X-Ray Safety Manual

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Department of Environmental Healt and Safety

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1 X-ray Radiation Safety at Queen's University

1.1 Introduction

Queen's University's Health & Safety Policy requires conformance to all applicable health and safety regulations and standards for the prevention of illness and injury of its employees, students, and members of the broader University community, in accordance with the *Policy Statement on Health and Safety* issued by the University Secretariat and Legal Counsel.

Consistent with this Policy, all activities involving radiation emitting devices shall be conducted in a manner that minimizes risk and prevents unnecessary exposure. The University requires that radiation hazards be identified, assessed, and effectively controlled. Queen's University is firmly committed to the principle that all radiation exposures shall be maintained **As Low As Reasonably Achievable (ALARA)**.

The Queen's University X-Ray Safety Manual is designed to assist members of the university community in meeting the requirements of the Ontario Ministry of Labour, Immigration, Training and Skills Development (MLITSD), Radiation Protection Service, as part of the Radiation Protection Program.

1.2 Applicable Standards and Regulations

Occupational exposure to X-rays of energies less than 1 MeV, are under provincial/territorial jurisdiction in Canada. In Ontario, occupational X-ray safety is overseen by the Ontario Ministry of Labour, Immigration, Training and Skills Development (MLITSD), Radiation Protection Service. The Radiation Protection Service is responsible for enforcing Regulation 861 - X-Ray Safety under the Occupational Health and Safety Act (OHSA).

The Safe use and operation of X- Ray equipment at Queens University also follows the recommendations and safety procedures outlined in the following documents:

- Safety Code 32 – Safety Requirements and Guidance for Analytical X-Ray Equipment, portable, handheld , X-ray tube based open bean XRF devices, and the
- Safety Code 28 – Radiation Protection in Veterinary Medicine. Recommended Safety Procedures for the Installation and Use of Veterinary X- Ray Equipment.
- Safety Code 34 – Radiation Protection and Safety for Industrial X-ray Equipment

1.3 Regulatory Framework

Ontario Regulation 861/90 – *X-Ray Safety* under the **Occupational Health and Safety Act (OHSA)** defines:

- An **X-ray machine** as *"an electrically powered device, the principal purpose of which is the production of X-rays."*
- An **X-ray source** as *"any device, or portion of any device, that emits X-rays, whether or not the device is an X-ray machine."*

In accordance with this Regulation, Queen's University maintains oversight and control of all X-rays emitting devices falling within these definitions.

Under this regulatory framework, the University controls and manages, including but not limited to:

- X-ray cabinet systems;
- Portable X-ray devices;
- X-ray tubes;
- X-ray analytical instruments (e.g., XRF, XRD);
- Any other electrically powered device capable of emitting X-rays.

All such equipment must comply with the design, shielding, inspection, posting, and operational requirements set out in this manual.

1.4 Scope of Application

The X-Ray Safety Manual applies to all activities involving X-ray emitting devices used within Queen's University facilities, including but not limited to:

- Teaching laboratories;
- Research or development laboratories;
- Core facilities;
- Field or outdoor activities;
- Mobile or temporary installations under University control.

This program applies to all faculty, staff, students, contractors, and visitors who operate, maintain, supervise, or work in proximity to X-ray emitting equipment.

The program ensures:

A. Registration and inventory control of X-ray devices;
B. Shielding assessments and safety evaluations;
C. Training and authorization of operators;
D. Posting and area classification;
E. Incident investigation and corrective action;
F. Periodic inspection and program review.

1.5 Program Authority and Oversight

The Principal of Queen's University has appointed the University Radiation Safety Committee to carry out the advisory responsibilities for the overall operation of the University Radiation Protection Program. The University's X-Ray Safety Program is administered through Environmental Health & Safety (EH&S) and operates separately from the CNSC-regulated Radiation Protection Program (RPP), unless the device falls under federal jurisdiction.

Queen's University has a designated person competent to exercise direction over the safe use and operation of the X-ray machine. The designated competent person is hereinafter named the University Radiation Safety Officer (URSO). The URSO reports directly to the Director of the Department of Environmental Health and Safety.

1.6 Roles and Responsibilities

1.6.1 University Radiation Safety Committee

The Committee has authority from the Principal:

1) to advise concerning the authorization and control of the use of radiation producing devices at the University in compliance with the X-ray registrations issued by the Ontario MLITSD: Occupational Health & Safety Act, Ontario.
2) to advise the suspension, when necessary, of the use of any X-radiation producing devices at the University, regardless of the source or authorization.

Responsibilities

The Committee is responsible for:

1) developing University policy with respect to the safe use of techniques capable of producing X-ray emission.

2) advising the University, its faculties, departments, cross-appointees and researchers of the Committee's policy and of the special requirements relating to research and teaching involving the use of X-rays.
3) making recommendations to the University, through the Vice-Principal (Operations and Finance), concerning the actions to be taken on specific aspects of X-ray related matters as they arise.
4) advising the development of appropriate procedures for the handling of emergency situations relating to X-ray emitting devices within the University.
5) serving on behalf of the University as reviewing agency for all installations involving X-rays.
6) providing at appropriate intervals to the University and to external agencies, as required, reports on:

    i) situations and activities involving X-rays.

    ii) all incidents and accidents that require reports on safety aspects.

