Radiation Producing Machines

Safety Manual

University of Wisconsin- Milwaukee

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Introduction

Radiation Safety is the responsibility of all individuals at the University of Wisconsin-Milwaukee (UWM) including faculty, staff, students, researchers, and visitors. The use of X-ray machines or radiation producing devices at UWM makes strict compliance to Federal and State regulations, and university policies important for safety and protection of all individuals at UWM.

Purpose

The use of machines which produce ionizing radiation are necessary to carry out the research and teaching responsibilities at UWM. The guidelines contained in the Radiation Producing Machines Safety Manual have been established by the Radiation Safety Officer for the following purposes:

- To provide for the protection of the University population and the general public against radiation hazards associated with its use of machines and equipment that emit ionizing radiation.
- To provide for the University's compliance with State and Federal regulations.

The intent of the Radiation Safety Officer (RSO) and University Safety and Assurances (USA) is to ensure that all employees and students are provided a safe working/learning environment, and an environment that employees and students feel free to raise safety concerns to University Safety and Assurances or the Radiation Safety Officer without fear of retaliation. Formal complaints should be in writing delivered to the Radiation Safety Officer.

Scope

This manual details the Wisconsin Department of Health Services, Radiation Protection Section and UWM's requirements for equipment procurement and validation, procedure developments, and education of personnel. This manual is not intended to be a fully comprehensive reference. Further advice concerning hazards associated with specific X-rays or radiation producing devices and/or the development of new and unfamiliar procedures should be obtained through consultation with the RSO.

Importance of Radiation Safety

The improper or unsafe use of radiation producing sources or equipment has the potential to create a health hazard for not only the user but the general public in the environment surrounding the area of use. The licenses that are issued to UWM by WI DHS specify what equipment may be used and how it must be handled. If you work with radiation producing devices you must abide by safe work practices and follow the requirements of this manual.

Radiation safety is the responsibility of all users. Radiation safety policies are established for everyone's benefit and require everyone's support. All personnel using radiation sources are expected to become familiar with this manual and to conduct their operations accordingly. Failure to adhere to the requirements in this manual and/or State regulations could jeopardize the University's ability to use radiation producing devices.

Wisconsin X-ray Regulations

The following link is to the State of Wisconsin Department of Health Services X-ray website, https://www.dhs.wisconsin.gov/radiation/xray/index.htm . Wisconsin Admin. Code ch. DHS 157 is the regulation that this manual is based off of. Not all requirements specified in the regulations are restated

in this manual. The manual is meant to summarize the requirements and indicate additional requirements determined by the Radiation Safety Officer and USA. Please contact the Radiation Safety Officer at 414-430-7507 if you have any questions.

Abbreviations

For the purpose of this Manual:

- AU – Authorized User
- ALARA – As Low As Reasonably Achievable
- DDE – Deep Dose Equivalent
- LDE – Lens Dose Equivalent
- NVLAP – National Voluntary Laboratory Accreditation Program
- NRC – Nuclear Regulatory Commission
- PI – Principal Investigator
- PPE – Personal Protective Equipment
- RSO – Radiation Safety Officer
- SDE – Shallow Dose Equivalent
- SPD – Signed Pregnancy Declaration
- SU – Supervised User
- USA – University Safety and Assurances
- XRD – X-ray Diffraction
- XRF – X-ray Fluorescence

Administrative Organization

Radiation Safety Officer

General RSO Responsibilities for Radiation Producing Machines

- Be qualified by training and experience to assume the responsibilities of apprising him/herself of all hazards and precautions involved in handling the radiation machine(s) for which he/she is responsible.
- Give instructions concerning hazards and safety practices to persons who may be occupationally exposed to radiation.
- Oversees and annually reviews the Radiation Safety Program.

RSO Responsibilities for Analytical X-ray Equipment

- Establishing and maintaining operation procedures so that the radiation exposure of each worker is kept as far below the maximum permissible dose as is practical.
- Instructing personnel who work with or near radiation machines in safety practices.
- Maintaining a system of personnel monitoring.
- Arranging for establishment or radiation control areas, including placement of appropriate radiation signs and devices.
- Providing for radiation safety inspections of radiation machines on a routine basis.
- Reviewing modifications to x-ray apparatus, including x-ray tube housing, cameras, diffractometers, shielding, and safety interlocks.

- Investigating and reporting to proper authorities any cases of excessive exposure to personnel and taking remedial action.
- Being familiar with applicable regulations for control of ionizing radiation.

RSO Authority

To meet these responsibilities, the RSO has been given the following authority:

- To review and approve proposed uses of radiation producing machines.
- To grant, deny, or suspend authorization to use radiation producing machines by University personnel while on University property. Such action by the RSO follows a review of information relative tot eh authorization in question.
- To apply restrictions on the amount of occupational radiation exposure that any individual University personnel may receive during his/her University association.
- To terminate any activity employing radiation which is a threat to health or property after notification of person in charge.
- To recommend or order remedial action to correct safety or regulatory deficiencies.

Authorized Users

Receives authority from the RSO to posses and use radiation producing machines. An Authorized User has been approved to use a given radiation producing device by the RSO.

Responsibilities

- To help all personnel maintain doses ALARA.
- To submit a registration to the RSO requesting permission to possess and use a radiation producing machine.
- To maintain an up-to-date listing with the RSO of all supervised users.
- To ensure that students and staff using radiation producing devices under his/her supervision are trained in safe laboratory practices, are familiar with terms of the registration, and are complying with University policies and applicable regulations. The RSO offers training sessions upon request to assist the user in this regard.
- To inform the RSO of any proposed changes to operations.
- To provide supervision for all users under their authority.
- To provide training on the operation of the equipment to all users under their authority.
- To ensure that laboratory personnel wear the assigned dosimetry.
- To ensure that laboratory personnel are properly instructed in the guidelines involving radiation producing machines.
- To notify the RSO immediately of overexposure or suspected overexposure.
- Informing the RSO if they or any of the users have declared pregnancies (i.e. as defined by 10 CFR 20.1003, so stated in the U.S. NRC Regulatory Guide 8.13 attached as Appendix D).
- To only allow authorized people to use radiation producing machines and allowing only authorized people to enter the rooms that are specified as restricted areas.

