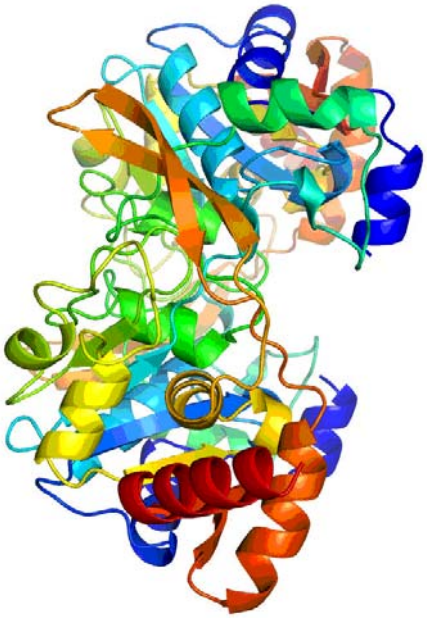
MANUAL FOR USERS OF

RADIATION-PRODUCING MACHINES

(*X-ray crystallography of anthrax courtesy of the University of Virginia Health System*)



University of California, Riverside
Department of Environmental Health and Safety
Radiation Safety

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Introduction

This manual assists University personnel in using radiation- producing machines in accordance with current standards of good practice, and the relevant state and federal regulations. Radiation- producing machines only produce radiation when energized. The types of Radiation-Producing Machines used on the UCR campus include X-ray diffraction units, electron microscopes, particle accelerators, E-beam evaporators, and dental/medical x-ray machines.

Campus Policy on the Use of Radiation-Producing Machines

It is the policy of UCR to implement a Radiation Safety program that maintains the level of exposure to students, faculty, staff and the public "As Low As Reasonably Achievable" (ALARA). The purpose of the radiation safety program is to protect health and minimize the risk to life, property and the environment in the use of ionizing radiation during research, instruction and service.

The Radiation Safety Committee and the Radiation Safety Officer are authorized by the Chancellor to limit, suspend, or revoke an individual's authority to use sources that produce ionizing radiation if such use is immediately dangerous to the life and health of individuals or violates health and safety codes.

Organization and Responsibility

Chancellor

According to the UCR Policy on Environmental Health and Safety, the Chancellor is responsible for the existence of a radiation safety program that will maintain compliance with relevant local, state, and federal regulations. The Chancellor has delegated responsibility for development/ operation of the radiation safety program to the committees, departments, and individuals.

Radiation Safety Committee (RSC)

The RSC is a body of faculty and other experts appointed by the Chancellor to establish policies and procedures governing the use of ionizing and non-ionizing radiation at UCR to maintain surveillance over activities involving them and to report on the status to the chancellor. Surveillance activities include but are not limited to review/ approval of use applications and review of EH&S Radiation Safety operations.

Environmental Health and Safety (EH&S)

Environmental Health and Safety (EH&S) implements the radiation safety program. This program includes surveillance of all users of radiation-producing machines and equipment. Specific functions include: monitoring of exposure levels, investigation of incidents, safety consultation, training in radiation safety, radiation safety services, and management of radioactive wastes.

Director of Environmental Health and Safety

The EH&S Director is an ex-officio member of the RSC responsible for the review of UCR policies on radiation and radiation safety.

Radiation Safety Officer (RSO)

The RSO is responsible for developing and operating the radiation safety program, for assuring that radiation uses are in conformance with UCR policies and applicable government regulations, and for referring matters to the RSC requiring its review and approval. The RSO is a full voting member of the RSC.

Principal Investigator (PI)

PI is the individual who has applied for and received an authorization from the Radiation Safety Committee to use Radiation-Producing Machines. Each PI is responsible for ensuring that the laboratory environment is safe for use by laboratory personnel and in compliance with local, state, and federal regulations, and the conditions of the Radiation Use.

GENERAL PROCEDURES FOR ALL USERS OF RADIATION-PRODUCING MACHINES (RPM)

Instructions for Obtaining Authorized User Status for Use of Radiation-Producing Machines

- The application as well as the process for applying for authorization to use Radiation-Producing Machines at UCR has been updated.

- The application can be found on the UCR website under radiation safety.

- Please call the RSO to find out the date of the next Radiation Safety Committee (RSC) meeting. **The completed application is to be returned EH&S Radiation Safety no later than 2 weeks prior to this date.** The Radiation Safety Officer will contact you to inform you if the package seems acceptable or if specific changes are necessary.

