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University of Arizona
Sealed Source Protection Reference Guide

Research Laboratory & Safety Services
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Research Laboratory & Safety Services (RLSS) is the primary coordinating unit responsible for the radiation safety program at the University of Arizona. The Sealed Source Protection Reference Guide is maintained at RLSS at 1717 E Speedway Blvd, Suite 1201, Tucson, AZ, and is readily available to anyone via the RLSS website (rlss.arizona.edu).

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I. Introduction

The Sealed Source Protection Reference Guide serves to describe the Sealed Sources program at The University of Arizona (UA) and to provide information regarding the safe use of radioactive sealed sources. The responsibilities of the UA Research Laboratory & Safety Services (RLSS), Approval Holders, Approval Safety Coordinators and Radiation Workers are also described.

The program is intended to:

- Provide a basic introduction to radioactive materials and the hazards associated with their use;
- Provide guidance to Approval Holders and workers authorized under their Approvals;
- Provide instruction on the acquisition, safe use, transport, security, transfer, and disposal of radioactive sealed sources;
- Maintain regulatory compliance with applicable state and federal regulations, and
- Inform Approval Holders of the resources available to them through the Research Laboratory & Safety Services (RLSS).

All personnel working with sealed sources must complete the Sealed Source Protection Course prior to use of these radioactive materials (for Electron Capture Device workers, see training requirements in Education and Training section). Course materials and schedules are available on the RLSS website. Approval Safety Coordinators must also complete an Approval Holders Orientation (provided by RLSS personnel).

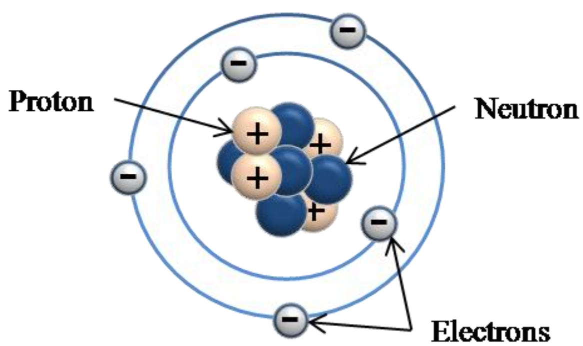
II. Physics

A. Atomic Structure

The basic unit of matter is the atom. The basic atomic model, as described by Ernest Rutherford and Niels Bohr in 1913, consists of a positively charged core surrounded by negatively-charged shells (see Figure 1). The central core, called the nucleus, is held together by nuclear forces.

Protons (p+) are positively charged particles and neutrons (n) are uncharged particles; both are located in the nucleus of the atom. Electrons (e-) are negatively charged particles that travel in structured orbits, or energy shells, around the nucleus.

Figure 1: Atomic Structure



An atom is electrically neutral if the total electron charge equals the total proton charge. The term ion is used to define atoms or groups of atoms that have either a positive or negative electrical charge. Isotopes are forms of an element that have the same number of protons, but different numbers of neutrons.

B. Ionizing Radiation

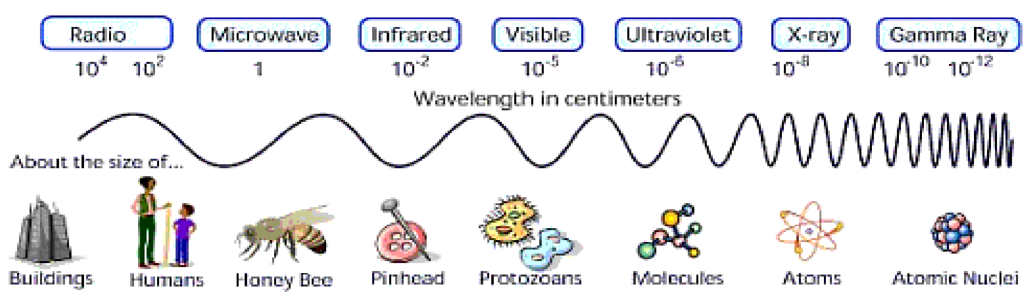
Radiation is the transfer of energy, in the form of particles or waves, through open space. Radiation with sufficient energy to create ions by physically removing electrons from neutral atoms is referred to as ionizing radiation. Ionizing radiation includes alpha particles, beta particles, electromagnetic waves, and neutrons. Radiation that lacks the energy to cause ionization is referred to as non-ionizing radiation. Examples of non-ionizing radiation include radio waves, lasers, microwaves, and visible light. The following are four main categories of ionizing radiation.

1. **Alpha Particles**
The alpha particle is similar to a helium nucleus, comprised of two protons and two neutrons (without surrounding electrons). Alpha particles are heavier and generally more energetic compared to other common types of radiation; however, typical alpha particles travel less than a few inches in air and are stopped by a sheet of paper or the outermost layer of dead cells which protect the skin.

2. **Beta Particles**
Beta particles are charged particles that come in positive and negative forms. When an unstable atom converts a surplus neutron in the nucleus to a proton, it emits an electron. When an unstable atom converts a surplus proton in the nucleus to a neutron, it emits a positive electron (or positron). Positrons, such as those emitted by ^{18}F, interact with electrons, destroying both and yielding energy (annihilation radiation). That interaction represents a conversion of mass to radiant electromagnetic energy, which can be harmful if not properly controlled. A beta particle has less mass and less charge than an alpha particle, which allows it to travel farther in air, deeper into skin, and through thin shielding and clothing.

3. **Electromagnetic Waves: Gamma Rays (Gammas) and X-Rays**
Gamma and x-rays differ only in their origin. Gammas originate from an unstable atomic nucleus and x-rays originate from accelerated electrons interacting with matter. Unlike alpha and beta particles, gammas and x-rays penetrate deeply into objects because they do not interact as readily with matter. This is due to their extremely small mass and lack of charge. Both are electromagnetic radiation and differ from radio waves and visible light in that they have a much shorter wavelength, higher frequency and higher energy (see Figure 2).

Figure 2: Comparison of Wavelengths



4. **Neutrons**
Neutrons are nuclear particles that have an exceptional ability to penetrate other materials. Of the types of ionizing radiation discussed here, neutrons are the only ones that can make objects radioactive. This process, called neutron activation, produces many of the radioactive sources that are used in medical, academic, and industrial applications (including oil exploration).
Because of their exceptional ability to penetrate other materials, neutrons can travel great distances in air and require very thick hydrogen-containing materials (such as paraffin or water) to absorb them. Neutron radiation primarily occurs inside a nuclear reactor, where many feet of water provide effective shielding.

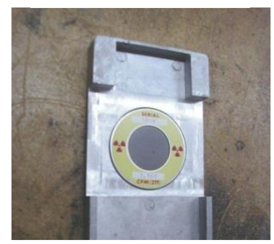
C. Principles of a Sealed Source

A radioactive sealed source is radioactive material (RAM) that has either been enclosed in metal or plastic or plated as a thin film onto metal or plastic, or it is a solid element that has become radioactive via exposure to a neutron flux (been activated). These sources come in a variety of shapes and sizes; they can be as small as the tip of a match or as large as a can of paint. Sealed sources may contain radioactive neutron, alpha or beta particle emitting materials.

Figure 5: Encapsulated Sources

1. **Encapsulated Radioactive Sealed Source**s
   Encapsulated radioactive sealed sources (see Figure 5) consist of a capsule that is sealed around radioactive compounds. “Special Form” source encapsulations are the most durable type and are specifically designed, tested and certified to withstand extreme heat and pressure. Non-special form source encapsulations may lose their integrity and release radioactive material if twisted or used incorrectly.