7) acting as a resource body for the University and its staff to provide:

    i) dissemination of up-to-date information regarding current government regulations concerned with licencing, training procedures and other related matters as they arise.

    ii) arrangement for providing monitoring facilities, through the office of the Vice-Principal (Operations and Finance), for both personnel and equipment.

    iv) instructional services in radiation safety.

    v) relevant planning advice for new construction and modification of university buildings.

8) providing liaison with the Radiation Committees of the Hospital regarding items of mutual concern.

1.6.2 University Radiation Safety Officer (URSO)

The URSO is the person responsible for the management, coordination, effectiveness, and control of an employer's radiation safety program. The RSO must be trained through a course designed to meet the expectations of the MLITSD with regards to X-ray safety. In the event that the person assigned as URSO changes, the MLITSD will be informed within 15 days.

Authority

1) The URSO will work under the advice of and report to the chairman of the Committee and the Director of Environmental Health and Safety on all matters pertaining to radiation safety.
2) The URSO is to assume control in an emergency involving radiation hazards and to take such actions as may be necessary to ensure the safety of personnel, property, and equipment, and report these actions at the earliest possible time to the Chairman of the Committee.
3) The URSO will have the authority to shut down temporarily any process or laboratory that is considered to be in violation of University policy or Government regulations.
4) the URSO will have authority to enter research areas to conduct tests required for monitoring safe handling and disposal of radiation sources.
5) the URSO will be required to report to the Committee or to its Executive at the discretion of the Chairman on his/her activities, including advice given and actions taken or recommended.

Responsibilities

1) administering the policy of the University and its Radiation Protection Program and acting as liaison with regulatory agencies.
2) reviewing all applications for X-ray use.
3) reviewing orders for the purchase of X-radiation devices and to ensure that the x-rays have been registered with the appropriate government agency.

4) maintaining a campus-wide inventory of X-ray sources..
5) inspecting and surveying laboratories and other sensitive areas in which X-ray emitting devices are used.
6) administering the Health Canada personnel dosimeter service and maintaining all necessary records.
7) advising the Committee on new and proposed Federal and Provincial legislation or items which may affect the use of X-ray emitting devices on campus.
8) serving as the Committee representative when plans are being formulated for new X-ray laboratory facilities or alterations to existing X-ray laboratories.

1.6.3 X-Ray Supervisors

X-ray supervisors will be responsible for the education and training requirements for x-ray safety, the potential x-ray hazards and associated control measures for all x-rays under the supervisor's authority. The supervisor will be familiar with general operating procedures of x-rays under their control.

Responsibilities

1) Instructing all workers, prior to employment in X-ray radiation laboratories, to make them aware of the potential hazards of X-ray radiation, including genetic effects.
2) Ensure each authorized employee completes the **X-Ray Worker Registration Form** (Appendix 1).
3) Arranging for adequate facilities, equipment, instruments, supervision and instruction in compliance with the University's radiation protection standard.
4) Ensuring that personnel wear appropriate protective equipment, radiation monitoring badges and/or pocket dosimeters as required.
5) Allowing only authorized persons to enter rooms that are specified as restricted areas.
6) Ensuring that the URSO has an up-to-date listing of all users.
7) Posting of radiation warning signs and labels as required.
8) Reporting all radiation accidents and near-miss incidents to the URSO.
9) Informing all students involved in courses or research activities in X-ray laboratories of the procedures to be adopted during any authorized use of X-ray equipment and to ensure that the student is fully aware of those procedures by requiring him to indicate this by his signature in the X-ray laboratory record book.
10) Supplying the URSO with a copy of the written instructions on safety procedures to be followed at each X-ray installation.

1.6.4 Users of X-ray Equipment

1) Only authorized operators are allowed to use the X-ray machine, and access to the X-ray machine must be restricted when not in use to limit exposure to workers. Users of X-ray equipment are responsible for complying with the X-ray system supervisor’s instructions regarding the use of the X-ray emitting equipment.
2) Users must complete the **X-Ray Worker Registration Form** (Appendix 1).
3) Before becoming an authorized operator, the worker must undergo training, as described **in Section 1.10.**

Responsibilities

Authorized operators required to perform testing using the X-ray machine will have the following duties over and above their regular duties:

1) Use the X-ray machine in a safe manner
2) Ensure access to the X-ray machine is restricted when not is use
3) Perform maintenance as per manufacturer’s instructions

4) Undergo all required safety training.

1.7 Classification of Workers, Dose Limits, and Dose Monitoring

The MLITSD's Regulation respecting X-ray Safety (Regulation 861/90) identifies two different types of workers:

1. **X-ray Worker**: a worker who, as a necessary part of the worker's employment, may be exposed to X-rays and who may receive an occupational dose (whole body) of more than the annual dose limits of Column 4 of the Schedule; and

2. **A Worker who is not an X-ray Worker**: a worker who cannot be exposed to an occupational dose (whole body) greater than the annual dose limits of Column 4 of the Schedule.

The dose limits for these workers, from the Schedule of the Regulations are reproduced below in Table 1.

