



**THE UNIVERSITY OF WESTERN ONTARIO**  
**Human Resources**  
**Occupational Health and Safety**

# **SAFETY MANUAL FOR NON-MEDICAL X-RAY EQUIPMENT**

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## **Section 1: Organization of the X-ray Safety Program**

### **1.1 Internal Permit Holders and X-ray Users**

The University issues an Internal Permit to a University employee who is the Principal Investigator or Person in Charge of the location where the X-ray equipment is used or stored. All Permit Holders and Users must meet the following requirements:

1. Be 18 years of age.
2. Have an Internal Permit or work under an Internal Permit.
3. Be designated as X-ray Worker.
4. Comply with the University Policies, Health Canada Safety Code 32, X-ray Safety Regulation 861 and follow the safe use and operation of the X-ray equipment.
5. Be familiar with the X-ray Safety Manual.
6. Wear the required dosimeters.
7. A Permit Holder must ensure that all X-ray users under their permit complete the University of Western Ontario X-ray Safety Training Program: X-ray Safety Training Course by Occupational Health and Safety. Additional, specific hands-on training on a particular X-ray machine must be given by the Permit Holder or Person in Charge of the X-ray facility.
8. A Pregnant X-ray Worker must inform her Permit Holder and the Radiation Safety Coordinator as soon as she is aware of her condition.

### **1.2 Radiation Safety Coordinator**

The Radiation Safety Coordinator (RSC) administers the X-ray safety program and serves as the primary contact for the Ministry in matters of X-ray safety. RSC exercises direction over the safe use and operation of the X-ray facilities and equipment at the University of Western Ontario.

### **1.3 Senior Management**

The Senior Management has overall corporate responsibility for Occupational Health and Safety Act and regulatory compliance with X-ray safety.

### **1.4 Radiation Safety Committee**

The Radiation Safety Committee is a sub-committee of the University Health and Safety Committee, with its authority delegated directly from the University President's Office. This committee is composed of individuals with expertise or a stake in radiation safety matters. The individuals are appointed by the Deans of Faculties and act to advise Senior Management and the University Radiation Safety Coordinator on matters of all radiation safety including nuclear substances and radiation devices, X-ray equipment and lasers/laser systems.

The University Health and Safety Committee constitutes the Radiation Safety Committee membership to achieve equal representation from the five faculties involved in the Radiation Safety Program

Membership

Voting Members:

Office of Vice-President Research (1)

Faculty of Science (3)

Faculty of Medicine and Dentistry (2)

Faculty of Social Science (1)

Faculty of Engineering (1)  
Faculty of Health Sciences (1)

Non-Voting Members:

Director of Occupational Health and Safety  
Radiation Safety Coordinator  
Environmental Safety Specialist  
Physical Plant Department Representative  
Department Chair

## **1.5 University Health and Safety Committee**

The University Health and Safety Committee is the senior safety committee of the University. It has the responsibility for reviewing the overall safety performance of the University, for recommending health and safety policy, and for overseeing of any sub-safety committees reporting to it. This advisory committee reports directly to the President of the University.

Membership

Voting Members:

Vice-President (Administration): Chair  
Provost & Vice-President (Academic)  
Vice-President (Research)  
Assistant Vice-President-Human Resources Division  
Physical Plant Department  
Two Deans, one from Engineering Science, Medicine or Science, appointed by the Provost for a 3 year renewable term

Non-Voting Members:

Director of Occupational and Health and Safety  
Chairs, Subcommittees  
Resource Persons

## **Section 2: Standard Operating Procedures and Safety Information**

### **2.1 Application for New X-ray Internal Permit**

1. Applicant must be a University employee who is the Principal Investigator or Person in Charge of the location where the X-ray equipment is used or stored.
2. Complete the “Non-Medical X-ray Permit Application” form with the approval of Department Chair and send it to the Radiation Safety Coordinator. Application form is available in the Appendices.
3. The application is reviewed and approved by the Radiation Safety Coordinator and Radiation Safety Committee Chair or Designate.