Figure 5: Plated Source



2. **Plated Radioactive Sealed Sources**
   Plated radioactive sealed sources (see Figure 5) have radioactive materials incorporated onto a metal or plastic substrate, usually by electrodeposition. The radioactivity is bonded into the substrate, creating a very thin active layer on the surface. These types of sources are often used for alpha and low energy beta emitting radioactive materials. The common uses for plated sources in the laboratory are for instrument calibration or sample ionization.

Figure 5: Activated Source

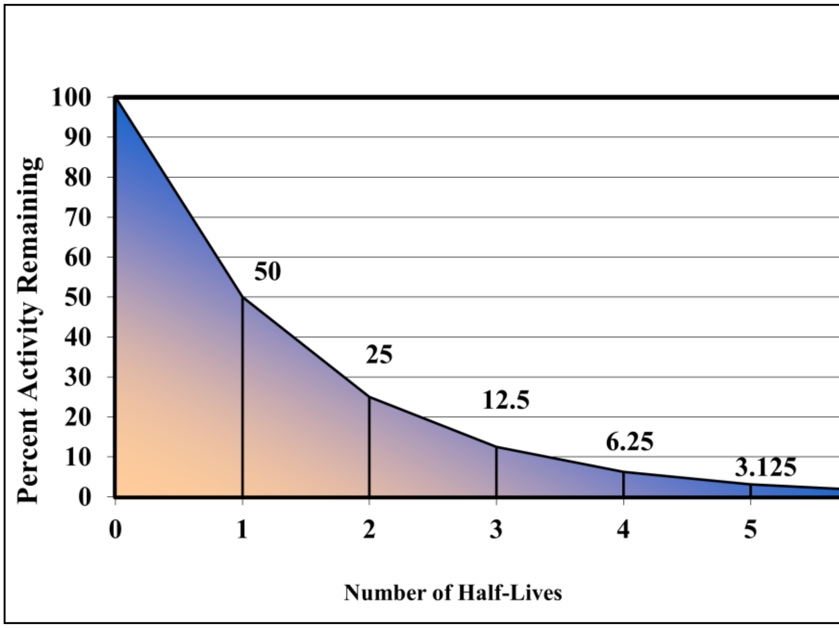
3. **Activated Radioactive Sealed Sources**
   Activated radioactive sealed sources (see Figure 5) consist of a rod, wire or foil that has been exposed to a neutron flux. The neutron flux irradiates the metal, creating a radioactive isotope of the original material. Sometimes activated sources have a plastic or epoxy coating applied so that the activated material does not separate from the main source body.

D. Radioactivity and Units of Radiation Measurement

The energy of ionizing radiation is usually measured in electron volts (eV). The electron volt is defined as the kinetic energy gained by an electron when it accelerates through an electric potential difference of one volt.

1. **Radioactive Decay**
   When an unstable atom (or radionuclide) emits energy to become more stable, the radionuclide is said to be "radioactive" and the process of change is called radioactive decay. Radioactive decay is measured in half-life, which is the time required for a radionuclide to lose 50% of its original radioactivity (or activity) by decay. Each radionuclide has a unique half-life ranging from microseconds to billions of years. Radionuclide vendors provide the assay date and assay activity to users so that the original amount of activity on a specified date is known and the remaining activity on any subsequent date can be determined based on the half-life of the specific radionuclide (see Figure 6).

Figure 6: Radioactive Decay/Half-Life Equation



Half-Life Equation

$$A = A_0/2^{t/T_{1/2}}$$

Where,

A =	activity (Ci, µCi, kBq, etc.) at time desired
A_0 =	original activity (in same activity unit as A)
$T_{1/2}$ =	half life of the radionuclide
t =	time after the original assay date (in same units as $T_{1/2}$).

2. **Radioactivity Units of Measure**
Radioactivity is the rate at which radioactive atoms decay. The quantity of a radioactive material is referred to in relation to its activity rather than its mass (e.g. 2 curies of ^{32}P, not 2 grams of ^{32}P).

The two most common units of activity are the curie and the becquerel. One curie is equal to 3.7 x 10^{10} (37 billion) radioactive disintegrations per second (dps). The becquerel is the System International (SI) unit of activity and one becquerel is equal to one dps. The curie is a very large amount of activity and the becquerel is a very small amount. To make discussion of common amounts of radioactivity more convenient, millicuries (mCi) and microcuries (µCi) or kilobecquerels (kBq) and megabecquerels (MBq) are used (see Table 1).

Table 1: Units of Radioactivity

Units	Disintegrations per second	System International (SI) units
1 curie (Ci)	3.7 x 10^{10} (dps)	37 gigabecquerel (GBq)
1 millicurie (mCi)	3.7 x 10^{7} (dps)	37 megabecquerel (MBq)
1 microcuries (µCi)	3.7 x 10^{4} (dps)	37 kilobecquerel (kBq)
1 nanocurie (nCi)	37 (dps)	37 becquerel (Bq)
1 picocurie (pCi)	.037 (dps)	37 millibecquerel (mBq)

3. **Exposure**
Radiation exposure refers to absorption of ionizing radiation or ingestion of a radionuclide. Electromagnetic waves (gammas and x-rays) can produce ionization of air. The unit of measure for ionization of air by electromagnetic waves is the Roentgen (R), where:

$1\ R = 2.58 \times 10^{-4}$ Coulombs/kg of air

4. **Absorbed Dose**
   When predicting biological effects, it is important to determine the energy deposited in human tissue rather than in air or other matter. The total ionizing radiation energy deposited per unit mass of material is the absorbed dose. The rad is the traditional unit of radiation absorbed dose.

   1 rad = 100 ergs/gram
   1 R = ~0.87 rad (in air); up to 0.96 rad (in tissue)

   The SI unit of radiation absorbed dose is the gray (Gy).

   1 gray = 1 joule/kg

   The relationship between the gray and the rad is:
   1 gray = 100 rad

5. **Dose Equivalent**
   The dose equivalent is used to measure the biological effects of ionizing radiation on the human body. It is a function of the absorbed dose and the type of radiation absorbed. The weighting factor used according to the type of radiation absorbed is called the quality factor (QF). The rem is the product of the absorbed dose in tissue (the biological dose), calculated by multiplying the rad by a quality factor (see Table 2). This quality factor is used to address the fact that, for the same absorbed dose, different types of ionizing radiation have differing biological effects in the scope of exposure to low levels of radiation.

Table 2: Quality Factors for Different Radiations

Radiation	Quality Factor
X, gamma, or beta radiation and high-speed electrons	1
Neutrons of unknown energy	10
High-energy protons	10
Alpha particles, multiple-charged particles, fission fragments, and heavy particles of unknown charge	20

   Because the quality factor for commonly used ionizing radiation (x-rays, gammas and betas) is one, for radiation safety purposes it may be assumed that:

   1 R = 1 rad = 1 rem

   The SI unit for dose equivalent is the sievert (Sv). As it was between the gray and the rad, the relationship between rem and sievert is:

   1 Sv = 100 rem

III. Biological Effects of Radiation

A. Origins of Biological Damage from Radiation Exposure

Biological effects can be categorized as direct or indirect based on how cellular damage occurs. An indirect effect occurs when free radicals produced by the ionization of water molecules in the body, interact with other molecules or intracellular structures. Most of the time, free radicals interact with molecules that cells can easily survive without.