Table 1: Annual Dose Limits of the Ontario Occupational Health and Safety Act, from the Schedule within Regulation 861

Part of Body Irradiated	Exposure Conditions and Comments	Dose Equivalent Annual Limit* (millisieverts, mSv)	
Column 1	Column 2	X-ray Workers	Other Workers
		Column 3	Column 4
Whole body or trunk of body	Uniform irradiation	50	5
Partial or non-uniform irradiation of body	Limits apply to the Effective Dose Equivalent, as defined in Note a) of the Schedule in the Regulation	50	5
Lens of eye	Irradiated alone or with other organs or tissues	150	50
Skin	The limit applies to the mean dose equivalent to the basal cell layer of the epidermis for any area of skin of 1 square centimetre or more	500	50
Individual organs or tissues other than lens of eye or skin	The limit on effective dose equivalent applies, with an overriding limit on the dose equivalent to the individual organ or tissue	500	50

* The annual limits do not include any dose equivalent received by a worker from background sources or received as a patient undergoing diagnostic or therapeutic procedures. The annual limits do include any dose equivalent received by a worker, because of his or her occupation, from all sources of ionizing radiation.

It should be noted that although the regulation has a dose limit of 5 mSv for a non-X-ray worker, following best international practices and the recommendations of the International Commission for Radiological Protection, the annual dose to members of the public should not exceed **1 mSv (one millisievert).**

1.7.1 Workers who are not X-ray Workers

Generally, non-X-ray workers work or may work near locations where an X-ray machine is used. This may include employees whose assigned duties do not include the use of an X-ray machine, but who work in the vicinity. In cases, where radiation doses are anticipated to not exceed 5 mSv per year, as in the case of operation of the X-ray machine, workers who work with an X-ray machine are not required to be designated as X-ray workers.

In general, X-ray machines should be located as far away as possible from areas occupied by non-X-ray workers. Employers must ensure not only that the radiation levels in areas adjacent to X-ray machine locations do not lead to dose limits for non-X-ray workers being exceeded, but that doses remain As Low As Reasonably Achievable.

1.7.2 X-ray Workers

An X-ray worker is defined by Regulation 861/90 as a worker who, as a necessary part of their employment, has a reasonable probability of receiving a radiation dose greater than 5 mSv (whole body) or any of the other limits in Column 4 of the Schedule per calendar year in the course of their work (see Table 1, above).

Workers who are authorized to operate an X-ray machine as a regular part of their job will be required to be X-ray Workers only when their annual dose equivalent is reasonably likely to exceed 5 mSv (whole body).

1.7.3 Personal Dose Monitoring

Ontario's Regulation respecting X-ray Safety (Reg 861/90) specify that personal monitoring is required for each X-ray worker who has a reasonable probability of receiving a radiation dose of 5 mSv/year (whole body) or greater.

When proper procedures are followed, X-ray machine operators do not require dosimetry, as doses are not expected to approach 5 mSv per year (see Section 1.7.4). Moreover, in most emergencies, the X-ray machine is shut off (not energized) and radiation exposure is not possible.

1.7.4 Approach for Determination of X-ray Worker Status and Dosimetry

X-ray machine Operators with reference to Reg. 861/90

Based on the definition of an X-ray worker, compliance to Regulation 861/90's Section 17 leakage limits, and a typical annual working year of 2000 hours, an X-ray machine worker would not exceed any of the annual does limits as outlined in Column 4 of the Schedule (see Table 1, above). Therefore, they would not need to be designated as X-ray workers. This is calculated as follows:

5 µGy (micrograys) per hour (the leakage limit) times 2000 hours equals 1 mGy (milligray), which corresponds to 1 mSv (millisievert) of effective whole-body dose, for the X-ray energies used by the X-ray machine. This is much less than the 5 mSv limit.

As an ALARA principle, authorized X-ray machine operators must follow appropriate radiation protection procedures and spend the least amount of time in close proximity to the machine.

1.8 MLITSD Registration and Installation Acceptance

The possession, use, storage, and transfer of any X-ray machine at Queen's University, requires completing its registration with the Environmental Health and Safety Department before it can be put into service. Register X-ray device at https://safety.queensu.ca/x-ray-registration.

The URSO will be responsible for completing and submitting a registration package to the Radiation Protection Service (RPS) od the MLITSD (RadiationProtection@Ontario.ca.) if:

- a new X-ray source is going to be installed in a permanent location

- an X-ray source that is designed for portable or mobile use, that is regularly installed or used in one location

The MLITSD installation approval package must include:

- complete the Application for Registration and Installation of an X-ray Source (Form ON0057E)
- Plan location drawings that meet the requirements in subsection 6(4) of *Regulation 861 – X-ray Safety*, as required
- Technical information from the X-ray manufacturer, such as a brochure.
- Scatter radiation data provided by the manufacturer or appropriate third-party (for cabinet X-ray sources and some other X-ray sources).
- A full radiation shielding calculations for each barrier. This is not necessary for cabinet X-ray sources that meet the requirements of section 17 of *Regulation 861 – X-ray Safety*. Shielding Calculations can be provided by a third party upon confirmation of their expertise to perform these calculations.

Upon revision and approval by the Office we will receive an email containing the floor plan with acceptance information, including the technical factors that were used to evaluate the installation.

A copy of this email must be kept onsite as part of the facility's record. The MLITSD radiation protection inspectors will ask to see a copy during a workplace inspection.

