

## FRCM CHAPTER 2 RADIOLOGICAL STANDARDS

### Revision History

<b>Author</b>	<b>Description of Change</b>	<b>Revision Date</b>
J. D. Cossairt	<ol style="list-style-type: none"><li>1. Incorporate suggestions made since the last revision.</li><li>2. Provide clarification concerning accidental beam loss criteria.</li><li>3. Improve cross-referencing to FRCM Chapter 8 concerning accelerator radiation shielding assessments.</li><li>4. Correct editorial errors.</li></ol>	August, 2011

## CHAPTER 2 RADIOLOGICAL STANDARDS

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**PART 1 DOSE LIMITS AND ADMINISTRATIVE GOAL****211 Dose Limits**

1. A worker who is not classified as a radiation worker shall not be allowed to routinely receive an effective dose of greater than 100 mrem in a year.
2. Dose limits provided in Table 2-1 shall not be exceeded by individuals. For purposes of compliance with this document, effective dose equivalent to the whole body may be used as effective equivalent for external exposures. All occupational exposure received during the current year, with the notable exceptions of Emergency Exposures (Article 922), Planned Special Exposures (Article 921), and the Non-Uniform Irradiation of the Skin over areas of less than 10 cm<sup>2</sup> (Appendix 2B), shall be included when demonstrating compliance with the Table 2-1 limits. Further information as to the definitions of dosimetric terms is found in the Glossary and Chapter 8 of this Manual.
3. Radiological workers from DOE or other DOE contractor facilities may receive occupational exposure as a radiological worker if they fulfill the requirements stated in Article 612.2 and, if possible, provide a record of the total radiation dose received during the current calendar year and previous accumulated lifetime dose.
4. If it is determined that a radiological worker's occupational exposure has exceeded any of the applicable limits specified in Table 2-1, the employee shall not be permitted to return to work in radiological areas during the current calendar year. An exception to this can be made if all of the following conditions are satisfied:
  - a Written approval has been obtained from the Senior Radiation Safety Officer, the Laboratory Director and the Manager of the DOE Fermi Site Office (DOE-FSO).
  - b The individual has received counseling from radiological protection and medical personnel regarding the consequences of receiving additional occupational exposure for the year. The topics discussed during this session shall be retained as part of the individual's exposure history.
  - c The affected individual has expressed, in writing, a desire to return to radiological work.
  - d Consideration is given to establishing special control levels (see Article 215).

All occupational exposures received during the calendar year by the individual shall be recorded in the affected individual's occupational exposure history.

5. 10 CFR 835.202, 1301, and 1302 give provisions for planned special exposures and authorized emergency exposures. These must be followed. See also Article 645.6.

*Table 2-1 Summary of Dose Limits*

None of the limits shall be exceeded in a year. Exposures should be well below the limits in this table and maintained as low as reasonably achievable (ALARA). The Fermilab Administrative Goal for limiting exposure is described in Article 214.

In accordance with the *Federal Register* Notice Vol. 72, No. 100, page 31908, issued June 8, 2007 that amended 10 CFR Part 835, "...historical doses recorded and reported to individuals and dosimetry results acquired from other institutions (both DOE and non-DOE) prior to complete implementation of the new system of radiation dosimetry should still be considered to be the official doses of record."

TYPE OF EXPOSURE	ANNUAL LIMIT
Radiological Worker: Whole Body (total effective dose)	5 rem
Radiological Worker: Lens of Eye (equivalent dose)	15 rem
Radiological Worker: 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 the eye	50 rem
Radiological Worker: Sum of the equivalent dose to the skin or to any extremity for external exposures and the committed equivalent dose to the skin or to any extremity.	50 rem
Declared Pregnant Worker: Embryo/Fetus (equivalent dose) for entire gestation period	0.5 rem
Minors and Students (under age 18): Whole body (internal + external) (total effective dose)	0.1 rem

**Notes to Table 2-1:**

1. Internal dose to the whole body shall be calculated as committed effective dose equivalent. The committed effective dose equivalent is the resulting dose committed to the whole body from internally deposited radionuclides over a 50-year period after intake. See Appendix 2A for the weighting factors to be used in converting organ dose equivalent to effective equivalent for the whole body and Appendix 8A for radiation weighting factors to convert from absorbed dose to effective dose.
2. Doses from background, therapeutic and diagnostic medical radiation, 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.
3. Concerning dose to the embryo/fetus, substantial variation above a uniform exposure rate that would satisfy the stated limit shall be avoided. If it is likely that the embryo/fetus is determined to have already exceeded 0.5 rem (0.005 Sv) by the time a worker declares her pregnancy, the declared pregnant worker shall not be assigned to tasks where additional occupational exposure is likely during the remaining gestation period.
4. See Appendix 2B for guidance on non-uniform exposure of the skin.
5. Separate Lens of Eye doses are only measured on a case-by-case basis where appropriate. In the absence of specific monitoring, the equivalent dose to the lens of the eye is taken to be equal to the equivalent dose at a tissue depth of 300 mg/cm<sup>2</sup>.

