FRCM CHAPTER 3
CONDUCT OF RADIOLOGICAL WORK

Revision History

Author	Description of Change	Revision Date
K. Graden	• Revision of Article 342 to prohibit eating and drinking in areas where sealed radioactive sources are in use.	November 2021
M. Quinn	• Revision of Article 323 to clarify RWP content requirements. • Revision of Article 333 to clarify possible supplemental dosimetry requirement for entry into Radiation Areas, as determined by the RSO.	December 2020
J. D. Cossairt, M. Quinn, C. Greer, E. Mieland, E. Korzeniowski, K. Graden	• Revision of Article 346 to better clarify policies pertaining to management of radioactivity that could lead to surface waters and sewers. • Transfer of portions of the previous Article 346 to Chapter 11 Article 1106 and portions of Article 345 to Chapter 11 Article 1107. • Replacing reference to ESH&Q Section with ES&H Section following the reorganization of February 1, 2019. • In Article 348 correct FESHM reference to Stop Work authority to FESHM 1010. • Add requirement for operators of radiation-generating devices to be radiological workers qualified by training. In Article 362. • Addition of provisions addressing soil moisture gauges to Article 362. Editorial corrections as needed.	January 2020
M. Schoell J. D. Cossairt M. Quinn W. Schmitt	• Updated Article 337 to reflect current Controlled Access rules, general procedure, and critical steps. Removed the role of “Entry leader”. • Updated Article 352 to indicate that RSOs may collectively act as the ALARA coordinator in a centralized ESH&Q organizational structure. • Revise Article 347 to include correct 10 CFR 835 DAC values. • Minor editorial changes throughout.	January 2019
J. D. Cossairt	• Consolidate content of Article 312 and 354 to remove duplication and clarify requirements. • Revise Article 335.5.g to clarify language pertaining to contamination control for sealed sources.	January 2018

	• Revise Article 337 for modifications in controlled access policies. • Update DAC values in Article 347, Table 3-2. • Revised to incorporate more specific details concerning DD and DT Generators in Article 362.	
J. D Cossairt	• Updated for Fermilab-wide ESH&Q reorganization. • Added Article 337 to reflect Controlled Access rules.	September 2016
J. D. Cossairt	• Editorial changes to reflect ESH&Q reorganization.	July 2015
J D. Cossairt	• Revise Article 362 to improve management of Radiation Generating Devices and consistency with FESHM 2010.	March 2013
J. D. Cossairt	• Clarify Article 312.6 to correct confusion resulting from Nov 2012 rev.	January 2013
J. D. Cossairt	• Revise provisions of Article 312.6 to lower the thresholds for notification of the SRSO for work in extremely high dose rate fields. • Correct Article 335.5 to replace a vague threshold with a specific one expressed also in Article 346.5. • Modify the threshold for labeling in Article 346.3 for consistency with other thresholds for considering a person to be a radiation worker. • Correct several errors in Table 3-1.	November 2012
J. D. Cossairt	• Implemented amendments of 10 CFR 835 finalized on April 13, 2011 pertaining to Derived Air Concentrations and new Derived Concentration Standards in DOE-STD-1196-2011 April 2011.	September 2011

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PART 1 PLANNING RADIOLOGICAL WORK

311 Requirements

Technical requirements for the conduct of work, including construction, modifications, operations, maintenance and decommissioning, and dismantling for reuse shall incorporate radiological criteria to ensure safety and maintain radiation exposures ALARA. The primary methods used to maintain exposures ALARA shall be engineered controls and physical design features. These features may be augmented by administrative and procedural requirements where engineered controls and physical design features are impractical. To accomplish this, the design and planning processes should incorporate radiological considerations in the early planning stages. The checklist in Appendix 3A is helpful in reducing occupational radiation exposure.

312 Planning for Maintenance, Operations and Modifications

1. Maintenance and modification plans and procedures shall be reviewed to identify and incorporate radiological requirements, such as engineering controls, and dose and contamination reduction considerations where applicable. Performance of this review is the responsibility of division/section heads, in cooperation with the Radiological Control Organization (RCO), chiefly by the assigned Radiation Safety Officer (RSO). General environment, safety and health review procedures are specified in the Fermilab ES&H Manual and all environment, safety and health concerns other than radiological protection shall be addressed in harmony with radiological protection in such planning activities.

2. For routine tasks, such as surveillance, tours and minor maintenance, performance of the above review and documentation of identified radiological requirements may be conducted as part of the Radiological Work Permit process (see Article 321).

3. ALARA trigger levels and thresholds for special approvals are stated in Article 354. Article 355, which addresses ALARA review elements, should be used for general guidance on pre-job planning, pre-job briefings and post-job reviews.

4. For emergency exposures, see Article 645.6.

313 Infrequent or First-Time Activities

Special management attention should be directed to radiological activities that are infrequently conducted or represent first-time operations, and where the trigger levels of Article 354 are approached. Planning for such activities should include:

1. Formal radiological review in accordance with Article 355.

2. Enhanced line and Radiological Control Organization management oversight during the initiation and conduct of the work.

3. Activities conducted in the course of civil construction.

314 Temporary Shielding

Temporary shielding should be evaluated by the Radiological Control Organization on a case-by-case basis, as it can sometimes become more of a hindrance than help and cause a job to take much longer thereby increasing doses. Temporary shielding installed in order to reduce residual dose rates in beam enclosures should generally be removed prior to resumption of beam in order to avoid it becoming activated and thus an additional source of exposure. The benefits from the use of temporary shielding should be balanced against other ALARA considerations. The following items should be addressed:

1. The installation use and removal of temporary shielding should be evaluated by the assigned RSO for dose savings.

2. The effects of the additional weight of temporary shielding on systems and components should be evaluated and established by qualified personnel to be within the design basis prior to installation.

3. Installed temporary shielding should be periodically inspected and surveyed to verify shielding effectiveness and integrity. Locking mechanisms or labeling are ways of making integrity evident for such verification.

4. Temporary shielding used to mitigate beam-on radiation hazards is controlled according to the procedures specified in Chapter 8.

5. Unless radiation levels are already understood, radiation surveys should be performed during the installation, alteration, or removal of installed temporary shielding if the shielding is being used to mitigate radiation hazards due to radioactive sources or induced activity.

6. If unauthorized removal of installed temporary shielding is possible, appropriate measures should be taken to ensure that it is not moved.

7. Installed temporary shielding should be periodically evaluated to assess the need for its removal or replacement with permanent shielding where such replacement is feasible.

315 Technical Work Documents

1. Technical work documents and procedures for radiological work, including accelerator/beamline "running conditions" and "access procedures," work packages, or job or research plans should be used to control hands-on work with radioactive materials and/or in radiation areas and the radiological aspects of accelerator operations.

2. Technical work documents used to control radiological work activities should be reviewed by the Radiological Control Organization. They are usually, but perhaps not exclusively, written by the members of the Radiological Control Organization and approved and issued by the assigned RSO.

3. Radiological Control Hold Points or their procedural equivalents should be incorporated into technical work documents for steps that require action by members of the Radiological Control Organization to prevent radiation exposures in excess of Administrative Goals, high airborne radioactivity concentrations, or the release of radioactivity to the environment.

316 Minimization of Internal Exposure

Control and prevention of internal exposure presents special challenges to a radiological control program and warrants particular attention when significant surface and/or airborne contamination exist in a facility. Assessment of dose due to internally deposited radioisotopes is based upon special sampling protocols and is more complicated and uncertain than assessment of exposures due to external radiation sources. At particle accelerators such as Fermilab, the occurrence of surface and airborne radioactivity at levels that could lead to reportable exposure is perhaps not as common as at other types of radiological facilities. Nonetheless, constant surveillance for identifying such sources of internal exposure is required so that evidence of compliance for regulatory purposes is available.

1. Clean up accelerator/beamline enclosures prior to operations in order to remove excessive dirt, dust, or other material that could lead to the production of significant levels of contamination.

2. In circumstances where contamination exists, decontamination should be employed:

   a. If internal radiation exposure can be avoided; and

   b. If the external dose received from decontamination effort does not exceed the internal dose which would be received if the work was done without decontamination; and

   c. After consideration has been given to environmental conditions and work duration; and

   d. If there are credible pathways for contamination to be released to non-radiological areas or off-site.

3. Engineering controls, including containment of radioactive materials that possess <u>removable</u> radioactivity ("contamination") at the source wherever practicable, should be a primary method of

minimizing internal exposure to individuals and the potential for the spread of contamination to other areas.

4. Administrative controls, including access restrictions and the use of specific work practices designed to minimize contamination, should be used as a secondary method to minimize internal exposure to individuals.

5. When engineering and administrative controls have been applied and the potential for airborne radioactivity still exists, respiratory protection should be used to limit internal exposures. Use of respiratory protection (see Chapter 3 Part 5) should be considered under the following conditions:

   a. Entry into posted Airborne Radioactivity Areas.

   b. During breach of contaminated systems or components.

   c. Work in areas or on equipment with removable contamination levels greater than 100 times the values in Table 2-2.

   d. During work on contaminated or activated surfaces with the potential to generate airborne particulate radioactivity.

6. The selection of respiratory protection equipment should include consideration of the individual's safety, comfort and efficiency. The use of positive pressure respiratory protection devices is recommended wherever practicable to alleviate fatigue and increase comfort.

7. In specific situations, the use of respiratory protection may be inadvisable due to physical limitations or the potential for significantly increased external exposure. Specific justification of the need to accept the internal exposure shall be documented by the assigned RSO.

8. The following controls are applicable for activities authorized in accordance with the above:

   a. Stay time limits to limit intake should be established for the entry.

   b. Evaluation of workplace airborne radioactivity levels should be provided through the use of continuous air monitors or air-samplers with expedited assessment and analysis of results.

   c. Use engineering controls and containment devices such as glovebags and tents with HEPA ventilation where appropriate.

PART 2 WORK PREPARATION

321 Radiological Work Preparation

1. The responsibility for ensuring adequate planning and control of work activities resides with line management. The line management responsible for an activity or area requiring a Radiological Work Permit (RWP) or alternative written authorization, as determined by the assigned RSO, should assure that one is prepared by the Radiological Control Organization before starting work or is already in place. Generally, the RWP would be prepared by the assigned RSO with the support of the personnel who will perform the work.

2. The RWP shall be based on current radiological surveys, where applicable, as determined by the assigned RSO. RWPs for controlled access are to be based upon anticipated radiological conditions, making allowance for realistic difficulties that might be encountered.

3. Job-specific RWPs should have the concurrence of the supervisor responsible for the work. All RWPs shall have the written approval of the assigned RSO. Revisions or extensions to RWPs shall be subject to the same approval process.

4. Commensurate with other hazards present, the RWP process may incorporate or be incorporated in the assessments of other hazards carried out in the provisions of Integrated Safety Management set forth in FESHM Chapter 2060.

5. Special provisions apply to some radiological tasks involving shipments of radioactive materials (See Article 423).

322 Requirements for Written Authorization

1. RWPs, or alternative written work authorization which satisfies the intent of the requirements of this Part, shall be used to control the following activities:

   a. Entry into a designated radiological area.

   b. Handling of materials with removable contamination that exceed the values of Table 2-2.

   c. Used of radioactive sealed sources and operations of Radiation Generating Devices.

2. Job-specific RWPs, or their equivalent, shall be used to control operations or work in areas with changing radiological conditions. The job-specific RWP shall remain in effect only for the duration of the job. (NOTE: Normal operations of the Fermilab accelerators/beamlines - which may change with time - are covered by the procedures in the general RWPs.)

