

Radiographic Sciences and Analytical X-ray Machines Study Guide

Technical Safety Office, Phone: 282-2310/2311
(Rev. 08/07)

GLOSSARY

Absorbed Dose: The mean energy per unit mass imparted to any matter by any type of ionizing radiation.

Committed Dose Equivalent (CDE): The dose equivalent to organs or a tissues of reference that will be received from an intake of radioactive material by an individual during the 50-year period following the intake.

Committed Effective Dose Equivalent (CEDE): The sum of the products of the weighing factors applicable to each of the body organs or tissues that are irradiated and the committed dose equivalent to these organs or tissues.

Deep Dose Equivalent (DDE): The dose equivalent at a tissue depth of 1 cm, resulting from whole body external exposure.

Dose Equivalent (DE): The product of the radiation absorbed dose and the radiation weighing factor, and all other necessary modifying factors at the location of interest.

Effective Dose Equivalent (EDE): The sum of the products of the dose equivalent to the organ or tissue, and the tissue weighing factors applicable to each of the body organs or tissues that are irradiated.

Exposure: Usually refers to any condition which creates the potential for any individual to receive a radiation dose, either from external irradiation or from internal contamination with radioactive materials.

Extremity: Means hand, elbow, arm below the elbow, foot, knee, and leg below the knee.

Eye Dose Equivalent: Applies to the external exposure of the lens of the eye and is taken as the dose equivalent at a tissue depth of 0.3 cm (300 mg/cm²).

Penetrating: The dose rate from photons at 1 meter from a point source of 1 millicurie, assumed to be proportional to the inverse of the square of the distance between the point source and the receptor.

Radioactive Half-life: The amount of time that it takes for a radioactive isotope to be reduced by one half of its value through the process of radioactive decay.

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Radioactive Material: Any material having a specific activity greater than 70 Bq/g (0.002 mCi/g), in accordance with 49 CFR 173.403. Also, any non-radioactive material (activity less than 70 Bq/g) with surface contamination (both fixed and non-fixed/removable) that, when averaged over each 300 cm² (46.5 in²) of all surfaces, is equal to or greater than 0.4 Bq/cm² (10⁻⁵ mCi/cm²) for beta and gamma emitters and low-toxicity alpha emitters; and equal to or greater than 0.04 Bq/cm² (10⁻⁶ mCi/cm²) for all other alpha emitters.

Shallow-dose Equivalent: Applies to the external exposure of the skin or an extremity and is taken as the dose equivalent at a tissue depth of 0.007 cm (7mg/cm²) averaged over an area of 1 square centimeter.

Tissue Weighing Factors: The proportion of the risk of stochastic effects resulting from irradiation of that organ or tissue to the total risk of stochastic effects when the whole body is irradiated uniformly.

Total Effective Dose Equivalent (TEDE): Sum of the deep dose equivalent and committed effective dose equivalent.

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COURSE OBJECTIVE

Upon completion of this training course, the participant will have an introductory knowledge of the radiation safety concerns associated with radiation producing devices for radiography and scientific analysis (this does NOT include accelerators).

RADIATION INTRODUCTION COURSE OUTLINE

Radiation introduction training is designed to familiarize the student with Idaho State University's requirements for personnel who have the potential to come in contact with radiation producing devices. At the completion of the course, the participant must successfully complete a written examination in order to work independently with radiation producing machines. Seventy percent (70%) on the written test is considered a passing score.

ISU'S ORGANIZATIONAL ENTITIES

Vice President for Research (VPR)

The Vice President for Research is the official spokesperson for the University on matters pertaining to radiation protection. The VPR appoints RSC members.

Radiation Safety Committee (RSC)

The Radiation Safety Committee is the governing body for all aspects of radiation protection within the University, including affiliated research, clinical, instructional and service units using radiation sources in facilities owned or controlled by the University. The RSC will ensure that all possession, use and disposition of radiation sources by University personnel complies with pertinent federal and state regulations and with the specific conditions of licenses issued to the University, and that all concomitant radiation exposures are maintained as low as reasonably achievable (ALARA). The RSC is empowered and directed to promulgate policies, rules and procedures for the safe use of ionizing radiation. The RSC reports to the VPR. The RSC has many knowledgeable faculty with expertise in radiation protection.

