

Radiological Worker Training Study Guide

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Lesson 1 Introduction

A. Department of Energy (DOE) Safety Policy

The Department of Energy, in conjunction with Fermilab, is firmly committed to having a radiological control program of the highest quality. This program, as outlined in 10 CFR Part 835, *Occupational Radiation Protection* and the Fermilab Radiological Control Manual (FRCM), requires that managers and supervisors at all levels are to be involved in the planning, scheduling and conduct of radiological work. Adequate radiological safety shall not be compromised to achieve research objectives.

B. Course Objective and Overview

1. The goal of this course is to provide the participant with the necessary information and skills to work safely in areas controlled for radiological purposes.
2. Radiological Worker training is required for the worker whose job assignment requires unescorted access into radiological areas, works with radioactive materials, or has the potential of being exposed to at least 100 mrem in a year from occupational sources of radiation.
3. Radiological Worker training is designed to prepare the worker to work safely in and around radiological areas and present methods to ensure radiation exposure is maintained As Low As Reasonably Achievable (ALARA).
4. To be classified as a Radiological Worker, an individual must successfully complete the written examination and the practical factors training.
5. *Theory Portion of Radiological Worker Training:* The topics discussed provide information that a radiological worker must know to work safely around radiological hazards. A written examination is required in which a passing score of 80% or better is required. Successful completion of the written examination is a prerequisite to Practical Factors Training.

6. *Practical Factors Training*: Generic practical exercises allow the radiological worker to apply the theory portions of this course in a simulated, controlled work environment. This exercise will be evaluated against pre-established criteria. A rating of Satisfactory is required for successful completion of Practical Factors Training.
7. As a trained radiological worker, you will be qualified to work on, with, or in the proximity of radiation producing machines or radioactive materials.

Lesson 2 Radiological Control Organization (RCO)

- A. The RCO is responsible for implementing Fermilab's radiological control program. Fermilab's radiological control program requirements are described in the Fermilab Radiological Control Manual.
- B. Roles and Responsibilities
 1. Area Radiation Safety Officers (RSOs)
 - Area RSOs are your primary contact with the RCO.
 - Area RSOs handle day-to-day radiological control activities within their division/section/center (D/S/C).
 - Area RSOs establish radiological controls, approve Radiological Work Permits, arrange for area posting, ensure that individuals are qualified for radiological work, and provide emergency response.
 2. Radiological Control Technicians (RCTs) assist Area RSOs in their respective division/section/center in the conduct of daily activities.
 3. The ES&H Section conducts all lab-wide aspects of the radiological control program, including the radioactive sealed source program, the dosimetry program, radioactive waste, and instrument maintenance and calibration.

Lesson 3 Radiological Fundamentals

A. Atomic Structure

1. Atom: Basic unit of matter.
2. Nucleus: Central portion of atom which contains the protons and neutrons.
3. Electrons: Particles in orbit around the nucleus.

B. Definitions

1. Radiation: Energy in the form of particles or rays.
2. Ions: Atoms or molecules with a different number of protons than electrons giving them a net electrical charge.
3. Ionizing Radiation: Radiation that can produce ions when passing through material. *This is the type of radiation we are concerned about at Fermilab.*
4. Radioactive Decay: Release of excess energy from an unstable atom. It is the result of the atom's reconfiguration of its protons, neutrons, or electrons.
5. Half-life: The time it takes for one-half of the radioactive atoms present in a material to decay.
6. Radioactive Material: Any material that can spontaneously emit radiation.
7. Radioactivation: Any material, equipment or system component determined to be made radioactive by exposure to particle beams or beam spray. All material that is or has been inside a beamline enclosure has the potential to be radioactivated.

C. Types of Ionizing Radiation

1. Alpha Particles: Not generally produced at Fermilab; emitted by manufactured alpha sources that are in use at Fermilab.
2. Beta Particles: Mainly found in beamline enclosures and workshop storage areas due to beam interaction with material or components; also emitted by manufactured beta sources in use at Fermilab.
3. Muons: Found at high energy accelerators (Fermilab) only when the proton beam is operating.
4. Gamma rays and X-rays (photons): Major source of radiation exposure at Fermilab; mainly found in beamline enclosures due to beam interaction with material or components rendering them to be radioactive; also emitted by manufactured sources in use at Fermilab.
5. Neutrons: Emitted by manufactured sources in very limited use at Fermilab; produced during beam transport. Produced by beam interactions during beam operation. May be associated with any posted area in and around the enclosure while the beam is operational.

D. Sources of Radiation at Fermilab

	Alpha	Beta	Muon	Gamma Rays & X-Rays	Neutrons
Accelerators (except Cockcroft-Walton)		X	X	X	X
Klystrons, Septa, Separators, and Cockcroft-Walton				X	
Activation Products		X		X	
Radioactive Sources	X	X		X	X

Lesson 4 Radiological Units and Measurements

A. Roentgen (R)

1. Defines exposure of gamma and X-rays in air. Does not pertain to any types of radiation other than photons.
2. Does not describe biological effects of radiation to humans.
3. Many instruments at Fermilab have read outs in Roentgen or milliRoentgen (mR); example: Log Survey Meter (LSM), Wallflower.
4. 1000 milliRoentgen = 1 Roentgen
5. For typical gamma and X-rays, 1 R is approximately equal to 1 rad of absorbed dose (see below).

B. rad (radiation absorbed dose) – The custom in the United States is to use a special set of units, but the rest of the world uses a different set called SI for Systeme Internationale.

1. Defines the amount of radiation energy absorbed by a material.
2. 1 rad = 100 ergs/gram.
3. Applies to all types of radiation and all types of materials.
4. SI unit is the Gray (Gy). 1 Gray = 100 rads.
5. Does not account for potential effect on human body due to different types of radiation.
6. 1000 millirads = 1 rad

C. rem (roentgen equivalent man)

1. Defines the amount of radiation dose delivered to humans.
2. Describes biological effect on humans by taking into account the effect on the human body due to different types of radiation. Weighting factors are assigned to different types of radiation to classify their biological hazard.
3. Applies to all types of radiation.

4. SI unit is the Sievert (Sv). 1 Sievert = 100 rem.
5. Used as legal unit for exposure reports where it is called equivalent dose.
6. 1000 millirem = 1 rem

D. Dose Rate and Exposure Rate

1. Measured over a given period of time.
2. Dose rate is typically measured in mrem/hr.
3. Exposure rate is measured in mR/hr; most widely used on survey instruments at Fermilab when measuring gamma and X-rays emitted by radioactive materials.

E. Radioactivity

1. Defined as the number of disintegrations (decays) a piece of radioactive material undergoes over a given period of time.
2. Typically correlated with a measurement of counts per minute (cpm) on a Frisker instrument.

