UCONN

Analytical X-ray Safety Program

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Analytical X-ray Safety Program	
Title:	Analytical X-ray Safety Program
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Applies To:	Employees, students, and others working in UConn laboratories with analytical X-ray equipment
Contact:	EHS, Radiation Safety Manager, RSO

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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, fluorescence, or spectroscopy measurements at the University of Connecticut (UConn) 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 equipment users whose work involves the use of analytical X-ray equipment at UConn.

III. POLICY STATEMENT

Analytical X-ray producing equipment in the possession of UConn is subject to registration with the State of Connecticut and other applicable state and federal regulations. UConn Environmental Health and Safety (EHS) Radiation Safety 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. Radiation Safety 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 UConn required training prior to equipment use.

UConn is committed to keeping exposures to radiation ALARA (As Low As Reasonably Achievable). 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.

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 UConn Student Conduct Code.

The UConn EHS Radiation Safety Manager is the Radiation Safety Officer (RSO) and 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 is Reasonably Achievable): Making every reasonable effort to maintain exposures to radiation as far below the dose limits as is practical, consistent with the purpose for which the licensed activity is undertaken, taking into account the state of technology, the economics of improvements in relation to state of technology, the economics of improvements in relation to benefits to the public health and safety, and other societal and socioeconomic considerations, and in relation to utilization of nuclear energy and licensed materials in the public interest.

Fail-safe characteristic: a design in which all realistically anticipated failures of indicators or safety components result in a condition in which individuals are safe from exposure to radiation. For example, if a light indicating "X-RAY ON" fails, the production of X-rays shall be prevented, or if a shutter status indicator fails, the shutter will close.

Local components: parts of radiation generating equipment including areas that are struck by X-rays such as radiation source housings, beam port and shutter assemblies, collimators, sample holders, cameras, detectors, and shielding but do not include power supplies, transformers, amplifiers, readout devices, or control panels.

Normal operating procedures: step-by-step instructions necessary to accomplish the task. These procedures may include sample insertion and manipulation, equipment alignment, routine maintenance, and data acquisition procedures related to radiation safety.

Open beam X-ray equipment: X-ray equipment in which the beam path could be entered by any part of the body at any time. An analytical X-ray system is considered to be an open-beam system unless the requirements for an enclosed beam system outlined in Section IX of this document are met.

Primary beam: the ionizing radiation coming directly from the radiation source through a beam port into the volume defined by the collimation system.

Safety device: a device, interlock or system that prevents the emission of the primary X-ray beam or that causes the primary X-ray beam to shut off when any portion of an individual's body attempts to enter the primary X-ray beam's path.

VI. PERSONNEL REQUIREMENTS

A. Training for Operators or Users and Non-Users

No individual shall be permitted to operate or maintain analytical X-ray producing equipment until such individual has received an acceptable amount of training in radiation safety as approved by the UConn Radiation Safety Manager as follows:

1. All users must successfully complete the online X-ray Safety Training found on the EHS website; and

2. All users and non-users must complete the required laboratory-based training conducted by the laboratory supervisor which can be found on the EHS website or through the link provided in Section XIII of this document.

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;

5. Proper procedures for reporting an actual or suspected exposure; and

6. Standard procedure to use a survey meter, if applicable to the laboratory.

Radiation Safety training or experience or both completed at another university and documented with the UConn Radiation Safety Manager may be sufficient to fulfill a portion(s) of the initial training requirements.

B. Training for Ancillary Workers

Online training for incidental personnel not directly associated with an analytical X-ray lab, e.g., University facilities or maintenance, housekeeping, and emergency responders will be provided by EHS and required initially prior to working in laboratories and annually thereafter.

C. Personnel Exposure 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.

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 UConn Radiation Safety Manager based on regulatory requirements and exposure potential.

No dosimetry device is required for routine users of an enclosed beam system.

VII. 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 people 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 Manager 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 must pay particular attention to the eyes and to the skin of the hands and face.

B. Operator

Each operator of X-ray producing 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 responsible supervisor or both, follow the recommendations and instructions that have been developed in the interest of radiation protection.

2. Each worker shall utilize protective devices and radiation dosimetry, if provided. If the UConn Radiation Safety Manager provides dosimetry to a worker, the dosimeter 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 dosimeter must be replaced at the frequency established by the Radiation

Safety Committee.

3. A dosimeter badge shall be worn at the proper height. Both dosimeter badges and film rings, if provided, shall be worn facing the radiation source.

4. 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.

5. 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.

6. Each worker shall inform the Radiation Safety Manager of known or suspected abnormal radiation exposure to themselves or others.

7. Each worker shall keep radiation exposure to themselves and others ALARA.

8. 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 they operate.

VIII. ANALYTICAL X-RAY EQUIPMENT ACQUISITION, REGISTRATION, AND TRACKING

Prior to acquiring, purchasing, or moving analytical -X-ray equipment, the equipment supervisor must notify the EHS Radiation Safety Manager to assess the intended space to ensure minimum requirements are met and consult with Facilities as needed. In general, the X-ray equipment supervisor must be full-time faculty or staff of UConn.

