CHAPTER 3 CONDUCT OF RADIOLOGICAL WORK

TABLE OF CONTENTS

PART 1 PLANNING RADIOLOGICAL WORK 3
311 Requirements 3
312 Planning for Maintenance, Operations and Modifications 3
313 Infrequent or First-Time Activities 4
314 Temporary Shielding 4
315 Technical Work Documents 5
316 Minimization of Internal Exposure 5

PART 2 WORK PREPARATION 7
321 Radiological Work Preparation 7
322 Requirements for Written Authorization 7
323 Documentation of Written Authorizations 8
324 Pre-Job Briefings 9
325 Personal Protective Equipment and Clothing 9

PART 3 ENTRY AND EXIT REQUIREMENTS 10
331 Controlled Areas 10
332 Radioactive Material Areas 10
333 Radiation, High Radiation and Very High Radiation Areas 11
334 Contamination, High Contamination and Airborne Radioactivity Areas 13
335 Special controls for Limiting the Spread of Contamination in the Workplace 14
336 Monitoring for Personnel Contamination 17

PART 4 RADIOLOGICAL WORK CONTROLS 19
341 Requirements 19
342 Work Conduct and Practices 19
343 Response to Abnormal Situations 21
344 Controls for Bench Top Work, Laboratory Fume Hoods, Sample Stations and Gloveboxes 21
345 Controls for Highly Activated Material Fragments or Particles 22
346 Control of Radioactivated Cooling Water 22
Table 3-1 Derived Concentration Guides* for Accelerator-produced Radionuclides in Water 24
347 Control of Airborne Radioactivity 24
Table 3-2 Derived Concentration Guides in Air (μ Ci/m^3) for radiation workers and for the general population. 25
348 Radiological Stop Work Authority 26

PART 5 FERMILAB ALARA (AS LOW AS REASONABLY ACHIEVABLE) PROGRAM 26
351 Fermilab ALARA Policy 26
352 Responsibilities 28
353 Radiological Design Review 31
354 ALARA Trigger Levels 31
355 Formal ALARA Review Elements 32
356 Records 35

PART 6 SPECIAL APPLICATIONS 36
361 Uranium Operations 36
362 X-Ray Generating Devices and Radiography Sources 38

PART 7 CONSTRUCTION AND RESTORATION PROJECTS 40
371 Requirements 41
372 Environmental Conditions 41
373 Other Workplace Hazards 41
Appendix 3A Checklist for Reducing Occupational Radiation Exposure 42
Appendix 3B Use of Personal Protective Equipment (PPE) and Step Off Pads 44
Appendix 3C Guidelines for Monitoring for Contamination 46

Fermilab is in the process of implementing revised requirements stated in 10 CFR 835 (July 9, 2007 Revision). Changes that cannot be made by January 4, 2008 are identified in this Manual as "**To be updated by July 8, 2010.**" as permitted by 10 CFR 835.

PART 1 PLANNING RADIOLOGICAL WORK

311 Requirements

Technical requirements for the conduct of work, including construction, modifications, operations, maintenance and decommissioning, 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, with support and concurrence from the Radiological Control Organization (RCO). 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 are covered 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 for any hot, complicated or new radiological tasks.

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

5. Radiation Safety Supervision: Entry into areas in which the dose rate exceeds 1 rem/hr is prohibited without continuous radiation safety supervision. The RSO

should seriously consider the use of two RCO personnel to cover jobs when the exposure rates exceed 25 R/hr (see Article 234.8 - 234.10, Article 333.4).

6. Prior Notification of the SRSO: When work is to be done in areas where the dose rate exceeds 100 rem/hr, or the total dose to all personnel can be expected to exceed 1 person-rem, approval of the SRSO must be obtained in advance (see Article 234.9).

7. Prior approval by the Laboratory Director_is required prior to entry of personnel into Very High Radiation Areas (see Article 333).

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 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 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 Radiological Control Organization.

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

3. Installed temporary shielding should be periodically inspected and surveyed to verify effectiveness and integrity. 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 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.

3. Radiological Control Hold Points or their procedural equivalents should be incorporated into technical work documents for steps that require action by 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.

   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 removable 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 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 responsible division/section.