F. Mathematical Examples

1. After working in a radiation field of 5 mR/hr, what would you expect your pocket dosimeter to read after 4 hours?

$$5 \text{ mR/hr} \times 4 \text{ hr} = 20 \text{ mR}$$

2. The survey meter readout on your instrument indicates 30 counts per minute (cpm). If you are on the x10 scale, what is the actual count rate?

$$30 \text{ cpm} \times 10 = 300 \text{ cpm}$$

Lesson 5 Background Radiation

A. Average Annual Background Dose

1. 620 mrem per year from background radiation.
2. Background dose increased 70% since the 1980's mostly as a result of more medical imaging procedures, many of which have greatly improved health care.
3. 48% of background dose is from computed tomography (CT scans), nuclear medicine, and fluoroscopy (about 300 mrem).
4. Approximately 37% of background dose is from indoor radon (230 mrem per year).
 - Radon gas originates from radium in the soil and building materials. It decays to give off radon gas. Indoors it can build up to levels that are potentially hazardous when inhaled.
 - Radon can also be found here at Fermilab and is typically discovered during personal frisking. It can be attracted to plastic hard hats and clothing by static electricity.
5. Approximately 13% of background radiation is from cosmic, terrestrial, and internal radiation.
6. Background dose is much higher than the doses typically received at Fermilab.

Total Average Annual Background Radiation Dose from All Sources

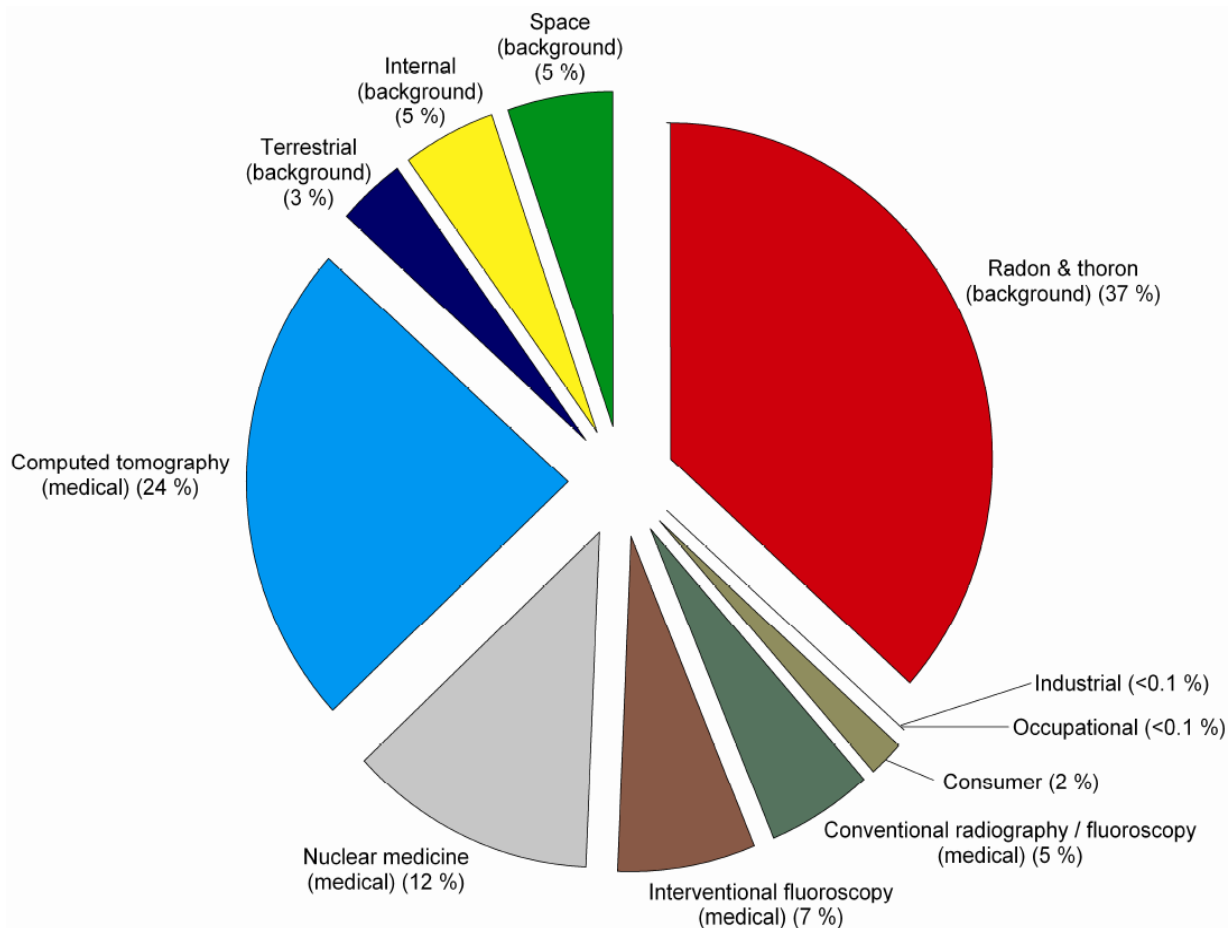


Figure 1 Pie Chart from National Council on Radiation Protection (NCRP) Report No. 160, "Ionizing Radiation Exposure of the Population of the United States" (2009)

Typical Background Exposures from Various Sources of Man-Made Radiation

Man-Made Background Radiation Source	Typical Dose (mrem)
Head/Neck X-ray	20
Chest X-ray	10
Lumbar Spinal X-ray	130
Heart Stress Test (^{99m}Tc , 34 mCi total)	1,000
CT Scan	1,000 - 2,500 depending on type of scan
Airport Body Scanner (backscatter machine)	0.01
Airplane Flight	0.6 mrem per hour of flying

Table 1 Information in above table may be found at http://www.radiationanswers.org/radiation-blog/Airport_xray_scanners.html and <http://www.iem-inc.com/toolexpo.html>

Lesson 6 Biological Effects of Radiation and Prenatal Exposure

A. Basis for Human Effects

1. Early radiation workers
2. Survivors of atomic bombs
3. Radiation accidents
4. Radiation therapy

B. Factors Influencing Biological Effects

1. Total Dose: The greater the dose, the more severe the biological effect.
2. Dose Rate: The faster the dose is received, the less time the cell has to repair itself and the more severe the effect.
3. Type of Radiation: Externally, neutrons are more damaging than betas or gammas. Alpha particles are not an external hazard because they cannot penetrate the outer layer of skin. Alpha particles are an internal exposure hazard if inhaled or ingested.
4. Area of Body Exposed: The larger the area exposed, the greater the effect.
5. Location of Exposure: The torso of the body contains critical organs, so an exposure to the torso has a greater effect than an exposure to the hands or feet.
6. Cell Sensitivity: Some types of cells are more sensitive than others.
7. Individual Sensitivity: Some individuals/age groups are more sensitive than others.