**212 Dose Limit for Visitors, Individuals Under 18 Years of Age, and Members of the Public**

1. Visitors to Fermilab shall be limited to a total effective dose of 100 mrem in a calendar year. Occupational doses are not to be included in this total.
2. A person under the age of 18 shall not be employed in any radiological areas in such a manner that he/she has the potential to receive doses of greater than 100 mrem in a year total effective dose, and/or 10% of the other dose limits established in Table 2-1 for radiological workers (see Article 931).
3. The total effective dose received by any member of the public shall not exceed 100 mrem in a year as a result of all DOE activities.

By order of the Director as a long-standing policy, off site exposures due to Laboratory operations have been subject to a guideline of 10 mrem in a calendar year. The SRSO shall notify the Director when the accumulated off site dose rate is measured or estimated to have exceeded 7.5 mrem in any calendar year. See occurrence reporting criteria of FESHM 3010.

**213 Embryo/Fetus Dose Limits**

The dose limit for the embryo/fetus from conception to birth (entire gestation period) is 500 mrem. In the absence of fetal monitoring, the embryo/fetal dose equivalent is equal to the total effective dose received by the declared pregnant worker for the gestation period. See notations pertaining to Table 2-1. Article 951 contains detailed information regarding Fermilab's prenatal policy and procedures.

**214 Administrative Goals**

1. The Fermilab Director has established an Administrative Goal of 1,500 mrem total effective dose for a calendar year for occupational radiation exposures. The Fermilab ALERT System has been established to ensure the Administrative Goal is not inadvertently exceeded.
2. Any individual who meets or exceeds 350 mrem whole body (deep) dose by primary dosimeter in a calendar quarter will be assigned to the ALERT list.
3. Exposure limits and controls for individuals assigned to the ALERT List will be developed on a case-by-case basis by the division/section/center head, the Area RSO and the individual's supervisor. These agreements will be documented using R.P. Form 3. In addition, these instructions will include a reference to this section of the Fermilab Radiological Control Manual. Additional controls may include, but are not limited to:
  - a. A pocket dosimeter to be worn at all times while in areas controlled for radiological purposes.

- b. An electronic dosimeter worn in addition to a pocket dosimeter while in High Radiation Areas.
  - c. More restrictive stay times.
  - d. Increased radiological surveillance of the work area.
  - e. Use of engineered controls.
  - f. Additional dosimetry, such as finger rings.
  - g. Change to or modification of assigned tasks.
4. The individual and his/her supervisor will be instructed by the Division/Section/Center Radiation Safety Officer (RSO) on dose minimizing techniques.
  5. Before exceeding 1,500 mrem in a calendar year, an individual must have the written approval of the Laboratory Director.

### **215 Special Control Levels**

Certain situations may require lower individualized exposure goals. These goals may be developed for individuals who have received substantial occupational exposure in the past. Individualized exposure goals may also be developed for individuals who are receiving diagnostic or therapeutic nuclear medicine or external radiation treatments and who desire to minimize their total exposure. If the Radiological Control Organization is made aware of these circumstances, the establishment of special control levels can be considered. In addition to recommendations from radiological control and medical personnel, advice from human resources personnel and legal counsel may be sought in establishing such special control levels.

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**PART 2 CONTAMINATION CONTROL AND CONTROL LEVELS**

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Control of removable radioactive contamination at Fermilab is achieved by containing contamination at the source. At Fermilab, the hazard due to removable contamination is generally much smaller than the hazard due to induced radioactivity. Nevertheless, it is good management practice to control removable radioactive contamination to the extent possible.

