developed for the airborne radioactivity monitoring program. The technical basis document should provide the basis for air monitor selection, placement, and operation.

8. The proper operation of continuous air monitoring equipment should be verified daily by performing an operational check. Operational checks should include positive airflow indication, non-zero response to background activity, and internal check sources or 60 Hz electronic checks when available. Continuous air monitoring equipment operation should be verified weekly by checking for instrument response with a check source or with ambient levels of radon and thoron daughters.

9. Preliminary assessments of air samples utilizing field survey techniques should be performed promptly upon removal of the sample medium from the sampler. In situations where background levels of radon and thoron daughters interfere with evaluation of alpha air samples, prompt field assessments may not be possible. Activity due to background levels of radon can be determined by holding the air sample for a period of time to ascertain whether the radioactivity level goes down, indicating contribution to the original activity level from the presence of radon daughter products in the sample.

10. Air sample results should be evaluated as quickly as practicable for evaluation of the need for respiratory protection, area evacuation (if necessary), worker intake, and worker relief from respirator use.

PART 6 Instrumentation and Calibration

561 Standardization

SLAC uses commercially-available radiological instrumentation to the extent practicable.

562 Inspection, Calibration, and Performance Tests

1. Radiological instruments shall be used only to measure the radiation for which their calibrations are valid. SLAC uses, to the extent appropriate, the requirements contained in IEEE N323[60] for radiological instrumentation calibration. Calibrations shall use NIST traceable sources.
2. Calibration procedures should be developed for each instrument type and include frequency of calibration, pre-calibration requirements, primary calibration requirements, periodic performance test requirements, calibration record requirements, and maintenance requirements.
3. Electronic dosimeters should be routinely calibrated and maintained on an established frequency. The recommended frequency is at least annually and in accordance with Article 562.1.
4. Radiation instrumentation response to interfering ionizing and non-ionizing radiation and environmental conditions should be determined. The effects such interfering radiation has on an instrument should be known prior to use.
5. Functional tests should be used to assess instrumentation designs that include alarms or that involve a process control. A functional test should be developed to test all components involved in an alarm or trip function and it should be performed at least annually.
6. In unusual and limited situations, it may be necessary to use an instrument in an application other than that envisioned by the manufacturer. Special calibrations should be performed for use of instrumentation outside manufacturer's specifications. The instrument should be adjusted, calibrated, and labeled to identify the special conditions and used *only* under the special conditions for which it was calibrated.
7. Instruments should bear a label or tag with the date of last calibration and date calibration is due.

60 Institute of Electrical and Electronics Engineers (IEEE) N323, "Radiation Protection Instrumentation Test and Calibration" (IEEE N323)

8. Instruments whose "as found" readings indicate that the instrument may have been used while out of calibration shall be reported to the RP Department. The RP Department should review surveys performed with the instrument while it was out of calibration.

563 Maintenance

1. A program for annual preventive and corrective maintenance and calibration of radiological instrumentation shall be established and documented.
2. Preventive and corrective maintenance should be performed using components and procedural recommendations at least as stringent as those specified by the manufacturer of the instrument.
3. Radiological instruments shall undergo calibration prior to use following any preventive or corrective maintenance or any adjustment that voids the previous calibration. A battery change is not normally considered maintenance.

564 Calibration Facilities

1. Calibration facilities should take the following actions:
   A. Locate activities in a manner to minimize radiation exposure to operating personnel and to personnel in adjacent areas
   B. Minimize sources of interference, such as backscatter and non-ionizing radiation, during the calibration of instrumentation and correct for interferences as necessary
   C. Operate in accordance with the referenced standards
   D. Generate records of calibration, functional tests, and maintenance in accordance with the referenced standards
2. SLAC's Radiological Calibration Facility (RCF) shall be operated as required by the latest version of the *Radiological Calibration Facility Use Safety Procedures.*[33]
3. When contracted calibration services are required, they shall be performed in accordance with the referenced standard.

CHAPTER 6 TRAINING AND QUALIFICATION

PART 1 Radiological Control Training and Qualification

611 Purpose

This chapter establishes provisions to ensure that individuals have the requisite training to work safely in and around Radiological Areas and to maintain their individual radiation exposure and the radiation exposures of others as low as reasonably achievable (ALARA). Training provisions in this chapter apply to personnel entering Controlled Areas at SLAC. This chapter also contains the levels of training SLAC considers to be commensurate with the radiological hazards and required controls for entry into Controlled Areas, Radiologically Controlled Areas, Radiological Areas, Radioactive Material Areas, Radioactive Material Management Areas, and other areas established to protect individuals from exposure to radiation or radioactive materials.

612 Standardization

10 CFR 835.901 establishes requirements for radiation safety training programs for two classes of individuals: 1) individuals who are permitted unescorted access to Controlled Areas or occupationally exposed to radiation; and 2) individuals who are permitted unescorted access to Radiological Areas or perform unescorted assignments as a radiological worker. Within this *Manual*, these training programs are referred to as General Employee Radiological Training (GERT), and Radiological Worker Training I and II, respectively. In addition, 10 CFR 835.103 establishes requirements for the education, training, and skills of individuals who are responsible for developing and implementing measures necessary for ensuring compliance with 10 CFR 835. DOE sponsored the development of core courses and training materials and recommends the use of these materials to achieve consistency in the level and quality of training given Department-wide. In establishing local training programs, DOE's core courses should be utilized to the extent practicable and supplemented with site-specific information. Core course training material developed and maintained by DOE consists of lesson plans, viewgraphs, student handbooks, qualification standards, question banks, and other sources. For SLAC training programs, the radiation safety courses are presented and SLAC site-specific information is added. SLAC training includes the expanded course content for radiation and activation products consistent with an accelerator-based training program.

1. 835 **Each individual shall complete radiation safety training on the topics established at 10 CFR 835.901(c) commensurate with the hazards in the area and the required controls.** [10 CFR 835.901(a)]

   The radiological training categories at SLAC are GERT, RWT I and RWT II.

2. The summary of training requirements needed for entry into particular areas is in Table 6-1, "Radiological Worker Entry Training Requirements."

3. Successful completion of the core academic component of the standardized courses for GERT, RWT I, RWT II, and RCT at other DOE sites within the past two years can be recognized by SLAC after individuals:

   A. Have their training date(s) verified by documentation which they provide to SLAC

B. Receive SLAC site-specific radiation safety training as needed and

C. Receive other ESH required training

Allowances may also be made for individuals who have completed other types of radiological control training within the past two years. Documentation of previous training should include the name of the individual, date(s) of training, topics covered, and name of the certifying official. In addition, the individual shall complete the requirements in Article 612.3.A through 612.3.C listed above.

4. The SLAC Radiological Control Manager (RCM) or designee shall concur on radiation safety training material generated at SLAC.

Table 6-1 Area Entry Training Requirements

Area	Total Effective Dose (TED) Rate	Minimum Unescorted Access Training Requirements	Dosimeter Required	Further Description
Controlled Area (CA)	< 100 mrem/year	GERT	No	Any area to which access is managed in order to protect individuals from exposure to radiation and/or radioactive materials.
Radiologically Controlled Area (RCA)	< 100 mrem/year	GERT	Yes	Controlled Area that requires dosimetry for entry. The radiation level in certain localized areas within an RCA may vary, requiring limited occupancy.
Radioactive Material Area (RMA)	various	GERT	No within CA Yes for all others	Dosimetry and training requirements may vary with the area dose rates.
Radioactive Material Management Area (RMMA)	various	GERT	Yes	
Radiation Area	5-100 mrem/h @ 30 cm	RWT I	Yes	RWP required.
High Radiation Area	> 100 mrem/h @ 30 cm	RWT I	Yes	RWP and supplemental dosimeter required.
Very High Radiation Area	> 500 Rad/h @ 1 m	No entry allowed	N/A	Not accessible.
Personnel Exclusion Area	various	RWT I with RP approval	Personnel dosimeter and supplemental dosimeter as directed by RP	Area secured by physical controls other than a personnel protection system (PPS) to restrict access during accelerator beam operations.
Radiological Buffer Area	various	RWT I	Yes	An intermediate area established outside a contamination area to prevent the spread of radioactive contamination
Contamination, High Contamination, or Airborne Radioactivity Area	various	RWT II	Yes	RWP required

613 General Provisions

1. 835 **Radiation safety training shall include the following topics, to the extent appropriate to prior training of the individual, work assignments, and degree of exposure to potential radiological hazards:**

   A. **Risks of exposure to radiation and radioactive materials, including prenatal radiation exposure;**

   B. **Basic radiological fundamentals and radiation protection concepts;**

   C. **Physical design features, administrative controls, limits, policies, procedures, alarms, and other measures implemented at the facility to manage doses and maintain doses ALARA, including both routine and emergency actions;**

   D. **Individual rights and responsibilities as related to implementation of the facility radiation protection program;**

   E. **Individual responsibilities for implementing ALARA measures required by 10 CFR 835.101; and**

   F. **Individual exposure reports that may be requested in accordance with 10 CFR 835.801.** [10 CFR 835.901(c)]

2. Examinations for RWT I, RWT II, and HPT II qualification shall be used to demonstrate satisfactory completion of theoretical and classroom material. Examinations for GERT qualification shall be used to demonstrate satisfactory completion. Examinations should be written; however, the RCM may approve alternatives to accommodate special needs. Alternative examinations should be equivalent in content to written examinations. The examination process should require:

   A. That a minimum passing score of 80% be required

   B. Minimize the number of true or false questions, and not allow open-book examinations

   C. Use of questions randomly selected from a question bank that includes SLAC-specific questions

   D. That competence in required skills is measured using performance-based examinations

   E. Remedial actions for failure to meet the minimum score

   F. That questions be selected to test what the student is expected to remember months after the training, rather than to test short-term memory of theoretical material

   G. Acknowledgement by signature that the student participated in a post-examination review

3. Training should address both normal and abnormal situations in radiological control.

4. GERT training shall be completed every two years after receiving initial GERT training. Changes to the program should be incorporated as they are identified and a decision made

if retraining prior to the two-year period is needed. The *General Employee Radiological Training Study Guide*[61] is also made available for self-study and refresher at any time.

5. 835 **Radiation safety training shall be provided to individuals when there is a significant change to radiation protection policies and procedures that may affect the individual and at intervals not to exceed 24 months. Such training provided for individuals subject to the requirements of 10 835.901(b)(1) and (b)(2) shall include successful completion of an examination.** [10 CFR 835. 901(e)]

   At SLAC, RWT I, RWT II, and HPT retraining shall abide by these requirements. In the alternate year when retraining is not performed, refresher training should be considered if or when there are significant changes to radiation protection policies and procedures that may affect the individual and at intervals not to exceed 24 months.

   RWTs who successfully challenge the RWT Exam will receive a briefing on recent changes to radiation protection policies and procedures that may affect the individual. This briefing will be administered during the RWT practical portion of RWT training.

6. Site-specific training and refresher training should include changes in requirements and relevant updates of lessons learned from operations and maintenance experience and occurrence reporting, for the site and across the DOE complex.

7. Verification of the effectiveness of radiological control training will be accomplished through the SLAC Internal Audits process.

8. Requirements for respiratory protection training are included in Article 531.

9. Training programs developed for radiological control should meet the requirements for performance-based training and, when applicable, training accreditation.

