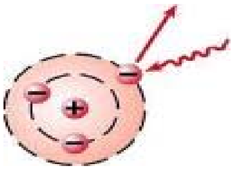
UNIVERSITY OF CALIFORNIA, IRVINE
ENVIRONMENTAL HEALTH & SAFETY
RADIATION SAFETY DIVISION

RADIATION-PRODUCING MACHINE SAFETY

TABLE OF CONTENTS



I. DEFINITIONS

A. **Radiation:** The emission and transport or energy in the form of electromagnetic waves or high-energy subatomic particles. *Not the same thing as "radioactivity", which refers to radioactive atoms that decay and emit radiation.*

B. **Ionizing Radiation:** Radiation that contains enough energy to knock electrons out of atoms. X-rays are a form of ionizing radiation, as are protons, heavy ions and neutrons generated by accelerators. Visible light, ultraviolet radiation, infrared radiation, and microwaves are all forms of non-ionizing radiation.

C. **Photon:** Discrete packets of electromagnetic radiation which travel at the speed of light. X-rays, microwaves, and visible light are all forms of photon radiation; protons and neutrons are not.

D. **X-rays:** Penetrating photon radiation emitted during energy level transitions of inner atomic orbital electrons and when electrons rapidly decelerate as they interact with matter, which is what occurs with x-ray machines. X-ray photon energies are generally given in electron volt units, abbreviated eV, with 1 eV = 1.6 x 10^{-19} joules. *In most cases x-ray energies are in the range of thousands of electron volts, or keV.*

E. **Attenuation:** The reduction in the quantity of radiation during its passage through matter resulting from interactions with the matter.

F. **Useful x-ray beam:** That part of the x-ray radiation that passes through the machine aperture. This is the radiation which is useful for conducting experiments, taking medical or dental x-rays, etc.

G. **Leakage radiation:** All radiation except the useful beam coming from an x-ray machine.

H. **Accelerator:** An electrostatic or electromagnetic device such as a cyclotron or neutron generator which produces high-energy particles or ions and focuses them on a target.

I. **Geiger counter:** Radiation detector useful for x-ray measurements. *[Ion chambers are much less commonly used.]*

J. **Shielding:** Material placed between the radiation source and personnel to reduce their radiation exposure.

K. **Radiation dosimeter:** Device to measure the accumulated dose or radiation.

L. **Radiation Use Authorization (RUA):** Document issued by EH&S authorizing a Principal Investigator to use a radiation-producing machine in his/her lab.

✋

II. ATTENUATION OF X-RAYS

X-rays are absorbed in an exponential manner:

$$\mathbf{I = I_0 e^{-\mu x}}$$

where I_0 is the original x-ray intensity, I is the x-ray intensity transmitted through an absorber of thickness x, e is the base of the natural logarithm system, and μ is the slope of the absorption curve (the linear attenuation coefficient with units cm^{-1}). The linear attenuation coefficient is related to the density of the absorber (μ for lead >> μ for wood). The **half-value layer (HVL)** is the thickness of a radiation absorbing material which will reduce the x-ray intensity by ½ and it is related to μ as follows:

$$\mathbf{HVL = 0.693/\mu}$$

Inserting this expression into the equation above yields:

$$\mathbf{I = I_0 e^{-(0.693x/HVL)}}$$

For a thickness of 2 HVLs, the photon intensity is reduced to 1/4 the original value. For a thickness of 3 HVLs, the photon intensity is reduced to 1/8 the original value, and so on. *A shielding thickness of 7 HVLs is needed to reduce the photon intensity to less than 1% of the original value.* This is a good rule to remember when you need to determine the amount of shielding to use to properly attenuate x-ray radiation.