C. Acute Doses

1. A large amount of dose received in a short period of time.
2. If great enough, radiation sickness develops with symptoms shown in organs or systems with rapidly dividing cells (bone marrow, gastrointestinal tract). Severity depends on dose.

3. No biological effects to humans seen at doses <10,000 mrem.
4. Probability of an acute dose at Fermilab is extremely remote; a lot of radioactive material is present but it is usually of a very low level; safety features in place do not allow employees to receive large doses.

D. Chronic Doses

1. A small amount of radiation received over a long period of time such as background radiation and occupational doses received at Fermilab.
2. The human body handles chronic doses better than acute doses.

E. Biological Effects of Chronic Radiation Doses

1. No detectable physical changes, but chronic exposure could affect the DNA of the cell.
2. Possible Effects to DNA in Cells:
 - Somatic Effects: Seen in a person who receives a chronic dose. Examples are cancer and cataracts. There is an extremely low chance of somatic effects occurring as a result of occupational doses received at Fermilab.
 - Genetic Effects: Seen in future generations due to damage in reproductive cells. There is an extremely low chance of genetic effects occurring as a result of occupational doses received at Fermilab.

F. Prenatal Radiation Exposure

1. Potential Biological Effects

- In studies of children exposed in utero to radiation from atomic bombs, few effects were observed at doses <15,000 mrem.
- At very high doses of >15,000 mrem, low birth weights and mental retardation were observed in some infants.
- An increased chance of childhood cancer has been suggested, but not proven at very high radiation doses.

2. DOE Embryo/Fetal Dose Limits

- Dose limit of 500 mrem for entire gestation period.
- At present occupational dose limits, risk from radiation dose is minimal compared to general risks of pregnancy. DOE dose limits are set as an additional measure of protection.

3. Fermilab's Prenatal Policy

- Applies only to Fermilab employees
- All women routinely being monitored for radiation exposure shall receive appropriate information concerning prenatal radiation exposure.
- If a woman knows or suspects that she is pregnant, she may:
 - Notify the Medical Office in writing. Under this option, she would then become a Declared Pregnant Worker. An Area RSO will conduct an evaluation of her work area and assigned tasks.
 - Choose not to notify the Medical Office. Under this option, the usual occupational exposure limits will continue to be applied.
- Declared Pregnant Workers employed by Fermilab may:
 - Request a temporary reassignment to work in areas involving a lower potential for radiation exposure.
 - Request a leave of absence.
 - Continue with the same job assignment and control her exposure such that the embryo/fetus dose limits are not exceeded.
 - Terminate employment at the Laboratory.
- For a Declared Pregnant Worker, effort will be made to maintain dose to the fetus to <50 mrem/month. Fetal monitoring badges are available.
- If dose to embryo/fetus is calculated at >500 mrem, a Declared Pregnant Worker will not be assigned to tasks where additional exposure is likely.

Lesson 7 Dose Limits, Dosimetry, and Records

A. Dose Limits

1. DOE Legal Dose Limits:

- Whole Body: 5,000 mrem/yr
- Lens of the Eye: 15,000 mrem/yr
- Extremities: 50,000 mrem/yr
- Skin: 50,000 mrem/yr
- Declared pregnant worker: 500 mrem during gestation period
- Minors and students under the age of 18: 100 mrem/yr

2. Fermilab Administrative Dose Limit: 1,500 mrem/yr.

- 95% of permanent Fermilab workers receive <100 mrem/yr.

B. Dosimetry Devices

1. Dosimetry Badge

- Legal record of exposure.
- Fermilab's dosimetry badge measures beta, gamma, and neutron.
- Badges are sent off-site for processing.
- Do not open or tamper with dosimetry badges.

2. Finger Ring

- Worn if there is a chance for significant dose to extremities.
- Finger rings are assigned to individuals by Area RSOs.

3. Pocket Dosimeter

- Direct reading dosimeter used to keep track of exposure during work.
- Measures gamma dose.
- Should be worn next to dosimetry badge.
- Should be zeroed when >75% of full scale.
- It is the back up for the dosimetry badge in case badge is lost.

4. Digidose

- Small electronic dosimeter used for high dose jobs.
- Measures gamma dose.
- Beeps once for each accumulated mrem of dose.
- Specified by Area RSO when required.

C. Policies for ALL Dosimetry Devices

1. To be worn only by person to whom device is issued.
2. To be worn at all times when required by signs, RWP, or radiological control personnel.
3. Do not take dosimetry devices off-site.
4. In a radiological area, if any dosimetry device becomes lost, off-scale, damaged, or contaminated:
 - Put work in a safe condition.
 - Alert others in the vicinity.
 - Immediately exit the area.
 - Notify the Area RSO or Division/Section/Center ES&H Group.

D. Policies for Dosimetry Badges and Finger Ring Badges

1. Should be returned for processing as scheduled or upon request.
 - Dosimetry badges and finger ring badges are to be turned in on the first working day of January, April, July, and October.
2. One's dosimetry badge should be worn facing forward on the chest area, on or between the waist and the neck, or as specified by the Area RSO.
3. Should be stored in a proper storage location, an area with a low background and without excessive heat or moisture.
4. Should not be worn at off-site radiological facilities unless specifically authorized by the Senior Radiation Safety Officer. If this happens, the individual should immediately report to the ES&H Section Dosimetry Program Manager.

5. Should not be knowingly exposed to security X-ray devices, excessive heat, moisture, or medical sources of radiation. If such exposure occurs, promptly return the dosimetry badge/finger ring badge to the ES&H Section Dosimetry Program Manager or Area RSO with an explanation.

E. Policies for Pocket Dosimeters and Digidoses

1. When required, shall be worn next to one's dosimetry badge.
2. Return when the device is due for calibration. The pocket dosimeter is due on the last day of the month indicated by the sticker. Pocket dosimeters can be obtained from the stockroom.
3. The user is responsible for recording the dose from a pocket dosimeter. The difference between the initial reading and the final reading at the end of the day or job gives an indication of how much radiation has been received. Each division/section/center has its own policy regarding maintenance of these records. Contact your Area RSO for more details.
4. Digidoses are typically issued by the Area RSO and will be collected upon completion of the job for which they were issued.

F. Dose Records

1. Obtaining Dose Reports

- Annual summary sent to badge holders.
 - Temporary personnel receive quarterly reports.
 - A current dose report can be obtained by submitting a written request to the ES&H Section Dosimetry Program Manager.
2. Each radiation worker is responsible to contact his/her Area RSO or the Dosimetry Program Manager if monitored for radiation exposure elsewhere.

G. Medical Exposures

1. Although it is not required, a radiological worker who has received a medical procedure involving radioactive materials should inform the Medical Office, the Area RSO, or the Dosimetry Program Manager.
2. Doses from medical exposures are not to be included in one's occupational exposure history record.