10. Reading and comprehension skills in the English language are necessary for GERT training. The RCM is authorized to approve alternative temporary training methods for those lacking reading and comprehension skills in the English language until adequate English language skills can be achieved. Training in an alternate language should be equivalent to training in English. The alternative measures should be sufficient to ensure that the affected individuals can respond appropriately to any audible or visible warnings that they may encounter in the facility. Visitor orientation and the use of trained escorts provide an alternate to training with the concurrence of the RCM.

    Requirements for training records and course documentation are provided in Article 725.

11. The Radiological Control Manager (RCM) or designee should concur in radiation safety training material.

614 Instructor Training and Qualifications

1. Instructors should have the technical knowledge, experience, and instructional skills required to fulfill their assigned duties.

2. Instructors-in-training should be monitored by a qualified instructor.

61 General Employee Radiological Training Study Guide (SLAC-I-760-0A004G-001)

3. Subject matter experts without instructor qualification may provide training in their areas of expertise. However, these subject matter experts should be provided instructor training when a need for them to provide training occurs on a routine basis.

PART 2 General Employee Radiological Training (GERT)

621 SLAC Personnel

835 **Each individual shall complete radiation safety training on the topics established at 10 CFR 35.901(c) commensurate with the hazards in the area and the required controls:**

- **Before being permitted unescorted access to controlled areas; and**
- **Before receiving occupational dose during access to controlled areas at a DOE site or facility** [10 CFR 835.901 (a)]

1. GERT training includes the radiation safety course training materials, including the required material in 10 CFR 835.901(c), and SLAC-specific information.
2. Workers who have never received GERT or equivalent training shall complete SLAC's web-based GERT. For any subsequent requalification, a challenge examination may be taken. If unsuccessful in one attempt, GERT must be retaken. The challenge examination is available online.
3. GERT-qualified individuals are permitted to enter unescorted into the areas shown in Table 6-1. GERT-qualified individuals are not permitted to enter unescorted into any Radiological Areas (e.g., Radiation Areas, High Radiation Areas, Contamination Areas, Airborne Radioactivity Areas, etc.). To enter a Radiological Area, a GERT-qualified individual shall be escorted by someone who has at least RWT-I training and prior RP Department approval (See Article 621.6 below).

   Additionally, GERT-qualified individuals must not conduct any work that involves handling or working with radioactive materials, including activated beamline components. RWT I training is required for these activities.

   However, GERT-qualified individuals with additional sealed source training are permitted to handle sealed sources (<5 mR/h @ 30 cm).
4. Information may be communicated by classroom lecture, videotape, or other applicable methods.
5. To retain a GERT qualification, GERT must be completed once every 24 months. The latest *GERT Study Guide* is available[61].
6. If an escort is used in lieu of training, then the escort shall have completed the level of training required for the area(s) to be entered and the work to be performed and shall ensure that the escorted individual complies with the Radiation Protection Program [see 10 CFR 835.901(e)].

622 Radiological Safety Training and Orientation for Members of the Public

1 [reserved]

2. SLAC escorts members of the public in Controlled Areas. Members of the public who have completed the requirements of Article 622.3 may be allowed to be unescorted in Controlled Areas provided the RCM or his designee has approved the exception to the escort requirements and provided that:

   A. Appropriate limitations are established on the areas to be entered and the activities to be undertaken.

   B. The individual does not receive occupational radiation exposure.

   C. The individual receives an enhanced orientation providing information commensurate with the areas to be entered and activities to be undertaken while unescorted.

3. Escorted members of the public who enter Controlled Areas shall receive a safety briefing delineating the potential hazards relative to the area or areas being entered.

4. Information may be communicated verbally or by means of computer-based training. An examination is not required.

   A. Members of the public who need unescorted access to Controlled Areas shall obtain qualification as GERT-trained individuals (see Article 621).

   B. Reserved

   C. Members of the public may not enter Radiological Areas.

   D. 835 **When an escort is used in lieu of training in accordance with 10 CFR 835.901(a) or (b), the escort shall:**

      1) Have completed radiation safety training, examinations and performance demonstrations required for entry to the area and performance of the work; and

      2) Ensure that all escorted individuals comply with the documented radiation protection program. [10 CFR 835.901(d)]

5. Member of the public sign-in logs and/or forms may be used as safety briefing records as required by Article 725.4

6. Requirements for Tours, Dignitaries, Visiting Scientists and Specialists are addressed in Article 657.

7. For users, including students and visiting scientists, a knowledgeable SLAC employee must authorize their experiment prior to release in accordance with the work planning and control (WPC) process.[62] As with any work activity at SLAC, should the experimental conditions change, reauthorization is required to ensure that potential hazards that may have been introduced are controlled (See also the SLAC Area Hazard Analysis library[63]).

8. For other users such as contractors, the point of contact must assume responsibility for the work planning and control at SLAC.

62 *SLAC Environment, Safety, and Health Manual* (SLAC-I-720-0A29Z-001), Chapter 2, "Work Planning and Control"

63 Area Hazard Analysis

PART 3 Radiological Worker Training (RWT)

631 General Provisions

1. 835 **Each individual shall demonstrate knowledge of the radiation safety training topics established in 10 CFR 835.901(c), commensurate with the hazards in the area and required controls, by successful completion of an examination and performance demonstrations:**

   A. Before being permitted unescorted access to radiological areas; and

   B. Before performing unescorted assignments as a radiological worker.

   [10 CFR 835.901(b)]

2. RWT I shall be completed by an individual prior to entering Radiological Areas or if they will be performing work beyond the scope defined for GERT workers.

3. RWT II is required for entry into Contamination Areas, High Contamination Areas, and Airborne Radioactivity Areas. Additional training is required for special job functions with radiological consequences per Article 634.

4. Workers who never received RWT or equivalent training shall complete SLAC's web-based RWT. For any subsequent requalification, a challenge examination may be taken. If unsuccessful in one attempt, RWT must be retaken. The challenge examination is available online. Challenges do not apply to the SLAC specific portions, where program changes and operational experience are updated. Challenges do not apply to the practical exercise examination for RWT I or RWT II. "Practical" skills shall be satisfactorily demonstrated at each qualification cycle.

5. RWT I at SLAC incorporates the High Radiation Area entry-related material of the RWT II radiation safety training program. RWT I is a prerequisite for the complete RWT II program.

6. RWT I at SLAC expands on the topic of hands-on work with radioactive material and prepares the worker to deal with higher levels of radiation. RWT II at SLAC expands on RWT I by preparing the worker to deal with radioactive contamination. Individuals with current RWT I may be upgraded to allow unescorted access to Contamination Areas by completing only the additional training provided in RWT II.

632 Radiological Worker I

1. Workers whose job assignments require access to Radiation Areas or High Radiation Areas, or handling of radioactive material, or who will be operating radiation-generating devices (RGDs) shall complete RWT I training before being permitted to work.

   The training needed for entry into particular areas is given in Table 6-1, "Area Entry Training Requirements."

2. RWT I training uses appropriate portions of the DOE radiation safety course training material and, in addition, emphasizes SLAC-specific information.

3. SLAC-specific RWT I training encompasses the following practical factors:

A. Entering, exiting, and working in simulated Radiation Areas and High Radiation Areas

B. Use of radiation survey instruments

C. Anticipated response to alarm situations

D. Anticipated response to simulated abnormal situations

E. Removal of material from accelerator housings

F. Personnel Protection System (PPS) introduction

4. Unescorted worker access to High Radiation Areas is permitted upon successful completion of RWT I training with the High Radiation Area training module. Completion of this training does not authorize access to Contamination Areas, High Contamination Areas, Soil Contamination Areas, or Airborne Radioactivity Areas.

633 Radiological Worker II

Workers whose job assignments involve entry into Contamination Areas, High Contamination Areas, and Airborne Radioactivity Areas, or machining radioactive materials shall complete all parts of RWT II training.

1. RWT II contamination-control training uses appropriate portions of the DOE radiation safety course training material and, in addition, shall emphasize SLAC-specific information.
2. SLAC-specific RWT II training encompasses the following practical factors:

   A. Donning protective clothing

   B. Entering a simulated Contamination Area to perform a task

   C. Anticipated response to simulated situations

   D. Anticipated response to simulated alarms or faulty radiological control equipment

   E. Removing protective clothing and equipment and subsequently exiting the simulated area

   F. Performance of frisking for personnel contamination

   G. Verification of instrument response

3. Course length may vary, depending on the amount of SLAC-specific material needed to meet changes in the research program. Normally, because of the limited number of SLAC workers requiring the contamination training module, workers will be RWT I trained first. Workers will complete the contamination module portion of RWT II training only when they are assigned duties requiring that level of training.

634 Specialized Radiological Worker Training

Specialized Radiological Worker training should be completed for non-routine operations or work in areas with changing radiological conditions. This training is in addition to RWT I and RWT II and is required for personnel planning, preparing, and performing jobs that have the potential for high radiological consequences. Such jobs may involve special containment devices, the use of

mock-ups, and ALARA considerations. In some cases, depending on SLAC-specific criteria, pre-job briefings provide an acceptable alternative to Specialized Radiological Worker training.

PART 4 Health Physics Technician II (HPT II) or Higher Qualification

641 General Provisions

Training and qualification of HPT IIs or higher and their immediate supervisors should address routine operations and also focus on recognizing and handling situations in both normal and changing radiological conditions. Newly qualified technicians and those still in training should be given the opportunity to work with qualified experienced technicians to foster development.

642 Qualification Standards for Health Physics Technicians (HPTs)

1. Qualification Standards define the requirements for demonstrating completion of training; see RP Department *Health Physics Technician Qualification Standard.*[64] Signatures on the forms in Qualification Standards provide documentation of satisfactory proficiency.
2. The Qualification Standards shall be supplemented and, if necessary, revised to include SLAC-specific elements.
3. Qualification Standards for the HPT position shall include on-the-job practical training to provide hands-on experience directly applicable to the job.

   Before performing a job function without direct supervision, a trainee with partially completed qualifications shall have completed the qualifications for that task.

5. HPT IIs are authorized to conduct their routine work without direct supervision. HPT IIs who are not fully qualified can conduct their routine work functions without direct supervision with the exception that they must obtain review and approval via signature and date on the record of any radiological survey which they perform. The review and approval by signature and date must come from an HPT II or higher.
6. An HPT II or higher at SLAC shall demonstrate knowledge of the radiation safety training topics established in Article 613.1, commensurate with the hazards and required controls, by successful completion of an examination and appropriate performance demonstrations prior to performing unescorted assignments (See RP Department *Health Physics Technician Qualification Standard*.[64]
7. The training for HPT IIs or higher should either precede performance of tasks assigned to them or be concurrent with such task assignments if the individual is accompanied by and under the direct supervision of a trained individual**.** HPT II or higher training shall use the *RP Department Health Physics Technician Qualification Standard*[64] and appropriate portions of the DOE radiation safety course training materials and, in addition, should emphasize SLAC-specific information.
8. HPT II or higher candidates who have prerequisite knowledge, such as college credit, operational experience, or related qualifications (such as the National Registry of

64 Health Physics Technician Qualification Standard (SLAC-I-720-2A04G-006, FO 017)

Radiation Protection Technologists [NRRPT] registration), may satisfy individual sections of the radiation safety course training requirements by passing comprehensive challenge examinations. Completion of American Board of Health Physics certification (CHP) or NRRPT registration may be used in lieu of the initial core academic/fundamental lessons.

