THE UNIVERSITY OF ARIZONA ®

Gamma Irradiator Protection

Reference Guide

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Table of Contents

I. Irradiator Facility Radiation Hazards

Gamma irradiators are used in a variety of medical, research, industrial and agricultural applications. Those who routinely use an irradiator are able to do so safely because they are knowledgeable about the hazards that the irradiator may pose as well as the established engineered controls and procedural practices to minimize their radiation dose. The gamma irradiators in use at the University of Arizona (The Arizona Cancer Center Irradiation Facility and the Engineering Building Irradiator Facility) have a flawless safety history. Radiation doses received by previous irradiator facility users have been small.

A. Principles of the Co-60 Irradiator

Researchers at the U of A have typically used both irradiator facilities for irradiation of numerous things such as animals, insects, cell cultures, bacteria and electronics. The gamma irradiators are large devices that rely on relatively small capsules which contain radioactive Cobalt-60 in an alloy matrix to produce a flux of high energy gamma radiation. The capsules within the irradiator device have been certified as “Special Form” radioactive sources. This certification ensures that the encapsulating material (usually steel) around the radioactive Co-60 is extremely durable. Special Form sources are able to withstand extreme trauma and heat before rupturing and dispersing their radioactive contents. Therefore, the irradiator facility does not pose a radiological contamination hazard under normal circumstances.

The radioactive capsules, or sources contained in the irradiator devices are either in an ***exposed position*** or ***shielded position***. The radiation dose rate near the irradiator devices is very high only when the source is in the exposed position. The radiation dose rate near the irradiator is very low when the source is retracted into its shielded position. Both irradiator facilities employ engineered safety controls that must be observed or utilized and use rules that must be followed.

The Arizona Cancer Center Irradiation Facility irradiator has multiple engineered safety and security controls to ensure that facility users and the public are not exposed at any significant proportion of their regulatory dose limits. Engineered controls include the following;

1. Catcard required for access
   All authorized users must have a Catcard to attain access into the irradiator facility. Users are required to swipe their Catcard when both entering and exiting the facility.
2. Security code required for access
   The security alarm guarding entrance to the irradiator facility requires that users be registered with the security contractor by the irradiation facility Approval Holder or Radiation Safety Coordinator previous to use.
3. Key control program
   Access to facility keys are restricted by the facility Approval Holder and Radiation Safety Coordinator. Facility keys allow for source activation, dosimeter access and internal doors and closets.
4. Facility CCTV monitor
   The CCTV monitor is located directly above the control panel. This monitor displays multiple views of the irradiator device room in order to ensure that nobody is in the irradiator device room and allows facility users to view two indicators (blinking radiation monitor, source exposure indication stick) of elevated radiation levels.
5. Facility radiation monitors

The facility radiation monitors have visual blinking displays that may be viewed outside of the irradiator device room. These monitors blink due to the source being in the exposure position and elevating the radiation levels above 4mrad per hour.

6. Source exposure indication stick

The source exposure indication stick protrudes from the front overhead surface of the irradiator device when the source is in the exposed position.

7. Main power switch

The facility main power terminal is in the operator's room. Throwing the main power supply switch to the downward off position will retract the source to the shielded position.

8. Door interlocks

The door to the irradiator room is equipped with an interlock to ensure that the irradiator source cannot remain in the exposed position. Opening the door will immediately cause the source to retract to the shielded position.

9. Control Panel Operation Indicator Light

The irradiator control panel will have a light that when illuminated when the irradiator source is in the exposed position.

The Engineering Building Irradiator Facility irradiator has multiple engineered safety and security controls to ensure that facility users and the public are not exposed at any significant proportion of their regulatory dose limits. Engineered controls include the following;

1. Key control program

Access to facility keys are restricted by the facility Approval Holder and Radiation Safety Coordinator. Facility keys allow for source activation, dosimeter access and internal doors and closets.

2. Facility radiation monitors

The facility radiation monitor has a large readout face that may be observed from outside the irradiator room through the leaded glass viewing window.

3. Main power switch

The facility main power terminal is in the operator's room. Throwing the main power supply switch to the downward "off" position will retract the source to the shielded position.

4. Door interlocks

The door to the irradiator device room is equipped with an interlock to ensure that the irradiator source cannot remain in the exposed position. Opening the door will immediately cause the source to retract to the shielded position.

5. Control panel operation indicator light

The irradiator control panel will have a light that is illuminated which indicates when the irradiator source is in the exposed position.

II. Origins of Radioactivity

The concept of the atom began with the early scientists of ancient Greece who meticulously measured mass and volume of different known substances and concluded that the "building blocks" of elements existed on a very small "invisible" scale. Between then and now many models of the "invisible" atom have been discussed, created and discarded. For the purposes of this course, Neils Bohr's atomic model will be used. The atoms inner energy or nucleus consists of positively charged particles and non charged particles called nucleons tightly packed together and surrounded by outer orbital shells of negatively charged particles called electrons. The electrons can be thought of as a fuzzy "cloud" that is able to fill the whole space around a nucleus. The nucleus is so extremely dense that it occupies an area 10,000 times smaller than the greater area of its surrounding electrons.