3. The radioactivity within the body may interfere with the conduct of radiation surveys of equipment and individuals.
4. If a dosimetry badge was worn during a medical procedure, the badge should be sent to the vendor for processing and an exposure investigation must be initiated.
5. The affected individual should contact his/her Area RSO upon returning to work.
6. The Area RSO or designee should conduct a whole body frisk.
 - If no radioactivity above background can be detected, the individual can be released to perform radiological work.
 - If levels exceed background, the individual should be restricted from radiological work until levels return to background.
7. The Area RSO should visit the individual's workbench/desk area to ensure the prevailing dose rates are below 0.25 mR/hr the majority of the workday.
8. Waste materials (paper products and chewing gum, in particular) may be contaminated after use. Care must be taken to isolate these materials by placing them in temporary storage or the affected individual should take the materials home for disposal. The Area RSO or designee should make the appropriate arrangements.

H. ALERT List

1. Fermilab's ALERT List is used to keep workers' annual radiation exposure below the Fermilab administrative limit of 1,500 mrem/year.
2. An individual will be placed on the ALERT List if his/her whole body dose is >300 mrem in a quarter.
3. Individual and supervisor are instructed on techniques to minimize dose and a more rigid monitoring system is imposed.

Lesson 8 Keeping Exposures ALARA

A. ALARA Concept

1. ALARA stands for As Low As Reasonably Achievable.
2. ALARA is not a dose limit but a process with the objective of keeping doses as far below the applicable limits as is reasonably achievable.

B. Responsibilities

1. Individual: Ultimately responsible to maintain his/her dose ALARA and to report any radiological problems and concerns.
2. Management and Radiological Control Organization: Provide resources and assistance. Examples are as follows:
 - Review work plans and procedures.
 - Plan tasks.
 - Perform dose estimates for individuals and groups.
 - Conduct radiological surveys and monitoring.
 - Ensure personnel receive appropriate training.

C. External Dose Reduction: Time, Distance, and Shielding

1. Minimize Time

- Pre-plan the job.
- Procure the necessary equipment prior to starting work.
- Never loiter in an area controlled for radiological purposes.
- Remove parts/components to areas with lower dose rates to perform work.
- Use mock-ups and practice runs that duplicate work conditions.

2. Maximize Distance

- Be familiar with radiological conditions in the area. Stay as far away as possible from the source of radiation, moving to lower dose rate areas during delays.
- Use tools with long handles or other remote handling devices when possible.

3. Use of Shielding

- Take advantage of permanent shielding such as non-radioactive equipment or structures.
- If the job warrants, temporary shielding can be installed; consult with Area RSO.

D. Internal Dose Reduction

1. Internal exposure occurs as a result of radioactive material entering the body through inhalation, ingestion, absorption through the skin, open wounds, or cuts.
2. One of Fermilab's isotopes of concern is tritium (radioactive form of hydrogen) which is found in some cooling water systems and vacuum pump oil.
 - Note that the radioactive form of an element reacts the same way chemically as the stable form of the element. For example, tritium reacts the same way chemically as hydrogen.
3. Methods to prevent radioactive material from entering the body:
 - Do not eat, drink, smoke, chew, or apply cosmetics in any radiologically posted area.
 - Comply with the requirements of all work documents.
 - Bandage wounds, cuts, rashes, and abrasions before entering any area where contamination may be present.
 - Wear respirators properly when they are required.

Lesson 9 Radiological Postings and Worker Responsibilities

A. General

1. All signs, postings, and labels have the following things in common:
 - Yellow background with black or magenta lettering.
 - Standard 3-bladed propeller shaped symbol.
2. All access points must be posted.
3. Barriers must be used when necessary and must be conspicuously posted.
4. Entrance points must have signs and all radiological hazards must be noted.

B. Radiological Postings

1. *CAUTION: Controlled Area*

- Denotes any area where access is controlled to protect personnel from exposure to radiation and/or radioactive material.
- A Controlled Area is not a radiological area.
- Requirements for Entry: General Employee Radiation Training (GERT).

2. *CAUTION: Radioactive Material*

- Any area within a Controlled Area, accessible to individuals, where items or containers of radioactive material exist and the total activity of radioactive material exceeds specified 10 CFR Part 835 values.
- A Radioactive Material Area is not a radiological area.
- Requirements for Entry: GERT; however, Radiological Worker training is required to work with the materials in the area.

3. *CAUTION: Radiation Area*

- An area, accessible to individuals, in which radiation levels could result in an individual receiving a dose to the whole body in excess of 5 mrem in 1 hour at 30 centimeters from the source or from any surface that the radiation penetrates.
- Requirements for Entry: Radiological Worker training, signature on RWP as appropriate, and dosimetry badge.
- Requirements to Exit: Refer to RWP instructions.

4. *DANGER: High Radiation Area*

- An area, accessible to individuals, in which radiation levels could result in an individual receiving a dose to the whole body in excess of 100 mrem in 1 hour at 30 centimeters from the radiation source or from any surface that the radiation penetrates.
- Requirements for Entry: Radiological Worker training, signature on RWP as appropriate, dosimetry badge, and pocket dosimeter.
- Requirements to Exit: Refer to RWP instructions.
- 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.

5. *GRAVE DANGER: Very High Radiation Area*

- An area, accessible to individuals, in which radiation levels could result in a person receiving an absorbed dose in excess of 500 rads in one hour at 1 meter from a radiation source or from any surface that the radiation penetrates.
- Requirements for Entry: Radiological Worker training, worker signature on RWP or written authorization by the Area RSO to enter the area, dosimetry badge and supplemental dosimeters, and survey meters or dose rate indicating device available at the work area.
- Access points will be secured by control devices, locks, etc.
- Additional requirements will be imposed by the Area RSO when dose rates exceed 1000 mrem/hr.
- Requirements to Exit: Post-job briefing, dosimetry records completed, and whole body frisking as applicable.
- Access to such areas is extremely rare at Fermilab.

C. Posting Contamination, High Contamination, and Airborne Radioactivity Areas

1. *CAUTION: Contamination Area*

- Any area, accessible to individuals, where removable surface contamination levels exceed or are likely to exceed the removable surface contamination values specified in Chapter 2, Table 2-2 of the FRCM, but do not exceed 100 times those values.

2. *DANGER: High Contamination Area*

- Any area, accessible to individuals, where removable contamination levels exceed or are likely to exceed 100 times the removable surface contamination values specified in Chapter 2, Table 2-2 of the FRCM.

