CHAPTER 2
RADIOLOGICAL STANDARDS

PART 1 Administrative Control Levels and Dose Limits

Exposure to ionizing radiation, however small, is presumed to involve some risk. To minimize radiation dose to personnel, engineered and administrative controls are employed at Jefferson Lab. Physical design features are the primary means by which unnecessary radiation exposures are prevented. The Shielding Policy for Ionizing Radiation (Appendix 2C), contains design criteria used to accomplish this. Although all facilities have been designed and constructed to minimize exposure, administrative controls are used as supplemental measures to control radiation exposure. For these controls to be effective, individual workers must understand and exercise their responsibilities in the RPP.

211 Quantities and Units Used in Radiation Control

Unless otherwise specified, the quantities used in the records required by 10 CFR 835 and in the radiation control program at Jefferson Lab (except as noted below) shall be clearly indicated in special units of curie (Ci), rad, roentgen or rem, including multiples and subdivisions of these units or other conventional units such as dpm, dpm/100 cm^2 or mass units. The Standard International (SI) units becquerel (Bq), gray (Gy), and sievert (Sv) may be provided parenthetically for reference with scientific standards. Standard international units should not be used in records required by DOE for the radiation control program; however, SI units shall be used whenever required by the United States Department of Transportation (DOT) hazardous materials regulations.

212 Administrative Control Level

Jefferson Lab has established a number of administrative limits for exposure to ionizing radiation.

The administrative control (or action) level is 1 rem per calendar year (whole body) – no person shall be allowed to exceed the action level without prior approval of the Laboratory Director. If an exposure exceeding the action level occurs in the absence of prior planning and approval, the notable event process will be employed to investigate the cause of the condition and implement any needed corrective actions.

An administrative control level of 20 percent of the relevant limit in 10 CFR 835 is established for dose to individual organs or tissues. The approval and event investigation requirements above also apply to these limits. The Program Secretarial Official (or designee) should be notified prior to allowing a radiological worker to exceed 2 rem (whole body).

The administrative design goal (alert level) of 250 mrem is established to maintain positive control of radiation worker exposure. When a worker's annual radiation dose approaches or exceeds
250 mrem, the worker and his/her supervisor shall be notified. The worker should then consult with his/her supervisor and with the RCD to discuss ways to minimize exposure to radiation as much as possible and adhere to the ALARA process.

The alert level for general employees who are not radiation workers is 10 mrem. (This dose may be determined by either estimation or measurement.) Exposures shall be kept below the limits in Table 2-1A and maintained ALARA. [§ 835.1003(a)]

Table 2-1A Occupational Limits and Administrative Control Levels (total effective dose)[a, b]

	Radiological Workers	**General Employees** (total)
Annual Limit	5 rem (50 mSv)	100 mrem (1 mSv)
Action Level	1 rem (10 mSv)	50 mrem (0.50 mSv)
Lab Design Goals (Alert Level)	250 mrem (2.5 mSv)	10 mrem (0.1 mSv)

[a] Except for planned special exposure conducted consistent with § 835.204, and emergency exposures authorized in accordance with §835.1302, the occupational dose received by employees shall be controlled such that the limits in the table are not exceeded in a year.

[b] See 10 CFR 835.2 for definitions of dosimetric terms not defined in this manual.

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 §§ 835.202(a) and 835.207. [§ 835.202(b)] Annual organ/extremity equivalent dose limits are presented in Table 2-1B.

Table 2-1B Annual Organ/Extremity Equivalent Dose Limits & Levels

Type of Exposure*	**Annual Limit**	**Action Level**	**Alert Level**
Equivalent dose to lens of eye	15 rem	3 rem	1 rem
The sum of the equivalent dose to the skin or any extremity (hands and arms below the elbows; feet and legs below the knees) for external exposures and the committed equivalent dose to the skin or to any extremity.	50 rem	10 rem	2.5 rem
The sum of the equivalent dose to the whole body for external exposures and the committed equivalent dose to any organ or tissue other than the skin or the lens of eye,	50 rem	10 rem	2.5 rem

* See 10 CFR 835.202 for definitions and 10 CFR 835.205 for determination of non-uniform dose to the skin.

Doses from background, therapeutic, and diagnostic medical radiation and participation as a subject in medical research programs shall not be included in dose records or in the assessment of compliance with occupational dose limits. [§ 835.202(c)]

For the purpose of monitoring individual exposures to internal radiation, internal dose evaluation programs (including routine bioassay programs) shall be conducted for radiological workers who, under typical conditions, are likely to receive 100 mrem (0.001 Sv) or more committed effective dose, and/or 5 rem (0.05 Sv) or more committed equivalent dose to any organ or tissue, from all occupational radionuclide intakes in a year.

