



X-Ray Safety Policies and Procedures

General Considerations

Research and medicine uses many types of x-ray equipment including analytical, medical, dental, fluoroscopic, veterinary, cabinet systems and electron microscopes. All radiation generating devices such as x-ray machines must be registered with the Radiation Safety Services (RSS). The device is registered by obtaining a Permit issued by RSS. This Permit specifies the Authorized User, usually a Faculty Member, use restrictions and approved machine operators. All operators, except for electron microscope users, must register with RSS and receive training before using any x-ray equipment. Training and permitting is required to ensure that the user is aware of the hazards posed by the high radiation intensities of these beams. While these device produce a large amount of radiation in a small diameter beam, it is readily shielded and protected from causing human exposure. The common x-rays used in diffraction and fluorescent x-ray spectroscopy are in the range of 0.5 to 10×10^{-1} m. With this low energy or wavelength, the intensity of these x-rays can be easily reduced by a factor of ten with a thickness of only a few mm of Al, Fe, or Pb. This is the principle that is used to create the common Cu Ka x-ray used in x-ray crystal radiography. It is the ability of these radiations to be readily absorbed in tissue that poses the for radiation safety problems, especially because of the intense beam; see Biological Effects of Acute Radiation Exposures below.

Regulations vary according to the type of x-ray equipment. As a result, guidance is given by machine type below. RSS will classify the equipment at the time of permitting to determine the regulatory and safety requirements.

1. Analytical X-Ray

The predominant x-ray-producing equipment used in research is analytical x-ray. It produces intense beams of low-energy x-rays. Exposure to the direct beam can cause severe injury. To prevent exposures, newer instruments are designed with hood enclosures, interlocks and beam shielding to minimize the risk of inadvertent exposures. It is possible that the radiation exposure rate from the primary beam can be up to 40,000 Roentgen per minute. With this high exposure rate, the hazard is not limited to the primary beam, but can also be related to leakage or scatter radiation. As result, these x-ray machines should not be modified without the authorization of RSS. A radiation survey should be done whenever a new sample is placed in the beam, the beam is diffracted, experimental setup changed or equipment is replaced. The analytical x-ray machines usually have a low energy that can be readily shielded with about 1 mm of lead. Due to the intensity of the primary beam, leakage and scatter may create a significant source of unwanted radiation. Use shutters and collimators, secure unused ports, reduce the beam cross-section by collimation, and whenever appropriate enclose the entire beam path or use a sufficient beam stop. Consider additional sources of x-rays from miscellaneous support equipment such as high-voltage supplies.

Dosimetry

All equipment operators are required to wear ring and whole body dosimeters. While equipment is designed to keep exposures to a minimum it is possible that unusual events such as the alignment for sample manipulation could lead to inadvertent exposures. These operations should never be attempted without appropriate safety precautions.

Laboratory Safety

Training

All users must attend RSS Radiation Users Training Session and must also be provided specific written instructions by the Permit Holder before using the equipment. These instructions include notice of radiation hazards; machine specific safe work practices; and symptoms of acute, localized exposure to radiation.

Postings

The following document should be placed near the controls of each analytical x-ray unit and readily accessible to the operator:

- Specific written instructions
- Analytical x-ray Emergency Procedure
- Symptoms of Injury from Acute Local Exposure to Radiation
- Radiation Hazards from Analytical x-ray Units
- Safe Working Practices for Analytical x-ray

Labels

Analytical x-ray equipment will be posted and labeled with:

- A label bearing the words "Caution Radiation This Equipment Produces Radiation When Energized" near the tube activation switch.
- A sign "Caution High-Intensity x-ray Beam," next to each tube-head. The sign must be clearly visible to any person operating, aligning, or adjusting the unit or handling or changing a sample.
- A posting on the exterior side of the room's doors indicating the presence of x-ray producing equipment such that visitors to the lab will see the sign.

Indicators

All x-ray machines will contain an operational and clearly visible indicator of an active x-ray beam near the x-ray tube. In addition, there must be a shutter status indicator that unambiguously reports if the shutter is open or closed.

Interlocks and Safety Devices

Operational interlocks and safety devices will be provided to ensure that the primary x-ray beam cannot be interrupted by any portion of an individual's body or extremities or by machine equipment under any operating condition. If the beam is interrupted, this interlock will shut off the primary beam. Interlocks and safety devices may not be altered without the written authorization of RSS. Approved temporary modifications must be terminated as soon as possible, specified in writing and posted near the x-ray machine tube and operators console. Securely close any unused tube ports to prevent accidental opening.

Analytical X-Ray Emergency Procedure

If there is a suspected or actual case of accidental radiation exposure, turnoff the system power and notify RSS immediately. If required, exposed individuals should go to the University Health Services Urgent Care Clinic to seek medical attention.

See the [**X-Ray Diffraction/Fluorescence General Safety Checklist**](#).