Visitors

Non-UWM individuals may need to be in areas operating radiation producing machines. In such cases, the visitor must have the proper dosimetry (if needed) and be in direct physical supervision of the authorized user.

Dose Limits and Assessment

Maximum Permissible Dose Limits

Exposure to ionizing radiation, both internal and external, shall be kept As Low As Reasonably Achievable (ALARA). The external and internal exposure from sources of radiation shall be controlled in such a way as to provide reasonable assurance that no individual shall receive an absorbed dose in excess of the permissible value.

Radiation Workers

Maximum permissible dose limits for adult radiation workers (listed in Fig. 1) apply to any combination of dose received from external or internal exposure. These limits do not apply to doses received from background radiation or from medical procedures or exams. An adult radiation worker is defined as an individual 18 years of age or older that works with or around sources of radiation. Child labor laws prohibit individuals under the age of 18 from working with certain types of radioactive materials or in certain areas where occupation radiation exposures may occur. It is the policy of USA that minors are not permitted to work with sources of ionizing radiation at UWM.

Annual Maximum Permissible Dose Limits		
5,000 mrem (5 rem)	50 mSv (0.05 Sv)	Whole Body Deep Dose Equivalent *(Head, trunk (including male gonads), arms above the elbow, legs above the knee)*
50,000 mrem (50 rem)	500 mSv (0.5 Sv)	Whole Body Shallow Dose Equivalent *(Skin of the whole body)*
15,000 mrem (15 rem)	150 mSv (0.15 Sv)	Lens of Eye Dose Equivalent *(Eye)*
50,000 mrem (50 rem)	500 mSv (0.5 Sv)	Extremities *(Hands, forearms, elbows, knees, leg below the knees, and feet)*

Fig. 1 – Annual Maximum Permissible Dose Limits

Declared Pregnant Radiation Worker

Under State and Federal law, the whole body dose limit of a pregnant radiation worker remains at 5,000 mrem (50 mSv) per year until she specifically declares her pregnancy in a written and signed statement directed to the RSO. The declaration is voluntary. Following the RSO's receipt of a signed pregnancy declaration, the dose limit to the worker's embryo/fetus is limited to 500 mrem (5 mSv) for the duration of the pregnancy. Upon the receipt of the signed declaration, the RSO will provide monitoring for potential internal and/or external exposure to the embryo/fetus as appropriate.

The RSO recommends that a pregnant radiation worker declare her pregnancy so that her occupational radiation exposure potential can be evaluated to ensure that the dose to the embryo/fetus does not exceed 500 mrem (5 mSv) over the duration of the pregnancy.

General Public

The limit to members of the general public (including employees not involved in working with sources of ionizing radiation) is 100 mrem (1 mSv) per year from licensed or registered activities at UWM. The dose rate limit is 2 mrem in any one hour.

Determination of Exposure

Dosimeters

Personal dosimeters used to record occupational radiation exposures are supplied and processed through a National Voluntary Laboratory Accreditation Program (NVLAP) approved commercial dosimeter service. The administration and management of the personnel monitoring program is provided by the RSO.

Dosimetry is required for adults likely to annually receive external dose in excess of 10% of the annual permissible dose limits found in Fig. 1. Dosimetry is also required for individuals that enter a high or very high radiation area. Personal dosimeters are also available upon request.

Personal dosimeters are exchanged on a quarterly basis. Copies of dosimetry reports are available from and are maintained on file by the RSO. Contact 414-430-7507 if you have any questions concerning dosimeters or dosimeter reporting.

Documented completion of RSO radiation safety training applicable to job function is required as a prerequisite to obtaining a personal dosimeter. Contact the RSO for more information regarding applicable training for your job function.

Types of Dosimeters

Whole Body dosimeters provide measurement of penetrating and non-penetrating radiation exposure. Penetrating radiation is designated on reports as “DDE” for Deep Dose Equivalent and includes exposure to the whole body (head, trunk, active blood-forming organs, and reproductive organs). Non-penetrating radiation is designated as “SDE” for Shallow Dose Equivalent, and includes exposure to the skin and extremities. Lens of the eye dose equivalent is designated as “LDE”. Whole body dosimeters are to be worn on the torso in the region likely to receive the highest radiation exposure. If a protective lead apron is worn, wear the whole body dosimeter underneath your lead apron.

Ring dosimeters provide measurement of radiation exposure to the extremities (hands and forearms). The ring dosimeter is to be worn under any gloves and on the hand most likely to receive the highest radiation dose.

Accidental Exposure Assessment

Anyone suspecting that they have received an overexposure due to radiation emitted from a radiation producing machine must call the RSO immediately, 414-430-7507.

ALARA Program

The maximum permissible occupational dose limits established by regulation are based on limiting individual radiation dose to what is considered to be an acceptable level of occupational risk. Although

there is no documented evidence linking any health effect with exposures less than 10,000 mrem (100 mSv) delivered at a high dose rate, it is assumed that any radiation exposure may carry some risk. Therefore, regulation requires that UWM provide a program designed to reduce exposures As Low As Reasonably Achievable (ALARA) to the extent practical, utilizing procedural and engineering controls.

UWM's ALARA Program provides a process for the RSO to Review the radiation safety program annually, review all proposals for radiation producing machine usage, and review all occupational radiation exposure reports.