An atom is first identified and labeled according to the number of protons in its nucleus. This atomic number (Figure 6) is given the symbol Z. All atoms with the same atomic number have identical chemical properties. A bar of pure uranium would consist entirely of atoms with the atomic number 92 or have 92 protons. The periodic table of the elements assigns one place to every atomic number, and each of these places is labeled with the common name of the element, such as carbon, sodium, or phosphorus. The total number of neutrons and protons in the nucleus is given the symbol A, or atomic mass number (Figure 6).

Figure 6

$$^{14}_{6}\mathrm{C} \qquad\qquad ^{A}_{Z}\mathrm{X}$$

A (Atomic Mass Number)
X (Element Symbol)
Z (Atomic Number)

Atomic Mass Number and Atomic Number

Different elements have different numbers of both radioactive and non-radioactive, stable isotopes. Isotopes always retain the same atomic number (Z); however the amount of neutrons may change due to natural or man-made processes. Unstable atoms spontaneously discard excess mass or energy from their nucleus to become a stable atom. This process is called radioactive decay.

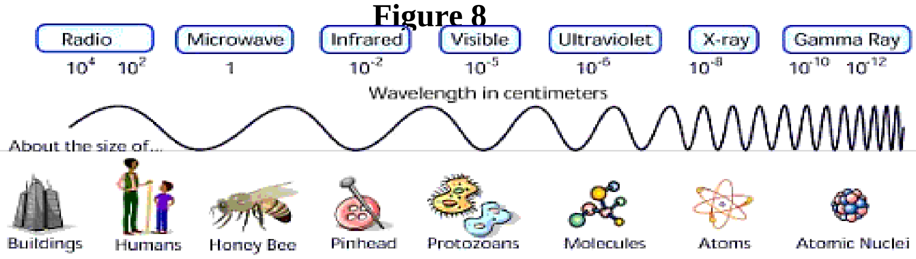
B. Radioactive Particle Hazards

1. The beta particle is very similar to an electron in size and charge. The irradiator source contains radioactive beta particle emitting materials. Significant beta particle exposure is extremely unlikely from an irradiator source because of their incapacity to escape the source encapsulation.
2. The alpha particle is very similar to a helium nucleus. It is comprised of two protons and two neutrons. Typical alpha particles will travel no more than a few inches in air and are stopped by a sheet of paper or your outermost dead layer of skin. Alphas can create neutrons by interacting with Beryllium.

C. Photon Radiation Hazards

Cobalt-60 beta decay is accompanied by gamma photon radiations and may cause incidental X-ray photon radiations via interaction with surrounding atoms. The gamma photons occur directly after the Cobalt atom transforms its nucleus (via beta decay) into stable Nickel-60 since it will be in an excited state during that specific timeframe. These electromagnetic radiations differ from radio waves and visible light in that they have a much shorter wavelength, higher frequency and higher energy (Figure 8). Unlike beta particles, these photons can penetrate deeply into objects because they do not interact as readily with matter due to their quantum mass and lack of charge. Therefore, a non-ruptured operational irradiator source always presents a photon radiation hazard.

Figure 8

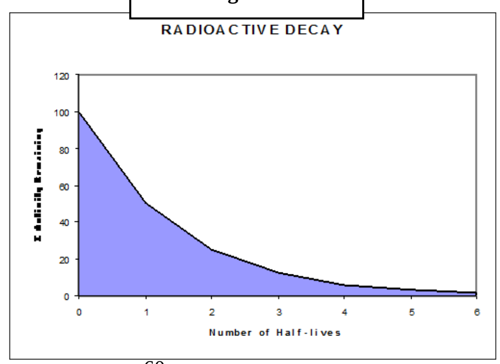


D. Measuring the Activity in Radioactivity

Table 2 Units of Radioactivity		
Units	Disintegrations per minute	SI units
1 Curie (Ci)	2.2 x 10^{12} (dpm)	37 Gigabecquerel (GBq)
1 millicurie (mCi)	2.2 x 10^{9} (dpm)	37 Megabecquerel (MBq)
1 microcurie (uCi)	2.2 x 10^{6} (dpm)	37 kilobecquerel (kBq)
1 nanocurie (nCi)	2.2 x 10^{3} (dpm)	37 Becquerel (Bq)
1 picocurie (pCi)	2.2 (dpm)	37 millibecquerel (mBq)

For most uses of radioactive material, the important quantity to measure is not the number of radioactive atoms present, but the rate that unstable radioactive atoms "decay" to stable atoms. This is known as radioactivity or simply activity. While addressing a source of radioactive material, it is customary to refer to its activity rather than its mass (*e.g. I have 10 millicuries of Co-60, not 10 grams of Co-60*). The two most common units of activity are the curie and the becquerel. In 1962, the International Commission on Radiological Units recommended one curie to be equal to 3.7×10^{10} (37 billion) radioactive disintegrations per second. A 5 millicurie source of *Co-60* emits ~ 1,850,000,000 beta particles per second! The becquerel is the newer *System International* unit of activity. One becquerel is equal to one disintegration per second. Therefore, 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, we often talk in terms of milli and microcuries (mCi / uCi) or Mega and Gigabecquerels (MBq / GBq) (Table 2).