**221 Contamination Control Levels**

1. A surface shall be considered contaminated if either the removable or total radioactivity is detected above the levels in Table 2-2. If an area cannot be decontaminated promptly, then it shall be posted as specified in Article 235 and controlled in a manner commensurate with the physical and chemical characteristics of the contaminant, the radionuclide(s) present and the fixed and removable contamination levels. Refer to Chapter 3 for more details.
2. Surfaces exceeding the values of Table 2-2 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. Volume activated material is not considered to be fixed contamination. A fixative coating shall not be applied without the approval of the SRSO.
3. In addition to the posting criteria in Article 235, appropriate administrative procedures are to be established and exercised to maintain control of Fixed Contamination Areas. These procedures shall include all of the following:
  - a. Radiological surveys shall be performed to detect contamination that may become removable over time.
  - b. A formal inventory shall be maintained of Fixed Contamination Areas.
  - c. Markings shall be kept legible.
  - d. Markings should include the standard radiation symbol, be clearly visible from all directions and contrast with the colors of the surface coatings and include the words "CAUTION - FIXED CONTAMINATION."
4. A Fixed Contamination Area may be located outside Controlled Areas unless unrestricted access is likely to result in a dose to any person greater than 100 mrem in a year or the dose rate at 30 cm from the source requires posting as a radiological area.

**222 Airborne Radioactivity Control Levels**

1. Personnel should not be exposed unnecessarily to airborne radioactivity and the potential for such exposure must be evaluated before allowing entry into areas where airborne radioactivity may be present. Through the use of engineering and administrative controls, personnel exposure to airborne radioactivity at Fermilab is rare. (See Article 316 and 334.)
2. Accessible areas with airborne concentrations of radioactivity shall be posted as specified in Article 235.
3. Derived Air Concentrations or DACs are provided in 10 CFR 835 and shall be used in the control of occupational exposures to airborne radioactive material. The concept of working level shall not be employed for the consideration of radon concentrations.



Table 2-2 Summary of Contamination Values<sup>1</sup>

NUCLIDE	REMOVABLE (dpm/100 cm <sup>2</sup> ) <sup>2,4</sup>	TOTAL (FIXED + REMOVABLE) <sup>2,3</sup> (dpm/100 cm <sup>2</sup> )
U-natural, U-235, U-238 and associated decay products	1,000 alpha <sup>7</sup>	5,000 alpha <sup>7</sup>
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 <sup>5</sup> .	1,000 beta-gamma	5,000 beta-gamma
Tritium and STCs <sup>6</sup>	10,000	See Footnote 6

Notes:

- 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.
- 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.
- The levels may be averaged over one square meter provided the maximum surface activity in any area of 100 cm<sup>2</sup> 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 (2) it is determined that the sum of the activity of all isolated spots or particles in any 100 cm<sup>2</sup> area exceeds three times the applicable value.
- The amount of removable radioactive material per 100 cm<sup>2</sup> 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 less than 100 cm<sup>2</sup> 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.
- This category of radionuclides includes mixed fission products, including the Sr-90 which is present in them. It does not apply to Sr-90 which has been separated from the other fission products or mixtures where the Sr-90 has been enriched.
- 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 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<sup>2</sup> 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.
- These limits apply only to the alpha emitters within the respective decay series.

**PART 3 POSTING****231 Entry Control Requirements**

For each established radiological area (see Articles 234, 235, 236, and Chapter 3 Part 1), personnel entry control shall be maintained. The degree of control shall be commensurate with existing or likely radiological hazards within the area and accessibility by unauthorized individuals.

1. One or more of the following shall be used to ensure control:
  - Signs and barricades;
  - Control devices on entrances;
  - Conspicuous visual and/or audible alarms;
  - Locked entry ways; or
  - Administrative controls.
2. 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.
3. Physical barriers should be placed so that they are clearly visible upon approach to the area and, when necessary, 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 (NFPA 101 - The Life Safety Code).
4. General Requirements for Radiological Postings and Barricades
  - a. Radiological postings 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. Areas may be exempted from the posting requirements of Articles 233-236 for periods 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.
  - b. Signs shall contain the standard radiation warning trefoil colored black or magenta on a yellow background. Lettering shall be either black or magenta. Black on yellow is the recommended Laboratory standard.
  - c. Rope, tape, chain and similar barriers used to designate the boundaries of posted areas should be yellow and black or magenta in color whenever possible.
  - d. Radiological postings should be displayed only to signify actual or likely radiological conditions. Signs used for training should be clearly marked "For Training Purposes Only."
  - e. Posted areas should be as small as practicable.

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- f. Postings should be maintained in a legible condition and updated based upon the results of the most recent surveys. Signs may include radiological control instructions.
- g. If more than one radiological condition, such as contamination and high radiation, exists in the same area, each condition should be identified.
- h. Postings of doors should be such that the postings remain visible when doors are open or closed. If the area is bounded by fences, ribbons or ropes, signs shall be placed in a conspicuous manner around the perimeter spaced about 50 feet apart.
- i. A radiological posting signifying the presence of an intermittent radiological condition may include a statement specifying when the hazard is present, such as "CAUTION: RADIATION AREA WHEN RED LIGHT IS ON." Note that posting of accelerator/beamline enclosures is treated in Article 236.
- j. All radiological signs and labels shall be disposed of as radioactive waste.