Acquisition of a Radiation Producing Machine

Pre-Registration

Prior to obtaining a radiation producing machine, the Authorized Users must:

- Pre-register with the RSO by providing the following information:
    - Name and address of the person having administrative control and responsibility for the proposed facility.
    - Location where the device(s) is to be stored or used.
    - Plans and specifications (shielding, etc.) for the proposed facility.
    - The model name/number/serial number of the device.
    - Other information as requested.

Registration of a Radiation Producing Machine

All machines capable of producing ionizing radiation must be registered with the Wisconsin Department of Health Services (DHS) within 30 days of the occurrence.

The RSO will register the machine with DHS based on the information provided by the authorized user.

Registrants using radiation producing machines shall provide the RSO with documentation of the type, make, model, serial number, and maximum radiation output of the device before installation. The registrant shall also provide the date of initial operation (or the approximate intended date) of the radiation producing machine.

A copy of the radiation survey performed at the installation and acceptance testing shall be maintained for inspection, including exposure rates in all adjacent rooms. Radiation surveys shall be repeated after major maintenance, modification or relocation of the device.

An initial radiation safety survey of the equipment and all adjacent rooms shall be conducted, and a copy maintained. Similar radiation surveys shall be repeated after major maintenance, modification or relocation.

The RSO must be notified prior to any device installation, maintenance, modification or relocation, discontinuation or transfer of a radiation-producing device. Reports of transfer (surplus, sale, gift, etc.) must include the name and address of the transferee. The RSO must be notified when an X-ray machine arrives and of the scheduled installation date. Installation must be performed and documented by a manufacturer representative or a state agency registered service provider. Following installation, a certificate of installation is required of certified units. For non-certified units, an equivalent report from the manufacturer representative or agency registered service provider must be provided to the RSO. At a minimum, the below listed documents must be provided to the RSO after installation within 30 days.

- Purchase records
- Receipt/Installation records (Includes transfers or donations)

- SOP for each X-ray machine including start-up, shut-down, safety device by-pass, alignment, and emergency
- Calibration, maintenance, and modification records

In addition to the documents listed above, AUs must maintain the below documents.

- Equipment manuals
- Safety devices (interlocks, activation warning lights, etc.) information
- Other requested information by the RSO, regulations, or the University policies
- X-ray log book unless the X-ray machine is solely used by the AU or a computerized automatic log available

Safeguarding Radiation Producing Devices

State regulations require that all radiation producing devices must be secured from unauthorized use or access. It is essential that everyone take responsibility for ensuring that all radiation producing equipment is either under direct observation by authorized personnel, or when unattended, be secured at all times. The test for compliance with this security requirement is straightforward: Can someone remove or use the device in your area without you or another authorized person in your area knowing it? If the answer is "yes," then the security in your area of use is not satisfactory.

Basic X-ray Safety Guidelines

General Guidelines

The X-ray AU should designate a primary responsible operator for the X-ray machine if the AU cannot be in the X-ray use area or on the campus during operation all the time. The primary responsible operator's responsibility will be the same as the AU when AU is not present on the campus including interlock bypass keys, perform the alignments, and manufacturer required changes/maintenance on the X-ray machines. The primary responsible operator can also coordinate calibrations, repairs, and modifications of the equipment with the company or manufacturer representative. X-rays can only be operated when the AU or the designated primary responsible operator is present in the X-ray lab or in the campus. The AU or the designated primary responsible operator must know who uses the machine when the machine is in use. When neither of them are available to supervise the X-ray operation, the X-ray must be turned off and the key must be removed from the machine to secure it from unauthorized operation.

Operational Procedures

An SOP including start up, shut down, alignment, and emergency procedures for all X-ray machines must be written and readily available to and acknowledged by all users. The safety and basic operations sections in the manufacturer's manual can be used but a standalone specific X-ray manual is strongly recommended. The X-ray operation must follow basic radiation safety practices. All users should minimize their exposures to keep their occupational doses As Low As Reasonably Achievable (ALARA). Certified and closed unit X-ray machines should have enough shielding to reduce radiation level below 2 millirem (mrem) per hour or 2 milliRoentgen (mR) per hour during operation. If the shielding is not sufficient to maintain the radiation level below the 2 mR per hour from the surface where any person can have access, the AU must contact the Radiation Safety Office to consult to have additional access controls added for using the X-ray machine, such as key card access, or an X-ray in use indicator at the entrance.

Records

Certain records are required to be maintained by all X-ray AUs and readily available for the radiation safety annual audit and DHS inspections. All records should be maintained in one central location in the lab. Minimum required records are:

- Equipment manuals
- Purchasing/Receipt/Installation records (Includes transfers or donations) –AU can keep these records in his/her office
- SOP for each X-ray machine
- Calibration, maintenance, and modification records
- Use log book

Radiation Safety Training

All individuals using radiation-producing machines shall receive radiation safety training offered by the Radiation Safety Officer or a source approved by the Radiation Safety Officer. Training must be completed prior to using a radiation-producing device. In addition, individuals shall be trained on the operation of the particular radiation producing device he/she will be using and actions to take in the event of an emergency. This use training shall be provided by the Authorized User or other person approved by the Radiation Safety Officer. All individuals who wish to operate diagnostic, analytical, or cabinet X-ray systems shall receive instruction in and demonstrate ability in:

- General properties of ionizing radiation.
- Principles of radiation detection.
- Radiation hazards associated with the use of the equipment.
- Biological effects of ionizing radiation.
- Procedures to minimize exposure.
- UWM's Safety requirements.
- Emergency procedures.

Ability shall be demonstrated by passing a on-line examination administered by the Radiation Safety Officer. Machine specific hands-on training must be provided by experienced personnel.

In some cases, the Authorized User will give the safety training, with the course content approved by the Radiation Safety Officer.

Exceptions to radiation safety training requirements maybe granted because of pervious training, experience, or education at the sole discretion of the RSO.

