NATIONAL ACCELERATOR LABORATORY

ENVIRONMENT, SAFETY & HEALTH DIVISION

Radiological Worker I Study Guide

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Acronyms and Abbreviations

ABD	A-Beam Dump
ACL	administrative control level
ACR	Accelerator Control Room
ACS	accelerator cooling system
ALARA	as low as reasonably achievable
BAS	Beam Analyzing Station
BDE	Beam Dump East
Bq	becquerel
BSOIC	beam shut-off ion chamber
BSY	Beam Switchyard
CA	controlled area
CAM	continuous air monitor
Ci	curie
DOE	Department of Energy
dpm	disintegration per minute
dps	disintegration per second
DREP	Dosimetry and Radiological Environmental Protection
eV	electron volt
FACET	Facility for Advanced Accelerator Experimental Tests
GERT	General Employee Radiological Training
GeV	giga-electron volt
Gy	gray
HRA	high radiation area
KCS	klystron cooling system
keV	kiloelectron volt
LCLS	Linac Coherent Light Source
LCW	low-conductivity water
linac	linear accelerator
LRCA	limited radiologically controlled assistant
MeV	mega-electron volt

mR	milliroentgen
mrad	millirad
mrem	millirem
NLCTA	Next Linear Collider Test Accelerator
PPE	personal protective equipment
PPS	personnel protection system
R	roentgen
RA	radiation area
rad	radiation absorbed dose
RBA	radiological buffer area
RCA	radiologically controlled area
RCT	radiological controls technician
rem	roentgen equivalent man
RF	radio frequency
RMA	radioactive material area
RMMA	radioactive material management area
RP	Radiation Protection
RPFO	Radiation Protection, Field Operations
RWP	radiological work permit
RWT	radiological worker training
SI	International System of Units
SLAC	SLAC National Accelerator Laboratory
SLED	SLAC Energy Doubler
SPEAR	Stanford Positron Electron Accelerating Ring
SSRL	Stanford Synchrotron Radiation Lightsource
Sv	sievert
TED	total effective dose
VHRA	very high radiation area
WCS	wave guide cooling system
WR	radiation weighting factor

1 Introduction

The SLAC National Accelerator Laboratory is a multi-purpose facility for astrophysics, photon science, and accelerator and particle physics research. This type of research is conducted with high-energy machines that produce many types of potentially hazardous energy, including ionizing radiation.

SLAC is committed to keeping radiation doses ALARA (as low as reasonably achievable) and far below occupational exposure limits. In order to achieve this goal and stay in compliance with Department of Energy (DOE) requirements, SLAC's Radiation Protection (RP) Department establishes and manages the radiation protection program, which includes this training and the requirements that you will be learning about.

1.1 Who Must Become Radiation Worker I Qualified

Radiological Worker I Training (RWT I, ESH Course 116) is mandatory for

- Personnel who are likely to enter posted radiation, high radiation, and radiological buffer areas
- Personnel who may potentially receive a total occupational radiation dose exceeding 100 millirem (mrem) per year
- Designated operators of Class IV or V radiation generating devices
- Personnel who handle radioactive materials (this includes assembly, disassembly, working on, or moving radioactive material, including all accelerator beamline components)
- Personnel who will become RWT II qualified

Note *Additional radiological training is required for entering a contamination area and for machining radioactive materials. See ESH Course 250, Radiological Worker II Training (ESH Course 250).*

1.2 RWT I Qualification Requirements

1.2.1 Prerequisite

The prerequisite for RWT I is the General Employee Radiological Training (GERT).

Note *RWT I is the prerequisite for RWT II.*

1.2.2 RWT I Qualification and Requalification

Becoming RWT I qualified the first time involves these steps:

1. View the web-based training.
2. Pass the web-based exam with a score of 80 percent or higher.

3. Schedule a practical exam with the RP (ext. 4299) and pass the exam with a score of 80 percent or higher.

RWT I expires every 24 months. At that time, you can requalify by passing the challenge exam and scheduling a practical.

For more information, see the RWT I course description.

Note *A copy of the current version of this study guide is available online at all times for anyone preparing for a challenge exam.*

1.3 Course Objectives

This study guide contains the information you need to know to perform your work in a manner compliant with SLAC policies. It covers the following essential information:

- Radiological fundamentals, including the nature of radioactivity, units of measure, and workplace radiation sources
- Work practices associated with helping to keep doses ALARA
- Purpose of personnel and supplemental dosimetry and requirements for use
- Radiological postings and controls
- Radiological work permit requirements
- Entry requirements and radiological controls for radiation and high radiation areas
- Proper response to an emergency in any radiological area
- Practical exam review

2 Radiological Fundamentals

This section provides a basic understanding of fundamental radiological concepts and units of measure that you will need in order to understand radiological hazards and postings.

2.1 Objectives

Upon completion of this section, you will be able to

- Identify the basic particles of an atom
- Define ionizing radiation, radioactive material, and radioactive contamination
- Define radioactivity and radioactive half-life
- Convert units of measure from United States to International System of Units (SI) and convert multiples of a unit of measure
- Identify the following characteristics for ionizing radiation types:
  - Physical characteristics
  - Range
  - Shielding
  - Sources at SLAC

2.2 Atomic Structure

This section defines the most fundamental terms associated with atomic structure. These include the basic unit of matter, the atom, and the three basic particles of the atom (protons, neutrons, and electrons).

Note *You may wish to consult a periodic table of the elements for additional information as you read through this section.*[1]

2.2.1 Protons

The number of protons in an atom determines the atomic number and the elemental identity of the atom. If the number of protons in an atom changes, the element also changes.

1 Radiochemistry Society. Periodic Table of the Elements

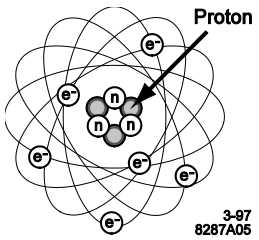


Figure 2-1 Protons

A proton is an elementary nuclear particle that

- Is located in the nucleus of the atom
- Has a positive electrical charge

2.2.2 Neutrons

A neutron is an elementary particle with a mass approximately the same as that of a proton but is electrically neutral. Atoms of the same element have the same number of protons but can have a different number of neutrons.

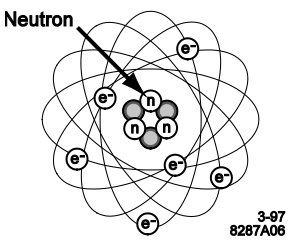


Figure 2-2 Neutrons

Neutrons

- Are located in the nucleus of the atom
- Have no electrical charge

2.2.3 Electrons

Electrons determine the chemical properties of an atom.

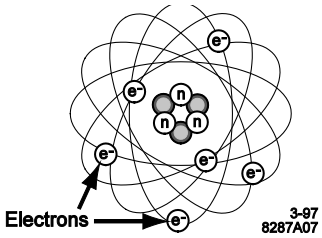


Figure 2-3 Electrons

Electrons

- Orbit around the nucleus of an atom
- Have a negative electrical charge
- Can be emitted from some nuclei as beta particles

2.2.4 Positrons

Positrons are the anti-matter counterpart of electrons.

Positrons

- Can be emitted from some nuclei as beta particles
- Are a product of high-energy interactions
- Can interact with electrons to create annihilation gammas

2.2.5 Ions

The number of electrons and protons determines the overall electrical charge of the atom. The term *ion* is used to define atoms or groups of atoms that have a positive or negative electrical charge.

- **No charge (neutral).** If the number of electrons equals the number of protons, the atom is electrically neutral and does not have an electrical charge.
- **Positive charge (+).** If there are more protons than electrons, the atom is positively charged.
- **Negative charge (–).** If there are more electrons than protons, the atom is negatively charged.

2.2.6 Isotopes

For each atom

- The number of protons determines the chemical element.
- The mass number (total number of neutrons plus the number of protons) determines the isotope of the element. The isotope is normally expressed by its chemical symbol (for example, O is the symbol for oxygen). The mass number is indicated with a superscript on the left (as shown in the top row of Figure 2-4). Alternatively, the isotope can be expressed as the chemical symbol followed by the mass number. For example O-15, O-16, O-17.
- Different isotopes of an element have the same number of protons and a different number of neutrons.

Isotopes occur naturally and can be artificially produced, and they may or may not be radioactive. For example, the naturally occurring isotopes of oxygen are stable and not radioactive (^{16}O, ^{17}O, and ^{18}O). The other isotopes shown can be produced but will be unstable and radioactive. (For the half-life of ^{15}O, see Table 3-1.)

	^{12}O	^{13}O	^{14}O	^{15}O	^{16}O	^{17}O	^{18}O	^{19}O	^{20}O
Protons	8	8	8	8	8	8	8	8	8
Neutrons	4	5	6	7	8	9	10	11	12

Naturally occurring

Figure 2-4 Isotopes of Oxygen

Note *This table illustrates that each isotope of oxygen has the same number of protons (8) and a different number of neutrons (4 through 12). The number of protons added to the number of neutrons determines the mass number and the isotope. For ^{16}O, the mass number is 16 (8 protons + 8 neutrons = 16.) The two ways to denote this isotope of oxygen are ^{16}O and O-16.*

Examples of other naturally occurring radioactive isotopes include carbon-14, potassium-40, radon-220, radium-226, thorium-232, and uranium-238.

2.2.7 Particle Beams

Charged particles such as electrons and positrons can be accelerated to very high energies to produce beams that can be directed onto targets or stopped by a *dump*. The beam energy is measured in electron volts (eV), most commonly in these multiples

- keV (k = kilo = 1,000 = 10^3)
- MeV (M = mega = 1,000,000 = 10^6)
- GeV (G = giga = 1,000,000,000 = 10^9)

2.3 Ionizing Radiation

Radiation can be classified as non-ionizing and ionizing. Radiation that has enough energy to eject electrons from atoms, leaving behind charged atoms, or *ions*, is known as ionizing radiation. Any material that emits ionizing radiation is called *radioactive material* and undergoes radioactive *decay*. The basic types of radiation of concern are alpha particles, beta particles, gamma and x-rays, neutrons, and muons. Some of these types of radiation only occur as a result of the operation of specialized high-energy machines such as klystrons and accelerators, and this radiation may be *prompt* or *residual*. Each radiation type is discussed below in terms of physical characteristics, range, shielding, and sources at SLAC.

Note *For a summary of the relative biological hazard of each radiation type see Table 2-1.*

2.3.1 Prompt and Residual Radiation

The operation of such high-energy machines as klystrons and accelerators produces unstable atoms. The resulting radiation may be prompt and/or residual.

Prompt radiation is the type of radiation that occurs only when the machine is on and ceases as soon as the machine is shut off. A klystron operating at 350 keV is an example of a machine that produces only prompt radiation because there is no residual radiation when the machine is turned off.

Residual radiation will be created if a machine operates near or above 10 MeV, which is the energy threshold that *activates* material, that is, causes it to be radioactive. An accelerator that operates at above 10 MeV is an example of a machine that produces both prompt and residual radiation.

Residual radiation is present in components that absorb beam energy, including beam dumps, targets, and collimators. Residual radiation may also be present in objects and structures in the immediate vicinity of the beam. See Appendix B, “SLAC Facilities Overview,” for machine specifications to help determine the type of radiation that a machine is likely to produce.

2.3.2 Alpha Particles

2.3.2.1 Physical Characteristics

The alpha particle has a large mass and consists of two protons, two neutrons, and no electrons (a positive charge of plus two). It is a highly charged particle that is emitted from the nucleus of an atom.

Alpha particles are not considered an external radiation hazard because they are easily stopped by the outer layer of skin. If an alpha emitter is inhaled or ingested, however, it becomes a source of internal exposure. Internally, the source of the alpha radiation is in close contact with body tissue and can deposit large amounts of energy in a small volume of body tissue.

2.3.2.2 Range

The alpha particle deposits a large amount of energy in a short distance. This large energy deposit quickly depletes the energy of the alpha particle, which limits the penetrating ability of the alpha particle to a very short distance. The penetrating range through air is about 1 to 2 inches (2.5 to 5 centimeters), depending on the energy of the particle.

2.3.2.3 Shielding

Most alpha particles are stopped (shielded) by a few centimeters of air, a sheet of paper, or the outer (dead) layer of skin.

2.3.2.4 Sources at SLAC

At SLAC, alpha particles are emitted by material found in *sealed sources* and may be present in certain radioactive samples at the Stanford Synchrotron Radiation Lightsource (SSRL).

2.3.3 Beta Particles

2.3.3.1 Physical Characteristics

The beta particle is an electron or positron that is emitted from the nucleus of an atom and has an electrical charge of plus one or minus one (β- or β+). This charge may cause ionization to occur.

Externally, beta particles are potentially hazardous to the skin and eyes. Internally, beta particles are a hazard because the short range causes the whole energy of the beta to be absorbed by the internal organs of the body.

2.3.3.2 Range

The penetrating range through the air is several feet, depending on the energy of the particle.

2.3.3.3 Shielding

Most beta particles can be successfully shielded by plastic, glass, metal, or foil.

2.3.3.4 Sources at SLAC

Beta particles are emitted by some isotopes that are produced by accelerator operations. They are also emitted by sealed sources.

2.3.4 Photon Radiation

2.3.4.1 Physical Characteristics

Photon radiation produced at SLAC includes the following types:

- **Gamma and x-ray ionizing radiation** differ from each other primarily in their origin (gammas originate in the nucleus, x-rays can originate from electron orbital shells or from the acceleration of charged particles). Gamma and x-ray ionizing radiation
  - Can ionize matter indirectly as a result of interactions with orbital electrons
  - Are also referred to as *photon radiation*
- **Synchrotron radiation** is emitted by the electron beams circulating in the SSRL storage ring or in the Linac Coherent Light Source (LCLS) undulator. Synchrotron radiation has an energy range that extends from visible light to x-rays and is generally intense and collimated into narrow beams.
- **Bremsstrahlung radiation** is produced by the deceleration of a charged particle when deflected by another charged particle. The moving particle loses kinetic energy, which is converted into photons. One example is an electron deflected by an atomic nucleus.