**232 Posting Controlled Areas**

1. Areas within the site boundary should be clearly posted to alert personnel to the presence of radiation and radioactive materials above natural background levels. Each access point to such an area shall be posted "CAUTION, CONTROLLED AREA" whenever one or more radiological areas or radioactive material areas exist within a larger area that is accessible to Laboratory personnel.
2. Persons who enter only the Controlled Area without entering any radiological areas are not expected to receive more than 100 mrem in a year.
3. Radiation levels in normally occupied areas such as portakamps, offices and workbenches shall be maintained at less than 0.25 mrem/hr time averaged over 8 consecutive hours or less than 0.05 mrem/hr average dose rate in areas of continuous occupancy. For such areas subject to prompt radiation fields (see also Article 236), the time-averaged effective dose rate, normally over a period of 8 consecutive hours, shall be maintained less than these values. Additional controls shall be imposed by the Area RSO to ensure Article 232.2 is satisfied along with other requirements such as training (see Chapter 6) and dosimetry monitoring (see Chapter 5) that are tied to the effective dose that might be received during one calendar year.
4. If the boundaries of the Controlled Area and Radiological Area or Radioactive Material Area are congruent, the appropriate sign identifying the greater hazard is considered to be sufficient. However, if multiple Radiological Areas (Articles 234, 235) or Radioactive Material Areas (Articles 233) are found within a given Controlled Area, the latter may be specifically posted. If there is the potential for prompt radiation to be present in an area, additional posting specified in Article 236 is also required.

**233 Areas Containing Radioactive Materials**

1. The definition of, and labeling requirements for, discrete items of radioactive material are in Chapter 4, Part 1 of this Manual.
2. Areas within a Controlled Area (see Article 232) accessible to individuals in which items or containers of radioactive material exist shall be posted "CAUTION -- RADIOACTIVE MATERIAL" or "CAUTION, RADIOACTIVE MATERIAL AREA", unless:
  - a. the area boundary is congruent with a Radiological Area boundary, in which case the Radiological Area posting is sufficient;
  - b. each item or container is labeled in accordance with Article 413 such that individuals entering the area are made aware of the hazards; or
  - c. the radioactive material of concern consists solely of structures or installed components which have been activated.
3. Cabinets, boxes, bins and other such items used to segregate radioactive material from nonradioactive material shall be labeled "CAUTION -- RADIOACTIVE MATERIAL."
4. Perimeters painted on floors may be a good choice in some circumstances. If this is done, proper maintenance to assure visibility and readability shall be conducted.

**234 Posting Radiation Areas for Beam-Off Conditions**

This article addresses the posting of Radiation, High Radiation, and Very High Radiation Areas created by the presence of sealed sources and other radioactive material. It also addresses the posting of accelerator/beamline enclosures during beam-off conditions. In situations where gamma rays sources from residual activation dominate the radiation field, the exposure unit "Roentgen (R)" is considered equivalent to the unit of effective dose, the "rem", or the absorbed dose, the "rad", despite the technical difference between the 3 quantities. See Article 236 for posting of accelerator/beamline enclosures during beam-on conditions.

1. Areas shall be posted to alert personnel to the presence of external radiation in accordance with Table 2-3 or Article 236. General entry/exit requirements may be included on the sign.

*Table 2-3 Criteria for Posting Radiation Areas*

AREA	DOSE RATE CRITERIA	POSTING
Radiation Area	$\geq 5$ mrem/hr and < 100 mrem/hr or	CAUTION-RADIATION AREA
High Radiation Area	$\geq 100$ mrem/hr and < 500 rad/hr	DANGER-HIGH RADIATION AREA or CAUTION-HIGH RADIATION AREA
Very High Radiation Area	$\geq 500$ rad/hr	GRAVE DANGER-VERY HIGH RADIATION AREA