X-rays – General

The following items apply to x-ray producing machines in general. These, therefore, apply to diagnostic x-ray, x-ray diffraction, x-ray fluorescence instruments, etc. Please contact the RSO if you have any questions.

- Individuals operating x-ray systems shall be adequately instructed in safe operating procedures and shall be competent in the safe use of the system.

- Written safety procedures and rules for the particular x-ray system shall be posted in a conspicuous place beside each x-ray system's control panel and a copy of these administrative regulations shall be made available in each general work area.
- Records of surveys, calibrations, maintenance and modifications performed on the x-ray system along with the names of persons who performed the service shall be kept.
- If protective clothing is worn on portions of the body and a monitoring device(s) is(are) required, at least one (1) monitoring device shall be utilized as follows:
    - If an apron is worn, the monitoring device shall be worn at the neck area outside of the apron; and
    - If more than one (1) device is used and a record is made of the data, each dose shall be identified with the area where the device was worn on the body.

Analytical X-ray

This section applies to instruments that employ methods like x-ray diffraction and x-ray fluorescence. Specifically, enclosed beam configurations are addressed. Contact the RSO with any questions.

X-ray diffraction and spectrographic devices generate in-beam radiation dose rates of 30 to 7000 rads/sec. Severe tissue damage can be inflicted by very brief exposures to these high dose rates. Surgical treatment or amputation may be required when small body parts, such as fingers, receive greater than 1000 rads.

It is imperative that stringent safety precautions be applied when using these devices. Safety precautions include mechanical and electrical interlocks as well as proper training and instruction. The following safety procedures have been established to help prevent accidents. Adherence to these rules is mandatory.

- Normal operating procedures shall be written and available to analytical x-ray equipment workers. No individual shall be permitted to operate analytical x-ray equipment in a manner other than specified in the procedures unless the individual has obtained written approval of the Radiation Safety Officer.
- Safety interlocks shall be tested monthly. Record the results of the test, the date, and the name of the person conducting the test.
- A label bearing the words, "Caution -Radiation -This Equipment Produces Radiation When Energized" shall be placed near the switch that energizes the tube.
- A sign bearing the words, "High Intensity X-ray Beam" shall be in place adjacent to each tube housing.
- Unused ports on radiation source housings shall be secured in the closed position.
- Under no circumstances shall shutter mechanisms or interlocks be defeated or in any way modified, except as approved in writing by the Radiation Safety Officer.
- If it is necessary to temporarily, intentionally alter safety devices (e.g., bypassing interlocks or removing shielding) this action shall be:
    - Specified in writing and posted near the x-ray tube housing so that other persons know the existing status of the machine; and
    - Terminated as soon as possible.
    - When a safety device or interlock has been 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.
- Be alert to the beam status. Stay constantly aware of the on/off status of the X-ray beam by repeatedly checking the status indicators.
- Avoid the beam path. Stay out of the beam path.

- Only experienced, skilled workers should perform beam alignments. Concentrate fully on the job when doing alignments. Wear the finger and body radiation monitor badges.
- No person shall be permitted to operate academic X-ray machines until they have:
    - received instructions in relevant radiation hazards and safety
    - received instructions in the theory and proper use of the machine
    - demonstrated competence, under direct supervision, to safely use the machine
- Operators must wear extremity (finger) and whole body radiation badges, as applicable, while using the equipment. The RSO will assist in determining applicability based on the individual's involvement with the machine (e.g., operation, maintenance and repair, beam alignment, etc.)
- Operators shall remain in constant attendance while the X-ray beam is on, or the device shall be secured against access by unauthorized persons.
- Any changes in the status or location of a device shall be referred to the Radiation Safety Officer for prior approval.
- Periodically monitor for scatter radiation. Sheet lead, lead foil, lead tape or leaded acrylic are all useful for auxiliary shielding.
- Be aware of non-radiation hazards. Cryogenic liquids and gases, high voltage and heavy metals are some examples of other lab hazards that require precautions.

Annual Inspections

Analytical X-ray facilities shall be inspected annually by the RSO.

Emergency Procedures

If you are exposed to the direct x-ray beam or suspect an exposure, IMMEDIATELY follow these steps:

- Shut off the x-ray beam.
- Remain calm.
- Call the Radiation Safety Officer.
- If there is a medical emergency in addition to the exposure, call University Police.
- Arrange for a medical examination. Important: Notify the examining physician that exposure to low energy x-rays may have occurred.

Radiation Safety Officer: **414-430-7507**
University Safety and Assurances: **414-229-6339**
University Police: **9-911**

General Safety Guidelines

X-Ray diffraction and spectrographic devices generate in-beam radiation dose rates of 30 to 7000 rads/sec. Severe tissue damage can be inflicted by very brief exposures to these high dose rates. Surgical treatment or amputation may be required when small body parts, such as fingers, receive greater than 1000 rads.

It is imperative that stringent safety precautions be applied when using these devices. Safety precautions include mechanical and electrical guards as well as proper training and instruction. The following safety procedures have been established to help prevent accidents. Adherence to these rules is mandatory.

1. No person shall be permitted to operate analytical x-ray machines until they have:
    a. Received instructions in relevant radiation hazards and safety.
    b. Received instructions in the theory and proper use of the machine.
    c. Demonstrated competence, under direct supervision, to safely use the machine.

2. Radiation exposure to the operator and others shall be kept ALARA (As Low As Reasonably Achievable).
3. Operators shall wear monthly exchanged finger-ring and body radiation badges (if applicable). The RSO will assist in determining applicability based on the individual's involvement with the machine (e.g., operation, maintenance and repair, beam alignment, etc.)
4. Operators shall remain in constant attendance while the x-ray beam is on, or the device shall be secured against access by unauthorized persons, unless an interlock device is provided to prevent accidental entry into the primary beam.
5. Safety interlocks shall be tested monthly.
6. ANY changes in the status or location of a device shall be referred to the Radiation Safety Officer for prior approval.