Note *In electron accelerators such as those at SLAC, the initiating events for prompt radiation are* bremsstrahlung *interactions, which cause a broad spectrum of x-rays to be produced, up to nearly the initial electron beam energy.* Bremsstrahlung*, or* braking*, radiation, refers to radiation that is produced as electrons undergo an abrupt stop or loss of energy.*

2.3.4.2 Range

Because gamma and x-ray radiation has no charge and no mass, it has very high penetrating power. Depending upon the energy, the radiation may travel several hundred feet through the air.

2.3.4.3 Shielding

Gamma and x-ray radiation is best shielded by very dense material such as lead, iron, or concrete. Synchrotron radiation produced by SSRL can easily be shielded with thin lead sheets because of the low energy of the x-ray.

Gamma and x-ray radiation can result in external radiation exposure to the whole body.

2.3.4.4 Sources at SLAC

- Gamma rays are emitted by
  - Material that has been activated
  - Radioactive sources
  - Positron annihilation of electrons
- X-ray radiation is emitted
  - By machines such as klystrons and radiofrequency (RF) cavities
  - As bremsstrahlung radiation by accelerated electron and positron interaction with beamline components
  - In the form of synchrotron radiation at SSRL and LCLS

2.3.5 Neutrons

2.3.5.1 Physical Characteristics

Neutron radiation consists of neutrons ejected from the nucleus. Neutrons have no electrical charge: they ionize matter indirectly by means of charged particles that originate in the collision between a neutron and a nucleus. Due to their high ionizing ability, neutrons have a large radiation weighting factor. (See Table 2-1.)

2.3.5.2 Range

Depending on the neutron energy and the type of material, the penetration power of neutrons varies greatly. Like gammas, neutrons can easily travel several hundred feet through air.

2.3.5.3 Shielding

Shielding varies depending on neutron energy:

- Low- to moderate-energy neutrons are effectively shielded by materials with high hydrogen content such as water, plastic, polyethylene or concrete.
- High-energy neutrons are most effectively shielded with steel or lead.

2.3.5.4 Sources at SLAC

At SLAC, neutrons may be present outside accelerator housings during operation and are emitted by certain sealed sources.

2.3.6 Muons

2.3.6.1 Physical Characteristics

Muons are charged particles that are physically similar to electrons but are about 200 times heavier. Muons are not usually seen in significant amounts in machines with energies less than 1 GeV, as they require photon energies greater than 212 MeV to be produced.

Muons are an external radiation hazard.

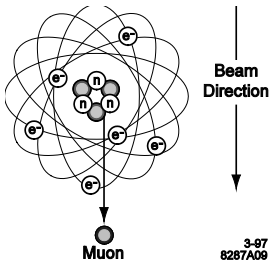


Figure 2-5 Muons Travel in the Same Direction as the Beamline

2.3.6.2 Range

Muons travel mainly in the direction of the beam that produced them, with very little deviation from the beam path. They may be a concern directly downstream of targets and beam dumps. Muons lose energy only through ionization and are very penetrating.

2.3.6.3 Shielding

Muons are effectively shielded by large amounts of iron and/or concrete.

2.3.6.4 Sources at SLAC

Muons are produced by high-energy electron beams (above 10 GeV) such as those at LCLS.

2.4 Radiological Dose Units

2.4.1 Radiation Absorbed Dose (rad)

Absorption of radiation energy is referred to as *dose*. Dose is defined as the amount of energy absorbed in matter, and the *radiation absorbed dose (rad)* is the dose measurement unit. It applies to all types of ionizing radiation and does not take into account the potential effect that different types of radiation have on the body.

The corresponding unit in the International System of Units (SI) is the gray (Gy), which is based on the joule, J, which is the SI unit for energy, and kilogram (kg), which is the unit for mass.

1 rad = 1,000 millirad (mrad) = 10^{-2} J/kg

1 Gy = 100 rad = 1 J/kg

Note *The roentgen (R) is a unit of measure of an obsolete quantity called* exposure, *defined as the amount of electron charge released per unit of air mass. Some types of supplemental dosimeters measure this quantity. For practical purposes, R, rad, and rem (defined below) can be considered to be equal for measuring gamma and x-rays.*

2.4.2 Roentgen Equivalent Man (rem)

The roentgen equivalent man (rem) is a radiation quantity that is used to describe dose.

The *effective dose* is the sum of the equivalent doses in tissues and organs in the body, each weighted by a tissue weighting factor, W_T. It is a derived quantity that is used for comparison with dose limits. Effective dose takes into account

- The *equivalent dose,* which is a quantity that describes the absorbed dose (rad) and the biological effect on humans due to different types of radiation, expressed as a *radiation weighting factor*, (W_R). Its value depends on the radiation type and its energy, as shown in Table 2-1.
- W_T, which is the fraction of the overall health risk resulting from uniform, whole body irradiation attributable to specific tissue (T), as shown in Table 2-2.
- Internal and external exposures. Note: At SLAC, internal exposures are very unlikely, so the effective dose is generally considered to consist of external exposure only.

Equivalent dose: rem = rad x W_R

Effective dose: rem = rad x W_R x W_T

Most common multiple: mrem 1 rem = 1,000 mrem

Corresponding SI unit: sievert (Sv) 1 Sv = 100 rem

Table 2-1 Radiation Weighting Factors

Type and Energy Range	Radiation Weighting Factor, W_R
Photons, electrons and muons, all energies	1
Neutrons, energy < 10 keV	5
Neutrons, energy 10 keV to 100 keV	10
Neutrons, energy > 100 keV to 2 MeV	20
Neutrons, energy > 2 MeV to 20 MeV	10
Neutrons, energy > 20 MeV	5
Protons, other than recoil protons, energy > 2 MeV	5
Alpha and heavier particles	20

Table 2-2 Tissue Weighting Factors

Organs or Tissues, T	Tissue Weighting Factor, W_T
Gonads	0.20
Red bone marrow	0.12
Colon	0.12
Lungs	0.12
Stomach	0.12
Bladder	0.05
Breast	0.05
Liver	0.05
Esophagus	0.05
Thyroid	0.05
Skin	0.01
Bone surfaces	0.01
Remainder	0.05
Whole body	1.00

2.4.2.1 Dose Rate

A *dose rate* is a dose of radiation per time period, such as mrem per year (mrem/y) or mrem per hour (mrem/h). To calculate the dose, multiply the dose rate by the length of time.

Note *Always use a consistent unit for time. For example, convert 30 minutes into 0.5 hours if the rate is given in hours.*

2 mrem/h x 0.5 h = 1 mrem dose

For occupational dose limits, see Table 4-1.

2.4.3 Radiological Dose Units Summary

Table 2-3 Radiological Dose Units Summary

Traditional Units (used in the US)	Conversion Factor	Corresponding SI Unit	Quantity and Purpose
radiation absorbed dose (rad)	1 rad = 10^{-2} J/kg 100 rad = 1 Gy 0.1 rad or 100 mrad = 1 mGy	gray (Gy)	Dose. Measures the amount of energy absorbed in matter from radiation
roentgen equivalent man (rem)	100 rem = 1 Sv = Gy x W_R x W_T 0.1 rem or 100 mrem = 1 mSv rem = rad x W_R x W_T	sievert (Sv)	Effective dose. Measures the dose defined by weighting factors (radiation [W_R] and tissue [W_T]) that account for potentially damaging biological effects on humans
mrem/y mrem/h			Dose rate. Used to characterize occupational doses

2.4.4 Radioactivity Units of Measure

2.4.4.1 Radioactivity

Radioactivity is measured in the number of disintegrations that radioactive material undergoes per unit time. Two common units of measure for radioactivity are the curie (Ci) and the corresponding SI unit, the becquerel (Bq). These units

- Define the actual amount of radioactive material present
- Are used to classify radioactive sources
- Are used to establish control limits for radioactive contamination
- Describe the decay rate of radioactive atoms

1 Bq = 1 disintegration per second (dps)

Ci =

- 3.7×10^{10} Bq or dps
- 2.2×10^{12} disintegrations per minute (dpm)

The following table lists commonly used multiples of the curie and conversion factors for the becquerel.

Table 2-4 Radioactivity Units of Measure

Traditional Units and Multiples (used in the US)	Conversion Factor	Corresponding SI Unit
Curie (Ci) 1 Ci = 1×10^3 mCi (milli) = 1×10^6 µCi (micro) = 1×10^{12} pCi (pico)	1 Ci = 3.7×10^{10} Bq = 37 GBq (giga)	3.7×10^{10} Bq
Disintegration per second (dps)	3.7×10^{10} dps = 1 Ci 1 dps = 1 Bq 3.7×10^4 dps = 1 µCi	1 Bq
Disintegration per minute (dpm)	2.2×10^{12} dpm = 1 Ci 60 dpm = 1 Bq 2.2×10^6 dpm = 1 µCi 2.2 dpm =1 pCi	60 Bq

2.4.4.2 Radioactive Half-life

Half-life is the time it takes for the radioactivity of an isotope to decay by half.

- Half-lives of various isotopes vary greatly, from a few seconds to billions of years.
- After 7 half-lives, less than 1 percent of radioactive atoms remain.
- After 10 half-lives any remaining radioactivity is generally not detectable.

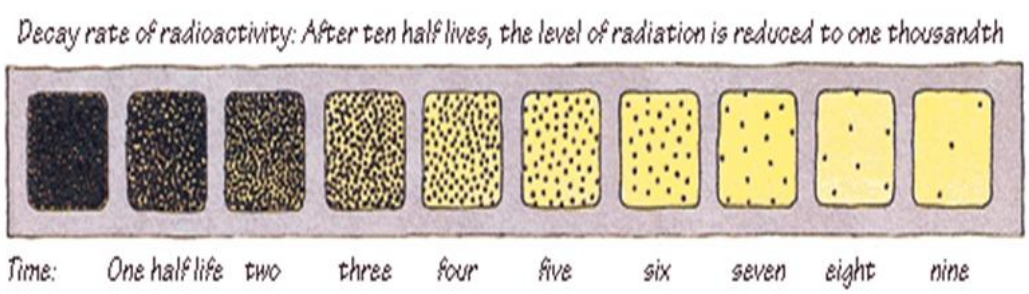


Figure 2-6 Radioactive Decay

Table 2-5 lists the half-lives of some of the radioactive isotopes that may be present when copper, which is a common element at SLAC, becomes activated by interaction with the beam. Note that the activation of copper created isotopes that include cobalt. The half-life varies, from 9.8 minutes (for ^{62}Cu) to 5.2 years for (^{60}Co). Note also that each isotope emits gamma radiation in addition to either β+ or β-.

Table 2-5 Half-life and Radiation Type for Radioactive Isotopes of Copper

Element	Radioactive Isotopes	Half-life	Radiation Type
Copper (Cu)	^{62}Cu	9.8 min	β+, Gamma
	^{61}Cu	3.3 hours	β+, Gamma
	^{64}Cu	12.8 hours	β+, Gamma
Cobalt (Co)	^{60}Co	5.2 years	β-, Gamma
	^{58}Co	71 days	β+, Gamma

2.5 Radioactive Contamination

When radioactive material is properly contained, it may still emit radiation and be an external dose hazard, but it will not be a contamination hazard. Radioactive material that is not contained (loose) it is referred to as *radioactive contamination*.

Radioactive contamination

- Is radioactive material that can be removed (loose) from surfaces by non-destructive means such as casual contact, wiping, brushing, washing, or the use of solvents
- Normally consists of superficial particles, and may not be visible
- May be fixed so that it cannot be easily removed from surfaces
- Is measured in units of dpm per 100 square centimeters (dpm/100 cm^2)

Exposure to radiation will not cause a worker to become contaminated.

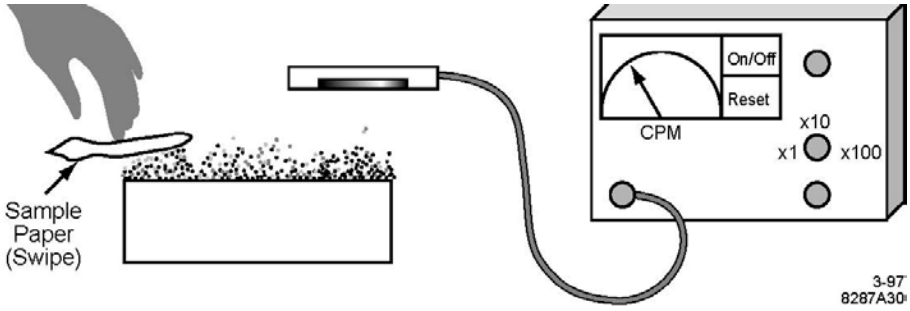


Figure 2-7 Loose Radioactive Material Can Become a Contamination Hazard

Study Questions

1. Complete the table by filling in the blanks.

Elementary Particle	Charge	In Nucleus? (yes or no)
Proton		
	Negative	No
Neutron		
Positron		

2. All radioactive material causes contamination. **True** or **False**?
3. Loose radioactive material that can be easily transferred is radioactive contamination. **True** or **False**? Ionizing radiation may take the form of a _____ or a _____.
4. Types of ionizing radiation include

   _____

   _____

   _____

   _____ and/or _____

5. Synchrotron radiation is a form of what type of ionizing radiation?_____
6. Exposure to radiation _____ (does/does not) result in the radiological worker becoming contaminated.
7. The type of ionizing radiation with the highest radiation weighting factor is _____ radiation.
8. 1 rem = _____ mrem 500 mrem =_____ rem
9. 10 mrem = _____ rem 100 mrem = _____ mSv
10. 1 Ci = _____ mCi
11. The SI equivalent for

    rem is _____

    dps is _____

    rad is _____

12. Fill in the blanks:

Radiation Characteristics

	Particle/photon	Mass (large, small, none)	Charge (-, +, none)	Range
Gamma				Not applicable
X-ray				
Alpha				
Beta				
Positron				
Neutron				

13. If you were to remain in a radiation field of 50 mrem/h for 3 hours, your dose would be _____.
14. If you were to remain in a radiation field of 200 mrem/h for 15 minutes, your dose would be _____.
15. Isotopes of an element have the same number of _____, but a different number of _____.

3 ALARA Program

Figure 3-1 Linac Building

As low as reasonably achievable (ALARA) is the underlying principle for the radiation protection program for DOE and SLAC. ALARA is not a dose limit but a process that has the objective of attaining doses as far below the applicable limits as is reasonably achievable, taking into account social, technical, economic, practical, and public policy considerations.