Radiation that deposits energy directly into intracellular structures (including DNA) results in a direct effect. Changes to DNA can produce cell death, the inability to reproduce, the inability to function, or a change in the function of the cell (mutation), which could lead to cancer. DNA has the ability to repair itself, reverting to its original state or mutating, depending on the type and extent of the damage.

B. Exposure Risks

1. **Acute Radiation Dose Exposure**
Acute radiation dose is exposure to a large radiation dose over a short time (the period of exposure is considered short when the dose is delivered so quickly that damaged DNA cannot repair itself). At low levels of radiation exposure, the amount of cell death or mutation that results is usually irrelevant and does not impact the function of an entire organ. With an acute radiation dose, large numbers of cells may die and impact the ability of organs to function. Acute radiation dose results in a specific and prompt effect called acute radiation syndrome (or radiation sickness). The dose at which symptoms occur depends on the sensitivity of various cells to radiation. In general, the faster a cell divides and the less specialized it is (e.g. an immature blood cell is less specialized then a mature one), the more sensitive it is to radiation. Immature blood cells are the most radiation-sensitive cells. Effects and outcomes of the three acute radiation syndromes are shown in Table 3. Radiation levels when using radioactive sealed sources at The University of Arizona are too low to result in acute radiation syndrome.

Table 3: Acute Radiation Syndromes

	Hematopoietic Syndrome (affects blood cell formation)	**Gastrointestinal Syndrome**	**Central Nervous System Syndrome**
Dose (rad)	200-1000	> 1000	> 2000
Time to Death (if fatal)	3-8 weeks	3-10 days	< 3 days
Organ/System Damaged	Bone Marrow	Small Intestine	Brain
Signs & Symptoms	• Decreased number of stem cells in bone marrow • Increased amount of fat in bone marrow • Pancytopenia (reduction in red/white blood cells and platelets) • Anemia (reduction in red blood cells) • Hemorrhage (bleeding) • Infection	• Denudation of villi in small intestine • Neutropenia (reduction in white blood cells) • Infection • Bone marrow depression • Electrolyte imbalance • Watery diarrhea	• Vasculitis (inflammation of the blood vessels) • Edema (water-retention) • Meningitis (inflammation of the brain/spinal cord membranes)
Recovery Time	Dose dependent, 3 weeks to 6 months; some individuals do not survive.	None; fatal	None; fatal

2. Chronic Low Level Radiation Exposure

Chronic low level radiation exposure is exposure to low levels of radiation over long periods of time. The dose effects from chronic low level radiation exposure are delayed effects and include an increased risk of cancer and hereditary effects.

Some other effects, such as skin reddening, cataract formation and temporary sterility in males, occur after receiving a threshold dose (the minimum dose that will produce a detectable degree of any given effect); however, none of these effects have been seen at occupational levels. It is important to realize that the potential risks associated with occupational radiation exposure are similar to, and sometimes less than, risks encountered in daily life (accidental death and the impact of lifestyle choices).

3. Sealed Source Radiation Hazards

Alpha and beta particle exposure from a sealed source is unlikely to cause harm unless the source is very strong or the encapsulation is ruptured. However, injuries have occurred with these types of sources when placed in shirt pockets or through incorrect use. Neutrons can cause ionization of matter. Since radioactive neutrons lack charge, they can escape the capsule and pose an exposure hazard.

Alpha, beta and neutron particles may also generate gammas and x-rays (electromagnetic radiations), which can penetrate deeply into matter. Therefore, a non-ruptured sealed source still presents a photon radiation hazard. ^{241}Americium, a common radioactive isotope encapsulated in sealed sources, decays to eleven different radioactive element isotopes via emission of gamma rays, alpha and beta particles until becoming stable lead (see Figure 7).

Figure 7: Americium Decay Products

IV. Radiation Exposure and Protections

Individuals are exposed to radiation in the normal course of everyday life. Sources of radiation exposure can be classified as natural, man-made, and occupational.

A. Natural Radiation

Natural radiation is the background radiation that is always present in the environment. The main sources of natural radiation are: cosmic radiation which comes from the sun and stars, terrestrial radiation which comes from the earth, and internal radiation which exists within all living things.

B. Man-Made Radiation

Man-made ionizing radiation includes medical exposures (such as diagnostic x-rays, fluoroscopy, and other types of imaging, and nuclear medicine diagnostic and treatment procedures), building materials, combustible fuels (including gas and coal), x-ray security systems, smoke detectors, luminous watches, and tobacco.

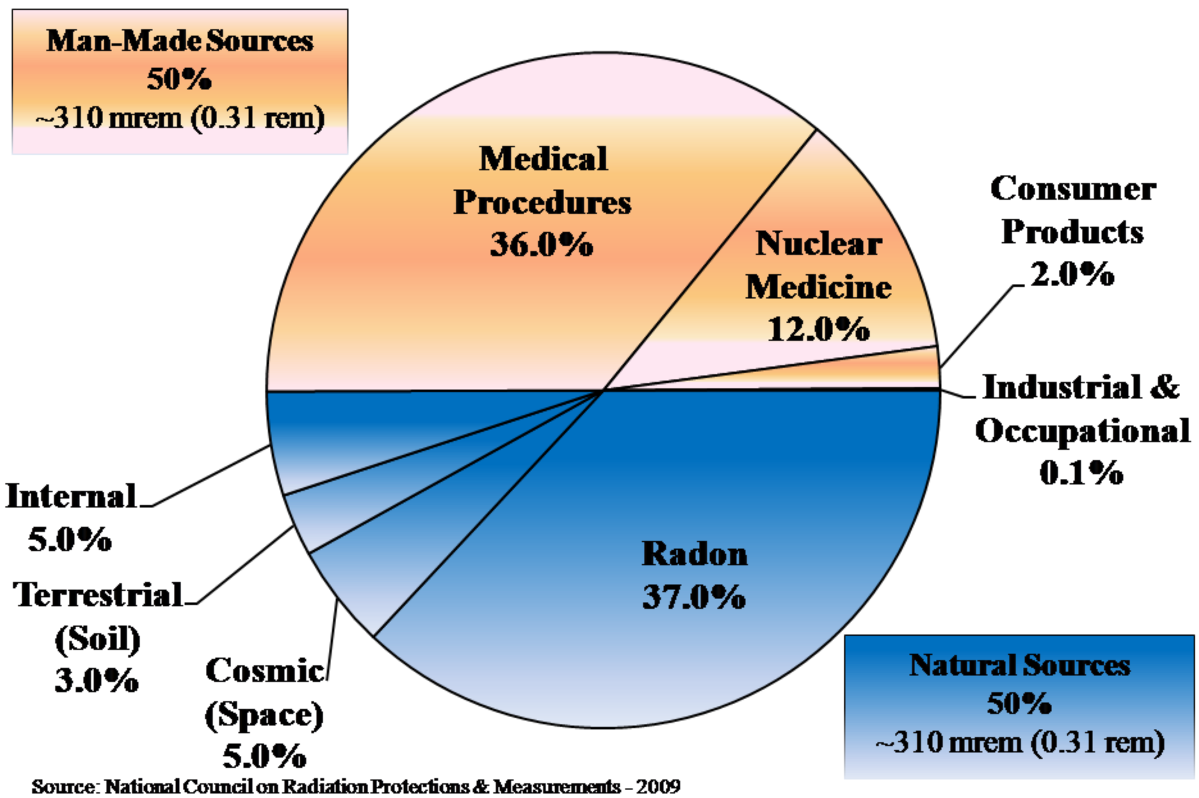
C. Occupational Dose

Occupational dose is the total dose received by radiation workers in the course of their work. It is important to note that industrial and occupational exposure accounts for only about 0.1% (0.62 mrem) of the average total radiation exposure experienced by an individual annually.