X-ray machine Transfer, Donation, and Disposal

Transfer or Donation

An X-ray unit can be transferred or donated to another organization as long as the organization has appropriate registration. AUs must contact UWM's Purchasing Office and the Radiation Safety office before processing the transfer or donation

Disposal

Most newer X-ray units don't contain hazardous materials except beryllium and lead.

Generally, beryllium is contained within the X-ray tube and must be removed from the system and disposed of as chemical waste. You must verify the manufacture's information about the X-ray tube. Most of the time, it is indicated on the tube. Before the disposal process, the AU must remove the head, being careful not to break the X-ray tube. The tube is under vacuum and, if broken, could splinter and cause injuries and exposure to beryllium. Some X-ray systems have beryllium windows and a "poison" sign on the window unit that warns users that the window unit contains a very toxic chemical and must be disposed of properly. If you need assistance, please contact the Radiation Safety Office.

For disposal of X-ray units, contact the Surplus Department. Contact the Radiation Safety office to assist in disposing of the unit.

PCBs-X-ray machines made before July 1979 may contain a toxic chemical called polychlorinated biphenyls or PCBs, in the transformer oil. If your machine is older than 1979 or around that time frame, oil must be tested before the process of disposal. If the test results show that the oil contains PCBs, you need to contact University Safety and Assurances, Environmental Protection to remove the oil and disposed of as chemical waste.
Hazardous Metals-Older equipment may contain hazardous metals. Before taking a machine out of service you need to be aware of what's in the machine and what needs to be done to dispose of it properly. How you go about this could either save or cost you a lot of money. Contact the Radiation Safety Office and the USA if you need assistance. The Radiation Safety office and USA can help you to determine if your old machine contains a hazardous waste metal regulated by the U.S. Environmental Protection Agency and assist you to properly dispose of it.

Definitions

Exposure – term used to describe the amount of ionization produced in air from a radiation source. The unit used for this measurement is Roentgen (R) or milliroentgen (mR). Most portable survey instruments measure exposure. Exposure rate measurements can be used to calculate dose or dose equivalent.

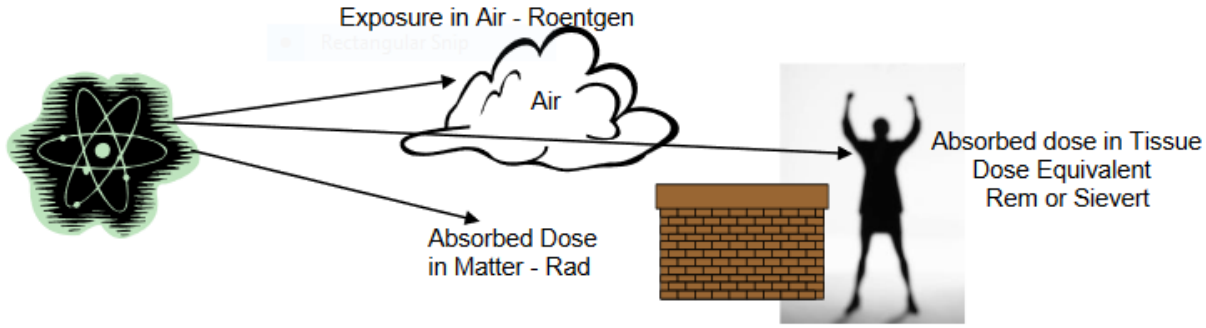
Absorbed Dose – means the energy imparted by ionizing radiation per unit mass of irradiated material. The units of absorbed dose are the rad and the Gray (Gy).

Rad – is the special unit of absorbed dose. One rad is equal to an absorbed dose of 100 ergs/gram.

Gray – is the SI unit of absorbed dose. One gray is equal to an absorbed dose of 1 Joule/kilogram (100 rads)

Rem – is the special unit of any of the quantities expressed as dose equivalent. The dose equivalent in rems is equal to the absorbed dose in rads multiplied by the quality factor (1 rem=0.01 sievert (Sv))

Sievert – is the SI unit of any of the quantities expressed as dose equivalent. The dose equivalent in sieverts is equal to the absorbed dose in grays multiplied by the quality factor (1 Sv = 100 rems)



Dose Equivalent – is a measure of how much energy is absorbed by the body from radiation. Dose equivalent means the product of the absorbed dose in tissue, quality factor, and all other necessary modifying factors at the location of interest. The units of dose equivalent are the rem and sievert (Sv). 100 rem = 1 Sv. These are also the units reported on your dosimetry report and quantify how much dose you have received.

Deep Dose Equivalent (DDE) – which applies to external whole-body exposure, is the dose equivalent at a tissue depth of 1 cm.

Lens Dose Equivalent (LDE) – applies to the external exposure of the lens of the eye and is taken as the dose equivalent at a tissue depth of 0.3 cm.

Shallow Dose Equivalent (SDE) – applies to the external exposure of the skin of the whole body or the skin of an extremity, is taken as the dose equivalent at a tissue depth of 0.007 cm.

Effective Dose Equivalent (EDE) – is the sum of the products of the dose equivalent to the organ or tissue and the weighting factors applicable to each of the body organs or tissues that are irradiated.

Total Effective Dose Equivalent (TEDE) – means the sum of the deep-dose equivalent (for external exposures) and the committed effective dose equivalent (for internal exposures).

MeV – Mega electron volt (1 million electron volts). Unit of measurement which quantifies the amount of energy carried by particulate or electromagnetic radiation, e.g. Cs-137 emits a 0.662 MeV gamma ray and P-32 emits a 1.7 MeV Beta particle.