A form must be update and resubmitted if:

- the X-ray source changes ownership
- there is a change to the contact information
- there are changes to the original installation that could result in increased radiation exposure for an employee

Examples of changes that could result in an increase in radiation exposure include, but are not limited to:

- replacing or upgrading an existing X-ray source with a new unit, such as replacing a conventional film X-ray source with a digital unit
- increasing the frequency or workload of the X-ray source beyond the value accepted in the original application, such as increasing the number of X-rays taken per week
- making changes to a space adjacent to the X-ray room, horizontally or vertically, that would alter its use or increase its occupancy. An example is converting a storage room to a reception area
- making any changes to the walls of the X-ray room
- making any changes to the shielding in or around the X-ray room or the X-ray source
- any other work, such as service work or repair that requires a change to the installation of an existing X-ray source

The X-ray source must not be installed or modified before receiving written approval from the RPS.

1.9 The ALARA Principle

The ***ALARA*** principle requires that radiation exposures be kept ***As Low As Reasonably Achievable***, taking social and economic factors into consideration.

All work associated with the X-ray machine will be governed by considerations for potential radiation hazards. As stated

in Section 10 of Regulation 861/90, exposures must be kept ALARA to ensure that the following are not exceeded:

- Occupational doses to individuals who are not X-ray workers shall not exceed the annual dose limits set out in Column 4 of the Schedule (Reg 861/90 and reproduced here in Table 1, within Section 1.7: Classification of Workers, Dose Limits, and Dose Monitoring).
- Occupational doses to individuals who are X-ray workers shall not exceed the annual dose limits set out in Column 3 of the Schedule (Reg 861/90 and reproduced here in Table 1, within Section 1.7: Classification of Workers, Dose Limits, and Dose Monitoring).
- The mean dose equivalent received by the abdomen of a pregnant X-ray worker does not exceed 5 millisieverts during the pregnancy.

As a best practice and recommendation of the International Commission for Radiological Protection, an annual dose to members of the public should not exceed one millisievert (mSv).

1.9.1 Transportation

Transportation of an X-ray machine is unrestricted but would be governed by provincial/territorial/federal legislation involving the importation/registration/installation of such a device. The respective authority (for Ontario it would be the MLITSD) must be informed of the employer no longer having possession of a registered X-ray machine.

1.9.2 Usage

Only authorized operators are allowed to use the X-ray machine, and access to the X-ray machine must be restricted when not in use to limit exposure to workers. For more procedures concerning the use of the X-ray machine, see Section 2.

1.9.3 Storage

When not in use, access to the X-ray machine must be restricted by storing the key or password required to energize the X-ray machine from unauthorised users. Furthermore, the appropriate signage will be posted, per Section 2.5.

1.10 Worker Training

1.10.1 Training Requirements

1.10.1.1 University Radiation Safety Officer

The URSO must have sufficient training and qualifications to allow him/her to properly manage the radiation safety program of Queen's University, including X-ray Radiation Safety Officer training, X-ray shielding calculations and be familiar with all X-ray machines/sources in Queen's University's possession.

1.10.1.2 Authorized Operators

Workers who are required to operate the X-ray machine must read this Radiation Safety Manual, particularly APPENDIX 1 X-Ray Worker Registration Form

The undersigned worker will participate in the Queen's University X-Ray Safety Program

X-Ray Manual

The undersigned has read and is familiar with the contents of the Queen's University X-Ray Safety Manual.

Standard Operating Procedures

The undersigned has read and is familiar with the contents of the Standard Operation Procedures for the X-ray(s) listed below.

Personal Protective Equipment

The undersigned has the personal protective equipment described in the Standard Operating Procedure available to them and is familiar with their care and use.

Description of X-Ray(s)

Location _____

Manufacturer _____ Model _____

Description _____

Manufacturer _____ Model _____

Description _____

Manufacturer _____ Model _____

Description _____

Supervisor _____ Signature_____

Authorized worker designation

X-ray worker (annual exposure above 5 mSv/year) ☐ No X-ray Worker (annual exposure below 5mSv/year)☐

Whole body dosimeter ID : _____ No dosimeter required ☐

Worker _____ Signature_____

Date _____

Please return the completed form to:

University Radiation Safety Officer

Environmental Health and Safety (safety@queensu.ca)

Appendix 2 – Information on Health Effects from Exposure to Ionizing Radiation.

Once the above training is completed, the X-ray supervisor will ensure that the X-ray machine operator receives hands-on training on the safe use of the machine. The X-ray supervisor will review, with the worker:

- The safety features of the X-ray machine,

- The procedures for the safe use and maintenance of the X-ray machine as per the manufacturer's manuals,
- How to determine a problem with the X-ray machine and/or survey meter when conducting leakage measurements
- All emergency procedures.

Records of the hands-on training must be kept on file along with all other training records.

Only trained and authorized individuals are allowed to use the X-ray machine.

1.10.1.3 General Facility Personnel

Due to the presence of an X-ray machine in the facility, general facility personnel working in the immediate vicinity of the X-ray machine require some awareness training, even though they do not operate the device themselves. This training will be provided by the URSO.