3. General RWPs may be used to control routine or repetitive activities in areas with well-characterized and stable radiological conditions. General RWPs should not be approved for

periods longer than 1 year. General RWPs are typically used to cover the following aspects of accelerator/beamline operations:

a. Routine entry, either "controlled access" or "supervised access" under conditions defined within the RWP.

b. Routine maintenance, replacement, and inspections of instrumentation and ancillary equipment of the accelerator/beamline under conditions defined within the RWP.

c. "Opening up" or other radiation surveys by personnel so authorized by the assigned RSO under conditions defined within the RWP.

4. Radiological surveys shall be routinely reviewed to evaluate adequacy of RWP requirements. RWPs shall be updated if radiological conditions change to the extent that protective requirements need modification.

5. RWPs should be posted at the access point to the applicable radiological work area or, alternatively, at the location where keys permitting access to the work area or enclosure are issued.

6. Workers shall acknowledge by signature or through electronic means, where automated access systems are in place, that they have read, understand, and will comply with the RWP prior to initial entry to the area and after any revisions to the RWP or as otherwise directed by the assigned RSO. For such purposes, "initial" entry is defined as the first entry made under a given edition of the RWP.

323 Documentation of Written Authorizations

The RWP or alternative shall inform individuals of area radiological conditions and entry requirements. It may be combined with other technical work documents provided the intent to establish radiological controls are clearly stated. Non-radiological hazards and control measures should be addressed via other work control documents (see FESHM 2060). The RWP should include the information below:

1. Description of work.

2. Work area radiological conditions.

3. Dosimetry requirements.

4. Pre-job briefing requirements, as applicable.

5. Training requirements for entry and/or work.

6. Protective clothing and respiratory protection requirements, as applicable.

7. Radiological Control coverage requirements and stay time controls, as applicable.

8. Limiting radiological conditions that may void the RWP.

9. Special dose or contamination reduction considerations.

10. Special personnel frisking considerations.

11. Technical work document number, as applicable.

12. Unique identifying number.

13. Date of issue and expiration.

14. Identification of responsible personnel.

15. Survey instruments required.

16. Procedures or survey maps (attached to the RWP), if applicable.

324 Pre-Job Briefings

Pre-job planning, pre-job briefings and post-job reviews are covered in Article 355.

325 Personal Protective Equipment and Clothing

1. Personnel shall wear protective clothing during the following activities:

    a. Handling of contaminated materials with removable contamination in excess of Table 2-2 levels.

    b. As directed by the assigned RSO or designee or as required by the RWP.

2. Protective clothing dress-out areas should be established directly adjacent to the work area when possible. Workers should proceed directly to the radiological work area after donning Personal Protective Equipment and clothing.

3. Personal Protective Equipment and clothing shall be selected as prescribed by the applicable RWP. General guidelines for protective clothing selection and use are provided in Appendix 3B.

4. The use of lab coats as radiological protective clothing is appropriate for limited applications such as those discussed in Appendix 3B where the potential for personal contamination is limited to the hands, arms, and upper front portion of the body.

5. The use of Personal Protective Equipment or clothing (including respiratory protection) beyond that specified by the Radiological Control Organization detracts from work performance and is contrary to ALARA principles and waste minimization practices. Such use should not be authorized or otherwise encouraged unless the Personal Protective Equipment or clothing is necessary to mitigate other hazards identified during the work planning process. The FESHM should be consulted for discussions of other PPE recommendations and requirements.

6. Fermilab-issued clothing, such as work coveralls and shoes, may be used for radiological control purposes when conditions and hazards indicate.

PART 3 ENTRY AND EXIT REQUIREMENTS

Details of specific training requirements for workers, experimenters or contractors are covered in Part 2 of Chapter 6. Requirements for visitors, tours, and minors (i.e., individuals under the age of 18) are covered in Articles 931 and 941.

331 Controlled Areas

General Employee Radiological Training (GERT) shall be required for unescorted entry or access to any posted Controlled Area.

332 Radioactive Material Areas

1. General Employee Radiological Training (GERT) shall be required for unescorted entry or access to any posted Radioactive Material Area.

2. Work with radioactive materials or radioactive sources, including those installed in equipment, requires Radiological Worker Training (RW), which includes both an online class, Radiological Worker – Classroom (Virtual), and a hands-on portion, Radiological Worker – Practical Factors.

333 Radiation, High Radiation and Very High Radiation Areas

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

   a. Radiological Worker Training.

   b. Written authorization (e.g., a RWP or posting) to enter the area by the assigned RSO or designee.

   c. Personnel dosimetry monitoring badge.

   d. Note: Supplemental dosimeters may also be required for entry into Radiation Areas, as determined by the assigned RSO and noted on applicable RWPs and/or postings.

2. Physical controls to prevent inadvertent or unauthorized access to High and Very High Radiation Areas shall be maintained in accordance with Chapter 10.

3. Minimum requirements for entry into High Radiation Areas shall include the following:

   a. Radiological Worker Training.

   b. Written authorization (e.g, a RWP) to enter the area by the assigned RSO or designee.

   c. Personnel and supplemental dosimeters as follows:

(1) Personnel dosimetry monitoring badge.

(2) <u>Self-Reading Dosimeters ("Pocket Dosimeters")</u>: Pocket Dosimeters are required for entry into all High Radiation Areas.

(3) <u>Special Monitoring</u>: If the radiation fields are non-uniform, personnel radiation monitoring badges and other dosimeters shall be worn on that part of the trunk of the body receiving the highest dose (i.e., that part closest to the strongest source of radiation).

(a) If any question exists as to which part of the body is receiving the highest dose, the assigned RSO should require two badges to be worn at appropriate locations. Each must be labeled as to location worn, and they must not be interchanged. Arrange appropriate badge processing through the Dosimetry Program Manager.

(b) If the work requires handling of objects where the dose to the hands can be expected to exceed 1 rem/quarter, ring badges should also be worn.

d. Monitoring as necessary during the access to determine the exposure rates to individuals.

4. Minimum requirements for entry into High Radiation Areas where dose rates exist such that a person could exceed a whole-body dose of 1 rem in one hour shall include those items listed in Article 333.3 and, in addition, the following:

a. A determination of the person's current dose based on available primary and supplemental dosimeter readings.

b. Supplemental dosimetry provided by electronic dosimeters.

c. Pre-job briefing, as specified by the RWP.

d. Review and determination by the assigned RSO or designee regarding the required level of Radiological Control Technician coverage. Access to areas with levels in excess of 1 rem/hr. is subject to the additional requirements of Article 354.

5. Workers shall only be permitted entry into Very High Radiation Areas under the direct supervision of members of Radiological Control Organization designated by the assigned RSO. Prior approval of the Laboratory Director is required. For accelerator/beamline enclosures, in addition to the controls required in Articles 333.3 and 333.4, a survey shall be made by authorized personnel upon the first entry to the area after accelerator operations have terminated.

6. The number, issue and use of keys shall be strictly controlled where locked entryways are used to control access to High and Very High Radiation Areas (see FRCM Chapter 10).

7. The RSOs should be aware of the location of potential High and Very High Radiation Areas within their respective areas of responsibility.

8. Visual inspections, at least semiannually, of the physical access controls to High and Very High Radiation Areas should, when possible, be made and documented to verify that controls are adequate to prevent unauthorized entry.

   a. For outdoor areas, this inspection may consist of documented "drive-by" inspections of fencing and gates.

   b. For accelerator/beamline enclosures during operational periods, the physical access controls to accomplish this objective is provided by the accelerator/beamline interlock systems specified in Chapter 10 of this Manual.

334 Contamination, High Contamination and Airborne Radioactivity Areas

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

   a. Radiological Worker Training.

   b. Radiation dosimetry monitoring badge

   c. Written authorization (e.g., a RWP) to enter the area by the assigned RSO or designee.

   d. Protective clothing as specified by the assigned RSO or designee.

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

   a. Radiological Worker Training.

   b. Radiation dosimetry monitoring badge

   c. Written authorization (e.g., a RWP) to enter the area by the assigned RSO or designee.

   d. Pre-job briefing for High Contamination or Airborne Radioactivity Areas

   e. Protective clothing as specified by the assigned RSO or designee.

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

    a. Remove any protective clothing as specified in Appendix 3B.

    b. Perform frisking to detect personnel contamination in accordance with Article 336.

4. Exit points from Contamination, High Contamination or Airborne Radioactivity Areas (if there is a possibility of contamination from airborne radioactivity) should include the following, if appropriate:

    a. Step-off pads, maintained free of radioactive contamination, located outside the exit point, contiguous with the area boundary. (Multiple step-off pads should be used at the exits from High Contamination Areas, if appropriate. Use of multiple step-off pads is described in Appendix 3B.)

    b. Labeled containers for the collection of protective clothing and equipment.

    c. Contamination monitoring equipment located as close to the contamination area exit as background radiation levels permit.

5. If there is a possibility of contamination from airborne radioactivity, tools or equipment being removed from areas posted for surface or airborne radioactivity control shall be monitored for release in accordance with Article 421 or 422.

6. Administrative procedures shall be developed as necessary to implement area access controls. These procedures shall address measures implemented to ensure the effectiveness and operability of entry control devices, such as barricades, alarms, and locks.

7. Chapter 5, Part 2 describes the requirements and procedures of Fermilab's internal dosimetry program.

335 Special controls for Limiting the Spread of Contamination in the Workplace

The measures given below should be used in general to prevent the spread of contamination across the boundary of Contamination Areas, High Contamination Areas and Airborne Radioactivity Areas. Note that for Airborne Radioactivity Areas, these measures are more appropriate for airborne particulate contamination rather than air activation, which is the most likely source of an Airborne Radioactivity Area at Fermilab. Article 235 and Tables 2-2, Table 2-3 and 2-5 establish the standards for dealing with radioactive contamination and the posting of contamination areas. More specific details concerning practices at Fermilab are given in Appendix 3B and 3C.

1. Use solid barriers to enclose areas wherever practicable.

2. Mark and secure hoses, pipes, or systems that may transport contaminated fluids when:

   a. the activity level of the contaminated fluid exceeds that permitted for surface discharge (see Article 346 and FRCM Chapter 11), and,

   b. access to such hoses, pipes and systems by unauthorized personnel is possible.

3. Control and direct airflow from areas of lesser to greater removable contamination in areas where significant airborne contamination is credible (or turn off airflow systems) unless the ventilation is established to allow for the decay of radioactive materials prior to exhaust.

4. Use engineering controls and containment devices such as glovebags and tents with HEPA ventilation where appropriate.

5. Experience at Fermilab indicates that contamination should be suspected and wipe surveys should be performed (or control measures taken if wipes are not appropriate) in the circumstances listed below:

   a. **Radioactive Water ("RAW") or Closed Loop Cooling Water:** See also Article 346. The water (or water/glycol mixture) in closed loop systems used to cool targets, beam absorbers, or other high beam loss components, may contain high concentrations of tritium and other radionuclides. See Chapter 8 and references therein for a more complete discussion of the production of radionuclides in water. The following are synopses of the major radionuclides found in water:

      1) Tritium (^3H), a low energy beta emitter, is the isotope of greatest concern because of its long half-life. Other radionuclides produced in water are normally trapped in ion exchange resins. Tritium can enter the body through ingestion, absorption through the skin by contact with the water and by inhalation of tritiated water vapor.

      2) ^7Be is produced by the spallation of oxygen in water. It is easily removed from the water by the resins used to keep the water conductivity low. When resins are regenerated, the

^{7}Be is extracted and collected with other radionuclides in particulate form and disposed of properly. Special waste management requirements may apply. At the present time, a settling tank is used to collect the radionuclides and salt from the regeneration of resins.

3) ^{11}C and other shorter-lived nuclides such as ^{13}N and ^{15}O are also produced by oxygen spallation and emit 0.511 MeV gamma rays. The 20-minute half-life of ^{11}C is long enough that water can be transported from the beam loss point inside an interlocked area to a location outside, such as a heat exchanger, and still have sufficient activity remaining to pose an external radiation hazard.