Activity – when talking about radioactive material, the units of Curie or Becquerel (SI unit) or number of nuclear disintegrations per minute (dpm) are used to describe the quantity of material that is present.

Analytical X-Ray System Inspection

Building/Room #: _____ Date: _____

Principle Investigator: _____

X-Ray System:

Manufacturer/Model: _____ Serial #: _____

Type: Cabinet Open Closed

Maximum: _____mA _____ kVp

1. Device present to prevent entry into primary beam: Yes No
   a. Warning light present for Tube Status Beam) Yes No (Required for Open
   b. Warning light present for Shutter Status Beam) Yes No (Required for Open

2. Any unused ports secured in a manner to prevent casual opening: Yes No N/A

3. Labels required for an analytical x-ray system:
   a. ***Caution: High Intensity X-Ray Beam*** Yes No
   On x-ray source housing
   b. ***Caution Radiation: This Equipment produces Radiation when energized*** Yes No
   Near any switch that energizes an x-ray tube
   c. **Caution Radioactive Material** Yes No N/A
   If the radiation source is a radionuclide
   d. ***Caution X-Ray Equipment*** Yes No (On Lab Door)

4. An "X-Ray On" light located near control panel: Yes No

5. X-Ray exposure survey:
   a. 5 cm away from closed shutters: _____ (<2.5 mR/hr)
   b. 5 cm away from generator cabinet _____ (<0.25 mR/hr)
   c. 5 cm away from exterior surfaces: _____ (<0.5 mR/hr)
   d. Surveys performed annually (maintain for 3 years) or after installation, maintenance, changes, abnormal conditions (>50% increase in doses) Yes No

6. Standard Operating Procedures readily available: Yes No
   a. Emergency Procedures Included: Yes No

7. Any safety bypasses or modifications present: Yes No
   Explain:_____

8. Are Operators trained in the following areas:
    a. Radiation hazards associated with use: Yes No
    b. Significance of warning devices: Yes No
    c. Proper/Safety operating procedures: Yes No
    d. Symptoms of acute localized exposures Yes No
    e. Procedures for reporting exposures: Yes No

9. Dosimetry available for personnel: Yes No N/A
    a. Any high exposures since last survey Yes No
    Explain:_____

10. Interlocks are tested every 12 months: Yes No

11. Postings:
    a. Current registration posted: Yes No
    b. "Notice to Employees" posted: Yes No
    c. Emergency Procedures posted: Yes No

12. Usage Log Maintained: Yes No

Additional Notes:

_____
_____
_____
_____

Inspected By: _____ Date: _____

Meter and Serial Number Used: _____ Calibration Date: _____

DEPARTMENT OF HEALTH SERVICES
Division of Public Health
F-47097 (Rev. 08/06)

STATE OF WISCONSIN
ss. 254.35, Wis. Stats.
608-267-4782

APPLICATION FOR REGISTRATION OF X-RAY DEVICES

FOR OFFICE USE ONLY	County_____
	Registration No. _____

Completion of this form is required. Failure to do so may result in a forfeiture of not less than $10.00 or more than $500.00. Registration does not imply approval of installation.

Name of Business

Business Address-Street, City, State, Zip

Mailing Address If Different than Business Address

Telephone No. (include extension if any)

( ) -

Name and Title of Person Responsible for Radiation Safety

Application

☐ Medical ☐ Dental ☐ Hospital ☐ Chiropractor ☐ Veterinary
☐ Osteopath ☐ Podiatrist ☐ Industrial ☐ Other (Explain)

List number of X-Ray units. In "Use" column show "R" for radiographic, "F" for fluoroscopic; "T" for therapeutic and "O" for other. If "Other, please explain. If more space is needed, please attach a separate sheet.

Max kVp	Max. mA	Model Name	Serial No.	Manufacturer's Name	Year Installed	Use

If you are responsible for x-ray units at locations other than listed above, please list the locations.

SIGNATURE – Person Responsible for radiation safety Title Date signed (mm/dd/yy)

The registration fee is based on the facility type and the number of x-ray tubes. Make check payable to the Department of Health Services and submit with this application. Contact the Radiation Protection Section at (608) 267-4782 for the correct fee or link to the web site at http://dhs.wisconsin.gov//dph_beh/BEH/Xray/index.htm

Mail completed original form to:

Department of Health Services
Division of Public Health
Radiation Protection Section, RM B157
P.O. Box 2659
Madison, WI 53701-2659

Note: Multiple x-ray devices at a single location and under the control of one person may be considered a single registration and only one registration fee is required. If, however, the devices are located at separate addresses, it will be necessary to consider each location as a separate registration and an additional fee is required for each location. **All permits expire on December 31 regardless of issue date.**

UNIVERSITY SAFETY AND ASSURANCES

RADIATION SAFETY PROGRAM

PERSONAL DOSIMETER APPLICATION

Male: ☐ **Female:** ☐

NAME: Last First MI/Maiden	
BIRTHDATE: Month Day Year	SOC. SEC. NO:
EMAIL ADDRESS:	PRIMARY INVESTIGATOR:
LAB ADDRESS:	LAB PHONE:

1. Check the statement that applies to you:

☐ I will be working directly with radioactive materials at UWM

☐ I will be working in a lab where others will use or store radioactive materials. I do not expect to handle radioactive materials myself.

List the major type and millicurie quantities of radioactive materials you will be exposed to in any one time:

I WILL WORK DIRECTLY WITH:		**OTHERS IN MY LAB WORK WITH:**	
RADIONUCLIDE	**QUANTITY**	**RADIONUCLIDE**	**QUANTITY**

☐ I will be working directly with an irradiator or a machine that produces ionizing radiation (e.g., x-ray diffraction unit).

☐ I will be working in a lab or facility where others will use a machine that produces ionizing radiation. I will not use the machine personally.