Basic tenets include

- No radiation exposure without an overall benefit
- Radiation doses well below regulatory limits
- All persons bear responsibility for reducing radiation exposure

This section introduces you to the ALARA program. The program's purpose is to reduce, manage, and control personnel radiation exposures.

3.1 Objectives

After completing this section you will be able to

- Identify the purpose of the ALARA program
- Identify ALARA responsibilities and dose limits
- State and explain three primary ALARA practices that reduce dose
- Identify Radiation Protection (RP) Department tools and radiological controls that reduce exposure
- Identify dose reduction methods such as minimizing radioactive and mixed waste

3.2 ALARA Program

Any SLAC activity that involves the use of radioactive material and radiation generating devices must incorporate the ALARA principle and practices as specified below.

3.2.1 Individual SLAC ALARA Level

SLAC's ALARA dose level for each radiological worker is 360 mrem per year, but each directorate should adopt or set a value lower than this, as appropriate. No radiological worker should exceed the ALARA dose level without prior approval from these three levels of management, in this order: division or department head, associate lab director, and radiological control manager.

The responsibility lies with the supervisor of each radiological worker to exercise timely planning and review radiological work, tasks, and anticipated doses to ensure that 360 mrem per year is not exceeded.

3.2.2 Responsibilities

3.2.2.1 ALARA Committee

The ALARA Committee is responsible for reviewing work that has the potential for unusually high levels of radiation exposure to individuals or groups. Trigger levels for ALARA committee review are

- > 200 mrem per day per person per job or 400 mrem per week
- > 2,000 mrem collective per job
- > 1,000 mrem/h at 30 cm from the radiation source

3.2.2.2 Management

Management is responsible for

- Making a firm commitment to the radiological protection program
- Ensuring that
  - Workers are trained to the appropriate level
  - Work is thoroughly planned in radiological areas
  - Personal protective equipment (PPE) is available and worn as intended
- Reviewing individual exposures to ensure that the SLAC ALARA level of 360 mrem/year threshold is not exceeded. If it is expected to be exceeded, approval is required by all of the following (in this order): division/department head, associate lab director, and radiological control manager.

3.2.2.3 Radiation Protection Department

RP is responsible for

- Implementing the requirements of the radiological protection program
- Providing tools that allow radiation workers to avoid a radiation dose, including radiation survey meters, survey maps, and postings
- Providing guidance in the form of interpretation of federal regulations and procedures. Requirements are established in
  - Title 10, *Code of Federal Regulations*, "Energy," Chapter 3, "Department of Energy," Part 835, "Occupational Radiation Protection" (10 CFR 835)

- DOE orders listed in the *Environment, Safety and Health Manual*, Chapter 9, "Radiological Safety"
- Radiological Control Manual (SLAC-I-720-0A05Z-001)
- Radiation Protection Department
- Department of Energy Standard 1098-2017, "Radiological Control" (DOE-STD-1098-2017)
- Department of Energy Guide 441.1-1C Change 1, "Radiation Protection Programs Guide for Use with Title 10, Code of Federal Regulations, Part 835, Occupational Radiation Protection" (DOE G 441.1-1C Chg1 [Admin Chg])

3.2.2.4 Radiation Protection Field Operations Group

Radiation Protection Field Operations (RPFO) technicians are responsible for

- Characterizing and providing the most current radiological conditions in an area
- Determining radiological controls
- Providing radiological information concerning work assignments
- Addressing radiological questions and concerns

3.2.2.5 Personnel, Visitors, and Users

Each person involved in radiological work must

- Be familiar with radiological conditions in the work area
- Know and minimize personal exposure
- Comply with rules and written/oral instructions
- Only perform work for which the required training has been completed
- Respond properly to unusual or emergency situations

3.3 Radiation Area Locations

As discussed in Section 2, "Radiological Fundamentals," many machines at SLAC produce prompt radiation, and certain machines reach energies high enough to produce residual radiation. Such areas must be posted by RP. Because radiological conditions may change, it is important to note the postings and current conditions. Postings are further explained in Section 5, "Radiological Posting and Controls."

This section introduces you to the areas that you will be applying the ALARA practices of minimizing time, maximizing distance, and using shielding. These practices will be discussed in detail in Section 3.4, "External Radiation Dose Reduction."

3.3.1 Prompt Radiation Locations

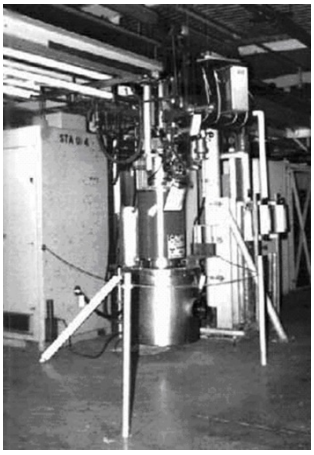


Figure 3-2 Klystron Prompt Radiation Posting

Prompt radiation may be present in the following areas:

- Operating klystrons in the Klystron Gallery, the Klystron Test Lab, and SSRL
- The klystron SLAC Energy Doubler (SLED) cavities in the Klystron Gallery
- The radio frequency cavity bunker in the Klystron Test Lab
- The SSRL beamlines, hutches, and linac
- LCLS beam halls and hutches
- All accelerator housings during operation

3.3.2 Residual Radiation Locations

Induced radioactivity, or residual radiation, persists after the machine is turned off. This can be also be referred to as *photo-activation products* and *neutron-activation products*. Components that absorb most of the photon beam energy are the most susceptible to photo activation. Such components include

- Dumps
- Targets
- Collimators
- Any narrow beam aperture (septa)
- Any point of beam scraping or loss

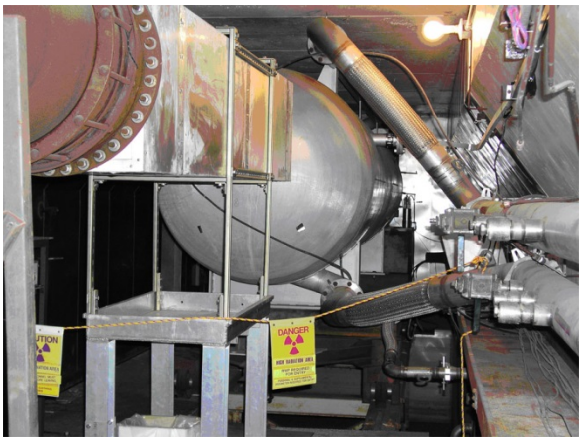


Figure 3-3 Residual Radiation Remains after the Beam Is Off

Areas at SLAC where prompt radiation is present during machine operation and where residual radiation is likely include

- All accelerator housings such as the linac, NLCTA, LCLS
- SPEAR, booster, and linac housings at SSRL

3.4 External Radiation Dose Reduction

The main goal of the ALARA program is to reduce radiation doses (external and internal) to a level that is as low as reasonably achievable. This section discusses basic practices that keep doses ALARA:

- Minimize the time in a radiation field
- Maximize the distance from a radiation source
- Use shielding whenever possible

3.4.1 Limiting Exposure Time

3.4.1.1 Practices

Reduce the amount of time in a radiation field to lower the dose as follows.

Before entering the area:

- Pre-plan and thoroughly discuss the task.
- Review current radiological information.
- Make sure all necessary tools are present.
- Perform as much work outside the area as possible.

Once you have arrived:

- Use only the required number of workers.

- Work efficiently, swiftly, and accurately the first time.
- Never linger in the area once work is complete.

3.4.1.2 Delayed Access after Beam Shut-off

Reduce radiation at the source by letting short-lived isotopes decay before entering accelerator housing after the beam is shut off. Wait at least one hour before entering certain accelerator locations. Requirements for certain locations may include a cool down period or RP survey for radiation before entry. See RP's Classification of Radiological Areas or call ext. 4299 for additional information.

Less than 1 percent of radioactivity remains after approximately seven to eight half-lives. The Table 3-1 lists the half-lives of some of the more common isotopes produced at SLAC along with the radiation type.

Table 3-1 Half-life and Radiation Type for Elements Commonly Activated at SLAC

Element or Media	Radioactive Isotopes	Half-life	Radiation Type
Aluminum (Al)	Na-24	15 hours	β-, Gamma
	Na-22	2.6 years	β+, Gamma
	F-18	1.8 hours	β+
Copper (Cu)	Cu-62	9.8 min	β+, Gamma
	Cu-61	3.3 hours	β+, Gamma
	Cu-64	12.8 hours	β+, Gamma
	Co-60	5.2 years	β-, Gamma
	Co-58	71 days	β+, Gamma
Iron (Fe)	V-48	16 days	β+, Gamma
	Cr-51	27.8 days	Gamma
	Mn-54	303 days	Gamma
Gaseous and liquid media	O-15	122 seconds	β+
	N-13	9.9 min	β+
	C-11	20 min	β+
	Ar-41	1.8 hours	β-, Gamma
	Be-7	53 days	Gamma
	H-3	12.3 years	β-

β+ denotes positrons, β- denotes beta particles

3.4.1.3 Stay Time

In rare cases RP may limit the amount of time a radiological worker may stay in an area. This limitation is referred to as a *stay time*. If you have been assigned a stay time, do not exceed it.

3.4.2 Maximizing Distance from Radioactive Sources

Methods for maximizing the distance from radiation sources include

- Staying as far away as practicable from the radiation source
- Moving to lower dose rate areas during work delays
- Using remote handling devices when possible
- Being familiar with radiological conditions (especially hot spots in the area) by reviewing radiation survey maps. Maps should be located at enclosure entrances and in the Accelerator Control Room (ACR).

For point sources, the dose rate follows the inverse square law:

- If you double the distance, the dose rate falls to 1/4 of the original dose rate.
- If you triple the distance, the dose rate falls to 1/9 of the original dose rate.

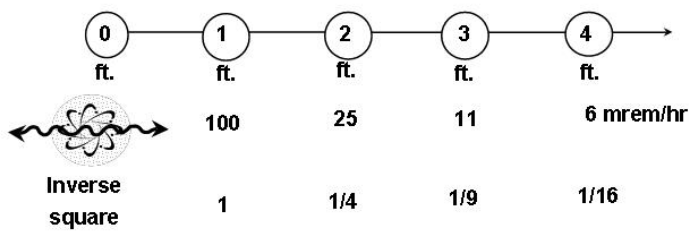


Figure 3-4 Inverse Square Law for the Relationship between Distance and Dose

Tools available to help maintain distance include

- Survey maps posted near some entrances and at the RPFO web pages (Appendix B, “SLAC Facilities Overview,” includes a copy of the survey map)
- Radiological signs
- Radiation survey meters, which are available to all radiation workers from the RPFO

3.4.3 Using Shielding

Shielding reduces the radiation dose. Different materials shield against different types of radiation.

3.4.3.1 Shielding Materials

Typical shielding materials used at SLAC include

- Concrete, wax, polyethylene, and water to shield neutrons
- Lead and iron shield gamma, x-ray, and muons. Two inches of lead will reduce a gamma dose rate to one tenth (1/10) of the original value (for a 2.5 MeV gamma).

3.4.3.2 Minimizing Exposure Using Existing and Temporary Shielding

To reduce exposure:

- Take advantage of permanent shielding such as non-radiological equipment and structures.

- Install temporary shielding (lead or concrete blocks) when procedures such as a radiation safety work control form are used. Once installed, the temporary shielding cannot be removed without proper authorization.

Temporary shielding, as well as other radiation safety devices, are always marked or labeled with descriptive wording such as TEMPORARY SHIELDING – DO NOT REMOVE WITHOUT PERMISSION or RADIATION SAFETY DEVICE.

Important A radiation safety work control form is required before altering any installed shielding.

The type of radiation (photon, particle) and energy affect the type and amount of shielding necessary to attenuate the radiation. Photon radiation can be more difficult to shield than beta. The placement of portable shielding requires careful thought, as it may actually increase the total dose due to the number of hours involved in the proper placement of the shielding. RP assists with designing, engineering, and calculating shielding.

3.5 Internal Radiation Dose

Receiving an internal radiation dose at SLAC is very unlikely because of the type of facilities, the materials, and the protections in place.

3.5.1 Internal Radiation Dose Pathways

Internal exposure is a result of radioactive material being taken into the body. Radioactive material can enter the body through one or more of the following pathways:

- Inhalation
- Ingestion
- Absorption through the skin
- Absorption through wounds

3.5.2 Internal Radiation Dose Reduction

Radiation workers must comply with the following practices to reduce the potential for radioactive material to enter the body:

- RWT I qualified persons must not enter any areas where contamination may be present; to enter such areas, RWT II must be completed and the qualification must be current.
- Comply with work document requirements.
- Before machining, drilling, filing, grinding components or structures in accelerator housings, contact RPFO for radiological surveys.
- Do not enter any contamination area unless qualified.
- Wear respirators as required and wear them properly (personnel must first complete training and pass a medical examination before becoming qualified to wear a respirator).

3.6 Radioactive Waste

The two types of radioactive waste are

1. Ordinary waste resulting from work with radioactive materials including paper, tape, bags, rags, and used gloves
2. Materials or waste that are classified as hazardous and that have also become radioactive. This type of waste is called *mixed waste* and includes batteries and solvents.

Generating radioactive waste must be minimized both to keep personnel exposure to a minimum and to keep costs associated with the handling, packaging, and disposing of radioactive waste as low as possible. Ways to accomplish this are listed below.

Figure 3-5 Radioactive Waste Must Be Properly Labeled

3.6.1 Waste Minimization

Workers can minimize radioactive waste by

- Minimizing the volume of material used for radiological work
- Taking only the specific tools and materials for the job into areas controlled for radiological purposes, especially contamination areas
- Unpacking equipment and tools in a clean area to avoid bringing excess clean material to the job site
- Not leaving material unnecessarily in accelerator enclosures where it can become activated
- Substituting non-hazardous material for hazardous material when possible
- When cleaning, using only the actual amount of material required to effectively clean the area

3.6.2 Waste Segregation

3.6.2.1 Radioactive and Non-radioactive Waste

To separate radioactive waste from non-radioactive waste:

- Place radioactive waste only in the receptacles identified for radioactive waste (clear uncolored bags), never in receptacles for non-radioactive waste.
- Do not throw non-radioactive waste or radioactive material that may be reused into radioactive waste containers.
- Segregate compactable material from non-compactable material.
- Use good housekeeping techniques.
- If in doubt, identify radioactive material by calling RP for assistance.