- First-time applicants at UCR will be required to meet with the RSO to discuss the application in more detail as well as to perform an initial review of your laboratory space. The RSO will contact you to arrange an appointment at mutual convenience for you.

- When any needed changes are complete, the application is put on the agenda for the Radiation Safety Committee meeting. You will be informed immediately of the Committee's decision, which may require that you incorporate some minor corrections. If so, these are to be made in the final version of the proposal, since the proposal will be used in your laboratory to provide detailed directions to personnel who use the machine it authorizes. Upon receipt of the final proposal by the RSO, a letter of approval will be sent to you authorizing use the radiation-producing machine.

Guidance to the Applicant

Project summary
The project summary is written for the purpose of obtaining approval for Radiation-Producing Machines. What is expected is described in the following section:

- A brief statement of the purpose of the experiment
- A description of the machine (type of machine, manufacturer, model, year of manufacture, maximum and usual energy, and beam current)
- A description of the facility and any required safety interlocks/ devices
  NOTE: For machines that are manufactured commercially and equipped with engineering controls that will effectively contain the radiation that is produced, provide a copy of the manufacturers specifications and drawings for review.
- Shielding requirements (if necessary)
- PPE that will be used during the experiment
- How the machine will be secured from unauthorized access.
- Survey requirements (if necessary)
- Dosimetry requirements (if necessary)
- *Sample copy of the Use Log.

***The Use Log should include the name of the user, description of use and date of use, Also, if there were any problems/malfunctions, this should be noted as well along with the corrective action along with a record of routine service performed on the machine.**

A copy of the application can be found on our website by clicking on:
http://www.ehs.ucr.edu/radiation/

Training Requirements

Training

All users of Radiation-Producing Machines (RPM) including the Principal Investigator must attend a new lab worker training session that is given by EH&S Radiation Safety. Annual retraining is not required for users of RPM **only**. Training must include the following topics:

a) A description of ionizing radiation
b) Radiation effects
c) Radiation exposure limits
d) Potential exposures related to the work being done
e) Methods to reduce exposure
f) Special radiation monitoring methods/ techniques, if required
g) A description of pertinent Federal, State, and local regulations
h) An introduction to the radiation safety program at UCR (see "UCR Radiation Workers Guide")
i) Required notices, signs, warnings, and labels
j) Operating procedures for the equipment being used
k) Reporting and dealing with high/ over exposures

Exemptions from Training

Only state-certified dental/medical technicians, Doctors of Dental Surgery, and physicians are exempt from taking the new lab worker training.

Site-Specific Training

In addition to the general training, each user must undergo site-specific training, which is equipment-specific. This training is given by the PI for each piece of equipment. This training should include a demonstration of the proper use of the equipment (operation of all controls, safety interlocks, and the proper start-up and shut-down procedures). The individual should also be instructed on what to do in the event of an equipment malfunction. Site-specific training must be documented and available for review by Radiation Safety.

Site-specific training should be done if a new unit is purchased, or an existing unit is modified (i.e., primary beam direction change, or shielding modification). Documentation of site-specific training is required and must be maintained by the PI. This documentation should include the following information: Worker's name, employee/student ID number, date of training, topics discussed, and worker's signature.

You can sign up for training by clicking on the following link:
http://ehs.ucr.edu/training/index.html

GENERAL PROCEDURES FOR ALL USERS OF RPM (cont'd)

Purchase/Transfer/Disposal of RPM

EH&S Radiation Safety must register all Radiation-Producing Machines (RPM) with the State of California, Radiologic Health Branch within 30 days after initial operation. This requirement can be met only if EH&S Radiation Safety is notified immediately when a new machine is acquired.

Purchase of RPM

The appropriate information must be e-mailed to the RSO as soon as the equipment is purchased and no later than 60 working days before the equipment arrives. Information should include the manufacturer of the equipment, the model number, the serial number, and the date of purchase. UCR is required to notify the State of California Department of Health Services (CDHS) of any equipment added to our registration.

External Transfer of RPM

An e-mail should be sent to the RSO 30 days prior to the equipment being transferred. Information should include the manufacturer of the equipment, the model number, the serial number, and the date of the transfer, as well as the name of the institution that is receiving the equipment. UCR is required to notify the CDHS of any transfer of RPE that is under our registration.

Internal Transfer of RPM

If the individual is a PI, an e-mail should be sent to the RSO prior to the transfer. Information should include the manufacturer of the equipment, the model number, the serial number, building and room number of the new location, the date of the transfer, as well as the name of the PI that is receiving the equipment. The PI receiving the machine must complete the new lab worker training if he/she has not already done so.