The total effective dose during a year is determined by summing the effective dose from external exposures and the committed effective dose from intakes during the year. [§ 835.203(a)]

Equivalent dose to the whole body may be used as effective dose in evaluating external exposures. Determination of the effective dose shall be made using the radiation and tissue weighting factor values provided in 10 CFR 835.2. [§ 835.203(b)] For the case of uniform external irradiation of the whole body, a tissue weighting factor equal to one (1) may be used in determination of the effective dose.

Any method used for internal and external monitoring shall be adequate to demonstrate compliance with limits for radiological workers, declared pregnant radiation workers, minors and members of the general public.

213 Radiation Worker Dose Limits for Routine Occupational Exposure

A radiological worker is any individual 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 per year total effective dose. Following are limits that have been established at Jefferson Lab for occupational exposure to ionizing radiation.

- The annual exposure limits for radiological workers are found in Tables 2-1A and 2-1B. Occupational exposure to radiation workers resulting from DOE activities (other than planned special exposures and emergency exposure situations indicated below), shall be controlled so the annual limits listed in these tables are not exceeded. [§ 835.202(a) and § 835.1003(a)]

- Occupational doses received as a result of the following activities (which are excluded from the regulation) and RAM transportation, shall be included to the extent practicable in determining compliance with occupational dose limits:
  - activities conducted under the authority of the Deputy Directors for Naval Reactors as described in Pub. L. 98-525 and 106-65
  - activities that are regulated through a license by the Nuclear Regulatory Commission (NRC) or a state under an agreement with the NRC, including activities certified by the NRC under section 1701 of the Atomic Energy Act

- activities conducted under the Nuclear Explosives and Weapons Surety Program relating to the prevention of accidental or unauthorized nuclear detonations
- Department of Energy activities conducted outside the US on territory under the jurisdiction of a foreign government to the extent governed by occupational radiation protection requirements agreed to between the US and the cognizant government
- radioactive material transportation not performed by DOE or a DOE contractor

- A radiological worker whose occupational exposure has exceeded the numerical value of the applicable limits specified in Tables 2-1A and 2-1B (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. [§ 835.1301(a)]
  - approval is first obtained from contractor management and the head of the responsible DOE field organization
  - the individual receives counseling from radiological protection and medical personnel regarding the consequences of receiving additional occupational exposure during the year
  - the doses exceeding the limits specified in Tables 2-1A and 2-1B have been recorded in the individual's occupational dose record [§ 835.1301(b)]
  - the affected employee agrees to return to radiological work

  The table in Appendix 2A contains Guidelines for Control of Emergency Exposures.

- When the conditions under which a dose was received in excess of limits specified in Tables 2-1A and 2-1B (except those doses received in accordance with provisions for planned special exposures) have been eliminated, Lab Management will notify the TJSO Manager or designee. [§ 835.1301(c)]

- Operations that use or produce ionizing radiation or radioactive material, and which have been suspended after an emergency or accidental exposure in excess of the limits specified in Tables 2-1A and 2-1B, will be resumed only with the approval of the appropriate DOE authority, as indicated in the DOE-approved Jefferson Lab Occurrence Reporting and Processing System (as described in ES&H Manual Chapter 5300 *Occurrence Reporting to Department of Energy (DOE)*). [§ 835.1301(d)]

- Jefferson Lab does not anticipate rescue or recovery actions resulting in exposures in excess of applicable limits. However, the risk of injury to those individuals involved in rescue and recovery operations will be minimized. [§ 835.1302(a)] Lab Management will weigh actual and potential risks to rescue and recovery individuals against the benefits to be gained. [§ 835.1302(b)] Volunteers will perform any rescue actions that might involve substantial personal risk. [§ 835.1302(c)] Any individual authorized to perform emergency actions likely to result in occupational doses exceeding the limits for radiological workers (in Tables 2-1A or 2-1B) shall be trained in accordance with § 835.901(b) and be briefed beforehand of the known or anticipated hazards to which the individual will be subjected. [§ 835.1302(d)]

214 Planned Special Exposures for Radiation Workers

A planned special exposure may be authorized for a radiation worker to receive doses (in addition to and accounted for separately from the doses received under the limits specified in Tables 2-1A and 2-1B), provided that the following conditions are satisfied:

- the planned special exposure is considered only in an exceptional situation when alternatives that might prevent a radiological worker from exceeding the limits in Tables 2-1A and 2-1B are unavailable or impractical [§ 835.204(a)(1)]
- the RCM and Laboratory Director (and employer, if the employer is not Jefferson Lab) specifically request the planned special exposure and submit the request in writing for approval by the DOE [§ 835.204(a)(2)]
- joint written approval from the appropriate DOE Headquarters program office and the Secretarial Officer responsible for Environment, Safety and Health is received [§ 835.204(a)(3)]

Prior to requesting an individual participate in an authorized planned special exposure, the individual's dose from all previous planned special exposures and all doses in excess of occupational dose limits shall be determined. [§ 835.204(b)]

An individual shall not receive a planned special exposure that, in addition to the doses determined in Article 213, would result in a dose exceeding the following:

- in a year, the numerical values of the applicable dose limits established in Tables 2-1A and 2-1B [§ 835.204(c)(1)], or
- over the individual's lifetime, five times the numerical values of the dose limits established in Tables 2-1A and 2-1B [§ 835.204(c)(2)]

Prior to a planned special exposure, written consent shall be obtained from each individual involved [§ 835.204(d)], including:

- the estimated doses and associated potential risks, and specific radiological conditions and other hazards which might be involved in performing the task [§ 835.204(d)(2)]
- the purpose of the planned operations and procedures to be used [§ 835.204(d)(1)]
- instructions on the measures to be taken to keep the dose ALARA considering other risks that may be present [§ 835.204(d)(3)]

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 Article 213. [§ 835.204(e)]

The dose from planned special exposures is not to be considered in controlling future occupational dose of the individual under Tables 2-1A and 2-1B, but is to be included in records and reports required by 10 CFR 835. [§ 835.204(f)]

215 Dose Limits to Minors

No individual under the age of 18 shall be allowed into a radiologically controlled area (RCA) without the permission of his/her parent or guardian, the RCM and the Jefferson Lab Director. The annual dose limit to any minor occupationally exposed to radiation and/or radioactive materials from Jefferson Lab activities is 100 mrem (1 mSv) total effective dose, and 10% of the occupational dose limits specified in Table 2-1B. [§ 835.207] The administrative control levels for non-radiation workers in Table 2-1A shall be applied to occupationally exposed minors. Monitoring requirements for occupationally exposed minors are specified in Chapter 5 of this Manual.

216 Dose Limit for Visitors and Members of the General Population

The total effective dose limit for members of the public exposed to radiation and/or radioactive material during access to a controlled area is 100 mrem (1 mSv) in a year. [§ 835.208] The administrative control levels for non-radiological workers in Table 2-1A are applicable to members of the public; however, specific actions triggered by approaching or exceeding the values listed are to be tailored appropriately considering the context of the exposure scenario. For instance, if a member of the public were to receive an effective dose of 10 mrem, the individual and their escort/sponsor would be informed that the dose had reached the design goal, and every reasonable effort would be made to prevent further exposure. Monitoring requirements for members of the public entering a controlled area are specified in Chapter 5 of this Manual.

In accordance with DOE Order 458.1 Admin Chg 3, the total effective dose limit for members of the public offsite, from all routine DOE activities is 100 mrem in a year. The ALARA process shall be used to reduce doses to the public as far below this limit as is reasonably achievable. Lab-specific environmental protection measures, including activities related to DOE environmental protection orders, are described in the *Environmental Radiation Protection Program* (RCD-PRG-13 #001) and applicable portions of the ES&H Manual and Environmental Protection Supplement.

In keeping with the limits and reporting requirements for exposures to members of the public in Order 458.1 Admin Chg 3, Jefferson Lab has established an action level for total effective dose where, under plausible exposure conditions, a person at the site boundary could receive 50 mrem in a year. Further, the design goal for such exposures is established at 10 mrem in a year. For the purpose of computing "radiation budget" values for experiments, the goal value of 10 mrem per year is not to be exceeded under conditions of continuous exposure (8760 hours) at any boundary location from any and all experimental halls. For other purposes, realistic occupancy factors can be applied in other scenarios.

217 Embryo/Fetus Dose Limits

A declared pregnant worker is a woman who has voluntarily declared to her employer, in writing, her pregnancy for the purpose of being subject to occupational dose limits to the

embryo/fetus as provided below. (This declaration may be revoked, in writing, at any time by the declared pregnant worker.)

The declaration of pregnancy shall include an estimated date of conception, and may be completed prior to conception by a woman who is planning a pregnancy. After a female radiation worker declares pregnancy, she should receive counseling concerning prenatal radiation exposure by the RCM (or designee) and may seek additional counseling and information from Occupational Medicine.