### **2.2 Application for Permanent X-ray Location**

1. This application must be submitted for the following reasons: Opening of a new facility, additional of sources, relocation of sources, replacement of old sources in existing facilities.
2. The Permit Holder completes part B of Form 2 “Application for Review of Permanent X-ray Location”, signs and sends it to the Radiation Safety Coordinator. Application form is available in the Appendices.
3. The Radiation Safety Coordinator completes part A of Form 2 and sends the completed form to Ontario Ministry of Labour.
4. The Radiation Safety Coordinator will inform the Permit Holder when Ontario Ministry of Labour approves the permanent X-ray location.
5. X-ray source(s) can be installed, stored or used at the approved location.

### **2.3 Purchasing New X-ray Equipment**

1. The Permit Holder completes the requisition and sends it to the Radiation Safety Coordinator for approval.
2. The approved requisition will be forwarded to Purchasing Department.

### **2.4 Permit Amendments**

The Permit Holder is responsible to notify in writing to the Radiation Safety Coordinator in the following changes:

1. X-ray sources (add, delete or dispose of, move, modify etc.)
2. Permanent X-ray location (add, delete, renovate, etc.)
3. X-ray users (add, delete, training, etc.)

The Radiation Safety Coordinator will confirm the changes in writing and send the updated permit to the Permit Holder.

### **2.5 Safety Operating Procedures for Analytical X-ray Equipment**

1. The equipment should be used under the guidance and supervision (available on campus) of Permit Holder or Person in Charge of the X-ray facility.
2. The equipment should be operated in such a way, that the authorized user does not expose any part of the body to the direct beam, and no other person is accidentally exposed.
3. Personal dosimeter badges must be worn when operating X-ray equipment. Finger dosimeter badges shall be worn when close approach to the direct beam is unavoidable. Such badges shall be designated and used for extremities only.
4. Shutters must be closed when loading sample.
5. The equipment should be located in a locked room that can be entered only by authorized users. If equipment must be located in unrestricted areas, appropriate barriers should be installed and a key control switch must be installed to prevent unauthorized use.

6. Warning signs must be affixed on the outside of the room, on the door that provides access to the equipment. The sign must be clearly legible and visible at a distance of 2 meters to personnel approaching the room door. Warning labels must be affixed to the equipment.
7. Warning light must be provided when the X-ray tube is energized. Warning light must also indicate when the beam shutter is open.
8. All lights, meters, controls must be properly labeled and marked as to its function.
9. Necessary shielding should be provided before the X-ray tube is energized. The radiation levels are within the permissible regulatory limit.
10. A fail-safe shutter should be fitted as close to the X-ray tube port as possible, and it can not remain open unless a collimator or other attachment is in position.
11. Where appropriate and feasible, fail-safe interlocks should be installed on accessories or components for which their removal would cause direct access to the primary beam or to high radiation areas on the equipment. No interlocks or safety device shall be deliberately defeated.
12. Repairs or adjustment shall not be made when the tube is energized or with any safety cover removed.
13. Any defect in X-ray equipment shall be reported immediately to Permit Holder and Human Resources, Occupational Health and Safety.
14. Extraordinary arrangements of equipment attachments such as camera, sample, etc., or modifications for the purpose of protection, shall be documented and filed. All arrangement shall be monitoring for safety during and after construction.
15. Pre-operational Safety Checks (interlocks, safety devices, shutters etc.) should be performed periodically to insure their proper operation. Records of inspections, surveys and repairs shall be maintained.

## **2.6 Emergency Procedure: Failure of equipment or incident**

1. Stop the operation immediately.
2. Turn off the X-ray equipment.
3. Alert everyone in the facility.
4. Report to the Permit Holder as soon as possible.
5. Report to the Radiation Safety Coordinator the failure of any X-ray equipment or other incident occurs that may have resulted in an X-ray worker receiving a radiation exposure.

Note: Failure of equipment due to interruption of electrical power is not required to report to the Radiation Safety Coordinator unless the equipment becomes non-functional or safety devices are not working properly.