9. Entry-level prerequisites shall be established to ensure that HPT IIs or higher meet the standards for physical condition and education. At a minimum, these standards should include the following:
   A. High school education or equivalency.
   B. Fundamentals of mathematics, physics, chemistry, and science.
   C. Systems and fundamentals of process, operations, and maintenance.
   D. Reading and comprehension level sufficient to follow procedures, write permits, prepare survey maps, write reports, and prepare shipping and transfer permits.
   E. Ability to work in a support role, including communicating verbal instructions to others.
   F. Physical requirements to handle Personal Protective Equipment (PPE) and other equipment, and to assist others in work locations commensurate with assignment.
10. Fully-qualified HPT IIs or higher are encouraged to pursue registration by the National Registry of Radiation Protection Technologists (NRRPT).
11. Credit toward completion of radiation safety training academic requirements will be given for NRRPT registration.

643 Oral Examination Boards

The oral examination board provides an opportunity to identify areas of strength and weakness related to performance of HPT duties and supervisor functions. The oral examination board also provides the opportunity to identify additional training needs to enhance radiological control technician and supervisor training programs.

1. An oral examination board should determine the initial qualification and requalification of candidates for HPT and HPT supervisor positions.
2. The Radiological Control Manager should designate the board members and appoint a chairperson.
3. The board constituted to evaluate HPT qualification should be composed of at least three persons to include an HPT supervisor, radiological control staff, and line management operations department supervisors and staff personnel, as applicable. HPT instructors may participate as non-voting members.
4. The board should assess the candidate’s response to normal and emergency situations. Questions should be of the type that is not normally covered in a written examination.
5. The board constituted to evaluate HPT supervisor qualification should not include peers or subordinates as voting members.

644 Continuing Training for HPTs

1. Following qualification, the HPT should be requalified every two years and commence continuing training for that purpose.
2. Every HPT requalification shall include completion of practical training and a comprehensive written examination.
3. Continuing training should provide continued improvement in the knowledge and skills of the HPT.
4. Continuing training should include written examinations as applicable, demonstrations of proficiency controlled by qualification standards, and oral examinations, if needed, to prepare for the comprehensive biennial requalification.
5. Infrequently performed tasks, such as those for emergency response, may require annual training. Other tasks may require retraining prior to initiation.
6. Personnel who maintain qualifications as HPTs shall also satisfy the requirements of RWT II.

645 Health Physics Technician (HPT) Supervisors

1. HPT supervisors shall have previously qualified as HPTs and should participate in continuing radiation safety training programs.
2. HPT supervisors should have supervisory and leadership capabilities to direct the work of technicians; effectively interact with crafts, line supervisors, professional staff, and other managers; and be able to respond and direct others in emergency and abnormal situations.
3. HPT supervisors shall be requalified every two years by completing the Core Academic Functions examination as a minimum.

646 Subcontracted Radiological Control Technicians (RCTs)

1. Subcontracted RCTs should have the same knowledge and qualifications required of SLAC fully-qualified HPT IIs or higher who are performing the same duties. The training and qualification program should include the following elements in order to ensure that subcontracted RCT have the knowledge and training commensurate with their assignments:
    A. Review of résumés to identify technicians with experience in jobs similar to those for which they will be employed.
    B. Verification of DOE RCT core exam completed within 24 months. If a subcontractor has not completed DOE core exam within the past 24 months, the subcontractor RCT must pass the exam before any work assignment.
    C. Identification of the duties technicians will be authorized to perform.
    D. Training in facility procedures and equipment associated with the authorized duties.
    E. Training on site specific information, including practical factors, as applicable assigned tasks.

F. Observation of on-the-job performances by the HPT supervisor.

2. Subcontracted RCTs who work at the facility for more than one year should receive continuing training and an Oral Board examination commensurate with their assigned tasks.

PART 5 Other Radiological Training

651 Management Training

Training and education standards for line managers of radiological control programs (or elements of those programs) should be consistent with DOE Standard 1107-1997, "Knowledge, Skills, and Abilities for Key Radiation Protection Positions at DOE Facilities."[65] Line managers who manage, supervise, or provide oversight of the Radiation Protection Program should be trained in the principles of this *Manual* and 835 **…shall have the appropriate education, training, and skills to discharge these responsibilities.** [10 CFR 835.103] Such training should be based on standardized radiation safety course training material supplemented by SLAC-specific procedures and be completed by new personnel prior to formally assuming line supervision and management responsibilities. Incumbents should participate in continuing training. The continuing training should emphasize self-assessment and external evaluations, including performance indicators, root causes, and lessons learned based on operational experience.

652 Technical Support Personnel

Appropriate technical support personnel (engineers, schedulers, procedure writers) should be trained in the principles of as low as reasonably achievable (ALARA) and dose reduction techniques. They should also participate in selected portions of job-specific and specialized training, particularly in situations using mock-ups.

653 Planners

Planners who develop detailed work plans involving or associated with radioactivity or radioactive material should have Radiological Worker training to the level required by the workers using the work plans. At SLAC, it is recommended that planners have RWT I and in some cases RWT II.

654 Radiological Control Personnel

1. Radiological Control senior staff (see Article 141) and management should have:

   A. A combination of education and experience commensurate with their job responsibilities

65 Department of Energy Standard 1107-1997, Change Notice 1, "Knowledge, Skills, and Abilities for Key Radiation Protection Positions at DOE Facilities" (DOE-STD-1107-1997, Change Notice 1)

B. Continuing training based on an assessment of job responsibilities to maintain and enhance proficiency

C. Continuing training to remain cognizant of changes to the facility, operating experience, procedures, regulations, and quality assurance requirements

2. Radiological support personnel include, but are not limited to, dosimetry technicians, instrument technicians, medical personnel, records clerks, and analysis laboratory personnel.

3. Radiological support personnel should have:

A. Training on radiation safety course topics from RWT I, RWT II, HPT, 10 CFR 835.901(c), and additional job-specific topics, as applicable

B. Training appropriate to the tasks to be performed

C. Continuing training to provide continued improvement in knowledge and skills

4. Training and education standards for radiological control senior staff and support personnel should be consistent with DOE-Standard 1107-97 Change Notice 1.[66]

5. Certification and involvement with professional industry organizations should be encouraged.

655 Radiographers and Radiation Generating Device (RGD) Operators

For SLAC employees,

1. Radiographers shall have training in accordance with 10 CFR 34.43.

2. Radiation generating device custodians, operators, and users should be trained in accordance with the device classification (classes I-V). For example, Class I device custodians, operators and users require GERT only, as well as a briefing on the RGDAS. All custodians, operators, and users would generally be considered to be subject to the education, training, and skill requirements of 10 CFR 835.103 and should have training appropriate for the radiation source involved and commensurate with the level described in 10 CFR 34.43.

3. RGD custodians, operators, and users who will not encounter single or mixed-radiation fields potentially producing more than 0.05 mrem/h TED @ 30 cm and who do not change the operating parameters of the RGD should be GERT-trained.

For non-SLAC employees,

SLAC General Employee Radiological Training (GERT) or Radiological Worker Training (RWT) and dosimeter will not be required nor provided by SLAC for the activities associated with radioactive materials and operations that are properly licensed under state regulations. Subcontractor employees must wear their company-issued dosimeters per the company's radiation safety plan.

66 Department of Energy Standard 1107-1997, Change Notice 1, "Knowledge, Skills, and Abilities for Key Radiation Protection Positions at DOE Facilities" (DOE-STD-1107-1997, Change Notice 1)

656 Emergency Response Personnel

Provisions shall be in place to accommodate rapid site and Radiological Area access by on-site and off-site emergency workers such as firefighters, medical personnel, and security personnel.

1. Emergency response personnel may be required to work in Radiological Areas.
2. Emergency response personnel should receive special radiological worker training commensurate with the situations they are likely to encounter.
3. Such training should be based on the Radiological Worker radiation safety course and SLAC-specific training material.
4. If such workers are not trained, trained escorts should be assigned.
5. Emergency worker training should include coverage of Appendix 2A, "Guidelines for Control of Emergency Exposures." Training should make it clear that lifesaving has priority over radiological controls.
6. Records of this training shall be maintained.

657 Training for Tours, Dignitaries, Visiting Scientists, and Specialists

1. Escorted tours, dignitaries, visiting scientists, and specialists that enter Controlled Areas shall be considered members of the public subject to Article 622.2.
2. Visiting scientists and specialists actively involved in experiments or other activities at SLAC are general employees as defined in 10 CFR 835.2(a) and thus are subject to the requirements of Articles 621 and 631– 634.

658 Limited Radiological Control Assistant

Operations personnel may be assigned to duties described in Article 551.2 during off shifts and when fully qualified HPT IIs or higher are not available. This training is analogous to the operator assistance programs seen at other DOE facilities. In addition to RWT I, in order to ensure that adequate skills to perform these duties have been provided in SLAC-specific training, the following objectives have been established for the indicated target employee population that will function as Limited Radiological Control Assistants (LRCAs):

1. Upon completion of LRCA training, participants will be able to:
   A. Conduct limited radiation surveys but may not redo radiological posting.
   B. Conduct limited radioactive material surveys but cannot release materials from radiological controls.
   C. Escort for initial entries to designated High Radiation Areas.
   D. Know how to use a Beam Authorization Sheet (BAS) or a Beam Line Authorization (BLA) sheet.
   E. Take appropriate actions in emergencies.
   F. Take appropriate actions for abnormal conditions.
2. Groups at SLAC who may require this training are the following:

A. Linac operators at Accelerator Control Room (ACR).

B. Operators at Stanford Synchrotron Radiation Lightsource (SSRL).

C. SSRL beamline operators.

D. Next Linear Collider Test Accelerator (NLCTA) operators.

E. Or other operators approved by the RCM.

PART 6 Training For Special Applications

661 Plutonium Facilities

The following topics should be considered in addition to radiation safety training requirements at plutonium facilities, elements of which may be provided to SLAC personnel involved in experiments with plutonium:

- Properties of plutonium
- Special radiological surveys and techniques
- External exposure control (neutrons)
- Internal exposure control
- Containment and glovebox operations and procedures
- Special instruments and measurement techniques
- Personnel protection
- Inventory control and accountability
- Criticality safety
- Biological effects

662 Uranium Facilities

The following topics should be considered in addition to radiation safety training requirements at uranium facilities, elements of which may be provided to SLAC personnel working with uranium targets and/or shielding:

- Properties of uranium
- Special radiological surveys and techniques
- External exposure control
- Toxicological properties and behavior of uranium
- Release of uranium-contaminated material
- Instruments and measurement techniques
- Personnel protection

- Inventory control and accountability
- Criticality safety
- Biological effects

663 Tritium Facilities

The following topics should be considered in addition to radiation safety training requirements at tritium facilities, elements of which may be provided to SLAC personnel involved in experiments with tritium targets:

- Properties of tritium
- Sources of tritium
- Exposure pathways and forms of tritium
- Exposure control
- Tritium containment
- Special instruments and measurement techniques
- Personnel protection
- Inventory control and accountability
- Airborne tritium measurement
- Airborne tritium controls
- Effluent recovery systems
- Tritium releases
- Bioassay program
- Biological effects

664 Accelerator Facilities

The following topics are discussed in addition to SLAC's RWT I radiation safety training, all of which are covered in the SLAC site-specific training program:

- Activation products
- Special radiological surveys and techniques
- Component source terms
- Interlock and warning devices and systems
- Personnel Protection Systems (PPS) and beam containment system
- Special instruments and measurement techniques
- Biological effects

CHAPTER 7 RADIOLOGICAL RECORDS

PART 1 Requirements

711 Purpose

This chapter prescribes practices for preparing and retaining radiological control records at SLAC. Radiological control records shall be maintained as necessary to document compliance with the requirements of 10 CFR 835. The work force and management are required to use records to document radiological safety afforded to personnel on-site. Records of radiological protection programs may be required to support worker health studies and future disputes or claims. Therefore, these records should be of high quality, readily retrievable, and managed for the prescribed retention period. Records should be handled such that personal privacy is protected.