Radiation Safety Officer (RSO)

The Radiation Safety Officer is the individual appointed by the VPR and approved by the Nuclear Regulatory Commission (NRC) to administer the radiation protection program and to provide technical guidance to the RSC and to radiation users. The RSO is authorized and directed to promulgate and enforce such procedures as are necessary to assure compliance with applicable federal

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and state regulations and to ensure the accurate interpretation and effective implementation of the policies and rules established by the RSC. The RSO is responsible for receipts, uses, transfers and disposal of radioactive materials. Additionally, the RSO is responsible for investigating deviations from approved radiation safety policy such as spills, losses, thefts, variations from approved radiation safety practice, and implementing corrective actions as necessary. The RSO receives direction from the RSC with regard to policy. The RSO provides technical advice to the RSC, radiation users and the administration.

Technical Safety Office (TSO)

The Technical Safety Office is the organizational entity that provides administrative and technical services in support of the radiation protection program. The Director of the Technical Safety Office, who is normally the RSO, reports to the VPR.

Responsible User

A "responsible user" is an individual authorized by the Radiation Safety committee to acquire (via the TSO) and use specific radiation sources and to supervise such use by others. Responsible users are typically the faculty in charge of the research project.

Radiation Users

A "radiation user" is any individual whose official duties or authorized activities include handling, operating, or working in the presence of, any type of radiation source, (sealed, unsealed, machine), whether or not such use is confined to a restricted area.

"Badged personnel" are individuals who may receive more than one tenth (10%) of the occupational radiation dose limit in any calendar quarter. This category includes those personnel who rarely receive more than 100 mrem in any calendar quarter, but who work with radiation sources or radiation producing devices that could produce such a dose under certain conditions. The radiation exposures received by these individuals are individually monitored.

"Potentially exposed" personnel are individuals who have a need to enter *restricted areas* as part of their job description or have a potential of exposure to a radiation source or radiation producing device but do not normally work in the presence of a radiation field. This category includes custodial, receiving and security personnel.

CONCEPTS IN RADIATION PHYSICS

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Atomic structure

The basic particles of the atom:

- Protons
- Neutrons
- Electrons

Only certain combinations of neutrons and protons in the nucleus result in stable atoms; unstable atoms will emit particles or energy to become stable and are referred to as radioactive.

Types of radiation

Radiation is classified as either ionizing or non-ionizing. **Ionization** occurs when enough energy is supplied to an atom and an electron is removed from the atom. The resulting atom will have a positive charge. Non-ionizing radiation includes radiant heat, radio waves, ultraviolet radiation, and light.

Common ionizing radiation includes:

- Alpha particles
- Beta particles
- Photons (gamma-rays and x-rays)
- Neutrons

Only x-rays from radiation producing devices are discussed here.

X-ray radiation

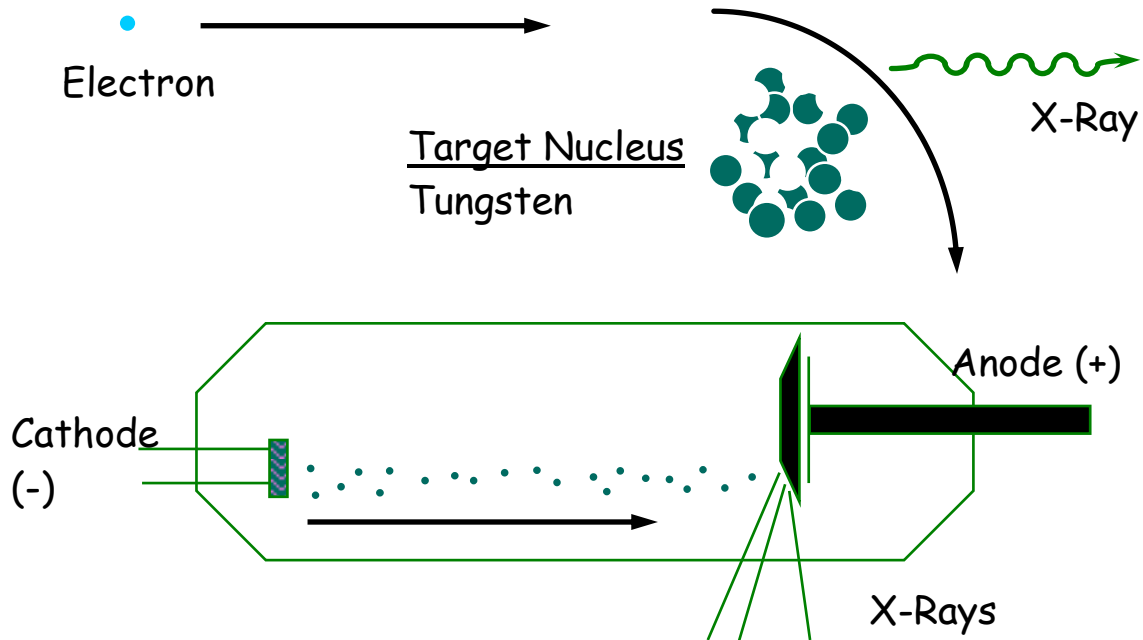
X-rays are generated when energetic electrons strike a target. They result from shell transitions of orbital electrons in the target. They are also formed from the deceleration of electrons interacting with matter (this is known as bremsstrahlung).