2. In accordance with the requirements of 10 CFR Part 835, dose rate measurements used to classify areas as Radiation and High Radiation Areas shall be made at a distance of 30 centimeters (~1 ft) from the radiation source or from any surface through which the radiation penetrates. Exposure rate measurements to determine if the criteria for a Very High Radiation Area are satisfied should be made at a distance of 1 m from the radiation source or from any surface through which the radiation penetrates.
3. Measures should be taken to identify sources of elevated radiation levels while conducting routine surveys or opening up radiation surveys of accelerator/beamline enclosures.
4. An appropriate exposure rate sticker/label marking the location of areas with elevated dose rates should be placed on or near the spot. These stickers should be initialed or signed and also dated by the surveyor.
  - a. In beam enclosures, to keep survey doses ALARA, it is common to establish a minimum posting level of 20 mR/hr.
  - b. To keep exposures to personnel conducting the survey ALARA, it is often desirable to not label individual hot components in areas in which no one is scheduled to work. This may be done provided the area is roped off and posted with signs indicating the unlabeled area and the radiological hazard present. Should the exposure rates exceed 100 mrem/hr, the requirements in Article 234.6 are applicable.
5. At certain times, radiation may in fact not be present in what is posted as a radiation area because fixed, rather than real-time signs are used. However, as long as signs are present their instructions and associated requirements are to be strictly adhered to by all personnel.
6. When dose rates exceeding 100 mrem/hr are confined to a small region inside a much larger area, ribbons or ropes and suspended signs must be used to demark the High Radiation Area.

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7. Additional Requirements for Areas Exceeding 1 rem/hour -- areas in which the dose rate exceeds 1 rem/hr must be fenced off with rigid barriers and must have signs giving the dose rate and prohibiting entry without continuous radiation safety supervision. Article 312 outlines work controls for such areas.
  
8. Additional Requirements for Areas Exceeding 25 rem/hour -- areas in which the dose rate exceeds 25 rem/hr must be secured against unauthorized access when radiation safety personnel are not present. Survey maps should be posted at the entrances and shall be included with the Radiological Work Permit. Article 312 outlines the work controls for such areas.
  
9. Additional Requirements for Areas Exceeding 100 rem/hr -- areas in which the dose rate exceeds 100 rem/hr must satisfy the criteria as stated in Article 234.7 and 234.8. Article 312 outlines the work controls for such areas.
  
10. "Occupancy Time" labels are used in accelerator/beamline radiation areas on normally stationary objects as a guide in determining the length of time one could work in a particular area and keep doses below 100 mrem per week.

***Table 2-4 Occupancy Time per week Labels Used in Accelerator and Beamline Enclosures***

<b>Dose Rate</b>	<b>Maximum Occupancy Time</b>
20-50 mrem/hr	2 hours
Over 50 - 100 mrem/hr	1 hour
Over 100 - 200 mrem/hr	30 minutes
Over 200 mrem/hr	Contact Division/Section/Center RSO

**235 Posting Contamination, High Contamination and Airborne Radioactivity Areas**

1. Accessible areas shall be posted to alert personnel to the presence of contamination in accordance with Table 2-5. Further technical information is provided in Chapter 5. Signs may include specific entry/exit requirements.
  
2. Areas having concentrations of radionuclides exceeding one DAC shall be posted as Airborne Radioactivity Areas only if they are occupied by personnel under such conditions. In other words, beamline enclosures are only posted as Airborne Radioactivity Areas if levels exceeding one DAC are present during access or if personnel present could receive an intake exceeding 12 DAC hours in one week. Normally, allowance for decay of the short-lived accelerator-produced radionuclides is the preferred approach in accordance with ALARA.
  
3. Derived Air Concentration (DAC) values for use with Table 2-5 are found in CFR 835, Appendices A and C. Those in 10 CFT 835 Appendix C may be modified to account for submersion in an atmospheric cloud of finite dimensions. Values of

DAC's for airborne radionuclides encountered at Fermilab are listed in Table 302. Further technical information is provided in Chapter 5.

**Table 2-5 Criteria for Posting Contamination, High Contamination and Airborne Radioactivity Areas**

AREA	CRITERIA	POSTING
Contamination	Levels (dpm/100 cm <sup>2</sup> ) > Table 2-2 Values but ≤ 100 times Table 2-2 values	CAUTION-CONTAMINATION AREA
High Contamination	Levels (dpm/100 cm <sup>2</sup> ) >100 times Table 2-2 values	DANGER-HIGH CONTAMINATION AREA or CAUTION – HIGH CONTAMINATION AREA
Fixed Contamination	Removable contamination below applicable levels Table 2-2	CAUTION-FIXED CONTAMINATION
Airborne Radioactivity	<ul style="list-style-type: none"> <li>• Concentration exceeds the DAC value in Appendix A or C of 10CFR835;</li> <li>• Concentrations that could result in 12 DAC-hours in a week to an individual without respiratory protection</li> </ul>	CAUTION-AIRBORNE RADIOACTIVITY AREA

**236 Posting Requirements for Accelerator/Beamline Areas for Prompt Radiation**

This article describes the posting criteria and the controls for Fermilab accelerator/beamline areas for beam-on conditions. Posting for areas where prompt radiation is not present is addressed in Article 234. In this section the term “dose” is applied to the effective dose to be assigned to an individual person based upon the appropriate radiological weighting (or quality) factor (see Tables 8-1 and 8-2) used to take the composition of the radiation field into account. See FRCM Chapter 8 for more details on the radiation dosimetry of prompt radiation fields.