Figure 9



E. Radioactive Decay

Half-life is defined as the time required for the activity of radioactive material to be reduced to one-half of its original value (Figure 9). All isotopes have a unique half-life. Some half-lives are very long, while others are extremely short. Therefore, an ^{241}Am source would have a longer service life (half-life ~433 years) than a ^{60}Co source (half-life ~5.271 years). An isotopes half life is not affected by external factors such as temperature or pressure.

III. Biological Effects of Radiation Exposure

Radiation interacts with the human body exactly as it interacts with anything else; it ionizes the atoms and molecules that it traverses. The most common molecule in the human body is water. After a water molecule is ionized, it falls apart and produces free radicals ($H_2O \rightarrow H_2O^{+} + e^{-} \rightarrow OH^{\cdot} + H^{+} +$ e). The free radicals produced by the ionization of water are extremely chemically reactive and will react with just about anything, whether biologically important or not.

Deoxyribonucleic acid (DNA) is the blueprint of the cell. It is a double helix macromolecule (Figure 10) that "unzips" for transcription and reproduction. Undesirable changes (mutations) to DNA from radiation exposure can result in cell death, the inability of the cell to reproduce, the inability to properly function or drastic change cell function that may include the induction of cancer. Radiation can interact with DNA, either by direct ionization or through chemical attack by producing free ($OH^{.}$) radicals in the intracellular fluids. The clear majority of damage to cells from radiation exposure is caused via the ionization of the intracellular fluids. Although DNA has the ability to repair itself, once it has become altered, it may revert to its original state or it may reform as a slightly changed molecule. Almost all other interactions between radiation and other biological molecules do not result in any significant biological effect to the cell.

A. Acute Radiation Dose Syndromes

At low levels of radiation exposure, the amount of cell death / mutation is typically irrelevant. The loss of a few cells will probably not affect the function of an entire organ. In contrast, when large radiation doses are accrued over a short period of time (at a rate where DNA cannot repair itself), the amount of cells that die have an elevated probability of being biologically detrimental. This rapid loss of healthy cells constitutes a specific, unique syndrome called the acute radiation syndrome. The dose at which the symptoms occur depends on the sensitivity of various cells or organs to radiation exposure. In general, the faster a cell divides and the less specialized (e.g. an immature blood cell is less specialized then a mature one) it is, the more sensitive it is to radiation exposure. *Remember that the acute radiation syndrome is only relevant for large doses given over a short period. Heavy irradiator source use at the U of A rarely exposes users beyond 0.05 rem/year; compare that to the doses listed on table 3.*

Table 3 - Acute Radiation Syndromes

	Hematopoietic Syndrome	**Gastrointestinal Syndrome**	**Central Nervous System Syndrome**
Dose (rad)	200-1000	> 1000	> 2000
Time of Death	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, anemia, hemorrhage, infection	Denudation of villi in small intestine, neutropenia, infection, bone marrow depression, electrolyte imbalance, watery diarrhea	Vasculitis, edema, & meningitis
Recovery Time	Dose dependent, 3 weeks to 6 months; some individuals do not survive.	None	None

B. Chronic Low Level Exposure Risk

There are two types of dose effects that may be of concern to the irradiator user - the induction of cancer and hereditary effects. There is no direct evidence of either of these effects occurring at occupational doses below the annual dose limits. The probability of these effects occurring has been conservatively calculated from taking the worst-case scenario from higher exposures, especially the Hiroshima and Nagasaki survivors. The high percentage of individuals (20-25% and rising) getting cancer and genetic mutations makes it impossible to see any effect of occupational doses above statistical noise. Therefore, it is impossible to say with our current data that low levels of radiation increase the risk of getting cancer or that it has no effect on the rate. However, to be conservative, occupational dose limits are set well below the statistically significant threshold of observed radiation induced cancer.

There is still no firm evidence that radiation can produce hereditary effects in humans, however there is concrete evidence for other mammals. Because the stakes are high, all regulation and safety protections assume that hereditary effects can occur. There were whole body effects observable in embryo/fetuses that were in the womb during the bombing of Hiroshima and Nagasaki.

Some effects, such as cataracts, temporary sterility and reddening of skin, occur after a threshold dose has been received. For doses above the threshold, the biological effect is proportional to the dose received. None of these effects occur from occupational exposures within the annual occupational dose limits.

So, what does this mean to the irradiator source user?

Everything in life has risks and benefits; we are constantly making risk versus benefit decisions although we really don't know it. For example, do I really want that piece of chocolate cake? It sure would taste good, and the sugar might keep me awake through this boring handout, but I will gain weight and my clothes won't fit. We don't need to discuss the safety of driving to work in Tucson!

