RADIOLOGICAL WORKER TRAINING
STUDY GUIDE

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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 the 10CFR835, *Occupational Radiation Protection* and the Fermilab Radiological Control Manual, requires that mangers and supervisors at all levels are to be involved in the planning, scheduling and conduct of radiological work. This directive also requires that adequate radiological safety shall not be compromised to achieve production or research objectives.

COURSE OBJECTIVE:

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.

A radiological worker is an individual whose job assignment requires work on, with, or in the proximity of radiation producing machines or radioactive materials <u>and</u> has the potential of being exposed to at least 100 mrem a year from occupational sources.

COURSE OVERVIEW:

Radiological Worker training is required for the worker whose job assignment requires unescorted access into Radiological Areas and work with radioactive materials.

Radiological Worker training is designed to:

- prepare the worker to work safely in and around radiological areas and
- present methods to use to ensure radiation exposure is maintained As Low As Reasonably Achievable or ALARA.

This course is divided into 14 lessons.

<u>Theory portion</u> -- The first 14 lessons discuss the theory that the worker must know to work safely around radiological hazards. A written examination based on the course objectives will be given at the end of this portion. A passing score on the written examination is a prerequisite to the practical factors exercise.

Practical Factors exercise -- Generic practical exercises are incorporated into some of the lessons. This allows the worker to apply the theory portions of this course in a simulated, controlled work environment. This exercise will be evaluated against pre-established criteria.

To be classified as a Radiological Worker, an individual must successfully complete the written examination and the practical evaluation. A score of 80% or better on the written exam and a satisfactory on the practical evaluation is considered successful completion of this course.

LEARNING OBJECTIVES:

Upon completion of this lesson, the participant should be able to:

1. DESCRIBE the roles and responsibilities of the various members of the Radiological Control Organization (RCO).

I. CHARTER

The RCO is responsible for implementing Fermilab's radiological control program

Program is contained in Fermilab Radiological Control Manual (FRCM)

II. ROLES AND RESPONSIBILITIES

Fermilab Director - Has overall responsibility for radiation safety and compliance with all applicable laws and regulations. The director appoints the Laboratory Senior Safety Officer.

Senior Radiation Safety Officer (SRSO) - issues radiation safety policy; responsible for radiological control program and ensures compliance.

Division/Section Heads - sees that lab radiation safety program (including training and postings) is implemented in their Division/Section.

Area RSOs - your primary contact with the RCO; handles day-to-day activities of radiological control program; establishes radiological controls, approves Radiological Work Permits, arranges for area posting, ensures that individuals are qualified for radiological work, provides emergency response.

Radiological Control Technicians (RCTs) - assist RSOs in their respective Division/Section in the conduct of daily activities.

ES&H Section - work on the lab-wide aspects of the program, including: radioactive source usage, dosimetry program, radioactive waste, instrument maintenance and calibration.

Radiation Safety Subcommittee - Made up of members from Divisions/Sections who deal with radiological issues, work to find solutions to radiological problems of a lab-wide nature, and meet to discuss various aspects of the radiological protection program.

LEARNING OBJECTIVES:

Upon completion of this lesson, the participant should be able to:

1. DEFINE the term ionizing radiation.
2. DEFINE radioactive decay and half-life.
3. DESCRIBE characteristics of the various types of ionizing radiation.
4. LIST the sources of ionizing radiation at Fermilab.

I. ATOMIC STRUCTURE

- Basic unit of matter
- Nucleus - central portion of atom which contains the protons & neutrons
- Electrons - particles in orbit around nucleus

II. DEFINITIONS

- Radiation - energy in the form of particles or rays
- Ions - atoms or molecules with a different number of protons than electrons giving them an overall electrical charge
- Ionizing radiation - radiation that can produce ions when passing through material. This is the type of radiation we are concerned about in this course.
- 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.
- Half-life - the time it takes one-half of the radioactive atoms present in a material to decay

III. TYPES OF IONIZING RADIATION

- Alpha - not generally produced at Fermilab; only present in manufactured sources
- Beta - mainly found in beamline enclosures and workshop storage areas due to beam interaction with material or components; also present in manufactured sources
- Muon - found only at high energy accelerators (Fermilab) only when beam is operating
- Gamma rays & x-rays (photons) - major source of radiation exposure at Fermilab; mainly found in beamline enclosures due to beam interaction with material or components; also present in manufactured sources
- Neutrons - present in manufactured sources; produced during beam transport. May be associated with any posted area in and around the enclosure while beam is being transported.

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

LEARNING OBJECTIVES:

Upon completion of this lesson, the participant should be able to:

1. DEFINE the basic radiological units of roentgen, rad and rem.
2. DEFINE dose equivalent rate and its unit.
3. DEFINE the units of radioactivity.
4. Perform basic calculations using radiological measurements.

I. ROENTGEN (R)

- Defined only for gamma and x-ray in air
- Does not describe biological effects of radiation to humans
- Many instruments at Fermilab have read outs in Roentgen or milliroentgen (mR); example: LSM, wallflower
- 1000 milliroentgen = 1 Roentgen

II. rad (radiation absorbed dose)

- Applies to all types of radiation and all types of materials
- Does not account for potential effect on human body due to different types of radiation
- 1000 millirads = 1 rad

III. rem (roentgen equivalent man)

- Unit for measuring dose equivalent
- Describes biological effect on humans by taking into account the effect on the human body due to different types of radiation
- Applies to all types of radiation
- Used as legal unit for exposure reports
- 1000 millirem = 1 rem

IV. DOSE EQUIVALENT RATE AND EXPOSURE RATE

- Measured over a given period of time
- Dose equivalent rate is typically measured in mrem/hr
- Exposure rate is mR/hr; most widely used on survey instruments at Fermilab