4) In addition to radioactivity directly produced in water, water can pick up activity from objects through which it passes. Radionuclides found include ^{22}Na from spallation of aluminum, ^{45}Ca and ^{54}Mn from copper and iron, ^{60}Co from stainless steel, and ^{175}Hf from tungsten. These radionuclides are also absorbed by resins in deionizer bottles. Closed-loop water systems are sampled at regular intervals to measure their radioactivity levels. When the specific activity exceeds the limit specified in Article 346.5, the water is to be removed and disposed of as radioactive waste. This is done in order to limit the concentration and total amount of radioactivity in the event of a leak or accidental spill.

b. **Machining of Radioactive Material:** Machining operations (cutting, welding, grinding, filing, drilling, etc.) on radioactive items will produce small particles that may constitute radioactive contamination. Containment or collection of dust or "chips," protective clothing, wipe surveys, and decontamination after the work are usually sufficient controls. There is no on-site machine shop specifically designated for the machining of radioactive items. Small radioactive objects can, however, be machined at various on-site shops, if precautions similar to those outlined in this Article are taken, and only with the approval of the assigned RSO.

c. **Vacuum Pumps:** Tritium in the form of tritiated water vapor may be removed by vacuum pumps which service beam transport lines and around beam absorbers and targets. Since the volumes of air pumped are quite small when the vacuum is maintained, the exhaust can be vented to the atmosphere without restriction. However, tritiated water can accumulate in the pump oil or in the exhaust line, especially if there is a water leak into the vacuum (at a water-cooled target or dump, for example). In the case of a water leak into the vacuum, the concentration of tritium can be quite high in the pump reservoir, water separator, and exhaust line. Concentrations of tritiated water 50 times higher than closed-loop water system concentrations have been observed (5 mCi/ml in the worst case to date with no other radionuclide present to indicate high concentrations if one used a survey meter).

d. **Items from Beamline Enclosures**: An item that has been in an operating primary beamline has the potential to become radio activated and contaminated. Consideration shall be given to the "condition" of the item. For example, grease or oil may have been used as a lubricant inside (internal bearings), paint may have flaked, rust may have formed, etc. Experience indicates that removable contamination should be suspected where a beamline component's residual radiation level exceeds 100 mrem/hr. at one foot. Contamination may be found at lower dose rates if the item has easily removable material associated with it.

e. **Depleted Uranium Work:** Areas where depleted uranium is being handled (e.g., for calorimeter assembly or disassembly) may present removable surface contamination and potential airborne hazards due to the possible removal of uranium oxide from the plates. Uranium work may occur only in designated areas where specific controls and procedures have been established. See Article 361 for additional guidelines related to uranium work.

f. **Hazardous Materials:** Materials exist which, by their chemical or physical nature, are generally considered hazardous (see Fermilab ES&H Manual Chapter 8021). These materials if exposed to the accelerator beams may become radioactive, thus posing a dual hazard. These materials, if activated, may require special treatment at the time of disposal (see Fermilab ES&H Manual Chapter 8021) and are commonly called “mixed waste”. Their use in beamline enclosures should be avoided to the extent possible, and otherwise minimized (see Fermilab ES&H Manual Chapter 8021 and 8022).

g. **Radioactive Sources:** Radioactive sources are used throughout the technical areas of the Laboratory for experiments, reference measurements and calibrations. Sources may be damaged through abrasion, dropping, electrical arcs, or other types of industrial accident. Any breach of integrity of the source or its container can cause the spread of contamination.

6. Further specific techniques found at Fermilab to prevent the creation and spread of contamination are given below. Consult Appendix 3B for more information.

   a. Careful selection of target materials based on past experience, avoiding materials that would vaporize, oxidize or flake.

   b. Coating surfaces to prevent oxidation. Activated oxides are easily removed and transported.

   c. Disposal of unused activated materials in accord with Laboratory-approved procedures. Good housekeeping will reduce the risk of the spread of contamination.

   d. Store activated materials in designated areas. Consult Article 415 for proper storage procedures for radioactive materials.

336 Monitoring for Personnel Contamination

See Appendix 3B for more details on contamination control and decontamination procedures.

1. Personnel shall perform a frisk as directed by the RWP, verbally by members of the Radiological Control Organization, or as posted (i.e., flowcharts). The frisk shall cover, at a minimum, the hands, feet, other body parts and clothing that may have touched potentially contaminated surfaces (i.e., kneeling on the ground or leaning against a beamline component). Frisks of the hands and

feet may be recommended or required, as appropriate, by the assigned RSO or designee upon exiting collision halls or experimental halls.

2. Where frisking cannot be performed due to high background radiation levels (e.g., > 100 cpm on a frisker) at the exit, personnel shall:

   a. Remove all protective equipment and protective clothing at the exit and handle these materials as directed.

   b. Proceed directly to the nearest designated monitoring station.

   c. Conduct a frisk as specified above.

   (At Fermilab, such high background levels may be due to the presence of activated components, cooling water pipes, or muon radiation fields in the vicinity.)

3. Personnel frisking shall normally be performed before removal of protective clothing. If contamination is found, then a whole-body frisk shall be performed after removal of protective clothing. In all cases, a frisk of the bare hands shall be performed after removal of protective clothing.

4. Personnel frisking shall be performed using instruments that can detect contamination levels of at least the values specified in Table 2-2. Instruments for frisking are provided and calibrated by the Environment, Safety, and Health Section.

5. The use of automated personnel contamination monitors is encouraged where available. At Fermilab, the use of these expensive items of capital equipment is restricted to locations where continuous operations with the potential for contamination exist.

6. Personal items, such as hardhats, notebooks, papers and flashlights, shall be frisked if the person carrying them must frisk.

7. Guidelines for personnel frisking are provided in Appendix 3C. Instructions for personnel frisking should be posted adjacent to or attached directly to personnel frisking instruments or monitors.

   Personnel are considered contaminated by β–γ if a pancake type GM instrument reads 100 or more counts per minute above background at contact in a low background area (≤ 50 cpm). If personnel contamination is found, call 3131 and report that a person has been contaminated.

8. The personnel frisking requirements contained in this Article are not applicable in those instances where only radionuclides, such as tritium, that cannot be detected by currently available hand-held or automated frisking instrumentation are present. For these situations, reliance should be placed on worker bioassay and routine contamination and air sampling programs.

337 Controlled Access Requirements

A Controlled Access is a means by which two or more people may safely enter an interlocked enclosure. A Controlled Access is typically used instead of a Supervised Access when it is desired to efficiently resume operation after an access. Because a controlled access does not involve a full radiation survey, configuration control, or searching and securing the enclosure, it minimized disruption to accelerator operations.

Personnel entering enclosures under controlled access conditions are subject to increased hazards due to a reduction in the level of protection. Because of this, personnel making controlled accesses must have additional training in order to know what safeguards have been reduced and to understand the procedures necessary to ensure their safety.

This Article contains only summary information. More details of actual practice are provided in the content of the Controlled Access Training Course and associated handout (Fermilab Course FN000311/CR – "Fermilab Controlled Access").

1. Controlled Access Rules

   Personnel who violate the rules pertaining to controlled access are subject to disciplinary action. See FRCM Article 111. For employees, this may include revocation of Controlled Access qualification, leave without pay, and possible termination. Non-employees may be denied use of Fermilab facilities.

   a. Training Rules

      1) Training will be verified for each individual prior to making a Controlled Access.

      2) Controlled Access and Radiological Worker Training status must be current.

      3) Based upon the location of the work and the nature of the tasks to be performed, other ES&H training requirements such as Lockout/Tagout (LOTO) and Oxygen Deficiency Hazard (ODH) and others may be required.

   b. Enter Key Rules

      1) Enter keys for most Accelerator Division enclosures are located at the Main Control Room (MCR). Other Enter keys are located at remote key trees near the enclosure entrances.

         (a) Ensure that at least one Enter key is left in the key tree in case emergency access to the enclosure is required.

      2) Each Controlled Access qualified individual will be issued an Enter key for the enclosure(s) to be accessed.

         (a) Each person on a Controlled Access shall verify they have the correct Enter key for the enclosure to be accessed.

         (b) Each person on a Controlled Access shall maintain control of the Enter key they have returned it.

(c) Each person on a Controlled Access shall have the Enter key issued to them physically on their person while in an interlocked enclosure.

3) No individuals to whom Controlled Access Enter keys are issued shall ever give the Enter key to another individual, even if they know he/she is qualified to make controlled accesses. The Enter key is assigned only to specific, named individuals.

4) No individual on a Controlled Access possessing the correct Enter key for the area to be entered shall ever permit entry to another person who does not have the correct Enter key for the area entered. Thus, each individual on a Controlled Access is responsible for checking that everyone who makes the Controlled Access with them possesses the correct Enter key. Each person entering an interlocked enclosure must physically display his/her Enter key to other personnel participating in the access.

5) Enter keys used to make Controlled Access shall not be removed from the Fermilab site.

6) Each individual shall personally return their Enter key to the MCR or remote key tree as soon as the Controlled Access has been completed.

c. <u>Pre-Tunnel Rules</u>

1) RWP

(a) Read the Controlled Access RWP for the enclosure to be accessed, if an RWP exists, and completely fill out the sign in sheet. Each individual must do this each time they obtain an Enter key, even if they have made an access earlier in the day. RWPs are not static documents. Entrants may encounter conditions during a Controlled access that can result in the RWP being altered. Different requirements may then apply to subsequent accesses.

(b) Each individual on a Controlled Access shall verify that the Enter key they were issued corresponds with the enclosure they are entering by checking the Enter key barcode number on their Enter key against the range specified on the Controlled Access RWP sign-in sheet. This 4-5 digit barcode number is what the RWP sign-in sheet is asking to be written down, not the enclosure sequence number (typically 1-2 digits).

(c) If the applicable RWP requires an LSM for the enclosure to be entered: each individual on the Controlled Access shall obtain an LSM from the MCR or Radiation Safety personnel, perform checks (calibration check, look for damage, battery check, & source check), and make sure you know how to properly use the instrument. See “Fermilab Controlled Access Training” training for more information.

2) LOTO

(a) MCR Group LOTO Boxes – Certain enclosures require LOTO II training and have group LOTO boxed in the MCR. Enclosures with group LOTO boxes will be noted on the RWPs for those enclosures. If the enclosure to be entered has a group LOTO box, all individuals entering that enclosure are required to follow LOTO requirements and place their individual LOTO lock on the appropriate group LOTO lock box prior to accessing the enclosure.

(b) General and Written LOTO – Perform LOTO on individual components in accordance with Fermilab ES&H Manual (FESHM) Chapter 2100, Fermilab Energy Control Program (Lockout/Tagout).

3) Group Check Enter Keys at the Enclosure Entrance

(a) **Possession of the correct Enter key is the required and best way to protect access participants from direct beam-on radiation and electrocution hazards, therefore the Enter key is required for entry into enclosures.** In order to ensure that everyone making a controlled access has the correct Enter key in their possession, all members of the access party are responsible for physically displaying their Enter key to everyone else, and also visually verifying everyone else's Enter key before accessing the enclosure.

d. <u>Tunnel Rules</u>

1) Two-Person Rule

(a) All Controlled and Supervised accesses are considered a hazardous work activity that requires application of the two-person rule, even if the entry will be brief and only in the immediate area beyond the gate. At least two people are required to enter the enclosure for a proper controlled access. For supervised accesses, personnel may pass through the door/gate alone only if they are joining a work group already in the enclosure. No one should never be in an enclosure alone.

2) Personal Protective Equipment (PPE)

(a) All persons making a Controlled Access shale wear the personal protective equipment (PPE) specified in the applicable RWP for the enclosure(s) to be entered and the type of work to be performed. There are tables detailing the PPE levels required for different work/tasks with the RWPs.