Declared pregnant workers who are Jefferson Lab employees will be provided the option of a mutually agreeable assignment of work tasks, without loss of pay or promotional opportunity, such that further occupational radiation exposure to her is unlikely. (Radiation workers not employed by Jefferson Lab should also be provided this option.)

The equivalent dose limit for the embryo/fetus from the period of conception to birth, as a result of occupational exposure of a declared pregnant worker, is 0.5 rem (5 mSv). [§ 835.206(a)] Substantial variation above a uniform exposure rate that would satisfy the 500 mrem limit shall be avoided. [§ 835.206(b)]

The dose to the embryo/fetus from radiation external to the mother is taken as the equivalent dose to the whole body to the mother's abdomen or torso.

An internal dose evaluation program, including a routine bioassay program, shall be conducted for declared pregnant workers likely to receive an intake resulting in an equivalent dose to the embryo/fetus in excess of 10% of the limit stated above.

If the dose to the embryo/fetus is determined to have already exceeded 500 mrem (5 mSv) when a worker declares her pregnancy, she shall not be assigned to tasks where additional occupational radiation exposure is likely during the remainder of the gestation period. [§ 835.206(c)]

218 Special Control Levels

Certain situations require lower individualized exposure control levels. In addition to considering recommendations from the RCM and medical officials, the Lab Director should obtain advice from legal counsel and professionals in other disciplines, such as human resources, in establishing special control levels. As planned special exposures carry additional legal notification requirements (as indicated in Article 214), the Director may wish to establish these special control levels with the advice of the RCM, the Occupational Medicine Physician, and the JRRP.

A special control level for annual occupational exposure shall be established for each person with a lifetime occupational dose exceeding N rem, where N is the age of the person in years. The special control level will not exceed 1 rem and should allow the person's lifetime occupational dose to approach N rem as additional occupational exposure is received.

Although background, therapeutic and diagnostic medical exposures are not included in either personnel radiation dose records or assessment of dose against the limits of Tables 2-1A and 2-1B, special control levels taking these exposures into account may be established as agreed upon by management and the individual. (Notification to the RCD should be made if any radiological worker has been medically administered a long-lived radionuclide. The RCD shall make a determination if any special control levels should be applied.)

A special control level (normally 100 mrem) shall be established for any individual for whom formal records of previous exposure during the year have not been obtained. Any radiological worker whose previous recorded or estimated exposure for the year is greater than (>) 1 rem shall have a special control level established, and approved consistent with the ALARA principle and Article 212.

PART 2 Contamination Control and Control Levels

Jefferson Lab maintains appropriate methods of control which prevent the inadvertent transfer of removable contamination to locations outside of radiological areas under normal operating conditions. These methods ensure that contamination is controlled in a manner commensurate with the physical and chemical characteristics of the contaminant, the radionuclides present, and the fixed and removable contamination levels. Control of radioactive contamination is achieved by using engineered and administrative controls to contain contamination at the source, reducing existing areas of contamination, and to the extent feasible, promptly decontaminating areas that become contaminated.

221 Personnel Contamination Control

Personnel exiting contamination areas, high contamination areas, or airborne radioactivity areas shall be monitored, as appropriate, for contamination as required by Article 338. Personnel monitoring is normally not required when exiting areas posted for airborne radioactivity when the posting is based solely on the presence of gaseous activation products, but is appropriate when posting is required due to airborne particulates.

Monitoring for contamination should be performed using monitoring equipment that is sensitive enough to detect total contamination to the levels specified in Appendix 2B, Contamination Control Limits.

Personnel found with contamination on their skin or personal clothing, other than gases or natural background radioactivity, should be promptly decontaminated as described in Chapter 5 Part 4.

222 Contamination Control Levels

A surface shall be considered contaminated if either the removable or total surface radioactivity is detected above the levels in Appendix 2B. If an area cannot be decontaminated promptly, it shall be posted as specified in Article 234.

In this document, a potentially contaminated item or area is defined as:

- an item that has been used or stored in a radiological area that is known or suspected to contain unconfined radioactive material, or
- an item or area suspected to be contaminated, based on experience or process knowledge

Surfaces exceeding the values of Appendix 2B 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, other than that used for a temporary work condition, shall not be applied without approval by the RCM.

It is important to note that volume-activated materials that *are not contaminated on the surface are not subject to contamination controls*.