3. *CAUTION: Airborne Radioactivity Area*

- Any area, accessible to individuals where (1) the concentration of airborne radioactivity, above natural background, exceeds or is likely to exceed the Derived Air Concentration (DAC) values listed in Appendix A or Appendix C of 10 CFR 835 or (2) an individual in the area without respiratory protection could receive an intake exceeding 12 DAC-hours in a week.

4. Requirements for Entry/Exit to/from Contamination, High Contamination, and Airborne Radioactivity Areas

- Entry: Radiological Worker training, worker signature on RWP, dosimetry badge and supplemental dosimetry as required by RWP, protective equipment/clothing required by the RWP, and pre-job briefing as required.
- Exit: Whole body frisk before removal of protective clothing as specified by RWP, Radiological Control personnel, or as posted.

D. Responsibilities of the Worker

1. Read all signs before entering area.
2. Comply with all information on signs, postings, and labels. Do not remove or relocate them.
3. Disregarding or removing/relocating signs, postings, or labels can lead to:
 - Unnecessary or excessive radiation exposure.
 - Personnel contamination.
 - Disciplinary action or denial of use of Fermilab facilities.

4. Within an area controlled for radiological purposes:
 - Always practice ALARA.
 - Follow the area policy concerning eating, drinking, smoking, and chewing.
 - Obey any posted, written or oral requirements from Radiological Control personnel.

5. Report to the Area RSO or division/section/center ES&H Group any unusual situation you identify, or any situation where radiological controls are not adequate or are not being followed.

Lesson 10 Radiological Work Permits (RWPs)

A. Purpose of RWPs

1. To inform workers of area radiological conditions.
2. To inform workers of entry requirements into the areas.
3. RWPs are posted at the access point into the area or where keys are obtained.

B. Circumstances Requiring an RWP

1. Entry and work in certain posted radiological areas.
2. Handling of materials with removable contamination exceeding the specified limits.

C. Information Included in RWPs

1. Unique identifying number.
2. Work location.
3. Permit type.
 - General RWP: Routine or repetitive activities in areas with well characterized and stable radiological conditions.
 - Job Specific RWP: Non-routine work or work in areas with changing radiological conditions.

4. Date of issue and expiration.
5. Description of work.
6. Access type.
7. Work area conditions.
8. Time limits and dose limits.
9. Work documents.
10. Dosimetry requirements.
11. Training requirements for entry.
12. Portable survey instrumentation.
13. Protective clothing and equipment requirements.
14. Additional instructions.
15. Survey maps show specific area dose rates, location of "hot spots", and levels of contamination in the vicinity.
16. Special requirements including, in some instances, protective measures against other hazards.
17. Authorizing signatures.

D. Worker Responsibilities

1. Sign the RWP. This indicates one has read and understands the requirements of the RWP.
2. Obey the instructions on the RWP.
3. If any part of the RWP is not understood, contact your supervisor or Area RSO.

Lesson 11 Control of Radioactive Material

A. Fermilab Radioactivity Class System

1. Activated material is classified by external exposure rate.
2. The appropriate class label needs to be affixed when an item is removed from an enclosure or when it is disassembled.
3. Check items when practical and if warranted, reclassify. Remove labels when item is no longer radioactive. Questions should be directed to your Area RSO.

Radioactivity Class Labels

Class Label	At Least	Less Than
Exposure Rate (mR/hr @ 1 ft)		
CAUTION: RADIOACTIVE MATERIAL CLASS 1	<ul style="list-style-type: none"> • 50 cpm above background* on a Frisker OR • 2000 cpm above background* on a Bicon Analyst**, if background is 2000-3000 cpm OR • Count rate* is equal to or greater than twice the mean background rate in a low background area (< 2000 cpm) 	1 mR/hr
CAUTION: RADIOACTIVE MATERIAL CLASS 2	1	10 mR/hr
CAUTION: RADIOACTIVE MATERIAL CLASS 3	10	100 mR/hr
DANGER: RADIOACTIVE MATERIAL CLASS 4	100	1000 mR/hr (= 1 R/hr)
DANGER: HIGHLY RADIOACTIVE MATERIAL CLASS 5	1 R/hr	----
* Measured at contact.		
** Bicon Analyst scintillation probe on x10 scale.		

B. Surveying and Labeling Materials

1. Survey all items coming out of radiological areas. Frisk yourself first, then the materials.
2. Verify that the survey instrument is on and appears to be functioning properly. Set to the proper scale (x1) and ensure that the audio output can be heard.
3. Verify that the instrument is within its calibration period.
4. Check background levels to ensure that you are in a low background area. If the background count rate is greater than 100 cpm on a Frisker, contact the Area RSO.
5. Perform a response check by using the radioactive source mounted on the instrument.
6. Perform a contact survey, moving the probe SLOWLY (no faster than 1 inch per second) over the item to allow the detector to respond. All accessible surfaces need to be surveyed. If the Frisker reads more than 50 cpm above the background level at any time during your survey, the item is considered to be radioactive. Always assume the instrument reading is correctly.
7. If the item is determined to be radioactive using the Frisker, then use a Wallflower to determine the class label that should be applied.
 - Using the probe at 1 foot, survey at the spot which had the highest reading on the Frisker. The highest activity class rating indicated on the meter is the one that you should affix to the item.
 - If the Wallflower indicator remains in the green or "OK" region, a Class 1 label still needs to be applied because the item was found to be radioactive using the Frisker.
 - Complete all information on the label: date, exposure rate, your first initial and last name and/or your Fermilab ID number.
 - If any material is determined to be Class 2 or greater, contact the Area RSO or a Radiological Control Technician for additional instructions.

C. Transport of Radioactive Material

1. Ensure that radioactive materials have been properly labeled before transport.

2. Confirm that the receiver is allowed to receive the materials. Certain buildings on-site have restrictions on the types of radioactive material that can be brought to them. For example, restrictions are in place for use of radioactive materials in Wilson Hall.
3. Do not transport radioactive material in private vehicles. Radioactive materials must be transported in government vehicles.
4. Radioactive materials cannot be transported in Fermilab taxis.
5. Radioactive materials must be transported directly to the destination with no unnecessary stops along the way. "Side trips" off-site or to facilities frequented by the public (i.e. recreational facilities) on-site are prohibited.
6. A Material Move Request must be completed when:
 - Business Services Section (BSS) transports radioactive material on-site between Divisions/Sections/Centers.
 - On-site transport of Class 3 or higher items.
 - Off-site transport of radioactive material.
7. A Material Move Request requires a determination of whether the material is radioactive. If the possibility exists that the material is radioactive, a radiation survey must be performed. Only specially trained personnel can perform this survey. Contact your Area RSO if you have material which needs to be surveyed.
8. If the material is radioactive and is being shipped off-site, contact the ES&H Section Hazard Control Technology Team so that it can be packaged appropriately for transportation.