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.

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 Radiation Work Permit (RWP) or alternative written authorization 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 landlord organization responsible for the area, but other arrangements may be made for special circumstances.

2. The RWP shall be based on current radiological surveys. RWPs for controlled access may be based upon anticipated radiological conditions.

3. Job-specific RWPs should have the concurrence of the supervisor responsible for the work. All RWPs shall have the written approval of the appropriate RSO or designee approved by the SRSO. 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.

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.

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 Radiological Control Organization 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, which 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 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. 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.
6. Protective clothing and respiratory protection requirements.
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).

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 Radiological Control Organization 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 controlling 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)**.**

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) to enter the area by the landlord RSO or designee.

    c. Personnel dosimetry monitoring badge.

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 RSO or designee.

    c. Personnel and supplemental dosimeters as follows:

        (1) Personnel dosimetry monitoring badge.

        (2) Self-Reading Dosimeters (“Pocket Dosimeters”): Pocket Dosimeters are required for entry into all High Radiation Areas.

        (3) Special Monitoring: 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 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 Digital Dosimeters.

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

d. Review and determination by the 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 312.

5. Workers shall only be permitted entry into Very High Radiation Areas under the direct supervision of the Radiological Control Organization. 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 (see Article 312.6 for further requirements).

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 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 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 can be 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 RSO or designee.

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

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

   e. Protective clothing as specified by the 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 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. 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 exceed those permitted for surface discharge, 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 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. **Closed Loop Cooling Water:** 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 (^{3}H), 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) ^{7}Be 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 gets too high, the water is 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, <u>if</u> precautions similar to those outlined in this Article are taken, and <u>only</u> with the approval of the area Radiation Safety Officer.

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 radioactivated 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). Their use 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 Laboratory for experiments, references 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 the Radiological Control Organization, or as posted. The frisk shall cover, at a minimum, the hands, feet, other body parts and clothing that may have touched potentially contaminated surfaces. Frisks of the hands and feet may be recommended or required, as appropriate, by the 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. 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 ($\leq$ 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.

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 or 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 prework status.

10. To minimize intakes of radioactive material by personnel, smoking, eating, applying cosmetics, or chewing 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 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 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 <u>not</u> considered accessible. Such supervision is also strongly <u>recommended</u> 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 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.

343 Response to Abnormal Situations

The Fermilab Emergency Response Plan 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 divisions and sections to prepare 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 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. Glove boxes should be inspected for integrity and operability prior to use.

    b. Glove boxes should be marked with or survey measurements should be posted to identify whole body and extremity dose rates, as appropriate.

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. The Senior Radiation Safety Officer, or designee should be consulted if new contamination of this type is confirmed to be present.

346 Control of Radioactivated Cooling Water

In addition to worker protection measures discussed in Article 335.5 that primarily pertain to closed loop (“RAW”) water systems, the management of all systems involving radioactivated water must include considerations pertaining to environmental protection requirements. See Chapter 8 and references therein for a more complete discussion of the production of radionuclides in water.

Discharges to surface waters from any sources other than storm or cooling systems or as specified in a National Pollution Discharge Elimination System (NPDES) permit are strictly prohibited. Numerous sumps located throughout the site collect and drain stormwater from building footings and from under beamline tunnels. Water collected by these sumps often contains detectable concentrations of radionuclides (primarily tritium) that have been leached by rainwater from radioactive soil near beam targets and absorbers or accidentally released to the sumps from beamline cooling water systems.

1. Allowable releases of various radionuclides to surface waters are documented in DOE Order 5400.5 as Derived Concentration Guides (DCGs). Selected values of DCG's are presented in Table 3-1.

2. To account for the presence of multiple radionuclides, for the water to be considered to be less than 1 DCG, the set of individual radionuclide concentrations in the water, C_i, must satisfy the following inequality:

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

where DCG_i is the DCG for the i^{th} radionuclide.

3. Closed-loop water systems ("RAW" systems) exceeding five times the Derived Concentration Guide (10,000 pCi/ml for tritium) shall be labeled “Caution, Contaminated Liquid” and with the known levels of tritium concentration.

4. 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 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 domestic 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.