1. The following general rules apply to the posting specified in this article.
  - a. Given the nature of accelerator operations, it is often not feasible to remove radiological area postings when the beam is disabled even though lesser radiological hazards may exist. Radiation may in fact not be present in what is posted as a radiation area because fixed rather than real time signs are used. However, as long as signs are present their instructions and associated requirements are to be strictly adhered to by all personnel.
  - b. This article is closely coupled with the radiation safety interlock systems which shall meet the requirements of FRCM Chapter 10 and thus must be used in conjunction with that Chapter.
  - c. Where boundaries of the areas covered by this Article are identical with the boundaries of the corresponding Controlled Area, the Controlled Area posting is not required.
  - d. Signs may be annotated to denote unusual radiation hazards.
  - e. Accelerator/beamline enclosures to which personnel access is excluded during operations by the radiation safety interlock system are posted for the radiological conditions anticipated when the beam is off and personnel access is permitted.

## 2. Posting Requirements

### a. Definitions

- (1) The maximum dose is that which can be delivered under the worst credible accident in that area, taking into consideration circumstances and controls, which serve to limit the intensity of the maximum beam loss and/or its duration. Some examples of accident scenarios are (1) beam intensity significantly greater than the nominal beam intensity; (2) unanticipated beam losses; and (3) single pulse full machine loss on an element.

The maximum dose is to be determined through the safety analysis, which shall document calculations and measurements of possible radiation exposures, radiation shielding, beam optics and other relevant information. The safety analysis must be forwarded to the SRSO for a timely review prior to construction and/or operation of the beam. Chapter 8 of this Manual provides additional information regarding the analysis.

- (2) Likely is a term that refers to the risk associated with a hazard, while potential is a term that implies the existence of a hazard. Once the hazard has been identified, it is more sensible to control the risk to personnel.



- (3) Minimal occupancy area is any area which is not normally occupied by people more than 1 hour in 8 consecutive hours.
- b. Required Controls
- (1) Accelerator/beamline areas shall be posted and controlled for the normal operating conditions in accordance with Table 2-6 when the safety analysis documents that delivering the maximum dose to an individual is unlikely.
  - (2) Accelerator/beamline areas shall be posted and controlled in accordance with Table 2-7 when the safety analysis documents a scenario in which it is likely that the maximum dose may be delivered to an individual.
  - (3) For roads over berms, culverts, parking areas adjacent to beamlines, and berm areas considered to be minimally occupied, if the safety analysis indicates an unlikely scenario which could result in a maximum dose corresponding to a posting status of no higher than a radiation area during the unlikely scenario, and no precautions are required for the normal operating condition, then no posting is required if the duration of the unlikely scenario is less than one hour.
  - (4) Based on actual running conditions, the Area RSO may impose additional controls.

**Table 2-6 Control of Accelerator/Beamline Areas for Prompt Radiation Under Normal Operating Conditions (refer to Article 236.2(b))**

Dose Rate (DR) Under Normal Operating Conditions	Controls
$DR < 0.05$ mrem/hr	No precautions needed.
$0.05 \leq DR < 0.25$ mrem/hr	Signs (CAUTION -- Controlled Area). No occupancy limits imposed.
$0.25 \leq DR < 5$ mrem/hr	Signs (CAUTION -- Controlled Area) and minimal occupancy (occupancy duration of less than 1 hr).
$5 \leq DR < 100$ mrem/hr	Signs (CAUTION -- Radiation Area) and rigid barriers (at least 4' high) with locked gates. For beam-on radiation, access restricted to authorized personnel. Radiological Worker Training required.
$100 \leq DR < 500$ mrem/hr	Signs (DANGER -- High Radiation Area) and 8 ft. high rigid barriers with interlocked gates or doors and visible flashing lights warning of the hazard. Rigid barriers with no gates or doors are a permitted alternate. No beam-on access permitted. Radiological Worker Training required.
$DR \geq 500$ mrem/hr	Prior approval of SRSO required with control measures specified on a case-by-case basis.