V. Radioactivity

- Measured by the number of disintegrations (decays) a radioactive material undergoes over a given period of time.
- counts per minute (cpm) as measured on frisker

VI. Mathematical Examples

A. Special controls are imposed if you are in a radiation field of 1 rem/hr. Your instrument reads out in mrem/hr. What would your instrument have to read before additional controls would be imposed?

$$1\frac{rem}{hr}\times\frac{1000mrem}{rem}=1000\frac{mrem}{hr}$$

B. After working in a radiation field of 50 mR/hr for 3 hours, what would you expect your pocket dosimeter to read?

$$50\frac{mR}{hr}\times 3hr=150mR$$

C. The meter readout on your instrument indicates 200 counts per minute (cpm). If you are on the X10 range, what is the actual count rate?

$$\frac{200\ counts}{min}\times 10=2000\frac{counts}{min}$$

LEARNING OBJECTIVES:

Upon completion of this lesson, the participant should be able to:

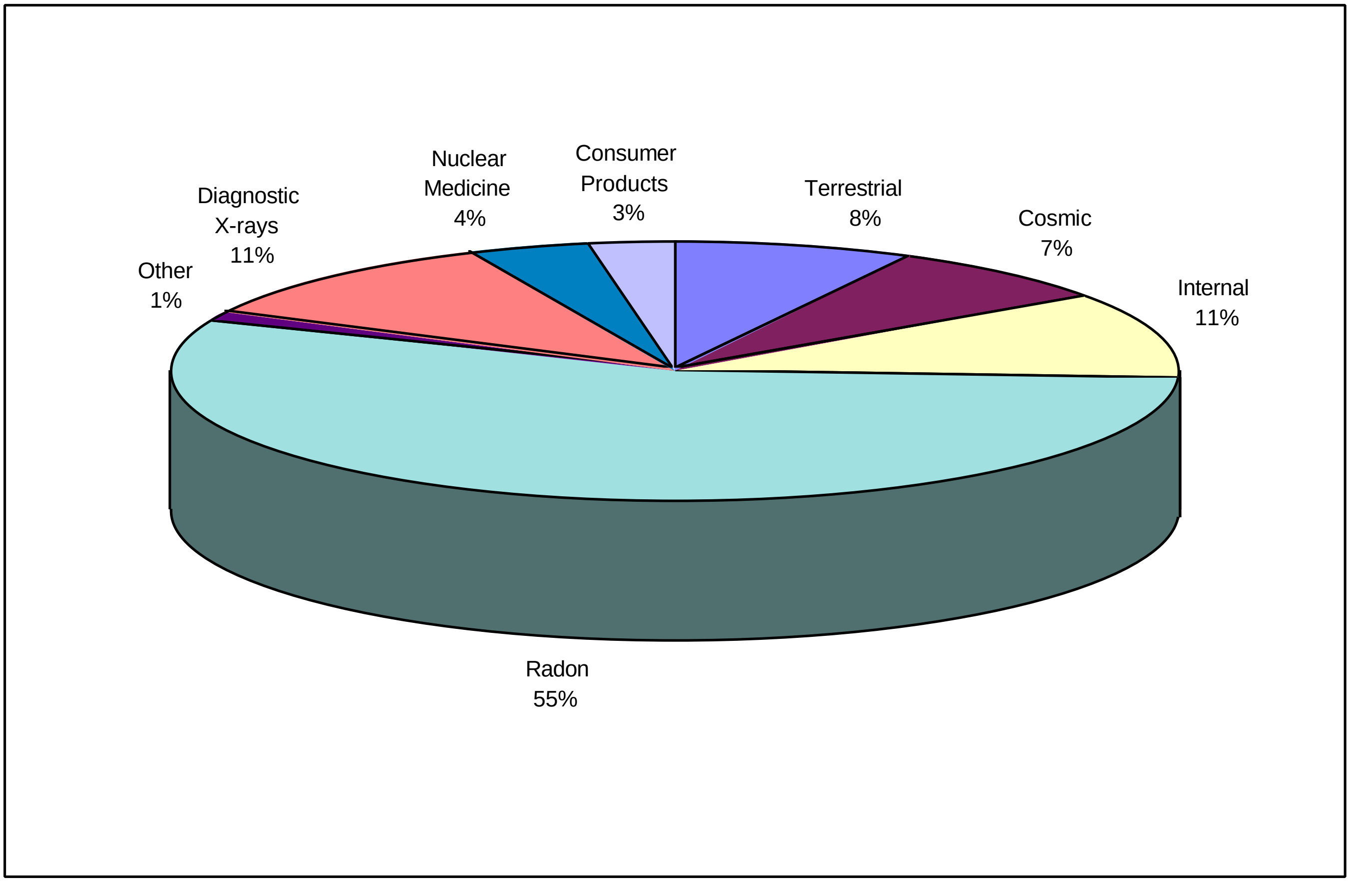
1. IDENTIFY the basic sources of natural background radiation.
2. IDENTIFY the major sources of man-made background radiation.

I. AVERAGE ANNUAL DOSE

- 360 mrem
- Normally the background dose is <u>much higher</u> than the doses typically received at Fermilab.