The average radiation dose received by individuals in the U.S. is about 620 mrem/yr (310 mrem/yr from natural sources and about 310 mrem/yr from human-generated sources, including occupational dose). Previously, the total annual dose was estimated at 360 mrem and the change in the current estimate is mainly the result of increased exposure from medical diagnostic and treatment procedures.

Figure 8 illustrates sources of radiation exposure experienced in the U.S and the percentage each represents of an individual's total annual dose. These are only average doses and an individual's dose can vary depending on geographic location, the amount of medical exposures experienced, and various

Figure 8: Sources of Radiation Exposure in the United States



lifestyle choices. For example, smoking (30 cigarettes/day) will expose the lungs to the equivalent of 1.5 rem to the whole body.

D. Occupational Dose Limits

The State of Arizona is a regulatory Agreement State and as such, the U.S. Nuclear Regulatory Commission (NRC) has given the Bureau of Radiation Control (BRC) jurisdiction in regulating work with radioactive materials within the State of Arizona. Limits on occupational doses are based on data regarding known biological effects of ionizing radiation. The International Commission on Radiological Protection and the National Council on Radiation Protection and Measurements publish guidance for setting radiation protection standards. Federal Regulations set regulatory requirements related to radiation exposure and BRC sets regulatory requirements related to radiation protection in the State of Arizona. These limits are set to ensure that the probability of detrimental biological effects from occupational exposure to ionizing radiation is equivalent to what has been observed in other safe industries.

A radiation worker is an individual who has received both general and specific radiation safety training and is authorized to use radioactive materials and/or radiation-producing machines. A non-radiation worker is an individual who is not trained or authorized in the use of radioactive materials and/or radiation-producing machines. The radiation dose received by radiation workers in the course of their work is defined as occupational dose.

Occupational radiation dose limits set by the State of Arizona for different parts of the body and for minors range from 0.5 rem to 50 rem per year (see Table 4). Occupational radiation dose limits are set well below the exposures that cause acute radiation syndrome.

Table 4: Occupational Radiation Dose Limits	
Whole Body	5 rem (5000 mrem)
Lens of Eye	15 rem (15,000 mrem)
Skin of Any Extremity	50 rem (50,000 mrem)
Skin of Whole Body	50 rem (50,000 mrem)
Non-Radiation Worker	0.1 rem (100 mrem)
Minors (personnel under 18 years of age)	10% of adult dose limits
Fetus (total for entire gestation period)	0.5 rem (500 mrem)

1. Pregnant Women: Dose Limits

If a radiation worker is planning to become pregnant or is pregnant, it is recommended that she request information from the Research Laboratory & Safety Services (RLSS) concerning radiation exposure to a fetus. A pregnant woman may choose to declare her pregnancy to RLSS. A declared pregnant woman is a woman who has voluntarily informed RLSS in writing of her pregnancy and the estimated date of conception. It is a regulatory requirement that a declared pregnant woman be provided information about the potential risks of radiation exposure to a fetus.

As part of counseling, RLSS will conduct a review of the work situation and previous exposure history of a declared pregnant woman (or a woman planning to become pregnant) and will provide her with information about her potential for fetal exposure. Based on the work situation review, an additional dosimeter to be worn at the waist and monthly urine bioassay samples may be required for a declared pregnant woman. The dose limit to an embryo/fetus is 500 mrem over the entire pregnancy. It is also required that every effort be made to avoid substantial variation above a uniform monthly dose rate of 50 mrem/month.

It is a woman's right to “undeclare" her pregnancy at any time. This decision terminates RLSS’s involvement with her pregnancy even though she may still be pregnant and had previously declared the pregnancy.

2. Minors: Dose Limits

Occupational dose limits for minors are 10% of the adult limits. The University of Arizona only allows a minor to become a radiation worker as part of an educational experience, not solely for employment.

E. Protection Against External Radiation Exposure

The concept of ALARA (<u>A</u>s <u>L</u>ow <u>A</u>s <u>R</u>easonably <u>A</u>chievable) is mandated by both Federal and State of Arizona regulations. The ALARA principle is to maintain radiation dose as far below the occupational limits as is reasonably achievable. This regulatory requirement is based on the following:

- No practice shall be adopted unless its introduction produces a net positive benefit;

- All exposures shall be kept as low as reasonably achievable (ALARA), economic and social factors being taken into account; and
- The dose equivalent to individuals shall not exceed the limits recommended for the appropriate circumstances by the regulatory authority.

The ALARA policy is based on the linear, non-threshold (LNT) dose-effect hypothesis. The LNT hypothesis assumes that the known effects of high doses of ionizing radiation may be used to predict the possible effects of long-term, low-dose radiation exposure. According to the LNT hypothesis, there is a relationship between radiation dose and the occurrence of cancer such that any increase in dose, results in an incremental increase in risk. Even though there is disagreement as to whether the LNT hypothesis overestimates or underestimates this risk, Federal and BRC regulations require that The University of Arizona demonstrate that the ALARA principles are being applied.

1. **Keeping Exposures <u>A</u>s <u>L</u>ow <u>A</u>s <u>R</u>easonably <u>A</u>chievable (ALARA)**
   When working with radioactivity, it is essential to keep the radiation exposure to a minimum. The four ALARA principles of time, distance, shielding and minimizing source strength during occupational exposure to radiation are intended to minimize exposure.

   a. **Time**
   The dose of radiation a worker receives is directly proportional to the amount of time spent in a radiation field. Reducing the amount of time spent in a radiation field by one-half will reduce the radiation dose received by one-half. Workers should always spend as little time as possible around radioactive materials. The following actions may be used to minimize time of exposure:

   - plan work carefully
     - read and understand the experiment protocol prior to performing tasks with radiation
     - read and understand equipment manuals, if applicable
   - rehearse the work procedure with non-radioactive material to identify possible complications
   - transport the sealed source correctly
   - have all necessary equipment in one place
   - ensure all equipment is in good working condition before work begins
   - repeat experiments only when absolutely necessary

   b. **Distance: The Inverse Square Law**
   Radiation exposure decreases rapidly as the distance between the worker and the radiation source increases. The decrease in exposure from a point source can be calculated by using the inverse square law. This law states that the amount of radiation at a given distance from a point source varies inversely with the square of the distance. Therefore, if the distance to the source is doubled, the exposure decreases by a factor of 4 and if the distance is tripled, the exposure decreases by a factor of 9. The change in percentage of intensity resulting from an increase or decrease in distance from a radiation source is shown in Table 5.