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RADIATION GENERATORS

X-ray machine - a device that converts electrical energy into X -ray energy.



QUANTITIES AND UNITS

Dosimetry

Dose and dose rate

- dose is the amount of energy per unit of mass
- dose rate is the dose divided by the time in which the dose is received

Roentgen (R)

- Is the unit of exposure to ionizing radiation and applies only to gamma and x -rays.
- Corresponds to the generation of approximately 2.58×10^{-4} C/kg in dry air at standard temperature and pressure (STP).
- 1R = 1,000 milliroentgen (mR).

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Rad (unit of absorbed dose)

- 1) Is the amount of energy from any type of radiation deposited in the unit mass of any material.
- 2) Measures absorbed dose on different types of material but does not take into account the effect that different types of radiation have on the body.

Rem (unit of dose equivalent)

- 1) Takes into account the energy absorbed in tissue as well as the biological effect on the body that different types of radiation have (dose equivalent).
- 2) 1 rem = 1000 millirem (mrem).

Gray/Sievert

These are the SI unit equivalents to rad and rem

$$1 \text{ Gy} = 100 \text{ rad}$$

$$1 \text{ Sv} = 100 \text{ rem}$$

BIOLOGICAL EFFECTS

Introduction

Since we do not precisely know what the risks are at low levels of radiation exposure, we can only accept the risk associated with working around radiation by comparing it to other daily risks.

The basis of our knowledge of biological effects is due to past studies on:

- Early radiation workers
- Radium dial watch workers
- Accident victims
- Nuclear weapons testing/use
 - a. The survivors of Hiroshima and Nagasaki
 - b. Those exposed accidentally during Bikini Island tests
- Persons undergoing nuclear medicine treatment

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Average estimated days lost due to daily activities

| health risk | days lost |
|-------------------------------|-----------|
| Unmarried male | 3,500 |
| Cigarette smoker (1 pack/day) | 2,250 |
| Unmarried female | 1,600 |
| Coal miner | 1,100 |
| 25% overweight | 77 |
| Alcohol (U.S. average) | 365 |
| Construction worker | 227 |
| Driving a motor vehicle | 207 |
| 100 mrem/year for 70 years | 10 |
| Drinking coffee | 6 |

This next table addresses the estimated days lost of life expectancy due to radiation exposure at radiation-related facilities as compared to other industries.

Average estimated days lost due to daily activities

| health risk | days lost |
|--|-----------|
| Mining | 328 |
| Construction | 302 |
| Agriculture | 277 |
| Radiation dose of 5,000 mrem/year for 50 years | 250 |
| Transportation/Utilities | 164 |
| All industry | 74 |
| Government | 55 |
| Service | 47 |
| Manufacturing | 43 |
| Trade | 30 |
| Radiation accidents (deaths from exposure) | <1 |

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SOURCES OF EXPOSURE

Natural exposure

The average annual radiation dose to a member of the general population from natural radiation sources is about 360 millirem (mrem).

The four major sources of naturally occurring radiation exposures are:

- Cosmic radiation
- Sources in the earth's crust (terrestrial radiation)
- Sources in the human body (internal sources)
- Radon

Medical exposure

X-ray Procedure

Normal chest examination
Normal dental examination
Rib cage examination
Gall bladder examination
Barium enema examination
Pelvic examination

Average Dose*

10 millirem
10 millirem
140 millirem
170 millirem
500 millirem
600 millirem

**Variations by a factor of 2 (above and below) are not unusual.*

Nuclear medicine procedures tend to deliver even higher doses.