List the type(s) of radiation producing machine(s) you will work with:

_____

☐ None of the above applies. I need a badge for the following reason:

_____

2. Have you ever been issued a radiation dosimeter at this or any other institution?

Yes ☐ No ☐ Uncertain ☐

a. If the dosimeter was issued at the University of WI – Milwaukee, please list your supervisors name and department:

Name:	**Dept:**

b. If dosimeter was issued by some other employer(s) please fill out the requested information for each employer (attach additional pages if necessary):

Most Recent Employer	**Other (Previous) Employer**
Name:	Name:
Address:	Address:
City:	City:
State,Zip:	State,Zip:
Dates: From: To: (MMYY)	Dates: From: To: (MMYY)
Type of Work:	Type of Work:
Estimated Dose: mrem	Estimated Dose: mrem

I certify that I have received training in the radiation source(s) and/or equipment I will be working with and will implement the ALARA principles to keep my radiation dose as low as reasonably achievable. To my knowledge, I have not exceeded any Federal or state radiation exposure limits (see above) prior to my work here at UWM.

Signed: _____ Date: _____

My signature authorizes the Radiation Safety Program to request my radiation exposure from previous employers.

Privacy Act Statement: Title 10 Code of Federal Regulations (CFR) Part 19l.13 (NRC), Title 29 CFR Part 1910.96 (OSHA) and Wisconsin Health and Family Services (HFS) Part 157.88 (3) require each employer to obtain all of your radiation exposure records to document previous exposure history. The information is used in the evaluation of risk exposure to ionizing radiation or radioactive materials. It permits meaningful comparison of both current (short-term) and long-term exposure to ionizing radiation or radioactive material. The social security number is used to assure that UW-Milwaukee has an accurate identifier not subject to the coincidence of similar names or birth dates among the large number of persons on whom exposure data is maintained. Data on your exposure to ionizing radiation or radioactive materials is always available to you upon request.

Return this completed application to: Radiation Safety Program

University Safety and Assurances (Lapham Hall W217)

Fax: 229-6729

Radiation Safety Office

University of Wisconsin-Milwaukee

In accordance with the State of Wisconsin regulation, DHS 157.3(90) I am declaring that I am pregnant. I believe I became pregnant in _____ (only the month and year need to be provided).

In accordance, State of Wisconsin regulation DHS 157.22 (8) DOSE EQUIVALENT TO AN EMBRYO OR FETUS, I understand the radiation dose to my embryo/fetus during my entire pregnancy will not be allowed to exceed 0.5 rem (500 mrem) (unless that dose has already been exceeded between the time of conception and submitting this letter). I also understand that meeting the lower dose limit may require a change in job or job responsibilities during my pregnancy.

_____

(Your signature)

_____

(Your name printed)

_____

(Date)

Please return the completed form to:

Radiation Safety Office

Lapham Hall W217

X-RAYS AND X-RAY PRODUCING EQUIPMENT

HAZARDS OF X-RAYS

X-rays are electromagnetic energy traveling as waves. They are the same as gamma rays except that gamma rays are emitted from the nucleus of an atom while x-rays originate in the atom's electron cloud. Analytical x-rays are produced by accelerated electrons from a cathode to an anode (target) in an x-ray tube.

X-rays can be very penetrating. The voltage of the system indicates how penetrating the x-rays will be. The higher the voltage of the generator, the more penetrating the radiation. Just like gamma rays, x-rays interact with molecules in the body to produce ion pairs. To protect personnel from these penetrating rays, thick, dense material (e.g., lead, steel, etc.) is used as shielding.

Certain analytical systems, (e.g., x-ray diffraction), have sufficient voltage to produce low energy (e.g., 1 - 50 keV) or soft x-rays. The soft x-rays with energies from 1 to 20 keV are absorbed in the first few millimeters of the skin, although for extremities, some of this radiation may also be absorbed to the bone. Excessive exposure from this type of radiation often produces skin reddening at exposures of approximately 300 rem (300,000 mrem) while severe skin burns can result for exposures above 500 rem. Because some types of analytical x-ray systems can produce exposure rates between 1000 and 1,000,000 mrem/hr, even short exposures to the beam are capable of producing damage. For that reason, the primary radiation beam must always be contained in a shield.

RADIATION PROTECTION TECHNIQUES

The basic radiation protection principles of time, distance and shielding, apply equally to x-ray and radioisotope sources. Implementation of these principles include:

- TIME: When you need to use an x-ray system, work quickly and efficiently. Experiments should be carefully planned and rehearsed to minimize the exposure time.
- DISTANCE: Because radiation is significantly reduced by distance, remaining at least 6 feet away from an x-ray radiation source provides a great deal of protection. When an x-ray system is being used, if you are not required to be near the system, move away. Note that many analytical systems use narrow x-ray beams. With narrow beams, even being 6 feet away from the system may result in much of the radiation beam being absorbed by your body.
- SHIELDING: On installation, primary consideration should be given to insure each tube is protected by fixed shielding. Reliance should not be placed on protective aprons and other shielding worn by the person using the system. Emplaced shielding is the most effective mechanism of protecting workers from unnecessary x-ray exposure. Always operate these systems with all shielding and safety components in place; never tamper with system interlocks.

ANALYTICAL X-RAY SYSTEMS

Analytical x-ray machines (e.g., x-ray diffraction, etc.) are used extensively for microstructure analysis in various research and teaching activities. Tubes for this purpose usually operate about 35 - 40 kV and 10 - 40 mA. In such equipment, the primary x-ray beam is permitted to impinge on the specimen and the scattered radiation is measured by a radiation detector located at various angles with respect to the sample. The principal hazards with this type of equipment is the possibility of exposure of the hands to the direct beam if a change in specimens is attempted while the tube is still energized. These

precautions and operational guidelines, considered to be the minimum requirements followed, help insure that radiation exposures will be as low as reasonably achievable when working with analytical x-ray systems.