*Table 2-7 Control of Accelerator/Beamline Areas for Prompt Radiation Under Accident Conditions When It is Likely that the Maximum Dose Can Be Delivered (See Article 236.2b for more details)*

Maximum Dose (D) Expected in 1 hour	Controls
D < 1 mrem	No precautions needed.
1 < D ≤ 10 mrem	Minimal occupancy only (duration of credible occupancy < 1 hr) no posting
1 ≤ D < 5 mrem	Signs (CAUTION -- Controlled Area). No occupancy limits imposed. Radiological Worker Training required.
5 ≤ D < 100 mrem	Signs (CAUTION -- Radiation Area) and minimal occupancy (duration of occupancy of less than 1 hr). The Division/Section/Center RSO has the option of imposing additional controls in accordance with Article 231 to ensure personnel entry control is maintained. Radiological Worker Training required.
100 ≤ D < 500 mrem	Signs (DANGER -- High Radiation Area) and rigid barriers (at least 4' high) with locked gates. For beam-on radiation, access restricted to authorized personnel. Radiological Worker Training required.
500 ≤ D < 1000 mrem	Signs (DANGER -- High Radiation Area) and 8 ft. high rigid barriers with interlocked gates or doors and visible flashing lights warning of the hazard. Rigid barriers with no gates or doors are a permitted alternate. No beam-on access permitted. Radiological Worker Training required.
D ≥ 1000 mrem	Prior approval of SRSO required with control measures specified on a case-by-case basis.

- c. Table 2-7 includes the corresponding maximum dose permitted in any one hour. If after a single trip, or multiple trips, the maximum allowable dose in one hour is reached, the beam must remain disabled to that area for the remainder of the hour. It is the responsibility of the operating division/section/center to limit the number of allowable trips per hour of any interlocked detector based on the shielding assessment for that area. System hardware is the preferred method to control the number of trips per hour. However, administrative controls are allowed.
- d. With concurrence of the relevant Division/Section/Center Head(s) and the SRSO, and supported by appropriate documentation, the Division/Section/Center RSO can be granted the authority to adjust a shielding assessment accident criteria beam loss to less than one hour duration if the duration of such a beam loss for a period as long as one hour is unlikely.
- e. The interlocks referred to in the table must remove the beam, and thus the radiation, if any of the gates are opened.
- f. The signs referred to in Table 2-6 and Table 2-7 must meet the requirements of Article 231.

- g. With the prior approval of the SRSO, continuous coverage may be used as a substitute for fence and interlock requirements for up to 8 hours.
  - h. If the maximum dose is greater than 500 mrem, consideration should be given to performing a rigorous search and secure after each interlock trip.
3. Access Control of Accelerator/Beamline Areas When Prompt Radiation is Present
- a. If the area is posted with "CAUTION -- Controlled Area", dose rates shall not exceed 5 mrem/hr.
  - b. Prior to access, the following must be satisfied:
    - 1) Prior approval of the RSO must be obtained.
    - 2) The potential dose rates must be documented, based on beam parameters, controls and safety interlocks.
    - 3) Dose rates to personnel within the vicinity due to potential loss points (normal or accidental) shall be estimated and communicated to those making such an access.
    - 4) Barriers (e.g., fences or shielding) around potential loss points shall be erected prior to beam operation. If shielding is used, the design and construction shall be reviewed and approved by members of the Division/Section/Center RSO. The adequacy of the shielding shall be demonstrated through calculation and/or by measurement as appropriate.