## **2.7 Safety Devices for Analytical Equipment**

Most X-ray analytical equipment uses conventional X-ray tubes operated at voltages up to 100 kVp. However, they are usually operated within the range 20 – 60 kVp. The radiation which escapes from the tube windows consists of a continuous bremsstrahlung spectrum with maximum energy corresponding to the peak operating voltage, together with a line spectrum of characteristic X-radiation of the target element.

### **2.7.1 Shielding**

It is obviously desirable that X-ray equipment shall be provided with sufficient shielding to ensure that all occupational radiation doses shall be limited in accordance with the ALARA principle and to within the dose equivalent annual limit of Schedule [1] in X-ray Safety Regulation 861.

Since X-ray energies are low in the analytical X-ray equipment, it is not usually difficult to provide enough shielding, even though a dose-rate reduction by a factor of  $10^{10}$  or  $10^{11}$  may be needed. Lead strongly absorbs X-rays of the energies used. For example: X-ray generated at 50 kVp, attenuation by 2 mm of lead gives a dose-rate reduction by about a factor of  $10^{11}$ . Tube- shields must provide adequate protection against primary radiation. Shutter inserts for absorption of primary beams have commonly been made of lead.

The American National Standards Institute gives its standard for analytical X-ray equipment, thickness of lead necessary to give adequate attenuation of primary beams at a distance of 5 cm from the focal spot as in table 1.

Table 1			
Thickness of Lead to give adequate attenuation of primary beams at a distance of 5 cm from the focal point			
Anode current (mA)	Thickness of Lead (mm) at:		
	50 kVp	70kVp	100kVp
20	1.5	5.6	7.7
40	1.6	5.8	7.9
80	1.6	5.9	-
160	1.7	-	-

For terminating the collimated beam beyond the specimen under examination, about 2 mm of lead, or the equivalent thickness in brass or steel may be used. The minimum thickness of brass or steel necessary to almost completely absorbs the primary X-rays from a copper target as in table 2.

Table 2			
Minimum thickness of brass and steel which almost completely absorb the primary X-rays generated in a copper target at various peak voltages and tube currents. (101)			
	kVp	mA	Thickness (mm)
Brass	30	25	1.6
	40	20	3.2
	50	16	4.8
Steel	30	25	2.4
	40	20	4
	50	16	7.2

The shielding data are listed in tables 3, 4, 5 and 6 (section 4.2.3)

### 2.7.2 Enclosures and Control of Access

Enclosures for X-ray equipment often have a shielding function and act as a barrier to prevent the insertion of hands and fingers into X-ray beams.

Some powder cameras provide enclosure of the path of the collimated beam and also provide shielding against the beam and diffracted and scattered radiation.

Other cameras (ie. goniometers) are constructed that the collimated beam is exposed. It is desirable that some form of enclosure shall be provided to prevent hand and fingers access.

It is preferable to have a large enclosure surrounding the X-ray equipment with the interlock system. However, some old X-ray equipment have the “open beam”, the control of access to the beam is necessary to prevent the radiation exposures to the users including controlling of the room, shielding, barrier and interlock system

### 2.7.3 Safety Shutters

The essential function of the safety shutter is to prevent access to the primary beam. In diffraction equipment, it must be designated so that whenever X-rays are being generated, either a camera or collimator is properly in place at the tube port or the beam is intercepted by a closed shutter.

There are several safety shutters methods: lock-on shutters, gravity and spring-loaded shutters and electrically operated shutters.

#### **2.7.4 Interlocks**

Interlocks are necessary to prevent access to primary, uncollimated radiation and to restrict access to collimated beams. Mechanical or electrical interlock can be used on X-ray equipment. However, electrical interlocks are more versatile and are more commonly used. When microswitches or other form of limit switch are used, it is generally recommended that they should be used “positively”: the switch should be forced, by pressure on the operating pin, into the safe position. If the pin is stuck or the return spring is broken then the equipment will be left in a safe condition.