712 Records Management Program

1. A Radiological Records Management Program has been established at SLAC. This program should ensure that auditable records and reports are controlled through the stages of creation, distribution, use, arrangement, storage, retrieval, media conversion (where applicable), and disposition. The SLAC Records Management Program shall be sufficient to ensure that 835 **Records shall be maintained to document compliance with this part and with radiation protection programs required by 10 CFR 835.101** [10 C FR 835.701(a)] and should include the following:
   - A. Radiological policy statements
   - B. Radiological control procedures
   - C. Individual radiological doses
   - D. Internal and External Dosimetry Policies and Procedures (including Technical Basis Documents)
   - E. Personnel training (course records and individual records)
   - F. ALARA Committee records
   - G. 835 **Results of maintenance and calibration performed on instruments and equipment as required by 10 CFR 835.401(b)**[10 CFR 835.703(d)]
   - H. Radiological surveys
   - I. Area monitoring dosimetry results
   - J. Radiological work permits
   - K. Radiological performance indicators and assessments
   - L. Radiological safety analysis and evaluation reports
   - M. Quality assurance records for the Radiological Control Program
   - N. Radiological incident and occurrence reports (and critique reports, if applicable)

O. Accountability records for sealed sources

P. 835 **Results of monitoring for the release and control of material and equipment as required by 835.1101** [10 CFR 835.703(c)]

Q. Reports of loss of radioactive material

2. When radiological services (for example, dosimetry and laboratory analyses) are purchased, there should be a clear agreement regarding records responsibility during performance of the service. Records of results should reside in the custody of the originating organizational element at SLAC.

3. DOE Order 200.1A, "Information Management Program," provides implementation options, implementing guidance, records inventory requirements, disposition schedules, and provisions for formal transfer of records.[67]

4. 835 **Detailed information concerning any individual's exposure shall be made available upon request of that individual, consistent with the Privacy Act (5 U.S.C. 552a).** [10 CFR 835.801(d)]

713 Recordkeeping Standards

1. Radiological control records should be accurate and legible. The records should include the following:

   A. Identification of the facility, specific location, and function

   B. Signature or other identifying code of the preparer and date

   C. Legible entries in ink

   D. Corrections identified by a single lineout, initialed, and dated

   E. Supervisory signature to ensure review and proper completion of forms

2. The Radiation Protection (RP) Department should maintain a file of names, signatures, and initials for future identification of the person who signed or initialed a record.

3. Radiological control records should not include:

   A. Opaque substances for corrections.

   B. Shorthand or other non-standardized terms.

4. Similar procedural standards should be established for computerized records.

5. Unless otherwise specified, radiological control records for reporting to the DOE shall use the special units of curie, rad, and rem, including multiples of these units. Use of the international system of units (becquerel, gray, and sievert) should be limited to calculational, scientific, or reference purposes.

67 Site Compliance Plan for Department of Energy Order 200.1A, "Information Technology Management" (DOE O 200.1A SCP)

PART 2 Employee Records

721 Employment History

Records detailing the pre-employment and employment history of an individual and the associated radiation dose shall be maintained for workers whose occupational dose is monitored in accordance with 10 CFR 835.402. 835**For radiological workers whose occupational exposure is monitored in accordance with 10 CFR 835.402, reasonable efforts shall be made to obtain complete records of prior years occupational internal and external doses.** [10 CFR 835.702(e)]

If complete records of previous occupational dose cannot be obtained, a written estimate signed by the individual may be accepted to demonstrate compliance. [10 CFR 835.702(d)]

Where practical, the association between the radiation dose and job function should be preserved for trending purposes and future worker health studies. The following information should be maintained:

1. Previous work history detailing radiological work assignments, and yearly occupational doses at other DOE and non-DOE facilities to the extent practicable.
2. Nuclear Regulatory Commission Form 4 or equivalent occupational dose history form that documents previous occupational radiation doses.
3. Ongoing work history documenting work assignments and radiation doses; the facility and occupational codes defined in DOE Order 231.1B, "Environment, Safety, and Health Reporting,"[68] should be used for this process when appropriate.
4. When issued and where appropriate, DOE standardized forms to document previous and ongoing radiation doses will be used at SLAC.

722 Personnel Radiological Records

1. 835 **Except as authorized by § 835.702(b), records shall be maintained to document doses received by all individuals for whom monitoring was conducted and to document doses received during planned special exposures, unplanned doses exceeding the monitoring thresholds of 10 CFR 835.402, and authorized emergency exposures.** [10 CFR 835.702(a)]
2. Radiation dose records shall contain information sufficient to identify each person, including social security, employee number or other unique identification number.
3. Routine and special records related to radiation doses shall be retained for each person monitored. These files shall include records of no dose detected above the minimum detectable dose above background. 835 **Data necessary for future verification or reassessment of the recorded doses shall be recorded.** [10 CFR 835.702(g)]
4. External dose records should include the following:

68 Site Compliance Plan for Department of Energy Order 231.1B, Change 1, "Environment, Safety, and Health Reporting" (DOE O 231.1B, Chg 1 [Admin Chg] SCP)

A. Extremity and whole body dose results measured with personnel dosimeters, including all results from any individual wearing more than one dosimeter.

B. Evaluations resulting from anomalous dose results, such as unexpected high or low doses.

C. Dose reconstructions from lost or damaged dosimeters, or for workers without dosimeters, except members of the public who did not enter a Radiologically Controlled Area.

D. Evaluations of non-uniform radiation doses.

E. 835 **The records required by this section shall:**

(1). **Be sufficient to evaluate compliance with subpart C of this part;**

(2). **Be sufficient to provide dose information necessary to complete reports required by subpart I of this part**; [10 CFR 835.702(c)(1)(2)]

F. The individual monitoring records required by this *Manual* shall include the following quantities for external dose received during the year:

(1). 835 **The effective dose from external sources of radiation (equivalent dose to the whole body may be used as effective dose for external exposure)** [10 CFR 835.702(c)(3)(i)]

(2). **The equivalent dose to the lens of the eye;**

(3). **The equivalent dose to the skin; and**

(4). **The equivalent dose to the extremities.** [10 CFR 835.702(c)(3)(ii)(iii)(iv)]

5. Internal dose records for intakes received during the calendar year should include the following, with measurement assistance from accredited or otherwise recognized third-party service providers as deemed appropriate by the Radiological Control Manager:

A. Whole-body and lung counting results (including chest wall thickness measurements where applicable).

B. Urine, fecal, and specimen analysis results, including estimated intake and identity of radionuclides.

C. Dose assessment, as required.

D. The individual monitoring records required by 10 CFR 835.702 shall be sufficient to:

(1). 835 **Be sufficient to evaluate compliance with subpart C of this part;**

(2). **Be sufficient to provide dose information necessary to complete reports required by subpart I of this part.** [10 CFR 835.702(c)(1)(2)]

E. The individual monitoring records required by 10 CFR 835.702 shall: 835 **include the following information for internal dose resulting from intakes received during the year:**

(1). **Committed effective dose;**

(2). **Committed equivalent dose to any organ or tissue of concern; and**

(3). **Identity of radionuclides** [10 CFR 835.702(c)(4)(i)(ii)(iii)]

6. Individual monitoring records required by 10 CFR 835.702 shall: 835 **include the following quantities for the summation of external dose and internal dose:**

   A. **Total effective dose in a year;**

   B. **For any organ or tissue assigned an internal dose during the year, the sum of the equivalent dose to the whole body from external exposures and the committed equivalent dose to that organ or tissue;**

   C. **Cumulative total effective dose** [10 CFR 835.702(c)(5)(i)(ii)(iii)]

   D. 835 **The following information shall be documented and maintained: Results of monitoring used to determine individual occupational dose from external and internal sources.** [10 CFR 835.703(b)]

7. The 835 **equivalent dose to the embryo/fetus of a declared pregnant worker** [10 CFR 835.702(c)(6)] shall be maintained with the occupational exposure records for that worker**.**

8. Counseling of persons about radiological concerns should be conducted and documented, and this documentation retained by the Occupational Health Center in the medical record of the employee. It is desirable that the counseled people sign the documentation to acknowledge participation. 835 **Written declarations of pregnancy, including the estimated date of conception, and revocations of declarations of pregnancy shall be maintained.** [10 CFR 835.704(d)]

9. Records of authorization to exceed Administrative Control Levels shall be retained.

10. 835 **The dose from planned special exposures is not to be considered in controlling future occupational dose of the individual under 10 CFR 835.202(a), but is to be included in records and reports required under this part.** [10 CFR 835.204(f)]

11. 835 **Recording of the non-uniform equivalent dose to the skin is not required if the dose is less than 2 percent of the limit specified for the skin in 10 CFR 835.202(a)(4).** **[**10 CFR 835.702(b).1]

    Note: Table 2-1 of this *Manual* corresponds to the skin dose limits in 10 CFR 835.202(a)

    Recording of internal dose (committed effective dose or committed equivalent dose) is not required for any monitoring result estimated to correspond to an individual receiving less than 0.01 rem (0.1 mSv) committed effective dose. The bioassay or air monitoring result used to make the estimate shall be maintained in accordance with 10 CFR 835.703(b) and the unrecorded internal dose estimated for any individual in a year shall not exceed the applicable monitoring threshold in 10 CFR 835.402(c). **[10 CFR 835.702(b).2,.3]**

    (see Article 723 for requirements for records of radiological incidents and occurrences).

12. 835 **When a DOE contractor** i**s required to report to the Department, pursuant to Departmental requirements for occurrence reporting and processing, any exposure of an individual to radiation and/or radioactive material, or planned special exposure in accordance with 10 CFR 835.204(e), the contractor shall also provide that individual with a report on his or her exposure data included therein. Such**

report shall be transmitted at a time not later than the transmittal to the Department. [10 CFR 835.801(e)]

Being a DOE contractor, SLAC shall abide with the occurrence-reporting-based dose reporting requirements of 10 CFR 835.204(e).

723 Other Personnel Radiological Records

1. The complete records of radiological incidents and occurrences involving personnel dose shall be retained in the occupational dose file for the individual. This file shall include unplanned or emergency exposures exceeding the limits in Table 2-1, "Summary of Occupational Dose Limits."
2. Records of employee radiological safety concerns that have been formally investigated and documented should be maintained.
3. Records of the formal written declaration of pregnancy shall be maintained. Records of revocations of such declarations, as well as records indicating that the pregnancy has concluded (therefore, the conditions of Article 216 do not apply), should also be maintained.