5. 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 0.67 μCi/ml for tritium in water (0.67 x 10^6 pCi/ml, 335 times the DCG). This evaluation should be done by the division/section with the input of the Radiological Control Organization. Both potential occupational and environmental radiation exposures should be considered prior to making a decision to drain and refill such a system. The basis for this guideline is derived in Fermilab Radiation Physics Note #7 "Internal Dosimetry Technical Basis Document".

Table 3-1 Derived Concentration Guides* for Accelerator-produced Radionuclides in Water **(To be updated by July 8, 2010)**

		Derived Concentration Guide pCi/ml	
Isotopes	Half-life	Surface Water	Groundwater
H-3	12.3 y/4506 d	2,000	20**
Be-7	53.3 d	1,000	40
Na-22	2.6 y/949 d	10	0.40
Ca-45	165 d	50	2
Mn-54	312 d	50	2
Co-57	270 d	100	4
Co-58	71.3 d	40	1.6
Co-60	5.27 y/1924 d	5	0.2
Zn-65	245 d	9	0.36
Cs-137	30 y	3	0.12
Au-195	183 d	100	4
U-238	4.47 x 10^9 y	0.06	2.4 x 10^{-3}

*Taken from DOE Order 5400.5 using the most conservative choices of G-I tract absorption factor.
**Taken from USEPA regulations 40 CFR 141 where a specific limit is stated for this nuclide for drinking water supplies.

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 radioactivation of air.

1. Derived Air Concentrations (DACs) for radiation workers (corresponding to 5 rem/year) are given in 10 CFR 835 Appendices A and C while Derived Concentration Guides (DCGs) for inhaled air for members of the public (corresponding to 100 mrem/year) are given in DOE Order 5400.5. Prominent examples are given in Table 3-2. For radionuclides not listed, the 10 CFR 835 Appendices A and C or DOE 5400.5 should be consulted for occupational

exposures and exposures to members of the public respectively. More details with respect to environmental protection aspects are given in Chapter 11. The production and monitoring of radionuclides in air is discussed in more detail in Chapters 5 and 8.

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 weighted- sum of the mixture is, then, the fraction of the DAC for the mixture.

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 not require such monitoring during 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.

Table 3-2 Derived Concentration Guides in Air ($\mu Ci/m^3$) for radiation workers and for the general population for airborne radionuclides commonly encountered at Fermilab. **(To be updated by July 8, 2010)**

Isotope	Radiation Worker 5 rem/year 40 hours/week exposure	General Population 0.1 rem/year 168 hours/week exposure	Lung Retention Class[d]
^{3}H	20.0[a]	0.1[c]	Not assigned
^{7}Be	8.0[a]	0.04[c]	Y
^{11}C	200.0[a]	1.0[c]	D
^{13}N	41.0[b]	0.02[b]	Not assigned
^{15}O	27.0[b]	0.02[b]	Not assigned
^{22}Na	0.3[a]	0.001[c]	D
^{41}Ar	47.0[b]	0.01[b]	Not assigned
^{54}Mn	0.3[a]	0.002[c]	W
^{60}Co	0.07[a]	4×10^{-4} [c]	Y
^{238}U	2×10^{-5} [a]	1×10^{-7} [c]	Y

Notes:

a. 10 CFR 835 Appendix A and C.
b. M. Hoefert, "Radiation Hazard for Induced Activity in Air...", Proc. Second Intl. Conf. on Accel. Dosimetry and Experience, 1969. The values for radiation workers taken from this work are based on β exposure to the skin resulting from submersion in a cloud of 4 meter's radius. MPC's for the general population are based on γ exposure from a hemispherical cloud of infinite radius based on Fermilab Radiation Physics Note #20.
c. DOE Order 5400.5, Chapter III, Derived Concentration Guides for Controlling Exposure to members of the Public.
d. "D", "W", and "Y" correspond to lung retention classes of "days", "weeks" and "years" as specified by 10 CFR 835.

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

5. 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.

6. Radiological Control Personnel must 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.

7. Regarding the control of airborne radionuclides, the design objective shall be, under normal conditions, to avoid releases to the workplace atmosphere and in any situation, to control the inhalation of such material by workers to levels that are ALARA; confinement including allowing for decay, and ventilation shall normally be used.