D. Storage of Radioactive Material

1. Before storage is considered for any radioactive material, its "value" should be determined. Unless it is an item of significant value, disposal or decontamination is the preferred alternative to storage.
2. Radioactive materials should only be stored in designated areas which have been approved by the Area RSO. Storage of non-radioactive material in such designated areas should be minimized.

3. Prior to long-term storage, all items must be surveyed. It is the responsibility of the person requesting storage to make all necessary arrangements. Your Area RSO or division/section/center ES&H personnel can assist you.
4. Radioactive material should be stored in a manner that reduces combustible loading. The use of cardboard containers for storage is discouraged.
5. Outdoor storage of radioactive material requires Area RSO approval. In cases where outdoor storage is necessary, care should be taken to choose a container that will prevent release of radioactive material to the environment.
6. Radioactive material shall not be stored off-site. Nor shall it be stored in any on-site housing or established eating and drinking areas, i.e. lunchrooms, offices or vending areas.

E. Moratorium on Metals Recycling

The DOE issued a moratorium on the unrestricted release for recycling of scrap metals from radiological areas. Fermilab personnel who offer metals for recycling must comply with the following:

1. All metals offered for recycling must continue to be checked for radioactivity in accordance with Fermilab release criteria. All metals found to be radioactive must be disposed of as radioactive waste.
2. If the metals are found not to be radioactive, they may be offered for recycling. These metals must be physically segregated into two groups before the Business Services Section will pick them up:
 - Group 1: Items that did not originate from a radiological area before being offered for recycling.
 - Group 2: Items that did originate from a radiological area.
3. Business Services Section will proceed to recycle the items from Group 1.
4. Per Fermilab policy, items originating from Radioactive Material Areas are considered Group 2 and cannot be recycled.
5. Group 2 items will be stored pending further instructions from the DOE.

F. Sealed Radioactive Source Controls

1. Manufactured radioactive sources are to be used only by authorized individuals. Radioactive Source training is available online from the ES&H Section. Radiological Worker training is a prerequisite.
2. Sources are not to be brought to or taken from Fermilab without advance approval from the Senior Radiation Safety Officer. This includes sources contained in instruments or equipment.
3. Figures 2, 3, and 4 below show typical radioactive source configurations used at Fermilab.

Figure 2 Gamma Emitting Wand Source



Figure 3 Beta Gun

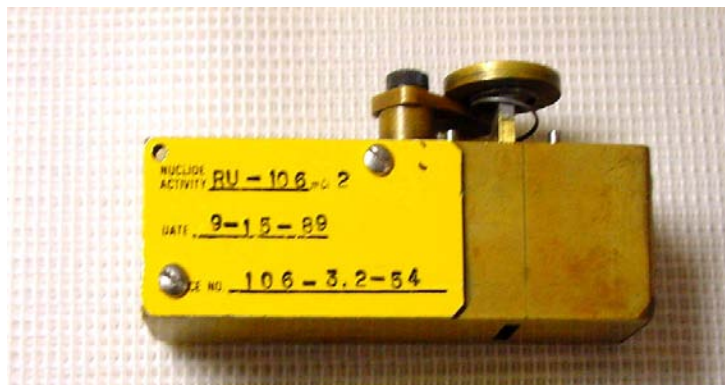


Figure 4 Disk Source



4. When sources are in use, the area must be posted with a "CAUTION: RADIOACTIVE MATERIAL" sign. If the source creates a radiation field over 5 mrem/hour at 30 cm from the source, the area will be posted with a "CAUTION: RADIATION AREA" sign.
5. When not in use, radioactive sources shall be stored in designated locked boxes/cabinets bearing the sign "CAUTION: RADIOACTIVE MATERIAL."
6. Should you come across a source that is unattended and unsecured, contact the ES&H Section Source Physicist or your Area RSO.
7. Radioactive sources have source ID labels and/or tags attached to them. If you find a source tag loose or what you think may be an unlabeled source, contact the ES&H Section Source Physicist or your Area RSO.
8. If you suspect that a source is broken or causing contamination, call x3131 immediately. If there is a chance that you may be contaminated, ask someone else to call. Do not handle the source or even attempt to move it. Keep others away from the area.

Lesson 12 Contamination Control

A. Radioactive Contamination

1. Defined as radioactive material that has been deposited on the surfaces of structures, areas, objects, or personnel.
2. Loose surface contamination can be transferred by contact with other surfaces. Found in beamline enclosures. Proper use of protective clothing helps to control the hazard.

B. Decontamination

1. The removal of radioactive materials from locations where it is not wanted. Decontamination is usually performed by Radiological Control Organization personnel.

C. Sources of Radioactive Contamination

1. Leaks or breaks in systems containing radioactive liquids (e.g. vacuum pumps or cooling water systems on target stations).
2. Dust, debris, grease, dirt, and oil within or from a beam/beamline enclosure because it may have become activated.
3. Certain operations, such as grinding, cutting, or welding on activated materials.
4. Damage to radioactive sealed sources.

D. Contamination Control Methods

1. Understand and comply with the radiological work controls, including protective clothing, respiratory equipment, containment devices, and frisking requirements when working in a posted Contamination Area.
2. Use good work practices such as good housekeeping and cleaning up after jobs.
3. Identify and report leaks in radiological systems before they become a serious problem.

4. Make sure that required contamination surveys are performed before removing items from posted Contamination Areas.
5. Avoid unnecessary contact with contaminated surfaces.
6. Place contaminated tools, equipment, etc. inside bags when work is finished.
7. Avoid stirring up contamination because it could become airborne.
8. Exit the area immediately if an injury occurs involving a cut or wound and call x3131.
9. Minimize the production of contamination and reduce the levels of contamination prior to work. This is called source reduction. An example of source reduction is the final clean up of the Main Injector tunnel at the end of an extended shut down. Magnets are wiped down, floors are swept, and general cleaning is done to minimize the amount of dust and debris that may be activated once the beam is run again.
10. No machining of radioactive material is allowed without prior Area RSO approval.

E. Selecting and Putting On Protective Clothing

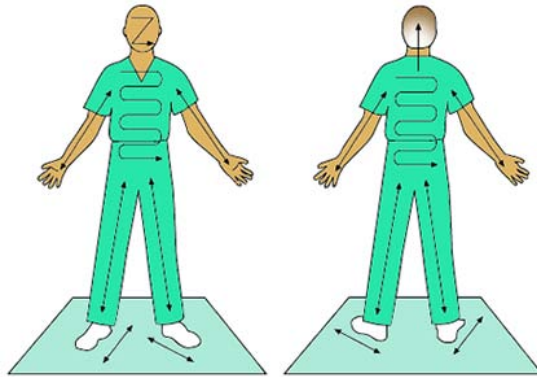
1. The protective clothing required for the work will be specified in the applicable RWP or the Area RSO or the RCT assigned to cover the job will provide instructions.
2. Check clothing for rips and tears. Replace if necessary.
3. There is no particular order in putting on protective clothing.
4. Supplemental pocket or electronic dosimeters should be placed on the outside of the protective clothing so that you can access them.