In accordance with the exemption granted June 8, 1998, Jefferson Lab uses a special limit of 30,000 dpm/100 cm^2 for Be-7 (beryllium-7) in lieu of the 10 CFR 835, Appendix D limits for beta-gamma emitters (see Appendix 2B). Beryllium-7 is produced in air and water exposed to high-energy beams and can build up on surfaces and in systems in beam enclosures. The following conditions are applicable:

- Posting and controls used in controlled areas only: release of materials from controlled areas must comply with other applicable requirements. In general, this involves meeting the requirements for release delineated in DOE O 458.1 Admin Chg 3, including the release criteria incorporated from Figure IV-1 in DOE O 5400.5. For nuclides of concern at Jefferson Lab, the limits for unrestricted release are the same as those in 10 CFR 835, Appendix D. With the exception of Be-7, therefore, the contamination control values used to identify contamination areas are the same as those for unrestricted release. Technical bases and written procedures provide specific requirements and protocols for release surveys that are consistent with the exemption requirements.

- The exemption requires that areas historically known to contain Be-7 above the Appendix D values be identified and posted, marked or labeled to warn workers not to enter without appropriate authorization. The processes that result in production and buildup of Be-7 on or in components and systems are well understood. Historically, locations that have been affected are electrical rack spaces and electronic components, air handling equipment, and various cooling water systems within beam enclosures. Typically, levels only exceed Appendix D values where there is significant beam loss, such as in experimental Halls A and C. However, the potential for buildup of Be-7 exists to some degree in any beam enclosure, and the equipment for which there is significant potential for such buildup is marked accordingly. In addition, administrative procedures, such as the General Access Radiological Work Permit (GRWP), identify this condition and reinforce the required

work authorizations. Written procedures address survey and posting requirements consistent with the exemption.

223 Airborne Radioactivity Control Levels

Personnel should not be exposed unnecessarily to airborne radioactivity. Use of engineered and administrative controls to reduce the potential for internal exposure should be evaluated before allowing personnel, with or without respiratory protection, to enter areas with airborne radioactivity.

The derived air concentration (DAC) values given in Appendices A and C of 10 CFR 835 shall be used to control occupational exposures to airborne radioactive material. [§ 835.209(a)] Occupied areas with airborne concentrations of radioactivity that are greater than, or potentially greater than, 1 DAC, or where an individual without respiratory protection could exceed 12 DAC-hours per week, shall be posted as specified in Article 234. For most radionuclides, air containing a DAC results in a committed effective dose of approximately 100 mrem if inhaled for 40 hours in one work week.

The estimation of internal dose shall be based on bioassay data rather than air concentration values unless bioassay data are: (1) unavailable, (2) inadequate, or (3) internal dose estimates, based on representative air concentration values, are demonstrated to be as, or more accurate than, bioassay data. [§ 835.209(b)]

PART 3 Posting

231 General Requirements

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. Signs required by 10 CFR 835 shall be clearly and conspicuously posted and may include radiological protection instructions. [§ 835.601(b)] Signs shall contain the standard radiation symbol (trefoil) in magenta or black on a yellow background [§ 835.601(a)] and lettering in magenta or black. Standardized signs, as described in written procedures, should be used where practicable.

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”.

Posted areas should be as small as practicable for efficiency. Postings should be maintained in a legible condition and updated based upon the results of the most recent surveys. If more than one radiological condition (such as contamination and high radiation) exists in the same area, each condition shall be identified.

In areas of ongoing work activities, the dose rate or range of dose rates should be included on, or in conjunction with each posting, or should be otherwise available at the work area. Entrance points to areas of ongoing radiological work should state basic entry requirements.

Radiological barriers should be employed in a manner commensurate with the radiological hazards in the area and be used according to the following guidelines.

- rope, tape, chain and similar barriers used to designate the boundaries of posted areas should be yellow and magenta in color
- barriers should be clearly visible from all directions and at various elevations
- radiological boundaries may be defined by natural physical boundaries such as the walls of a room or container
- barriers should clearly denote the scope and extent of the area, and not contain gaps that would allow inadvertent entry
- these barriers shall be set up such that they do not impede the intended use of emergency exits or evacuation routes
- where appropriate for access/egress considerations, boundaries may be established by use of designations such as prominent painted lines or use of a series of posted stanchions that are visible from all directions of approach

Doors should be posted such that the postings remain visible when doors are open or closed. 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.