Occupational exposure

Any individual whose official duties or authorized activities include handling, operating or working in the presence of any type of radiation source or radiation producing device is a subject to occupational exposure.

TYPES OF RADIATION EXPOSURE

Chronic radiation exposure involves low levels of ionizing radiation over a long period of time. Among the possible effects of chronic exposure are the increased risk of developing delayed somatic effects such as cancer and cataracts. Also, research indicates possible genetic effects in humans from radiation damage to sperm and egg cells. Genetic damage may result in birth defects passed along to future generations.

- **Somatic effect** is the biological effect that occurs on the exposed individual.

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- **Genetic effect** refers to biological changes on the descendants of the exposed individuals due to mutation of their genetic materials.
- **Hereditary effect** is a genetic effect that is inherited or passed onto an offspring.
- **Teratogenic effects** are birth defects, experienced when an embryo or fetus is exposed to **large** doses of radiation. Radiation induced genetic abnormalities have not been identified in human populations. However, they have been observed in less genetically complex species.

Acute radiation exposure is delivered in a short period of time. Larger acute exposures are often associated with deterministic effects. The following possible outcomes can be produced as a result of a large acute exposure:

| | |
|-----------------------|---|
| 25 - 100 rads | <i>Minor blood changes, some illness anticipated</i> |
| 100 - 300 rads | <i>Illness (lowering of the white blood cell count, nausea, bacterial infections, vomiting, loss of appetite, diarrhea, fatigue, hair loss, and possible sterility), at the end of this range death may occur but this is infrequent and would be associated with those individuals undergoing simultaneous physiological stress. These are the classic signs and symptoms of the radiation sickness syndromes.</i> |
| 300 - 450 rads | <i>Anticipated death of 50% of population within 30 days, if medical assistance is not provided. Death caused by complications associated with radiation sickness syndromes.</i> |

When severely exposed, the victim may suffer fever, abdominal pains, explosive diarrhea, internal bleeding, infection, shock, convulsions, coma, and ultimately death. Acute exposure delivering 300 rads and above in a short period of time could possibly produce these outcomes.

Radiosensitivity is a term that describes how sensitive a given cell is to radiation damage. Scientists have found that the rate of mitosis and the degree of cellular differentiation determine radiation sensitivity.

The possible effects that could occur due to radiation exposure to cells are:

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- There is no cell damage
- Cells repair the damage and operate normally and/or cannot reproduce.
- Cells are damaged and operate abnormally.
- The cells die as a result of the damage.

The following cells are considered to be the most radiosensitive because of their reproductive rate:

- Cells of the unborn child.
- Blood and blood producing organs.
- Reproductive cells (sperm/egg).
- Digestive tract cells.
- Immature white blood cells.

Those, which reproduce slowly and are considered the least radiosensitive are nerve, muscle and bone cells. Of course, radiation affects each person differently depending on such factors as total dose, dose rate, type of radiation, the area of body exposed, cell sensitivity, individual sensitivity, age, medical history, and physiological condition.

INDIVIDUAL DOSE LIMITS

Federal and State Authorities establish legal dose limits that an employee should not exceed in a calendar year. Administratively, ISU establishes more conservative values than allowed by Federal and State authorities and the ALARA goals (explained in the next section) are set and self imposed by the ISU Radiation Safety Committee in order to minimize personnel exposure.

"NRC" occupational dose limits

The annual adult (persons 18 years of age or older) occupational dose limit established by the United States Nuclear Regulatory Commission is the more limiting of:

- The total effective dose equivalent being equal to 5,000 mrem (5 rem); or
- The sum of the deep-dose equivalent and the committed dose equivalent to any individual organ or tissue other than the lens of the eye being equal to 50,000 mrem (50 rem).
- An eye dose equivalent of 15,000 mrem (15 rem), and

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- A shallow dose equivalent of 50,000 mrem to the skin or to each of the extremities (50 rem).

"Idaho State University's" Administrative Occupational Dose Limits (legal limits set by ISU)

The annual adult occupational dose limit is the more limited of:

- The total effective dose equivalent being equal to 2,000 mrem (2 rem); or
- The sum of the deep-dose equivalent and the committed dose equivalent to any individual organ or tissue, being equal to 10,000 mrem (10 rem).

ISU's administrative occupational dose limits are far less than the occupational dose limits set by the NRC or the State of Idaho.