Departing UCR

Notify EH&S ten (10) working days prior to leaving the University. It is the responsibility of the PI to ensure that all RPM is either disposed of or transferred to another PI prior to leaving UCR.

Disposal of RPM

E-mail the RSO prior to disposal of x-ray equipment. Information should include the manufacturer of the equipment, the model number, the serial number UCR is required to notify the CDHS of any disposal of RPM that are under our registration.

GENERAL PROCEDURES FOR ALL USERS OF RPM (cont'd)

Dosimetry

Radiation-Producing Machines must be used according to the instructions provided by the manufacturer and recommendations by EH&S Radiation Safety. In all cases machines must be used such that the radiation exposure to operators and individuals in surrounding areas is as low as reasonably achievable and does not exceed the limits specified in the UCR Radiation Safety Manual.

CDHS Annual Dose Limits

Whole body	5,000 mrem
Shallow (skin, hands, feet)	50,000 mrem
Lens of eye	15,000 mrem
Fetus during gestation	500 mrem

Dosimetry Requirements for Different Types of RPM

Individuals that use electron microscopes and other self-contained low kV/mA machines are not required to wear a badge.

Body Badge required: *Particle Accelerators, Industrial Radiographic and dental and medical units.

Ring Badge required: *Particle Accelerators

A ring and body badge is required for x-ray diffraction units if the user performs an alignment with the interlocks defeated and the beam exposed.

*Personnel will be required to wear neutron dosimetry as well as a bubble dosimeter. Contact Radiation Safety at 951-827-5528 if you have any questions.

Obtaining a Badge

Badges are obtained by going to the EH&S website and filling out the dosimetry form Click on the link: http://ehs.ucr.edu/forms/dosimeter.html to access this form.

Badge Exchange Frequency

Badges are exchanged monthly or when an accidental exposure in excess of regulatory limits is suspected. Badges are to be returned promptly at the end of each

cycle to assure the Radiation Safety Office can take timely action, consistent with implementation of ALARA (As Low As Reasonably Achievable), in the event any significant dose is measured.

GENERAL PROCEDURES FOR ALL USERS OF RPM (cont'd)

Lost or Damaged Badges

Report lost or damaged badges (crushed, broken, melted, washed, accidentally exposed, contaminated, heated in any way, etc.) to Radiation Safety as soon as you are aware of the situation so that a new badge can be issued.

Pregnant Workers

Any radiation worker who is pregnant, or thinks she may be pregnant, may declare herself a Pregnant Worker by calling Radiation Safety and completing a Declaration of Pregnancy Form. Declaration of pregnancy is voluntary. Counseling will be provided and an additional dosimeter will be issued which is exchanged every month. This additional fetal badge is worn such that any dose to the developing baby is conservatively measured.

Proper Use and Care of Dosimeters

- The whole body badge shall be worn between the neck and waist. If, however, one area of the body is more likely to be exposed than the rest, the badge should be worn in that area.

- The front of the badge must be exposed toward the source of radiation, with no obstruction, such that it correctly samples the actual exposure of the radiation worker.

- The badge shall be worn outside of any personal protective equipment (e.g. apron or laboratory coat).

- Extremity badges (ring badges) should be worn under any protective gloves on the hand most likely to receive the greatest exposure. The front of the ring badge should face toward the radiation source.

- Badges are issued to a single user and shall not be shared.

- Store the badge in a radiation-free area, such as a desk drawer, when not in use. Do not take the dosimeters home.

GENERAL PROCEDURES FOR ALL USERS OF RPM (cont'd)

RPM Records and Record Keeping

Changes in RPM and/or Personnel

Monthly Update
Each month the individual who is responsible for a radiation producing machine must submit the monthly report to EH&S Radiation Safety. This form is sent to each PI at the beginning of each month. Any changes in personnel as well confirmation of machines currently on your inventory must be noted on this form.

RPM Status Classes at UCR

RPM can exist in two status classes:

Active: The equipment is assembled and functional.

Inactive*:* The equipment is not assembled but may be assembled and made functional without the use of tools.

The equipment is assembled but is not in use

Radiation Safety must be notified immediately of any RPM status change.

RPM Audits

Audits of all RPM are performed by EH&S Radiation Safety on an annual basis.