724 Medical Records

1. Pre-employment medical records, if available, and reports of periodic medical examinations should be maintained only by the SLAC Occupational Health Center.
2. Physical examination reports and fit testing results for respirator use should be maintained for respirator users, where such needs exist at SLAC.
3. Medical evaluations and treatment performed in support of the radiological control program should be documented and all records retained in the SLAC Occupational Health Center files.
4. Maintenance of records of non-occupational radiation doses, such as therapeutic or large amounts of diagnostic radiation doses for medical purposes, is encouraged. Where practical, maintenance of records of pre-employment non-occupational radiation doses is encouraged. These records should be retained by the SLAC Occupational Health Center.

725 Radiological Training and Qualification Records

1. Records of training and qualification in radiological control shall be maintained to demonstrate that a person received appropriate information to perform the work assignment in a safe manner. Qualification standard records are retained for on-the-job and practical factor training, as well as for formal classroom training.
2. Formal records of training and qualification should be readily available to first-line supervision and management of involved personnel to aid in making work assignments involving radiological work.
3. SLAC personnel 835 **training records shall be controlled, maintained and retained, as necessary, to demonstrate compliance with 10 CFR 835.901.** [10 CFR 835.704(a)] At a minimum, these records shall include the following:

A. Course title.

B. Attendance sheets with name of the instructor.

C. Name, identification number, and signature of the employee.

D. Date of training.

The following information should also be retained in training records:

E. Identification of the examination or evaluation form when and where appropriate, including sufficient data to identify which test each person completed.

F. Verification document or record confirming satisfaction of training requirement

G. Documentation related to exceptions for training requirements and extensions of qualification.

H. Quizzes, tests, responses, and acknowledgments of training, with the date and signature of the person trained (see Article 725.3.B. above).

I. Receipt of special instructions to females, their supervisors, and coworkers concerning prenatal radiation dose, acknowledged by the signature of the worker (available to all female workers as part of the DOE Radiological Fetal Protection Program).

4. 835 **Training records shall be maintained, as necessary, to demonstrate compliance with 10 CFR 835.901.** [10 CFR 835.704(a)] At a minimum, these records should include the following:

A. General Employee Radiological Training (GERT)

B. Radiological Worker Training (RWT I and RWT II)

C. Periodic retraining

D. Respiratory protection training

E. Training of radiological control personnel

F. Instructor training

G. Qualifications for special tests or operations

H. Orientation and training of members of the public

I. Training of emergency response personnel

5. The following instructional material should be maintained:

A. Course name, with revision and approval date

B. Manuals, course content, or lesson plans containing the instructor's topical outlines

C. Video and audio instructional materials, including the dates and lessons for which they were used

D. Handouts or other material retained with the master copy of the course

E. Job-specific training documents, such as instrument use, radiological procedures, Radiological Work Permit (RWP) special training requirements, pre-job briefings, and mock-up training

6. Documentation of training and qualification received at another DOE location need not be duplicated. Such records should be provided to the home office of the person for retention.

7. Records shall be maintained as necessary to demonstrate that individuals who are responsible for the development and implementation of measures necessary to ensure compliance with 10 CFR 835 have the appropriate education, training, and skills to execute these responsibilities [see 10 CFR 835.103 and 835.701(a)]. These records should include records of the training provided in accordance with Parts 4 and 5 of Chapter 6 of this *Manual*.

PART 3 Visitors

731 Record Requirements

For visitors entering an area where radiation monitoring is required, the following records should be maintained:

1. Documentation of completion of Radiological Safety Orientation training, if administered.

2. Radiation dose records, including those showing no dose above the minimum detectable level above background. It is expected that no visitor will receive over 100 mrem total effective dose (TED) at SLAC.

732 Reports

For any visitor with dose above the minimum reportable level, SLAC should report that dose to the visitor as soon as the dose determination is available, but no later than 90 days after the end of the visit. In any event, SLAC shall provide a dose report to any visitor who requests it.

PART 4 Radiological Control Procedures

741 Policies, Procedures, and Radiological Work Permits

Records of the Radiation Protection Program should consist of policy statements, procedures, RWPs, and supporting data. The records should be maintained in a chronological sequence that will allow correlation with the corresponding supporting information. For example, procedures for performing radiation surveys should be identifiable with the survey results. Completed RWPs, which are to be completed by the cognizant engineering organization, should be maintained.
835 **Changes in equipment, techniques, and procedures used for monitoring shall be documented.** [10 CFR 835.704(e)]

742 ALARA-Related Records

835 **Actions taken to maintain occupational exposures as low as reasonably achievable, including the actions required for this purpose by 10 CFR 835.101 as well as facility design and control actions required by 10 CFR 835.1001, 835.1002, and 835.1003, shall be documented.** [10 CFR 835.704(b)] These records should include the minutes of the SLAC ALARA Committee and the Radiation Safety Committee. Other records include ALARA plans and goals, records of pre-job briefings, and post job evaluations.

743 Quality Assurance Records

835 **Records shall be maintained to document the results of internal audits and other reviews of program content and implementation.** [10 CFR 835.704 (c)] Records of quality assurance reviews and audits developed for radiological control functions shall be retained to ensure that sufficient records are specified, prepared, reviewed, approved, and maintained to accurately reflect completed work. The information in DOE Order 414.1E, "Quality Assurance,"[69] should be used to develop quality assurance records programs. Quality assurance records should include:

1. Assessment checklists
2. Assessment methods
3. Assessment results
4. Assignment of corrective actions
5. Completion and verification of corrective actions

PART 5 Radiological Surveys

751 Requirements

1. The Radiological Control Program at SLAC requires the performance of radiation, airborne radioactivity, and contamination monitoring and radiological surveys to determine existing conditions in given locations. Maps with sufficient detail to permit identification of original survey and sampling locations should be maintained. Records should contain sufficient detail to be meaningful even after the originator is no longer available. Radiological surveys should be recorded on appropriate standard forms and include the following common elements:
   A. Date, time, and purpose of the survey
   B. General and specific location of the survey
   C. Name and signature of the surveyor and analyst
   D. Pertinent information needed to interpret the survey results
   E. Reference to a specific RWP if the survey is performed to support the permit

69 Site Compliance Plan for Department of Energy Order 414.1E, "Quality Assurance" (DOE O 414.1E SCP)

2. 835 **Records shall be maintained to document:**

   A. 835 **Results of monitoring for radiation and radioactive material as required by subparts E and L of this part except for monitoring required by 10 CFR 835.1102(d).** [10 CFR 835.703(a)]

   B. 835 **Results of monitoring used to determine individual occupational dose from external and internal sources.** [10 CFR 835.703(b)]

   C. 835 **Results of monitoring for the release and control of material and equipment as required by 10 CFR 835.1101.** [10 CFR 835.703(c)]

   D. Compliance with the 835 **requirements of 10 CFR 835.1201 and 835.1202 for sealed radioactive source control, inventory, and source leak tests.** [10 CFR 835.704(f)]

   E. Results of surveys of radioactive materials packages received from transportation.

   F. 835 **Changes in equipment, techniques and procedures used for monitoring.** [10 CFR 835.704(e)]

752 Radiation Surveys

In addition to the elements provided in Article 751, records of radiation surveys should include, at a minimum, the following information:

1. Instrument model and serial number
2. Results of the measurements of area dose rates
3. Locations of hot spots and other radiological hazards
4. Facility conditions existing during the survey that may have affected radiological conditions

753 Airborne Radioactivity

In addition to the elements provided in Article 751, records of airborne radioactivity monitoring should include, at a minimum, the following information:

1. Model and serial number of the sampler and laboratory counting instrument; locations of fixed samplers may be used as identifiers where model and serial numbers are not available; location of portable air samplers used for a survey; and appropriate supporting parameters including counting efficiency, counting time, and correction factors.
2. Concentrations of airborne radioactivity in general areas and breathing zones.
3. Supporting parameters, including collection efficiency, flow rate, duration of sampling, correction factors, and filter medium.

754 Contamination Surveys

In addition to the elements provided in Article 751, records of contamination surveys should include, at a minimum, the following information:

1. Model and serial number of counting equipment

2. Contamination levels (using appropriate units) and supporting parameters including counting efficiency, counting time, correction factors, type of radiation, and whether the contamination was fixed or removable
3. Location of areas found to contain hot particles or high concentrations of localized contamination
4. Follow-up survey results for decontamination processes cross-referenced to the original survey

755 Sealed Radioactive Source Leak Tests and Inventories

1. In addition to the elements provided in Article 751, records of sealed radioactive source leak tests should include, at a minimum, the following information:
   A. Model and serial number of counting equipment
   B. Contamination levels (using appropriate units) and appropriate supporting parameters including counting efficiency, counting time, correction factors, and type of radiation
   C. Corrective actions for leaking sources
2. Records of accountable sealed radioactive source inventories shall include, at a minimum, the following information [see 10 CFR 835.704(f) and 835.1202(a)]:
   A. The physical location of each accountable sealed radioactive source
   B. Verification of the presence and adequacy of associated postings and labels
   C. Verification of the adequacy of storage locations, containers, and devices

PART 6 Instrumentation and Calibration Records

761 Calibration and Operational Checks

1. Information shall be documented and maintained for 835 **results of maintenance and calibration performed on instruments and equipment as required by 10 CFR 835.401(b)** [10 CFR 835.703(b)] Records of calibration and periodic operational checks of fixed, portable, and laboratory radiation measuring equipment are maintained by SLAC. These records should include frequencies, method, dates, personnel, training, and traceability of calibration sources to National Institute of Standards and Technology (NIST) or other acceptable standards.
2. Calibration records shall be maintained for the following equipment if applicable:
   A. Portable survey instruments
   B. Bioassay measurement equipment
   C. Laboratory, counting room, and fixed radiation measuring equipment
   D. Process and effluent monitors and sampling equipment
   E. Radiation area monitors

F. Portal monitors and other personnel contamination monitors

G. Electronic dosimeters

H. Air sampling equipment

I. Tool and waste monitoring equipment

J. Protective clothing and equipment monitors

3. Maintenance histories, including the nature of any defects and corrective actions taken, and calibration results for each instrument and device should be created and retained.

4. Documentation of instrument operational checks shall be maintained as required by 10 CFR 835.401(b)(4). The accepted period of retention is for a period not less than the calibration period of the instrument.

762 Special Calibration Records

Records of additional tests and checks of instrumentation used in conjunction with a suspected overexposure, questionable indication, or unusual occurrence should be retained. In addition, records of special instrument calibrations and modifications made in accordance with Article 562.6 should be retained.

PART 7 Records Management

771 Media

A combination of media may be used for a comprehensive records system. For records that have long-term retention requirements and are stored on media subject to degradation or obsolescence, the records system should provide for conversion to a more stable medium. All records should be stored in a manner that ensures their integrity, retrievability, and security.