II. NATURAL BACKGROUND SOURCES

- Cosmic - from outer space
- Terrestrial - rocks & soil, drinking water, and building materials
- Radon - radium in soil & building materials decays to give off radon gas; hazard when inhaled; largest portion of background dose (˜ 200 mrem/yr); static electricity attracts radon to some items (polyesters & plastics) Radon is a special case of terrestrial radiation. It is a gas that comes from the radioactive decay of radium which is present in soil and building materials. It can collect in basements and other poorly ventilated locations in a building. It is a hazard when inhaled. Radon is the largest contributor (approximately 200 mrem/yr) to background radiation exposure. It can also be found here at Fermilab and is typically discovered during personal frisking. It can be attracted to plastic hard hats and polyester clothing by static electricity.
- Internal - food you eat, air you breathe, & water you drink



III. MAN-MADE SOURCES

- Medical - diagnostic, therapeutic
- Consumer items

  Televisions
  Welding rods
  Lantern mantles
  Camera lenses
  Dental Prostheses
  Smoke detectors
  Tobacco products
  Fertilizers

- Other: Nuclear power, fallout

LEARNING OBJECTIVES:

Upon completion of this lesson, the participant should be able to:

1. LIST the factors that influence the degree/severity of biological effects.
2. IDENTIFY acute biological effects.
3. DESCRIBE the potential that a radiation worker at Fermilab has for receiving an acute dose.
4. IDENTIFY chronic biological effects.
5. COMPARE risks from chronic radiation dose to risks in daily life.

I. BASIS FOR HUMAN EFFECTS

- Early radiation workers
- Survivors of atomic bombs
- Radiation accidents
- Radiation therapy

II. FACTORS INFLUENCING BIOLOGICAL EFFECTS

- Total dose - the greater the dose the more severe the biological effects
- Dose rate - the faster the dose is received the less time the cell has to repair itself and the more severe the effect
- Type of radiation - neutrons are more damaging than betas or gammas
- Area of body exposed - the larger the area exposed, the greater the effect
- Location of exposure - the torso of the body contains critical organs so an exposure here has a greater effect than an exposure to the hands or feet
- Cell sensitivity - some types of cells are more sensitive than others
- Individual sensitivity - some individuals/age groups are more sensitive than others

III. ACUTE DOSES

- Large amount of dose in a short period of time
- 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
- **<u>NO</u>** biological effects to humans seen at doses <10,000 mrem
- 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 (interlocks, shielding, administrative controls).

IV. CHRONIC DOSES

- Small amount of radiation over a long period of time
- Examples:

  Background doses

  Occupational doses received at Fermilab

  Medical and dental x-rays
- Human body handles a chronic dose better than an acute dose

V. BIOLOGICAL EFFECTS OF CHRONIC RADIATION DOSES

- **<u>NO</u>** detectable physical changes, but it may affect the DNA of the cell
- Possible effects to DNA in cells:

  Somatic Effects - seen in person who receives chronic dose (examples: cancer, cataracts). There is an **extremely low** chance of these somatic effects happening as a result of occupational doses at Fermilab.

  Genetic Effects - seen in future generations due to damage in reproductive cells; **extremely low** chance of happening as a result of occupational doses at Fermilab

VI. RISK COMPARISON

- Human body is efficient in detecting and repairing radiation damage - health risk to occupational workers is less than risk associated with everyday activities.

  The following are common daily activities in our society that are associated with a risk of dying at a rate of 1 in a million.

  - Smoking 1.4 cigarettes
  - Eating 40 tablespoons of peanut butter
  - Spending 2 days in New York City
  - Driving 40 miles in a car
  - Flying 2500 miles in a jet
  - Canoeing for 6 minutes
  - Receiving 10 mrem of radiation

LEARNING OBJECTIVES:

Upon completion of this lesson, the participant will be able to:

1. STATE the dose limits for the whole body.
2. DESCRIBE the various types and purpose of dosimetry used at Fermilab.
3. DEMONSTRATE a working knowledge of the policies and procedures governing the use of dosimetry devices.
4. STATE the methods by which someone could obtain his/her dose record.
5. COMPLETE a Dosimeter Record.
6. STATE worker responsibilities for reporting radiation dose received from other sites and from medical applications.
7. EXPLAIN the Fermilab ALERT system.

I. DOSE LIMITS

- Whole Body:

  DOE : 5,000 mrem/yr - this is the DOE legal dose limit

  Fermilab: 1,500 mrem/yr - this is the administrative dose limit established by Fermilab.

  95% of permanent Fermilab workers receive <100 mrem/yr
- Lens of eye: 15,000 mrem/yr
- Extremities: 50,000 mrem/yr
- Skin: 50,000 mrem/yr

II. DOSIMETRY DEVICES

- TLD Badge - Legal record of exposure; measures beta, gamma, neutron; sent off-site for special processing; DO NOT OPEN OR TAMPER WITH TLDs
- Finger Rings - worn if chance for significant dose to extremities; specified by RSO
- Pocket Dosimeter - used to keep track of exposure; measures gamma; worn next to TLD; it can be read at any time and should be zeroed when >75% of full scale; it is the back up for TLD
- Digidose - small electronic dosimeter used for high dose jobs; records gamma dose; beeps once for each accumulated mrem of dose; specified by RSO when required

III. POLICIES AND PROCEDURES FOR DOSIMETRY USE

For all dosimetry devices

- Worn **only** by person to whom issued
- Worn at **all** times when required by signs, RWP, or Radiological Control personnel
- DO NOT take dosimetry off-site
- In radiological area, if lost, off-scale, damaged or contaminated:

  Put work in safe condition

  Alert others in vicinity

  Immediately exit area

  Notify area RSO or Division/Section ES&H Group

Policies for badges and finger rings

1. Should be returned for processing as scheduled or upon request. Dosimeters are to be turned in on the first working day of January, April, July and October.

2. One's 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 the potential for such exposure is discovered, the

device should be returned to the ES&H Section Dosimetry Program Manager, or Area RSO with an explanation.

Policies for pocket dosimeters and digidoses

1. When required, shall be worn next to one's TLD.
2. Return when the instrument 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 or some RCO Technicians.
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 you an indication of how much radiation you have received. Each division/section has its own policy regarding maintenance of these records. Contact your Area RSO for more details.
4. Digidoses are typically issued by the RCO and will be collected upon completion of the job for which they were issued.