The interlocks shall meet the essential requirements:

1. Reasonably reliable
2. Reasonably proof against accidental over-riding.

#### **2.7.5 Warning Lights and Signs**

Every X-ray machine must be provided with a conspicuous means of alerting the user to the fact that X-rays are being generated. Illuminated signs are usually preferred. These should be sited as near as possible to the relevant tube-head, and the words “X-RAYS ON” should be clearly displayed. Also, it must be a warning light when the shutter is open. Both “X-RAYS ON” and shutter state warning signs must operate automatically.

Note: All warning lights and signs may not be applicable to some old X-ray equipment.

### **2.8 Security and Control Access of X-ray Equipment**

All X-ray rooms are restricted areas and must be locked at all times when unattended. Only the Permit Holder and authorized X-ray users listed on the permit are allowed to be left alone in the X-ray room when X-ray equipment is in operation or can be operated.

All visitors must be accompanied by the Permit Holder or authorized users listed on the permit and follow all applicable regulations, policies, guidelines and procedures.

## **Section 3: Regulation and University Policies**

### **3.1 Ontario X-ray Safety Regulation**

There are several government bodies that have jurisdiction over the use of X-ray sources including Ontario Ministry of Labour, Ontario Ministry of Health and Canadian Nuclear Safety Commission (CNSC). Recommendations from the International Commission on Radiological Protection (ICRP) are also used to formulate the rules and conditions under which nuclear substances and radiation emitting devices are used.

The University of Western Ontario is currently registered with the Ontario Ministry of Labour for the use of non-medical X-ray sources under Ontario X-ray Safety R.R.O. 1990, Reg. 861 (section 4.2.3). This regulation does not apply to X-ray sources that are licensed under CNSC or Ontario Ministry of Health. The University also follows the Safety Requirements and Guidance for Analytical X-ray Equipment, Safety Code 32 from Health Canada (section 4.2.2)

### **3.2 ALARA Policy**

All occupational radiation doses shall be limited in accordance with the ALARA (As Low As Reasonably Achievable) principle and to within the dose equivalent annual limit of Schedule [1] in X-ray Safety Regulation 861.

The University of Western Ontario is committed to taking every reasonable precaution, as is practical, to maintain radiation exposure to staff, students and the public to ALARA. The X-ray Safety Program is designated to keep radiation exposures to ALARA by:

1. Management control over work practices.
2. Personnel qualification and training.
3. Control of occupational and public exposure to radiation.
4. Planning for emergency situations.

### **3.3 Personal Exposure Policy**

Each X-ray worker will be monitored with a suitable personal dosimeter that will provide an accurate measure of the dose equivalent in accordance with section 12 of X-ray Safety Regulation 861. The nominal cost of this service is provided by the X-ray worker's Department. All actual or suspected exposures must be reported to the Radiation Safety Coordinator. The action level for radiation exposure is 2 mSv/year for X-ray worker. The University must retain an X-ray worker's personal dosimeter records for a period of at least three years

### **3.4 Purchase and Disposal Policy**

All X-ray equipment must be reviewed and approved by the Radiation Safety Coordinator prior to purchasing or transfers from external off-campus and internal on-campus. Authorized staff within the UWO Purchasing Department will purchase all X-ray equipment on behalf of the Internal Permit Holder.

The Internal Permit Holder is responsible to notify the Radiation Safety Coordinator that she/he no longer has possession of any X-ray sources. In the absence of the Internal Permit Holder, the Department Chair will assume these duties.

### **3.5 Permanent X-ray Location Policy**

The Internal Permit Holder is responsible to provide all necessary information, floor plan and specifications of the permanent X-ray location to the Radiation Safety Coordinator. An X-ray source shall not be installed or

used until the permanent X-ray location is reviewed and acceptable to Ontario Ministry of Labour according to section 6 of X-ray Safety Reg. 861.

### **3.6 Training Policy**

X-ray users including permit holders must complete the University X-ray safety training course offered by Occupational Health and Safety. Permit holder or person in charge of the X-ray facility is responsible to provide specific hands-on training on a particular X-ray machine to X-ray users. X-ray users including permit holders are retrained every two years.