F. Conducting a Whole Body Frisk

1. Verify that the Frisker is on, appears to be functioning properly, is in calibration, is set to the proper scale (x1 scale), and the audio output can be heard during frisking. If the instrument does not appear to be functioning properly or is not in calibration, contact your Area RSO.

2. Frisk your gloved hands before picking up the probe. If your gloves are contaminated, remove all protective clothing and dispose of it properly.
3. After frisking your hands, source check the instrument. If the source check fails, contact the Main Control Room and request assistance from Radiological Control personnel.
4. If the source check is satisfactory, hold the probe less than 1/2 inch from the surface being surveyed. Move the probe SLOWLY over the surface, approximately 1 inch per second. A whole body frisk should take AT LEAST 3 to 5 minutes.
5. If you are working with another person, help each other by surveying each other's shoe bottoms.
6. Perform a whole body frisk in the following order, pausing at places that may have come in contact with contamination. If the count rate increases during frisking, pause over the area to provide adequate time for the instrument to respond.
 - Dosimetry & keys
 - Head
 - Neck and shoulders
 - Arms
 - Chest and abdomen
 - Back, hips, seat of pants
 - Legs
 - Shoe tops
 - Shoe bottoms
 - Personal belongings including hard hat, if applicable

Figure 5 Proper Whole Body Frisk



7. If you are not required to perform a whole body frisk at the exit, follow the posted instructions.
8. Remove your gloves and then frisk your hands again. 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 frisk their hands before handling the probe.
9. There may be isolated cases where the frisking station is located inside the enclosure. When exiting these areas, check the background level in the vicinity to ensure that you are in a low background area (<100 cpm on the Frisker). If you are not in a low background area, move to a low background area or contact your Area RSO.
 - Remove all protective clothing at the exit.
 - Proceed to the nearest designated monitoring station. If no alternative location is designated, contact your Area RSO.
 - Conduct your frisk.

G. Disposal of Protective Clothing

1. If clothing has no contamination, dispose of it in the regular trash.
2. If any portion of the protective clothing exceeds 50 cpm above background, remove it in a manner that will minimize the spread of contamination and prevent you from becoming contaminated. In this case, all of your protective clothing needs to be disposed of in a radioactive waste bag or drum unless instructed otherwise. You will be required to perform a whole body frisk upon its removal.

3. If you are performing a frisk after removing your protective clothing and find more than 100 cpm above background, you are contaminated. Minimize your movements to reduce the spread of contamination, and call or have someone call x3131.
4. If during the frisk of your personal belongings, you find greater than 50 cpm above background, contact your Area RSO for further instructions.

H. Frisking Procedure When No Protective Clothing Is Worn

1. Instrument checks are the same as for a frisk when wearing protective clothing.
2. At a minimum, frisk your hands and shoe bottoms.
3. Frisk other areas of your body which may have come in contact with surfaces while inside the enclosure.
4. Frisk your hard hat, if applicable.

Lesson 13 Radioactive Waste Management

A. Radioactive Waste

1. Radioactive waste is radioactive material that is no longer useful. This may be:
 - Material that has been activated by the beam.
 - Items that have come in contact with radioactively contaminated material and are now contaminated.
2. Radioactive waste bags, radiation warning signs, and radioactive class labels shall not be thrown away in normal trash cans or dumpsters. These items are to be reused, if possible, or collected as radioactive materials in radioactive waste drums or other suitable containers whether or not they are determined to be radioactive.

B. Mixed Waste

1. Mixed waste is chemically hazardous or toxic waste which is also radioactive.

2. Mixed wastes are a special problem because it is extremely difficult and expensive to dispose of them.
3. Individuals who generate waste must certify that the waste contains no hazardous materials at the time of disposal. If the waste is radioactive and contains hazardous materials, special instructions apply. Some typical hazardous materials used at Fermilab are ethyl alcohol, Freon, methanol, acetone, lead, lead based solder, beryllium, sodium chloride, and Simple Green detergent.

C. Waste Minimization

1. The concept of waste minimization as applied to radioactive material focuses on reducing or eliminating the volume of radioactive and mixed waste sent for disposal, thus reducing the impact on the environment and the public, and also reducing disposal costs.
2. The minimization of the generation of mixed waste is especially important because the disposal of such waste is very difficult.
3. The following are ways to reduce the amount of radioactive and mixed waste that is generated:
 - Use good housekeeping techniques.
 - Segregate all activated and/or contaminated materials from all other hazardous and non-hazardous materials.
 - Ensure that all materials not required to be in a radiological area are removed upon completion of the work.
 - Prevent the generation of mixed waste by substituting non-hazardous materials for hazardous materials, both in the engineering design phase and in everyday practice.
 - Do not use hazardous materials to clean radioactive components unless the components have no removable radioactive contamination present.
 - Except for certain special circumstances, water and KPC 820N are the only approved cleaners which may be used on radioactive materials.

D. Radioactive Waste Generator Responsibilities

1. You must contact your supervisor and/or rad waste coordinator to discuss the details of how your division/section/center handles its radioactive waste. You must contact one of these individuals prior to generating any waste.

2. Radioactive waste generators must comply with Fermilab's Low Level Waste Certification Program. Divisions/Sections/Centers have waste coordinators to assist in complying with this program.
3. Ensure that any waste you generate, or are responsible for, is properly and promptly characterized and packaged for disposal.
4. Ensure that unknown wastes are not generated. Characterizing unknown waste can be very time consuming and expensive.
5. Ensure that mixed wastes are not generated if at all possible. Written approval may be required before using certain items.
6. All radioactive waste generators are required to characterize waste with sufficient accuracy to permit proper identification, minimization, segregation, transportation, treatment, storage, and disposal. This responsibility cannot be delegated or deferred. Radioactive waste materials may not be left unattended for disposal at a later time.
7. Radioactive items being transported to designated collection areas should either be labeled with class tape or be placed in radioactive waste bags. Radioactive materials shall not be stored or transported in bags used for normal trash. Radioactive materials must be transported in Laboratory vehicles.
8. All dry, solid materials that are collected as radioactive waste must be surveyed to ensure that they are radioactive prior to placement in a waste disposal container.
9. Water collected on tunnel or enclosure floors cannot be disposed of without prior permission from the Area RSO.
10. Radioactive waste items shall promptly be taken to radioactive waste collection areas. Persons who are issued containers are generally available to open them for waste disposal during normal working hours.
11. During off hours, supervisors are required to designate in advance the location (e.g., locked storage cabinet) where materials can be stored until proper radioactive waste disposal containers can be opened. When radioactive waste is placed in a designated temporary storage cabinet, the radioactive waste generator must sign the "Radioactive Waste Certification and Pickup Request Form."