3.6.2.2 Mixed Waste

Mixed waste is hazardous material that is also radioactive. The disposal of hazardous materials is strictly regulated. Materials categorized as hazardous that are commonly used at SLAC include

- Oil, fuel, solvents, paint, and paint thinner
- Acids, degreasers, and rust inhibitors
- Heavy metals, lead, mercury, and items containing heavy metals such as fluorescent light tubes and batteries
- Asbestos, PCBs, and many other classes of materials listed by regulators[2]

Because of the special handling requirements and high disposal cost of this type of waste, avoid using material that is hazardous in a radioactive area. To reduce (minimize) mixed waste:

- Substitute non-hazardous material when possible.
- Do not leave hazardous material or waste in accelerator housings.

The Radiation Protection Department Radioactive Waste Group web page lists additional information.

2 For more information, see *SLAC Environment, Safety, and Health Manual* (SLAC-I-720-0A29Z-001), Chapter 17, “Hazardous Waste”

Study Questions

1. Which of the following statements is not a work practice to reduce your radiation exposure?
    1. Plan work before entering a radiation area with a radiological work permit.
    2. Locate high radiation areas on a survey map before entering, and stay as far from those sources as possible.
    3. While performing a job in a radiation area you realize you need another tool from the truck. You ask your partner to retrieve the tool for you. While you wait, you stand outside the radiation area.
    4. Always wear a personnel dosimeter in a radiation area.
2. ALARA stands for _____

3. What is the individual ALARA dose level at SLAC? _____ mrem/year

4. Explain the difference between prompt and residual radiation.

5. List the three basic protective measures used to reduce radiation exposure:
    1.
    2.
    3.
6. Discuss two examples for each radiation exposure reduction measure listed in question 4:
    1.
    2.
7. Which type of ionizing radiation, beta or gamma, is more difficult to shield against?

8. Neutron radiation is best shielded by these four types of materials:
    1.
    2.
    3.
    4.
9. Which SLAC organization works with various groups to design, engineer, and evaluate project shielding?

10. Besides phoning RPFO, list two ways to find out what the current radiation dose rates are in the area in which you will be working:

    1.

    2.

11. When you increase distance from a radiation source you will **increase** or **decrease** your exposure?

12. Why is it SLAC's policy to wait one hour after shutting down the accelerator before personnel are allowed into certain locations?

    Where would you find a list of these areas?

13. Name two ways that radioactive material might enter the body:

    1.

    2.

14. State two methods for reducing radioactive waste:

    1.

    2.

15. If you leave tools or other material in the accelerator housing during operations, might they become radioactive and therefore generate more radioactive wastes and material?

16. Give an example of

    1. A prompt radiation source
    2. A residual radiation source

17. What is the definition of mixed waste?

18. What should you do to reduce the potential for ingesting radioactive materials or reducing the spread of radioactive contamination?

4 Individual Monitoring

4.1 Objectives

Upon completion of this section, you will know

- How doses are determined
- Which types of dosimeters are used at SLAC
- How to obtain your dose records
- What your responsibility is for reporting any dose received elsewhere

4.2 Personnel Dosimeters

4.2.1 Requirements

Occupational radiation dose measurements are required by law.

Personnel (whole body and extremity) dosimeters are the dosimeters of record. They must be worn properly and processed quarterly, or more often as directed by RP.[3]

- A whole body dosimeter must be worn on the front torso to monitor whole body exposure.
- An extremity dosimeter monitors dose to the hands and feet. These are rarely necessary at SLAC, but may be issued in special cases by RP.

A *supplemental* dosimeter provides real-time dose information for a specific work assignment. The use of a supplemental dosimeter is specified on a radiological work permit (RWP).

You must wear your dosimeter

- As specified by signs, an RWP, or RP personnel
- To enter a radiologically controlled area (RCA)
- While in radiological areas such as a radiation area or high radiation area
- When handling radioactive material

It is your responsibility to

- Keep your dosimeter at SLAC
- Report a lost or damaged dosimeter immediately
- Notify RP when your work assignment at SLAC has ended

---

3 See Radiological Safety: Personnel Dosimeter Requirements (SLAC-I-760-0A07S-001)

4.2.2 Dose Evaluation

Dosimeters use the principle of either optical stimulation or thermo-luminescence. Electrons in the crystal of the material are freed from their normal energy state in the atom to a higher energy state. The electrons are stored at this higher energy state until the material is heated. When processed during the reading of the dosimeter to determine dose, the electrons return to their normal energy state. When they do, visible light is emitted. The amount of visible light emitted is proportional to the dose of radiation received.

Note *The Dosimetry and Radiological Environmental Protection (DREP) Group has passed performance evaluations with very high marks in the monitoring of high-energy photon and neutron radiation, and this has been recognized by the DOE Laboratory Accreditation Program.*

4.2.3 Supplemental Dosimeters

Although radiation levels at most SLAC locations are low, it is essential to measure personnel radiation doses to ensure that dose levels are ALARA. Electronic supplemental dosimeters used at SLAC provide an interim measurement of radiation exposure and are worn in addition to the personnel dosimeter.

Note *The official record of your exposure is the personnel dosimeter, not the supplemental dosimeter.*

A supplemental dosimeter is required

- When entering a high radiation area
- When working under a radiological work permit (RWP) that specifies that a supplemental dosimeter be worn

An electronic dosimeter is used when exposure to radiation may be relatively high, since it measures real-time and location-specific dose.

Note *Use of a supplemental dosimeter does not eliminate the need for surveys by RP or control operators.*

The electronic dosimeter is to be used only to measure personal accumulated exposure, which must be recorded on the RWP. Never remove it from your person to take exposure rate measurements on components, since this will result in an inaccurate personnel exposure reading.

The RPFO group provides Rados (RAD-50R and 60) electronic dosimeters to radiation workers. These electronic dosimeters are easy to use because they

- Are zeroed with the touch of a button
- Provide simultaneous digital read out of exposure rate and integrated exposure
- Have programmable alert and alarm settings (typically set for 100 mR/h and 100 mR)
- Have programmable dose rate chirp settings (typically will be set for 0.1mR/chirp)
- Clearly display exposure and exposure rates

Important Electronic dosimeters must be returned to RP once per year for calibration.

Figure 4-1 Rados Electronic Dosimeter

4.2.3.1 Using the Dosimeter

Before entering any area that requires a supplemental dosimeter (including all high radiation areas):

- Zero the instrument, if required
- Record the reading on the RWP
- Wear it next to the personnel dosimeter in the chest area or as directed in the RWP
- When wearing a full set of protective clothing, place on outside of the coveralls. A second supplemental dosimeter may also need to be worn inside of the coveralls.

While in the high radiation area:

- Read as often as necessary to monitor exposure.
- Do not take it off to measure radiation of an area or material.

After leaving the high radiation area, log the reading on the RWP.

In case of an off-scale reading or if an electronic dosimeter alarm sounds:

- Secure work activities.
- Alert others.
- Immediately exit the area.
- Call ext. 5555, notify your supervisor, and notify RP at ext. 4299.

4.2.3.2 Extremity Dosimeters and Monitoring

Dosimeters designed to monitor dose to the extremities (hands and feet) are rarely necessary at SLAC, but may be issued in special cases by the RP. When extremity dosimeter is appropriate, RP will specify requirements on the applicable RWP. Contact RPFO for more information.

Note *Examples of extremity dosimeters include a finger-ring or dosimeter chip that may be placed on your hand. An extremity dosimeter is worn in addition to the required whole body dosimeter.*

4.3 Radiation Dose Records

You have the right to request your dose record:

- Dose records are maintained by RP.
- Anyone who is issued an RWT dosimeter automatically receives an annual report.
- Anyone who has at any time had a SLAC-issued dosimeter may request their dose record.

4.3.1 Dosimeter Requirements

- Keep your dosimeter at SLAC.
- Report a lost or damaged dosimeter immediately.
- Notify RP when your work assignment at SLAC has ended.

4.3.2 Non-SLAC Dose Notification

Anyone who wears a SLAC dosimeter and must notify the Dosimetry and Radiological Environmental Protection (DREP) Group before and following any radiation dose received elsewhere, including medical exposures (especially nuclear medicine) and other occupational exposures (past and current) at other DOE sites.

Note *If you will be undergoing a medical procedure that involves radiopharmaceuticals to diagnose and/or treat disease, RP may require your personnel dosimeter be temporarily removed to keep occupational and medical exposures separate.*

4.3.3 Internal Monitoring

SLAC has an internal dosimetry program that includes internal dose assessments and bioassays. However, based on the type of facilities, the materials, and the protections in place SLAC does not have a current need to conduct routine internal monitoring.

4.3.4 Assignment to a Non-DOE facility

Your SLAC-issued dosimeter is intended to measure only any dose you receive at SLAC. Each individual who is acting in an official capacity at a non-DOE facility and is monitored for occupational radiation exposure must provide the monitoring results to their employer within 30 days of receipt. If you are assigned to work at a non-DOE facility please contact Radiation Protection.

4.4 Occupational Radiation Dose Limits

Table 4-1 Radiation Exposure Limits for Radiological Workers, mrem/year

	Radiation Exposure Limit
SLAC ALARA level	360[a]
SLAC administrative control level (ACL)	500
DOE whole body dose limit [b]	5000
DOE eyes	15,000
DOE skin and extremity	50,000
Declared pregnant worker, gestation period	500 [c]

[a] This value may only be exceed with the approvals of the department head, the associate lab director, and the radiological control manager.

[b] The whole body extends from the top of the head down to just below the elbows and knees. Because this area contains the radiation sensitive blood-producing system and vital organs, it requires the lowest limit.

[c] Per gestation period for an RWT qualified worker, also recommended to avoid exceeding 50 mrem/month.

Study Questions

1. What is the purpose of the whole body dosimeter?

2. How do you know when you are entering an RCA?

3. While in a radiation area you notice that your dosimeter is missing. What should you do?

4. State five (5) rules, policies, or practices governing the use of the dosimeter:
   1.
   2.
   3.
   4.
   5.
5. You are not required to wear a dosimeter to enter an RCA, but are required to wear a dosimeter upon entering a radiation area. **True** or **False**?
6. What is the purpose of a supplemental dosimeter?

7. An electronic dosimeter must always be worn in which of these areas? (Circle all that apply.)

Radiation area	High radiation area	Radioactive material area
Accelerator area	Radiologically controlled area	Controlled area

8. Which SLAC organization should you notify if you received radiation exposure at another facility?

9. Which SLAC organization should you notify if you received internal medical radio-isotope treatment?

10. List the two types of supplemental dosimeters used at SLAC:
    1.
    2.

5 Radiological Posting and Controls

This section describes all radiological postings and requirements. Radiological postings alert personnel to the presence of radiation and radioactive material. They also assist in implementing the ALARA process to reduce radiation exposure.

Note *With an RWT I qualification the only areas you may not enter are those posted as a* contamination area.

Figure 5-1 The Trefoil Indicates a Radiological Posting

5.1 Objectives

After completing this section you will be able to

- Identify radiological areas that RWT I qualifies you to enter
- State and explain the requirements for entering radiological areas
- State the purpose of the three types of radiological work permits (RWPs) and understand the radiological controls they convey
- Identify contamination areas that you may not enter unless you successfully complete RWT II
- Identify additional radiological postings and controls associated with radioactive material and sources

5.2 Radiological Posting

5.2.1 General Requirements

Areas controlled for radiological purposes are

- Designated with a magenta or black standard three-bladed radiological warning symbol (trefoil) on a yellow background
- Demarcated by yellow and magenta ropes, tapes, chains, or other barriers that are clearly visible from every side
- Clearly posted at the entrance with entry requirements, such as personnel dosimeter and RWP (with the radiological conditions, such as dose rate, included on or near each posting, as applicable)

Important Since radiological conditions may change, check signs for current radiological conditions every time you enter a posted area. An area that was only a radiation area before may be a high radiation area now.

Appropriately marked labels or tags are used to warn of specific radiological hazards, such as radioactive material that is stored in drums, boxes, or other containers. Immediately report any unusual instances to RPFO in the following instances

- Radiological controls are not adequate
- Radiological controls are not being followed
- There is possible unidentified radioactive material outside of any accelerator housings
- Radiological instruments show unusual radiological readings

Be aware of changing radiological conditions. Make sure that your activities do not create a radiological hazard for others. Be alert to any activities that may change the radiological conditions where you are working.

5.2.2 Radiation Areas

A *radiation area* is an area in which radiation levels could result in an individual receiving an equivalent 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. Postings or signs for a radiation area will indicate CAUTION, RADIATION AREA, RWP, RWT, PERSONNEL DOSIMETER REQUIRED FOR ENTRY.

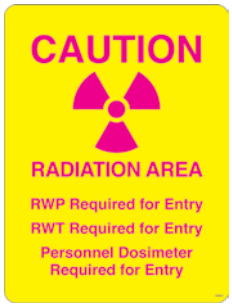


Figure 5-2 Radiation Area Posting

Note *The dose rate in a radiation area is defined at a distance of 30 cm. The dose rate on a surface may be higher if you are closer than 30 cm.*

When entering a radiation area, keep exposures ALARA and do not stay in the area any longer than necessary. Requirements and qualifications for unescorted entry into a radiation area include

- Routine area RWP required for entry
- RWT I qualification
- Personnel dosimeter

5.2.3 High Radiation Area

A *high radiation area* is an area in which radiation levels could result in an individual receiving an equivalent 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. The postings or signs will indicate DANGER, HIGH RADIATION AREA, RWP, RWT, PERSONNEL AND SUPPLEMENTAL DOSIMETER REQUIRED FOR ENTRY.

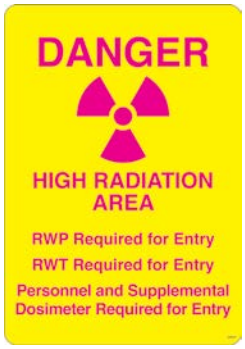


Figure 5-3 High Radiation Area Posting

Remember, the surface dose rate on material posted as high radiation may have much higher radiation dose rates.