Permit Holder must ensure that all X-ray users under the permit are complete the X-ray safety training program. X-ray users are responsible for the safe use of X-ray equipment

### **3.7 X-ray Worker Policy**

All X-ray users are designated as X-ray workers at the University of Western Ontario and must complete the Acceptance of Designation as X-ray Worker form.

The Permit Holder is responsible to notify the Radiation Safety Coordinator of any changes including deleting or adding of X-ray workers under the permit. The University of Western Ontario shall maintain a list of all X-ray workers according to section 9(2) of X-ray Safety Reg. 861.

### **3.8 Inspection Policy**

Inspection of X-ray facility/equipment is necessary to reduce or eliminate the risk of incident to X-ray users, staff, students and public and to comply with the act, regulation and safety code.

The Permit Holder and Person in Charge of the X-ray facility are responsible for their own in-house inspection on the regular basis in accordance with the regulation, safety code and the University policies. The Permit Holders are responsible for maintaining the quality control/quality assurance of their X-ray facility/equipment.

The Radiation Safety Coordinator will inspect all X-ray facility/equipment at least once a year or at anytime using the UWO inspection checklist. The inspections can be announced or un-announced. The inspection result will be graded A, B, C or D. All deficiencies must be corrected and reported in writing to the Radiation Safety Coordinator. Any operations that are considered unsafe will be immediately suspended.

The Ministry of Labour Inspector may enter in upon any workplace at anytime without warrant or notice. All University personnel shall give a Ministry of Labour Inspector all reasonable assistance to carry out his/her duties and functions under the Occupational Health and Safety Act.

### **3.9 Compliance Enforcement Policy**

The University of Western Ontario assumes the responsibility of ensuring to the Ministry of Labour that the use of X-ray equipment in compliance with the Occupational Health and Safety Act and X-ray Safety Regulation. To aid in determining the level of risk or immediate danger to safety and health, all compliance violations will be categorized as major and minor offences. Any offence occurring twice in any one year period will be considered as a second offence and so on.

A major offence would result from violations that cause immediate risk or danger to health and safety of any person or place the Ministry of Labour Registration in jeopardy. For example, a major offence would be one of the following deficiencies:

1. Radiation dose rate exceeds the regulatory limit.
2. Failed interlock for cabinet X-ray equipment
3. Inadequate or no training for X-ray user.
4. Non-participation in the personal exposure monitoring program.
5. Unauthorized possession of X-ray equipment.
6. Unauthorized X-ray permanent location.

Major Offence Actions:

1. First Offence: An inspection report will be sent to Permit Holder, copy to Department Chair, Director OHS and Radiation Safety Committee Chair. The corrective action must be taken immediately by the Permit Holder and a written reply must be sent to the Radiation Safety Coordinator within 7 days of the inspection report. If the written reply is not received after 7 days, the second notice will be sent to Permit Holder, copy to the Dean of Faculty, Department Chair, Director OHS and Radiation Safety Committee Chair. A meeting will be arranged with the Permit Holder, Department Chair, Director OHS, Radiation Safety Committee Chair and Radiation Safety Coordinator if there is no response from the Permit Holder after 7 days of the second notice.
2. Second Offence: The Permit Holder will be notified in writing by the Radiation Safety Coordinator that the permit will be suspended until a meeting with the Radiation Safety Committee can be held.
3. Third Offence: The Radiation Safety Coordinator will recommend permit cancellation to the Radiation Safety Committee.

Note: For the second and third offences, notification of the above actions will be copied to the Dean of Faculty, Department Chair, Director OHS and Radiation Safety Committee Chair.

A minor offence would be an infraction that poses no immediate risk to health and safety of any person. For example, a minor offence would be one of the following deficiencies:

1. Inadequate warning signs.
2. No standard operating procedures posted.
3. Failing to notify X-ray worker's departure.

Minor Offence Actions:

1. First Offence: A written inspection report will be sent to Permit Holder, copy to Department Chair, Director OHS and Radiation Safety Committee Chair. The corrective action must be taken as soon as possible by the Permit Holder and a written reply must be sent to the Radiation Safety Coordinator within 21 days of the inspection report. If the written reply is not received after 21 days, the second notice will be sent to Permit Holder, copy to Dean of Faculty, Department Chair, Director OHS and Radiation Safety Committee Chair. A meeting will be arranged with the Permit Holder, Department Chair, Director OHS and Radiation Safety Coordinator if there is no response from the Permit Holder after 14 days of the second notice.
2. Second Offence: A meeting will be arranged with the Permit Holder, Department Chair, Director OHS, Radiation Safety Committee Chair and Radiation Safety Coordinator to review the issues.
4. Third Offence: The Permit Holder will be notified in writing by the Radiation Safety Coordinator that the permit will be suspended until a meeting with the Radiation Safety Committee can be held.
5. Fourth Offence: Radiation Safety Coordinator will recommend permit cancellation to the Radiation Safety Committee.

Note: For the second, third and fourth offences, notification of the above actions will be copied to the Dean of Faculty, Department Chair, Director OHS and Radiation Safety Committee Chair.

**Section 4: Appendices**

**4.1 Forms**

**4.1.1 Application Form for Non-Medical X-ray Permit**



**OCCUPATIONAL HEALTH AND SAFETY**

**NON-MEDICAL<sup>1</sup> X-RAY PERMIT APPLICATION**

Applicant (Person in Charge): \_\_\_\_\_

Contact Person: \_\_\_\_\_

Position: \_\_\_\_\_

Facility Telephone: \_\_\_\_\_

Office Telephone: \_\_\_\_\_

Emergency Telephone: \_\_\_\_\_

Office No: \_\_\_\_\_

Department: \_\_\_\_\_

E-mail: \_\_\_\_\_

Building: \_\_\_\_\_

**Experience and Training of the Applicant and/or Contact Person<sup>2</sup> regarding the Analytical X-Ray equipment:**

(Use separate paper if necessary)

**List of Authorized User<sup>3</sup>(s) using the X-Ray equipment under your supervision**

1. \_\_\_\_\_ e-mail: \_\_\_\_\_ Tel: \_\_\_\_\_

2. \_\_\_\_\_ e-mail: \_\_\_\_\_ Tel: \_\_\_\_\_

3. \_\_\_\_\_ e-mail: \_\_\_\_\_ Tel: \_\_\_\_\_

4. \_\_\_\_\_ e-mail: \_\_\_\_\_ Tel: \_\_\_\_\_

**This application is submitted for the following reason:**

New application

Renew application

Relocation of sources

Replacement of old sources

Additional sources

Acquisition of existing facility from:

**X-Ray Equipment General Information:**

Room #	Manufacturer	Date of Manufacture	Type	Model #	Serial #	kVp	mA	Use Freq.
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Note:

<sup>2</sup> Contact Person will be responsible for the X-Ray equipment when the Person in Charge is not available.

<sup>3</sup> Authorized User(s) shall wear Personal Dosimeters (where applicable) and receive specific hands-on training from the Person in Charge before operating the X-ray equipment.

\_\_\_\_\_  
Signed: Applicant Date

\_\_\_\_\_  
Signed: Department Chair Date

\_\_\_\_\_  
Signed: Radiation Safety Coordinator Date

\_\_\_\_\_  
Signed: Radiation Safety Committee Chair Date

<sup>1</sup> Not used on human

## 4.1.2 X-ray Worker Designation Form

# The University of Western Ontario

## Acknowledgement of Designation as X-ray Worker

The University of Western Ontario is committed to the health and safety of its employees. To this end, in the Radiation Safety program, the University will be designating all those working with X-ray equipment as X-ray Worker. In accordance with the Ontario Regulation respecting X-ray Safety under the Occupational Health and Safety Act, the University is required to inform you in writing that you are employed as an X-ray worker. The designation facilitates tracking by the National Dose Registry maintained by the Radiation Protection Bureau of Health Canada of each workers lifetime exposure to X-ray and radioactive material.

The University of Western Ontario is committed to taking every reasonable precaution, as is practical, to maintain the radiation exposure of X-ray Workers, staff, students and the public to ALARA, (As Low As Reasonably Achievable).