The following records should be made available for inspection:

- A list of all RPM authorized operators
- Notices of any transfers, installations, and disposals
- Documentation of RPE site-specific training
- RPM Use log
- Operating procedure(Must be made available in the immediate work area to all users

GENERAL PROCEDURES FOR ALL USERS OF RPM (cont'd)

General Posting Requirements for all RPM

A "Notice to Employees" (Form #RH-2364) posted at appropriate locations

A copy of specific operating procedures posted at or near each unit.

Warning signs as appropriate

Typical warning signs for RPM

Labeling of machines that are in storage

In addition to being locked out (either at the main switch or at the plug), these machines must be tagged with a notice posted indicating that the machine cannot be moved or used without clearance from Radiation safety. The notice posting can be obtained from Radiation Safety or can be made yourself. There is no specific wording requirement.

Safety Procedures for RPM

Surveys

Surveys are performed by Radiation Safety:

- Upon installation of a new piece of equipment.
- Following any change in the initial arrangement, number, or type of local components in the system.
- Following any maintenance requiring the disassembly or removal of a local component in the system.
- During the performance of maintenance and alignment procedures if the procedures require the presence of a primary x- ray beam when any local component in the system is disassembled or removed.
- If any changes in shielding, operation, or equipment could produce a greater radiation hazard than before.
- Any time a visual inspection of the local components in the system reveals any abnormal conditions.
- Whenever personnel monitoring reports show an unexplained increase over the previous monitoring period, or the readings are approaching the dose limits specified in 10 CFR 20.1201.

Safety Procedures for RPM (cont'd)

Safety and Security Requirements for all RPM

Personal Protective Equipment (PPE)

In general, personal protective equipment (leaded aprons, gloves, and goggles are useful only for low energy, less than about 100 kVp, x-ray sources. Recognizing this limitation, personal protective equipment should be used to protect any part of the body that may be exposed by a primary x-ray beam or whenever the exposure can be reduced significantly by their use, but not in place of other required engineering controls. Other than the voluntary use of PPE, all uses must be approved by EH&S Radiation Safety.

Safety Devices

Federal, State and local regulations require that many radiation producing machines have specified safety devices or features. In addition, EH&S Radiation Safety may specify safety features to address the specific use of the machine at UCR. Required safety devices/ features include:

a) Fail -safe warning lights
b) Fail- safe interlocks
c) Beam enclosures
d) Shielding/ shielding interlocks
e) Radiation survey meters
f) Radiation area monitors
g) Viewing windows

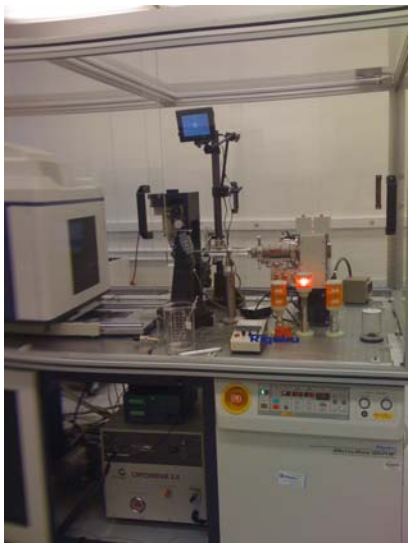
All required safety devices must be maintained in working order, and must not be replaced or modified without specific approval by EH&S Radiation Safety. No safety device is absolutely fail-safe or foolproof and should act only as a back-up, not as a replacement for proper procedures.

Safety devices must never be purposely defeated. If the design of a safety device makes a desired/ necessary operation inconvenient or impossible, an alternate safety device/ method must be developed that provides the same degree of protection as the original. Modified safety devices/ methods must be approved by EH&S Radiation Safety prior to operation of radiation producing machine. When safety devices are modified it may be necessary to modify existing operating procedures and to retrain operators. If a required safety device fails, the machine must not be operated until it is repaired and subsequently checked by EH&S Radiation Safety. EH&S Radiation Safety must be notified immediately if an unexpected personnel radiation exposure occurs or is suspected.

Machine Security

As a general safety precaution, and to allow security during unattended operation, it may be desirable to dedicate an entire room or area that can be secured to a radiation producing machine. When this is not possible/ desirable the machine should be placed in an area out of the main traffic flow and away from high occupancy areas. Unless confined/ limited by other means, primary beams must be intercepted by a primary barrier and limited such that personnel cannot be irradiated by them. Scatter/ secondary radiation must be controlled such that the radiation exposure is as low as reasonably achievable but in no case greater than the limits specified in this manual. With the exception of mobile x-ray and dental units, any change in location of a radiation producing machine must be approved by EH&S Radiation Safety.