When entering a high radiation area, keep exposures ALARA and do not stay in the area any longer than necessary. Requirements and qualifications for unescorted entry into a high radiation area include

- Routine area RWP required for entry
- RWT I qualification (GERT training is not sufficient)
- Personnel dosimeter
- Supplemental dosimeter

See Section 6, “High Radiation Area,” for more information.

5.2.4 Hot Spots

A *hot spot* is a localized source of radiation or radioactive material where radiation level is typically much higher than the surrounding area. Specifically, an area is posted as a hot spot when radiation is greater than 100 mrem/h on contact or greater than 5 times the general area radiation levels.

Hot spots will be posted within an already posted area such as a radiation or high radiation area. Signs are usually posted directly on items or next to them. Magnets and dumps are subject to becoming a hot spot. Avoid hot spots.

Figure 5-4 Hot Spot Posting

5.2.5 Radiological Buffer Area

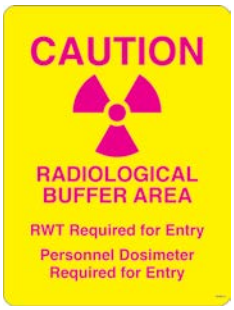


Figure 5-5 Radiological Buffer Area Posting

At SLAC, a *radiological buffer area (RBA)* is used to provide additional contamination control near a contamination area. Minimum requirements for entry into an RBA include an RWT I qualification and personnel dosimetry.

5.2.6 Contamination Area

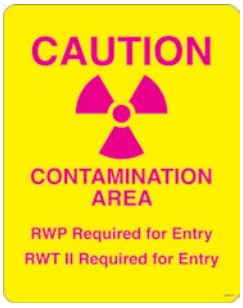


Figure 5-6 Contamination Area Posting

Radioactive contamination is radioactive material that can be easily transferred to surfaces by non-destructive means.

RWT II must be completed before entering an area posted as a *contamination area* or *high contamination area*.

Contamination areas are generally located around areas where there is a high potential to activate material, particularly next to beam dumps, collimators, and slits. Equipment such as sumps, alcoves, and pump pads may also be listed as contamination areas.

Call RP at ext. 4299 before performing work on a system that is posted as potentially containing contamination, such as LCW systems and beamline components.

The list of current contamination areas are on the Classification of Radiological Areas.

5.3 Low Conductivity Water Systems of Radiological Concern

The low conductivity water (LCW) systems in the Klystron Gallery consist of the accelerator cooling system (ACS), wave guide cooling system (WCS), and the klystron cooling system (KCS), among others. LCW systems around SLAC and the associated filters and resin columns create areas of potential radiological concern. For a current list, see the Radiation Protection Field Operations web page. Areas include

- ACS, Sectors 1, 2, and 3, 19, 20, 29, and 30
- 11-08 system at Sector 11
- WCS, Sector 28
- KCS, Sector 5
- Positron source at Sector 20
- Positron source at Sector 20 (PS 20)
- A-Beam Dump (ABD) LCW system
- Beam Analyzing Station (BAS) II at Sector 20
- Beam Switchyard (BSY) collimator LCW system
- BSY, A Magnet
- BSY, B Magnet
- Slit 10 (SL 10) LCW system
- Slit 30 (SL 30) LCW system
- Beam Dump East (BDE) LCW system

The systems itemized above are potentially radioactive. The following guidelines are to be observed when working on them:

- Contact RPFO before opening up any part of the system.
  - Contamination controls are required if >2 x 10^4 pCi/L tritium.
  - 2 x 10^4 pCi/L is the point at which RPFO may consider contamination controls for handling the water.
- Personnel may be required to wear rubber gloves when opening the system.
- RPFO must survey all system filters and strainers if the system is listed on the LCW Radiological Status Sheet, and LCW accelerator systems not on the sheet.

- Before discharging of some LCW system tanks and sump water into the sanitary sewer, the water must be sampled and analyzed for tritium (^3H) and other radionuclides. Other systems require sampling as part of the discharge. (See the status sheet for radiological controls regarding sampling and analysis.)
- Any resin bottles from listed systems must go to Radiation Protection Radioactive Waste Group for disposal and refilling of resin. Other resins are sampled for radioactivity before sending to vendor for recharging.
- See the RPFO procedure for resin media processing.

5.4 Radiological Work Permits

A *radiological work permit (RWP)* is a work authorization used to establish radiological controls and approvals for radiological work activities, including entering or working in a radiological area (radiation area, high radiation area and contamination area). There are also RWPs for establishing radiological controls for certain types of work. An RWP identifies

- Radiological conditions
- Entry requirements for specific radiological areas
- Required radiological controls
- Radiation doses received and relates them to specific work activities and locations

RWPs are usually located at the boundary of a radiological area. RWPs are controlled and issued by RPFO.[4]

5.4.1 Radiological Work Permit Types

The three types or RWPs are routine area, job type, and routine task.

Typical information on an RWP includes

- Date of issue
- Description and location of work
- Radiological conditions
- Dosimeter requirements
- Required level of training for entry
- Exposure controls
- Contamination controls
- Limiting radiological conditions that may void the permit
- Dose reduction requirements

4 Radiological Work Permits Procedure (SLAC-I-760-0A05C-002, FO 005)

5.4.1.1 Routine Area RWP

A routine area RWP must be posted and used for all entries into a

- Radiation area
- High radiation area
- Contamination area
- High contamination area

5.4.1.2 Job Type or Routine Task RWP

A job type or routine task RWP is required

- Where there is any machining of radioactive material
- For any work in a high radiation or high contamination area (a job type RWP is not required for personnel protection system [PPS] searches, observations, tours and most radiological surveys)
- Any job where the total effective dose may exceed 10 mrem individual per day, 20 mrem individual per week, and 30 person-mrem collective dose per job
- When radiological work in a radiation or contamination area involves work that may affect contamination or radiation hazards, or exceed 50 mrem per day or 100 mrem per week or collective dose of 200 person mrem for a job or task

5.4.2 Radiological Work Permit Approval

Persons authorized to approve an RWP are

- RP personnel
- Project leaders, managers, and supervisors

5.5 Other Radiation Safety Documents

5.5.1 Beam Authorization Sheets

A beam authorization sheet (BAS) is an RP document. A BAS authorizes beamline configurations and operating conditions.

5.5.2 Radiation Safety Work Control Form

A radiation safety work control form (RSWCF) to modify, repair, or remove any radiation safety device is required and must be approved by RP.

Note *The RSWCF is a RP Radiation Physics Group and Accelerator Department Safety Office document.*

5.5.3 Radiation Safety Labels

Radiation safety devices are labeled or tagged to identify their function.

Figure 5-7 Radiation Safety Device Labels

5.6 Radioactive Material Labeling

Figure 5-8 RPFO Technician Surveying Material from Accelerator Housing

At SLAC, radioactive material is defined as any material having detectable radioactivity levels above background. RP uses very sensitive instruments to measure for radioactivity.

All material inside accelerator housings is considered radioactive until proven otherwise. The material may or may not require identification labels. Once removed from the housing, all radioactive material is required to be identified as follows:

- Labels must have a yellow background with a magenta or black radiation symbol.
- Sealed sources may only have the standard radiation symbol.

Only RP and accelerator operators can attach this label to material.

Note *Either RP or an accelerator operator may survey material being removed from any accelerator housing.*

Figure 5-9 Radioactive Material Labels

Radioactive material is always indicated by a radioactive label. Any material that had the potential for being radioactive will be surveyed and labeled with a tag that indicates that it is released. The green label may be removed upon receipt.

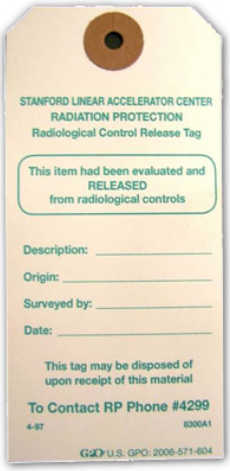


Figure 5-10 Released Item Label

5.7 Radioactive Sealed Sources

Figure 5-11 Radioactive Sealed Source

5.7.1 Source Custodians

RPFO has an inventory of sources for use on-site.

- Only authorized personnel designated and trained by RPFO as a *source custodian* may check out sealed radioactive sources.
- Source custodians are assigned by the RP and must be trained as radioactive source custodians by attending specialized training.

An individual assigned as a source custodian is responsible for ensuring the proper handling, inventory, and storage of the source. The source custodian is responsible for returning the source promptly when it is no longer needed.

Devices with installed radioactive sources must be clearly identified on the outside to indicate the device contains a sealed source. Sealed sources should be locked in a strong stationary container when not in use.

5.7.2 Source Categories

The category a source belongs to depends on the isotope and activity of the source.

- Accountable. If the source belongs in the “accountable” category, stricter controls are required per 10 CFR 835, Appendix E.
- Non-accountable. No special control is needed.

Yellow or white and black labels are used for shipping radioactive material outside of SLAC unless the package is classified as a limited quantity, or on radioactive material received at SLAC from the outside. More information regarding sealed sources is available from RP.[5]

To purchase or transport a radioactive source at SLAC, first contact RPFO. You must be able to account for radioactive sources consigned to you at all times.

5.8 Individual Responsibilities

Disregarding any posting or warnings or removing or relocating them without permission can lead to unnecessary or excessive radiation exposure and/or personnel contamination. It is each worker's responsibility to read and comply with all the information identified on radiological posting, signs, and labels. In addition,

- When using an RWP, all personnel are responsible for signing that they have read the RWP and understand the permit before entering the area

Important Personnel must log supplemental dosimeter readings for each entry and exit to areas that are controlled with an RWP that requires a supplemental dosimeter.

- If the RWP is not correct or unclear do not start the job and contact RPFO or your supervisor.
- Personnel must obey any instructions written on the permit. Never make substitutions for specified requirements.
- If any type of material used to identify radiological hazards is found outside an area controlled for radiological purposes, it should be immediately reported to RPFO.
- Only RP may alter any radiological posting.

Contact RPFO before any

- Disassembly of any beamline component suspected of being potentially contaminated inside or where a potential for elevated radiation dose rates is likely
- Machining or grinding on **any** material inside accelerator housings
- Removal of materials from accelerator housings that were in accelerator housings during beam

5.9 Radiological Posting and Access Controls Summary

Specific training requirements for access to any type of radiological area are summarized in Table 5-1.

5 Radioactive Sealed Source Procedure (SLAC-I-760-2A30C-005, FO 008)

Table 5-1 Radiological Area Postings by Type, Dosimetry, and Access Control Requirements

Posted Area	Total Effective Dose (TED) Rate	Dosimeter	Minimum Training (for unescorted access)	Visitors
Accelerator area	Negligible	None	Safety Orientation	Access is only allowed with an escort who has completed the required level of training for unescorted access to the area type
Controlled area (CA)	< 100 mrem/year	None	GERT	
Radiologically controlled area (RCA)	< 100 mrem/year	Personnel dosimeter	GERT	
Radioactive material area (RMA)	Various	Various[b]	GERT	
Radioactive material management area (RMMA)	Various	Personnel dosimeter	GERT	
Personnel exclusion area	Various	Personnel dosimeter and supplemental dosimeter as directed by RP	RWT I with RP approval	Not allowed
Radiation area (RA)	>5 mrem/h @ 30 cm	Personnel dosimeter	Escorting not allowed	
High radiation area (HRA)	> 100 mrem/h @ 30 cm	Personnel and supplemental dosimeter	Escorting not allowed	
Very high radiation area (VHRA)	Various	No entry allowed	No entry allowed	
Contamination area	>1000dpm/100 cm^2	Personnel dosimeter	RWT II	

a GERT qualified personnel are permitted to enter these areas if it will not result in an annual radiation dose greater than 100 mrem

b Dosimetry required if the area is also posted as an RCA or a radiological area

5.10 Eating and Drinking in Accelerator Housing

Eating is not allowed in any accelerator housing. Drinking is allowed under some situations and conditions as long as it is consumed during the course of work and if in accelerator housings is contained in closed type containers such as water bottles.

Table 5-2 Area Types and Eating and Drinking Requirements Summary

Posted Area Type	Liquid (must be in a closed container)	Food
Accelerator housings	Yes	No
Controlled area (CA)	Yes	Yes
Radiologically controlled area (RCA)	Yes	Yes
Radioactive material area (RMA)	Yes	Yes
Radioactive material management area (RMMA)	Yes	No
Radiation area (RA)	Yes	No
Contamination area	No	No
Airborne radioactivity area	No	No
High radiation area (HRA)	Yes	No

Study Questions

1. Define the following radiological areas:

   Radiation area _____to _____(rates) at _____ (distance).

   High radiation area_____ to _____ (rates) at _____ (distance).

2. Circle the standard colors that identify radiation sources and radioactive material. (Circle all that apply.)

   Green Yellow Red Gray

   Blue Black Orange Magenta

3. As an RW I, what type of posted area are you not allowed to enter?

4. Can a GERT qualified person enter a radiation area?

5. Can a GERT qualified person enter a radiation area when accompanied by a qualified escort?

6. All material that may have been in the accelerator housing during operations is considered radioactive until surveyed by RPFO. **True** or **False**?

7. Who may alter a radiological posting?

8. Is a radiologically controlled area always a radiation area? **Yes** or **No**?

9. Identify two areas at SLAC that are controlled as RMMAs.

   1.

   2.

10. List the three types of RWP:

    1.

    2.

    3.

11. When is a job type RWP required?

12. In what type of radiological areas would an RWP be posted?

13. When would an RWP be required for machining done in an accelerator housing?

14. Name three types of information found on a typical RWP.
    1.
    2.
    3.
15. When you sign an RWP, what are you verifying?

16. Which group at SLAC is responsible for shipping and receiving radioactive materials at SLAC, including sealed radioactive sources?

17. Why are some LCW systems controlled and sampled for radioactivity and disposed of via the sanitary sewer?

18. What is tritium?

19. When are radiation safety work control forms used?

20. What are the requirements for entering a
    1. Radiation area

    2. High radiation area

6 High Radiation Area

6.1 Objectives

This lesson is required for RWT personnel who will be entering high radiation areas and is included in this study guide to allow RWT I qualified employees to enter and work in a high radiation area.