772 Microfilm

Records may be microfilmed, provided the resulting film copy is capable of producing a clear, legible copy after storage for the specified period. The following controls should be administered:

1. Verification that the resultant copy is legible

2. Confirmation that printed sides are copied

3. Periodic quality audits of the final filmed copy

773 Computerization of Records

1. Records may be transferred to electromagnetic or optics-based storage media, provided certain precautions are taken to ensure that the information is maintained in a retrievable configuration.

2. Controls for the use and handling of magnetic storage media should include the following:

A. A master index of documents on magnetic storage media

B. A program to ensure back-up and retrievability of information

C. Quality control during data entry and analysis

D. An index identifying software applications used in conjunction with the data

E. Software validation and verification

F. Periodic quality audits of software

G. Prevention of unauthorized manipulation of data

H. Assurance that previously stored information is retrievable and usable after system modifications

774 Retention

1. 835 **Unless otherwise specified in this subpart, records shall be retained until final disposition is authorized by DOE.** [10 CFR 835.701(b)] 10 CFR 835 describes procedures for retaining records.

2. 835 **All records required by this section shall be transferred to the DOE upon cessation of activities at the site that could cause exposure to individuals.**
[10 CFR 835.702(h)]

3. Once a record has been created, reviewed, and signed by appropriate supervision, the record is considered complete and should not be modified. Subsequent errors identified in a completed record may be corrected by creating a supplemental record that includes traceability for the correction.

775 Physical Protection of Records

1. Methods for protecting documents should include vaults, file rooms with fixed fire suppression, fire rated cabinets, duplicate storage, or combinations of these methods.

2. Storage arrangements should address physical damage that could be caused by temperature extremes, moisture, infestation, electromagnetic fields, excessive light, stacking, theft, and vandalism.

3. Records should, at a minimum, be protected from:

   A. Exposure to fire, equivalent to an Underwriters Laboratories, Inc., “1.5-hour or greater” fire-resistance rating

   B. Exposure to water damage caused by a 100-year flood

   C. Exposure to windstorm velocities of 100-year recurrence

4. Records should be archived and stored in a secure records storage facility on a periodic basis.

PART 8 Radiological Reporting

781 Reports to Individuals

Upon request, the dosimetry 835 **records specified in this section that are identified with a specific individual shall be readily available to that individual.** [10 CFR 835.702(f)] **Radiation exposure data for individuals monitored in accordance with 10 CFR 835.402 shall be reported as specified in this section.** [10 CFR 835.801 (a)]

1. The radiation exposure data 835 **information shall include the data required under 10 CFR 835.702(c).** [10 CFR 835.801(a).1]
2. 835 **Each notification and report shall be in writing and include: the DOE site or facility name, the name of the individual, his or her social security number, employee number or other unique identification number.** [10 CFR 835.801(a).2]
3. 835 **Upon the request from an individual terminating employment, records of exposure shall be provided to that individual as soon as the data are available, but not later than 90 days after termination.** [10 CFR 835.801(b).1]
4. 835 **A written estimate of the radiation dose received by that employee based on available information shall be provided at the time of termination, if requested.** [10 CFR 835.801(b).2]
5. Personnel who are required to be monitored by the Personnel Dosimetry Program shall be provided an annual report of their dose. This requirement does not apply to visitors covered by Article 732. **835 Each DOE- or DOE-contractor-operated site or facility shall, on an annual basis, provide a radiation dose report to each individual monitored (at SLAC) during the year in accordance with 10 CFR 835.402.** [10 CFR 835.801(c)]

782 Annual Radiation Report

DOE Order 231.1B, "Environment, Safety, and Health Reporting,"[70] provides reporting requirements for the "Annual Radiation Dose Summary." This report includes internal (normally not a possibility at SLAC) and external radiation dose results for monitored DOE and DOE contractor employees, and for monitored visitors. This report is presently provided by SLAC to DOE.

70 Site Compliance Plan for Department of Energy Order 231.1B, Change 1, "Environment, Safety, and Health Reporting" (DOE O 231.1B, Chg 1 [Admin Chg] SCP)

GLOSSARY

abnormal situation: Unplanned event or condition that adversely affects, potentially affects, or indicates degradation in the safety, security, environmental, or health protection performance or operation of a facility

accelerator: A device and its components employing electrostatic or electromagnetic fields to impart kinetic energy to molecular, atomic, or sub-atomic particles and capable of creating a radiological area as defined by 10 CFR Part 835, Occupational Radiation Protection. Accelerator components include injectors, targets, beam dumps, detectors, experimental enclosures, accelerator enclosures, experimental areas, and experimental apparatus utilizing the accelerator. The accelerator also includes associated support and test facilities, equipment, systems, and utilities necessary to operate the accelerator or utilize the accelerated beam. [see DOE O 420.2D]

accountable sealed radioactive source: A sealed radioactive source having a half-life equal to or greater than 30 days and an isotopic activity equal to or greater than the corresponding value provided in Appendix 4A of this *Manual* [see 10 CFR 835.2(a)]

activation: Process of producing a radioactive material by bombardment with neutrons, protons, or other nuclear particles

activity median aerodynamic diameter (AMAD): a particle size in an aerosol where fifty percent of the activity in the aerosol is associated with particles of aerodynamic diameter greater than the AMAD

administrative control level: A numerical occupational dose constraint established at a level below the occupational dose limits provided in Chapter 2 to administratively control and help reduce individual and collective dose

airborne radioactivity: Radioactive material dispersed in the air in the form of dusts, fumes, particulates, mists, vapors, or gases [see 10 CFR 835.2(a)]

airborne radioactivity area: Any area, accessible to individuals, where: a) the concentration of airborne radioactivity, above natural background, exceeds or is likely to exceed the derived air concentration (DAC) values listed in Appendix A or Appendix C of 10 CFR 835; or b) an individual present in the are without respiratory protection could receive an intake exceeding 12 DAC hours in a week [see 10 CFR 835.2(a)].

annual limit on intake (ALI): The derived limit for the amount of radioactive material taken into the body of an adult worker by inhalation or ingestion in a year. ALI is the smaller value of intake of a given radionuclide in a year by the reference man (ICRP Publication 23) that would result in a committed effective dose of 5 rems (0.05 sieverts [Sv]) or a committed equivalent dose of 50 rems (0.5 sievert [Sv]) to any individual organ or tissue [see 10 CFR 835.2(a)].

As Low As is Reasonably Achievable (ALARA): The approach to radiation protection to manage and control exposures (both individual and collective) to the work force and to the general public to as low as is reasonable, taking into account social, technical, economic, practical, and public policy considerations. As used in this *Manual*, ALARA is not a dose limit but a process that has the objective of attaining doses as far below the applicable controlling limits as is reasonably achievable [see 10 CFR 835.2(a)].

ALARA Committee: Multi-disciplined forum that reviews and advises management on improving progress toward controlling radiation exposure and radiological releases

assessment: Evaluation or appraisal of a process, program, or activity to estimate its acceptability

background radiation: Radiation from

(1) Naturally occurring radioactive materials which have not been technologically enhanced;

(2) Cosmic sources;

(3) Global fallout as it exists in the environment (such as from the testing of nuclear explosive devices);

(4) Radon and its progeny in concentrations or levels existing in buildings or the environment which have not been elevated as a result of current or prior activities; and

(5) Consumer products containing nominal amounts of radioactive material or producing nominal amounts of radiation [see 10 CFR 835.2(a)].

becquerel (Bq): The International System (SI) unit for activity of radioactive material. One Becquerel is that quantity of radioactive material in which one atom is transformed per second or undergoes one disintegration per second.

bioassay: The determination of the kinds, quantities, or concentrations, and, in some cases, locations of radioactive material in the human body, whether by direct measurement or by analysis and evaluation of radioactive materials excreted or removed from the human body [see 10 CFR 835.2(a)]

calibration: The process of adjusting or determining either (1) the response or reading of an instrument relative to a standard (e.g., primary, secondary, or tertiary) or to a series of conventionally true values; or (2) the strength of a radiation source relative to a standard (e.g., primary, secondary, or tertiary) or conventionally true value [see 10 CFR 835.2(a)]

company-issued clothing: Clothing provided by the company for non-radiological purposes, such as work coveralls and shoes

containment device: Barrier, such as a glovebag, glovebox, or tent, for inhibiting the release of radioactive material from a specific location

contamination area: Any area, accessible to individuals, where removable surface contamination levels exceed or are likely to exceed the removable surface contamination values specified in Chapter 2, Table 2-2, but do not exceed 100 times those values [see 10 CFR 835.2(a)]

continuing training: Training scheduled over a specified time, such as over a two-year period, for the purpose of maintaining and improving technical knowledge and skills

continuous air monitor (CAM): Instrument that continuously samples and measures the levels of airborne radioactive materials on a “real-time” basis and has alarm capabilities at preset levels; also referred to as a real-time air monitor

contractor: Any entity under contract with the Department of Energy with the responsibility to perform activities at a DOE site or facility [see 10 CFR 835.2(a)]

contractor senior site executive: The individual at a DOE contractor-operated facility or site who has final on-site corporate authority and is often called president, general manager, site manager, or director

controlled area: Any area to which access is managed by or for DOE to protect individuals from exposure to radiation and/or radioactive material [see 10 CFR 835.2(a)]

counseling: Advice, information exchange, and guidance provided to employees on radiologically related topics, such as dose perspectives; potential health effects from radiation exposure; skin contaminations; contaminated wounds; internally deposited radioactivity; pregnancy; and radiation exposure. This advice and guidance are normally provided by knowledgeable, senior professionals from the radiological control organization and other organizations, such as Medical, as appropriate.

critical mass: The smallest mass of fissionable material that will support a self-sustaining chain reaction under specified conditions

critique: Meetings of personnel involved in or knowledgeable about an event (either a success or an abnormal event) to document a chronological listing of the facts

declared pregnant worker: A woman who has voluntarily declared to her employer, in writing, her pregnancy for the purpose of being subject to the occupational exposure limits to the embryo/fetus as provided in Article 215. This declaration may be revoked, in writing, at any time by the declared pregnant worker. [see 10 CFR 835.2(a)]

decontamination: Process of removing radioactive contamination from personnel, equipment, or areas

derived air concentration (DAC): For the radionuclides listed in appendix A of 10 CFR 835, the airborne concentration that equals the ALI divided by the volume of air breathed by an average worker for a working year of 2000 hours (assuming a breathing volume of 2400 m^3). For radionuclides listed in appendix C of 10 CFR 835, the air immersion DACs were calculated for a continuous, non-shielded exposure via immersion in a semi-infinite cloud of radioactive material. Except as noted in the footnotes to appendix A of 10 CFR 835, the values are based on dose coefficients from International Commission on Radiological Protection Publication 68, *Dose Coefficients for Intakes of Radionuclides by Workers*, published July 1994 (ISBN 0 08 042651 4) and the associated ICRP computer program, *The ICRP Database of Dose Coefficients: Workers and Members of the Public*, (ISBN 0 08 043 8768). These materials are available from Elsevier Science Inc., Tarrytown, NY. [see 10 CFR 835.2(a)]

derived air concentration-hour (DAC-hour): The product of the concentration of radioactive material in air (expressed as a fraction or multiple of the DAC for each radionuclide) and the time of exposure to that radionuclide, in hours [see 10 CFR 835.2(a)]

disintegration per minute (dpm): The rate of emission by radioactive material as determined by correcting the counts per minute observed by an appropriate detector for background, efficiency, and geometric factors associated with the instrumentation

*deterministic effect*s: means effects due to radiation exposure for which the severity varies with the dose and for which a threshold normally exists (e.g., radiation-induced opacities within the lens of the eye)

DOE: the United States Department of Energy

DOE activity: An activity taken for or by the DOE in a DOE operation of facility that has the potential to result in the occupational exposure of an individual to radiation or radioactive material. The activity may be, but is not limited to, design, construction, operation,

decontamination or decommissioning. To the extent appropriate, the activity may involve a single DOE facility or operation or a combination of facilities and operations, possibly including an entire site or multiple DOE sites. [see 10 CFR 835.2(a)]

DOELAP: Department of Energy Laboratory Accreditation Program for personnel dosimetry and bioassay programs

dose: A general term for absorbed dose, equivalent dose, effective dose, committed equivalent dose, committed effective dose, or total effective dose [see 10 CFR 835.2(b)]. Various technical terms, such as equivalent dose, effective dose, and collective dose are used to describe the amount of radiation an exposed individual receives. These terms are used to describe the differing interactions of radiation with tissue as well as to assist in the management of personnel exposure to radiation. Some types of radiation, such as neutron and alpha, deposit their energy more densely in affected tissue than gamma radiation, thereby causing more damage to tissue. The term equivalent dose, measured in units of rem, is used to take into account this difference in tissue damage. Therefore 1 rem from gamma radiation causes damage equivalent to 1 rem from alpha radiation. However, it takes one-twentieth as much energy from alpha radiation, as compared with gamma radiation, to produce this 1 rem equivalent dose.