E. Waste Characterization

1. At a minimum, radioactive waste characterization must include:
 - Physical description of the waste.
 - Chemical characteristics of the waste and any void-filling material or absorbent.
 - Volume of the waste.
 - Weight of waste.
 - Radionuclide distribution, concentration, and activity in waste matrix.
 - Method of assay or analysis used to determine radionuclide distribution and concentration.
 - Packaging details.
 - Packaging date, packaging weight, and total volume.
2. This information is to be placed on an inventory sheet which is maintained for each waste container as it is being filled.
3. The typical radiations emitted from dry, solid radioactive material may be detected with the Frisker. Typical background count rates found on the Frisker are about 30 to 50 cpm.
4. If the background count rate is greater than 50 cpm, it may not be possible to determine that an item is radioactive. Suspect materials should be taken to an area where the background count rate is at or below 50 cpm.
5. Tritium (radioactive hydrogen) cannot be measured with available hand-held instruments.
6. The following are waste violations/problems that have routinely occurred at Fermilab:
 - Pens - especially Magnum markers.
 - Water and/or oil in sump pumps. There is a check valve in the pump that contains about 1/2 cup of water.
 - Lead seals.
 - Printed circuit boards - they are in many places you don't expect.
 - Lead solder - almost EVERY type of electrical equipment contains lead solder.
 - Telephone handsets - contain a lot of lead solder.
 - Batteries - left in flashlights or other equipment.

F. Radioactive Waste Containers

1. All radioactive waste containers are to be kept locked up at all times so that waste characterization and control is maintained.
2. No free liquids or absorbed liquids of any type are to be placed in 55-gallon radioactive drums designated for dry, solid waste.
3. Compactible waste, such as shoe covers, gloves, other types of protective clothing, and dry rags or wipes, that has been determined to be radioactive should be placed in containers designated for compactible radioactive waste.
4. Oil or other liquids removed from vacuum pumps and from various devices, such as septa that have been in beam enclosures must be collected as radioactive waste. The liquids may contain tritium which is not detectable with hand-held instruments and may require special evaluation to determine if they are radioactive.
5. Liquids wastes are to be collected in properly labeled and approved containers appropriate for the quantity of waste generated. The following are approved containers for such wastes:
 - 55 gallon liquid drums
 - 5 gallon carboys
 - Polyethylene bottles
6. Radioactive liquid wastes of different types should normally be segregated. No water may be added to oil waste drums except for incidental water which may be present in vacuum pumps due to operation of the pump.
7. Sweeping compound used to clean beam enclosure floors may contain radioactive dust, metal grinding chips or filings, tie wraps, miscellaneous nuts, bolts, screws, and many other small parts. Sweeping compound must be collected in 55-gallon drums lined with large radioactive waste bags. Sweeping compound may not be dumped loose into unlined 55-gallon radioactive waste drums.
8. Non-compactible waste, such as contaminated lumber, structural steel, and beam pipe, is to be collected in 55-gallon drums separately from compactible waste.

9. Large quantities of materials such as radioactive cables may be collected in large steel boxes with lockable covers. Arrangements to obtain large steel boxes should be made in advance with your division/section/center ES&H Group.
10. Approved Fermilab radioactive waste containers for dry solids are:
 - Radioactive waste bags for dry compatibles.
 - 55 gallon drums; yellow, used for dry solids. NO LIQUIDS ALLOWED.
 - Steel boxes for scrap metal, wire cable, and other items too large for 55 gallon drums.
 - Bulk items too large to fit in steel boxes may be banded and placed on skids or cribbing.

G. Waste Pick-Ups

1. Once waste is properly characterized and in the appropriate container, pick-up can be arranged if:
 - A completed inventory form (HCTT Form 2 http://www-esh.fnal.gov:8001/HCT/HCT_MW_Form.pdf) has been submitted through the division/section/center waste coordinator.
 - All containers are properly secured to ensure no loss of contents during transport.
 - The container has been surveyed and labeled as "radioactive waste."
 - There is no radioactive contamination on the external surfaces of the container which is above the limit for release to uncontrolled areas.

Lesson 14 Radiological Emergencies

A. Emergency/Anomalous Situations

1. Emergency and anomalous situations are generally handled by the Area RSO and/or the division/section/center ES&H Group.
2. Lost, Off-Scale, Damaged, or Contaminated Dosimetry

If you are in an area controlled for radiological purposes and notice that your dosimetry badge, pocket dosimeter, Digidose, etc. is lost, off-scale, damaged, or contaminated:

- Place your work activities in a safe condition. For example, do not leave power tools operating.
- Alert others in the vicinity. Their dosimetry may also be lost, off-scale, damaged, or contaminated.
- Immediately leave the area.
- Notify the Area RSO or the division/section/center ES&H Group via the Main Control Room.

3. Area Contamination

In some instances, there may be possible area contamination where none is expected. Two potential indicators would be alarming contamination monitors and leaks, spills, or standing water around or near radioactive water systems. If you have reason to suspect this type of contamination:

- Do not enter the area.
- Keep others from entering the area.
- Immediately report the situation by contacting the Area RSO or the division/section/center ES&H Group via the Main Control Room.

4. Elevated Radiation Levels

Chipmunks and Scarecrows are used to monitor radiation fields due to accelerator operations. If you are working in an area and hear one of these instruments unexpectedly alarm:

- Alert others.
- Immediately leave the area.
- Contact the Main Control Room.

5. Airborne Radioactivity

There are a few continuous air monitors on-site, primarily used in Accelerator Division to monitor concentrations of airborne radioactivity. If you are working in an area and hear or see one of these instruments alarm (a whooper alarms and a red beacon begins flashing):

- Alert others.
- Immediately leave the area.
- Contact the Area RSO via the Main Control Room.

B. Emergencies Requiring Site-Wide Resources

The following are examples of emergencies that may require site-wide resources. When in doubt, assume that it is a serious emergency requiring site-wide resources.

1. Injuries in areas controlled for radiological purposes. Remember, lifesaving actions take priority over radiological control considerations.
2. Leak or spill of radioactive material outside of a radiological area.
3. Fire or smoke in a Radiation Area or involving radioactive materials.
4. Exposure to the operating beam.
5. Rupture or breakage of a radioactive source.
6. Personnel contamination (external or internal).
7. Actions in such an emergency:
 - Call x3131.
 - Stay on the phone to answer questions.
 - Keep others from entering the area.
 - Remain at the scene to the extent possible, but never endanger yourself.
8. Disregarding any of these radiological alarms or circumstances may lead to:
 - Possible excessive personnel exposure.
 - Unnecessary spread of contamination.
 - Disciplinary action.