(b) For large jobs extending over long periods of time (such as magnet changes), a job specific RWP may be requested. In these cases, Radiation Safety may survey the work area in question and write a job specific RWP with less restrictive PPE requirements. Requirements for work in the remainder of the enclosure would be dictated by the general controlled access RWP.

3) LSM Use

(a) Each individual on a Controlled Access is responsible for surveying their work area for radiological conditions. An LSM is to be used to check radiation levels in the area where individuals are working, as required by the applicable RWP, by holding the flat portion of the LSM probe parallel to the element at a distance of 1 foot.

(b) While inside, groups may split into smaller working groups as long as each working group has their own LSM.

5) Radiological Conditions/Communication

(a) If dose rates exceed 100 mR/hr at one foot in the work area, all individuals present shall leave the area and inform the Crew Chief and the assigned RSO via the MCR. Each individual working in such a radiation field must receive permission from the assigned RSO or designee prior to beginning work.

(b) If an individual unexpectedly encounter areas where dose rates exceed 500 mR/hr. at one foot, they are to immediately leave the enclosure, check closely for contamination, and inform the Crew Chief and the assigned RSO via the MCR. The Crew Chief and assigned RSO will determine subsequent action.

6) Response to Deviations

(a) If an individual on a Controlled Access should discover that they or another person has somehow entered an enclosure without the correct Enter key, or anyone has otherwise departed from the Controlled Access procedures in a manner that could lead to a safety concern, they shall immediately exit the enclosure by opening a door or gate without following the controlled access procedure, thereby dropping the interlocks. Then they shall call the MCR and report the circumstances. Dropping the interlocks if a person is found to have entered an enclosure on Controlled Access without the proper Enter key (or other departures from the procedure) will force a search and secure to be performed before running beam in the enclosure. This is necessary because the integrity of the controlled access process has been compromised, even if the access participants think they have accounted for all personnel after it is discovered that an individual has entered without the proper Enter key.

(b) If the safety system interlocks are inadvertently broken during the controlled access, the Crew Chief must choose between the following options:

1. Transition to Supervised Access – Entrants must leave the enclosure and read and sign the Supervised Access RWP after the radiation survey maps have been appended to it.

2. Re-Secure the Enclosure

a. Immediately re-secure – Entrants must vacate the enclosure while operators secure the enclosure.

b. Wait until access has concluded and then re-secure – Entrants must continue to follow controlled access rules.

2. General Controlled Access Procedure

All controlled accesses should follow the same general procedure, including:

a. Pre-planning

b. Obtaining the correct Enter key(s) for the enclosure(s).

c. Reading the applicable RWP(s) and filling out the sign-in sheets completely for the enclosure(s) to be accessed

d. Obtaining an LSM, if applicable

e. Obtaining a personal oxygen monitor, if applicable

f. Applying personal LOTO locks and tags to appropriate group LOTO box(es), if applicable

g. Donning PPE specified in applicable RWP

h. Checking the status of the interlocks on the panel next to the gate

i. Physically displaying Enter keys to access party

(a) Before anyone inserts and turn an Enter key in the interlock enter box, the members of the access party must physically display their Enter keys to each other. Each individual's Enter key is their protection. Each individual on the access shall verify that they and everyone else on the Controlled Access have the correct enclosure Enter key before entering the enclosure.

j. Providing clear communication

k. Performing the access following steps described in the Fermilab Controlled Access training and handout

l. Returning Enter key(s) to the MCR or remote key tree after access is complete.

3. Critical Step Summary for Each Individual on a Controlled Access:

a. Obtain or call for enclosure Enter key(s) from the MCR (x3721). Verify that you have been issued the correct Enter key(s) for the enclosure(s) being accessed. Your Enter key is your protection. It is the best protection that a person on a controlled access has to mitigate direct beam-on radiation and electrocution hazards found in the enclosures. Maintain possession of your Enter key, don't give it to anyone else.

b. Read RWP(s), follow all stated requirements, and completely fill out the sign-in sheets where applicable.

c. Perform LOTO before entry if needed.

d. Ensure you have required dosimetry, instruments, and PPE.

e. At the enclosure entrance, verify that you and everyone on the controlled access has the correct Enter key for the enclosure being entered. Never permit entry to another person who does not have the correct Enter key for the enclosure being accessed.

f. Survey your work area for radiological conditions.

g. If you hear a warning sound or message, drop the interlocks and exit immediately and call the MCR.

h. If you should discover that you or another person does not have possession of the correct Enter key, or you have otherwise departed from the controlled access procedure in a manner that could lead to a safety concern, immediately exit the enclosure without using the controlled access procedure, thereby dropping the interlocks. Then call the MCR (x3721) and report the circumstances.

PART 4 RADIOLOGICAL WORK CONTROLS

341 Requirements

1. Radiological work activities should be conducted as specified by applicable Radiological Work Permits or technical work documents.

2. Prerequisite conditions, such as tag-outs and system isolation, should be verified before work is initiated.

342 Work Conduct and Practices

1. Contamination levels caused by ongoing work shall be monitored and maintained ALARA. Work should be curtailed and decontamination performed at pre-established levels, taking into account personnel exposure.

2. Tools and equipment should be inspected to verify operability before being brought into radiological areas.

3. If appropriate, the use of radiologically clean tools or equipment in Contamination or High Contamination (or Airborne Radioactivity Areas if there is a possibility of contamination from that source) should be minimized.

4. Engineering controls, such as containment devices, portable or auxiliary ventilation and temporary shielding, should be inspected prior to use.

5. The identity of components and systems should be verified prior to work.

6. Work activities and shift changes should be scheduled to prevent idle time in radiological areas.

7. Where practicable, parts and components should be removed to areas with low dose rates to perform work.

8. Upon identification of radiological concerns, such as inappropriate work controls or procedural deficiencies, individuals should immediately report the concern to line supervision and the Radiological Control Organization.

9. Requirements for area cleanup should be included in the technical work documents and/or RWPs. Work activities should not be considered complete until support material and equipment have been removed and the area has been returned to at least pre-work status.

10. To minimize intakes of radioactive material by personnel, smoking, eating, drinking, applying cosmetics, chewing, or loitering shall not be permitted in Contamination, High Contamination or Airborne Radioactivity Areas or in other radiological areas where the Radiological Control

Organization has determined that there is the potential for an ingestion hazard. When a potential exists for personnel heat stress, drinking may be permitted within a Contamination Area under the following conditions and controls:

a. The potential for heat stress cannot be reduced by the use of administrative or engineering controls.

b. All drinking is from containers or sources approved by the assigned RSO or designee.

c. At a minimum, the individual's hands and face are to be monitored for contamination prior to drinking.

d. Participating workers are monitored as applicable.

e. The applicable requirements and controls are described in approved procedures.

11. Special procedures pertinent to work in Fermilab accelerator/beamline enclosures are covered in Article 355. Article 355 should be used for general guidance on pre-job planning, pre-job briefings and post-job reviews for radiological tasks.

12. **Continuous supervision** by radiation safety personnel (or other individuals trained for such work by the assigned RSO) shall be provided whenever anyone is working in an area with accessible spaces having dose rates over 1 rem/hr. Areas marked and fenced off by rigid barriers are not considered accessible. Such supervision is also strongly recommended when personnel are working for an extended time in areas with dose rates over 100 mrem/hr. (i.e., High Radiation Areas). The decision to require such supervision should be made by the assigned RSO on the basis of the nature of the work, the dose rates and estimated doses for the job, and the training and reliability of the personnel involved.

13. **Off Site Machining:** Circumstances may require that radioactive material be sent to an off-site shop for machining, repair, etc. Procedures found acceptable in the past for sending radioactive material off site to private vendors for servicing of any kind are outlined below.

a. All off-site shipments of radioactive material must be coordinated through the ES&H Section.

b. If off site machining of radioactive material is planned, the ES&H Section shall be contacted as early as possible in order to properly coordinate this work. Such arrangements can be time-consuming and must be handled on a case-by-case basis.

c. The off-site recipient normally must possess a valid license (either USNRC or Agreement State) or be a DOE-license exempt prime contractor authorized to receive, possess, and utilize the material in the manner intended.

d. The Laboratory is responsible for verifying whether or not the recipient possesses such a license. The license must cover not only possession, but also any operations that may be intended, such as machining or waste generation. The recipient is responsible for radiation safety aspects of work done under the provisions of the license.

e. Alternative arrangements involving the machining of radioactive materials by facilities that do not meet the requirements of part c. (above) will be developed on a case-by-case basis with a written plan coordinated between DOE and the applicable regulatory authorities. Prior concurrence with these authorities will be required. In general, the Laboratory will be required to assume responsibility for transportation, operational radiation safety, and radioactive waste disposal, if any, unless other arrangements can be made. The State or USNRC will likely have regulatory overview responsibility and authority.

f. Any communications with State agencies or the USNRC will be coordinated with DOE.

14. Eating and drinking are prohibited in areas where sealed radioactive sources or radioactive material are in use.

343 Response to Abnormal Situations

The Fermilab Comprehensive Emergency Management Plan (CEMP) has established requirements for all abnormal situations that may affect the environment, safety and health. This plan is comprehensive and includes appropriate radiological control measures. FESHM 8030 documents responsibilities for spill prevention, response, and remediation and outlines general procedures to be taken in the event of a spill or release. It requires the preparation of local plans for response to spills and releases from their equipment and/or areas. Plans also identify emergency procedures and necessary notifications.

344 Controls for Bench Top Work, Laboratory Fume Hoods, Sample Stations and Gloveboxes

The following are applicable to radiological work that has the potential to generate radioactive contamination in localized benchtop areas, laboratory fume hoods, sample stations, and glovebox operations located in areas that are otherwise contamination free.

1. A job-specific Radiological Work Permit (RWP) or equivalent should be issued to control radiological work in localized areas, laboratory fume hoods, sample sinks, and glove boxes.

2. The following controls apply to glovebox operations:

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

   b. Gloveboxes should be posted with survey measurements and other pertinent information as appropriate to identify whole body and extremity dose rates, as appropriate and other radiological protective measures.

345 Controls for Highly Activated Material Fragments or Particles

Activated material fragments or particles are small, discrete, highly radioactive and capable of causing high doses to a localized area in a short period of time. While the presence of such fragments or particles is rare at Fermilab, they do occur under some conditions. Contamination of this type may be present as a result of corrosion, generated when contaminated systems are opened, or when highly radioactive materials are subjected to mechanical stresses (cutting, grinding, or other machining, flaking or vibration) resulting in minute fragments. The Radiological Control Organization will verify the existence of such contamination and determine the appropriate controls.

1. Work being performed with the potential to generate this type of contamination shall be controlled by a job specific RWP. The RWP should address respiratory protection, as these fragments or particles may or may not be breathable.

2. Posting should be annotated to specifically identify the presence or potential for this type of contamination.

3. Survey techniques should be modified to detect activated material fragments or particles (refer to Article 423 for further details).

4. Additional controls should be imposed if highly activated materials with the potential to generate this type of contamination are to be transported (refer to Article 423 further details).

5. Contamination controls (i.e. sticky mats, material packaging) should be instituted to prevent the spread of this type of contamination.

6. Report any radiological problems and concerns, along with any corrective actions, to the assigned RSO.

7. The SRSO or designee should be consulted if new contamination of this type is confirmed to be present.

346 Control of Radio activated Cooling Water

In addition to worker protection measures discussed in Article 335.5 that primarily pertain to contamination controls for closed loop ("RAW") water systems, the management of all systems involving radio activated water must inevitably include considerations pertaining to environmental protection requirements. See FRCM Chapter 11, notably Article 1106, and FESHM Chapter 8025 and 8026 and references therein for a more complete discussion of the environmental protection measures pertaining to the production of radionuclides in water. The focus of this Article is on management of radio activated cooling water within beam enclosures and related support facilities from the perspective of mitigation the risks of spills or unplanned discharges related to protection of occupational radiation workers.