Not all the news is bad, for example, a study in England showed that University professors gained 500 days of life. Studies in the United States have suggested that service by mobile intensive care units produces a net gain of 110 days of life and smoke alarms net a gain of 10 days. A college education produces a 2.6 year net gain to life span.

C. Background Radiation

Radiation is found everywhere and has always been on earth. Radiation comes from the skies, the ground, within our own bodies and the air we breathe (Figure 11). The major components of background dose are from the uranium decay chain. The main three naturally occurring extremely long-lived half-life radionuclides are ^{235}U, ^{238}U and ^{232}Th (they have been around since the big bang). These nuclides are the start of a long chain of radioactive nuclides ending with stable lead. One element of particular concern is radon. Radon is an odorless colorless gas that decays to a series of radioactive metals (aka radon daughters or progeny). These daughters attach themselves to particles in the air and may be deposited in the lungs during respiration. Most of average natural background radiation dose comes from the inhalation of radon daughters. The terrestrial dose or the dose coming from the earth is primarily due to gammas emitted during these chains.
In addition to the naturally occurring series, there are other isotopes that give dose to humans, ^{40}K (potassium), ^{14}C and ^{3}H. Most of the dose coming from internal exposure comes from radioactive potassium that comprises 0. 01% of all potassium.

Cosmic radiation is produced by high-energy particles from the sun and other sources in space. The higher the altitude the higher the dose as the atmosphere provides shielding (e.g. Florida ~38 mrem, Wyoming ~78 mrem and Colorado ~140 mrem).

Man-made sources of radiation account for about 65 mrem, with about 53 mrem coming from medical exposures and almost the other entire dose coming from other consumer products. Less than one mrem is from nuclear fallout and the nuclear fuel cycle. The average background dose for the USA is approximately 360 mrem per year.

It is important to remember that these are only average doses and your dose can vary by where you live, the number of medical exposures you have had and various lifestyle choices. For example: smoking (30 cigarettes/day) will give your lungs the equivalent of ~1.5 rem per year.

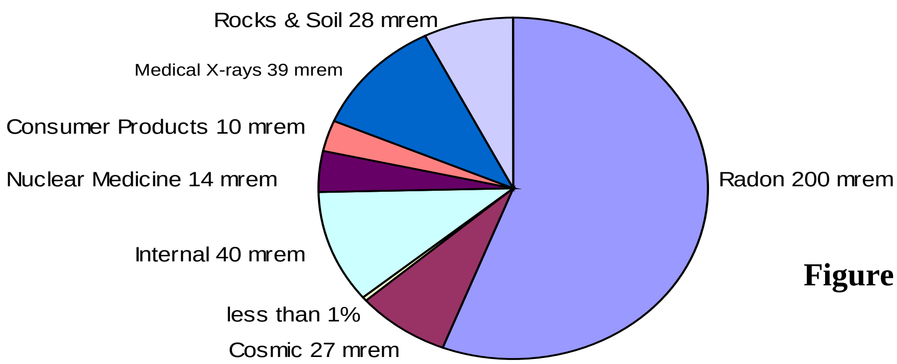


Figure 11

D. As Low As Reasonably Achievable

Both the Federal and the State of Arizona regulations mandate the concept of ALARA. This regulatory requirement is based on the following:

1. No practice shall be adopted unless its introduction produces a net positive benefit.
2. All exposures shall be kept **As Low As Reasonably Achievable** (ALARA), economic and social factors being taken into account.
3. The dose equivalent to individuals shall not exceed the limits recommended for the appropriate circumstances by the regulatory authority.

It is everyone's responsibility, from the individual irradiator user to management, to ensure that the ALARA principal is followed. ALARA is a goal required by law.

E. ALARA Practices of Time, Distance and Shielding

Whenever working with radioactivity, it is essential to keep your radiation exposure to a minimum. Applying the three ALARA radiation exposure reduction practices of **time**, **distance**, **shielding** during your occupational exposure to radiation will help keep your radiation dose as low as reasonably achievable. Fortunately, the irradiator facilities were carefully designed to take advantage of these three dose reduction methods to ensure that the user's radiation exposure is very near natural background levels.

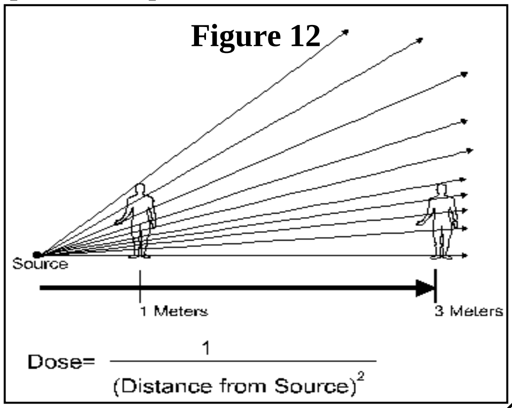
3. Time

The less time spent around your source, the less radiation exposure you will receive. Proper use of the irradiator has not acutely imparted a high radiation dose to any operator thus far.