Inverse Square Law

$$I_2 = I_1 (D_1/D_2)^2$$

I_1 = original intensity
D_1 = original distance
I_2 = new intensity
D_2 = new distance

Table 5: Effect of Inverse Square Law

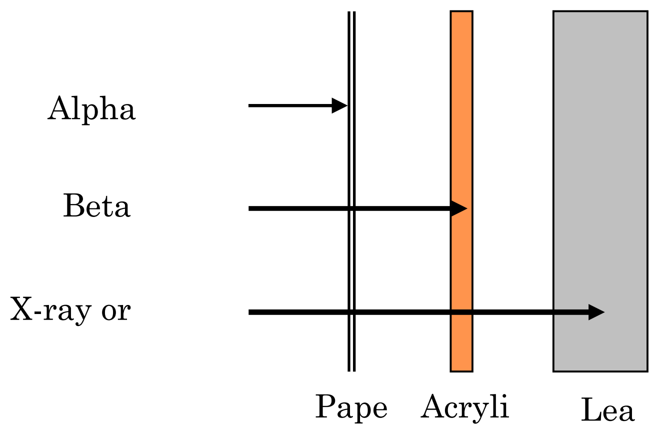
Distance	*Intensity*
1 foot	***100%***
2 feet	***25%***
4 feet	***6.25%***
10 feet	***1%***
6 inches	***400%***

Although the inverse square law does not accurately describe scattered radiation, distance will still dramatically reduce the intensity from this source of radiation. Maintaining a safe distance, therefore, represents one of the simplest and most effective methods for reducing radiation exposure to workers and non-workers.

c. Shielding

Shielding is the use of a material or obstruction to absorb radiation and thus protect personnel or materials from the effects of ionizing radiation. The thickness of the required shielding material is dependent on the energy level of the emitted radiation (higher energy requires thicker shielding). The appropriate type and thickness of shielding material must be used in order to reduce the dose rate of different types of ionizing radiation (see Figure 9). Efficacy of shielding is determined by contamination surveys.

Figure 9: Shielding Materials



Alpha particles can be completely stopped by almost anything (such as a sheet of paper). Beta particles can be shielded by a sheet of acrylic. Use of lead for shielding high-energy beta emitters is discouraged because the resulting bremsstrahlung x-rays can produce significant additional exposures.

Gamma and x-ray radiation is diminished in intensity by any given absorber but not completely stopped. Lead is an appropriate shield for gamma and x-ray radiation, and for photons. Concrete can also be used as a shield for gamma and x-rays; however, RLSS should be contacted prior to shielding gammas with anything other than lead. Stainless steel or lead- or tin-loaded acrylic viewing windows can also be effective barriers.

Neutrons differ from the ionizing radiation of photons or charged particles in that they are repeatedly bounced and absorbed by light nuclei. Effective shielding material therefore must contain high concentrations of hydrogen, such as is found in water, acrylic, sheets of paraffin, or concrete.

Storage areas for high activity sources may require shielding. All potentially contaminated containers and instruments, including stock solutions and working solutions, should be shielded when appropriate for the particular type of radionuclide.

d. Minimizing Source Strength

The less radioactivity used (given everything else remains the same), the less potential dose that will be received. Advances in modern scientific technique and equipment allow researchers to attain their desired results using smaller amounts of radioactivity than before. In order to minimize exposure and the risk of contamination, unnecessary radioactive material in the laboratory should be removed at the earliest opportunity. Additionally, accumulated waste should be transferred to RLSS on a regular basis for proper disposal.

F. Measurement of External Exposure to Radiation

Various types of radiation dosimeters (including badge, extremity or ring, and supplemental/secondary dosimeters) are used to measure an individual's external exposure to radiation; badge dosimeters cannot measure the absorbed dose from alpha or low energy beta particles because of their low energy. The need for personal dosimeters is dependent on the frequency, quantity and specific nuclides used. Individuals who are likely to receive at least 10% of the occupational dose limit will be assigned a dosimeter. Badge, extremity and supplemental/secondary dosimeters are issued free of charge by RLSS. Whether or not a dosimeter is assigned, or whether bioassays are required (for monitoring internal exposure), is determined by a health physicist.

Figure 10: Badge Dosimeter

(showing front of unit and front/back of holder)

1. **Badge Dosimeters**

   Badge dosimeters (see Figure 10) are the primary type of whole body personal dosimeter provided by RLSS. These dosimeters are typically collected by RLSS on a bimonthly basis and sent to their manufacturers to be analyzed. The dosimeter should not be exposed to temperatures above 150° F, as this may affect the exposure measurements that are obtained.

Figure 11: Extremity (Ring) Dosimeter

2. **Extremity (Ring) Dosimeters**

   Extremity (ring) dosimeters are used to measure exposure to the hands when whole body exposure and hand exposure could differ significantly (see Figure 11). The "chip side" of the finger ring must be aimed towards the palm and must be worn on the designated hand.

3. **Supplemental/Secondary Dosimeters**

Pocket ion chambers and electronic personal dosimeters are two types of supplemental/secondary dosimeters. An ion chamber is an instrument designed to measure the quantity of ionizing radiation in terms of the charge of electricity associated with ions produced within a defined volume. A pocket ion chamber is an ion chamber the size of a fountain pen and is used to detect gamma or neutron ionizing radiation exposure. It provides the user with an immediate measurement of exposure.

Figure 12: Electronic Personal Dosimeter

An electronic personal dosimeter is an electronic unit capable of measuring gamma, beta and x-radiation exposure. It provides the user with immediate feedback as to the current rate of exposure as well as exposure over a specified period of time (see Figure 12).

Pocket ion chambers and electronic personal dosimeters are only issued on an as needed basis and proper use requires additional training and documentation. The number of available units is limited due to high cost.

G. Protection Against Internal Exposure to Radiation

Radioactive material can be damaging to the body if absorbed, inhaled, or ingested (swallowed). Although it is uncommon for a sealed source to leak, there is a low risk of internal exposure due to improper use or leakage.

- Absorption
  Skin should be protected against the potential absorption of radioactive material from a leaking source. Laboratory coats, gloves, eye protection and other types of coverings should be used to reduce the risk of absorption. It is also recommended that open wounds be covered.
- Inhalation
  There is a potential for inhalation of sealed radioactive material when the source is leaking or when a device containing a sealed source needs to be exhausted; the use of fume hoods may be required.
- Ingestion
  Laboratory rules prohibiting eating (including chewing gum), drinking, smoking, or applying cosmetics in approved radiation work areas are intended to reduce the risk of internal exposure by ingestion.

H. Measurement of Internal Exposure to Radiation

The amount of radioactive material incorporated into the body may be measured through a bioassay. Bioassays are not commonly performed for sealed source users, but may be required if exposed to a leaking source. A bioassay is a test to determine the kind, quantity, or concentration (and sometimes the location) of radioactive material in the human body, either by direct measurement or by evaluation of bodily fluids or tissue. Bioassay services currently available from RLSS include urine sampling and thyroid gland scanning.

1. **Urine Bioassay**

Urine bioassays are used by RLSS to determine the presence of radioactive material in the body. Urine bioassays can be used to measure the internal levels of most radioactive isotopes.

2. **Thyroid Bioassay**
Thyroid bioassays are used by RLSS to determine the presence of radioactive iodine in the thyroid gland. This bioassay is available upon request, takes approximately five minutes, and involves a non-invasive scanning procedure.

V. Laboratory Practices

All individuals working with radioactive sealed sources should be aware of the location of the necessary documents, records, and guidelines that pertain to use approvals. A visiting RLSS or state inspector may ask to view this information at any time.

A. Education and Training

Individuals may not work with radioactive sealed sources until they have received appropriate training. In conjunction with RLSS, this is a two-part process that includes source specific training and completion of the Sealed Source Protection Course (if applicable, see training requirements for use of ECDs below). Course schedules and registration information are located on the RLSS website. Source transport is taught in this course and users under approvals that include routine transport of sources must receive Transport Refresher training every three years. RLSS notifies Approval Holders and Approval Safety Coordinators via email when source users are due for refresher training. RLSS training must be completed before an individual begins working in a new laboratory or under an additional approval.