IV. DOSE RECORDS

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 Manager.

Record adjustments

Each radiation worker is responsible to contact area RSO or dosimetry manager if monitored for radiation exposure elsewhere or involved in a medical procedure or treatment involving radioactive materials.

V. ALERT SYSTEM

- Used to keep workers' annual radiation exposure below the Fermilab limit
- >300 mrem/qtr whole body dose places individual on Alert List

- Individual and supervisor instructed on techniques to minimize dose; more rigid monitoring system imposed.

LEARNING OBJECTIVES:

Upon completion of this lesson, the participant should be able to:

1. STATE the potential effects associated with prenatal radiation exposure.
2. STATE the dose limit for the embryo/fetus.
3. DESCRIBE Fermilab policy concerning prenatal exposure.

I. POTENTIAL EFFECTS

- Studies of children exposed in utero to radiation from atomic bombs: few effects at dose <15,000 mrem
- >15,000 mrem possible effects are low birth weights and mental retardation
- Suggested but <u>not proven</u> is an increased chance of childhood cancer

II. FERMILAB'S PRENATAL POLICY (only pertains 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:

1. Notify the Medical Department **in writing**. Under this option, she would then become a declared pregnant worker and a RSO will conduct an evaluation of her work area(s) and assigned tasks.
2. Choose not to notify the Medical Department. Under this option, the usual occupational exposure limits will continue to be applied.

- Declared pregnant workers employed by Fermilab may:

1. Request a temporary reassignment to work in areas involving a lower potential for radiation exposure.
2. Request a leave of absence.
3. Continue with the same job assignment and control her exposure such that the embryo/fetus dose limits are not exceeded.
4. Terminate employment at the Laboratory.

III. EMBRYO/FETAL DOSE LIMITS

- At present occupational dose limits, risk from radiation is minimal compared to risks from pregnancy. Limits set as an additional measure of protection.
- 500 mrem for entire gestation period
- Efforts made to maintain dose <50 mrem/month for declared pregnant worker
- If dose to embryo/fetus is calculated at >500 mrem, a mother who is declared a pregnant worker is not assigned to tasks where additional exposure is likely.

LEARNING OBJECTIVES:

Upon completion of this lesson, the participant should be able to:

1. DEFINE ALARA
2. OUTLINE the responsibilities management, the Radiological Control Orgnaization and the individual workers have for ALARA.
3. STATE the three basic principles in reducing one’s external exposure.
4. PROVIDE examples of implementation of the basic principles in reducing sone’s external exposure.
5. STATE methods by which one can eliminate the potential for internal contamination.

I. ALARA CONCEPT

- ALARA stands for As Low As Reasonably Achievable.
- To the extent practical; reasonable efforts made to lower dose; an approach to manage and control exposures, not a limit

II. RESPONSIBILITIES

- Individual - ultimately responsible to maintain his/her dose ALARA and to report any radiological problems.
- Management and Radiological Control Organization - provide resources and assistance.

  Examples: review work plans and procedures
  plan tasks
  perform dose estimates for individuals and groups
  conduct radiological surveillances
  ensure personnel receive appropriate training

III. EXTERNAL DOSE REDUCTION

- **TIME; DISTANCE; SHIELDING**

A. Minimizing Time

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

B. Maximizing Distance

1. 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.
2. Use tools with long handles or other remote handling devices when possible.

C. Use of Shielding

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

III. INTERNAL DOSE REDUCTION

- Internal exposure is a result of radioactive materials entering the body through inhalation, ingestion, absorption through the skin, or wounds or cuts.
- 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.
- Methods to prevent radioactive material from entering the body:

1. Do not eat, drink, smoke, chew, or apply cosmetics in any radiologically posted areas.
2. Comply with the requirements of all work documents.

3. Bandage wounds, cuts, rashes, and abrasions before entering any area where contamination may be present.
4. Wear respirators properly when they are required.

LEARNING OBJECTIVES:

Upon completion of this lesson, the participant should be able to:

1. STATE the purpose of Radiological Work Permits (RWPs).
2. IDENTIFY the circumstances under which an RWP would be required.
3. LIST the types of information contained in a Radiological Work Permit.
4. EXTRACT pertinent information from an RWP and survey maps.
5. EXPLAIN the worker's responsibilities in using RWPs.

I. PURPOSE OF RWPs

- Inform workers of area radiological conditions
- Inform workers of entry requirements into the areas

RWPs are posted at access point into the area or where keys are obtained.

II. CIRCUMSTANCES REQUIRING AN RWP

- Entry and work in certain posted radiological areas
- Handling of materials with removable contamination exceeding the specified limits
- Handling of radioactive materials of Class 3 or above

III. INFORMATION INCLUDED IN RWPs

- Unique identifying number
- Work location
- Permit type

  General - routine or repetitive activities in areas with well characterized and stable radiological conditions

  Job specific - non-routine work or work in areas with changing radiological conditions

- Date of issue and expiration
- Description of work
- Access type
- Work area conditions
- Time limits, dose limits
- Work documents
- Dosimetry requirements
- Training requirements for entry
- Portable survey instrumentation
- Protective clothing and equipment requirements
- Additional instructions

  Survey maps show: specific area dose rates, location of “hot spots”, and levels of contamination in the vicinity

- Special requirements
- Authorizing signatures

IV. WORKER RESPONSIBILITIES

- Sign RWP - this indicates one has read and understands the requirements of the RWP
- Obey the instructions on the RWP
- If any part of the RWP is not understood, contact your supervisor or area RSO

LEARNING OBJECTIVES:

Upon completion of this lesson, the participant should be able to:

1. IDENTIFY the colors and symbols used on radiological postings, signs and labels.
2. DEFINE all types of areas controlled for radiological purposes.
3. STATE the entry, working in and exiting requirements for each area controlled for radiological purposes.
4. EXPLAIN the radiological and disciplinary consequences of disregarding radiological postings, signs and labels.
5. STATE the radiological and disciplinary consequences of unauthorized removal or relocation of radiological postings, signs and labels.