Definitions for dose terms necessary for various exposure calculations and recordkeeping purposes include the following:

absorbed dose (D): average energy imparted by ionizing radiation to the matter in a volume per unit mass of irradiated material. The absorbed dose is expressed in units of rad (or gray) (1 rad = 0.01 gray). [see 10 CFR 835.2(b)]

collective dose: The sum of the total effective dose values for all individuals in a specified population. Collective dose is expressed in units of person-rem (or person-sievert).

committed effective dose (E_{50}): the sum of the committed equivalent doses to various tissues or organs in the body ($H_{T,50}$), each multiplied by the appropriate tissue weighting factor (w_T) - that is, $E_{50} = \Sigma w_T H_{T,50} + w_{Remainder} H_{Remainder,50}$. Where $w_{Remainder}$ is the tissue weighting factor assigned to the remainder organs and tissues and $H_{Remainder,50}$ is the committed equivalent dose to the remainder organs and tissues. Committed effective dose is expressed in units of rems (or Sv).

committed equivalent dose ($H_{T,50}$): The equivalent dose calculated to be received by a tissue or organ over a 50-year period after the intake of a radionuclide into the body. It does not include contributions from radiation sources external to the body. Committed equivalent dose is expressed in units of rems (or Sv). [see 10 CFR 835.2(b)]

cumulative total effective dose: The sum of all total effective dose values recorded for an individual plus, for occupational exposures received before the implementation date (07/09/2010) of the June 8, 2007 amendment to 10 CRR 835, the cumulative total effective dose equivalent (as defined in the November 4, 1998 amendment to 10 CFR 835) values recorded for an individual, where available, for each year occupational exposure was received, beginning January 1, 1989 [see 10 CFR 835.2(b)]

dose assessment: Process of determining radiation dose and uncertainty included in the dose estimate, through the use of exposure scenarios, bioassay results, monitoring data, source term information, and pathway analysis

effective dose (E): The summation of the products of the equivalent dose received by specified tissues of the body (H_T) and the appropriate tissue weighting factors (w_T) - that is ($E= \Sigma\ w_T H_T$). It includes the dose from radiation sources internal and/or external to the body. For purposes of demonstrating compliance with the regulatory dose limits, equivalent dose to the whole body may be used as effective dose for external exposures. The effective dose is expressed in units of rems (or Sv). [see 10 CFR 835.2(b)]

equivalent dose (H_T): the product of average absorbed dose ($D_{T,R}$) in rad (or gray) in a tissue or organ (T) and a radiation (R) weighting factor (w_R). For external dose, the equivalent dose to the whole body is assessed at a depth of 1 cm in tissue; the equivalent dose to the lens of the eye is assessed at a depth of 0.3 cm in tissue, and the equivalent dose to the extremity and skin is assessed at a depth of 0.007 cm in tissue. Equivalent dose is expressed in units of rems (or Sv). Equivalent dose is expressed in units of rems (or Sv). [see 10 CFR 835.2(b)]

equivalent dose to the eye: The equivalent dose derived from external radiation at a depth of 0.3 cm in tissue [see 10 CFR 835.2(b)]

equivalent dose to the extremity: The equivalent dose derived from external radiation at a depth of 0.007 cm in tissue [see 10 CFR 835.2(b)]

equivalent dose to the skin: The equivalent dose derived from external radiation at a depth of 0.007 cm in tissue [see 10 CFR 835.2(b)]. Formerly addressed as “shallow dose.”

equivalent dose to the whole body: The equivalent dose derived from external radiation at a depth of 1 cm in tissue [see 10 CFR 835.2(b)]

external dose or exposure: That portion of the equivalent dose received from radiation sources outside the body (e.g., “external sources”) [see 10 CFR 835.2(b)]

extremity: Hands and arms below the elbow or feet and legs below the knee [see 10 CFR 835.2(b)]

internal dose or exposure: That portion of the equivalent dose received from radioactive material taken into the body (e.g., “internal sources”) [see 10 CFR 835.2(b)]

lens of the eye equivalent dose (a/k/a equivalent dose to the lens of the eye): The external exposure of the lens of the eye and is taken as the equivalent dose at a tissue depth of 0.3 cm [see 10 CFR 835.2(b)]

radiation weighting factor (w_R) the modifying factor used to calculate the equivalent dose from the average tissue or organ absorbed dose; the absorbed dose (expressed in rad or gray) is multiplied by the appropriate quality radiation weighting factor. The radiation weighting factors to be used for determining equivalent dose in rems are found in Appendix 2B of this *Manual*.

tissue weighting factor (w_T): The fraction of the overall health risk, resulting from uniform, whole body irradiation, attributable to specific tissue (T). The equivalent dose to the affected tissue (H_T) is multiplied by the appropriate tissue weighting factor to obtain the effective dose contribution from that tissue [see 10 CFR 835.2(b)].

total effective dose (TED): The sum of the effective dose (for external exposures) and the committed effective dose (for internal exposures) [see 10 CFR 835.2(b)]

whole body: For the purposes of external exposure, head, trunk (including male gonads), arms above and including the elbow, or legs above and including the knee [see 10 CFR 835.2(b)]

whole body dose: The sum of the effective dose for external exposures and the committed effective dose for internal exposures; also referred to as total effective dose (TED)

dosimeter: Radiation monitoring device used to record the exposure of personnel or areas to certain types of radiation

embryo/fetus: Developing human organism from conception until birth; same as unborn child

engineering controls: A special form of physical design feature in which components and systems such as piping, containments, ventilation, filtration, or shielding are used to reduce airborne radioactivity, radiation levels, and the spread of contamination

entrance or access point: Any location through which an individual could gain access to areas controlled for the purposes of radiation protection. This includes entry or exit portals of sufficient size to permit human entry, irrespective of their intended use. [see 10 CFR 835.2(a)]

facility: The accelerator, plant, buildings, structures, and equipment supporting the accelerator and its operations that are under the direct control of the contractor [see DOE O 420.2D]

filter integrity test: Test performed on high-efficiency particulate air (HEPA) filters to identify any damage to the filter or leakage around the filter [see 10 CFR 835.2(a)]

fixed contamination: Radioactive material that has been deposited onto a surface and cannot be readily removed by non-destructive means, such as casual contact, wiping, brushing, or laundering. Fixed contamination does not include radioactive material that is present in a matrix, such as soil or cement, or radioactive material that has been induced in a material through activation processes.

frisk or frisking: Process of surveying personnel for contamination. Frisking can be performed with hand-held survey instruments or automated monitoring devices.

general employee: An individual who is either a DOE or DOE contractor employee; an employee of a subcontractor to a DOE contractor; or an individual who performs work for or in conjunction with DOE or utilizes DOE facilities [see 10 CFR 835.2(a)]

gestation period: The time from conception to birth, approximately 9 months

gray (Gy): SI unit of absorbed dose; 1 gray is equal to an absorbed dose of 1 joule per kilogram (100 rads)

high-efficiency particulate air (HEPA) filter: Throwaway extended pleated medium dry-type filter with 1) a rigid casing enclosing the full depth of the pleats, 2) a minimum particle removal efficiency of 99.97 percent for thermally generated monodisperse di-octyl phthalate smoke particles with a diameter of 0.3 micrometer, and 3) a maximum pressure drop of 1.0 inch w.g. when clean and operated at its rated airflow capacity

high contamination area: Any area, accessible to individuals, where removable surface contamination levels exceed or are likely to exceed 100 times the removable surface contamination values specified in Chapter 2, Table 2-2 [see 10 CFR 835.2(a)]

high radiation area: Any area, accessible to individuals, in which radiation levels could result in an individual receiving an equivalent dose to the whole body in excess of 0.1 rems (0.001 Sv) in 1 hour at 30 centimeters from the radiation source or from any surface that the radiation penetrates [see 10 CFR 835.2(a)]

hot particle: Fuel, activated corrosion product, or other particles of small size that have a high specific activity as a result of nuclear fission or neutron activation. When in direct contact with the skin, hot particles are capable of producing an equivalent dose to the skin of 100 millirem or more in one hour to a localized area.

hot spot: Localized source of radiation or radioactive material normally within facility piping or equipment. The radiation levels of hot spots exceed the general area radiation level by more than a factor of 5 and are greater than 100 millirem (1 mSv) per hour on contact.

individual: Any human being [see 10 CFR 835.2(a)]

infrequent or first-time activities: Radiological work activities or operations that require special management attention and consideration of new or novel radiological controls. The designation of infrequent or first-time activities is specifically applicable to facilities that conduct routine and recurring process operations and is not applicable to facilities that routinely conduct first-time activities, such as experimental or research facilities.

irradiator: Any gamma- or neutron-emitting sealed radioactive material that has the potential to create a radiation level exceeding 500 rads (5 grays) in 1 hour at 1 meter and is operated within the requirements of an RGD installation. [see DOE G 441.1-1C Chg1 (Adm Chg)][71]

lifetime dose: Total occupational dose over a worker's lifetime, including external and internal dose

low-level waste: Waste that contains radioactive material and is not classified as high-level waste, transuranic waste, spent nuclear fuel, or byproduct material as defined in Section 11e(2) of the Atomic Energy Act, as amended. Test specimens of fissionable material irradiated only for research and development and not for production of power or plutonium may be classified as low-level waste provided the concentration of transuranic activity is less than 100 nCi/g.