1. Closed-loop water systems ("RAW" systems) associated with target stations and beam absorbers exceeding the Derived Concentration Standards discussed further in Chapter 11, Article 1106, shall be labeled “Caution, Contaminated Liquid” and with the known levels of radionuclide concentration. Above the DCS value, work on such systems constitutes radiological work due to exposure to this pathway alone, given the correlation of one DCS with the receipt of 100 mrem in a year for a hypothetical person using water at this concentration as their sole source of domestic (i.e., “household”) water.

2. Connections between accelerator cooling water systems and drinking water systems are prohibited.

3. Precautions shall be taken to reduce the possibility of accidental spills that could result in releases to surface waters. The precautions required will depend on both the radionuclide concentrations and total activity in the system and will be determined by the assigned RSO with the approval of the SRSO or designee. These precautions may include one or more of the following measures:

    a. Locking (where possible) and labeling of all associated plugs and valves.

    b. Using a retention pit, tank, or container to collect any water that leaks.

    c. Using a remote alarm to warn the operating crew when a leak occurs.

    d. Applying controls on make-up water to prevent overflow of the retention system and backflow into the supplying water system.

    e. Applying controls on sump pumps so that they may be temporarily disabled in case a closed-loop system leaks into the sump.

    f. Managing the discharges to sumps that may lead to sanitary sewers in a manner that incorporates the requirements of DOE Order 458.1 concerning discharges to sanitary sewers. (See FRCM Chapter 11, Article 1106.)

4. To limit the severity of any possible accidental release of radioactive water, closed-loop systems shall be evaluated periodically for draining and refilling before their specific activity reaches 1.0 microCi/ml for tritium in water. This evaluation should be done by the assigned RSO. Both potential occupational and environmental radiation exposures should be considered as part of making the decision to drain and refill such a system.

347 Control of Airborne Radioactivity

This section outlines precautions for protection against contamination and exposure of individuals by releases of radioactive gas and airborne particulate from beam enclosures, target stations, vacuum systems, and operations such as welding or grinding. It also addresses the problems associated with radio activation of air. Airborne radioactivity released to the environment is addressed further in FRCM Chapter 11, Article 1107.

1. Derived Air Concentrations (DACs) for radiological workers (corresponding to 5 rem/year) are given in 10 CFR Part 835 Prominent examples are given in Table 3-1. For radionuclides not listed, 10 CFR Part 835 should be consulted for occupational exposures and exposures to members of the public, respectively.

2. Since mixtures of radionuclides are commonly encountered at accelerators, one evaluates the sum of the ratios of the concentrations of the individual radionuclides to their individual DAC values. This <u>weighted-sum rule</u> of the mixture is, then, the fraction of the DAC for the mixture and is given by the following inequality:

$$\sum_i \frac{C_i}{DAC_i} \leq 1,$$

   where C_i is the concentration and DAC_i is the DAC value for the i^{th} radionuclide.

3. Retrospective Air Monitoring (air sampling during facility operations, followed by later analysis) shall be performed in occupied areas where weighted-sum of the concentrations is likely to exceed 0.1 on a time-weighted basis averaged over an 8-hour period. Accelerator/beamline enclosures that are exclusion areas do <u>not</u> require such monitoring <u>during</u> operations. Examples of retrospective monitors would be a personal air monitor, or an area monitor that collects particulate on a single filter and provide a single, integrated result.

4. Continuous air monitoring shall be performed in occupied workplace areas where the weighted sum of the concentrations divided by the DAC values exceeds unity. See Article 554 for more information.

5. For radionuclides that represent immersion hazards such as those addressed by 10 CFR 835 Appendix C, 10 CFR 835 permits adjusting the values of the DACs for air spaces of finite sizes. See Fermilab RP Note No. 158 for more discussion of such adjustments.

6. If retrospective air monitoring is performed and the results demonstrate that the temporary increases above the mean air concentrations do not exceed the DAC values, then it is permissible to rely solely on retrospective monitoring. If the retrospective monitoring indicates that 1.0 DAC was exceeded, then the assigned RSO shall conduct an investigation of the exposures of the persons involved.

7. Radiological Control Organization personnel shall evaluate hazards due to airborne radioactivity to assure that the instrumentation is properly chosen for the physical state (particulate or gaseous) of the radioactivity involved. See Appendix 5E for more information on detection methods.

8. Regarding the control of airborne radionuclides, the design objective shall be, under normal conditions:

   a. to avoid releases to the workplace atmosphere and in any situation,

   b. to control the inhalation of such material by workers to levels that are ALARA;

   c. to provide confinement including allowing for decay, and to provide appropriate ventilation.

Table 3-1 Derived Air Concentrations (DACs, 10 CFR 835) for occupational workers for airborne radionuclides commonly encountered at Fermilab. *

Isotope	**DACs - Radiation Worker 5 rem/year <u>40 hours/week exposure</u>**	
	($Bq\ m^{-3}$)	($pCi\ ml^{-1}$)
^{3}H (H_2O vapor)	**7.0E05**[a]	20.0[a]
^{7}Be	**4.0E05**[a]	10.0 [a]
^{11}C	**7.0E04**[b]	1.0[b]
^{13}N	**7.0E04**[b]	1.0[b]
^{15}O	**7.0E04**[b]	1.0[b]
^{22}Na	**1.0E04**[a]	0.2 [a]
^{24}Na	**1.0E04**[a]	0.4 [a]
^{38}C	**2.0E05**[a]	5.0[a]
^{39}Cl	**1.0E05**[a]	2.0[a]
^{41}Ar	**1.0E05**[b]	3.0 [b]
^{46}Sc	**4.0E03**[a]	0.1 [a]
^{51}Cr	**5.0E05**[a]	10.0 [a]
^{77}Br	**7.0E04**[a]	2.0 [a]
^{82}Br	**1.0E04**[a]	0.3 [a]

[a]Taken from 10 CFR 835 Appendix A, as amended April 2011 with most conservative choice of lung absorption type.
[b]Taken from 10 CFR 835 Appendix C, as amended August 2017.
[c]Taken from 10 CFR 835 Appendix C, as amended August 2017 as "default values" for radionuclides not specifically listed in Appendix C.
*Due to the origin of these values from primary references published International Commission on Radiological Protection (ICRP), the values given in SI units (i.e. $Bq\ m^{-3}$) should be taken as the primary values. Due to "round-off" customary in published regulations, the values in the customary units of $pCi\ ml^{-1}$ do not constitute exact matches to the SI values via the conversion factor 2,703E-05 ($pCi\ ml^{-1}/Bq\ m^{-3}$)

348 Radiological Stop Work Authority

1. Members of the Radiological Control Organization, ES&H Section Staff, Radiological Control Technicians and their supervisors, line supervision, and any employee has the authority and responsibility to stop radiological work activities for any of the following reasons:

   a. Inadequate radiological controls.

   b. Radiological controls not being implemented.

   c. Radiological Control Hold Point not being satisfied.

   d. Discovery of any non-radiological hazard that renders the operation unsafe.

2. Stop radiological work authority and work restart authority shall be exercised in accord with the provisions of Fermilab ES&H Manual Chapter 1010.

PART 5 FERMILAB ALARA (AS LOW AS REASONABLY ACHIEVABLE) PROGRAM

351 Fermilab ALARA Policy

Fermilab's ALARA policy is to conduct its activities in such a manner that worker and public safety, and protection of the environment are given the highest priority. Fermilab management is committed, in all its activities, to maintain any safety, health, or environmental risks associated with ionizing radiation or radioactive materials at levels that are As Low As Reasonably Achievable (ALARA).

1. Definition of ALARA

ALARA is an approach to manage and control exposures (individual and collective) to the work force and to the general public at levels as low as is reasonable, taking into account social, technical, economic, practical and public policy considerations. As used in this document, ALARA is not a dose limit, but a process that has the objective of attaining doses as far below the applicable limits as is reasonably achievable.

2. Management Commitment

Fermilab management is committed to use the ALARA process as described in the above definition. The commitment and support of Fermilab line management to the ALARA Program, as stated in this Article, is demonstrated by:

   a. Communicating this policy to all employees, users and contractors.

   b. Providing the personnel and resources for line management to implement the ALARA program effectively.

   c. Holding line management and all employees accountable for effectively implementing the program.

   d. Providing repeated emphasis of the importance of management's commitment to the ALARA principle.

3. Participation in the ALARA Program

   Participation in the ALARA program is required of all divisions/sections.

4. Radiation Safety Subcommittee of the Fermilab Environment, Safety, and Health Committee (FESHcom)

   One of the functions of the Radiation Safety Subcommittee (RSSC) is to serve as Fermilab's ALARA Committee. The official charter is posted on ES&H DocDB at: https://esh-docdb.fnal.gov:440/cgi-bin/ShowDocument?docid=812.

5. Training

Radiological training programs, including those for general employees, Radiological Workers, and Radiological Control Technicians shall incorporate relevant ALARA issues in order to heighten individual awareness of ALARA and inform the participants of their responsibilities with respect to the program's implementation.

6. Assessments

ALARA considerations are included in the assessments required by Article 122.

7. Optimization Methodology

The International Commission on Radiation Protection (ICRP) methodology for optimization of radiation protection is that all exposures shall be kept as low as reasonably achievable with economic, practical, environmental, technological, public policy and societal factors taken into account. Optimization is achieved when an option is selected and implemented which yields the minimum exposure possible for a reasonable and acceptable cost. Optimization techniques, sometimes including cost-benefit analysis, represent a fundamental part of radiological design analysis and work review. Because it is often impractical to perform quantitative cost-benefit analysis, qualitative assessments, which are an intrinsic part of the engineering review process, may be acceptable.

352 Responsibilities

1. Laboratory Director

The Laboratory Director is responsible to ensure that the authority, accountability and resources are assigned to all levels of the organization to implement the ALARA program and achieve the approved goals.

2. Division/Section Heads

Ensure that plans, procedures, equipment, new facilities, facility modifications, new experiments and research programs are reviewed for purposes of maintaining radiation doses, the spread of radioactive contamination, and the release of radioactive effluents at levels that are ALARA.

3. Senior Radiation Safety Officer

   a. Concur in the appointment of the Laboratory ALARA Coordinator(s).

   b. Provide technical assistance for maintaining exposure as low as reasonably achievable, including but not limited to training, evaluation of radiological work procedures, and review of new facility design and facility modifications.

   c. Review and submit to the Laboratory Director for approval, ALARA plans for any planned operation where the Laboratory's annual administrative exposure control goals may be exceeded.

   d. Develop and implement a radiological environmental monitoring program adequate to determine the effects of the Laboratory's radioactive effluents on the environment and the resulting radiation doses to the general public.

4. Laboratory ALARA Coordinator(s)

   a. Provide technical support and assistance to management and staff in the implementation of the ALARA program.

   b. Review alert list exposure investigations submitted by division/section radiation safety representatives.

   c. Maintain a central file of division/section formal ALARA reviews and ALARA documentation.

   d. Develop, document, review and revise elements of the ALARA program based on division/section input.

   e. In the present centralized ES&H organizational structure, Radiation Safety Officers (RSOs) may collectively act as ALARA Coordinators for the Laboratory, as this structure allows for continuous oversight of Lab activities by all RSOs simultaneously.