I. GENERAL

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

II. RADIOLOGICAL POSTINGS

A. **CAUTION: Controlled Area**

- Denotes any area where access is controlled to protect personnel from exposure to radiation and/or radioactive materials above background levels
- Requirements for entry: General Employee Radiation Training - GERT

B. **CAUTION: Radioactive Material**

- Designates areas where radioactive materials are used, handled or stored. Also used on cabinets, boxes, bins, etc. which segregate radioactive material from non-radioactive material.

- Requirements for entry: GERT; however, Radiological Worker training is required to work with the materials in the area.

C. **CAUTION: Radiation Area**

- Designates an area where radiation doses are $\geq$ 5 mrem/hr but < 100 mrem/hr
- Requirements for entry/exit: Radiological Worker training; signature on RWP as appropriate; TLD
- Requirements to exit: refer to RWP instructions

D. Postings for High and Very High Radiation Areas

DANGER: High Radiation Area

- Radiation dose rates $\geq$ 100 mrem/hr but < 500,000 mrem/hr

GRAVE DANGER: Very High Radiation Area

- Radiation dose rates $\geq$ 500,000 mrem/hr
- Requirements for entry: Radiological Worker training; worker signature on RWP or RSO approval; personnel and supplemental dosimeters; 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; personnel frisking as applicable

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

CAUTION: Contamination Area

- Contamination levels exceed specified levels

DANGER: High Contamination Area

- Contamination levels exceed 100 times specified levels

CAUTION: Airborne Radioactivity Area

- Airborne radioactivity exceeds specified levels
- Requirements for entry: Radiological Worker training; worker signature on RWP; personnel dosimeters; protective equipment/clothing required by the RWP; pre-job briefing as required.
- Requirements to exit: personal frisk before removal of protective clothing as specified by RWP, Rad Control personnel, or as posted.

IV. RESPONSIBILITIES OF THE WORKER

A. Read all signs before entering area.

B. Comply with all information on signs, postings, and labels. Do not remove or relocate them.

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

C. 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

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

E. If any material used to identify radiological hazards (labels, ropes, signs) is found outside an area controlled for radiological purposes it should be reported to the Area RSO immediately.

LEARNING OBJECTIVES:

Upon completion of this lesson, the participant should be able to:

1. DEFINE the term radioactive material.
2. DEFINE the term radioactivation.
3. IDENTIFY the proper procedure for labeling radioactive material according to the Fermilab Radioactivity Class System.
4. LABEL radioactive materials appropriately using a frisker and wallflower.
5. EXPLAIN the site policies for moving radioactive materials.
6. IDENTIFY the source program policies applicable to radiological workers.
7. RECOGNIZE typical source configurations.
8. DESCRIBE the actions that radiological workers should take regarding source use controls.
9. STATE the response to a source emergency.
10. DESCRIBE Fermilab policies regarding storage of radioactive materials.

I. RADIOACTIVE MATERIAL - any material that can spontaneously emit radiation.

II. RADIOACTIVATION - radioactivated material is 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 of being radioactive.

III. FERMILAB RADIOACTIVITY CLASS SYSTEM

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

Radioactivity Class Labels

Label	Exposure Rate (mR/hr @ 1 ft)	
	At Least	Less Than
CAUTION RADIOACTIVE MATERIAL Class 1	• 50 cpm above background* on a Frisker OR • 2000 cpm above background* on a Bicron Analyst**, if background is 2000-3000 cpm. OR • count rate* is equal to or greater than twice the mean background rate in a low (< 2000 cpm) background area	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.
** Bicron NaI scintillation probe on X10 scale.

IV. SURVEYING AND LABELING MATERIALS

- Survey all materials coming out of radiological areas. Frisk yourself first, then the materials.
- Verify the survey instrument is on, appears to be functioning properly, set to the proper scale (X1) and the audio output can be heard.
- Verify that the instrument is in calibration.
- Check background levels to ensure that you are in a low background area.
- Perform a response check by using the radioactive source mounted on the instrument.
- Perform a contact survey, moving the probe SLOWLY (no faster than 1" 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 CORRECT.

If the material is found to be radioactive using the frisker, you then use a wallflower to determine what label should be applied.

- Using the probe at 1 foot (usually demarked with ruler attached to the probe), 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 as the material was found to be radioactive using the frisker.
- Complete all information on the label: date, exposure rate and your first initial and last name.
- If any material is Class 2 or greater, contact the Area RSO or Rad Tech for additional instructions. No machining or radioactive material is allowed without prior approval.