As an X-ray Worker you must be aware of the following critical radiation levels:

- Natural background levels: 2.0 –3.0 mSv/year
- Typical Occupational level: 0.2-1.0 mSv/year
- Action level 2.0 mSv/year (Any value greater than this must be investigated)
- Dose equivalent annual limit 50mSv (R.R.O. 1990, Reg. 861)

You must also be familiar with the following documents, which are provided to you:

1. The applicable dose limits as specified in the R.R.O. 1990, Reg. 861
2. Dose limits for Pregnant X-ray Workers in the R.R.O. 1990, Reg. 861
3. Radiation Risk in Perspective, a position statement of Health Physics Society
4. Risk Assessment, a position statement of Health Physics Society

A pregnant X-ray worker must inform in writing, her Internal Permit Holder and the Radiation Safety Officer in writing as soon as she is aware of her condition.

I understand the risks, my obligations and the radiation dose limits and levels that are associated with being designated as an X-ray Worker.

Name \_\_\_\_\_ SIN: \_\_\_\_\_

Signature of X-ray Worker \_\_\_\_\_ Date: \_\_\_\_\_

Signature of Radiation Safety Officer \_\_\_\_\_ Date: \_\_\_\_\_

**4.1.3 Dosimetry Badge Application**

**THE UNIVERSITY OF WESTERN ONTARIO  
RADIATION SAFETY  
TLD BADGE REQUEST FORM**

***PLEASE PRINT***

NAME \_\_\_\_\_  
*First Initial Last*

E Mail \_\_\_\_\_

Contact Numbers: \_\_\_\_\_  
*Work Fax*

Organization: \_\_\_\_\_ Department: \_\_\_\_\_

Building: \_\_\_\_\_ Room # \_\_\_\_\_

Internal Permit Holder Name: \_\_\_\_\_

<input type="checkbox"/> Social Insurance Number (S.I.N.) _____
<input type="checkbox"/> OTHER (e.g. passport, work permit) _____ (specify)
Date of Birth: _____ <i>Month Day Year</i>
Sex: Male <input type="checkbox"/> Female <input type="checkbox"/>

Check One:

Graduate Student  Staff  Faculty  Undergraduate Student:   
Internal Permit Holder  Research Associate:  Lab Technician

Other (Specify) \_\_\_\_\_

Place of Birth: (Country or Province, if Canada) \_\_\_\_\_

Have you worn a monitor previously: Yes  No   
If yes, please provide dates: \_\_\_\_\_ and Prov/Country \_\_\_\_\_

**SOURCE OF IONIZING RADIATION**

1. Nuclear substance/radioisotope/radiation device, specify) \_\_\_\_\_
2. X-Ray emitting equipment: \_\_\_\_\_
3. Other (specify): \_\_\_\_\_

Radiation Safety Training Date: \_\_\_\_\_

X-Ray Safety Training Date: \_\_\_\_\_

Date: \_\_\_\_\_ Applicant Signature: \_\_\_\_\_

Signature of Authorized OHS personnel: \_\_\_\_\_ Date: \_\_\_\_\_



**Part B: Specific**

**Note: One copy of Part B required for each x-ray source for which review is sought.**

1. This sheet refers to x-ray source number \_\_\_\_\_ of \_\_\_\_\_ x-ray sources located in the room Designated as \_\_\_\_\_ and so marked on the accompanying drawings.

2. This x-ray source is used for

It is identified by:	Make/Model	Serial No.
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And has the following operating characteristics:

- a) the maximum rated tube voltage is \_\_\_\_\_ kilovolts
- b) the maximum rated tube current is \_\_\_\_\_ milliamperes
- c) the anticipated maximum workload is \_\_\_\_\_ milliampere - minutes per week

3. The composition of the boundaries of the room, including windows and doors, are (give material types and thicknesses):

Floor	Ceiling
Walls	North
	East
	South
	West

Direction	Occupancy (see note 1)		Usage Factor (See note 2)
	Type	Per Cent	Per Cent
Down			
Up			
North			
East			
South			
West			

**Note 1:** Occupancy type is the nature of use of the area in the indicated direction relative to the x-ray source (e.g. office, waiting room, parking lot, etc.) Occupancy per cent is the fraction, expressed as a percentage, of the time the area will be occupied while the source is on (omit if unknown.)