348 Radiological Stop Work Authority

1. Members of the Radiological Control Organization, ES&H Section Staff, RSOs, 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 nonradiological hazard that renders the operation unsafe.

2. Stop radiological work authority and restart authority shall be exercised in accord with the provisions of Fermilab ES&H Manual Chapter 1030.

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 Laboratory Safety Committee

One of the functions of the Radiation Safety Subcommittee (RSSC) is to serve as Fermilab's ALARA Committee. The official charter is contained in Fermilab ES&H Manual Chapter 1030TA.

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. Appoint the Laboratory ALARA Coordinator.

   b. Provide technical assistance for maintaining exposure as low as reasonably achievable, including but not limited to training, evaluation of radiation 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

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.

5. Division/Section Radiation Safety Officers or Points of Contact

a. As a part of the ALARA process, division/section RSOs or points of contact, if no division/section 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.

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 1030.

   c. Report any radiological problems and concerns, along with any corrective actions, to the division/section Radiation Safety Officer.

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 division/section RSOs and ES&H Section Radiation Physics Team members, 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 division/section 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 Chapter 8.

354 ALARA Trigger Levels

The following trigger levels, assessed in advance, require a formal ALARA review of nonroutine or complex work activities. These ALARA trigger levels are:

1. Estimated individual doses greater than 200 mrem for the task

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

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

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

5. Work in areas having removable contamination greater than 10 times the values in Table 2-2. At the discretion of the 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.

6. Potential radioactivity releases to the environment in excess of the limits specified by DOE 5400.5 (Chapter 2 Section 1 and Chapter 3).

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 checked 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 division/section 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.

   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.

m. Plan for waste minimization and proper waste disposal.

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

2. <u>Pre-Job Briefings</u>

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, division/section radiological control 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. Radiologically limiting conditions, such as contamination or radiation levels that may void the RWP.

f. Radiological Control Hold Points or their procedural equivalents.

g. Communications and coordination with other groups.

h. Provisions for housekeeping and final cleanup.

i. Emergency response provisions.

j. 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. Post-Job Reviews

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 division/section management 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 all whom can contribute.

(3) Attendance records.

(4) A listing of the facts in chronological order.

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

(6) (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. ES&H Section

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 to maintain exposure ALARA are documented by the division/section 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 by the division/section line organization.

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 tracer 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°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 X 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 Business Services 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 ES&H Section Head.

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 X-Ray Generating Devices and Radiography 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, klystrons and pelletrons. Operation of these devices requires appropriate radiological controls to limit exposure to operating and support personnel and to personnel in adjacent areas.

1. Non-medical Radiation-Generating Devices

   a. The Division/Section Radiological Control Organization (RCO) should 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. Each division/section shall maintain a current list of radiation-generating devices.

   c. Each division/section shall appoint a responsible person 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.

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

   f. Radiation-generating devices shall have visible 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 should be sensitive to the radiation field being measured with an efficiency that is understood by the Radiological Control Organization.

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

2. Radiation-generating devices for medical use shall be registered with the appropriate regulatory agency in accordance with the requirements of that agency.

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.

   Division/Section 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 division/section with prior approval of the SRSO or designee.

   b. When the source arrives on site, division/section radiological control personnel (as assigned by the 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 Area 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 remote 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. DOE Order 420.2B contains a list of exclusions of types of radiation-generating devices that are not considered to be accelerators for purposes of compliance with FESHM Chapter 2010.

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 for all types of restoration programs. Decontamination and Decommissioning (D&D) activities are covered in Chapter 8070 of 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. Heat stress.
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)
- 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

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

A. Selection and Use of PPE

1. FESHM 5101 requires a PPE assessment be performed in order to identify PPE needs. FESHM 5101 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 nonradiological 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 nonradiological 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 eyeware

   Full Set of anti-Cs generally consists of:

   a. Coveralls
   b. Impervious Gloves
   c. 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 βγ 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 area 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. 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.

10. 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.

11. 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 ($\leq$ 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 appropriate Area RSO or designee immediately.

C. Contaminated Protective Clothing

If at anytime 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 β–γ 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 Emergency Response Plan. 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.