This lesson discusses information regarding working in and controlling work in a radiation or high radiation area and handling material that emits radiation. Upon completion of this unit, personnel will be able to identify restrictions regarding entry and work in high radiation areas. They will be able to select the correct response to verify their ability to

- Define radiation area
- Define high radiation area
- Describe signs and posting used to identify these areas
- Identify sources and locations at SLAC that may produce a high radiation area
- State the requirements for entering and working in a high radiation area
- State the administrative and physical controls for access to a high radiation area
- Identify the correct response to an emergency and/or alarm within a high radiation area

6.2 Definitions

6.2.1 Radiation Area

A *radiation area* is an area in which radiation levels could result in an individual receiving an equivalent 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.

6.2.2 High Radiation Area

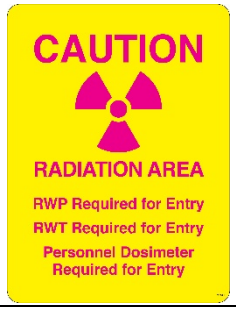
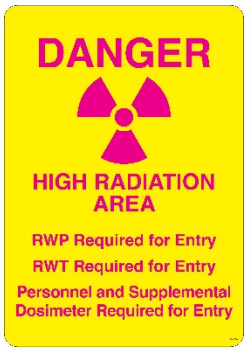
A *high radiation area* is an area in which radiation levels could result in an individual receiving an equivalent dose to the whole body in excess of 100 mrem in 1 hour at 30 centimeters from the radiation source or from any surface that the radiation penetrates.

6.3 Signs and Posting

Radiation and high radiation areas will have posted barriers in one of these forms:

- Signs on yellow and magenta ropes
- Signs posted on doors and gates

Table 6-1 Radiation and High Radiation Area Postings Summary

Posting	Area	Definition	Requirements
	Radiation area	Radiation levels could result in a person receiving an equivalent dose > 5 mrem/h at 30 cm from the radiation source	RWT I RWP required for entry Personnel dosimeter
	High radiation area	Radiation levels could result in a person receiving an equivalent dose > 100 mrem/h at 30 cm from the radiation source	RWT I RWP required for entry Personnel and supplemental dosimeter required

6.4 Potential Locations and Sources of High Radiation

Areas that may be classified as or contain radiation or high radiation areas include

- Accelerators during beam operation (prompt radiation)
- Sectors 19-20 (FACET)
- Beam Switchyard (BSY), (HRA below catwalk and possibly D10)
- Positron Vault
- LCLS Dumps
- Radiation Calibration Facility at Building 24 (HRA), when sources are open, including the roof

For current information see Classification of Radiological Areas at SLAC.

6.5 General Entry, Exit, and Work Controls

6.5.1 Radiation Area Entry

In order to enter a radiation area, a worker must

- Have successfully completed RWT I
- Review and sign the routine area RWP
- Have a job type or routine task RWP for radiological work with work procedure
- Wear a personnel dosimeter

6.5.2 High Radiation Area Entry and Exit

For entry to and exit from high radiation areas the worker must

- Have successfully completed RWT I
- Review and sign the routine area RWP
- Possess a job type RWP for all work with a work procedure
- Wear a supplemental electronic dosimeter
- When exiting, sign the RWP and log the supplemental dosimeter

Note *For high radiation areas in which the dose is greater than 1000 mrem/h at 30 cm, the boundary may be locked.*

6.5.3 Working Requirements for High Radiation Areas

Working in a high radiation area requires that personnel, in addition to the requirements listed in Section 6.5.2, “High Radiation Area Entry and Exit”

- Comply with work practices to keep exposures ALARA
- Observe hot spot posting
- Use a job type RWP for conducting work in high radiation areas
- Stay only as long as necessary
- Review latest radiation survey for the area at the access point
- Read supplemental dosimeters often while in area and upon exit

Figure 6-1 Signs Posted on or Adjacent to Doors and Gates

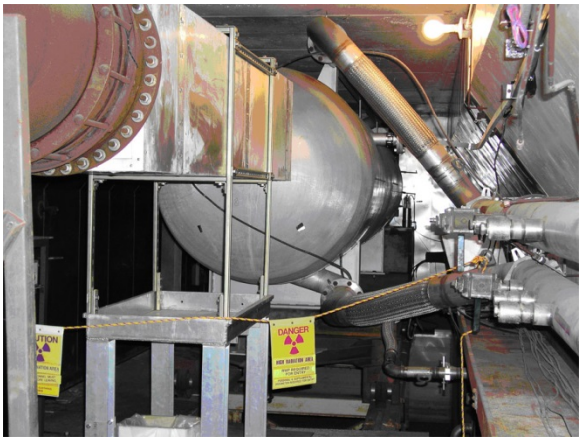


Figure 6-2 Signs Posted on Yellow and Magenta Ropes

When the dose rates are greater than 1 rem/hour at 30 cm, additional requirements may include

- Extensive planning
- Formal radiological review of non-routine or complex work
- ALARA Committee review
- Determination of worker's current dose
- Pre-job briefing, as applicable
- Direct RPFO coverage

6.5.4 Cool Down Period

Some areas listed in Section 6.4, “Potential Locations and Sources of High Radiation,” may require a one hour cool down period before personnel entry. For a list of areas that require a cool down before entry see Classification of Radiological Areas at SLAC.

6.5.5 Radiological Work Permits

- A routine area RWP is required for entry to perform tasks such as tours, observation, PPS searches and data collecting.
- A routine task or job type RWP is required for all work such as using tools.

6.6 Default Posting and Initial Entry / Survey Requirements

6.6.1 Entry Requirements

Several locations within the accelerator housing will typically be controlled and identified as a high radiation area and a contamination area immediately after the beam is shut down. These areas, listed in the Classification of Radiological Areas at SLAC, must be surveyed by RPFO to reduce entry requirements.

Radiological Survey Levels

- **Level 1.** Surveys are conducted by either RPFO or limited radiologically controlled assistants (LRCAs). Personnel will be escorted into these areas by RPFO or LRCA. The radiological status does not change.
- **Level 2.** Surveys are conducted by RPFO to verify radiological conditions before personnel entry. This is to identify and establish any new radiation, high radiation, or contamination areas prior to work.
- **Level 3.** Surveys are conducted by RPFO to reduce contamination, radiation and high radiation status, or to redefine boundaries.

Study Questions

Circle the best answer.

1. A survey indicates that a dose of 1.5 rem would be received in 1 hour at 30 cm from the surface of a radiation source. This would require the area be posted as which of the following?
   a. Radiation area
   b. High radiation area
   c. Contamination area
   d. Radiologically controlled area
2. Dose rate measurements used to determine criteria for high radiation areas should be at a distance of _____ from the radiation source.
   a. 300 cm
   b. 30 cm
   c. 1 m
   d. 3 m
3. When working in a high radiation area, what is always required?
   a. Supplemental electronic dosimeter
   b. Special high-energy dosimeter
   c. Neutron dosimeter
   d. Coveralls
4. When is a job type RWP not required for working in a high radiation area?
   a. Touring for a few minutes
   b. Performing work of removing a beamline component
   c. Observing a gauge
   d. Changing a water flow switch

7 Emergencies

7.1 Objectives

After completing this section you will

- Be able to identify possible radiological emergency situations that could occur at SLAC
- Know the types of protective systems and alarms in place and their purpose
- Know how to respond to a radiological emergency
- Understand possible consequences of disregarding radiological alarms or status indicators

7.2 Emergency Alarms

Equipment that monitors abnormal radiation dose rates and airborne contamination levels is placed in strategic locations throughout the facility. It is essential for workers to be able to identify the equipment and alarms and to be able to respond appropriately to each. Disregarding any of these radiological alarms may lead to possible excessive radiation dose and unnecessary spread of contamination.

7.2.1 Personnel Protection System

Interlocks are used on the personnel protection system (PPS). Personnel may not enter any beam housing during operation.

7.2.2 Emergency Beam Shut-off Button

An emergency beam shut-off button is located every 50 feet inside accelerator enclosures. Before energizing the beam and placing an area into a *no access mode*, an auditory announcement will warn of the impending condition and the overhead lights will flash. This warning announcement will last for 2 minutes.

If you hear this alarm and see flashing lights, take the following actions:

1. Push the nearest emergency button
2. Proceed to the nearest exit
3. Contact ACR at ext. 2151 to exit the area and to inform them of the occurrence

7.2.3 Beam Shut-off Ion Chamber

Beam shut-off ion chambers (BSOICs) are strategically placed around SLAC to monitor radiation external to the shielded barriers. The system shuts off the beam if the set radiation level is exceeded. Typical settings are 10 or 100 mrem/h. Do not tamper with these devices and never unplug an extension cord that powers a BSOIC.

Figure 7-1 A Beam Shut-off Ion Chamber Monitors and Controls Excess Radiation

7.3 Emergency Notifications

In a radiological work environment, it is important that you keep in mind these three points in the event of an emergency:

1. Responding to an alarm is the first step.
2. Responding to the emergency may require further actions.
3. First aid takes precedence over radiological controls.

In case of emergency

1. Stop work.
2. Alert others.
3. Immediately exit the area.
4. Make required notifications:
   - For *radiological emergencies* call your supervisor and ext. 5555.
   - For *life threatening emergencies* and/or fire: first call 911, then call SLAC Site Security at ext. 5555 (from a cell phone dial 650-926-5555), then notify your supervisor.

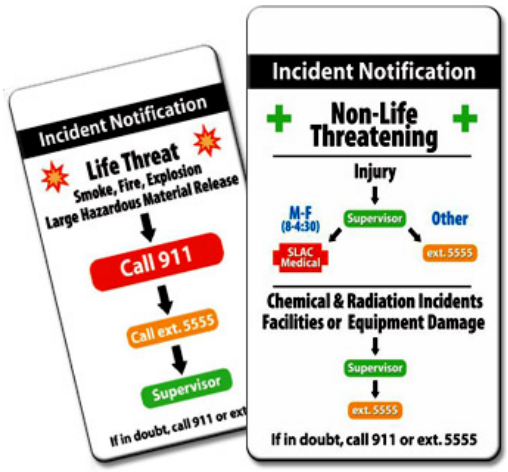


Figure 7-2 Emergency Notification Cards

7.4 Radiological Emergencies

7.4.1 Personnel Injuries

Important First aid takes precedence over radiological controls.

If an emergency arises during radiological work, additional precautions may be necessary. If personnel are injured in a radiological area:

1. Call 911.
2. Call SLAC Site Security at ext. 5555 (Security will make further required notifications).
3. Render first aid.

Moving an injured person out of a radiation area is generally not necessary. RPFO staff will address any radiological concerns once the injured person is stabilized. Conditions that may require immediate exit from an area controlled for radiological purposes include

- An accidental breach of a radioactive system that results in radioactive contamination being exposed
- An excessively high radiation level
- An audible warning that the beam is about to come on

7.4.2 Radioactive Material Spills

For spills of radioactive material

- S = Stop the spill, if possible
- W = Warn others in the area
- I = Isolate the area
- M = Minimize the spread

7.4.3 Low Conductivity Water System Spills

In the event of a spill in one of the LCW areas listed as a radiological concern:

1. First stop or secure the operation causing the spill, if possible.
2. Warn others in the area.
3. Notify RPFO.
4. Isolate the spill area if possible.
5. Minimize individual exposure and contamination.
6. Secure un-filtered and/or filtered ventilation (such as fans and open windows).

7.4.4 Elevated Radiation Levels

If unanticipated elevated radiation levels are indicated by elevated readings on a portable survey meter:

1. Stop work.
2. Alert others; have them read their supplemental dosimeter.
3. Immediately exit the area.
4. Call ext. 5555 and notify RPFO.

7.5 Rescue and Recovery Operations

Residual radiation levels at SLAC are typically low. Rarely, emergency exposure to higher levels of radiation may be necessary to rescue personnel or protect major property. Rescue and recovery operations that involve radiological hazards can be very complex with regard to the control of personnel exposure. The type of response is generally left up to the officials in charge of the emergency situation. The officials' judgment is guided by variables including determining the risk versus benefit of the action and how to involve other personnel in the operation. In most cases, first aid takes precedence over radiation controls.

Study Questions

1. If you are working inside a high radiation area and you hear an impending beam alarm, you leave the area immediately after pushing the EMERGENCY OFF button. **True** or **False**?
2. BSOICs are used to detect airborne radioactivity. **True** or **False**?
3. If someone is injured in a radiological area, you should move them out of the area before contacting emergency rescue personnel because the radiation levels are much more hazardous than an injury. **True** or **False**?
4. What is the phone number for contacting emergency rescue personnel?
5. What type of warning is given in accelerator housings before the beam is energized?
6. What are your actions if you hear the warning?
7. When reading your supplemental dosimeter you observe an abnormal reading. What actions should you take?
   a. Inform supervisor when you complete your task
   b. Stop work, alert others, exit the area, and notify RP
   c. Consider that the dosimeter has malfunctioned and continue working
   d. None of the above

8 Practical Exercises

8.1 Objective

To qualify as a Radiological Worker I, personnel must pass a written exam on radiological theory and satisfactorily demonstrate the following skills under simulated conditions.

8.1.1 Personnel Protection System

Personnel must identify a controlled access condition and know what the following lights indicate:

- Solid magenta
- Flashing magenta
- Solid amber

8.1.1.1 Controlled Access Entry

During a simulated controlled access entry, personnel must

- Observe radiation warning signs
- Observe radiation survey
- Phone ACR and state their name, location, and purpose for entry
- Take key from key bank
- Insert key into door, release box, and open entrance door
- After entry, ensure that the door is shut
- Block open inner door
- Leave inner door open until last person exits
- Know that for multiple entry, all personnel entering must take a key

8.1.2 Supplemental Dosimeters

Personnel must be able to turn on the electronic dosimeter, zero it, and turn it off.