4. Distance: Inverse Square Law

Emissions from a radioactive point source diverge equally in all directions from their source (Figure 12), thus the number of radioactive emissions decreases quickly with distance. Doubling the distance from a source of radioactive emissions brings your exposure down by a factor of 4. Reducing the distance from a source of radiation by half increases the exposure by a factor of 4 (i.e., An exposure of 100 mrem per hour at one meter from a radioactive point source will be cut to 25 mrem per hour at 2 meters from the same source. Exposure to the same source at a distance of half a meter would increase the dose to 400 mrem per hour). Our irradiator facilities place the operator at least three meters from an exposed source.

The student in Figure 11 is receiving 100 mrem per hour at 1 meter, what will the students dose rate be at 3 meters?



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

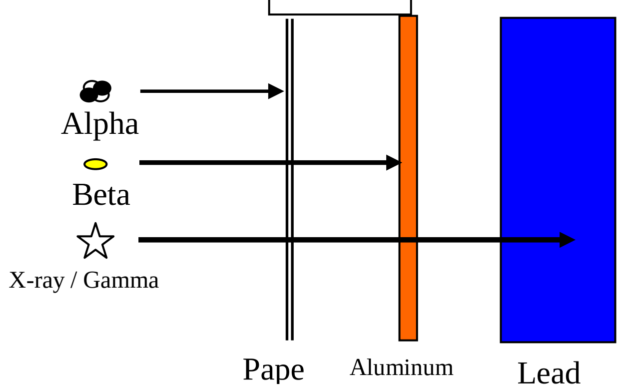
I_2 = 100mR/hr (1m / 3m)^2
I_2 = 100mR/hr (0.33)^2
I_2 = 100mR/hr (.011)
I_2 = 11.1 mR/hr at 3 meters

Both irradiation facilities are designed to have their operators outside of the shielded irradiator room while the source is exposed in order to take advantage of distance.

5. Shielding

Radioactive beta particles can be completely stopped in a known thickness of shielding. Beta particles should be shielded with Plexiglas or similar less dense (low-Z, or atomic number) material because bremsstrahlung x-ray production is a concern with dense, high-Z shielding.

Figure 13



Gamma and x-ray radiation is diminished in intensity by any given absorber but not completely stopped. Dense high-Z materials absorb photon radiations more efficiently than those with less density (low-Z). Therefore, for photon radiations, lead or depleted uranium is a good choice of shielding.

Every irradiator device room has lead shielded walls, doors and impregnated glass in order to keep dose low to the operators during operation when the source is in the exposed position.

The irradiator sources are heavily shielded with lead when they are not deployed in the exposed position. While the Cancer Center source is in the exposed position, irradiator gamma ray beams are collimated by depleted uranium shields.

F. Units of Radiation Absorbed Dose and Dose Equivalent

The term radiation dose is a general term applied to the effects of radiation on any given material.

1. Rad

The rad is the traditional unit of absorbed dose used in the United States. The rad is a measurement of energy deposited into any matter from radiation exposure. One rad is equal to 0.1 joules/kg of energy deposition into any matter.

2. Gray

The gray (Gy) is the System International unit of absorbed dose. One gray is equal to 100 rad.

3. Rem

The rem is traditionally used in the United States for reporting exposure to radiation. Since equal exposure to different types of ionizing radiation are not equally as harmful to human tissues, the rem is the product of the absorbed dose (rad in tissue) and a quality factor (Table 5). Therefore it is a unit of dose equivalent. The quality factor represents the biological consequence from that particular type of radiation exposure. Table 5 demonstrates that exposure to protons is ten times more damaging (per rad of absorbed dose) than gamma photons.

Table 5: Quality Factors for Different Radiations

Radiation	**Quality Factor** (Rem per Rad)
X ray, Gamma, Beta	1
Neutrons & Protons	10
Alpha Particules	20

4. Sievert

The Sievert (Sv) is the *Systeme International* unit of dose equivalent. One sievert is equal to 100 rem.

G. Occupational Radiation Exposure Limits

Table 6 details the maximum amount of radiation dose that is allowed for a irradiator user. By law, the ORCBS is obligated to track your radiation dose if it is likely that you will exceed 10% of any of these limits. All irradiator users must have their radiation doses monitored.

Table 6: Occupational Radiation Dose Limits

Whole Body	5 rem
Lens of Eye	15 rem
Extremities	50 rem
Skin	50 rem
Fetus (9 month)	0.5 rem
Personnel Under 18 Years of Age	10% of Adult Limits
General Public (Non-Occupational)	0.1 rem

H. Personnel Dose Monitoring

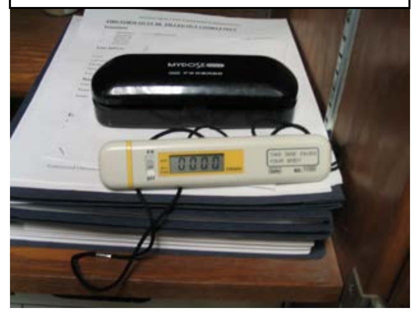
Personal radiation dose monitoring is required for irradiator users. The measurements obtained by these dosimeters are legal records of a person's individual radiation exposure while working for the U of A. The Luxel OSD (Figure 14) personal dosimeters are currently issued to irradiator users at the U of A. Personal dosimeters are issued to irradiator users by the ORCBS through the irradiator facility dosimetry coordinator. The irradiator facility dosimetry coordinator will advise their users about when and where to exchange their dosimeters.