III. X-RAY DETECTION

The instruments used at UCI to detect x-rays are:

A. Geiger counters

Geiger counters are the most common radiation detector at UCI and they are used to detect ***low levels of x-rays***. They can often be used to provide very rough estimates of x-ray dose rates *(see the relationship between radiation exposure in air and radiation dose in section IV).*

Geiger counters are relatively inexpensive, easy to use, reliable, durable, and very versatile. They are very useful for locating leaks of x-rays through shielding and x-rays scattered from a sample or subject. *{They are also good for measuring gamma radiation resulting from accelerator operations.}*

Before each use, the batteries need to be checked by the operator to ensure that they have sufficient charge. Most GM counters have a simple battery test feature, generally in the form of a button to press or is incorporated into the range adjustment switch. They also often have an audio feature so the quantity of radiation detected can be observed by listening to the instrument's audio output click frequency.

B. Ion Chambers:

Ion chambers are generally used to detect ***high levels of x-rays***; in fact, they are not useful in measuring low x-ray levels. They are frequently more expensive than Geiger counters and can be used to directly quantify the magnitude of an x-ray field as they have a linear response with respect to the x-ray energy, as opposed to Geiger counters which have a non-linear response (over-response at low x-ray energy < 100 keV; approximately linear response above 100 keV).

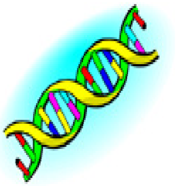
IV. RADIATION EXPOSURE AND DOSE UNITS

A. **Roentgen (R):** Unit of **radiation exposure**. This unit is related to the number of ion pairs produced by x-rays in air. The radiation exposure rate is generally measured in milliroentgens per hour (***mR = 0.001 R/h***). Most GM counters are scaled in units of mR/h only. Ion chambers can handle readings in the R/h range.

B. **Rad (radiation absorbed dose):** This unit is related to the quantity of energy *deposited in a medium* by radiation (1 rad = deposition of 100 ergs of energy per gram of medium). It turns out that if air is exposed to 1 R of x-ray radiation, the equivalent energy deposition dose in the air would be about 0.87 rad. *Thus, radiation exposure rates in R/h are often used to provide close estimates of the expected radiation dose rates in rads/h for penetrating forms of radiation such as x-rays.*

C. **Rem:** unit of **radiation dose equivalent**. The rem includes a quality factor (QF) related to the relative biological damage produced by deposition of a particular form of radiation in tissue. The dose equivalent in rems is equal to the dose in rads multiplied by the quality factor. X-rays have a quality factor of 1 so the dose in rads is equal to the dose equivalent in rems. This is not the case for other forms of radiation such as neutrons, for which the dose equivalent in rems can be 10 times the dose in rads since neutrons are much more densely ionizing than x-rays.

➔ rems = rads x QF

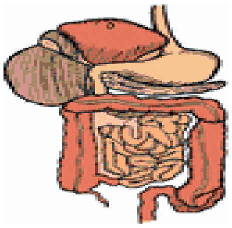


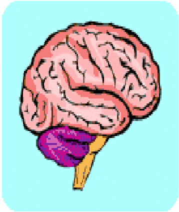
V. BIOLOGICAL EFFECTS OF IONIZING RADIATION

There are two types of exposure to ionizing radiation: a) **acute exposure** -- a single, generally accidental, exposure to a high dose of radiation during a relatively short period of time which produces severe biological effects very soon after exposure; and b) **chronic exposure** -- long-term or repeated exposure to a moderate dose of radiation higher much than the normal background ***(which is on the order of about 200 mrem/y in southern California)***, but much lower than that needed to produce acute effects. The health effects of chronic exposure, if they occur, may not be apparent until many years (often up to 20 years) after the period of exposure.

Some of the major biological effects produced by acute exposures and chronic exposures to **penetrating forms of ionizing radiation such as x-rays** are discussed below. *[Less penetrating forms of radiation, such as alpha and beta particles primarily affect the skin (providing the emitting radioisotopes are not inhaled or ingested), and do not produce many of the effects mentioned here.]*

As a general rule, the most radiosensitive cells in the body are the ones that are the most rapidly dividing such as those in bone marrow, the lining of the gastrointestinal tract, and the gonads. The least radiosensitive parts of the body are the hands and feet, and nerve cells.