V. RADIOACTIVE MATERIAL MOVEMENT

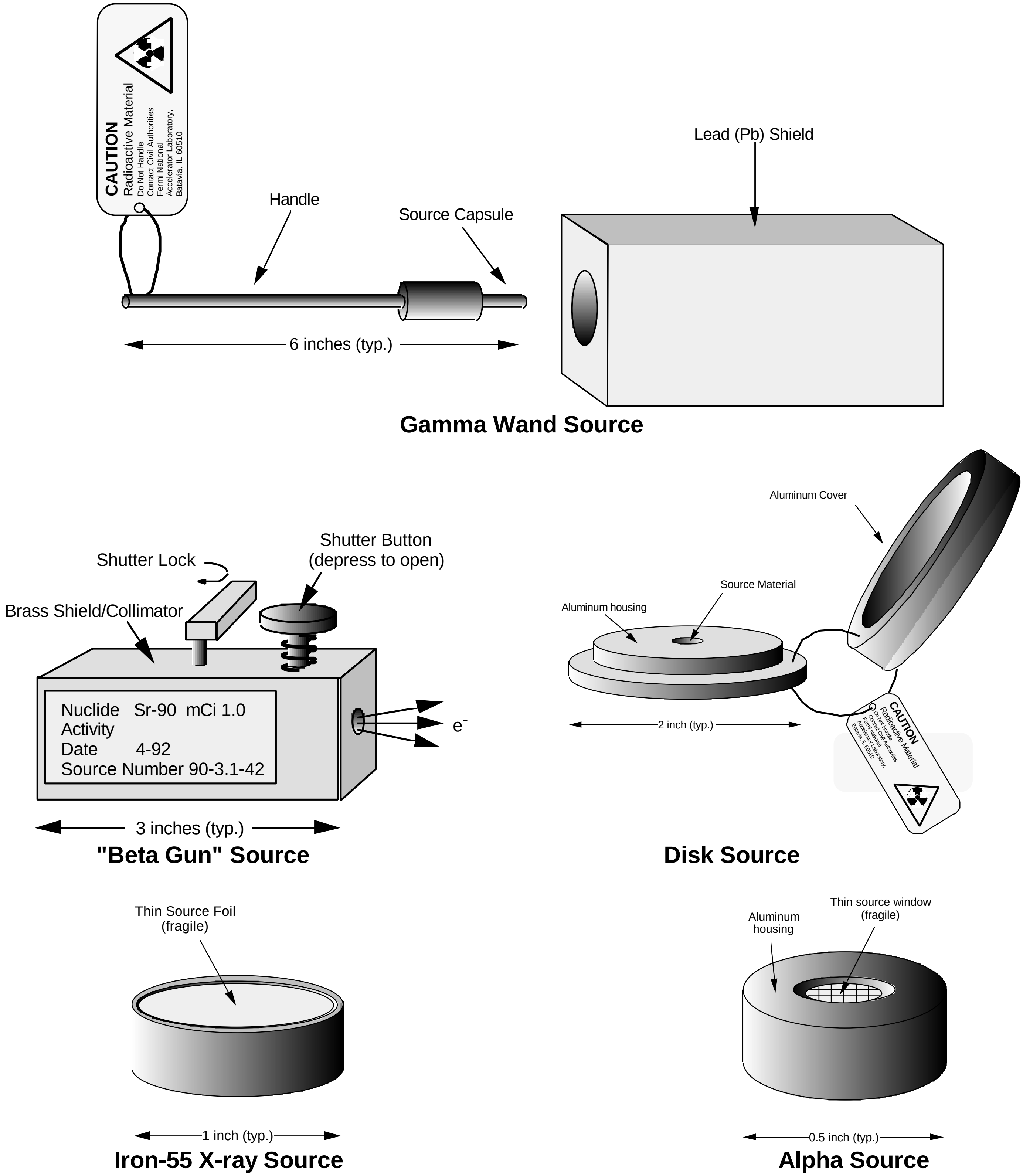
- Ensure that the materials have been properly labeled.
- Confirm that the receiver can receive the materials. Certain buildings on-site have restrictions on the types of radioactive material that can be brought to them. Wilson Hall is a prime example.
- Do not move the material in a private vehicle. Transfers must be in a government vehicle.
- Drive 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.

Whenever Business Services Section is asked to move the material or whenever a material is going off-site, a Material Move Request must be completed.

- Part of the Material Move Request is 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.
- If the material is radioactive and is being shipped off-site, contact Radiation Physics so that it can be packaged appropriately for transportation.

VI. SOURCE PROGRAM POLICY

- Manufactured radioactive sources are to be used **only** by authorized individuals. Source training is available from the ES&H Section.
- 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.



Typical Radioactive Source Configurations Found at Fermilab

VIII. SOURCE USE CONTROLS

- When sources are in use, the area will be posted with a "CAUTION -- RADIOACTIVE MATERIAL" sign. If the source creates a radiation field over 5 mrem/hour at approximately 1 foot from the source, the area will be posted with a "CAUTION -- RADIATION AREA" sign.
- When not in use, sources shall be stored in designated locked boxes/cabinets bearing the sign "CAUTION - RADIOACTIVE MATERIAL."
- Should you come across a source that is unattended, contact the ES&H Section Source Physicist, or the Area RSO.
- Radioactive sources have source ID labels/tags associated with them, which are usually physically attached to the source. If you find a source tag loose in the area, contact the ES&H Section Source Physicist, or the Area RSO.

IX. SOURCE EMERGENCY

- If you suspect that a source is broken, call X3131 immediately. DO NOT handle the source or even attempt to move it. Keep others away from the area.

X. RADIOACTIVE MATERIAL STORAGE

- 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.
  A. Radioactive materials should only be stored in designated areas which have been approved by the division/section RSO. Storage of non-radioactive material in such designated areas should be minimized.
  B. 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 ES&H personnel can assist you.
  C. Radioactive material should be stored in a manner that reduces combustible loading. The use of cardboard containers for storage is discouraged.

D. Outdoor storage of radioactive material requires 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.

E. Radioactive materials 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.

LEARNING OBJECTIVES:

Upon completion of this lesson, the participant should be able to:

1. DEFINE radioactive contamination.
2. DEFINE the term -- decontamination.
3. IDENTIFY potential sources of radioactive contamination.
4. LIST methods that can be used by a radiological worker to control radioactive contamination.
5. DEMONSTRATE the proper use of protective clothing.
6. DEMONSTRATE the proper frisking technique.
7. DESCRIBE the proper disposal of protective clothing.