1.10.1.4 Refresher Training Requirements

Personnel are to receive regular refresher training, according to the following frequency:

- URSO: every 3 years
- Authorized Operators: every 3 years
- General Facility Personnel (awareness training): every 3 years

Refresher training can be given more frequently than what is listed above, if desired. The URSO will keep records of all refresher training.

1.10.2 Training Records

All training information will be kept by the URSO, along with the other records listed in Section 1.10. An updated list of trained workers will be maintained and supplied to the MLITSD upon request.

2 Procedures and Requirements for the Safe Use of X-ray Machines

2.1 Use, Storage, and Control of the X-ray machine

All procedures are developed in accordance with the X-ray machine manufacturer's specifications and instructions as well as the expectations of the MLITSD. In particular, all operation, inspection, and maintenance of the X-ray machine will be performed according to the X-ray machine manufacturer's specifications and instructions. All workers working with the X-ray machine are trained with the corresponding manual to ensure they understand the procedures outlined by the manufacturer.

It is the policy of Queen's University to control and have records of the inventory of each X-ray machine from the time it is acquired until it is disposed of. These records will be available for MLITSD inspection.

2.1.1 Purchase and Receipt of X-ray Machines

Only X-ray machines registered with and having the installation location accepted by the MLITSD may be purchased, installed and used. Furthermore, Queen's University will only purchase X-ray machines whose manufacturers can confirm that their product is compliant with Health Canada's Radiation Emitting Devices Act and Regulations. The URSO will review and approve all acquisitions.

Upon receipt of an X-ray machine, either new or returning from servicing and/or calibration, the receiver will:

1) Review the shipping documents to ensure compliance with the terms of the agreement/invoice.
2) Inspect the package visually to determine if it has been damaged or tampered with.

3) Open the package and ensure that the contents of the package match the information on the shipping documents.
4) Record the receipt of the package and alter the inventory information to account for the new X-ray machine.

If a problem occurs at any point in the receipt of the package, the receiver will notify the URSO. The URSO will immediately contact the necessary bodies (carrier, consignor, etc).

2.1.2 Use

Only authorized workers have access to the X-ray machine. Furthermore, only authorized workers are permitted to operate the X-ray machine.

The following procedures must be followed when using the X-ray machine.

1. Use the X-ray machine according to the manufacturer's instructions and recommendations.
2. Always keep unauthorized persons away from the immediate vicinity of the X-ray machine.
3. Perform routine cleaning and maintenance according to the manufacturer's instructions and recommendations.
4. The authorized operator must contact the URSO immediately if
    a. The X-ray machine is missing
    b. He/she suspects theft, tampering, or unauthorized use
    c. An event occurs which may have resulted in a worker receiving a dose equivalent in excess of the annual limits set out in Column 3 of the Schedule (Reg 861/90).

2.1.3 Access Control

The X-ray machine will only be located according to the diagram provided in **Error! Reference source not found.** approved by the RPS. The only workers permitted access to the room containing the X-ray machine include the URSO, authorized operators, and laboratory workers who have undergone the X-ray radiation safety training.

If anyone discovers that the X-ray machine is missing, they must immediately contact the URSO and follow the emergency procedures outlined in Section 2.7.2.

2.1.4 Maintenance

The Department of Environmental Health and Safety will conduct annual leak test using a properly functioning and calibrated survey meter for each X-ray machine registered with the RPS. A copy of the most recent leakage test certificates (Appendix 4. Radiation Protection Equipment Survey) and calibration certificates will be kept on file.

Routine maintenance of the X-ray machine will be done in accordance with the manufacturer’s manual. If problems with the X-ray stress measurement machine or cabinet are detected at this point, a representative of the manufacturer will be contacted, and arrangements will be made to send the machine and/or cabinet for servicing.

2.1.5 Transfer or Disposal of An X-ray Machine

URSO authorization is required to either transfer an X-ray machine to another location (for example, for servicing or calibration of the X-ray machine), or to dispose of the X-ray machine.

Transfer of an X-ray machine with the intent of having it returned after calibration or servicing does not require MLITSD notification. However, when an X-ray machine is transferred so that it is no longer in possession of the employer, the MLITSD must be notified, preferably in a written form. When an X-ray machine is transferred or disposed of, the XSO will adjust the inventory accordingly.

2.1.6 Non-Possession of any X-ray Machine

When Queen's University no longer possesses an individual X-ray machine it will inform the MLTSD in writing. Queen's University's X-ray registration will terminate upon notification.

The X-ray machine will be disposed of according to the Ontario Ministry of Environment, Conservation, and Parks legislation.

For the disposal of an x-ray machine, the URSO shall observe the instructions provided by the manufacturer in the product manual or contact the manufacturer for information and guidance.

In a case where a manufacturer is no longer in the business of manufacturing, selling, or servicing industrial x-ray equipment, the following procedures shall be followed:

- the vacuum in the x-ray tube must be breached.
- the x-ray tube window should be investigated to determine whether or not it contains beryllium, and if it does, **special disposal procedures must apply since beryllium presents a toxic ingestion or inhalation hazard;**
- the transformer oil, if this exists, must be disposed of in accordance with pertinent environmental legislation; and
- the **lead must be recycled** accordingly.