Biological Effects of Acute Radiation Exposures

With a properly functioning machine, there is little risk of radiation exposure. However, one should know the signs of an acute exposure to a localized area of the human body. These symptoms are shown in Table 1. Be aware that these effects can be caused by contact with the beam for only a fraction of a second. Typical primary beam exposures are 100,000 to 400,000 rad per minute. The most common effects from a large radiation exposure from an x-ray device is reddening of the skin (erythema). With a dose of a few hundred rem the superficial layers of the skin are damaged and the skin will redden in a fashion similar but more complex than a sunburn. The erythema effect will most often reverse itself within a few weeks. It is also possible that doses on this level could damage cell division and temporarily stops hair growth and possibly causes the hair to fall out. With a low enough dose, hair growth should return. There could also be damage to the sebaceous glands that produce the skin oil, which could cause a temporary decrease in the amount of oil produced. There are other less common and less transitory responses. If a large area is exposure to a large amount of radiation, there could be changes in the skin pigmentation. This effect may not be reversible and could result in permanent skin changes. If the exposure is large the transitory damage to the skin, skin hair, or sebaceous glands could cause skin scarring or lead to Radiation Dermatitis, Chronic Radiation Dermatitis, or radiation induced skin cancer. To protect yourself from the radiation consider the following potential sources of radiation exposure:

1. The primary beam.
2. Primary beam leakage from poor shielding or guide tube replacement.
3. Beam penetration through stops and shutters.
4. Secondary radiations from beam interaction of the primary beam with the sample or shielding.
5. Radiation released from the diffraction of the beam.
6. Radiation produced from support equipment such as power supplies.

Table 1 Acute Local Radiation Exposure Symptoms	
<u>Received Dose</u>	<u>Symptoms</u>
200 - 300 rad to the skin	Erythema (redness of the skin). The area may turn red within two to three weeks after the exposure depending upon dose. Epilation (hair loss) is possible within two to three weeks.
1000 - 5000 rad to the skin	Wet or dry blisters within one to two weeks of exposure that usually break open and are subject to infection. Epilation may be permanent.
Over 5000 rad to the skin	Severe transepidermal injury that resembles intense scalding or chemical burn with the immediate onset of pain. Epilation is permanent.
Above 200 rad to the eye	There may be conjunctivitis (inflammation of the eye). It is possible that chronic exposures may lead to cataract formation.

Safe Working Practices for Analytical x-ray Equipment

Beam Alignment

1. Wear a finger dosimeter.
2. Whenever available, use electronic alignment.
3. Use long handles on the fluorescent alignment screens.
4. A trained and qualified user should only do an alignment.
5. If safety locks must be bypassed, first gain RSS approval and then post a sign indicating the safety switch status. Reinstate the safety switch as soon as possible.
6. Use the lowest power settings possible for beam alignment procedures.

Sample Changing

1. Ensure the x-ray beam is inactive by using a radiation detector.
2. Use the shutter to stop x-rays. Verify shutter activation that the shutter indicator is properly reporting shutter status.

General Operation

To ensure the safety of users and visitors of x-ray equipment, follow the safe-use requirements in the x-ray Diffraction/Fluorescence General Safety Protocol.

2. Cabinet x-ray Systems

A cabinet x-ray system is a x-ray system where the x-ray tube is enclosed in a structure that contains the irradiated material, provides radiation shielding, and excludes people.

Operating and Emergency Procedures

Since cabinet x-ray systems are designed to exclude people, they are exempt from many of the regulations that apply to other x-ray devices. However, these devices must be registered with RSS through a Permit ([link to Permit Application](#)) and have written operation and emergency procedures that are approved by RSS. These devices must follow the guidance listed in 'x-ray Cabinet General Safety Protocol'.

These documents must specify:

1. User training.
2. Use records and records maintenance.
3. Security of the x-ray system when not in use.
4. Biological effects of ionizing radiation (refer to **Table 1**).
5. Radiation hazards associated with the x-ray system.
6. Safety practices.
7. Procedure for notifying proper supervisory personnel in the event of an emergency and instructions to obtain medical assistance.
8. Maintenance and repair procedures.
9. Dosimetry requirements

See the [X-Ray Cabinet General Safety Checklist](#).

3. Electron Microscope Systems

An electron microscope system is a x-ray system where the x-ray tube is enclosed in a structure that contains the irradiated material, provides radiation shielding, and excludes people.

Each microscope shall bear the following labels:

- Place a label bearing the words "Caution--Radiation--This Equipment Produces Radiation When Energized" near any switch that energizes a tube.
- Place a sign with the words "Caution--High-Intensity x-ray Beam," adjacent to each tube head so it is clearly visible to anyone operating, aligning, or adjusting the unit or handling or changing a sample.

Operating and Emergency Procedures

Since electron microscopes are designed to exclude people, they are exempt from many of the regulations that apply to other x-ray devices. However, these devices must be registered with RSS through a Permit and have written operation and emergency procedures that are approved by RSS. These devices must follow the guidance listed in 'Electron Microscope General Safety Protocol'.

These documents must specify:

1. User training.
2. Use records and records maintenance.
3. Security of the x-ray system when not in use.
4. Biological effects of ionizing radiation (refer to **Table 1**).
5. Radiation hazards associated with the x-ray system.
6. Safety practices.
7. Procedure for notifying proper supervisory personnel in the event of an emergency and instructions to obtain medical assistance.
8. Maintenance and repair procedures.
9. Dosimetry requirements.

See the [Electron Microscope General Safety Checklist](#).

Email radiation_safety@harvard.edu to send comments and suggestions to Radiation Safety Services.