The posting and labeling requirements in 10 CFR 835 may be modified to reflect the special considerations of DOE activities conducted at private residences or businesses. Modifications (to posting requirements) made by Jefferson Lab will provide the same level of protection to individuals as the existing provisions. [§ 835.601(c)]

232 Controlled Areas

A controlled area is any area to which access is managed to protect individuals from exposure to radiation and/or radioactive material. Individuals who enter only controlled areas without entering radiological areas or radioactive material areas (RMA) are not expected to receive a total effective dose of more than 100 mrem (1 mSv) in a year. [§ 835.602(a)] Each access point to a controlled area shall be posted, identifying it as a controlled area, whenever radiological areas or radioactive material areas are present [§ 835.602(a)], and should be posted wherever there is a source of radiation that produces an RCA (defined below). Signs used for controlled areas only may be selected by Jefferson Lab to avoid conflict with local security requirements. [§ 835.602(b)] For access controls and training requirements refer to Article 331.

233 Radiologically Controlled Areas

Jefferson Lab has defined RCAs such that any person who works in such an area for one year might receive a whole body dose in excess of 100 mrem annual exposure from all pathways

(excluding natural background and medical exposures). These areas are typically posted based on the dose rate 30 cm from a surface emitting radiation (whole body dose rate); when this dose rate exceeds 0.05 mrem/h, the condition above is assumed to be met. Radiologically controlled areas shall be posted following standard signage formatting used at Jefferson Lab – the posting may contain additional information concerning entry requirements and/or the radiological conditions inside. Within RCAs, occupational exposure is controlled by establishing regulated radiological areas: radiation areas, high radiation areas, etc. This graded approach increases access requirements on the basis of the increasing potential for radiation exposure.

Radiologically controlled areas shall be designated on the basis of estimated or measured radiation dose rate or on account of levels of surface or airborne contamination above specified limits. As a general practice, RCAs should be posted whenever a radiological area exists to act as a "buffer zone" around radiological areas, as described above. Postings may be contiguous with radiological area boundaries, but only when it is impractical to create an RCA boundary at some point beyond the extent of the radiological area. Subject to approval by the RCM and the level of supervision present, relaxation of the definition of radiologically controlled area, in terms of dose rates, may be permitted on the grounds of infrequent or brief occupancy, or transient radiation conditions.

Persons who are not qualified radiation workers that need access to RCAs must be escorted by staff having active Radiation Worker I training.

234 Radiological Areas

Each access point to radiological areas shall be posted with conspicuous signs bearing the wording provided in this section (refer to Table 2-3 as well). The requirement for an RWP should be included either on, or in conjunction with each posting, as applicable.

Radiation Area
The words CAUTION, RADIATION AREA shall be posted at each radiation area (RA). [§ 835.603(a)] An RA is 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 1 hour (hr) at 30 cm from the source or from any surface that the radiation penetrates.

High Radiation Area
The words CAUTION, HIGH RADIATION AREA or DANGER, HIGH RADIATION AREA shall be posted at each high radiation area (HRA). [§ 835.603(b)] 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 rem (0.001 Sv) in 1 hr at 30 cm from the radiation source or from any surface that the radiation penetrates defines an HRA.

Very High Radiation Area
The words GRAVE DANGER, VERY HIGH RADIATION AREA shall be posted at each very high radiation area. [§835.603(c)] This is 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 1 hr at 1 m from a radiation source or from any surface that the radiation penetrates.

Contamination, High Contamination and Airborne Radioactivity Areas
The words CAUTION, CONTAMINATION AREA; CAUTION, HIGH CONTAMINATION AREA; or, DANGER, HIGH CONTAMINATION AREA, respectively, shall be posted at any area accessible to individuals where removable surface contamination values exceed or are likely to exceed the applicable removable surface contamination values listed in Appendix 2B of this Manual. [§ 835.603(e),(f)]

As well, the words CAUTION, AIRBORNE RADIOACTIVITY AREA or DANGER, AIRBORNE RADIOACTIVITY AREA shall be posted at any accessible area in which the concentration of airborne radioactivity above natural background, exceeds or is likely to exceed the DAC value listed in 10 CFR 835, Appendices A or C; or, an individual present in the area without respiratory protection could receive an intake exceeding 12 DAC-hours in a week. [§ 835.603(d)]

235 Radioactive Material Areas

Accessible areas in which items or containers of radioactive materials exist and the total activity of radioactive material exceeds the applicable values in 10 CFR 835, Appendix E shall be posted CAUTION, RADIOACTIVE MATERIAL(S). [§ 835.603(g)] Radioactive material areas shall be located within controlled areas and the posting shall meet the requirements in Article 231.

The definition of radioactive material as well as the requirements for labeling radioactive material are contained in Chapter 4.