8.1.3 High Radiation Area

When entering a high radiation area personnel must

- Properly attach a supplemental dosimeter next to their personnel dosimeter
- Read high radiation postings, including radiation levels
- Interpret radiation levels and locations on survey map

- Before entry, demonstrate familiarity with the radiological work permit by
  - Reading the routine area RWP
  - Signing the RWP
  - Logging in the supplemental dosimeter reading
  - Practicing ALARA processes while performing work
  - Periodically reading their supplemental dosimeter while in the high radiation area
  - Filling out the RWP after exiting by logging in their supplemental dosimeter reading

8.1.4 Radiation Area Entry

When entering a radiation area personnel must

- Read and sign routine area RWP
- Wear a personnel dosimeter
- Demonstrates policy for not escorting GERT or visitor

8.1.5 Handling Potentially Radioactive Material

Personnel must demonstrate an understanding of the handling of potentially radioactive material by

- Not removing material from accelerator housing
- Contacting the RPFO for a survey request

8.1.6 Emergency Actions

8.1.6.1 PPS Alert

During a PPS alert, personnel must

- Press EMERGENCY OFF button
- Exit the area immediately
- Phone the ACR after exiting

8.1.6.2 Suspect Supplemental Dosimeter Reading

If a supplemental dosimeter reading is suspect, personnel must

- Alert others in the area
- Exit area
- Contact the RPFO

8.1.6.3 Response to a First Aid Situation in a Radiological Area

8.1.7 Pre-work planning

Given task scenarios, worker must demonstrate knowledge of when a separate job-type RWP is required.

Table 8-1 RWT I Practical Exam Checklist

Topic	Knowledge or Skill to be Demonstrated	Possible Points	Earned Points
Personnel protection system (PPS)	Observes and states meaning		
	1. Flashing magenta light	2	
	2. Solid amber light	2	
	3. Demonstrates permitted access entry	4	
	4. Demonstrates controlled access entry / exit	10	
Radiological classification entry / exit	Radiation Area		
	5. Observes Radiation Area posting	5	
	6. Knows RWT required for entry – no GERT allowed	10	
	7. Reads and signs radiological work permit (RWP) before entry and exit	4	
	8. Demonstrates knowledge of attribute of RWP	4	
	High Radiation Area		
	9. Observes high radiation area posting	2	
	10. Knows RWT required for entry	10	
	11. Reads and signs RWP before entry and exit	4	
	12. Demonstrates knowledge of attribute of RWP	2	
	13. Properly interprets radiation levels from survey map	3	
	14. Properly zeros supplemental dosimeter	2	
	15. Properly attaches supplemental dosimeter next to personnel dosimeter	2	
	16. Properly reads pre-set supplemental dosimeter	2	
Material control	17. Demonstrates removal of material from RMMA	5	
	18. Contacts RPFO for survey request	2	
	19. Discuss and explain proper transport of RAM	5	
Emergency response	20. Demonstrates entering radiological areas to perform first aid as needed	5	
	21. Demonstrates response to beam on condition while in accelerator housing	5	
Pre-work planning	22. Knows when a job type RWP is required	5	
	23. Knows not to conduct machining in accelerator housing w/o RP approval	5	

9 Related Documents

The following are related documents and forms. Always locate and use the latest version, either online from the addresses below or from the originating unit.

Table 9-1 Related Documents

Title	Document Number	Originating Unit	URL
Radiological Safety Program			
Radiological Control Manual	SLAC-I-720-0A05Z-001	RP	https://www-group.slac.stanford.edu/esh/documents/RCM.pdf
SLAC Environment, Safety, and Health Manual, Chapter 9, "Radiological Safety"	SLAC-I-720-0A29Z-001	RP	https://www-group.slac.stanford.edu/esh/general/radiological_safety/
Radiological Safety: Work and Area Entry Requirements	SLAC-I-760-0A05S-002	RP	https://www-group.slac.stanford.edu/esh/eshmanual/references/radReqWorkEntry.pdf
Radiological Safety: Personnel Dosimeter Requirements	SLAC-I-760-0A07S-001	RP	https://www-group.slac.stanford.edu/esh/eshmanual/references/radReqDosimeterPersonnel.pdf
Classification of Radiological Areas at SLAC		RP	https://slac.sharepoint.com/sites/ESH/rp/fo/documents/Classification%20of%20Radiological%20areas.pdf
Radiological Work Permits Procedure	SLAC-I-760-0A05C-002, FO 005	RP	https://slac.sharepoint.com/sites/ESH/rp/fo/Procedures/FO%20005.pdf
Radiological Work Permit		RP	https://www-bis1.slac.stanford.edu/RWP/
Radioactive Sealed Source Procedure	SLAC-I-760-2A30C-005, FO 008	RP	https://slac.sharepoint.com/sites/ESH/rp/fo/Procedures/FO%20008.pdf
LCW Radiological Status Sheet		RP	https://www-internal.slac.stanford.edu/esh-db/radlab/home.aspx
Radiation Protection Department		RP	https://www-group.slac.stanford.edu/esh/rp/
Radiation Protection – DREP		RP	https://www-group.slac.stanford.edu/esh/rp/drep.htm

Title	Document Number	Originating Unit	URL
Radiation Protection – Field Operations		RP	https://www-group.slac.stanford.edu/esh/rp/fieldops.htm
Radiation Protection – Radioactive Waste Management		RP	https://www-group.slac.stanford.edu/esh/rp/radwaste.htm
ESH Course 115, General Employee Radiological Training (GERT)	ESH Course 115	RP	https://www-internal.slac.stanford.edu/esh-db/training/slaconly/bin/catalog_item.asp?course=115
ESH Course 116, Radiological Worker I Training (RWT I)	ESH Course 116	RP	https://www-internal.slac.stanford.edu/esh-db/training/slaconly/bin/catalog_item.asp?course=116
ESH Course 250, Radiological Worker II Training (RWT II)	ESH Course 250	RP	https://www-internal.slac.stanford.edu/esh-db/training/slaconly/bin/catalog_item.asp?course=250
ESH Chapters / Programs			
SLAC Environment, Safety, and Health Manual, Chapter 17, "Hazardous Waste"	SLAC-I-720-0A29Z-001	RP	https://www-group.slac.stanford.edu/esh/environment/hazardous_waste/
ESH Other			
SLAC Training - Web Based Courses		Training	http://training.slac.stanford.edu/web-training.asp
ESH Course 219, Environmental Safety and Health Orientation	ESH Course 219	ESH	https://www-internal.slac.stanford.edu/esh-db/training/slaconly/bin/catalog_item.asp?course=219
SLAC Other			
Radiation Safety Work Control Form	SLAC-I-040-305-011-01	ADSO	https://docs.slac.stanford.edu/sites/pub/Publications/%5b040-305-011-02_Safety%5dRSWCForm.pdf
SLACspeak		Archives and History Office	http://www.slac.stanford.edu/history/slacspeak/
Other			
Title 10, *Code of Federal Regulations*, "Energy," Chapter 3, "Department of Energy," Part 835, "Occupational Radiation Protection" (10 CFR 835)	10 CFR 835	GPO	http://www.ecfr.gov/cgi-bin/text-idx?SID=88bf1458767e8b5a72d64080e9f15b70&mc=true&node=pt10.4.835&rgn=div5

Title	Document Number	Originating Unit	URL
Department of Energy Guide 441.1-1C Change 1, "Radiation Protection Programs Guide for Use with Title 10, Code of Federal Regulations, Part 835, Occupational Radiation Protection"	DOE G 441.1-1C Chg1 (Admin Chg)	DOE	https://www.directives.doe.gov/directives-documents/400-series/0441.1-EGuide-01c-admchg1
Department of Energy Standard 1098-2017, "Radiological Control"	DOE-STD-1098-2017	DOE	https://www.standards.doe.gov/standards-documents/1000/1098-AStd-2017
Periodic Table of the Elements		Radiochemistry Society	http://www.radiochemistry.org/periodictable/index.shtml

A Glossary

The following definitions are from DOE Handbook 1108-2002, “Radiological Safety Training for Accelerator Facilities” (DOE-HDBK-1108-2002). For additional information on terms used at SLAC, see SLACspeak.

accelerator. A device employing electrostatic or electromagnetic fields to input kinetic energy to molecules, atomic, or subatomic particles. Training is provided because accelerators are capable of creating a radiological area or other radiological hazards.

access control system. Engineered or administrative systems that manage radiation dose to personnel by limiting personnel entry

activity. The rate at which a source emits radiation is called its activity. Activity is measured in terms of the number of disintegrations that take place every second. The unit for activity used at DOE sites is the curie (Ci). One curie is equal to 37 billion (3.7×10^{10}) disintegrations per second.

administrative control level. A numerical dose constraint established at a level below the regulatory limits to administratively control and help reduce individual and collective dose

attenuation. The process by which a beam of radiation is reduced in intensity when passing through some material. It is the combination of absorption and scattering processes and leads to a decrease in flux intensity.

beam. A flow of electromagnetic or particulate radiation that is either collimated and generally unidirectional, or divergent from a small source but restricted to a small solid angle

beam scrapers. Beam scrapers remove particles that have wandered from the central area of the beam

bremsstrahlung. Secondary photon radiation produced by deceleration of charged particles passing through matter

collider. An accelerator in which two opposed beams of particles collide head-on

continuous air monitor (CAM). Instrument that continuously samples and measures the levels of airborne radioactive materials on a real-time basis and has alarm capabilities at preset levels

detector. Any device that can detect the presence of an energetic electromagnetic radiation particle or nuclear fragment and measure one or more of its properties

electromagnetic radiation. A traveling wave motion resulting from changing electric or magnetic fields. Familiar electromagnetic radiation range from x-rays and gamma rays of short wavelength, through the ultraviolet, visible and infrared regions, radar and radio waves of relatively long wavelength.

enclosed beam. All possible x-ray beam paths are fully contained in protective enclosures so that no part of the body can intercept the beam during normal operation

electron volt. A unit of energy equivalent to the energy gained by an electron in passing through a potential difference of one volt

exclusion area. Any area to which access is prohibited for the purposes of protection of individuals

linear accelerator. A device that accelerates charged particles along a straight line

mixed waste. Waste containing both radioactive and hazardous components as defined by the Atomic Energy Act and the Resource Conservation and Recovery Act, respectively

muon. An elementary particle apparently identical to the electron except for being 200 times heavier

neutron. Elementary particle with a mass approximately the same as that of a hydrogen atom and electrically neutral

nucleus. The small, central, positively charged region of an atom that carries essentially all the mass

primary beam. Radiation that passes through the window, aperture, cone, or other collimating device of the source housing. Sometimes called *useful beam*.

prompt radiation. Radiation resulting from the accelerator beam or the interaction of the accelerator beam with surrounding matter that ceases shortly after the beam is removed. Activation products and area contamination are not considered prompt radiation.

proton. An elementary nuclear particle with a positive electric charge and an atomic weight of approximately one

radiation. Radiation refers to the emission and propagation of waves or particles through matter or space. Matter absorbs energy from radiation. In a microwave oven, for example, food absorbs energy from microwave radiation and is heated and cooked.

radioactivation or activation. The process of producing a radioactive material by bombardment with neutrons, protons, or other nuclear particles

redundancy. Duplication or repetition of elements in electronic or mechanical equipment to provide alternative functional channels in case of failure

scattered radiation. Radiation that, during passage through matter, has been deviated in direction. It may have been modified also by a decrease in energy.

search. A physical inspection carried out under controlled conditions to ensure that no personnel are left inside exclusion areas. Commonly referred to as a *sweep*.

septa. An area associated with an accelerator beamline where the beam is split into two or more beams, normally through the use of magnets. This area is prone to radioactivation due to the interaction of the beam with structural materials.

synchrotron. An accelerator in which the energy of charged particles is increased as they travel around a circular orbit of fixed radius

useful beam. Radiation that passes through the window, aperture, cone, or other collimating device of the source housing. Sometimes called *primary beam*.

volt. The term potential difference, symbolized by V, is defined as the work per unit charge done in moving a charge from one point to the other

B SLAC Facilities Overview

Originally a particle physics research center, SLAC is now a multipurpose laboratory for astrophysics, photon science, accelerator and particle physics research. Specifications for the main facilities are described in the tables below.

Stanford Linear Accelerator

The Stanford Linear Accelerator (linac) is a two-mile (three-kilometer)-long accelerator capable of producing electron and positron beams with energies up to 50 GeV.

Table B-1 Linac Design Parameters

Linac Characteristic	Value
Accelerator length	10,000 ft (3048 m)
Number of klystrons	240
Peak power per klystron	20 to 50 MW
Beam pulse repetition rate	1–120 pulses per second
Electron energy	50 GeV (maximum)
Electron peak beam current	70 mA
Electron peak beam power	800 kW (maximum)
Electron beam pulse length	10 ps-1.6 ms
Positron energy	50 GeV (maximum)
Positron average beam current	0.5 mA

Stanford Synchrotron Radiation Lightsource

The Stanford Synchrotron Radiation Lightsource (SSRL) creates synchrotron x-ray light by bending the path of electrons traveling the speed of light around the Stanford Positron Electron Accelerating Ring (SPEAR). The extremely bright x-rays can be used to view the nanoworld, leading to discoveries in fields including solid-state physics, materials science, environmental sciences, structural biology and chemistry. Some 2,000 scientists from universities, industries and laboratories around the world use SSRL's x-ray light each year.

Table B-2 SSRL Design Parameters

SSRL Characteristic	Value
Electron energy in storage ring, SPEAR	3 GeV
Booster	3 GeV
Linac	2.5 GeV

Linac Coherent Light Source

The Linac Coherent Light Source (LCLS) is an x-ray free electron laser. Pulses of x-ray laser light from LCLS are many orders of magnitude brighter and several orders of magnitude shorter than what can be produced by any other x-ray source available.

These characteristics enable frontier science in areas that include discovering and probing new states of matter, understanding and following chemical reactions and biological processes in real time, imaging chemical and structural properties of materials on the nanoscale, and imaging non-crystalline biological materials at atomic resolution.