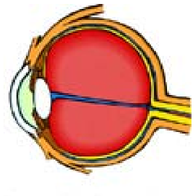
A. Acute effects:

The biological effects caused by very high acute radiation exposures are collectively referred to as the ***Acute Radiation Syndrome***. Radiation-produced changes in blood cell counts are the most sensitive indicator of a high acute radiation exposure. Radiation damages the bone marrow and with time there is a reduction in the circulating blood cells. This is caused by doses exceeding 70 rads with symptoms including anemia and increased likelihood of infections.

At doses above 1000 rads the cells lining the stomach and intestines are affected causing nausea, vomiting and diarrhea.

At doses above 5000 rads there is damage to the neurons in the brain, spinal cord, and in other areas of the body. Symptoms include confusion, unconsciousness, and ultimately death soon after the exposure.

Persons who receive a whole body dose of 400 rads have about a 50% likelihood of death within one month *(the so-called LD 50/30)*, and the likelihood of death climbs steadily with dose rates above 400 rads. ***Fortunately, doses this high have rarely occurred anywhere in the world, and never at UC Irvine, of course!***



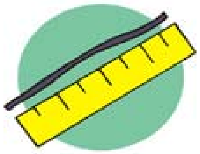
The Human Eye - Cut Away View

B. Chronic and skin effects:

There are several chronic effects that can be caused by long-term or repeated exposure to moderate levels of radiation. Such exposures increase the risk of cancer including bone cancer and leukemia, and cataracts in the lenses of the eye, which means that the lenses become clouded. Radiation exposure of DNA can cause genetic mutations increasing the risk of miscarriage and birth defects.

For low energy x-rays, the skin is exposed to a higher dose than other tissues further inside of the body. An acute dose of 200 rads to the skin can cause inflammation similar to a very severe sunburn (called erythema). Skin cancer can also occur years after the skin receives a very high acute dose, or a chronic skin dose to a moderate level of radiation.

☞ Considering the safety controls employed in labs in which x-ray machines and accelerators are used on the UCI campus, the radiation safety training of x-ray machine operators, and the results of radiation dosimetry monitoring of exposed individuals (very few individuals receive detectable radiation doses while at UCI), ***it is very unlikely that anyone here will suffer any harmful biological effects from exposure to radiation***, providing that the proper radiation safety precautions continue to be followed!!!



VI. METHODS TO REDUCE RADIATION EXPOSURE

A variety of safety features are incorporated into x-ray machines and accelerators to protect the operators, including shielding and interlocks. Caution must still be exercised since occasionally one of these safeguards can fail, but this rarely occurs.

The major goal of Radiation Safety in EH&S is to ensure that all radiation exposures are as low as reasonably achievable, or *ALARA*.

The three primary ways of reducing exposure to radiation are time, distance and shielding. Reducing the time spent operating or working near a radiation-producing machine will decrease the potential for radiation exposure. This does not imply that you should rush through your studies as that can increase the chance of accidents.

The greater the distance from a radiation-producing machine the lower the exposure. As a rough approximation, the radiation exposure drops as the inverse square of the distance from the radiation source. Thus, at 2x the distance, the exposure would be ¼ of the exposure at the original distance $(1/2^2)$.

An easy way of reducing radiation exposure is to place shielding between the machine operator and the source of radiation. Lead is commonly used for x-ray shielding. For low energy x-rays other materials including thick plastic, aluminum, and wood can sometimes be used. Concrete, compacted earth, and iron are often used for accelerator shielding.

A. X-ray shielding:

Shielding for protection against x-rays falls into two categories:

<u>Source shielding</u>

Source shielding is a lead shield that encloses the x-ray tube. This type of shielding is needed to protect against leakage radiation which is all radiation except for the useful x-ray beam.

<u>Structural shielding</u>

Structural shielding is designed to protect personnel from the useful x-ray beam <u>and</u> scattered x-rays. It encloses both the x-ray tube and the space in which the irradiated sample or subject is located. It can be a lead-lined box, shielding in room walls or ceilings, or perhaps plastic or wood shielding placed between the operator and the sample irradiated.

