
Analytical X-Ray Safety Program

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Applies To: Employees, Students, Others

For More Information contact: EHS, Radiation Safety Manager at 860-486-3613

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I. Purpose

The purpose of the Analytical X-Ray Safety Program is to specify the requirements for analytical x-ray producing equipment utilized for diffraction, scattering, or fluorescence measurements at the University of Connecticut and to ensure safe operation and compliance with State and Federal regulations.

II. Scope

The Analytical X-Ray Safety Program describes the requirements applicable to all x-ray producing devices, equipment supervisors, faculty, staff, students, and any users whose work involves the use of analytical x-ray equipment at the University of Connecticut.

III. Policy Statement

Analytical x-ray producing equipment in the possession of the University of Connecticut is subject to registration with the State of Connecticut and other applicable state and federal regulations. The University of Connecticut Radiation Safety Office must be notified of the possession of such equipment prior to utilization to ensure registration of the device and the completion of a safety survey and audit by Radiation Safety staff. The Radiation Safety Office must also be notified in advance of the acquisition, purchase, transfer, move, or disposal of analytical x-ray equipment. Individuals in charge of the installation (Equipment Supervisors) and all equipment operators shall be familiar with applicable operating procedures and regulations governing the x-ray installation and complete the University of Connecticut required training prior to equipment use.

IV. Enforcement

Violations of this policy program may result in appropriate disciplinary measures in accordance with University Laws and By-Laws, General Rules of Conduct for All University Employees, applicable collective bargaining agreements, and the University of Connecticut Student Conduct Code.

The University of Connecticut Radiation Safety Officer is empowered by the Radiation Safety Committee to immediately terminate the operation of analytical x-ray equipment found to be a threat to health, safety, or property until the violation is corrected.

V. Definitions

ALARA (As Low As Reasonably Achievable): The University of Connecticut is committed to keeping exposures to radiation ALARA. This means that every reasonable effort shall be made to maintain radiation exposures as far below the dose limits as practical, taking into account the state of the technology, the economics of the improvements in relation to the benefits, and other socioeconomic considerations.

Fail-safe characteristic: a design feature that causes beam port shutters to close upon failure of a safety or warning device.

Safety device: a device which prevents entry of any portion of the individual's body into the primary x-ray beam path or which causes the beam to be shut off upon entry into its path shall be provided on all open-beam configurations.

Local component: a part or areas of an analytical x-ray system that are struck by x-rays during operation. Examples of such components include radiation source housings, port and shutter assemblies, collimators, sample holders, cameras, detectors, and shielding but do not include power supplies, transformers, amplifiers, readout devices, and control panels.

Normal operating procedures: step-by-step instructions necessary to accomplish the analysis. These procedures shall include sample insertion and manipulation, equipment alignment, routine maintenance, and data recording procedures, which are all related to radiation safety.

Open beam system: an analytical x-ray system in which an individual could accidentally place some part of his/her body into the primary beam path during normal operation. An analytical x-ray system is considered to be an open-beam system unless the requirements for an enclosed beam system outlined in Section VII of this document are met.

Primary beam: the radiation that passes through an aperture of the source housing by a direct path from the x-ray tube or a radioactive source located in the source housing.

VI. Analytical X-Ray Equipment Acquisition, Registration, and Tracking

Prior to acquiring, purchasing, or moving analytical x-ray equipment, the equipment supervisor should complete and submit the University's Equipment Form found on the Environmental Health & Safety (EHS) website. The Radiation Safety Officer (RSO) should be notified in advance to assess the intended space in advance to ensure minimum requirements are met.

All analytical x-ray equipment purchases made by the University of Connecticut (UConn) through the University's Quali Financial System (KFS) must be done by using the EHS Restricted Equipment code and be registered with the State Department of Energy and Environmental Protection (DEEP) through EHS. In general, the x-ray equipment supervisor must be full time faculty or staff of UConn. If an analytical x-

ray unit is obtained from another source it must also be registered with EHS upon acquisition, prior to use.

Analytical x-ray units are registered with the State by notifying the RSO. The RSO will then arrange to meet with the x-ray unit supervisor to obtain the information needed to complete the registration process.