71 Department of Energy Guide 441.1C Change 1, "Radiation Protection Programs Guide for Use with Title 10, Code of Federal Regulations, Part 835, Occupational Radiation Protection" (DOE G 441.1-1C Chg1 [Admin Chg])

member of the public: An individual who is not a general employee. An individual is not a "member of the public" during any period in which the individual receives an occupational dose [see 10 CFR 835.2(a)].

minor: An individual less than 18 years of age [see 10 CFR 835.2(a)]

mixed waste: Waste containing both radioactive and hazardous components as defined by the Atomic Energy Act and the Resource Conservation and Recovery Act, respectively

monitoring: The measurement of radiation levels, airborne radioactivity concentrations, radioactive contamination levels, quantities of radioactive material, or individual doses and the use of the results of these measurements to evaluate radiological hazards or potential and actual doses resulting from exposures to ionizing radiation [see 10 CFR 835.2(a)]

occupational dose: An individual's ionizing radiation dose (external and internal) as a result of that individual's work assignment. Occupational dose does not include doses received as a medical patient or doses resulting from background radiation or participation as a patient in medical research programs [see 10 CFR 835.2(a)].

personal protective equipment: Equipment such as a respirator, face shield, and safety glasses used to protect workers from excessive exposure to radioactive or hazardous materials

personnel dosimeters: Devices designed to be worn by a single individual for the assessment of equivalent dose such as optically-stimulated-luminescence dosimeters

personnel monitoring: Systematic and periodic estimate of radiation dose received by individuals during working hours. Also, the monitoring of individuals, their excretions, skin, or any part of their clothing to determine the amount of radioactivity present.

planned special exposure: Preplanned, infrequent exposure to radiation, separate from and in addition to the annual dose limits

prenatal radiation exposure: The exposure of an embryo/fetus to radiation

primary dosimeter: A dosimeter worn on the body used to obtain the formal record of whole body radiation dose

protective clothing: Clothing provided to personnel to minimize the potential for skin and personal and company issued clothing contamination; also referred to as "anti-contamination clothing," "anti-Cs," and "PCs"

qualification standard: The explicit performance requirements for minimum proficiency in technical, academic, and site-specific knowledge and practical skills used in determining satisfactory completion of training programs. The qualification standard is used to qualify radiological control technicians at DOE facilities.

rad: Unit of absorbed dose; 1 rad is equal to an absorbed dose of 100 ergs per gram or 0.01 joules per kilogram (0.01 gray)

radiation or ionizing radiation: Alpha particles, beta particles, gamma rays, X-rays, neutrons, high-speed electrons, high-speed protons, and other particles capable of producing ions. Radiation, as used in this *Manual*, does not include non-ionizing radiation, such as radio waves or microwaves, or visible, infrared, or ultraviolet light [see 10 CFR 835.2(a)], and refers only to radiation above natural background levels.

radiation area: Any area, accessible to individuals, in which radiation levels could result in an individual receiving an equivalent dose to the whole body in excess of 0.005 rem (0.05 mSv) in one hour at 30 centimeters from the radiation source or from any surface that the radiation penetrates [see 10 CFR 835.2(a)

radiation generating device (RGD): A collective term for devices which produce ionizing radiation, including, certain sealed radioactive sources, small particle accelerators used for single purpose applications which produce ionizing radiation (e.g., radiography), and electron generating devices that produce x-rays incidentally [see DOE G 441.1-1C]

radioactive material: Any material that spontaneously emits ionizing radiation (e.g., X- or gamma rays, alpha or beta particles, neutrons). The term "radioactive material" also includes materials onto which radioactive material is deposited or into which it is incorporated and refers only to radioactive material above natural background levels. For purposes of practicality, both 10 CFR 835 and this *Manual* establish certain threshold levels below which specified actions, such as posting, labeling, or individual monitoring, are not required. These threshold levels are usually expressed in terms of total activity or concentration, contamination levels, individual doses, or exposure rates.

radioactive material area: Any area within a controlled area, accessible to individuals, in which items or containers of radioactive material exist and the total activity of radioactive material exceeds the applicable values provided in Appendix 4A of this *Manual* [see 10 CFR 835.2(a)]

radioactive waste: Solid, liquid, or gaseous material that contains radionuclides regulated under the Atomic Energy Act, as amended, and is of negligible economic value considering the cost of recovery

radioactivity: A natural and spontaneous process by which the unstable atoms of an element emit or radiate excess energy and/or particles from their nuclei and, thus change (or decay) to atoms of a different element or to a lower energy state of the same element

radiography: Examination of the structure of materials by non-destructive methods, using a radioactive source or a radiation generating device

radiological area: Any area(s) within a controlled area (but not including the controlled area) defined as a "radiation area," "high radiation area," "very high radiation area," "contamination area," "high contamination area," or "airborne radioactivity area" [see 10 CFR 835.2(a)]

radiological buffer area (RBA): An intermediate area established to prevent the spread of radioactive contamination and to protect personnel from radiation exposure

radiological control hold point: Cautionary step in a technical work document requiring the radiological control organization to perform some action or verification. The radiological control hold point requirements should be satisfactorily completed before the work is continued.

radiological control technician: A radiological worker whose primary job assignment involves assessment of workplace radiological conditions, specification of protective measures, and provision of assistance and guidance to other individuals in implementation of radiological controls

radiological label: Label on an item which indicates the presence of radiation or radioactive materials

radiological posting: Sign, marking, or label that indicates the presence or potential presence of radiation or radioactive materials

radiological work. Work involving any use of tools on beamlines or beamline components or beamline safety items such as shielding, PPS components, BCS components where radiological hazards may be affected. Any work on radiation Hot Spots. Radiological Work also is any work on radioactive low conductivity water (LCW) systems; that is, any LCW system with tritium in the water at a concentration greater than 2E4 pCi/liter.

radiological work permit (RWP): Permit that identifies radiological conditions, establishes worker protection and monitoring requirements, and contains specific approvals for radiological work activities. The radiological work permit serves as an administrative process for planning and controlling radiological work and informing the worker of the radiological conditions.

radiological worker: A general employee whose job assignment involves operation of radiation producing devices or working with radioactive materials, or who is likely to be routinely occupationally exposed above 0.1 rem (0.001 sievert) per year total effective dose [see 10 CFR 835.2(a)]

real property: Land and anything permanently affixed to the land such as buildings, fences and those things attached to the buildings, such as light fixtures, plumbing and heating fixtures

real-time air monitoring: Measurement of the concentrations or quantities of airborne radioactive materials on a continuous basis [see 10 CFR 835.2(a)]; see also *continuous air monitor*.

refresher training: Training scheduled in the alternate year when full training is not completed for Radiological Worker I and Radiological Worker II personnel

release to uncontrolled areas: Release of material from administrative control after confirming that the residual radioactive material meets the requirements in DOE O 458.1

rem: Unit of effective dose. Effective dose in rem is numerically equal to equivalent dose multiplied by the appropriate tissue weighting factor. The unit of effective dose is the rem (1 rem = 0.01 sievert). Equivalent dose is the absorbed dose in rad multiplied by a radiation weighting factor, and any other necessary modifying factor. Equivalent dose also is expressed in units of rem.

removable contamination: Radioactive material that can be removed from surfaces by non-destructive means, such as casual contact, wiping, brushing, or washing

respiratory protective device: An apparatus, such as a respirator, worn by an individual for the purpose of reducing the individual’s intake of airborne radioactive materials [see 10 CFR 835.2(a)]

sealed radioactive source: A radioactive source manufactured, obtained, or retained for the purpose of utilizing the emitted radiation. The sealed radioactive source consists of a known or estimated quantity of radioactive material contained within a sealed capsule, sealed between layer(s) of non-radioactive material, or firmly fixed to a nonradioactive surface by electroplating or other means intended to prevent leakage or escape of the radioactive material. Sealed radioactive sources do not include reactor fuel elements, nuclear explosive devices, and radioisotope thermoelectric generators [see 10 CFR 835.2(a)].

senior site executive: That person at a DOE contractor-operated facility or site who has final onsite corporate authority and is often called the president, general manager, site manager, or director.

sievert (Sv): SI unit of any of the quantities expressed as equivalent dose. The equivalent dose in sieverts is equal to the absorbed dose in grays multiplied by the radiation weighting factor (1 Sv = 100 rems).

site: An area managed by DOE where access can be limited for any reason. The site boundary encompasses controlled areas.

soil contamination area: An area in which soil contamination is present at levels that are not releasable in accordance with DOE's environmental protection standards

source leak test: A test to determine if a sealed radioactive source is leaking radioactive material [see 10 CFR 835.2(a)]

special tritium compound (STC): any compound, except for H_2O, that contains tritium, either intentionally (e.g., by synthesis) or inadvertently (e.g., by contamination mechanisms)

standard radiological warning trefoil: Symbol designed and proportioned as illustrated in ANSI/HPS N2.1[72]

step-off pad: Transition area between contaminated and non-contaminated areas that is used to allow exit of personnel and removal of equipment

sticky pad: Step-off pad provided with a tacky surface to reduce the potential for inadvertently tracking contamination out of a contaminated area

survey: An evaluation of the radiological conditions and potential hazards incident to the production, use, transfer, release, disposal, or presence of radioactive material or other sources of radiation. When appropriate, such an evaluation includes a physical survey of the location of radioactive material and measurements or calculations of levels of radiation, or concentrations or quantities of radioactive material present].

technical work document: A term used to generically identify formally approved documents that direct work, such as procedures, work packages, or job or research plans

transuranic waste: Without regard to source or form, waste that is contaminated with alpha-emitting transuranic radionuclides having half-lives greater than 20 years and concentrations greater than 100 nCi/g at the time of assay

unusual occurrence: Non-emergency occurrence that has significant impact or potential for impact on safety, environment, health, security, or operations. Examples of the types of occurrences that are to be categorized as unusual occurrences are contained in DOE Order 232.2, "Occurrence Reporting and Processing of Operations Information."[73]

very high radiation area: Any area, accessible to individuals, in which radiation levels could result in an individual receiving an absorbed dose in excess of 500 rads (5 grays) in one hour at

72 American National Standards Institute (ANSI)/Health Physics Society (HPS) N2.1, "Radiation Symbol" (ANSI/HPS N2.1)

73 Site Compliance Plan for Department of Energy Order 232.2A, Change 1, "Occurrence Reporting and Processing of Operations Information" (DOE O 232.2A, Chg 1 [MInChg] SCP)

1 meter from a radiation source or from any surface that the radiation penetrates [see 10 CFR 835.2(a)]

visitor: Individual accessing the site for purposes other than conducting work in support of the DOE mission or that otherwise involves access to DOE information or technologies, regardless of the duration of the visit. Visitors may include the following:

1. All individuals coming to SLAC to attend a meeting/conference/seminar and/or workshop that is held in the general access area of the laboratory and who are not performing any SLAC-related work or experiments or receiving payments or reimbursements from SLAC.

2. Anyone on-site for the sole purpose of attending SLAC public tours or public lectures.

3. Anyone attending special events at SLAC that do not require any training or work.

4. Anyone staying at the Guest House who is not affiliated with SLAC experimenters or work.

5. All delivery personnel/vendors making deliveries to SLAC or to construction/special projects.

week: A period of seven consecutive days [see 10 CFR 835.2(a)]

year: The period of time beginning on or near January 1 and ending on or near December 31 of that same year used to determine compliance with the provisions of 10 CFR 835. The starting date of the year used to determine compliance may be changed provided that the change is made at the beginning of the year and that no day is omitted or duplicated in consecutive years [see 10 CFR 835.2(a)].