236 Hot Spots

Contact readings should be used to determine the presence of hot spots which are defined as spots where the dose rate on contact is > 100 mrem/hr and more than five times the dose rate at 30 cm. Posting of hot spots is not required in areas requiring a Job-specific RWP or radiological briefing for entry.

237 Exceptions to Posting Radiological Areas and Radioactive Material Areas

Radiological areas and radioactive material areas may be excepted from the posting requirements of Articles 234 and 235 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. [§ 835.604(a)]

Areas may be excepted from the radioactive material area posting requirements of Article 235 when:

- posted in accordance with Article 234, or
- each item or container of radioactive material is labeled in accordance with Article 412, such that individuals entering the area are made aware of the hazard, or

- the radioactive material of concern consists solely of structures or installed components that have been activated, such as by being exposed to neutron radiation or particles produced in an accelerator [§ 835.604(b)]

Areas containing only packages that have been received from radioactive material transportation labeled and in non-degraded condition need not be posted in accordance with Article 234 or 235 until the packages are monitored in accordance with Article 432. [§ 835.604(c)]

Table 2-3 Criteria for Posting Radiological Areas

Area	Posting Criteria	Posting *
radiation	> 5 mrem in one hour (at 30 cm)	CAUTION, RADIATION AREA
high radiation	> 100 mrem in one hour (at 30 cm)	DANGER, HIGH RADIATION AREA or CAUTION, HIGH RADIATION AREA
very high radiation	> 500 rad in one hour (at 1 m)	GRAVE DANGER, VERY HIGH RADIATION AREA
contamination	levels (dpm/100 cm^2) > 1 time but ≤ 100 times Appendix 2B values	CAUTION, CONTAMINATION AREA
high contamination	levels (dpm/100 cm^2) > 100 times Appendix 2B values	DANGER, HIGH CONTAMINATION AREA
airborne radioactivity	concentrations (µCi/ml) > DAC value listed in 10 CFR 835 Appendices A or C, or an area in which a person without respiratory protection could receive an intake exceeding 12 DAC-hours in a week	CAUTION, AIRBORNE RADIOACTIVITY AREA or DANGER, AIRBORNE RADIOACTIVITY AREA

* appropriate access requirements should be included on the posting

238 Exclusion Areas

Exclusion areas are locations that are locked and interlocked to prevent personnel access while an accelerator is operating. At Jefferson Lab, a fully enclosed, locked and interlocked area is not considered to be accessible. Beam enclosure areas that are configured with a certified personnel safety system (PSS) are exclusion areas when the beam or high-power radio frequency (RF) is operable. [§ 835.502(c)] Signs and/or clearly labeled lights reflecting current interlock or beam status shall be provided at all accelerator enclosure entry doors. Beam enclosures, test facilities, shielded caves, etc., that are not fully enclosed, or not protected by a certified PSS are not exclusion areas, and shall be posted in accordance with the requirements for posting radiological areas.

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. The recommended dose limits for personnel performing these operations follow.

Dose Limit (whole body)	**Activity Performed**	**Conditions**
5 rem	all	all
10 rem	protecting major property	where lower dose limit not practicable
25 rem	lifesaving or protection of large populations	
>25 rem	lifesaving or protection of large populations	only on a voluntary basis to personnel fully aware of the risks involved

Notes

1. Values are from EPA Manual of Protective Action Guides and Protective Actions for Nuclear Incidents, EPA 400-R-92-001, and are guidelines only. Emergency operations would be conducted with due consideration given to maintaining doses as low as feasible under the circumstances.
2. The dose limit to the lens of the eye is three times the listed values.
3. The dose limit to the skin of the whole body and the extremities is ten times the listed values.
4. Doses received in authorized emergency response activities are accounted for separately from the doses received under the limits in § 835.202.

Appendix 2B

Contamination Control Limits

Summary of Contamination Limits[1]

Nuclide	Removable [2,4] (dpm/100 cm^2)	Total (Fixed + Removable) [2,3] (dpm/100 cm^2)
U-natural, U-235, U-238 and associated decay products	1,000[7]	5,000[7]
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, Be-7 and others noted above[5]	1,000	5,000
Tritium and Special Tritium Compounds (STC)[6]	10,000	see note 6
Be-7[8]	30,000	30,000