All analytical X-ray equipment purchases must be initiated in the University's purchasing system by using the "Equipment Request" button and the appropriate EHS Restricted Equipment code. This will ensure pre-approval by Facilities and EHS after review of the space requirements and potential hazards. Instructions and the list of the EHS restricted equipment codes can be found on the EHS website or through the link provided in Section XIII of this document.

Analytical X-ray equipment orders must not be placed with the University P-Card or other credit card; however, in special circumstances in which a vendor will not accept a purchase order (PO), exceptions to the policy may be made and will require written **pre-notification** to the Radiation Safety Manager and the University's Purchasing Department's P-Card Administrators. Individuals intending to purchase analytical X-ray equipment on a P-Card or other credit card must first email the Radiation Safety Manager a request to purchase and provide all information requested by EHS that pertains to the equipment. The Radiation Safety Manager may also consult with Facilities and may deny a purchase based on insufficient facilities, insufficient information, or if other program requirements cannot be met.

Once analytical X-ray equipment is purchased or acquired by other means, it must be registered prior to use with the State Department of Energy and Environmental Protection (DEEP) by EHS Radiation Safety. Analytical X-ray units are registered with the state by notifying the Radiation Safety Manager. If an analytical X-ray unit is obtained from another source, it must also be registered with EHS upon acquisition, prior to use. The Radiation Safety Manager or designee will then arrange to meet with the X-ray unit supervisor to obtain the information needed to complete the registration process.

The following activity is exempt from the registration requirements:

Equipment for which the primary purpose of operation is other than the production of radiation and does not produce radiation at the point of nearest approach in quantities sufficient to produce radiologic damage to an individual. This applies to electrical equipment that does not produce radiation greater than five-tenths millirem per hour (0.5 mr per hr) or five microsieverts per hour (5 µSv per hr) at any readily accessible point five centimeters (5 cm) from the surface. Such equipment shall not be exempt if it is used or handled in such a manner that any individual might receive a radiation dose exceeding one-tenth the regulatory limits for dose limits for individual members of the public. The production testing or production servicing of such equipment shall not be exempt. Contact EHS Radiation Safety to conduct a survey prior to use to ensure if this exemption applies or if registration is required, as applicable. The unit shall not be used until the determination is made by Radiation Safety.

The X-ray supervisor or designee must notify the Radiation Safety Manager prior to moving, transferring, or disposing of a unit. The Radiation Safety Manager will provide further instructions regarding the required forms and procedures or both to be followed.

For disposal or transfer of an analytical X-ray unit through University Surplus, the X-ray supervisor must notify the Radiation Safety Manager in advance of the pick-up or transfer and comply with the procedures and associated documentation specified on the University's Surplus website, which can be found in the link provided in Section XIII of this document. Equipment must not be transferred to Surplus until the Radiation Safety Manager 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.

IX. EQUIPMENT REQUIREMENTS

A. Enclosed Beam X-ray System

1. The radiation source, beam paths, sample, detector, and 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 partof the body during normal operation.

2. The inherent shielding of the chamber or enclosure walls shall be sufficient to limit the dose rate in all regions 5 cm from its outer surface to 0.25 mrem per hr during normal operations.

3. The system enclosure, sample chamber, etc. shall be interlocked with the X-ray tube high voltage supply and a shutter or both 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.

5. If the entire system, including the X-ray tube, is under one contiguous vacuum, and radiation leakage is less than 0.25 mrem per hr at 5 cm from the surface of the cabinet or enclosure, 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.

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 UConn's Radiation Safety Manager 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 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 UConn's Radiation Safety Manager. 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.

2. Shutter "open-closed" status located near each on the radiation source housing if the primary beam is controlled in this manner.

3. 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.

4. 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 to 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, particularly for accessible, open-beam configurations; or

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, port cover, or 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 (25 μSv) 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 μSv) in any one hour.

X. 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 surrounding the local component group that exceed the dose limits specified in applicable UConn, state, and 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, prior to routine operation, and at least once every 12 months thereafter. Annual dose rate measurements shall not be required if the Radiation Safety staff initially demonstrated compliance with applicable state and federal regulations and no modifications to the system, including relocation, have been made since the last dose rate measurement;

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 or area monitor shows readings that are at or exceed the investigational limits specified in applicable UConn ALARA program, state, and federal regulations.

7. 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.

8. If the laboratory has a survey meter, it must be maintained and calibrated by Radiation Safety and must be kept near the equipment at all times so that the operator may perform casual surveys frequently. It must 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.

XI. OPERATING REQUIREMENTS

A. Procedures

1. Normal operating procedures shall be provided by the equipment supervisor for the analytical X-ray equipment and made available to all analytical X-ray equipment users or operators. No individual shall be permitted to operate analytical X-ray equipment in any manner other than that specified in the instrument manufacturer’s specifications and laboratory standard operating procedures (SOPs) unless such individual has received written approval directly from the UConn Radiation Safety Manager.