The ***half value layers*** (HVLs) in millimeters of lead required to reduce the intensity of an x-ray beam to 50% of its unshielded intensity (see section II) are shown on the following page for commonly used x-ray tube kilovolt potentials, or ***kVp***, ***which is the operating voltage of the x-ray tube***. Normally a thickness of multiple half value layers is required. Plastic and wood have a density about 10% that of lead, so the thickness of those shields would need to be considerably greater. As previously mentioned, often the recommended shielding for x-rays is 7 half value layers so that less than 1% of the radiation is transmitted through it.

X-RAY HALF-VALUE LAYERS
(Millimeters of lead shielding)

Max. kVp	HVL
50	0.06
70	0.17
100	0.27
200	0.52

B. Accelerator shielding

Ion beam generators and accelerators often produce *secondary x-rays*. The ions or protons accelerated will drag some electrons along with them and when the electrons hit a target or specimen they are stopped rapidly, thus generating x-rays.

Accelerators are commonly placed in ***isolated areas*** to minimize the radiation risk to persons outside of the facility. Since they are often installed in basements below ground level, compacted earth and concrete are frequently used for shielding. Concrete, which is good for attenuating stray neutrons, protons and secondary x-rays, is sometimes used, as is iron.

Some accelerators such as those used in carbon-14 mass spectroscopy analysis emit very little radiation. However, accelerators used in high energy physics studies such as ion beam generators, linear accelerators, neutron generators and cyclotrons can emit very high levels of radiation. In those cases, substantial shielding is a must.

VII. RADIATION DOSIMETRY

Radiation dosimeters are devices that measure the accumulated dose of radiation. The dosimeters used on campus are thermoluminescent dosimeters, or ***TLDs***.

Some people on campus wear TLD body badges to measure their whole body radiation dose. However, many x-ray machine users wear ring badges only as their hands are by far the most likely part of the body to receive a measurable dose. Very few of the badges issued to UCI x-ray machine users ever have measurable doses. *{If significant doses are observed on ring badges, the affected personnel will then be issued body badges, as well. Body badges should be worn at collar level.}*

Not all x-ray machine users at UCI are provided with radiation dosimeters. Those operating cabinet-type machines and some shielded and interlocked x-ray diffraction machines are not provided with dosimetry unless it is specifically requested because measurable radiation doses are very unlikely.

Many accelerator operators do not need dosimetry because of the very low dose rates where they are stationed. Depending upon the type of accelerator used, operators might wear either *x-ray/gamma-ray type or neutron type dosimeters* – or both.

Dosimeters at UCI are issued for 3 month periods. A dosimeter issued at UCI main campus must not be worn at UCIMC which has its own dosimetry program, and it must only be worn by the person to whom it is assigned. When not being worn, all dosimeters must be stored well away from radiation sources since they are intended to measure the dose to the person not to the room!

In some cases *area monitor dosimeter badges* are posted in rooms containing a radiation-producing machine to measure the ambient level of radiation in potentially affected areas as that radiation might impact persons in nearby uncontrolled areas such as offices and conference rooms.

VIII. RADIATION DOSE LIMITS

The Federal government and State of California legal radiation dose limits are shown *(they are identical).* There are much higher dose limits for the hands and skin since they are not as radiosensitive as other parts of the body. EH&S strives to keep doses well below these levels. In fact, nobody who works with radiation-producing machines here comes close to receiving doses this high. As mentioned before, we strive to keep radiation doses as low as reasonably achievable, or ALARA.

LEGAL DOSE LIMITS FOR ADULTS

Category	**Badge Used**	**Limit(rems/year)**
Whole body*	**Body badge**	**5**
Lens of eye	**Body badge**	**15**
Shallow/skin	**Body badge**	**50**
Hands/fingers	**Ring badge**	**50**

IX. RADIATION USE AUTHORIZATIONS

All work with radiation-producing machines on campus must be performed under a ***Radiation Use Authorization (or RUA)*** issued by EH&S to the Principal Investigator responsible for the machine.

