INTRODUCTION

X-ray producing equipment is used in a variety of teaching and research applications. The university is required to regulate and supervise all activities associated with this type of equipment in order to protect health and safety. These procedures will specify university policy regarding the procurement, operation, maintenance, and use of x-ray producing equipment as required by WAC 246-228.

AUTHORIZATION

The Radiation Safety Committee must be notified, in advance, about procurement or modifications of existing x-ray equipment. Anyone who plans to fabricate, purchase, rent, lease, borrow, dispose of or accept a gift of x-ray equipment must immediately notify the Radiation Safety Officer (RSO) of the Environmental Health & Safety (EH&S) Department at least six weeks prior to the scheduled acquisition of the equipment. The following information must be provided at this time:

1. Current location and ownership of the equipment.
2. Description of the equipment.
3. Operation characteristics of the equipment.
4. Proposed location, including safety features already present and those planned for completion before arrival of the equipment [include visual aid if possible].
5. Proposed operator(s) and expertise required to operate the equipment.
6. List of personnel to be involved with the operation and maintenance, including background experience and training plus proposed future training.

The RSO will notify the Washington State Department of Health (DOH) within 30 days of receipt, transfer or disposal of any radiation machine. The RSO will renew registration of all radiation machines as required by the DOH.

Approval to operate x-ray equipment must be obtained from the Radiation Safety Committee. Approval is specific to the machine, location and user(s). The RSO must be notified of changes in personnel, machine location, and of machine repair or modification. EH&S must perform a brief survey of the machine after any of the aforementioned actions are performed in an effort to comply with regulations. Prior approval from the Radiation Safety Committee is required for all changes.

SAFETY

The authorized x-ray equipment user should be familiar with the regulations and specific hazards of their equipment.

1. Dosimeters
   Assigned dosimeters must be used when working with open beam x-ray generating equipment. Dosimeters not in use must be stored away from the machine or any other radiation source. Badges should be worn on the chest, belt or collar, and finger rings should
be worn in the position most likely to be exposed to radiation. A personal dosimeter must never be intentionally irradiated.

2. Safety Devices

Safety Devices such as warning lights, beam enclosures, interlocks, shielding and radiation survey meters are required for some x-ray equipment. All safety devices must be maintained in good working order. No safety device is absolutely fail-safe or fool-proof and nothing is more important than caution and good work practices. The function of a safety device is to act as a back-up, rather than a replacement for proper procedure.

Exposures have occurred when one operator has tampered with a safety device while the next user relied on it. Therefore, no user is allowed to override a safety device without prior approval from the Radiation Safety Committee. If a required safety device fails for an unknown reason, the machine must not be operated until it is repaired and checked by the RSO.

3. Posting and Labeling

All radiation-producing machines must be prominently labeled as such. In most cases an additional labeled warning device is required, which indicates when x-rays are being produced. It is recommended that safe operating procedures be posted near the equipment. The area or room with x-ray producing equipment must be posted with the appropriate caution sign.

4. Location

X-ray producing equipment should be located in an area that is not in the main traffic pattern of the laboratory or near other continuously occupied work areas. A room devoted solely to x-ray equipment is desirable, since it can be locked when not in use or during unattended operation. The machine must be situated so that scatter or stray beams will be directed away from the operator and toward an unoccupied area, preferably an outside wall.

5. Monitoring

Radiation survey meters are required for use of many x-ray producing machines. The survey meter must be appropriate for the type of radiation encountered. Since most equipment emits low-energy x-rays, a thin window probe is usually required. Metal window probes will not respond to x-ray energies of less than 50 keV. The probe should be small enough to fit into cramped areas without disturbing delicate machinery.

Personnel must be trained in the operation of monitoring equipment and make frequent use of it. A list of the users and their dates of training must be kept on file in a conspicuous area of
the lab. X-ray equipment will be surveyed at monthly intervals, as long as the machine has been in use within 30 days. A daily use log which will include the date, time in, time out and name of the user must also be maintained. If the machine is not going to be used for more than 30 days, the machine is to be unplugged and/or records of un-use must be provided in the daily use log. If the machine cannot be unplugged between extended periods of use, a monthly survey must be performed to ensure the machine and all safety features are still functional.