The x-ray supervisor or designee must notify the RSO prior to moving, transferring, or disposing of a unit. The RSO will provide further instructions regarding the required forms and/or procedures to be followed. For disposal or transfer of an analytical x-ray unit through University Surplus, the x-ray supervisor must notify the RSO in advance of the pick-up or transfer and comply with the procedures and associated documentation specified on the University's Surplus website. Equipment should not be transferred to Surplus until the RSO has been notified and formally released the unit for proper disposal. These requirements must be met to officially remove the unit from the State DEEP registration.

VII. Equipment Requirements

A. REQUIREMENTS FOR AN ENCLOSED BEAM X-RAY SYSTEM:

1. The radiation source, beam paths, sample, detector and/or other devices e.g. analyzing crystal, filters, etc. shall be enclosed in a chamber, coupled chambers, beam pipes, whole system enclosure, etc. that cannot be entered by any part of the body during normal operation.
2. The inherent shielding of the chamber/enclosure walls shall be sufficient to limit the dose rate in all regions 5 centimeters (cm) from its outer surface to 0.25 mrem/hr during normal operations.
3. The system enclosure, sample chamber, etc. closure shall be interlocked with the x-ray tube high voltage supply and/or a shutter in the primary beam so that no x-ray beam can enter the sample chamber while it is open unless the interlock has been consciously and deliberately defeated. The interlock shall be of fail-safe design.
4. If there is more than one port in the radiation source housing or more than one radiation source, all requirements must be satisfied for each port in every source housing associated with the system.

B. SAFETY DEVICES

An analytical x-ray equipment supervisor may apply for an exemption from the requirement of a safety device if compliance with the requirement is not

feasible. The application shall be submitted to the University of Connecticut's Radiation Safety Officer for review and shall include the following:

1. A description of the various safety devices that have been evaluated;
2. The reason each of these devices cannot be used; and
3. A description of the alternative methods that will be employed to minimize the possibility of an accidental exposure, including procedures to assure the operators and others in the area will be informed of the absence of safety devices.

An exemption is dependent upon review and formal approval from the University of Connecticut's Radiation Safety Officer. The x-ray equipment shall not be utilized until approval of the exemption.

C. WARNING DEVICES

An open-beam configuration shall be provided with a readily discernible indication of:

1. X-ray tube "on-off" status located near the radiation source housing, if the primary beam is controlled in this manner; and/or
2. Shutter "open-closed" status located near each on the radiation source housing, if the primary beam is controlled in this manner.

An easily visible warning light labeled with the words "X-RAY ON", or words having similar intent shall be located near any switch that energizes an x-ray tube and shall be illuminated only when the tube is energized.

Warning devices shall be labeled so that their purpose is easily identified. The warning devices shall have fail-safe characteristics.

D. PORTS

Each port on the radiation source housing must satisfy all the requirements related with the system, and shall be equipped with a shutter that cannot be opened unless a collimator has been connected.

Unused ports on radiation source housings shall be secured in the closed position in a manner that will prevent casual opening.

E. LABELING

All analytical x-ray equipment shall be labeled with a readily discernible sign or signs bearing the radiation symbol and the words:

1. "CAUTION - HIGH INTENSITY X-RAY BEAM", or words having a similar intent, on the x-ray source housing; and
2. "CAUTION RADIATION - THIS EQUIPMENT PRODUCES RADIATION WHEN ENERGIZED", or words having a similar intent, near any switch that energizes an x-ray tube if the radiation source is an x-ray tube; or
3. "CAUTION - RADIOACTIVE MATERIAL" or words having a similar intent, on the source-housing if the radiation source is a radionuclide.

F. SHUTTERS

On open-beam configurations, each port on the radiation source housing shall be equipped with a shutter that cannot be opened unless a collimator or coupling has been connected to the port.

G. RADIATION SOURCE HOUSING

Each radiation source housing shall be subject to the following requirements:

1. Each x-ray tube housing shall be equipped with an interlock that shuts off the tube if it is removed from the radiation source housing or if the housing is disassembled.
2. Each radioactive source housing or port cover or each x-ray tube housing shall be so constructed that, when all shutters are closed, the radiation measured at a distance of 5 cm from its surface is not capable of producing a dose in excess of 2.5 mrem (0.025 mSv) in any one hour. For systems utilizing x-ray tubes, this limit shall be met at any specified tube rating.

H. GENERATOR CABINET

Each x-ray generator shall be supplied with a protective cabinet that limits leakage radiation measured at a distance of 5 cm from its surface such that it is not capable of producing a dose in excess of 0.25 mrem (2.5 μ Sv) in any one hour.