Requirements for the safe use of X-ray Diffraction Units



Enclosed-Beam System

In an enclosed-beam system, all possible x-ray paths (primary and diffracted) are completely enclosed so that no part of a human body can be exposed to the beam during normal operation. Because it is safer, the enclosed-beam system should be selected over the open-beam system whenever possible.

The x-ray tube, sample, detector, and analyzing crystal (if used) must be enclosed in a chamber or coupled chambers. The sample chamber must have a shutter or a fail-safe interlock so that no part of the body can enter the chamber during normal operation.

The dose rate measured at 2 inches (5 cm) from the outer surface of the sample chamber must not exceed 0.25 mrem per hour during normal operation.

Open-Beam System

In an open-beam system, one or more x-ray beams are not enclosed, making exposure of human body parts possible during normal operation. The open-beam system is acceptable for use only if an enclosed-beam system is impractical for any of the following reasons:

a need for making adjustments with the x-ray beam energized,
a need for frequent changes of attachments and configurations,
motion of specimen and detector over wide angular limits, or
the examination of large or bulky samples.

An open-beam x-ray system must have a guard or interlock to prevent entry of any part of the body into the primary beam. Each port of the x-ray tube housing must have a beam shutter with a conspicuous shutter-open indicator of fail-safe design.

The dose rate at 2 inches (5 cm) from the surface of the source housing must not exceed 2.5 mrem per hour during normal operation.

Important Things to Remember When Using an X-ray Diffraction Unit:

a) All individuals using a unit must have documented training to use the specific equipment.

b) Follow approved, written operating procedures.

c) Establish a "Use Log" that is available for review.

d) Using an appropriate survey instrument, monitor radiation exposures at the time of initial operation and when modifications are made.

e) Wear appropriate radiation monitoring devices.

f) Required/ appropriate warning lights and other safety devices must be in place and operational.

g) Required/ appropriate radiation shielding must be installed on each x-ray diffraction unit. Required shields should be interlocked to prevent radiation exposure to personnel if the shield is removed or displaced.

h) All beam shutter mechanisms must be interlocked to prevent operation if the shutter is not properly closed.

i) Post required notices and radiation warning signs

j) Report unusual events/ exposures to EH&S Radiation Safety.

Requirements for the safe use of Electron Microscopes

Generally, electron microscopes present little risk of significant radiation exposure if they are not modified or damaged and if the manufacturers operating instructions are followed.

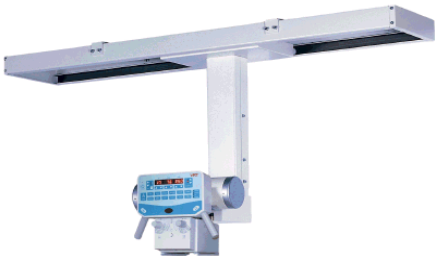
a) Follow the manufacturer's operating instructions

b) Stop operation and notify your supervisor if equipment is damaged (cracked windows) or if operating parameters are not within acceptable limits

c) The radiation exposure limits for electron microscopes must not exceed 0.5 mR/hour at 2 cm from the surface

d) Unless specified otherwise by EH&S Radiation Safety, radiation exposure monitors are not required for personnel who work with electron microscopes.

Requirements for the safe use of Medical Radiographic Machines (Dental and Medical)



Most of the man-made, non-occupational radiation exposure received by the general population is during routine medical radiographic procedures. To satisfy the regulatory requirements related to medical radiography and to minimize the radiation exposure received by patients and workers during medical radiographic procedures, it is essential to comply with the following requirements/ safety practices:

a) All x-ray equipment must satisfy appropriate requirements of federal, state and local regulations

b) Shielding of x-ray rooms must satisfy appropriate requirements of federal, state and local regulations

c) An "X-Ray On" warning light must be at each entrance

d) Post operating/ safety instructions must be near the equipment console

e) Patient radiography can be performed only when prescribed by a licentiate of the healing arts recognized by the State of California as a "Certified Supervisor/ Operator"

f) Patient radiography can only be performed by a radiologic technologist certified by the State of California

g) Equipment must be checked according to requirements of the State of California Radiation Control Regulations

h) Personnel working with radiation must wear personnel monitors

i) Only essential individuals can be in the x-ray room during the production of x-rays

j) Any individual required in the room during the production of x-rays must wear a leaded apron of at least 0.25 mm lead equivalent, or stand behind an approved protective barrier