"Idaho" Quarterly Occupational Dose Limits (applies to X-ray and accelerator users only)

- Whole body; head and trunk; active blood-forming organs; lens of eye or gonads **1,250 mrem/calendar quarter.**
- Hands and forearms; feet and ankles **18,750 mrem/calendar quarter.**
- Skin of whole body **7,500 mrem/calendar quarter.**

General Public Dose Limits

The dose limit for members of the general public, including all persons who are not classified as radiation users, is a total effective dose equivalent not to exceed 100 mrem per year. The State limit is actually 500 mrem per year, however, we use 100 mrem to be consistent with the Nuclear Regulatory Commission (NRC).

Fetal Dose

The embryo-fetus may be more susceptible to radiation effects than an adult and is, therefore, subject to a lower dose limit. The dose limit for the embryo-fetus is 500 mrem (5 mSv) during the entire gestation period. As a further precaution, this limit should not be experienced in an acute fashion, but rather distributed relatively uniformly during the gestation period if it is to be experienced (Regulatory Guide 8.13). This degree of protection for the embryo-fetus can only be achieved with the cooperation of the employee. It is recommended that she notifies her supervisor or the RSO as soon as the pregnancy is known. In order for a pregnant worker to take advantage of the lower exposure limit and dose

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monitoring provisions, the woman may declare her pregnancy in writing to the TSO. A sample letter for declaring a pregnancy is available on the TSO web page or by clicking [here](#). This notification is optional, and at the discretion of the employee the TSO encourages the act of notification, when appropriate. Unless a woman declares her pregnancy, ISU can not set special dose equivalent limits for her. A sample letter for declaring a pregnancy is available on the TSO web page.

Dose Limits for Minors

The dose limits for minors (persons under 18 years of age) are 10% of the adult occupational dose limits.

ALARA POLICY

Policy

Idaho State University is committed to an effective radiation protection program to eliminate unnecessary exposures to radiation and to reduce all exposures to levels that are **As Low As Reasonably Achievable (ALARA)**, taking into account social and economic considerations. The ALARA principle is a formal requirement of the Idaho Department of Health and Welfare as well as the NRC.

The ALARA principle is implemented by a comprehensive radiation protection program that includes specific requirements and procedures for:

1. training of all radiation users,
2. safety evaluations of proposed facilities or projects utilizing radiation in any way,
3. regular surveys of work areas for exposure rates,
4. monitoring of radiation exposures to groups and individuals,
5. investigations of all exposures that exceed predetermined levels, and
6. reviews of the program by the Radiation Safety Committee.

Idaho State University's ALARA Goals

The ALARA goals for Idaho State University are set by the Radiation Safety Committee. The RSC reviews the University's goal at least annually to verify all exposures at ISU are consistent with the ALARA policy of the NRC.

ALARA Goals for the Radiation Technology Program:

600 mrem/calendar year (150 mrem/calender quarter)

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All Other Radiation Safety Programs:

100 mrem/calendar year (25 mrem/ quarter - notification level).

If an ALARA goal is exceeded, the TSO will perform an investigation. The TSO's investigation is intended to determine if the personnel are following good radiation protection practices and if the ALARA goals are appropriate for the particular activity. Appropriate action will be taken based upon the results of the TSO's investigation.

TRAINING

Each individual working with or in the presence of radioactive materials or other radiation sources is required to receive training or provide documentation showing they have received training, in the applicable provisions of regulations and license conditions, in the potential health problems associated with exposure to radiation, in the precautions and procedures required for safe use of radiation, and in the proper use of protective and measurement devices (10CFR19.12). The extent of the training is to be commensurate with the potential risk of radiation exposure to the individual.

The primary responsibility for providing adequate training for radiation users rests with their responsible users or supervisors. Except for students in regularly scheduled laboratory courses, the responsible user or supervisor will generally fulfill this responsibility by assuring that each person participates in the appropriate training program offered by the RSO.

Following the initial training, each radiation user/responsible user is required to take on-line refresher training annually.

Users of X-ray machines (Radiographic Science students) will receive specific training from Radiographic Science instructors. In addition to the training outlined for normally exposed radiation users, Radiographic Science students must also receive instruction on:

- Effects of machine attributes and usage on patient dose.
- Source and intensity of scattered radiation.
- Proper use of gonadal shielding.
- Placement of dosimeters for monitoring partial-body exposures.
- Proper use of special shielding devices.