VIII. Area Requirements

A. RADIATION LEVELS

The local components of an analytical x-ray system shall be located and arranged and shall include sufficient shielding or access control such that no radiation levels exist in any area surrounding the local component group which could result in a

dose to any individual that may be present therein in excess of the dose limits specified in applicable University of Connecticut, state, and/or federal regulations. For systems utilizing x-ray tubes, these levels shall be met at any specified tube rating.

B. RADIATION SURVEYS

The Radiation Safety staff shall perform radiation surveys of all analytical x-ray systems sufficient to demonstrate compliance:

1. Upon installation of the equipment, and at least once every 12 months thereafter. Annual radiation measurements shall not be required if the Radiation Safety staff can demonstrate compliance with applicable state and/or federal regulations;
2. Following any change in the initial arrangement, number, or type of local components in the system;
3. Following any maintenance requiring the disassembly or removal of a local component in the system;
4. During the performance of maintenance or 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;
5. Any time a visual inspection of the local components in the system reveals an abnormal condition; and
6. Whenever a personnel monitoring device shows a significant increase over the previous monitoring period or the readings are approaching the limits specified in applicable University of Connecticut, state, and/or federal regulations.

Radiation Safety staff shall be notified immediately when the designated laboratory supervisor of analytical x-ray equipment becomes aware of any of the above conditions. The equipment shall not be utilized until Radiation Safety demonstrates compliance with these requirements.

If the laboratory has a survey meter, it must be maintained by Radiation Safety and should be kept near the equipment at all times so that the operator may perform casual surveys frequently. It should never be assumed that another operator or a service person left the equipment in a safe condition.

C. Posting

Each area or room containing analytical x-ray equipment shall be conspicuously posted with a sign or signs bearing the radiation symbol and the words "CAUTION - X-RAY EQUIPMENT" or words having a similar intent.

IX. Operating Requirements

A. Procedures

1. Normal operating procedures should be provided by the laboratory supervisor for the analytical x-ray equipment and made available to all analytical x-ray equipment workers. No individual shall be permitted to operate analytical x-ray equipment in any manner other than that specified in the procedures unless such individual has received written approval directly from the University of Connecticut's Radiation Safety Officer.
2. The radiation producing equipment supervisor shall ensure that a usage log is maintained for each x-ray producing machine. An entry shall be recorded on the usage log for each time the equipment is utilized. A period of use is defined as a consecutive period of time when x-rays are being generated. At a minimum, the following information shall be recorded for each period of use:
 - a. Operator Name
 - b. Date
 - c. Start Time
 - d. End Time
 - e. X-Ray Unit Make, Model, and Serial Number
 - f. Equipment Supervisor
 - g. Operating Parameters (voltage and current)
3. The equipment supervisor shall utilize either key control or other administrative controls in order to prevent unauthorized use of the x-ray equipment.
4. Additionally, when the x-ray unit is unattended, steps shall be taken to prevent entry to the x-ray beam.

B. BYPASSING

No individual shall bypass a safety device or interlock unless such individual has obtained prior approval from the University of Connecticut's Radiation Safety Officer. Such approval, if granted, shall only be made for a specified period of time. During the approved time that the safety device or interlocks are bypassed,

a readily discernible sign bearing the words "SAFETY DEVICE NOT WORKING", or words having a similar intent, shall be placed on the radiation source housing.

C. REPAIR OR MODIFICATION OF X-RAY TUBE SYSTEMS

Most severe injuries have occurred during non-routine operations such as repair and alignment. Alignment procedures recommended by the manufacturer of the x-ray system shall be utilized if available. Otherwise, alignment procedures should be developed and maintained by the equipment supervisor.

Except as specified in the section pertaining to bypassing, no operation involving the removal of covers, shielding materials, or tube housings or modifications to shutters, collimators, or beam stops shall be performed without ascertaining that the tube is off and will remain off until safe conditions have been restored. The main switch, rather than the interlocks, shall be utilized for routine shutdown in preparation for repairs.

If the entire system, including the x-ray tube, is under one contiguous vacuum, and radiation leakage is less than 0.25 mrem/hr at 5 cm, and a change in any part of the system will not increase the radiation level, then the entire system shall be considered to be an enclosed beam system.