k) If a patient must be held, the best choice is a non-pregnant parent or relative of the patient. Occupationally exposed individuals must not hold patients during x-ray exams, except in an emergency

l) Any individual who holds a patient during an x-ray examination must wear a leaded apron (at least 0.25 mm lead equivalent) and, if the hands are likely to be in the primary beam, leaded gloves (at least 0.50 mm lead equivalent)

m) Lead aprons, gloves, and other protective devices should be inspected once every six months to detect cracks and breaks in the shielding and should be replaced immediately if defects are found

n) Collimate the x-ray beam to the area of interest, but no larger than the film size

o) The technologist should inquire if a female patient is pregnant, particularly if the primary beam is likely to intercept the uterus

p) Exposure of pregnant females should be avoided particularly if the beam is likely to intercept the uterus

q) Use gonadal shielding if the reproductive organs are in the primary beam and if the shield will not interfere with the diagnostic information needed

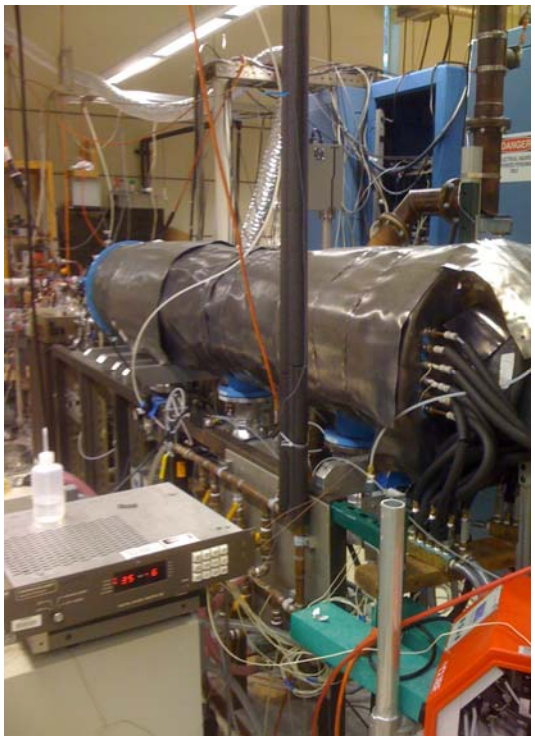
Requirements For The Safe Use Of Cabinet Radiography Units

By nature, cabinet radiography units present little risk of significant exposure if the shielding is not modified, if interlocks and warning lights operate properly, and if users follow approved operating procedures.

a) Unless approved by the Radiation Safety Committee the radiation exposure at a distance of 2 cm from the surface of a cabinet radiography units must not exceed 0.5 mR/hour

b) The necessity/ desirability for radiation dosimetry at each cabinet radiography unit will be determined by EH&S Radiation Safety.

Requirements for the Safe Use of Particle Accelerators



A particle accelerator uses electrostatic or electromagnetic fields to increase the speed (energy) of electrically charged particles or electrons and to direct the charged particles to a target. This interaction can produce ionizing radiation, which is generated when the primary beam is activated. In addition, ionizing radiation may be produced by interactions between the beam and the materials in the path of the beam, such as targets and enclosures and may cause addition exposure hazards. Neutron radiation may also be generated.

All Particle Accelerators should have an interlock system and all controls must be clearly identified**.**

An assessment will performed by EH&S Radiation Safety to ensure that dose rates do not exceed the annual dose limits for radiation workers and dose limits to the public. This will require the presence of area monitors that are located in the vicinity of the accelerator. Users will be required to wear a bubble dosimeter as well as a neutron badge. All dose readings obtained for the bubble dosimeter should be recorded and available for inspection by EH&S radiation safety. A sign will be posted outside the room indicating that the accelerator is in use and that entry to the room is prohibited.

If the accelerator contains a Faraday cup, a no-entrance “High Radiation Area” should be designated 1 meter from the cup.

The Radiation Safety Officer should be consulted on any planned addition or change of any materials potentially subject to 1.5MeV bombardment.

Beamline or Radiofrequency Quadrupole (RFQ) parts should be surveyed by the laboratory staff using a Geiger counter.

If the accelerator is to be disposed or transferred to another investigator outside of UCR, the accelerator as well as the room containing the accelerator must be decommissioned by an outside contractor due to the presence of potential activation products and air contaminants.

Regulatory References

Title 17 of the California Code of Regulations (17CCR) section 30253

10CFR 20.1101

OSHA Bulletin SHIB 07-31-2009