Users of analytical X-ray machines, in addition to the training outlined for normally exposed radiation users, must receive instruction on proper use of

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shutters, interlocks and other safety devices, and on the requirement for a safety survey following room re-entry or any machine's modification or repair.

CLASSIFICATION OF AREAS

Controlled Area: Any area, to which access is limited for any reason. X-ray rooms and accelerator rooms are controlled administratively by the personnel who operate the equipment.

Restricted Area: Any area, to which access is limited for the purposes of protecting individuals against undue risks from exposure to radiation and radioactive materials or radiation producing machines. It is an area that is defined by a responsible user for the purposes of working with radioactive isotopes or a radiation producing device. An area must be posted as a Restricted Area if the dose rate is **>2 mrem/hr**. A Restricted Area will have some type of marked or physical boundary so that untrained personnel will be prevented from accessing the area.

Radiation Area: Any accessible area in which an individual could receive a dose equivalent **exceeding 5 mrem in 1 hour at 30 cm** (1 ft) from the source or from any surface the radiation penetrates.

High Radiation Area: Any accessible area in which an individual could receive a dose equivalent **exceeding 100 mrem in 1 hour at 30 cm** (1 ft) from the source or from any surface the radiation penetrates.

Very High Radiation Area: Any accessible area, in which radiation absorbed dose exceeds 500 rad in 1 hour at 1 meter (3.28 ft) from the source or from any surface the radiation penetrates.

POSTING

For rooms containing X-ray machines a "CAUTION X-RAY EQUIPMENT" label should be used.

If any dose rate exceeds 2 mrem in any one hour at 30 cm (1ft.) from an accessible source or surface, the room shall be posted as a "RESTRICTED AREA" to prevent entry of unauthorized individuals. If any dose rate exceeds 5 mrem in any one hour at 30 cm (1ft.) from an accessible source or a surface, the room must be labeled with a "CAUTION RADIATION AREA" sign.

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A "**NOTICE TO EMPLOYEES**", available from the RSO, must be posted where any one entering the lab can see it.

SURVEY INSTRUMENTS

The responsible user shall ensure that instruments used for determining exposure rates are calibrated biannually and capable of responding appropriately to the types of radiation anticipated. The user must know the detection efficiency for each survey instrument and record it with all survey results.

EXTERNAL EXPOSURE

Careful planning of work, good handling techniques and thorough monitoring are all necessary to minimize exposure. Adequate shielding and distance from sources are also important factors in reducing exposure.

Workers can apply three principles to protect themselves from ionizing radiation exposure:

- Time
- Distance
- Shielding

Time

Obviously, the less time a person spends in a radiation field, the less exposure he/she will receive. Keep in mind that exposures to radiation may be additive in their effect.

Methods to minimize time of exposure to a radiation field:

- Preplan the task thoroughly prior to entering the area. Use only the number of people required for the job.
- Have all the necessary tools prior to entering the area.
- Work efficiently but swiftly.
- Do the job right the first time
- Perform as much work outside the area as possible.

Distance

The greater the distance you are from a source the smaller the exposure. Staying away from a radiation source, even a few feet, will greatly reduce worker

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exposure.

Methods to maximize distance:

- Be familiar with radiological conditions in the area.
- During work delays, move to lower dose rate areas.
- Do not hold patients.

Shielding

Shielding places protective materials between the worker and the source; for example, walls, barriers, or protective clothing (i.e. lead aprons).

Proper uses of shielding

- Take advantage of permanent shielding.
- Erect temporary shielding as necessary.

MONITORING OF EXTERNAL EXPOSURE

External exposures are monitored by using individual monitoring devices. These devices are required to be used if the worker is likely to receive an external exposure that will exceed 10% of the allowed annual dose. The most commonly used monitoring devices are:

- Thermo-Luminescent Dosimeter (TLD) - *(modern technology often uses Optically Stimulated Luminescence (OSL) Dosimeters)*
 - Whole body badge
 - Finger ring
- Direct Reading Dosimeter (DRD)
 - pocket dosimeter
 - electronic dosimeter

The whole body badge is worn to measure the exposure to the whole body (i.e., between the neck and the waist). **If lead apron is used, the whole body badge needs to be worn on the collar outside of the lead apron.** The DRDs are worn adjacent to the whole body badge.