D. RADIOACTIVE SOURCE REPLACEMENT, TESTING, OR REPAIR

Radioactive source housings shall be opened for source replacement, leak testing, or other maintenance or repair procedures only by individuals authorized to specifically conduct such procedures under a license issued by the U.S. Nuclear Regulatory Commission (NRC) or the applicable Agreement State.

X. Personnel Requirements

A. TRAINING

No individual shall be permitted to operate or maintain analytical x-ray diffraction or spectrographic equipment until such individual has received an acceptable amount of training in radiation safety as approved by the University of Connecticut's Radiation Safety Officer (RSO) as follows:

1. All users must successfully complete the online [X-Ray Safety Training \(HuskyCT\)](#) found on the EHS website; and
2. All users and non-users must complete the required laboratory-based training conducted by the laboratory supervisor.

Competence as to the following must be demonstrated by users prior to operating analytical x-ray equipment:

1. Identification of radiation hazards associated with the use of the equipment;
2. Significance of the various radiation warning, safety devices and interlocks incorporated into the equipment, or the reasons they have not been installed on certain pieces of equipment and the extra precautions required in such cases;
3. Proper operating procedures for the equipment;
4. Recognition of the symptoms of an acute localized exposure; and
5. Proper procedures for reporting an actual or suspected exposure.
6. Standard procedure to use a survey meter, if applicable to the laboratory.

Radiation Safety training and/or experience completed at another university and documented with the University of Connecticut's RSO may be sufficient to fulfill a portion(s) of the initial training requirements.

B. PERSONNEL MONITORING

To monitor exposures and to ensure adherence to ALARA practices, whole body and extremity dosimetry devices shall be provided to and utilized by:

1. Analytical x-ray equipment workers utilizing systems having an open-beam configuration and that are not equipped with a safety device; and
2. Personnel maintaining analytical x-ray equipment if the maintenance procedures require the presence of a primary x-ray beam when any local component in the analytical x-ray system is disassembled or removed.
3. Other individuals needing personnel radiation monitoring as determined by the operator's management and the University of Connecticut's Radiation Safety Officer based on regulatory requirements and exposure potential.
4. No dosimetry device is required for routine users of an enclosed beam system.

XI. Responsibilities

A. SUPERVISOR

The supervisor or person in charge of the equipment is responsible for informing Radiation Safety of analytical x-ray equipment in their possession, the development of standard operating procedures, the evaluation of needs, and adherence to policies with respect to radiation protection. They shall be responsible for the working conditions and for the instruction of all persons

working in the area regardless of radiation hazards and methods of control. They shall also be responsible for carrying out all specified instructions and maintaining prescribed operating conditions.

All shields, interlocks, and other safety devices shall be inspected periodically and appropriately serviced. Defective shielding shall be promptly repaired and the inspection shall be repeated to determine the original degree of protection has been restored. If there is doubt about the adequacy of the repair, the Radiation Safety Officer shall be consulted.

Additionally, the equipment supervisor shall ensure that adequate medical surveillance and radiation monitoring of personnel are carried out as necessary. If performed, a medical examination should pay particular attention to the eyes and to the skin of the hands and face.

B. OPERATOR

Each operator of x-ray diffraction or spectrographic equipment shall be responsible for all operations associated with that equipment, including radiation safety. In particular:

1. The operator shall, upon the instruction of Radiation Safety staff and/or responsible supervisor, follow the recommendations and instructions that have been developed in the interest of radiation protection.
2. Each worker shall utilize the protective devices and radiation dosimetry provided. If the University of Connecticut's Radiation Safety Officer provides dosimetry to a worker, it shall be worn by the operator during x-ray equipment use and stored in an appropriate location in the laboratory when not in use. The dosimetry devices must be replaced with new badges at the frequency established by the Radiation Safety Committee.

A dosimeter badge shall be worn at the proper height. Both dosimeter badges and/or film rings shall be worn facing the radiation source.

If an area monitor is assigned to an x-ray unit, it shall remain on the unit at all times and may only be removed to switch out with a new dosimeter provided by Radiation Safety. Dosimeters being switched out must be sent back to Radiation Safety in a timely manner.

3. Each worker shall bring to the attention of the laboratory supervisor in charge any defect or deficiency in radiation protection devices, procedures or x-ray equipment function.