2. The equipment supervisor shall ensure that an electronic usage record is maintained for each X-ray producing machine. An entry shall be recorded on the usage log 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:

    - Operator Name
    - Date
    - Start Time
    - End Time
    - X-ray Unit Make, Model, and Serial Number
    - Equipment Supervisor
    - 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, including when the unit is unattended.

4. The following additional operating requirements apply to handheld X-ray fluorescence (XRF) devices;

    - All routine operation of a handheld XRF device shall be done with the unit attached to a shielded workstation. If the device must be used in the field without the workstation, the following additional safety requirements must be followed:

    - No one but the operator(s) shall be allowed to be closer than 3 feet from the beam port.

    - Never hold sample up to the X-ray port for analysis by hand; always hold the instrument to sample.

    - Be aware of the direction the X-rays travel when the red light is on and avoid placing any part of your body (e.g., eyes, hands) near the X-ray port to stabilize the instrument during operation.

- Stand behind the equipment holding the handle with one hand; your other hand should also remain by your side and not be positioned in front of the equipment or near the X-ray port.

- Do not remove the nosepiece from the samples before testing is complete and the warning light stops blinking and the operator has verified the unit is not producing X-rays.

B. Bypassing

No individual shall bypass a safety device or interlock unless such individual has obtained prior approval from the UConn Radiation Safety Manager. 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 must 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.

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.

XII. EMERGENCY PROCEDURES

Emergency contact information and the X-ray Supervisor's emergency contact information must be posted in each analytical X-ray laboratory.

Should an accident or injury occur with the X-ray beam, or a non-beam hazard related to the analytical X-ray equipment, the following procedures must be followed:

A. Emergency Procedures for all X-ray Beam and Non-Beam Accidents

Any individual involved in an accident with analytical X-ray producing equipment must follow the procedures below:

1. If an X-ray beam or non-beam accident occurs, terminate equipment operations immediately, if safe to do so, by closing the X-ray beam shutter or turning off the X-ray system or both.

2. If there is a fire, relocate to a safe location, contact 911, follow the directions of the dispatcher, and wait for clearance by the Fire Department before reentering.

3. Notify the equipment supervisor of the accident.

4. Contact the Radiation Safety Manager at the first opportunity during normal working hours (M-F 8:00 AM – 4:00 PM) at 860-486-5399 or call University Safety Emergency Communications at 860-486-4800 after hours. Additional contact numbers are provided in Emergency Contact List.

5. Do not resume X-ray unit operations until the approval of the Radiation Safety Manager.

B. Emergency Procedures for X-ray Beam and Non-Beam Injuries

Any individual who suspects they have received an X-ray beam exposure or another non-beam injury must seek immediate medical attention as follows:

1. Dial 911 if it is an emergency.

2. For non-emergencies that involve suspected exposure to X-rays, employees should seek immediate medical attention from an approved "State of Connecticut Mandatory Initial Treatment location." Obtain medical assistance for other non-beam injuries within 48 hours.

3. Inform the examining physician if the exposure involved low-energy X-rays and if the suspected injury is a Workers' Compensation covered accident.

4. Undergraduate students may obtain medical assistance for non-beam injuries at Student Health and Wellness (SHaW) during normal business hours or to an emergency room or urgent care facility after hours.

5. Report all injuries involving an X-ray beam or a non-beam hazard at UConn, no matter how minimal.

    a. Supervisors must complete the WC-207 First Report of Injury form within 24 hours for employees. Injury reporting requirements and information for employees are available on the Workers' Compensation webpage.

    b. Supervisors must report injuries involving undergraduate students to EHS Radiation Safety for follow-up.

C. Emergency Contact List

University Safety Emergency Communications (to reach EHS after-hours), 860-486-4800 or 911 if emergency

EHS Radiation Safety Manager, RSO, 860-486-5399

EHS Radiation Safety Specialist, Analytical X-ray Safety, 860-486-0925

UConn EHS Office, 860-486-3613

Workers' Compensation Administrator, 860-486-0406

XIII. PROCEDURES AND FORMS

Analytical X-ray Producing Equipment Lab Based Training Check List

University Surplus Procedures

EHS Restricted Materials and Equipment Purchases Instructions and HuskyBuy Coding

XIV. REFERENCES

1. *CT DEEP Radiation Regulations,* https://portal.ct.gov/deep/radiation/radiation.

2. *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.

3. *Installations Using Non-Medical X-ray and Sealed Gamma-Ray Sources, Energies up to 10 MeV*, American National Standard, ANSI N43.3, 2008.

4. *Radiation Safety for X-ray Diffraction and Fluorescence Analysis Equipment,* American National Standard*,* Health Physics Society, ANSI and HPS N43.2, 2021.

5. *Suggested State Regulations for Control of Radiation, Volume I, Part H, Conference of Radiation Control Program Directors, Inc.,* https://crcpd.org/ssrcrs/, July 2016.