A machine RUA will include the type of machine used and its maximum operating parameters [**kVp, mA {beam current}**], the location where the machine is operated, a brief description of the procedures performed using the machine, required safety precautions, and a list of personnel trained and authorized to use the machine.

X. RADIATION SAFETY CONTROLS

There are three main categories of radiation-producing machine safety controls:

A. Engineering safety controls

Engineering controls include ***shielding and warning systems*** installed to prevent over-exposures to radiation. The x-ray head is always shielded, the beam path is often enclosed for some types of machines such as x-ray diffraction machines, and ideally there is shielding in place to absorb radiation scattered by the irradiated sample or subject. *Medical type x-ray machines do not have enclosed beams or shielding for scattered radiation*; for that reason the walls and ceiling of medical x-ray facilities sometimes have lead shielding in them and the operator controls are outside of the room. Accelerator beams are often shielded in iron.

An ***interlock*** is a device for precluding access to an area with a radiation hazard by either preventing entry while the machine is operating or shutting off the machine if entry into that area is attempted. Almost all x-ray diffraction machines and cabinet type machines are interlocked. No interlocks must ever be defeated as that can cause severe safety problems!

Almost all machines have red warning lights to indicate that the machines are in use and radiation is being generated.

Most radiation-producing machines can be locked using a key to ensure unauthorized persons do not attempt to activate them. ***Access to rooms containing the machines must be restricted to authorized personnel only – they need to be locked when nobody is present.***

B. Administrative safety controls

There are a variety of administrative safety controls. All persons who will be operating a radiation-producing machine on campus must receive ***general radiation safety training from EH&S*** such as this course, and ***on-the-job training*** performed by the Principal Investigator or another experienced person in the laboratory. In-lab training needs to be documented on an On-the-job Training form submitted to EH&S (you will be provided with a form when taking EH&S training).

Written ***standard operating procedures*** (SOPs) including all safety-related controls must be prepared and posted for easy access. Sometimes the machine manual will suffice.

Use logs contain entries made <u>every</u> time a machine is used including information such as the operator's name, the date, the procedure performed, operating parameters (kVp, mA) if they vary, and any unusual events.

The doors to all rooms containing a radiation-producing machine must be labeled with a ***"Caution – X-ray" sign or a "Caution - Radiation Area" sign***. In addition, the machine itself has to have a radiation label near its controls ("*Caution – This equipment produces radiation when energized*").

Persons who have a <u>reasonable</u> likelihood of receiving a radiation dose will be provided with radiation dosimeters by EH&S (see section VII).

EH&S performs radiation monitoring when a radiation-producing machine is initially used, after the machine is serviced or moved, during every annual radiation-producing machine safety inspection, and also upon request. If excessive radiation levels are detected, corrective actions are taken before the machine is cleared for further use.

C. Personal protective equipment/controls

In some cases personnel need to be near the x-ray beam or scattered x-rays during procedures. This often occurs with medical x-ray machines when animals are x-rayed, and especially during ***fluoroscopy*** procedures. For those applications **leaded gloves, leaded aprons and leaded eye protection** are very useful in reducing radiation exposure.

XI. TYPES OF RADIATION-PRODUCING MACHINES AT UCI

There are several types of radiation-producing machines in use at UCI. The most common types are x-ray diffraction and cabinet-type x-ray machines. Medical x-ray machines, especially those used in fluoroscopy, can be quite hazardous. There are currently 2 accelerators used at UCI and one X/SPECT machine. ***Electron microscopes and x-ray fluorescence machines are well shielded so they emit little or no leakage radiation and thus are no longer considered to be radiation-producing machines.***

A. X-ray diffraction machine safety

X-ray diffraction machines normally have tube potentials below 60 kVp. After exiting the tube the x-ray beam passes through an open area and then strikes the sample such as a powder or crystal. The radiation is diffracted in a characteristic manner at angles dependent upon the makeup of the sample (***x-ray crystallography***). The diffraction pattern is measured with radiation detectors or by film.