5. Radiation Safety Officers or Points of Contact

   a. As a part of the ALARA process, assigned RSOs or points of contact, if no assigned RSO has been appointed, should review exposure reports for personnel within their division/section. Any unusual or above normal exposures should be investigated and reported to the ES&H Section Dosimetry Program Manager as outlined in Articles 572 and 573.

   b. Serve on the Radiation Safety Subcommittee.

c. Provide technical support and assistance to supervisors, planners, schedulers, and design engineers in the implementation of the radiological design and control elements of the ALARA program.

d. Develop, document, and review the radiological design and control elements of the ALARA program consistent with the ALARA policy and procedures.

e. Review selected procedures involving radiological work, high dose/contamination jobs, and facility design changes for the purpose of recommending improvements to maintain dose, the spread of radioactive contamination, and the release of radioactive effluents at levels that are ALARA.

f. Provide technical support for the installation and uses of shielding and containments.

g. Collectively act as Fermilab ALARA Coordinator(s).

6. Radiological Control Technicians

a. As directed, conduct radiological surveillance, establish exposure and contamination controls, and prescribe protective requirements during radiological work to maintain dose, the spread of radioactive contamination, and the release of radioactive effluents at levels that are ALARA.

b. Stop work when conditions and practices are unsafe and/or would violate DOE requirements or safety policies. See Article 348 and Fermilab ES&H Manual Chapter 1010.

c. Report any radiological problems and concerns, along with any corrective actions, to the assigned RSO.

7. Design Engineers, Schedulers and Planners

a. Engineers, schedulers and planners should seek input from Fermilab's Radiological Control Organization as early in the design process as possible.

b. Based on input from assigned RSOs and members of the ES&H Section Radiation Physics Engineering and Radiation Physics Science Teams, incorporate radiological design considerations into new facilities, modifications to existing facilities, and construction projects, in order to maintain dose, the spread of radioactive contamination, and the release of radioactive effluents at levels that are ALARA.

8. Supervisors

a. Conduct pre-job and post-job briefings; attend pre-job planning meetings and Radiation Safety Subcommittee meetings, when appropriate.

b. Ensure that employees under their direction receive the appropriate training.

c. Carry out operations under their area of responsibility in such a manner that doses to workers, researchers, and the general public and releases to the environment are maintained ALARA.

d. Report radiological accidents, incidents, and other unsafe radiological conditions or workers' radiological concerns, as necessary, and any associated corrective actions to the assigned Radiation Safety Officer.

e. Review operating procedures to determine if controls have been established to maintain exposures ALARA.

f. Ensure that employees under their supervision use proper techniques to maintain exposures ALARA.

9. Individual Worker

a. Maintain his or her own, and to the extent possible, his or her coworker's radiation exposure to levels that are ALARA.

b. Minimize the spread of radioactive contamination and release of radioactive effluents.

c. Observe requirements of all radiological signs, postings, radiological work permits and radiological procedures. Follow instructions given by radiological control personnel.

d. Attend pre-job and post-job briefings.

e. Report any radiological problems and concerns, along with any associated corrective actions, to his/her first-line supervisor.

353 Radiological Design Review

ALARA design review phases include dose assessment, review of radiological conditions, identification of the applicable radiological design criteria, and consideration of optimum alternatives using ALARA optimization methods. A design review package should incorporate and document features to maintain dose, the spread of radioactive contamination and the release of radioactive effluents at levels that are ALARA. ALARA design review elements are contained in FRCM Chapter 8 and also FRCM Chapter 11.

354 ALARA Trigger Levels and Required Approvals

The following trigger levels, assessed in advance, require a formal ALARA review of non-routine or complex work activities. If any of the trigger levels are met, a formal ALARA plan and accompanying

RWP is required. If trigger levels are not met, ALARA plans and/or RWPs may be created at the assigned RSO's discretion. These ALARA trigger levels are:

1. Collective doses estimated to be greater than 1000 person-mrem for the task.

2. Work is to be done in radiation fields in excess of 1000 mrem/hr.

3. Predicted airborne radioactivity concentrations that would require posting as an Airborne Radioactivity Area (See Article 235).

4. Work in areas having removable contamination greater than 10 times the values in Table 2-2. At the discretion of the assigned RSO, the formal radiological review may be waived if the extent of contamination is confined to small, localized areas and is unlikely to be disturbed by the work activity.

5. Potential radioactivity releases to the environment in excess of the limits specified by DOE Order 458.1. See also FRCM Chapter 11.

The following approvals are required for non-routine or complex work activities:

6. Prior approval by the assigned RSO: The prior written approval of the assigned RSO is required before any individual may undertake work that is likely to cause his/her dose for the week to exceed 200 mrem.

7. Prior approval by the Senior Radiation Safety Officer (SRSO): When work is to be done in areas where the dose rate accessible to personnel during the work can realistically deliver more than 20 % of the annual limit of dose in a one hour period to the person or critical organ (e.g., skin or extremity) specified in Table 2-1, approval of the SRSO shall be obtained in advance.

    a. "Realistically deliver" means that for this requirement to be applicable, this person would be anticipated to work in a radiation field of this intensity or place a critical organ in the radiation field for a duration of time sufficient to deliver this dose.

    b. Entry into or work in areas in which the dose rate exceeds 1 rem/hr. is prohibited without continuous radiation safety supervision. The assigned RSO shall require the use of two or more RCO personnel to supervise work conducted when the exposure rates exceed 1.0 rem/hr. (see Article 234.8 - 234.10, Article 333.

8. Prior approval by the SRSO: When the total collective dose to all personnel can be expected to exceed 1 person-rem, approval of the SRSO shall be obtained in advance (see Article 234).

9. Prior approval by the SRSO for minors working in Radiological Areas or Radioactive Materials Areas (see FRCM Article 931).

10. Prior approval by the Laboratory Director as advised by the Chief Safety Officer and supported by the Senior Radiation Safety Officer is required prior to entry of personnel into Very High Radiation Areas (see Article 333).

11. Provisions pertaining to the transportation of radioactive items are provided in FRCM Article 423.

355 Formal ALARA Review Elements

Radiological work, maintenance, operations, construction, modifications or research activities that are estimated to exceed trigger levels specified in Article 354 require a formal documented ALARA review. Tasks in which the trigger levels listed in Article 354 may be exceeded include such work as target pile disassembly, target work, work on or near accelerator or beamline extraction devices.

The purpose of this review is to ensure the effective implementation of controls to maintain dose, the spread of radioactive contamination, and the release of radioactive effluents at levels that are ALARA. This review should consider the following elements, as applicable:

1. <u>Pre-Job Planning</u>

   Pre-job planning should include the following assessment of tasks for optimum approach and dose estimates.

   a. Development of a pre-job estimate of collective dose to be incurred for the job. An estimate should be made of the maximum dose that each person will be allowed to receive for this job based on the approximate length of time each person stays in the radiological area. This should be greater than the time required for that person's particular task, to allow extra time for mistakes and unforeseen problems.

   b. Plans may be made for timing the work and checking pocket and/or electronic dosimeters at appropriate intervals to make sure that the expected exposure is not exceeded. If two or more people are to work in a high radiation area without continuous radiation safety supervision, the assigned RSO or task supervisor should designate one member of the group to ensure that proper radiation safety practices are adhered to, and that authorized dose limits are not exceeded. If dose rates > 1 rem/hr. are present, the provision of Article 342.12 shall be followed.

   c. Determination of residual radiation and contamination levels in the work area. Reduce or eliminate radioactivity in the work area through the application of time, distance, shielding and decontamination.

   d. Preparation of an RWP that specifies any special radiological training, monitoring, protective clothing, and other applicable requirements.

e. Inclusion of radiological control holds points in the technical work documents or their procedural equivalents.

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

g. Determination of abnormal and emergency procedures and plans.

h. The optimum sequence of work from an exposure control standpoint should be determined through use of mock-ups for high exposure or complex tasks. A dry run of the activity should be performed using applicable procedures. This activity should describe each person's role when they are in the radiological area.

i. As much preparatory work as possible should be performed in areas of lowest dose rate. Prefabrication and shop work should be maximized to reduce worker exposure. All necessary tools, equipment, spare parts, and personnel should be assembled prior to commencement of the radiological work.

j. Use of work processes and special tooling (e.g., long-handled tools, ratchet wrenches, etc.) or remote handling devices should be evaluated and used to reduce time in the work area.

k. Use of engineered controls to minimize the spread of contamination and generation of airborne radioactivity.

l. Plan for waste minimization and proper waste disposal.

m. Consideration of emergency response planning needs.

n. Radiological tasks anticipated to exceed individual or collective dose criteria established in Article 354 shall be reviewed by the assigned RSO.

2. Pre-Job Briefings

Pre-job briefings should be held prior to the conduct of work anticipated to exceed the trigger levels identified in Article 354. Workers, supervisors directly participating in the job, Radiological Control Organization personnel and representatives from involved support organizations should attend pre-job briefings.

At a minimum, the pre-job briefing should include:

a. Scope of work to be performed.

b. Radiological conditions of the workplace.

c. Procedural and RWP requirements.

d. Special radiological control requirements.

e. Experience gained in performing similar radiological tasks in the past.

f. Radiologically limiting conditions, such as contamination or radiation levels that may void the RWP.

g. Radiological Control Hold Points or their procedural equivalents.

h. The need to consider improvements while working.

i. Communications and coordination with other groups working nearby.

j. Provisions for housekeeping and final cleanup.

k. Emergency response provisions.

l. A summary of topics discussed and attendance at the pre-job briefing should be documented. This documentation should be maintained with the technical work document and filed copies of applicable RWP.

3. <u>Post-Job Reviews</u>

During the conduct of radiological work and the handling of radioactive materials, abnormal events may occur which could indicate a weakness or area of programmatic breakdown. Prompt, consistent gathering of facts related to such events is required to satisfy reporting and investigation requirements and to formulate corrective actions to prevent recurrence. In addition, successful performance or completion of unique activities should be evaluated to identify and incorporate appropriate lessons learned. The provisions of FESHM 2060 also shall be complied with.

Post-job reviews involve meeting with personnel knowledgeable about an event (either a success or an abnormal event) in order to document facts in chronological order. This review should reveal areas where improvements can be made or where methods can be identified to prevent the recurrence of undesired results.

a. Post-job reviews should be conducted for successes and abnormal events by the Radiological Control Organization when such a process is deemed to be beneficial.

b. Post-job reviews should be conducted as soon as practicable after completion of the task, or occurrence of an incident. If possible, post-job reviews of abnormal events should be conducted before involved personnel leave for the day.

c. The general post-job review process may include one or more of the following elements:

1) Formal meetings led by a member of the Radiological Control Organization or the job supervisor or group leader.

2) Attendance by representative participants in the work.

3) Attendance records.

4) A listing of the sequence of events and actions taken at each step.

5) Supporting materials such as documents, records, photos, parts and logs.

6) The facts should be analyzed in order to determine areas where improvements can be made or where methods can be identified to prevent the recurrence of undesired results. This information becomes the "lessons learned."

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

356 Records

Records associated with the ALARA process and program, actions taken to attain and maintain occupational exposures ALARA, internal audits, training and other records are documented and maintained in accordance with Chapter 7.

1. <u>ES&H Section</u>

a. The ES&H Section maintains minutes of Radiation Safety Subcommittee meetings, generally held monthly, which include ALARA issues.

b. ALARA documentation and formal ALARA reviews are maintained in the ES&H Section central ALARA file.

c. The ES&H Section tracks and maintains records of individual and collective doses, records of intake, internal dose and dose received due to contamination.

d. The ES&H Section maintains documentation of approvals to exceed Fermilab administrative goals.

e. The ES&H Section Dosimetry Program Manager maintains records of individual exposure reports for the Laboratory and, as necessary, provides the ALERT list to divisions/sections.

2. Division/Section ALARA Records

Records of ALARA activities are documented by for the division/section by the assigned RSO that initiates the activity. These activities may include pre-job briefings, post-job reviews, job/experiment reviews, ALARA design reviews and radiological work permits**.** These activity records and supporting documentation are maintained for the division/section by the assigned RSO.