I. RADIOACTIVE CONTAMINATION

- Defined as radioactive material that has been deposited on the surfaces of structures, areas, objects or personnel.
- 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.

II. DECONTAMINATION

- The removal of radioactive materials from locations where it is not wanted. Normally performed by personnel from the Radiological Control Organization.

III. SOURCES OF RADIOACTIVE CONTAMINATION

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

IV. CONTAMINATION CONTROL METHODS

- Understand and comply with the radiological work controls, including protective clothing, respiratory equipment, containment devices and frisking requirements, imposed upon work in a posted contamination area.
- Use good work practices such as good housekeeping and cleaning up after jobs.
- Identify and report leaks in radiological systems before they become a serious problem.
- Make sure that required contamination surveys are performed before removing items from posted contamination areas.
- Avoid unnecessary contact with contaminated surfaces.
- Place contaminated tools, equipment, etc. inside bags when work is finished.
- Avoid stirring up contamination; it could become airborne.
- Exit the area immediately if a wound occurs and call X3131.
- 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 Ring 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 by the beam.

V. SELECTING & DONNING PROTECTIVE CLOTHING

- The protective clothing required for the work will be specified in the applicable Radiation Work Permit or the RSO or RCT assigned to cover the job.
- Check clothing for rips/tears. Replace if necessary.
- No order in donning clothing.
- Supplemental pocket or electronic dosimeters should be placed on the outside of the protective clothing so that you can access them.

VI. REMOVING PROTECTIVE CLOTHING AND EXITING THE AREA

- Personnel Frisking

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 Radiological Control personnel.
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 surface, approximately 1 inch per second. The performance of a whole body frisk should take at least 3 to 5 minutes.
5. Frisking order

   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 instrument response.

   1) Dosimetry & keys
   2) Head
   3) Neck and shoulders
   4) Arms
   5) Chest and abdomen
   6) Back, hips, seat of pants
   7) Legs
   8) Shoe tops
   9) Shoe bottoms
   10) Personal belongings

If you are not required to perform a whole body frisk at the exit, follow the posted instructions.

6. Remove your gloves and then frisk your hands again. Return the probe to its holder and leave the area. The probe should be placed its side or face up to allow the next person to monitor their hands before handling the probe.
7. 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 one that is.
   A. Remove all protective clothing at the exit.
   B. Proceed to the nearest designated monitoring station. If no alternative location is designated, contact Radiological Control personnel.
   C. Conduct your frisk.

VII. 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 contamination spread and prevent you from becoming contaminated. In this case, <u>ALL</u> of your protective clothing needs to be disposed of in a radioactive waste receptacle 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 and contamination spread, 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 the Area RSO or division/section ES&H Group for instructions.

VIII. 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 feet.
3. Frisk other areas of your body which came in contact with surfaces while inside the enclosure.

LEARNING OBJECTIVES:

Upon completion of this lesson, the participant should be able to:

1. DEFINE radioactive waste.
2. DEFINE mixed waste.
3. DEFINE roles and responsibilities of individuals as they pertain to the Low Level Waste Certification Program.
4. LIST methods that a radiological worker can use to minimize radioactive and mixed waste.
5. IDENTIFY generator responsibilities for characterizing waste.
6. LIST what is required to characterize waste.
7. RECOGNIZE approved radioactive waste containers.
8. IDENTIFY the requirements that must be met before a waste container can be picked up.

NOTE: This section of Radiation Worker Training does constitute Rad Waste training and qualifies you for all areas. **However** it is imperative you understand the mechanism by which your Division, Section, and Department deals with generated Radioactive Waste. You **must** contact your supervisor and/or rad waste coordinator to discuss the details of how your affiliated Division, Section, or Department handles its waste. You are **REQUIRED** to contact one of these individuals **prior** to generating any waste.

I. RADIOACTIVE WASTE

Defined as radioactive material that is no longer useful. This may be:

- Material that has been activated by the beam or
- Items that have come in contact with radioactively contaminated material and are now contaminated

Radioactive waste bags, radiation warning signs, and radioactive class tapes are not to 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 found to be radioactive.

II. MIXED WASTE

There is also the special category of mixed waste. Mixed waste is chemically hazardous or toxic waste which is also radioactive. Mixed wastes are a special problem because it is extremely difficult and expensive to dispose of them. Fermilab currently does not have approval to dispose of any mixed waste.

It is required that individuals who generate waste certify that the waste contains no hazardous materials at the time of disposal. If the waste is radioactive and does contain 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.

Except for certain special circumstances, water and KPC 820N are the only approved cleaners which may be used on radioactive materials.

III. LOW LEVEL WASTE CERTIFICATION PROGRAM

Fermilab policy is to reduce or eliminate the generation of waste material presented for disposal or released to any environmental medium. 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. Reducing or eliminating the generation of waste is given prime consideration in research, process design and plant operations. The minimization of the generation of mixed waste is especially important given the great difficulty in the disposal of such wastes because of disposal site restrictions.

- Generators of radwaste must comply with program
- Divisions/Sections have waste coordinators to assist
- As a rad worker your responsibilities are:
  1. Ensure that any waste you generate, or are responsible for, is properly and promptly characterized and packaged for disposal.
  2. Ensure that unknown wastes are not generated. Characterizing unknown waste can be very time consuming and expensive.
  3. Ensure that mixed wastes are not generated if at all possible. Written approval may be required before using certain items.

IV. WASTE MINIMIZATION

Ways to reduce the amount of radioactive and mixed waste that is generated include:

- 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 and everyday practice. Also, do not use hazardous materials to clean radioactive components unless the components have no removable radioactive contamination present.