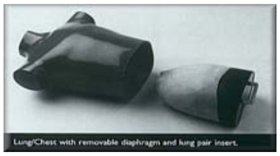
Most x-ray diffraction machines are in shielded, interlocked enclosures. Both “x-ray on” and “shutter open” warning lights are present on the control panel. The primary beam not scattered by the sample is blocked using a radiation-absorbing beam stop. Thick plastic or wood shielding is occasionally used to absorb scattered x-rays.

In most cases, x-ray diffraction machine operators are required to wear ring dosimeter badges.

B. Cabinet x-ray machine safety

Cabinet x-ray machines employ a wide beam of x-rays used for ***high magnification radiography***. Tube potentials are less than 120 kVp. The radiation is contained in a shielded, interlocked box, and there is an "x-ray on" warning light on the control panel. For a cabinet machine to operate, the door to the unit must be secured and a key is needed to operate it. These are simple to operate and are considered to be the safest type of x-ray system. Baggage scanners and mail and package screening systems at airports and post offices are cabinet x-ray machines.

Cabinet-type x-ray machine users are not provided with dosimeter badges.



C. Medical x-ray machine safety

Medical-type x-ray machines are sometimes used in ***biomedical research*** at UCI. They can have tube potentials up to about 150 kVp. The primary beam is normally directed at a human subject, animal subject, or a *phantom*, which is a simulated human torso or head made of tissue-equivalent material. The subject or phantom can scatter a large amount of x-rays producing a sizable radiation hazard in nearby areas.

For film-type machines the operator either leaves the room during shots or stands behind a lead shield in the machine room. During fluoroscopy, such as during cardiac catheter placement, the operator often needs to be relatively close to the subject. For that reason, operators wear leaded aprons and gloves, and in some cases, leaded spectacles. All medical x-ray machines have warning lights and they are generally key-operated.

Most persons who operated medical-type x-ray machines are issued body dosimeter badges. If fluoroscopy is performed, ring badges will be provided, as well.

D. X/SPECT machine safety

X/SPECT machines are used for ***small animal imaging studies***. They can image animals in an x-ray beam via computerized tomography (**CT**), and also have detectors for single photon emission computerized tomography (**SPECT**) in which radiation emitted by radioisotopes previously injected into the animals is imaged.

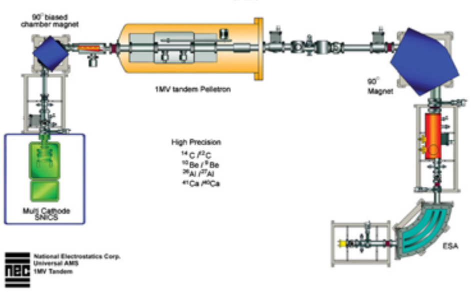
The animal and the radiation - both the x-rays and radiation emitted by injected radioisotopes - are enclosed for the most part by the machine housing. Most of the radiation which escapes from an X/SPECT machine is gamma rays from injected radioisotopes, not the lower energy x-rays.

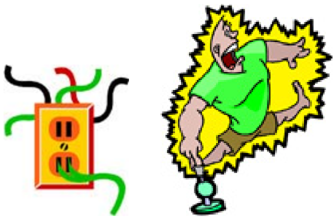
These machines have warning lights and are interlocked. Operators are issued both body and ring dosimeter badges mostly because of exposure to radiation emitted by the radioisotopes involved in the SPECT portion of the studies, not because of the CT x-rays.

E. Accelerator safety

There are 2 types of accelerators in use at UCI. One type is a ***neutralized ion beam generator***, and the other is an ***accelerator/mass spectrometer*** used for C-14 analysis. Both are set up such that the machine operators are distant from areas in which radiation hazards exist. The operator of the ion beam generator stands behind a shielding wall during operation. For the C-14 analyzer, a lockable cage surrounds the hazardous area. Warning lights are used to alert personnel that radiation is generated. Very low levels of secondary x-rays are produced by these systems. The main hazard is the primary accelerated beam, and personnel are not exposed to that radiation.