Notes

1. The values in this table, with the exception noted in footnote 6 below, apply to radioactive contamination deposited on, but not incorporated into, the interior or matrix of the contaminated item. Where surface contamination by both alpha- and beta-gamma-emitting nuclides exists, the limits established for alpha- and beta-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 < 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, (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, 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.) When removable contamination on objects of surface area < 100 cm^2 is determined, the activity per unit area shall be based on the actual area and the entire surface shall be wiped. 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 and the Sr-90 that 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 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 table 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/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 tritium compound particles are fixed to a surface.
7. These limits apply only to the alpha emitters within the respective decay series.
8. For use when Be-7 is suspected or known to be the primary constituent in the contamination. This limit applies to use of equipment and items in controlled areas only. Items released from the controlled area shall meet applicable DOE requirements for release. Locations known to have Be-7 contamination above the limits for beta-gamma emitters shall be identified and posted, marked or labeled to warn individuals not to enter without the proper radiological control authorization. See exemption decision letter, June 8, 1998.

Appendix 2C

Shielding Policy for Ionizing Radiation

General Requirements

Shielding design shall limit exposure to ionizing radiation to values consistent with Jefferson Lab's low hazard, non-nuclear facility designation. Shielding must follow Shielding Design Criteria (listed below) and implement the ALARA principle to minimize worker and public exposure to ionizing radiation. Permanent or temporary shielding shall be implemented as necessary to mitigate radiation exposure from:

- sources of prompt radiation generated by accelerator operation, around accelerator component test stands and any other radiation-generating devices
- activated accelerator components and activated utilities such as air or cooling water
- radiation sources and any other radioactive material on site

Ionizing radiation shielding design shall:

- incorporate permanent shielding to the maximum extent practicable
- comply with requirements in the design criteria for normal operation and credible accident scenarios
- specify required amounts and configuration of shielding materials such as earth, concrete or steel, alone or in combination (When required, labyrinths, mazes and penetrations through the shielding shall be designed to provide an equivalent level of radiation protection.)
- be validated by initial radiation surveys and subsequently checked for proper configuration at regular intervals
- be documented in as-built drawings
- be improved, or the operating power shall be reduced, whenever the RCD determines that the shielding configuration does not provide the required attenuation value
- be reviewed for the specific planned activity and approved by the RCD before the radiation source is present in the area being shielded

Configuration Management

All shielding affecting personnel radiation safety shall be subject to configuration controls. If identified in the Accelerator Safety Envelope (which has specific requirements regarding periodic evaluation of shielding integrity), shielding shall meet configuration management requirements specified for a Level 1 Configuration Management (CM) system in the *Conduct of Engineering Manual* (ENG-AD-01-001, Revision A).

Earth shielding shall be evaluated periodically to ensure its integrity. Excavation around accelerator areas that incorporate earth shielding shall be controlled through written authorizations such as dig permits. Shielding that can be altered by non-destructive means (e.g., moveable shielding) shall be: (a) approved by the RCD (design and installation); (b) appropriately identified by labels and/or signs; and (c) inspected periodically. For moveable shielding, preparation of the design package, configuration control and periodic inspections shall be described in a specific Health Physics Procedure.

Temporary Shielding

The use of temporary shielding should be limited to situations in which the radiation source is of a temporary nature. Installation and removal should be controlled through written requirements. Appropriate administrative configuration controls should be used to ensure that the temporary shielding is adequate and remains in place as long as needed. This may include the use of physical barriers and lockout devices.

Shielding Design Criteria

Shielding against ionizing radiation must be designed to specifications that will ensure compliance with radiation exposure limits listed in Chapter 2. Accelerator shielding design considerations must include both normal accelerator operations and accident conditions. Radiation shielding shall be designed to satisfy the following conditions.

1. *Normal operation* with continuous beam within the allowed beam power limits in specific areas
   a) integrated equivalent dose in occupied RCAs will not exceed 2.5 mSv (250 mrem)/y
   b) integrated equivalent dose in occupied areas other than RCAs will not exceed 1.0 mSv (100 mrem)/y
   c) integrated equivalent dose at the site boundary will not exceed 0.1 mSv (10 mrem)/y
   d) levels of radionuclides in groundwater will not exceed limits in the current VPDES permit

   Note 1: Use of appropriate occupancy factors is applicable in a), b) and c) above.

   Note 2: Shielding calculations for normal operation are based on beam losses that are expected and predictable. The variable magnitude and duration of beam loss in different experiments are regulated by limits imposed on the "radiation budget". These limits are specified by RCD in the Radiation Safety Assessment Document (RSAD) for each experiment.

2. The *maximum credible accident scenario* is defined as mis-steering or loss of control of the electron beam under conditions corresponding to the upper limit of the beam power possible in a specific area. Under such conditions the integrated equivalent dose per occurrence will not exceed 150 mSv (15 rem).