PRECAUTIONS AND GUIDELINES

- Get proper training/instruction from the person in control before operating x-ray producing machines.
- Never assume the unit was left in a safe working condition by the previous user, check the shielding before turning the unit on.
- Unless a pre-operational check was made, do not trust the warning lights when they are not lit. To check the lights operability, set the unit to its lowest kV and mA setting and check the warning lights and interlocks.
- Do not bypass any safety device or interlock without the approval of the person in control of the machine. In such cases, post a sign stating **Safety Device Not Working.** Return the system to its unmodified state with all interlocks operational as soon as possible.
- Wear all issued dosimeters at the proper height and facing the radiation source.
- Shielding should always be adequate so other factors need not be required for safety. However, exposure reduction techniques include, increasing your distance from the x-ray source, increasing shielding, and decreasing the time spent near the x-ray source.
- Do not work near the open, unshielded beam. However, if it is necessary to work near the unshielded radiation beam (e.g., for system alignment):
    * Reduce the beam current (mA) and the beam energy (kV) to the lowest settings possible to reduce exposure rates.
    * Keep hands and body at a safe distance from the beam by using appropriate alignment tools.
    * Carry out the manufactures alignment procedures.
    * Remember, you are in a potentially hazardous situation, think before each step.
- When working with open beam x-ray equipment the unit may not be left unattended and the operator must always be immediately present.
- Secure all unused ports from casual opening.
- In case of a radiation emergency or other situation where something has gone wrong, notify the Radiation Safety Program immediately (414-430-7507).

ANALYTICAL X-RAY EQUIPMENT RADIATION SAFETY REQUIREMENTS

X-ray producing devices at UWM are regulated by the State of Wisconsin, Department of Health Services (DHS), Radiation Protection Section. All applicable regulations and safety requirements should be adhered to whenever working with x-ray producing equipment. Some of the most important safety requirements are:

- A safety device must be provided which prevents entry of any part of an individual's body into the primary x-ray beam path or which causes the beam to be shut off immediately upon such entry.
- Warning devices must be provided near the radiation source housing which indicated the x-ray tube status (ON/OFF) or a shutter status (OPEN/CLOSED) indicator located near each port.
- Unused ports must be securely closed and shielded.
- X-ray equipment must be labeled with a sign bearing the conventional radiation symbol and the words **CAUTION - High Intensity X-ray Beam** and **CAUTION RADIATION - This equipment produces radiation when energized.**
- Equipment installed after 1/1/79 must be equipped (on each port) with a shutter that cannot be opened unless a collimator or coupling has been attached.
- A warning light labeled **X-ray On** must be located near any switch that energizes the tube and must go on only when the tube is energized.
- The leakage radiation from the x-ray tube housing, with all the shutters closed, must not exceed 2.5 mR/hr at 5 cm from the surface. The x-ray generator must have a protective cabinet which limits leakage radiation from the surface to 0.25 mR/hr or less.
- Each room containing x-ray equipment shall be posted with a sign bearing the conventional radiation symbol and the works **CAUTION - X-ray equipment**.
- Written operating procedures must be available to all persons who use the device.
- No safety devices may be bypassed without the approval of the person controlling the installation. In such a case, a conspicuous sign must be posed stating **Safety device not working**.
- No one may be permitted to operate an x-ray machine without receiving instruction on the radiation hazards involved, safety devices, operating procedures, symptoms of acute localized exposure and procedures for reporting a suspected overexposure.

LABORATORY BASED TRAINING
FOR ANALYTICAL X-RAY EQUIPMENT SAFETY

This laboratory-based training must be completed and on file with the Radiation Safety Office prior to working with or near radiation-producing equipment. This serves as supplemental training to the on-line X-ray Safety Training. The supervisor responsible for overseeing the laboratory's radiation-producing equipment must present this portion of the training to applicable individuals.

Name of Trainee (print): _____

Date On-line X-ray Safety Training Completed: _____

Trainee Signature: _____

Equipment Supervisor (print): _____

Date Laboratory Based Training Completed: _____

X-ray Unit(s) Covered by this Training: _____

Equipment Supervisor Signature: _____

REQUIRED TOPICS (check each item as it is discussed)

____ Identification of X-ray equipment and radiation hazards associated with them.

____ 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.

____ Informed of requirement to report potential safety or security concerns pertaining to the analytical X-ray equipment to the equipment supervisor and the Radiation Safety Officer (RSO).

____ Informed of monitoring badges used during instrument operation, if applicable, and routine survey and inspection performed by Radiation Safety.

____ Administrative controls, documentation requirements, procedures for equipment use, and location of procedures.

____ Limitations and conditions relative to the safe use of the equipment reviewed including the requirement to report unsafe conditions or operational change that could adversely impact radiation safety to the equipment supervisor and the RSO.

____ Survey and monitoring requirements reviewed to include procedures for survey meter checks and operation, if applicable and proper use, storage and exchange procedures for personal and/or area monitoring badges, if issued.

____ Steps to be taken to prevent entry into X-ray beam by user or unauthorized personnel when unit is left unattended.

____ Proper procedures for reporting an actual or suspected exposure and symptoms of an acute localized exposure.

UWM RADIATION SAFETY OFFICE

Kim Axtman, Radiation Safety Program
Work Cell: (414) 430-7507
Home Cell: (414) 335-9786
Melissa Spadanuda, Associate Director, University Safety and Assurances
Office: (414) 229-3173
Home Cell: (262) 442-4429
Zack Steuerwald, Associate Director, University Safety and Assurances
Work/Home Cell: (414) 430-1474

EMERGENCY NUMBERS

UWM Police - Emergency 9-911
UWM Police - Information/Assistance 229-4627