Table B-3 LCLS Design Parameters

LCLS Characteristic	Value
x-ray wavelength	1.5 to 15 Ångströms (on the scale of atoms)
Ultra-short pulse duration	1 to 230 femtoseconds
Peak brightness	0.8 to 0.06 x 10^{33} Photons/(s mm^2 $mrad^2$ 0.1% bandwidth) (10 billion times brighter than existing x-ray sources)
x-rays per pulse	1.1 to 29 x10^{12} (one trillion in a needle-thin beam)
Electron beam energy	4.5 to 14.3 GeV
Peak current	3.4 kA
Fundamental saturation power at exit	8 to 17 GW
Meters of undulator magnets to generate x-rays from electrons	112
Laser properties	coherent x-rays at same wavelength

Source: LCLS pamphlet dated April 2005; see "SLAC Linac Coherent Light Source," http://lcls.slac.stanford.edu/

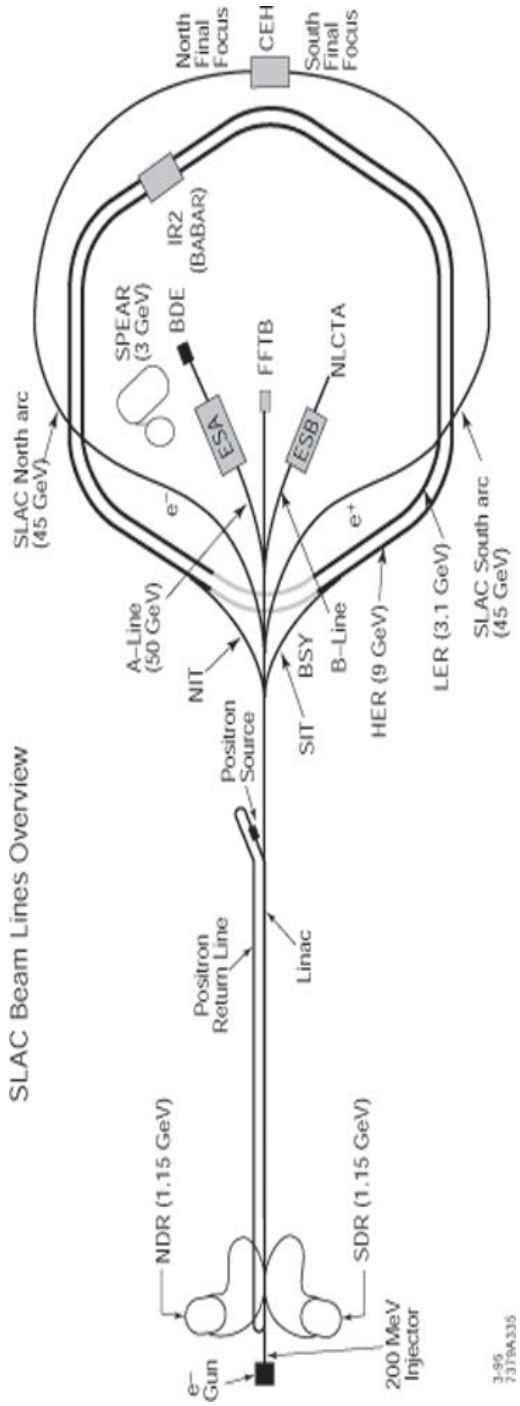


Figure B-1 SLAC Beamlines Overview

C Radiological Work and Area Entry Requirements

ENVIRONMENT, SAFETY & HEALTH DIVISION

Chapter 9: Radiological Safety

Radiological Work and Area Entry Requirements

Product ID: 237 | Revision ID: 2100 | Date published: 19 July 2019 | Date effective: 19 July 2019
URL: https://www-group.slac.stanford.edu/esh/eshmanual/references/radReqWorkEntry.pdf

1 Purpose

The purpose of these requirements is maintain personnel radiation doses below regulatory limits and as low as reasonably achievable (ALARA) and to prevent unplanned or accidental exposure to ionizing radiation. They cover authorizing radiological work and posting of and access to areas. They apply to workers, supervisors, points of contact, and project managers, Radiation Protection and any other group involved in these activities.

2 Requirements

2.1 Radiological Work

Radiological work is any work involving the use of tools on beam lines, beam line components, beam line safety items, radiation hot spots; or *radioactive low conductivity water (LCW)* systems. All radiological work at SLAC must be authorized by line management and approved by cognizant Radiation Protection (RP) Department personnel. Radiological work must be conducted by trained personnel who are following written procedures and/or a radiological work permit (RWP). (See the Radiological Work Permits Procedure and the Radiological Work Permit site for further information.)

2.2 Area Entry

2.2.1 Area and Worker Classification

Workers at SLAC are classified according to the level of their training, which determines the areas they can enter without an escort (see Chapter 55, "Site Access Control").

- General Employee Radiological Training (GERT)-qualified personnel can enter controlled areas (no dosimeter is required) and RCAs (a dosimeter is required). (See Controlled Areas and Radiologically Controlled Areas (RCAs) for a map of these areas.) The dose for GERT-qualified personnel is limited to 100 mrem total effective dose (TED) in a year. If a worker is likely to receive a dose higher than 100 mrem TED in a year, he or she must first complete RWT I training or higher.
- Radiological Worker Training (RWT) I or higher training and a dosimeter are required to enter any radiological area or a radiological buffer area.

2.2.2 Posting

All areas containing radiation hazards or having the potential to contain radiation hazards will be posted with the appropriate signs. 10 CFR 835 defines the radiological posting requirements. Any posting must

- Be clear, legible, conspicuously posted, and may include radiological protection instructions
- Contain the standard radiation symbol colored magenta or black on a yellow background, with black or magenta lettering
- Be used to alert personnel to the presence of radiation and radioactive materials, and to aid them in minimizing exposures and preventing the spread of contamination
- Be kept up to date by RP

Postings and signs inform personnel of potential or actual radiation hazards and to indicate requirements to enter, such as level of training, dosimeter types, and controls such as a radiological work permit (RWP) or specialized equipment.

Note *Postings and signs indicate radiological area types, which are associated with particular occupational radiation dose limits, expressed in units of mrem. The indicated level of training is required so that visitors and workers are prepared to recognize hazards, use specialized equipment, and abide by specified controls.*

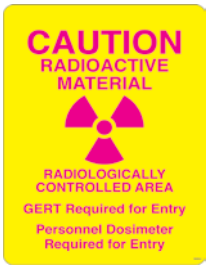
The postings and signs are organized by the required level of training that a person (or qualified escort) must complete before entering. The tables below list every radiological area type and the associated requirements in terms of signage, dosimetry, training, and controls.

Note *Certain types of areas are included for completeness but may not be encountered at SLAC.*

Table 1 Training Courses

Table	Minimum Required Training	Abbreviation	Notes
Table 2	General Employee Radiological Training (ESH Course 115)	GERT	A GERT-qualified worker or escort must be present, and special permission may be required as listed in Table 2.
Table 3	Radiological Worker I Training (ESH Course 116)	RWT I	
Table 4	Radiological Worker II Training (ESH Course 250)	RWT II	
Table 5	Varies		Signs that may be encountered in any type of area

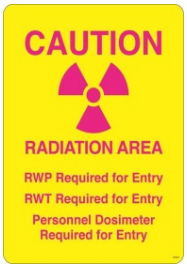
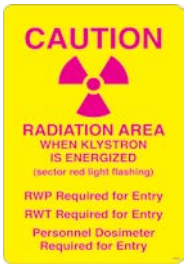
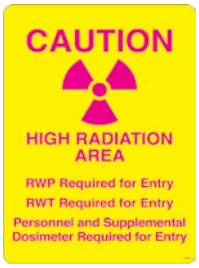
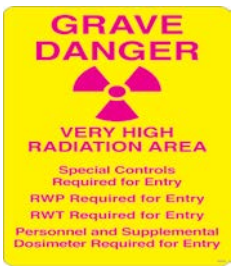
Table 2 Areas Requiring GERT Training

Representative Signage	Posted Area	Description	Dosimetry	Minimum Training[a]
	Controlled area	Area where access is managed by or for the DOE to protect individuals from exposure to radiation and/or radioactive material. A controlled area at SLAC is one where an individual is not expected to receive more than 100 mrem per year.	None	GERT [b]
	Radiologically controlled area (RCA)	A controlled area that requires dosimetry for entry due to the radiation levels in localized areas. The radiation level in certain localized areas within an RCA may vary, requiring limited occupancy. Individuals who enter only RCAs without entering radiological areas are not expected to receive a TED of more than 100 mrem in a year.	Personnel dosimeter	GERT[b]
	Controlled Area and Radioactive material area (Controlled Area + RMA)	A controlled area where items or containers of radioactive material exist and the total activity of radioactive material exceeds the applicable values provided in Appendix E of 10 CFR 835.	None	GERT[b]
	Radioactive material area (RMA)	Any area within a controlled area accessible to individuals in which items or containers of radioactive material exist and the total activity of radioactive material exceeds the applicable values provided in Appendix E of 10 CFR 835.	Personnel dosimeter required if the area is also posted as an RCA	GERT[b]
	Radiologically Controlled Area and Radioactive Material Area (RCA+ RMA)	A radiologically controlled area where items or containers of radioactive material exist and the total activity of radioactive material exceeds the applicable values provided in Appendix E of 10 CFR 835	Personnel dosimeter	GERT[b]

a Indicates the minimum training required for unescorted access. If training is not complete, the person seeking access must be accompanied by a GERT-qualified escort at all times.

b GERT-qualified personnel are permitted to enter these areas if it will not result in an annual radiation dose greater than 100 mrem.

Table 3 Areas Requiring an RWT I Qualification (no untrained individuals allowed in these areas)

Representative Signage	Posted Area	Description	Dosimetry	Permit, Control, or Approval	Minimum Training
	Radiation area (RA)	Area where radiation dose rates are greater than 5 mrem per hour @ 30 cm and less than or equal to 100 mrem per hour @ 30 cm	Personnel dosimeter	Sign routine area radiological work permit (RWP) upon entry and exit Job type or routine task RWP for any radiological work to be performed	RWT I
	Radiation area (RA) intermittent condition	A radiation area only when the klystron is energized (prompt radiation)	Personnel dosimeter	Sign routine area radiological work permit (RWP) upon entry and exit Job type or routine task RWP for any radiological work to be performed	RWT I
	High radiation area (HRA)	Area where radiation dose rates are greater than 100 mrem per hour at 30 cm and less than 500rad/hr at 100 cm	Personnel and supplemental dosimeter	Sign routine area radiological work permit (RWP) upon entry and exit. Job type RWP for any work to be performed	RWT I
	Very high radiation area	Area where radiation levels could result in an individual receiving an absorbed dose in excess of 500 rads in one hour at 100 cm from a radiation source	Personnel and supplemental dosimeter	Sign routine area radiological work permit (RWP) upon entry and exit. Job type RWP for any work to be performed Special controls	RWT I
	Personnel exclusion area	Area secured during beam operations due to the potential for abnormal ionizing radiation dose rates, that are not controlled by engineered personnel protection systems (PPS)	Personnel and supplemental dosimeter as directed by RP	For approval contact Accelerator Directorate Safety Officer (ADSO)	RWT I

Representative Signage	Posted Area	Description	Dosimetry	Permit, Control, or Approval	Minimum Training
	Radiological buffer area	Intermediate area established outside a contamination area to prevent the spread of radioactive contamination	Personnel dosimeter		RWT I

Table 4 Areas Requiring an RWT II Qualification (no untrained individuals allowed in these areas)

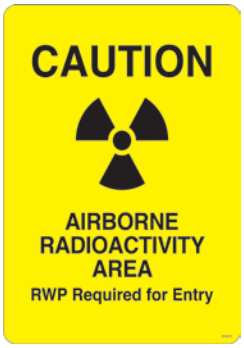
Representative Signage	Posted Area	Description	Dosimetry	Permit, Control, or Approval	Minimum Training
	Contamination area	Area accessible to individuals where the removable contamination levels exceed or are likely to exceed the removable surface contamination values specified in Appendix D of 10 CFR 835, but do not exceed 100 times those values	Personnel dosimeter	RWP upon entry,exit and to conduct work	RWT II
	High contamination area	Area accessible to individuals where the removable surface contamination levels exceed or are likely to exceed 100 times the removable surface contamination values specified in Appendix D of 10 CFR 835	Personnel dosimeter	RWP upon entry,exit and to conduct work	RWT II
	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 DAC values listed in Appendix A or C of 10 CFR 835; or 2) an individual present in the area without respiratory protection could receive an intake exceeding 12 DAC-hrs in a week	Personnel dosimeter	RWP upon entry, exit and to conduct work	RWT II
	Potential internal contamination	An LCW system where the low conductivity water or the resin bottle may be radioactive		Contact RP prior to opening the system. Depending on the activity/concentration additional radiological controls may be needed.	RWT II

Table 5 Additional Signage

Representative Signage	Posted Area	Description	Dosimetry	Permit, Control, or Approval	Minimum Training
	Radioactive material management area (RMMA)	Placed at the exits of accelerator housings. Indicates that materials that were in the RMMA while the beam was on could be radioactive. All potentially radioactive items must be surveyed by RPFO prior to removal.	Personnel dosimeter	All potentially radioactive items must be surveyed by RPFO prior to removal	GERT
	Hot spot	A localized area where the dose rate is > 100 mrem per hour on contact	Hot spots are posted within RCAs and radiological areas. Follow all dosimetry requirements during entry.	Hot spots are posted within RCAs and radiological areas. Follow all radiological controls during entry	GERT

3 Forms

The following are forms required by these requirements:

- Radiological Work Permit

4 Recordkeeping

- The Radiation Protection Department maintains radiological work permits following the requirements of 10 CFR 835.

5 References

SLAC Environment, Safety, and Health Manual (SLAC-I-720-0A29Z-001)

- Chapter 9, “Radiological Safety”
  - Radiological Safety: Personnel Dosimeter Requirements (SLAC-I-760-0A05S-001)
  - Radiological Safety: Safety Briefing (SLAC-I-760-0A05S-004)
- Chapter 55, “Site Access Control”

Other SLAC Documents

- Controlled Areas and Radiologically Controlled Areas (RCAs)

- Radiological Control Manual (SLAC-I-720-0A05Z-001)
- Radiological Work Permits Procedure (SLAC-I-760-0A05B-002, FO 005)
- Radiation Protection Department
- Radiation Protection (SharePoint)
- ESH Course 115, General Employee Radiological Training (ESH Course 115)
- ESH Course 116, Radiological Worker I Training (ESH Course 116)
- ESH Course 250, Radiological Worker II Training (ESH Course 250)

Other Documents

- Title 10, *Code of Federal Regulations*, "Energy", Chapter 3, "Department of Energy", Part 835, "Occupational Radiation Protection" (10 CFR 835)