Training requirements for approvals exclusively for the use of Electron Capture Devices (ECDs) differ from other sealed source approvals. Approval Holders who have not designated an Approval Safety Coordinator must complete the Sealed Source Protection Course in addition to the Approval Holder's Orientation. If an Approval Safety Coordinator has been designated, completion of both the Sealed Source Protection Course and the Approval Holder's Orientation is required. ECD users must receive their training directly from either the Approval Holder or Approval Safety Coordinator, whoever has completed the Sealed Source Protection Course. Training must be documented on the Training Record-Electron Capture Detectors and kept on file for each approval.

B. Approval to Use Radioactive Sealed Sources

An 'Approval to Use Radioactive Sealed Sources' is granted to an individual after the Radiation Safety Committee reviews and approves an Application for New Sealed Source Approval. The radionuclides that will be used, their activity, the protocols, the rooms where the material will be used and stored, and off-site locations must be specified in the application.

To change approved protocols, add radionuclides, raise activity limits, change or add storage locations, or modify the encapsulation or device in which the source is contained, an Approval Holder is required to submit an Application for an Amendment to Sealed Source Approval for review and approval by the Radiation Safety Committee.

In addition to RLSS approval, proposed experiments may require additional regulatory approvals from the Institutional Animal Care Use Committee (IACUC), the Institutional Review Board (IRB) at the Human Subjects Protection Program office, or the Institutional Biosafety Committee (IBC).

C. Posting and Labeling of Areas Containing Radioactive Materials

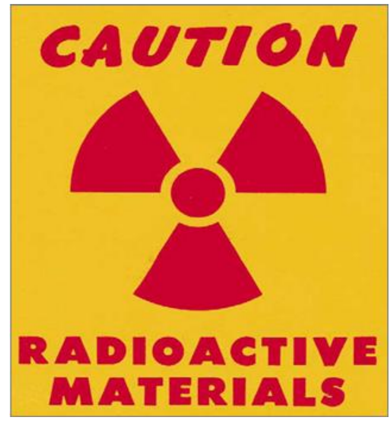
Once a room is approved for radioactive sealed source use or storage, RLSS will post the required signs. No work involving radioactive sealed sources may be initiated until the signs have been posted.

1. **"Caution Radioactive Materials"** (see Figure 13)

2. **Notice to Employees (Form ARRA-6)**
   This document summarizes the rights and responsibilities of State radiation workers, and radiation exposure protections required by the BRC.

3. **Radiation Emergency Procedures Form**
   This form provides brief information for emergency situations, phone numbers for Approval Holders and Approval Safety Coordinators approved to use the posted area, and RLSS and UAPD phone numbers.

Figure 13: Sample Sign



4. **Adjacent RAM Work Area Notice**
   This notice is posted in areas that have been designated for use of RAM in an open bay laboratory. The Approval Holder is responsible for training non-radiation workers in these areas.

5. **Labeling of Radioactive Materials, Containers and Ancillary Equipment**
   In addition to the signage provided by RLSS, it is the responsibility of all radiation workers under the approval to provide appropriate labeling for radioactive materials, tools, equipment, and areas within laboratories where radioactive materials are located or used.

   - “Caution Radioactive Material” (CRM) signs must be posted on each radioactive sealed source storage location and cabinets, etc., within a laboratory.
   - Radioactive sealed source containers and devices housing radioactive sources must also be clearly labeled.
   - Bench tops where radioactive sealed sources are used must be delineated with CRM warning tape.

D. Dosimetry Use

The measurements obtained by a dosimeter are a legal record of a person’s individual radiation exposure and RLSS maintains these records for personnel using RLSS-issued dosimeters. Personal dosimeters issued by RLSS may not be shared or exposed to any source of radiation outside of the specific work assignment for which they were issued. If a dosimeter is issued, it must be worn whenever working with radioactivity in the work assignment.

A lost or damaged badge should be reported immediately to RLSS. A worker may not perform any work with radioactive materials until a new badge has been obtained. RLSS will immediately replace any damaged or lost dosimeter; however, a replacement fee may be charged to the department for lost dosimeters; the department may pass the charge on to the responsible individual. Current information pertaining to the use of dosimeters, monitoring and documentation of exposure is located on RLSS web site.

E. Receipt, Inventory, Storage and Security of Radioactive Sealed Sources

All incoming and outgoing radioactive sealed sources must be routed through RLSS.

1. **Receipt**
   All incoming packages of radioactive sealed sources are surveyed for leakage by RLSS, assigned an RMR# (radioactive material receipt number) and source ID#, and entered into the inventory database. The shipment is then delivered to the requesting laboratory along with the packing slip.

2. **Inventory**
   Once the radioactive sealed source is delivered, the Approval Holder is required to maintain records of its use on the Sealed Source Use Log Form or an equivalent log sheet. The date used, person using the source, and analysis type must be logged for each use. For ECD approvals, the ECD Use Log must be completed to document date of each use and person using the ECD.

   Transfer of any radioactive sealed source, whether internally to another Approval Holder, or externally to another institution must be done via RLSS. Prior to any internal transfers, RLSS must be contacted to assure that the radionuclide and the transfer amount are permitted under the recipient's current Approval. At the same time, the radionuclide, amount and assay date of the source that is to be transferred must be reported to RLSS for inventory purposes. RLSS will provide a record of the transaction to both Approval Holders.

   For transfer to an external site, RLSS must be notified at least 24 hours before scheduling the transfer so that the appropriate paperwork may be completed in advance. A copy of the NRC/State license must be obtained from the intended recipient and may be faxed directly from the recipient company or institution to RLSS. Transfer of radioactive sealed sources to other countries may sometimes take months to arrange.

   All Department Of Transportation required hazardous materials (HAZMAT) shipping labels, forms and paperwork are available from RLSS. Transport supplies such as braces, chains, locks and/or cases must be purchased by the Approval Holder. Contact RLSS in advance before attempting to order, transfer, routinely ship, routinely transport or receive a new source.

3. **Permanent Storage Sites**
   Permanent storage (as identified in the approval) must meet the following conditions:
   a. The source and its container must be locked in a closet or room that is not readily accessible to the public.
   b. The source may not expose personnel to any dose rate that is three times the natural background rate from any location of high occupancy (e.g. desks, work stations or a residence).
   c. The storage location must be under the exclusive control of the Approval Holder or users listed under that Approval.
   d. The storage area must be appropriately labeled (contact RLSS for replacement postings if labels are missing).

4. **Temporary Storage Sites**
   Sources must remain under direct supervision at all times when in a temporary storage location. Temporary locations could include long term analysis sites (in a counter or when calibrating a device), overnight in a motel room, or while in transit.

1.

5. **Off-Site Storage**

Approval Holders must notify RLSS at least 30 days in advance when planning to store sources outside of Arizona or on private property.

a. Outside of Arizona

Source use or storage is restricted outside of the State of Arizona. Reciprocity agreements with other regulatory agencies may be required to use or store sources outside the State of Arizona (a fee may be required). The possession and use of the source while under a reciprocity agreement must adhere to the conditions set by the BRC and RLSS as well as by the regulations of the host state or nation.

b. On Private Property

Source storage on private property is restricted. If cooperative work with private entities requires the storage of sealed sources on private property, a written agreement that coordinates the use, security and storage of the sources must be signed between the land owner and The University of Arizona via RLSS prior to source storage.