Each worker shall inform the Radiation Safety Officer of known or suspected abnormal radiation exposures to themselves or others.

4. Each worker shall keep radiation exposures to themselves and others ALARA.
5. Each operator shall be familiar with all radiation safety requirements for x-ray producing equipment and be familiar with the safety procedures as they apply to the machine he/she operates.

XII. Emergency Procedures

Should an accident occur with the x-ray beam or a non-beam hazard related to the analytical x-ray equipment, the following outlines the proper procedures.

- a. Immediate Response and General Procedures for all X-Ray Beam and Non-Beam Accidents
 1. All accidents involving an injury from an x-ray beam or a non-beam hazard at the University of Connecticut, no matter how minimal, requires a report of the injury. Injury reporting requirements are found at: <http://www.payroll.uconn.edu/> under Workers' Compensation, equipment supervisor and employee responsibilities. Filing a completed [First Report of Injury form \(Form WC 207\)](#) and the equipment supervisor calling the injury in to the injury report line is what generates the claim number (within 24-48 hours). For questions, contact:

Tiffanie Klick
Workers' Compensation Administrator
University of Connecticut
Payroll Department
343 Mansfield Road U-1111
Storrs, CT 06269-1111
860-486-2279 telephone
860-486-6510 Fax or Main Payroll Fax 860-486-4296

2. If an individual suspects they have received an x-ray beam exposure or other non-beam injury, they should first seek immediate medical attention without delay.
3. When possible, close the x-ray beam shutter and/or turn off the x-ray system.
4. If there is a fire, pull the fire alarm, evacuate the building and contact 911.
5. The equipment supervisor of the injured individual(s) should be notified to ensure action is taken to prevent any further injury to other personnel.
6. After the initial reporting of the incident, the equipment supervisor shall notify the Radiation Safety Officer (RSO) at the first opportunity during EHS Radiation Safety's normal working hours (M-F 8:00 AM – 4:00 PM) at 860-486-3613 or after hours by contacting the Public Safety Dispatch at 860-486-4925.
7. Do not resume x-ray unit operations without RSO approval.

If a local radiation exposure is suspected, equipment operations shall be immediately terminated, the laboratory equipment supervisor shall be notified and the Radiation Safety Officer shall be notified at 860-486-3613. If a radiation emergency occurs after regular working hours, the Radiation Safety Officer may be contacted through the University of Connecticut Storrs Campus Police Dispatch at 860-486-4800.

Arrangements may be made to receive a medical examination by Student Health Services for students or UConn Health at Storrs Center for employees. The examining physician must be informed that exposure to low-energy x-rays may have occurred. Approved Workers' Compensation Physicians can be found at the following link: <http://hr.uconn.edu/workers-comp/>.

1. If the injury or suspected injury is a Workers' Compensation covered accident, inform the Physician during the initial contact.
 2. Follow the guidelines in Section a. Immediate Response and General Procedures for all X-Ray Beam and Non-Beam Accidents.
- b. Immediate Response and General Procedures for Non-Beam Accidents
1. Obtain medical assistance for injuries that are not x-ray exposures within 48 hours (non-beam injuries). If an ambulance is needed, contact 911.
 2. Follow the guidelines in Section a. Immediate Response and General Procedures for all X-Ray Beam and Non-Beam Accidents.

Emergency contact information should be posted in each analytical x-ray laboratory.

XIII. Procedures/Forms

[Analytical X-Ray Producing Equipment Lab Based Training Check List](#)

[Equipment Form](#)

[University Surplus Procedures](#)

XIV. References

1. *Hazards in the use of X-Ray Analytical Instrumentation*, R. Jenkins and D.J. Haas. Reprinted from X-Ray Spectrometry, Vol. 2, No. 3 July 1973 with permission from John Wiley and Sons Limited. Original manuscript received 20 February 1973; accepted 13 March 1973.
2. *Installations Using Non-Medical X-Ray and Sealed Gamma-Ray Sources, Energies up to 10 MeV*, American National Standard, ANSI N43.3, 1993.
3. *Radiation Safety for X-ray Diffraction and Fluorescence Analysis Equipment*, American National Standard/Health Physics Society, ANSI/HPS N43.2, 2001.
4. *Suggested State Regulations for Control of Radiation, Volume I (Ionizing Radiation)*, Conference of Radiation Control Program Directors, Inc., January 1991.