Figure 14

Irradiator users must wear their dosimeters whenever they enter the irradiation facility. Dosimeters must not be shared or exposed to any source of radiation outside of your occupational radiation exposure at the U of A. The ORCBS returns these dosimeters to their manufacturers for analysis. **DO NOT LOSE YOUR DOSIMETER, A $25.00 CHARGE WILL BE LEVIED AGAINST YOUR DEPARTMENT TO COVER REPLACEMENT AND ADMINISTRATIVE COSTS AND THE DEPARTMENT MAY PASS THAT CHARGE ONTO YOU.** Immediately report any lost or damaged badge to the ORCBS. The ORCBS will replace the damaged dosimeter free of charge.

ALOKA electronic dosimeters (Figure 15) are required for Cancer Center facility visitors. These dosimeters digitally display the dose that they receive after they are switched on until they are switched off. The visitor name and indicated radiation doses must be recorded on the irradiator usage log sheet in the irradiator logbook. The ALOKA electronic personal dosimeter use procedure is listed below:

Figure 15



1. Write down the name of anyone issued the ALOKA on the use log Observer’s area.
2. Turn the ALOKA on (switch is flush with long edge).
3. Ensure that the ALOKA does not continuously flash for more than 30 seconds.
    a. Call the ORCBS if the digital display continues to flash. Continuous flashing requires a battery replacement and recalibration by the ORCBS.
4. Place the lanyard around your neck, place the ALOKA upon your chest and orient the face of the ALOKA as per the instructed on the device.
5. After use, record the number on the digital display next to the name of the user.
6. Turn the ALOKA off

I. Pregnancy

Should you become pregnant or plan on becoming pregnant, you have the option of declaring your pregnancy to the ORCBS. Declaring your pregnancy ensures that you will receive counseling about the potential consequences of radiation exposure to your fetus and may result in the issue of an additional “fetal” dosimeter. We encourage pregnant radiation workers to contact the ORCBS for a review of your radiation exposure environment, previous exposure history and to receive an information pamphlet from the Nuclear Regulatory Commission about fetal exposure. It is a woman's right to "undeclare" her pregnancy at any time. This act terminates the ORCBS’s involvement with her pregnancy even though she may still be pregnant and has previously declared the pregnancy.

The dose limit to an embryo/fetus is 500 mrem over the entire pregnancy of a declared pregnant worker. It is also required that every effort be made to avoid substantial variation above a uniform monthly exposure rate (50 mrem/month).

J. Minors (under the age of 18)

Minors may only enter the irradiator facility if it is part of an educational program. Minors must complete irradiator facility specific training, submit a completed RC-088 Radiation Worker Data Form and complete the GIPC before they may work with any gamma irradiator.

K. Radiation Survey Meters

The ORCBS tracks the calibration status of every survey meter and electronic dosimeter at the irradiator facility. These instruments should have a calibration label affixed to them that clearly specifies the last calibration date and date that the next calibration is due. Do not use any equipment that is out of calibration. If you find an instrument that is out of calibration, contact the ORCBS.

Before you use a survey meter, perform the following preoperational checks:

1. Battery check.
2. Background check (background for a G-M meter should be 25-100 cpm; background for a scintillation meter should be 300-500 cpm).
3. Verify that the meter is within its specified calibrated period.
4. If provided, conduct a performance check of the instrument response using a check source. The expected check source reading is posted on the calibration label on the side of the meter. If the meter does not read within +20% of the expected check source reading (the listed count/dose rate parameters), do not use the meter. Contact the ORCBS to arrange for recalibration or repairs.

L. Irradiator Room Radiation Monitors

Both irradiator facilities have room radiation monitors that indicate when an irradiator's source is in the exposed position. Irradiators may not be used when these room monitors are not present.

IV. Approval to Use an Irradiator Facility at the University of Arizona

A. Letter of Trustworthiness

Recently published IAEA plans have required increased control and security measures for high activity sources, such as the Co-60 sources in both irradiators at the U of A. The Federal Nuclear Regulatory Commission and Arizona Radiation Regulatory Agency have the responsibility of ensuring that the upgraded security and control procedures are implemented. **Therefore, those who wish to attain unescorted access to the facility must have their Principle Investigator or Department Head prepare a brief, written memorandum that advocates their trustworthiness and details the protocols that will be performed at the facility.** A memorandum of trustworthiness must specifically state how long the person needs to use the facility and that the potential irradiator user must have unescorted access to the facility and deemed trustworthy and reliable. **The original copy of the memorandum must be submitted to the ORCBS either before or during the GIPC class and have an original ink signature. Those who do not submit a letter of trustworthiness will not be allowed to complete the class or attain a certificate.**

B. Arizona Radiation Regulatory Agency (ARRA)

The state of Arizona is a regulatory Agreement State. That means that the Nuclear Regulatory Commission (NRC) has given the ARRA jurisdiction in regulating work with radioactive materials within the state of Arizona. The U of A has been issued two licenses by the ARRA for work with radioactive materials. Irradiator use falls under both of these licenses, ARRA 10-24 and ARRA 10-44. The ARRA typically inspects University gamma irradiator Approvals once a year.