These steps will be taken by the department Radiation Safety Technician after completing the required Job Hazard Analysis. All the information for an application, disposal or any questions related to X-Ray safety procedures can be sent to our office at Safety@queensu.ca

2.2 Radiation Detection Instruments

A radiation survey meter must be readily available and used for measuring a dose rate during Radiation Protection Equipment Survey (Appendix 4).

The URSO will ensure that:

- Queen's University will have a survey meter readily available, preferably an ion chamber survey meter capable of detecting X-ray energies down to 5 keV.
- Queen's University will verify that any survey meter used has been calibrated within the preceding 12 months.
- Queen's University will schedule the calibration of any meters in their possession with consideration of timelines for delivery to and from the calibration facility so that there is always a survey meter readily available.
- The calibration service provider will ensure that calibrations are performed in accordance with MLITSD expectations. Ideally, such units will be calibrated for at least two X-ray energies.
- Records of the calibration certification will be kept by the URSO and a copy of the most recent certificate will be kept with the survey meter.
- Workers performing surveys are trained in the use and maintenance of the survey meters.

Before each use, workers will verify that the survey meter is properly functioning by performing inspections for:

- Physical Damage
- Battery power
- High voltage
- Calibration date

As the survey meters are sent for calibration once a year, the workers are not expected to do regular maintenance on the meters, aside from keeping them clean and in good working condition (e.g., careful handling and/or replacing batteries that are known to have expired). Should a worker have any reason to think a survey meter is not working properly, he/she will immediately contact the URSO, who will determine whether the survey meter needs to be sent for calibration/servicing before its next use.

2.3 Leakage Testing

Leakage measurements should be done upon initial installation, during regular quality assurance tests, and when maintenance, modification, damage, or overexposure incidents have occurred. If the X-ray machine's leakage measurement ever exceeds the legislated limit (5 micrograys per hour at 5 centimetres from the external surface):

- The X-ray machine must not be used.
- A competent service company will be contacted to investigate and repair the X-ray machine.

2.4 Records and Reporting System

2.4.1 Record Keeping

Records will be kept both electronically and in hard copy and retained until all X-ray machines are disposal of. The following records will be kept:

- X- Ray worker registration form
- Awareness training for general facility personnel
- RPS X- Ray Registration
- External dosimetry results, if applicable
- Inventory of an X-ray machines in possession
- Details of incidents involving an X-ray machine
- Purchases and transfers of an X-ray machine
- A copy of the registration package submitted to the MLTSD including Ministry Forms, floor plan drawing, technical manual, letter of registration acknowledgement and installation acceptance, along with the initial submission documents
- A copy of this Radiation Safety Manual (RSM)
- List of radiation detection equipment and annual calibration data
- Leakage test monitoring results
- Disposal details and notification to the MLTSD

All records pertaining to workers must be kept for a minimum of three years after the termination of the employment of the worker with Queen's University. All other records will be retained for a period ending three years after the disposal of the X-ray machine.

2.4.2 Reporting Radiation-Related Events to the MLITSD

The employer of a worker which has received doses in excess of

- A dose equivalent in excess of the annual limits set out in Column 4 of the Schedule of Regulation 861/90 (given in Section 1.7 Table 1 of this document) in a period of three months, or
- An accident, failure of any X-ray source or other incident may have resulted in a worker receiving a dose equivalent in excess of the annual limits set out in Column 3 of the Schedule of Regulation 861/90 (given in Section 1.7 Table 1 of this document)

shall, within two days after the occurrence, give notice in writing to the Director with the following information:

1. The name, address and type of business of the employer.

2. For an occurrence at a project, the name and address of the contractor.
3. The time, date and place of the occurrence.
4. The nature and circumstances of the occurrence, including a description of any machinery, equipment or procedure involved.
5. The steps taken to prevent a recurrence.

and retain a copy of the written notice for at least three years after the date the notice or report is made.

Queen's University will follow the expectations of the OHSA with respect to reporting of both radiological and non-radiological incidents.

2.5 Posting of Signs and Labelling of an X-ray Machine

Where an X-ray machine is used the following

1) X-ray warning signs or warning devices shall be posted or installed in conspicuous locations.
2) Every X-ray machine capable of producing an air kerma rate greater than 5 micrograys per hour at any accessible point shall be labelled at its operating controls as a source of X-rays.
3) A warning device that indicates when X-rays are being produced shall be mounted on or near the cabinet in such a way as to be conspicuous from any position from which the cabinet can be opened.

2.6 Internal Inspections/Audits

Radiation compliance inspections will be performed periodically by the URSO. The purpose of such inspections is to ensure that each worker is conducting their work in accordance with safe work practices, and in compliance to legislated and guideline requirements, and the procedures detailed in this Radiation Safety Manual as well as any further procedures instituted by Queen's University. A checklist will be used during the inspection, an example of which is provided in Appendix 3 – .

During the inspection, the URSO will:

- Address any radiation concerns or recurring comments expressed by workers who have access to the X-ray machine;
- Review all other records (shipping documents, training records, X-ray worker status documents for all workers who use the X-ray machine, servicing records, etc.);
- Ensure that the appropriate radiation warning signs are posted, along with other required information;
- Ensure that workers who use the X-ray machine are knowledgeable about the procedures and safety precautions to take with regards to the cabinet and X-ray machine;
- Ensure that all policies and procedures within this manual are followed and up to date;
- Verify that the necessary leakage tests have been done and the records are on file; and
- Verify that the survey instruments have been calibrated and the records are on file.