**PART 4 RELEASE CERTIFICATION PROGRAM FOR FACILITIES  
CONTAINING RADIOACTIVE MATERIALS****241 Release Procedures**

1. The ES&H Section is responsible for implementation of the release certification program for facilities containing radioactive materials and for coordination of annual update of the list of such facilities (Article 242). For purposes of this Article and Article 242, facilities “released” include facilities that are demolished.
2. Laboratory facilities in which radioactive materials have been produced, used, processed (e.g., machined) or stored must be certified by the ES&H Section as meeting established standards before they may be released for uncontrolled use by Fermilab personnel. The release of such facilities to unrestricted use by members of the public shall be approved by the Laboratory Director, or designee.
3. A radiation survey of the facility must be made, and removal of radioactive materials and decontamination must be carried out if needed in order to obtain the release certification. The surveys must indicate that the radiation and contamination levels throughout the facility are below the criteria stated in Article 411.
4. The Division/Section/Center to which the facilities are assigned is responsible for meeting standards for release. Documentation of surveys, measurements, decontamination, and all measures taken to meet release standards must be provided to the ES&H Section for review prior to certification for release.
5. The ES&H Section will provide technical assistance to divisions/sections/centers in order to meet the requirements of this Article.
6. For purpose of this Part, a given building or part thereof that contains several areas where radioactive materials are used or stored may be considered to be a single facility.
7. The intent of this Part is to specify the certification requirements for the permanent, or long-term release, of facilities containing radioactive materials to other uses. Individual radioactive materials areas may be created or deleted in accordance with other provisions of this Manual. Once such areas have been established, they shall remain on the list of facilities containing radioactive materials specified in Article 242 until they are certified as cleared in accordance with this Article.
8. This article does not pertain to the permanent release of real property on the Fermilab site to members of the public. Those are covered by DOE Order 5400.5 and subject to DOE approval.

**242 Maintenance of List of Facilities Containing Radioactive Materials**

1. Annual updates of the list of facilities containing radioactive materials will be requested by the ES&H Section and placed in the Laboratory Decontamination and Decommissioning files maintained by the ES&H Section.
2. Those facilities (e.g., labs, shops, service buildings) in which radioactive material is used, produced by activation, processed (e.g., machined) or stored shall be included in this list. Exceptions are facilities where only sealed check or calibration sources of less than 100  $\mu\text{Ci}$  and smoke detectors and similar devices are used. The Division/Section/Center Head having responsibility for a given facility is responsible for completing and updating records for that facility.
3. Individual facilities are to be listed in the first column and a code identifier placed in the appropriate year column.
4. The following code identifiers are used on RP Form #85, for documenting facilities containing radioactive materials, which is in the Forms section of this Manual.

**R** Classified as a facility containing radioactive materials.

**C** Certified by the ES&H Section as no longer a facility containing radioactive materials (indicate date).

**√** No change from the previous year.

**T** Responsibility for the facility transferred to/from another division/section/center (identifies other division/section/center and date).

An **R** will appear in the column of the first year a facility is designed as radioactive materials and checks (**√**) will appear for successive years.

5. Once designated as a facility containing radioactive materials, the facility must remain on the division/section/center list until properly certified as no longer a facility. Updates for a particular facility will no longer be required by a given Division/Section/Center if:
  - a. The SRSO certifies it as no longer a facility containing radioactive materials. Copies of relevant documentation and the certification memo signed by the SRSO are placed in the appropriate Laboratory D&D files maintained by the ES&H Section.
  - b. Responsibility for the facility is transferred to another organization.

**Appendix 2A: Weighting Factors for Organs and Tissues**

ORGANS OR TISSUES	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 <sup>1</sup>	0.05
Whole body <sup>2</sup>	1.00

## Notes:

- "Remainder" means the following additional tissues and organs and their masses, in grams, following parenthetically: adrenals (14), brain (1400), extra-thoracic 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 ( $H_{\text{remainder}}$ ), 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 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.
- 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.

**Appendix 2B: 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. In no case shall a value of less than 0.1 be used.

<b>AREA OF SKIN IRRADIATED</b>	<b>METHOD OF AVERAGING, ADDING TO OTHER DOSES RECEIVED, AND RECORDING NON-UNIFORM SKIN DOSE</b>
$\geq 100 \text{ cm}^2$	<p>Averaged over the <math>100 \text{ cm}^2</math> of skin receiving the maximum dose</p> <p>Added to any uniform equivalent dose also received by the skin</p> <p>Recorded as the equivalent dose (H) to any extremity or skin for the year</p>
$10 \text{ cm}^2 < \text{area} < 100 \text{ cm}^2$	<p>Averaged over the <math>1 \text{ cm}^2</math> of skin receiving the maximum dose (D), reduced by the fraction (f) which is the irradiated area in <math>\text{cm}^2</math> divided by <math>100 \text{ cm}^2</math> (i.e. <math>H=fD</math>). In no case shall a value of <math>f &lt; 0.1</math> be used.</p> <p>Added to any uniform equivalent dose also received by the skin</p> <p>Recorded as the equivalent dose to any extremity or skin for the year.</p>
$< 10 \text{ cm}^2$	<p>Averaged over the <math>1 \text{ cm}^2</math> of skin receiving the maximum dose</p> <p>Not added to any other dose equivalent, extremity or equivalent dose (skin) recorded for the extremity or skin for the year.</p> <p>Recorded in a person's radiation dose record as a special entry</p>