C. Radiation Safety Committee Approval Process

Approval to manage an irradiator facility is granted to a particular professor or researcher after the University or Medical Radiation Safety Committee, composed of other users of radioactive materials, reviews and approves their radioactive material Approval application. This application is known as the RC-10 *Application for Radioactive Material Approval* and can be downloaded from the Forms section of the ORCBS website. Once the applicant has submitted this form and obtained the appropriate Radiation Safety Committee's approval, they are referred to as "Approval Holders". Contact the ORCBS for assistance with Approval application (RC-10) submissions to the appropriate Radiation Safety Committee.

Approvals may also be inactivated over a period of time. The ORCBS would simply deny access to the facility for all users so during that time the Approval Holder is relieved of all responsibilities. Reactivation of the Approval (barring any changes from the last Approval) is an expedited process since approval had been previously attained.

D. Radiation Safety Committee Disciplinary Actions

The Radiation Safety Committees reserve the right to indefinitely stop or limit work in an irradiator facility. Historically, this has happened when unsafe practices have been observed or when Approvals have accumulated multiple warnings or "Notices of Violation" without mitigation.

E. Irradiator Facility Approval Special Conditions

The primary responsibility of the Approval Holder is to ensure that radiation workers are operating in a safe work environment that is in compliance with the gamma irradiator use rules. Approval Holders accomplish this task via close cooperation and coordination with the ORCBS. The ORCBS provides the Approval Holder with a myriad of expertise and service to ensure safety and compliance.

The Irradiator Facility Approval Holder is responsible for informing the ORCBS, at least 30 days in advance of the following special conditions:

1. Removal or replacement of an irradiator source requires ORCBS assistance and notification of the appropriate Radiation Safety Committee.
2. Approval Holders may designate another similar Approval Holder to temporarily take responsibility for their Approvals. This act must be coordinated by the ORCBS and approved by the Radiation Safety Committee.

F. Approval Holder Responsibilities

1. Training of irradiator users under their approval

No one is allowed to work with an irradiator facility until they have received appropriate training. At the University of Arizona, this is a two-part process: irradiator specific training and the GIPC. Approval Holders must maintain a copy of the GIPC certificates of completion for all of their active users to be available for inspection by the ORCBS and ARRA.

a. Irradiator Specific Training

   The Approval Holder is responsible for irradiator specific training. This training is conducted by the Approval Holder or designee and is documented by signing (both the future source user and Approval Holder/Radiation Safety Coordinator) and submitting the Form RC-088, "Radiation Worker Data Sheet & Training Record" to the ORCBS prior to any irradiator use. The RC-088 may be downloaded from the ORCBS website Forms section.

b. Gamma Irradiator Protection Course (GIPC)

   The GIPC is provided by the ORCBS. Those who successfully complete the GIPC course and examination will be emailed a certificate of completion. A copy of the certificate must be provided to the Approval Holder. Once a user has completed the

GIPS and received their dosimeters, they may be assigned to the Authorized User List.

2. Security of irradiator facilities
    a. Cancer Center Facility

    The Cancer Center Facility requires users to deactivate an alarm system; the Radiation Safety Coordinator will act as liaison with the security monitoring company to ensure that new authorized users are able to negotiate the alarm.

3. Online Quarterly Review

Approval Holders have access to their Approval data online via the ORCBS website once they create a password and register for online data access in the Approval Reviews section. Every calendar quarter, Approval Holders are notified about the Online Quarterly Review. This review requires the Approval Holder to verify all of their summarized data and affirm the current safe use guidelines. Be advised, this report must be completed within the calendar month that it is published, failure to do so may result in a Notice of Violation from the Radiation Safety Committee.

4. Approval Holder Orientation

The initial Approval Holder Orientation (AHO) is provided by the ORCBS to the Approval Holder and Radiation Safety Coordinator on a one on one basis immediately after the Radiation Safety Committee approves their application. The AHO has a three year frequency since laws, rules and procedures about radioactive material use changes and evolves. The ORCBS will notify Approval Holders and Radiation Safety Coordinators when they are due for refresher AHO training.

5. Maintenance of irradiator source Approval records

Approval Holders are required to maintain the following records for review by ORCBS auditors or ARRA inspectors:

a. Training certificates (GIPC) for all active workers
b. Irradiator source use log – A use log that documents irradiator use must be maintained for at least three years.
c. The irradiator facilities authorized users list.