6. Procedures
A safe operational procedure is well thought out, and makes use of built-in safety devices and careful technique. Each authorized user must carefully analyze and plan new procedures prior to carrying them out. Written operating and safety instructions must be prepared.

7. Non-radiation Hazards
Often, hazards other than radiation are associated with x-ray machines. X-ray generators usually have a high voltage supply; such units must have a written “lock out/tag out” procedure (as required by WAC 296-24-980).

In some cases, lead shielding is added to reduce scatter radiation. Such material must be permanently mounted so as not to pose a danger from falling. In many cases, when only very low energy x-rays are emitted, shielding may be made from light materials such as Lucite.

8. Emergencies
If any personal radiation exposure that is higher than normal is suspected, the RSO must be notified immediately and an Incident Report form must be completed and submitted to EWU EH&S at 101 Huston Hall. Procedures, machine parameters and configuration must be carefully noted and preserved so that the incident may be later recreated with radiation measuring devices in place. In the case of highly collimated beams, personal dosimeters may not give an accurate account of maximum radiation dose to the affected body. Hand or ring dosimeters, however, can give a good indication of whether or not an exposure to the beam occurred.

X-RAY DIFFRACTION MACHINES

Diffractometers usually put out a highly collimated x-ray beam with energies of 25 to 50 kVp with characteristic peaks from 5 to 17 keV. The primary beam is the most hazardous element, with a dose rate on the order of $10^5$ rem/minute near the port. After the beam strikes the sample, the diffracted beam may be directed at any angle with intensity up to 100 rem/hr. Scatter of the primary beam off the sample holder, beam stop, etc., may be as high as 10 rem/hr.
Several types of warning systems are required which indicate whether the tube is activated and if the shutters are open. Usually the system must be enclosed inside an interlocked chamber, although some operations are permitted with an accessible beam. A beam stop which fully attenuates the primary beam must always be in place, and should be located as close to the port as possible. Users must double check lead glass windows on powder cameras and alignment ports to make sure they are in place.

In the event that the beam path must be entered, the machine should be non-operational and powered down. The voltage and current indicators must be checked each time. An open-beam configuration must never be left unattended. Never trust automatic shutters or beam enclosure interlocks. It is recommended that the beam enclosure be in place at all times when the tube is on and safety glasses must be worn at all times. Ordinary lenses can attenuate low-energy x-rays by a factor of 5-10. Whenever a system is changed or realigned, radiation scatter should be checked with a survey meter. Leakage from the side of the shutter collimator area is common and is usually directed toward the operator. Wide beam collimators are especially prone to scatter. TLD ring dosimeters are required for all operators of such equipment.

**POTENTIAL HEALTH EFFECTS**

In general, the largest portion of low energy x-rays will be absorbed by the skin and eyes. Depending on individual sensitivity, doses as low as 500 REM may cause skin reddening and discomfort within a few hours. However, this effect may be delayed several days. There is always a delay before effects occur at doses less than several thousand REM. Regeneration of skin usually occurs with doses less than several thousand REM, but with larger doses the underlying tissue is affected and scar tissue is formed. Doses larger than 4,000 REM usually cause some permanent damage and the tissue may not heal at all.

Eyes show similar effects at the doses mentioned above. Several thousand REM produces enough damage for loss of sight. An exposure of 500 REM can also cause formation of cataracts. The most probable delayed effect of x-ray exposure is cancer production in 10 to 30 year. It has not been established whether there is a throughout dose for cancer production. An increase in tumor probability has been shown for doses larger than 100 REM.

The early effects described above are more likely to occur if the radiation is delivered in a very short time. Higher levels of exposure are needed to produce the same effects if the exposure is received at lower levels over a long period of time. Delayed effects, however, are much less dependent on dose rate.

Typical x-ray tubes operated at 30-50 kVp can generate dose rates of over 100,000 REM/minute. Radiation skin damage can occur at doses as low as 500 REM and delayed effects can be caused by much lower doses. Exposure to the direct beam for even a fraction of a second can be very serious. Call the EWU EH&S Department at 359-6455, if there are any questions or concerns.