PART 6 SPECIAL APPLICATIONS

This Part is applicable to those facilities where the majority of the work or operations involve the subject radionuclide as the significant source term. It is not intended to apply to facilities that use the subject radionuclides in limited or trace amounts, such as analytical laboratories.

361 Uranium Operations

Natural, depleted, and low-enriched uranium are unusual in that their chemical toxicity is more limiting in the human body than their radioactivity. Also, processed uranium can contain transuranic and other radionuclides from recycled materials. However, such processed uranium is never used at Fermilab. Except for small check sources, the only uranium used at Fermilab is in the form of depleted uranium.

For these reasons, in addition to the provisions of this Manual, the guidance contained in the document, *Health Physics Manual of Good Practices for Uranium Facilities*, EG&G-2530 has been used to prepare this Article of the Fermilab Radiological Control Manual. The EG&G document provides specific guidance related to management controls, radiological monitoring, contamination control, and internal and external exposure controls.

Fermilab has adopted the provisions of this Article to assure proper management of depleted uranium in order to accomplish both proper radiological control and material accountability.

1. Some Properties

   Uranium is a very heavy metal of density 19 g/cm^3, with a melting point of 1132^{o}C. It is very active chemically, has low corrosion resistance, and is oxidized very rapidly on exposure to air, going from a bright silvery color to a black surface powder. Formation of the oxide coating does not prevent oxidation of the underlying metal. Uranium dust or chips can be pyrophoric (i.e., they burst into flame spontaneously on exposure to air) depending on their size and surface area.

   Natural uranium consists of three radioactive isotopes: 99.275% ^{238}U, 0.720% ^{235}U, and 0.005% ^{234}U. The main isotope ^{238}U has a half-life of 4.5×10^{9} years, and is an alpha emitter. The uranium series includes a number of radioactive elements that emit X-rays, beta particles, and gamma rays. The ^{235}U fraction is separated to use in nuclear reactors leaving so-called depleted uranium which may contain less than 0.2% ^{235}U.

2. Radiation Hazard

   Uranium presents a potentially serious external and internal radiation hazard. The main external hazards are caused by the dose rate on the uranium surface due primarily to betas and X-rays. Internal contamination may result due to the easily removable loose black surface powder, which is formed upon oxidation, and can be inhaled or ingested. The main internal radiation hazard is due to the alpha activity. The radiation hazard due to external irradiation and contamination can be reduced considerably by plating the uranium surface, canning in stainless steel or other materials, or possibly by painting.

3. Guidelines for Receipt, Use, and Handling of Uranium

   a. Advance approval from the SRSO is required before any uranium is brought to Fermilab.

   b. The ES&H Section is available for consultation regarding proper packaging. In general, packaging should be done in such a way as to minimize contamination of the shipping container (primarily the external surfaces) and inhibit the spread of contamination when unpacking. For example, the manufacturer might seal bare plates in plastic wrap or foil or apply a protective coating. Bare plates should not be dropped or roughly handled since this may shake oxide loose from the plates, resulting in contamination of other surfaces.

   c. The requisitioner must coordinate the planned receipt (before the order is made) with both the heads of Facility Engineering Services Section and ES&H Section. This coordination must include prior notification of both Support Services (Shipping/Receiving) and the ES&H Section of the date of the expected arrival.

   d. Responsibility for the control of nuclear material such as uranium during its use at Fermilab is assigned as follows:

      1) The ES&H Section will be responsible for inspecting the uranium for proper packaging, levels of contamination, and storage before release to the user. Furthermore, since uranium or depleted uranium is a designated nuclear material it must be included in the nuclear material inventory records kept by the ES&H Section.

      2) The head of the division/section of the requisitioner of the uranium will be responsible for the security and adherence to the guidelines for safe use of the material while it is under the control and/or use of that division/section.

      3) The appropriate division/section head will be responsible for the security and adherence to the guidelines for safe use of the uranium while in the fixed target or colliding beams experimental areas.

   e. The transfer of any uranium from one location to another on site will be documented by internal memoranda between the heads of the ES&H Section and the other divisions/sections involved. Radiation Physics Form 57 shall be used for this purpose. No uranium or depleted uranium may be taken or sent off site for any purpose without prior consultation with, and approval of, the Chief Safety Officer.

   f. No assembling of uranium into the device or apparatus for which it was ordered may start without informing the SRSO who will advise on safety measures to be taken. In general, the assembly area must fulfill the established requirements for contamination monitoring and personnel monitoring. In view of the fire hazard associated with uranium, appropriate fire extinguishing materials must be available.

g. The uranium plates and pieces must be ordered in a form such that no modifications are necessary. No machining (filing, cutting, drilling, etc.) of uranium or depleted uranium will be permitted on the Fermilab site without written permission from the SRSO.

h. The handling of uranium requires special training (see Article 651).

362 Radiation Generating Devices, Radiography Sources, and Portable Density Gauges Based on Radioactive Sources

X-ray and/or gamma radiation is produced by x-ray tubes, electron microscopes, industrial radiography sources, stand-alone x-ray units for research applications, and high voltage devices such as accelerating cavities, electrostatic separators, klystrons and pelletrons. Many of these items are accelerator components as defined in FESHM 2010 *"Planning and Review of Accelerators and Their Operation"* and are managed using the provision of that chapter in accordance with DOE Order 420.2C, *"Safety of Accelerator Facilities"* or its successor Orders. The provisions of this Article do not apply to components of accelerators managed in accordance with FESHM 2010 (see definition of "accelerator component" in FESHM 2010).

FESHM 2010 contains a list of devices exempted from applicability of DOE Order 420.2C that must be managed in accordance with the provisions of this chapter. Operation of these devices requires appropriate radiological controls to limit exposure to operating and support personnel and to personnel in adjacent areas where measurable radiation exposures to personnel are possible. All operators of radiation-generating devices shall be qualified by training as Fermilab radiological workers.

1. Non-medical Radiation-Generating Devices

   a. The assigned RSO shall review and approve designs for new radiation-generating devices, transfer of devices from one place to another within a division/section, offsite transfers and proper disposal provisions.

   b. The assigned RSO shall maintain a current list of radiation-generating devices.

   c. Each division/section shall appoint a responsible person or organizational group for each radiation-generating device. Provisions for back up in the event of the responsible person's absence should be established. The responsible person should work with division/section radiological control organization personnel to ensure that appropriate radiological controls are established for each radiation-generating device.

   d. Written work authorizations shall be established for each type of radiation-generating device (see Part 2 of this chapter).

e. Radiological controls during operation and emergency procedures, as appropriate, shall be documented for each type of radiation-generating device.

f. Radiation-generating devices shall have visible signs and labels to indicate the presence of x-ray and/or gamma ray radiation when the device is energized (See Article 413).

g. Radiological monitoring shall be conducted and documented to confirm the nature and magnitude of radiation fields (See Chapter 2, Part 3 and Chapter 5, Part 5).

h. Instruments used in monitoring such devices shall be sensitive to the radiation field being measured with an efficiency that is reasonably well understood by the members of the Radiological Control Organization.

i. Radiation safety interlock systems provided for radiation-generating devices shall comply with the requirements set forth in Chapter 10 of this Manual or be approved by a documented review to provide an equivalent level of protection.

j. Deuterium-Deuterium (DD) and Deuterium-Tritium (DT) generators pose special hazards. These hazards are not limited to ones associated with ionizing radiation. RP Form No. 113 shall be completed and filed electronically to document their identification and hazard mitigation.

2. Radiation-generating devices for medical use shall be registered with the appropriate regulatory agency in accordance with the requirements of that agency if such requirements are determined to be applicable.

3. Radiography Sources

To minimize the hazard associated with the use of radiography sources at Fermilab, stringent controls are required. Industrial radiography sources present a serious radiological hazard to personnel safety unless handled with extreme care. The dose rates from these sources are typically between 50 and 300 rem/hour at 1 foot.

Radiological Control Organization personnel shall ensure the contractor has a valid Nuclear Regulatory Commission (NRC) or Agreement State license. Such licenses shall provide verification of radiographer certification and that operational and emergency procedures are current and available. Copies of current NRC or Agreement State licenses should be forwarded to the ES&H Section Source Physicist.

The following radiological control procedures shall be adhered to:

a. On site operations conducted by off-site contractors shall be approved by the affected assigned RSO with prior approval of the SRSO or designee.

b. When the source arrives on site, Radiological Control Organization personnel (as deployed by the assigned RSO) must be notified so that the proper paperwork can be completed and the source checked for safety.

c. Continuous radiological control supervision shall be provided by the assigned RSO or designee during operation of the radiography source.

d. When possible, radiography should be scheduled outside normal working hours to reduce possible exposure to personnel not directly involved in the procedure. Radiography inside buildings should be avoided.

e. If a source should become stuck and the problem cannot be solved by <u>remote</u> manipulation, cordon off the area and initiate the pre-approved emergency procedures. Call x3131 to report the incident and to initiate notification of appropriate Radiological Control Organization personnel.

4. Portable Density Gauges Based on Radioactive Sources

a. The Fermilab Source Physicist or backup must approve the use of a portable density gauge containing sealed sources before the device is brought on-site. Refer to *Fermilab Checklist for Approval of Receipt and Shipment of Radioactive Materials and Sealed Radioactive Sources* (R.P. Form #115) for receipt procedures and required documentation.

b. In order for approval, the contractor must notify the Fermilab Task Manager/Construction Coordinator (TM/CC) or other authorized Fermilab representative at least three days prior to portable density gauge coming on-site. The contractor must supply the following documentation for approval: Current US NRC or US NRC Agreement State Radioactive Materials License, portable density gauge safety procedures, and portable density gauge emergency procedures. The Fermilab TM/CC or other authorized Fermilab representative will forward this information to the Source Physicist or backup.

c. The ES&H Section Hazard Control Technology Team (HCTT) completes Record of Radioactive Material Receipts and Shipments form (R.P. Form #20) each time a portable density gauge comes on-site.

d. The authorized operators of the portable density gauge must comply with operating procedures, PPE, personnel monitoring requirements, control, accountability, security, transport, storage, and posting procedures required by the contractor's US NRC or US NRC Agreement State Radioactive Materials License and all applicable Code of Federal Regulations requirements. Additional PPE may need to be worn according to site access requirements.

e. If site-specific and/or corporate safety procedures as identified in the contractor's US NRC or US NRC Agreement State Radioactive Materials License are not followed, the Fermilab TM/CC will notify the appropriate contractor representative to resolve the issue. The Fermilab

TM/CC will communicate these concerns and corrective actions taken by the contractor to the Source Physicist, backup and/or assigned RSO. Fermilab Source Physicist or backup maintains documentation of issues and corrective actions taken.

f. Prior to allowing a portable density gauge to be stored on-site for an extended period of time, the Source Physicist, backup, or assigned RSO will approve the plan for use, storage location, storage container, and verify that the container is posted with "Caution, Controlled Area" and "Caution, Radioactive Material" signs.

g. The contractor must notify the Fermilab TM/CC or other authorized Fermilab representative if the plan for use of the portable density gauge changes or if the portable gauge leaves the Fermilab site. Upon return, an approval process is required (see items a and b of this Article).

h. In an emergency, call x3131. The authorized portable density gauge operators will follow their emergency procedures as documented in site-specific and/or corporate safety procedures.

PART 7 CONSTRUCTION AND RESTORATION PROJECTS

Construction and restoration projects, including decontamination and decommissioning (D&D), remedial action, or other actions involving materials which contain low levels of radioactivity may present special problems and require site-specific or program-specific control methods. Health and Safety Plans are normally developed to specify controls, including any necessary radiological surveying and monitoring activities, for all types of restoration programs. Decontamination and Decommissioning (D&D) activities are covered in the Fermilab ES&H Manual.