6. **Transportation of Radioactive Sealed Sources**

Shipping by common carrier (Federal Express, Yellow Freight, etc.) must be coordinated through and shipped by RLSS. All sealed source vehicle transport must be in accordance with DOT rules and regulations. Approval Holders are responsible for ensuring that all source users are trained and equipped to transport radioactive materials.

a. Sealed sources require two levels of security while in transport. The primary, most desirable level of security is direct observation. Locks, chains or cables are required to fulfill the secondary level of security. Lock shanks must either be shrouded or the lock itself must be a shankless design.

b. Sealed source containers must be properly labeled for transport. Prior to each transport, workers must inspect the container labels and confirm that they are all legible and present. Labels must not overlap or have tears or excessive fading. Labels that are not vinyl should be covered with transparent tape to protect them from the weather. Contact RLSS for replacement labels or forms.

c. Before transporting the source, workers must ensure that the container or box has no cracks, missing latches, missing internal packaging or broken internal/external pieces. Contact RLSS before attempting to ship a sealed source in a damaged case.

d. One copy of the Bill of Lading/Emergency Response laminated form (if applicable) must be attached to the source container and another copy must be available within reach of the driver and visible from outside the vehicle during transit.

e. The source transport container must be braced so that it cannot move more than one inch while in transport. Obtaining necessary equipment (such as transport braces, which are available locally) is the responsibility of the Approval Holder; contact RLSS for recommendations.

f. The source may not be transported in the passenger compartment of cars or the cab of trucks. The source must be secured as far away from passengers as possible.

g. The source transport container must be locked.

h. Transport guidelines by vehicle type:
   1) Cars with a trunk
      - The source container must be locked to the trunk suspension or vehicle body with a cable or chain.
   2) Cars without a trunk
      - The source container must be locked to the hatchback suspension or vehicle body with a cable or chain.
   3) Pickup trucks with locked camper shell, bed cover or Nux type case.
      - The source container and camper shell/bed/Nux cover must be locked shut. The shell/bed/Nux cover must be permanently affixed to the truck bed.
      - The source container must be locked to the truck bed frame with a cable or chain.
   4) Open bed pickup trucks.
      - The source container must be locked to the truck bed frame with a cable or chain.
      - Source transport in an open bed pickup truck requires that the source remain under constant surveillance.
      - Transport in an open bed pickup truck is the least desirable method of transportation.

7. **Security**

It is the responsibility of the Approval Holder to ensure that radioactive sealed sources are secure from unauthorized use or theft. All individuals who are authorized to enter a radiation use area have the responsibility to adhere to source security measures. These individuals may include radiation workers, non-radiation workers or others who are authorized to enter the radiation use laboratory (including University support personnel).

Unless determined otherwise by RLSS or the Radiation Safety Committee, radioactive sealed sources must be secured by:

- keeping them under constant “line of sight” surveillance by a radiation worker (authorized under that approval), or
- locking the approved laboratory, or
- by placing them in approved locked, permanent storage (such as a cabinet with a lock) within an approved use or storage area/laboratory, or
- by locking them in approved transportation modes according to Department of Transportation (DOT) rules and regulations (e.g., in a locked car trunk, attached to suspension or body of vehicle without a trunk or in open truck bed, inside locked camper shell or bed cover of truck)

Under the following conditions, sealed sources must be secured in a locked storage container (such as a cabinet with a lock) whenever not under constant “line of site” surveillance by a radiation worker.

- Approvals for a total of 50 mCi or more of sources, or
- approvals for use of sources in open bay laboratories.

Sealed sources classified as exempt by RLSS may have reduced security and control requirements; however, written instructions for exempt source use will be provided.

The physical securing of radioactive sealed sources must be combined with preventing unauthorized entry into the laboratory. Visitors must be questioned as to their purpose for being in a radiation laboratory. Visitors and outside contractors shall be under constant supervision by a radiation worker when in radiation use areas unless all sources have been secured. UA Facilities Management personnel and custodial staff have been trained to work safely around radioactive sources, so supervision is not required.

Any known or suspected loss or theft of sources must be reported immediately to RLSS.

F. Contamination Surveys

Approval Holders are responsible for ensuring that required surveys are performed and documented as part of a continuous radiation-monitoring program for their laboratories and facilities. However, RLSS will specify when surveys, if applicable, are required on a case by case basis. Surveys may be wipe surveys or instrument surveys, as is appropriate for the particular source type. If counts exceeding RLSS specifications are found during any survey, the area must be decontaminated, and initial and follow-up survey results recorded. The following types of surveys may be required:

1. **After Use Surveys**
   Surveys of work areas (hoods, sinks, bench tops, floors, etc.) after each use and at any time there is reason to suspect contamination, a spill, or an incident involving the radionuclide in use may be required. A permanent record of these use area surveys must be kept for three years even if no contamination is found.

2. **Monthly Surveys**
   A complete survey of all approved laboratories may be required on a monthly basis. These surveys are for all approved radionuclides and must include areas such as desks, cabinet handles, and phones, etc. For open bay laboratories, the scope of monthly contamination surveys must include both radiation use and non-radiation use areas of the laboratory (non-radiation use areas include adjacent RAM work area floors, equipment and bench tops, open bay entrance thresholds and doorknobs, high traffic floor areas, and equipment directly adjacent to source use areas).

3. **Follow-up Surveys**
   If decontamination of an area is required for any reason, a new survey of the contamination area must be performed to document the return to background levels.

G. Instruments

Geiger-Mueller (GM) type detectors, Low-Energy Gamma Scintillation Counters, Liquid Scintillation Counters, Dose Rate Meters (ionization chambers), and Alpha Detectors may be used in conjunction with experimental protocols or to perform surveys. The type of detector to be used is dependent on the type of sources being used or that are approved for use (see Table 6).

Table 6: Required Survey Instruments for Approved Radionuclides				
Emitter	**Detector**			
	GM (Pancake or End Window Probe)	**Low Energy Gamma Scintillator**	**Liquid Scintillation Counter**	**Alpha Detector**
Low Energy Betas (e.g., ^{14}C, ^{35}S, ^{3}H)			X	
High Energy Betas (e.g., ^{32}P)	X		X	
Low Energy Gammas (e.g., ^{51}Cr, ^{125}I)		X	X	
Alphas (e.g., ^{241}Am)				X

1. **GM Detectors**
   GM detectors are used with end-window or pancake probes (see Figure 14 and Figure 15). Some GM detectors include a scale in milliroentgen per hour (mR/hr), but survey results must be expressed in counts per minute (cpm).

2. **Low Energy Gamma (LEG) Scintillation Counters**
   LEG scintillation counters are more sensitive than and may have a higher background rate than GM detectors and are therefore useful in measuring low energy photons. These detectors are very fragile and must be handled carefully.

3. **Liquid Scintillation Counters**
   Liquid Scintillation Counters are used to measure activity found in wipe survey samples placed in liquid scintillation cocktail (LSC). This reading is compared to a background reading (determined by placing an unused wipe in LSC) in order to identify any areas requiring decontamination.

4. **Dose Rate Meters (Ionization Chambers)**
   Dose Rate Meters are used for measurement of absorbed dose rate (see Figure 16). They are used primarily by RLSS to determine dose.

5. **Alpha Detectors**
   Alpha Detectors are available in a wide variety of configurations which use different methods for detecting alpha particles; some may also detect beta or gamma radiations.