V. WASTE GENERATOR RESPONSIBILITIES

Anyone generating waste in a beam enclosure or potentially radioactive waste outside a beam enclosure is responsible for completely and accurately characterizing those waste materials prior to presenting them for disposal. This responsibility cannot be delegated or deferred. Radioactive waste materials may not be left unattended for disposal at a later time.

Radioactive items being transported to designated collection areas should either be labeled with class tape or be in radioactive waste bags. Radioactive materials shall not be stored or transported in bags used for normal trash. Radioactive materials should be transported in Laboratory vehicles.

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.

Water collected on tunnel or enclosure floors cannot be disposed of without prior permission from the Area RSO.

During normal working hours, radioactive waste items shall promptly be taken to collection areas designated by the department head or his/her designee for characterization and disposal. Persons who are issued containers are generally available to open them for waste disposal during normal working hours.

During off hours, persons who have access to radioactive waste containers are usually not available to open them. Many of the accesses for emergency repairs are performed after normal working hours and on weekends. Department heads, task managers, group leaders, or 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. As a generator of radioactive waste, it is your responsibility to be aware of the location of these storage cabinets. A storage cabinet that has a common department padlock can be used for this purpose. When the material is placed in the cabinet, it is recommended that the radioactive waste generator sign the "Radioactive Waste Certification and Pickup Request Form."

The Operations Group Duty Assistant, Crew Chief, or person designated by the Crew Chief is responsible to ensure that persons who are allowed to access the beam enclosures have been trained prior to issuing enclosure keys.

VI. WASTE CHARACTERIZATION

All radioactive waste generators are required to characterize their waste with sufficient accuracy to permit proper identification, minimization, segregation, transportation, treatment, storage and disposal. Waste should be characterized at or near the point of generation not only for convenience, but to also prevent cross-contamination. As a minimum the generator characterization of waste shall 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

This information is to be placed on an inventory sheet which is maintained for each waste container as it is being filled.

The following are waste violations/problems that have routinely occurred at Fermilab. It is very important that each waste generator follow the approved program in order to minimize waste and reduce the associated cost and man-power required to properly dispose of the waste.

- 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.

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 counts per minute (cpm). Items are considered to be radioactive if they have counts rates of 50 cpm above background.

NOTE: 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. Tritium (radioactive hydrogen) cannot be measured with available hand-held instruments.

VII. RADIOACTIVE WASTE CONTAINERS

All radioactive waste containers are to be kept locked up at all times so that waste characterization and control is maintained.

No free liquids or absorbed liquids of any type are to be placed in 55-gallon radioactive drums designated for dry, solid waste. These drums are to be used for dry, solid radioactive waste only.

Compactible waste, such as shoe covers, gloves, other types of protective clothing, and dry rags or wipes, that has been found to be radioactive should be placed in drums designated for compactible radioactive waste.

Oil or other liquids removed from vacuum pumps and from various devices, such as septa and separators, that have been exposed 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. The liquids are to be collected in properly labeled and approved containers.

The type of container used for collection of liquid radioactive wastes can be any of the following:

a. 30-gallon radioactive waste drum
b. 5-gallon carboy
c. 250-ml to 2-liter polyethylene bottles

The type of container used should be appropriate for the quantity of waste generated.

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.

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.

Non-compactible waste, such as contaminated lumber, structural steel, and beam pipe, is to be collected in 55-gallon drums separately from compactible waste.

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 the Division/Section ES&H Department.

The containers Fermilab uses for radioactive waste are:

- 55 gallon drums; yellow, used for dry solids; NO LIQUIDS ALLOWED
- 55 gallon galvanized drums; unpainted, used for mixed waste
- 30 gallon drums; yellow, used for either water or oil, but there cannot be any mixing of the two
- Steel boxes; scrap metal, wire cable and other items too large for a 55 gallon drum
- Radioactive Waste bags; DRY compactibles
- Bulk items too large to fit in steel boxes may be placed on skids and banded or banded and placed on cribbing

VIII. WASTE PICK-UPS

Once waste is properly characterized and in the appropriate container, pick-up can be arranged if:

- A completed inventory form (RP Form 31 or RP Form 71) has been submitted through the division/section 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.

LEARNING OBJECTIVES:

Upon completion of this lesson, the participant should be able to:

1. IDENTIFY situations/circumstances requiring emergency response.
2. IDENTIFY the correct responses to emergencies and/or alarms.
3. STATE the possible consequences for disregarding radiological alarms.

I. EMERGENCY/OFF-NORMAL SITUATIONS

A. Situations Handled by the Area RSO and/or Division/Section

1. 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 exit the area.
   - Notify the Area RSO or the division/section ES&H Group via the Main Control Room.
2. Potential Area Contamination. In some instances, there may be indicators of 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 contamination of an area where no contamination is expected,
   - Do not enter the area.
   - Keep others from entering the area.
   - Immediately report the situation by contacting the Area RSO, division/section ES&H Group via the Main Control Room.

3. 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.
4. Airborne Radioactivity. There are a few Continuous Air Monitors on-site, primarily used in Beams 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.
   - Personnel injuries in areas controlled for radiological purposes. Remember, lifesaving actions take priority over radiological control considerations.
   - Leak or spill of radioactive material outside of a radiological area.
   - Fire or smoke in a radiation area or involving radioactive materials.
   - Personnel exposure to operating beam.
   - Rupture or breakage of a radioactive source.
   - Personnel contamination (external or internal).

   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.

III. DISREGARD FOR RADIOLOGICAL ALARMS/CIRCUMSTANCES

Disregarding any of these radiological alarms or circumstances may lead to:

- Possible excessive personnel exposure
- Unnecessary spread of contamination
- Disciplinary action