371 Requirements

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

372 Environmental Conditions

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

1. The use of covers (including earth covers consisting of clay), windscreens and runoff collection basins to preclude the inadvertent spread of radioactive material.

2. Provisions for worksite personnel to assemble and be monitored prior to release or re-establishment of work.

3. Evaluation of work area to determine if a need exists for modified work controls or decontamination.

373 Other Workplace Hazards

Radiological controls should be implemented in a balanced way to ensure that protection from all workplace hazards can be implemented as outlined in the FESHM. A list of examples is given below:

1. General construction hazards.

2. Confined spaces.

3. Flammable materials.

4. Chemical exposures and reactive chemicals

5. Extreme temperatures.

6. Energized electrical equipment.

7. Biological hazards.

8. Rotating equipment.

9. Noise and vibration.

10. Excavations.

11. Access and egress considerations.

12. Cryogenic and oxygen deficiency hazards.

13. Stored energy sources addressed by lockout/tagout policies.

Appendix 3A Checklist for Reducing Occupational Radiation Exposure

Preliminary Planning and Scheduling

- Plan in advance
- Delete unnecessary work
- Determine expected radiation levels
- Estimate collective dose
- Sequence jobs
- Schedule work
- Select a trained and experienced work force
- Identify and coordinate resource requirements
- Preparation of Technical Work Documents
- Include special radiological control requirements in technical work documents
- Perform ALARA pre-job review
- Plan access to and exit from the work area
- Provide for service lines (air, welding, ventilation, etc.)
- Provide communication
- Remove or shield sources of radiation
- Plan for installation of temporary shielding
- Decontaminate
- Work in lowest radiation levels
- Perform as much work as practicable outside radiation areas
- State requirements for standard tools
- Consider special tools, including robots
- State staging requirements for materials, parts and tools
- Incorporate Radiological Control Hold Points
- Minimize discomfort of individuals performing task
- Revise estimates of person-rem
- Prepare Radiological Work Permits (RWPs)

Temporary Shielding

- Make sure shielding is not more of a hindrance than help
- Design shielding to include stress considerations
- Control installation and removal by written procedure
- Inspect after installation
- Conduct periodic radiation surveys
- Prevent damage caused by heavy lead temporary shielding
- Balance radiation exposure received in installation against exposure saved by installation
- Shield travel routes
- Shield components with abnormally high radiation levels early in the maintenance period

- Shield position occupied by the person
- Perform directional surveys to improve design of shielding by locating source of radiation
- Use mock-ups to plan temporary shielding design and installation

Rehearsing and Briefing

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

Performing Work

- Comply with technical work documents and RWPs
- Post radiation levels
- Keep excess personnel out of radiation areas
- Minimize radiation exposure
- Supervisors and employees keep track of radiation exposure
- Workers assist in radiation and radioactivity measurements
- Delegate radiological control monitoring responsibilities
- Evaluate use of fewer radiological workers
- Reevaluate reducing radiation exposures
- Compare actual collective dose against pre-job estimate
- Review work practices to see if changes will reduce dose
- Coordinate personnel at the job site to reduce nonproductive time
- Complete decontamination and restoration of the area in accordance with the RWP or instructions from the Radiological Control Organization
- Prepare waste for pickup and coordinate transportation of radioactive materials in accordance with the RWP or instructions in accordance with the Radiological Control Organization

Appendix 3B Use of Personal Protective Equipment (PPE) and Step Off Pads

A. Selection and Use of PPE

1. FESHM 4130 requires a PPE assessment be performed in order to identify PPE needs. FESHM 4130 provides guidance in conducting that assessment. PPE requirements shall be identified on the RWP. PPE should be selected based on the contamination level in the work area, the anticipated work activity, radiological worker health considerations, and regard for non-radiological hazards that may be present.

   The applicable RWP specifies the protective clothing required for a given task. Fermilab has a variety of protective clothing that is commonly used for radiological protection purposes. PPE also utilized to address non-radiological hazards must be harmonized with radiological PPE within the context of the hazard assessment process of integrated safety management (ISM). In most cases, one will only need a combination of the following:

   - Coveralls
   - Lab coat
   - Impervious Gloves
   - Shoe covers
   - Safety eyewear

   Full Set of protective clothing (PPE) for radiological contamination protection purposes generally consists of:

   - Coveralls
   - Impervious Gloves
   - Shoe covers

2. Check to make sure that your protective clothing has no rips or tears in it. Any defective items should be replaced with intact protective clothing.

3. There is no particular order in donning protective clothing. However, there may be some jobs in which you may have to don protective clothing in a specific manner. You will be made aware of this if it is required.

   For example, if you are required to wear a hood, it is to be put on over your coveralls to prevent contamination from getting inside your protective clothing.

4. Shoe covers and gloves may be secured or taped at the coverall legs and sleeves when necessary (as decided by members of the Radiological Control Organization) to prevent contamination of individuals. Tape should be tabbed to permit easy removal.

5. Supplemental pocket or electronic dosimeters should be placed on the outside of the protective clothing so that they are accessible to the worker. Supplemental pocket or electronic dosimeters should be placed in close proximity to each other and your personnel dosimeter.

   Workers should be instructed not to touch the skin or place anything in the mouth during protective clothing removal.

B. Monitoring for Contamination and Exiting the Area

Guidelines for monitoring for contamination are given in Appendix 3C.

C. Use of Step-Off Pads

1. Step-off pads should be used to control exit from High Contamination Areas, as appropriate. These pads define interim control measures within the posted area to limit the spread of contamination. The following should be considered:

   a. The inner step-off pad (if used) should be located immediately outside the highly contaminated work area, but still within the posted area.

   b. The worker should remove highly contaminated outer clothing prior to stepping on the inner step-off pad.

   c. Additional secondary step-off pads, still within the posted area, may be utilized as necessary to restrict the spread of contamination out of the immediate area.

   d. The final or outer step-off pad (as necessary) should be located immediately outside the Contamination Area.

Appendix 3C Guidelines for Monitoring for Contamination

GM type pancake probes are used in operational areas to check for contamination. Their efficiency for detecting radiation depends on the type (β, γ, α) of radiation being detected and its energy. For a typical efficiency of 10%, the pancake probe will register 100 counts per minute above background for 1000 dpm (0.5 nCi) of β–γ activity. (For more information about efficiencies see Chapter 4.) A low background (≤100 cpm) area should be used to count the activity. The minimum detectable response for a typical pancake probe is about 70 cpm. This corresponds to a detectable activity of about 0.3 nCi (or 660 dpm) for a 100 cm^2 area, assuming 10% counting efficiency. This level of efficiency is typical for detection of accelerator-produced radionuclides common at proton accelerators. The assigned RSO may choose alternate criteria upon which to base radiological work procedures tied to detection efficiencies of radionuclides actually verified to be present provided this is justified to the SRSO in writing.

A. General Requirements for Frisking Personnel and Equipment [1]

1. If possible, without touching the instrument, verify that the instrument is on, in calibration, and set to the proper scale. If necessary, adjust the audio output so that it can be heard during frisking.

2. If possible, without touching the instrument, check background levels to ensure that you are in a low background area (<100 cpm) on Frisker.

3. Frisk hands slowly, front and back, approximately 1 inch per second, if at all possible, without touching the instrument.

4. If the count rate increases, see steps 8 and 9. Otherwise continue as you now can safely touch the instrument without spreading contamination.

5. Source check the instrument to ensure that it is responding properly.

6. Now you can continue frisking the rest of your body as necessary. Hold probe less than 1/2 inch from surface being surveyed for beta and gamma contamination, approximately 1/4 inch for alpha contamination. Move probe slowly over surface, approximately 1 inch per second. If you are performing a whole-body frisk, it should take at least two to three minutes and should be done in the following order:

    a. Personnel and supplemental dosimeters
    b. Head (pause at mouth and nose for approximately 5 seconds)

[1] Comparable instructions to those presented here should be posted adjacent to monitoring instruments in accordance with Article 336.7.

c. Neck and shoulders
d. Arms (pause at each elbow)
e. Chest and abdomen
f. Back, hips and seat of pants
g. Legs (pause at each knee)
h. Shoe tops
i. Shoe bottoms (pause at sole and heel)
j. Personal belongings

7. If the count rate increases during frisking, pause for 5 to 10 seconds over the area to provide adequate time for instrument response.

8. If, while you are frisking your protective clothing or equipment, the count rate increases to a value greater 50 cpm above background in a low background area, then the item is considered radioactive. See Section B, Equipment Contamination, for guidelines on when equipment might be contaminated and how to proceed. See Section C, Contaminated Protective Clothing, for guidelines on how to proceed if your protective clothing is contaminated.

9. If your protective clothing is found to have no contamination, if it is disposable clothing, it can be removed in a manner that is most convenient for you and disposed of in the regular trash.

10. If during a frisk of your personal belongings, the count rate increases to greater than 50 cpm above background, contact Radiological Control personnel for instructions.

11. Return the probe to its holder and leave the area. The probe should be placed on its side or face up to allow the next person to monitor their hands before handling the probe.

12. Personnel should wash their hands (as soon as possible) with nonabrasive soap after working in a potentially contaminated area or working with radioactive materials, even if no contamination was discovered.

B. Equipment Contamination

Experience indicates that removable contamination should be suspected where a beamline component's residual radiation level exceeds 100 mrem/hr. at one foot. Because equipment having absorbed dose rates at one foot greater than 100 mrem/hour may be contaminated, a wipe survey should be made to determine if such items are contaminated since "frisking" will also detect the bulk activation. All items removed from magnet interfaces should be checked for contamination with a wipe survey. Equipment is considered contaminated by β–γ if a pancake type GM instrument reads 50 or more counts per minute above background on contact in a low background area (≤ 100 cpm) or has an activity of at least 0.5 nCi/100 cm^2. Under the direction of radiation safety personnel, items above this limit shall be decontaminated or other measures taken to protect personnel before the item leaves the area. If an unknown contaminated item is discovered outside a contamination area, notify the assigned RSO or designee immediately.

C. Contaminated Protective Clothing

If at any time during the protective clothing frisking procedures, the count rate on the Frisker increases to 50 cpm above the background levels, you MUST perform a whole-body frisk after removing all of your protective clothing. You should minimize your movements, not touch your skin, and not place anything in your mouth when removing contaminated clothing. ALL of your disposable protective clothing needs to be disposed of in a radioactive waste receptacle and you must perform a whole-body frisk after its removal. If your skin or personal clothing has a count rate of more than 100 cpm above background, see Section D, Personnel Contamination on how to proceed.

D. Personnel Contamination

If you are performing a frisk after removing your protective clothing and the count rate increases to more than 100 cpm above background, ASSUME THE INSTRUMENT READING IS CORRECT. Personnel are considered contaminated by $\beta-\gamma$ if a pancake type GM instrument reads 100 or more counts per minute above background at contact in a low background area ($\leq$ 100 cpm). Notify the emergency operator using the emergency phone number 3131. Report that a person has been contaminated and requires Radiation Safety assistance. The emergency operator will follow the Fermilab Comprehensive Emergency Management Plan (CEMP). See Section E, Personnel Decontamination, below for decontamination guidelines.

E. Personnel Decontamination

Minimize your movements and contamination spread, i.e. place a glove over a contaminated hand.

1. *Minor Contamination.* Under the direction of Radiological Control Organization, minor personnel decontamination can be performed using such readily available items as non-abrasive hand cleaner and disposable wipes or a roll of adhesive tape. If this is ineffective, use of the ES&H Section Decontamination Facility at Site 39 South may be required.

2. *Decontamination Facility (Site 39 South) Use.* ES&H Section Radiation Physics personnel should be called in to perform the decontamination effort if this facility is needed. Written procedures present at that facility are to be used to perform the decontamination. This facility is also equipped to handle minor injuries with contamination.