Communication of inspection findings will be reported to the X-ray Supervisor, who will provide a corrective action plan to eliminate those findings.

2.7 Emergency Procedures

The X-ray supervisor is the person to contact in case of an emergency involving the X-ray machine. Queen's University will maintain an up-to-date emergency contact listing, including the 24-hour telephone numbers to contact the URSO, the alternate for the URSO, the MLITSD, and any other required emergency contacts.

2.7.1 Overexposure

Although an overexposure is unlikely due to normal operation of an X-ray machine, it is possible to happen, particularly in emergency situations when the shielding, interlocks, or other safety mechanisms of the X-ray machine has been compromised, or safe work practices are not followed.

In the event of a potential overexposure of a person, specific actions must be taken.

1. Upon recognizing that an overexposure situation may exist, authorized operators or the URSO are to make the situation safe. They should therefore:
    a. Shut off the X-ray machine and disconnect power to it
    b. Remove the exposed person (themselves included, if applicable) from the machine.
    c. Secure the entry to the incident site.

    (If warranted, fire/first aid procedures should be followed first, followed by a & b.)
2. After taking actions to make the situation safe, operators should
    a. Identify all workers and persons who may be affected and ask them to remain to speak with the URSO, and in conjunction
    b. Immediately notify the URSO of the overexposure situation.
3. The URSO will assess the situation, and if required, provide additional resources (such as a medical assessment and mitigation) to assist.
4. If the incident results in a critical injury[1] as defined by the OHSA, which is very unlikely but not impossible, the X-ray Safety Officer will **immediately** notify the by telephone or other direct means of contact an inspector of the MLTSD (416-235-5922), the Joint Health and Safety Committee (JHSC), health and safety representative, and trade union, if any, and make a preliminary verbal report of the incident, per the requirements of Section 51(1) of the OHSA.
5. The URSO will investigate the overexposure, and obtain all possible information, including personnel distances from the machine, personnel time at the various distances, radiation field strength, etc. This information will be used to estimate the dose to personnel.
6. Assistance will be sought from the manufacturer or a radiation safety consultant as required.
7. All event details will be recorded chronologically.
8. If the shielding, interlocks, or other safety mechanism has been damaged or otherwise rendered unsafe, the X-ray equipment must be tagged out of service, repaired, and surveyed for proper performance before it can be returned to service.

[1] Under Regulation 420/21, Section 1(1), "critically injured" means an injury of a serious nature that places life in jeopardy, produces unconsciousness, results in a substantial loss of blood, involves a fracture of a leg or arm but not a finger or tow, consists of burns to a major portion of the body, or causes the loss of sight in an eye.

9. The URSO and workers will activate authorized follow-up procedures.
10. The URSO is to submit a written report to the MLITSD, the JHSC, health and safety representative, and trade union, if any within 48 hours with contents of the report describing the circumstances of the accident or failure of equipment that may have resulted in a worker receiving a dose in excess of the annual limits set out in Column 3 of the Schedule (50 mSv whole body, 150 mSv Lens of Eye or 500 mSv Skin).
11. In addition to the immediate preliminary report, the URSO is to submit a written report to the MLITSD, the JHSC, health and safety representative, and trade union, if any, within 48 hours with contents of the report describing the circumstances of the accident or failure of equipment that may have resulted in a worker being killed or critically injured.

2.7.2 Loss or Theft of an X-ray Machine

Loss or theft of an X-ray machine rarely occurs, however the MLITSD should be notified if it does happen. The following steps must be followed in the case of the disappearance of an X-ray machine:

1. Immediately notify the URSO
2. URSO will immediately notify the police or other appropriate local authorities
3. Interview all personnel who may know the location of the X-ray machine
4. Identify and search all possible locations of the X-ray machine
5. To meet the requirements of notice under Section 4 of Regulation 861/90, the employer shall forthwith notify the RPS Director advising the Director they no longer are in possession of the X-ray machine.

2.7.3 Fire or Explosion

In the event of a fire or explosion involving the area where the X-ray machine is located the following procedures should be followed:

1. Immediately sound the fire alarm by activating the alarm switch.
2. Call 911 and inform the URSO.
3. Shut off the X-ray machine (if safe to do so).
4. Follow local emergency procedures for fire.
5. Notify the MLITSD as required by the OHSA.

APPENDIX 1 X-Ray Worker Registration Form

The undersigned worker will participate in the Queen's University X-Ray Safety Program

X-Ray Manual

The undersigned has read and is familiar with the contents of the Queen's University X-Ray Safety Manual.

Standard Operating Procedures

The undersigned has read and is familiar with the contents of the Standard Operation Procedures for the X-ray(s) listed below.

Personal Protective Equipment

The undersigned has the personal protective equipment described in the Standard Operating Procedure available to them and is familiar with their care and use.