Dosimeter use and storage

Dosimetry devices issued from ISU's Radiation Safety Office are used to monitor the exposure that you receive while performing work at ISU only, and cannot be used at any other facility. It is important that they are returned to their proper

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storage location when they are not in use. This ensures that the badges are only recording your exposure from work performed at ISU; it also minimizes the chance of the badges being misplaced or lost.

If you are personally receiving radiation exposure for diagnostic or therapeutic purposes, **DO NOT** wear your dosimeter. Contact the RSO to discuss this situation. Be certain to contact RSO/TSO if you are exposed to radiation at other institutions.

The dosimeters will be picked up and replaced every three months for processing. Personnel that fail to return dosimeters, or fail to return them to their proper storage locations, will be restricted from continued radiological work at ISU.

Temporary Dosimetry

Temporary dosimetry will be issued on a case by case basis only. The professor in charge of the lab or facility will be responsible for the radiological actions of the potentially exposed individual. Temporary badges will not be issued as a vehicle to circumvent training requirements.

RECORDS AND REPORTS

All the records of surveys, measurements and individual monitoring are maintained at the TSO. Records of the doses to individuals are reported, at least annually to the workers in a format required by the NRC (10 CFR 20.2106). If a dose received by a worker exceeds any of the annual dose limits, any occupational exposure will be prohibited for the overexposed individual for the rest of that year (Reg. Guide 8.29).

Upon the request of a former ISU worker, the dose report for the period of time that the individual was engaged in ISU activities will be furnished to the worker (10 CFR 19.13).

If the workers are concerned about safety issues in their workplace, they may request that the NRC conduct safety inspections.

RADIATION EMERGENCY

Any accident, injury or loss of control of a radiation source or radiation producing device that could cause an excessive or uncontrolled radiation exposure to any

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individual is referred to as a radiation emergency. Each user of radiation sources should be familiar with the basic emergency responses listed below and methods for applying them in his or her own work area.

Workers are not permitted to enter rooms with X-ray machines and accelerators while the beam is on. Inadvertent entry into X-ray machine rooms or accelerator rooms is prevented by engineering and administrative controls. All the safety systems must meet **fail-safe characteristics**. This is a design feature that causes beam shutters to close, or otherwise prevents emergence of the primary beam, upon failure of a safety or warning device.

1. Protect People

The first consideration is to assist injured persons and to prevent any further injury. If the situation involves a radiation-producing machine, the machine should be turned off (if it is in your capability). Except for the usual precautions for moving an injured person, individuals should immediately leave the room or area until the extent of the radiological hazard has been evaluated. However, all individuals should remain available in the vicinity until they are checked for contamination and their exposure has been assessed. If you are qualified to render first aid, do so without regard to the presence of radioactivity.

2. Get Help

Each individual using radiation sources or radiation producing devices should know in advance whom to call in case of a radiation emergency. If fire injury or other emergency conditions are involved, first call the appropriate numbers listed on the 1st page of the Campus Directory.

Dial 911 immediately for medical assistance, and report the nature of the illness or injury. Inform the 911 dispatcher that the injured individual may be contaminated with radioactive material (generally not the case for X-ray machines and accelerators).

Next notify the Technical Safety Office at extensions 2310 or 2311 during normal working hours OR notify Public Safety, at 282-2515 during off duty hours. Public Safety will notify the TSO.

When reporting any emergency, be sure to state the exact nature of the emergency then give your name and the phone number from which you are calling, the exact location of the emergency (building, room, nearest entrance, etc.) and the name of the Responsible User, if known. Do not hang up! Let the

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person you called end the conversation after all pertinent information is clearly understood.

3. Contain the Hazard

Any of the following actions appropriate to the situation should be performed provided they can be carried out safely:

1. Turn off radiation producing machines.
2. Close doors to the area and post signs or guards to prevent unauthorized entry.
3. Allow no one to leave the area before someone from TSO has cleared them.

4. Follow-up Action

Any necessary repairs required after a radiation emergency shall be performed only under the direction of the Radiation Safety Officer (RSO) or his designee. Reentry or re-occupancy must be authorized by the RSO. The RSO shall evaluate, record and report, as necessary, any radiation exposures to personnel or damage to radiation facilities resulting from the emergency. If required by the RSO, individuals involved in a radiation emergency shall submit specimens for bioassay, surrender personal clothing or other articles for decontamination or assay, and provide pertinent information.