6. Annual compliance audit

Approval Holders are encouraged to take part in the annual compliance audits of their Approvals. At a minimum, the Radiation Safety Coordinator must participate. Approval Holder participation is only required during an audit when the Approval has no designated Radiation Safety Coordinator. Approval Holders and Radiation Safety Coordinators will always receive via email a written summary of the audit findings from the ORCBS.

G. Radiation Safety Coordinator Responsibilities

The Approval Holder may designate an irradiator source user within their Approval to act as their Radiation Safety Coordinator. This appointment can be coordinated with the ORCBS via telephone, email or during the Online Quarterly Review. Radiation Safety Coordinators have certain responsibilities:

1. Quarterly Online Review

Radiation Safety Coordinators are encouraged to register for online Approval data access via the ORCBS website and participate in the Quarterly Online Review process. Radiation Safety Coordinators can complete all but one of the required review sections for the Approval Holder.

2. Monthly Online Inventory Review

Radiation Safety Coordinators have access to a monthly snapshot of their source inventory records once they register online for access via the ORCBS website. Although review of the online inventory is not mandated, it is highly encouraged for security verification of inventory purposes.

3. Training of irradiator users under their Approval

Radiation Safety Coordinators are authorized to perform Irradiator Specific Training and therefore may act as signature authority on prospective source users RC-088, Radiation Worker Data Form.

H. Irradiator User Responsibilities

Irradiator users are responsible for following all of the rules listed below:

1. Rules for the safe use of irradiators

Every irradiator facility has specific rules or procedures for safe use. Once trained, it is every irradiator user's responsibility to follow the published rules for their particular irradiator facility.

2. Documentation of irradiator use

All irradiator use must be documented in the facilities use log.

3. Rules for security of irradiator sources

Irradiator sources must be under two modes of security at all times. Irradiator facility sources are secured via key access to the control panel, remote alarm monitoring, physical locks and barriers.

4. Rules in the event of an emergency or stolen source

Each source user must familiarize him/herself with the emergency procedures posting. The full name and telephone numbers of the Approval Holder and Radiation Safety Coordinator <u>must</u> be filled in at the bottom of the emergency procedures posting so that they can be contacted whenever necessary. In the event of an emergency:

a. Call the UAPD and the ORCBS from a safe place.
b. Protect others by keeping them out of the immediate accident area until the radiological situation has been evaluated and deemed safe. This is best accomplished by guarding the area and warning others until the UAPD arrive.
c. Never leave the accident scene other than to initiate appropriate notifications or to request assistance.
d. In the event of a fire, notify the fire department via 911immediately; notify the ORCBS once you are safe.

5. Updating ORCBS radiation worker records

A radiation worker needs to update their RC-088 Radiation Worker Datasheet whenever their citizenship status, identification number (passport/ssn/visa) or name changes. An RC-088 Radiation Worker Datasheet must be submitted for every Approval to that a worker is assigned.

I. Office of Radiation, Chemical, and Bilogical Safety Services for Irradiator Facility Approvals

The Office of Radiation, Chemical, and Bilogical Safety maintains licenses for the possession and use of radioactive material. In support of these licenses, the ORCBS provides the following services to irradiator source users:

1. Leak testing

Radiation Control auditors typically perform leak tests twice a year during Approval audits and inspections. These tests ensure that your encapsulated radioactive material has not been breached.

  a. If a leak test result indicates the five nanocurie limit has been exceeded, work with the irradiator source must stop and the source will be removed from service. The ORCBS will initiate appropriate notifications and corrective actions.

2. Records kept by the ORCBS

Records of Approval inspections, quarterly online Approval review results, source leak tests, physical inventories, source shipments and receipts are maintained by the ORCBS. All RC-088's and records of radiation safety training are retained as well.

3. Emergency response

The ORCBS is always available to assist with emergencies. Call 520-626-6850 during our normal business hours (M-F 7am-4pm) or the University of Arizona Police Department 520-621-8273 if after normal business hours to contact an ORCBS representative.

4. Annual audits and compliance inspections

The ORCBS provides every Approval one formal annual audit as well as one informal compliance inspection per year. Audit results are summarized for the Approval Holder and Radiation Safety Committee for review.

5. Postings and labels

The ORCBS provides all postings and labels required for irradiator facilities.

6. Training

The ORCBS provides all training, except for the aforementioned Irradiator Specific Training, for all University of Arizona Approval members.

7. Radiation surveys

The ORCBS ensures that dose rate surveys are performed for work areas surrounding source storage areas.

8. Dosimetry services

The ORCBS provides all dosimetry services for irradiator source approved users.

9. Survey instrument calibration services

The ORCBS will collect, calibrate and reissue radiological survey meters and irradiator facility room monitors. The ORCBS will assist with attaining calibration services for instruments they cannot calibrate themselves.

10. Liaison with outside entities

The ORCBS will act as liaison between the Approval Holder and outside regulatory agencies and other entities concerning the use of the irradiators.