Operators of the neutralized ion beam generator are provided with body badge and ring badge dosimeters. No dosimetry is required for accelerator/mass spectrometer operators.





XII. ELECTRICAL SAFETY

A. Health effects and safety controls

Since x-ray machines and accelerators are equipped with high voltage power supplies, considerable care must be taken to avoid electric shock. ***Only experienced electrical technicians may repair or service these machines. It is too risky to have untrained persons try to do this work***.

The *physiological responses to electric shock* are shown for both alternating current, or AC, and direct current, or DC. The “let-go current” is that which freezes the muscles so that the person shocked cannot let go of the energized device. At 100 milliamps AC or 500 milliamps DC, death occurs due to heart fibrillation and paralysis of breathing.

Milliamps	**Physiological Effect**
2 (AC), 10 (DC)	Sensation threshold; tingling
10 (AC), 60 (DC)	Let-go current
100 (AC), 500 (DC)	Death; heart fibrillation

Here are some general safety precautions to follow when working with electrical systems. Never handle electrical equipment when your hands, feet or body are wet including from sweat, when standing on a wet floor, or when using a sink. Wear non-conductive rubber-soled shoes or stand on a rubber floor mat.

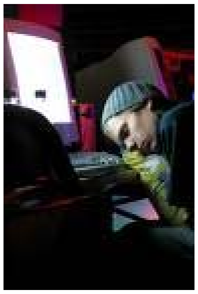
Remove all conductive jewelry and watches. Use one hand only if possible so that if a live contact is touched the current will not flow through your chest from one hand to the other.

Disconnect the power cord whenever possible before opening the protective housing, and remember that capacitors can remain charged well after the cord is unplugged. *Capacitors rated as low as the microfarad range can deliver a painful shock.* ***Ground all electrical equipment and make sure there are no exposed high voltage contacts.*** Report all shocks – no matter how minor – to your supervisor, since any shock can mean the electrical system is defective. ***Never overload circuits or use extension cords or power strips when high voltage equipment is used.***

B. Electrical emergencies

Here are important guidelines you should know related to preparing for and addressing electrical emergencies. Always use the ***buddy system*** by having another person present when you are working on high voltage systems. That way if there is an emergency somebody is available to call 911 and provide life support. This could include the need to perform cardiopulmonary resuscitation, or ***CPR***, so it is good to learn that in advance. CPR classes are offered at the *Anteater Recreation Center*, or ARC.

Work with high voltage equipment only when you are alert and are not taking medications that can affect your ability to concentrate. Always read the appropriate sections of the machine manual before performing the work as specific safety-related information is likely included. ***Have a <u>C-type</u> fire extinguisher available to fight an electrical fire, and <u>never</u> use water for this purpose.*** Fire extinguisher training is conducted by EH&S. Of course, call 911 as soon as possible if someone is seriously injured.



XIII. COMMON CAUSES OF ACCIDENTS

The most common causes of accidents related to the use of radiation-producing machines include:

Not following established safety precautions, such as defeating interlocks; ***not concentrating on the task at hand***; ***failure to train persons adequately*** regarding the safe operation of the machine; ***being complacent*** by thinking that accidents only happen to other people; ***being careless***; ***taking inappropriate shortcuts***; ***being mentally unprepared*** to use a potentially dangerous machine due to fatigue, medication, or illness; and ***failure of a safety system*** such as an x-ray machine interlock. Make every effort to avoid these problems to ensure the safe use of your machine.

Make sure that you use your **common sense and intuition**. If something seems unsafe, seek assistance immediately – do not launch into a potentially unsafe procedure.

XIV. CONCLUSION

Radiation-producing machine use at UCI is very safe as long as you take adequate precautions. Contact your Principal Investigator or EH&S if you have any questions or concerns regarding the safe use of your machine.

Thanks for taking the Radiation-producing Machine Safety Course!