Figure 14: Sample GM Detector

Figure 16: Detector Probes

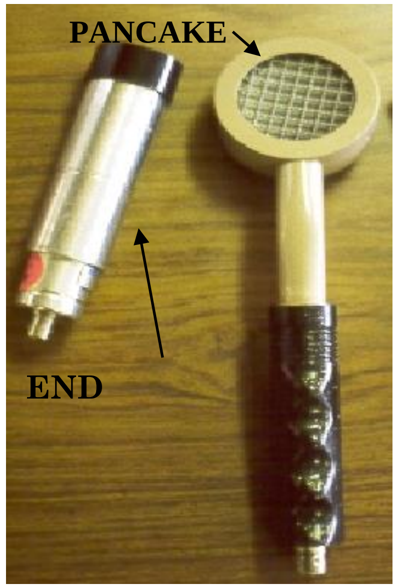


Figure 15: Dose Rate Meter

H. Disposal of Radioactive Sealed Sources

Disposal or disposition of all radioactive sealed sources must be coordinated with and conducted by RLSS.

VI. Emergency Procedures

Radiation workers should familiarize themselves with the Emergency Procedures document posted in each laboratory approved for work with RAM. The Approval Safety Coordinator is the designated person, other than the Approval Holder, who can provide information about source use in the laboratory in case of an emergency.

A. Leaking Sealed Sources

If a sealed source is damaged, the source capsule is ruptured, or if the source capsule integrity cannot be determined, there is a potential for contamination. RLSS must be notified immediately of suspected leaking sources and will coordinate decontamination efforts. Decontamination must not be attempted without instruction from RLSS personnel.

The initial steps taken in the event of potential contamination are represented by the acronym, SWIM.

Stop the spill
Warn other personnel
Isolate the area
Minimize exposure to radiation and contamination

1. **Actions**

   In the case of a potentially leaking source, the following actions should be taken by laboratory personnel as soon as possible:

   - Notify nearby people to leave the immediate area, but to remain nearby as a group so that they can be surveyed for contamination.

- Leave the area quickly and lock the door. Remove potentially contaminated gloves, shoes and laboratory coats before leaving the area.
- Notify RLSS immediately. If after business hours or if no answer at the RLSS telephone number, call University Police.
- Remain nearby to ensure that no one enters the area and to provide information when help arrives.

B. Fire Emergencies Involving Sealed Sources

- In case of fire, call '911' from a University telephone, notify dispatcher that radiation is involved, pull the nearest fire alarm, and vacate the building.
- Call RLSS (if after business hours or if no answer at the RLSS telephone number, call University Police).

C. Loss or Theft of Sealed Sources

Suspected loss or theft of a radioactive sealed source must be reported immediately to the Radiation Safety Coordinator and/or Approval Holder, and RLSS. If after business hours or if no answer at the RLSS telephone number, call University Police.

VII. Responsibilities By Role

The responsibility for maintaining radiation doses to workers and the public under the ALARA principles is shared by RLSS, the Approval Holder, the Approval Safety Coordinator, and each radiation worker.

A. Approval Holder Responsibilities

Approval Holders are the individuals ultimately responsible for the safe use of radioactive sealed sources under their control and listed on their Approval. Approval Holder Orientation is provided by RLSS at the time of approval, during audits, and/or at a minimum of every three years. Approval Holders have the responsibility to:

- Comply with the rules and regulations administered by the University Radiation Safety Committee or the Medical Radiation Safety Committee, RLSS, and the BRC;
- Properly train radiation workers to handle, secure, transport and dispose of radioactive sealed sources and in the use of ECDs under their Approval in accordance with the Radiation Training Policy and requirements for transportation of Radioactive Sealed Sources;
- Provide in-house training;
- Ensure that RLSS is notified of new proposed radiation workers;
- Provide adequate supervision of authorized radiation workers;
- Maintain a written inventory of source use;
- Confirm source use locations and workers under the approval on a quarterly basis via the online RLSS Approval Review;
- Participate in annual RLSS audit or ensure that Approval Safety Coordinator is available to participate during the audit.
- Ensure that contamination surveys are performed and documented, if required;
- Respond to information requests by RLSS in a timely manner;
- Notify RLSS immediately if source leakage has occurred or is suspected;
- Maintain all required postings and labeling for use areas, for sources, and for devices associated with source use;
- Provide and ensure proper use of personal protective equipment, if required;

- Notify RLSS prior to relocation or transfer of sources (to internal or external sites), other than previously approved routine transport of sources;
- Notify RLSS if the Approval Holder will be absent from the institution for an extended time that will reduce the effective oversight of laboratory operations. If an extended absence is planned, an agreement must be reached with an appropriate substitute to oversee the use of the approved sources while the Approval Holder is away.

B. Approval Safety Coordinator Responsibilities

Some Approval Holders may not have the time or resources to personally monitor the day-to-day operation of a laboratory. Therefore, Approval Holders may appoint a Approval Safety Coordinator to operate under their Approval, but the ultimate responsibility for use of radioactive sealed sources remains with the Approval Holder. The Approval Safety Coordinator, in addition to attending the Sealed Sources Protection Course will receive an Approval Holder Orientation from RLSS personnel (initially, during audits, or at a minimum of every three years). At the direction of the Approval Holder, the Approval Safety Coordinator may be assigned extra responsibilities such as those in the above list (including training of ECD users).

C. Radiation Worker Responsibilities

Radiation Workers have the responsibility to:

- Complete the Sealed Source Protection Course and any other required training prior to beginning work;
- Notify RLSS if transferring to a new Approval Holder's group or laboratory;
- Comply with the requirements for the safe use, transport and security of radioactive sealed sources, and for proper disposal of the source;
- Document each use or transport of the sealed source (if the approval includes routine transportation of sealed sources, transport refresher training must be completed every three years);
- Perform and document contamination surveys, if required;
- Report all accidents and exposures (known or suspected) to the Approval Safety Coordinator and/or Approval Holder, and to RLSS.

D. Research Laboratory & Safety Services (RLSS) Responsibilities

RLSS has responsibility to:

- Provide training (e.g., Sealed Source Protection Course, Approval Holder's Orientation, Transport Refresher training);
- Receive shipments of radioactive sealed sources and inspect for leakage prior to delivery to requesting laboratory, and at periodic intervals;
- Maintain a current inventory of approved sources;
- Coordinate state reciprocity agreements;
- Ship or dispose of sources, as needed;
- Calibrate survey instruments;
- Perform dose rate surveys in work areas surrounding source storage areas;
- Provide signs for entrances to use areas, for labeling of storage areas;
- Provide DOT required source transport documentation;
- Provide personnel dosimeters and area monitors, if necessary;

- Maintain exposure records for Radiation Workers;
- Perform audits and laboratory inspections (at least annually);
- Provide assistance in contamination surveys and decontamination procedures, as needed.

VIII. Purchasing Sealed Sources

A. Contact RLSS

Prior to purchasing radioactive sealed sources, the Approval Holder must notify RLSS of the planned purchase. RLSS confirms that the purchase is appropriate under the current approval and license, whether there are any special requirements related to the particular source, and whether an amendment to the current approval is necessary. Once cleared, the AH generates a Purchase Requisition (see requirements below). Departmental Purchasing Cards may not be used to purchase RAM; this violates University mandated Policy Restrictions that apply to the Purchasing Card.

The purchase requisition must contain all of the following items (applies to new and replacement shipments).

- Approval Holder name
- Approval Number
- Radionuclide
- Activity being ordered in mCi or µCi
- Chemical form and Catalog number
- Protocol Number
- Object Code 5240

All incoming shipments of radioactive materials must be delivered to:

Attn: Research Laboratory & Safety Services
Medical Receiving Dock
1501 N Campbell Ave
Tucson, AZ 85724

OR

Research Laboratory & Safety Services
University of Arizona
College of Medicine, Phoenix Campus
425 N 5th Street
Phoenix, AZ 85004