Description of X-Ray(s)

Location _____

Manufacturer _____ Model _____

Description _____

Manufacturer _____ Model _____

Description _____

Manufacturer _____ Model _____

Description _____

Supervisor _____ Signature_____

Authorized worker designation

X-ray worker (annual exposure above 5 mSv/year) ☐ No X-ray Worker (annual exposure below 5mSv/year)☐

Whole body dosimeter ID : _____ No dosimeter required ☐

Worker _____ Signature_____

Date _____

Please return the completed form to:

University Radiation Safety Officer

Environmental Health and Safety (safety@queensu.ca)

Appendix 2 – Information on Health Effects from Exposure to Ionizing Radiation

As was discussed in Section 1.7 of this Radiation Safety Manual, the difference between a "other worker" and a "X-ray worker" is the amount of radiation dose a worker is allowed to receive from occupational exposures within one year. Whereas a "other worker" is only allowed to receive at most **5 mSv** of radiation dose per year, an X-ray worker is allowed to receive **50 mSv of dose in a year.** An authorized X-ray machine operator is classified as an "other worker" as their radiation exposure is not expected to exceed the "other worker" dose limits in Column 3 of the Schedule in Reg 861/90. What is the risk associated with varying levels of exposure?

Health Canada estimates that Canadians receive on average **2-4 mSv** of radiation dose each year from *background radiation*. Background radiation is radiation which is always all around us. Most background radiation is from natural sources, such as the Sun (cosmic radiation), radioactive particles like uranium, radium, and radon, found in soil or emanating from the soil (terrestrial radiation), and radioactive particles, like potassium-40 and carbon-14, found in food (internal radiation). This type of radiation exposure has never been shown to lead to adverse health effects.

The International Commission on Radiological Protection (ICRP, an independent organization of scientist) estimates that for every **1000 mSv** of radiation dose, accumulated over 50 years, the risk of getting a fatal cancer increases by **4%**. This number was used to create the dose limits for nuclear energy workers in Canada.

Finally, an acute exposure to a large amount of radiation can lead to immediate health effects, such as nausea, fatigue, and even death. A person would need to receive at least **250 mSv** of radiation dose within a short period of time to feel any such immediate effects. The severity of the effect would then increase with increasing dose. Between 250 and 2000 mSv, a person would expect to have radiation sickness, characterised by fatigue, nausea, possible diarrhea, and general malaise. Receiving **3500 mSv** of radiation dose suddenly will be lethal for 50% of the people exposed, if untreated. Other effects, such as effects on embryos and specific organs in the body, also require doses far above the limits on radiation dose to nuclear energy workers.

Though an "other worker" worker can get up to 5 mSv of radiation dose in one year, typically, workers that use an X-ray machine do not receive exposures above background.

Appendix 3 – X-Ray Laboratory Annual Inspection Checklist

Inspection date:

Laboratory:

X-Ray equipment:

MOL Registration:

X- Ray supervisor:

Inspected by

URSO:

EH&S representative:

X-Ray Safety Policy Section 9.	Observation	Recommendations
1) instructing all workers, prior to employment in X-ray radiation laboratories, to make them aware of the potential hazards of X-ray radiation, including genetic effects. Complete Appendix 1 (**X-Ray Worker Registration Form**)	☐ **Yes** ☐ **No**	.
2) arranging for adequate facilities, equipment, instruments, supervision and instruction in compliance with the University's radiation protection standard. (**in accordance with MOL Registration)**	☐ **Yes** ☐ **No**	
3) ensuring that personnel wear appropriate protective equipment, radiation monitoring badges and/or pocket dosimeters as required. (**in accordance with MOL Registration)**	☐ **Yes** ☐ **No**	
4) allowing only authorized persons to enter rooms that are specified as restricted areas.	☐ **Yes** ☐ **No**	
5) ensuring that the URSO has an up-to-date listing of all users.	☐ **Yes** ☐ **No**	

6) posting of radiation warning signs and labels as required	☐ **Yes** ☐ **No**	
7) reporting all radiation accidents and near-miss incidents to the URSO.	☐ **Yes** ☐ **No**	
8) informing all students involved in courses or research activities in X-ray laboratories of the procedures to be adopted during any authorized use of X-ray equipment and to ensure that the student is fully aware of those procedures by requiring him to indicate this by his signature in the X-ray laboratory record book. **(SOP in place)**	☐ **Yes** ☐ **No**	
9) supplying the URSO with a copy of the written instructions on safety procedures to be followed at each X-ray installation.	☐ **Yes** ☐ **No**	

Other observations:

Recommendations:

Appendix 4 – Example Radiation Protection Equipment Survey

Radiation Protection Survey of <Model, Model #, Serial #>

kVp (typical/max):_____/_____ mA (typical/max):_____/_____

Scatter medium:_____

Survey meter used (make, model, serial number):_____

Calibration date of survey meter:_____

Measurement Results (expressed in micrograys per hour at 5 cm from the external surface at typical/maximum operating conditions (as stated above))

Measurement Location	Result @ 5cm from surface for Typical / Maximum Operating Conditions			
	Instrument units Specify units: _____		Converted (if needed) µGy/h	
	Typical	Maximum	Typical	Maximum
Front				
Back				
Left Side				
Right Side				
Bottom				
Top				

Verified that interlock is functional and can only be reset at the control screen/panel after tripped and closed:

_____ (initial)

X-ray on warning device conspicuous placed on or near cabinet from any position that it can be opened: _____ (initial)

Date of Survey: _____ Operator:_____