**Note 2:** The usage factor is the fraction of the time the beam will be pointed in the direction indicated, as a percentage of the total time the source is on. For uncollimated, panoramic, or multiple beams, the sum may exceed 100 per cent.

The information given in this Part must correspond with that given on the accompanying floor plans.

## 4.2 Additional Safety Information

### 4.2.1 Shielding Data from A Guide to the Safe Use of X-ray Diffraction and Spectrometry Equipment by E.B.M. Martin

Table 3						
Transmission through lead of X rays generated at constant potential						
	Transmission at:					
Thickness (mm)	20 kV	30 kV	40 kV	50 kV	75 kV	100 kV
0.0635	$5.18 \times 10^{-5}$	$3.88 \times 10^{-4}$	$2.74 \times 10^{-3}$			
0.127	$1.78 \times 10^{-7}$	$6.05 \times 10^{-6}$	$2.64 \times 10^{-4}$			
0.1905		$4.52 \times 10^{-7}$	$4.52 \times 10^{-5}$			
0.250				$2.7 \times 10^{-3}$	$3.2 \times 10^{-2}$	$7.6 \times 10^{-2}$
0.254		$3.17 \times 10^{-7}$	$1.058 \times 10^{-5}$			
0.500				$9 \times 10^{-5}$	$5.3 \times 10^{-3}$	$2.4 \times 10^{-2}$
1.00				$\sim 10^{-6}$	$3.3 \times 10^{-6}$	$4.1 \times 10^{-3}$
2.00				$\sim 10^{-11}$	$5.7 \times 10^{-6}$	$2.3 \times 10^{-4}$
3.00						$1.7 \times 10^{-5}$
4.00						$1.4 \times 10^{-6}$

Table 4						
Transmission through steel of x rays generated at constant potential						
	Thickness of steel (mm) at:					
Transmission	10kV	15kV	20kV	30kV	40kV	50kV
$10 \times 10^{-1}$	0.03	0.028	0.031	0.035	0.038	0.04
$10 \times 10^{-2}$	0.076	0.07	0.081	0.12	0.16	0.26
$10 \times 10^{-3}$	0.126	0.116	0.146	0.3	0.54	0.87
$10 \times 10^{-4}$	0.175	0.116	0.222	0.55	1.09	1.9
$10 \times 10^{-5}$	0.226	0.206	0.302	0.82	1.76	3.1

Table 5				
Transmission through brass of X rays generated at constant potential				
	Thickness of brass (mm) at:			
Transmission	20kV	30kV	40kV	50kV
$10 \times 10^{-1}$	0.036	0.043	0.059	0.069
$10 \times 10^{-2}$	0.072	0.085	0.123	0.157
$10 \times 10^{-3}$	0.126	0.157	0.252	0.439
$10 \times 10^{-4}$	0.209	0.289	0.479	
$10 \times 10^{-5}$	0.315	0.43		

Table 6				
Rough lead-equivalents for brass and steel				
	Lead-equivalents (mm) at:			
Thickness	(mm)	60kV	85kV	100kV
Brass	1	0.36	0.26	0.23
	2		0.71	0.48
	3			0.79
	4			1.12
Steel	1	0.15	0.16	0.19
	2	0.39	0.29	0.36
	3		0.47	0.52
	4		0.67	0.71

## 4.2.2 Safety Code 32 from Health Canada

### **Safety Requirements and Guidance for Analytical X-Ray Equipment**

#### **Safety Code 32\***

Environmental Health Directorate  
Health Protection Branch

Published by authority of the Minister  
of National Health and Welfare

Également disponible en français sous le titre  
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recommandations en matière de sécurité – Code de  
sécurité 32*

\*Safety Code 32 supersedes Safety Code 19 –  
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## Foreword

While the term *analytical x-ray equipment* generally refers to all types of x-ray diffraction and spectrographic systems designed primarily for performing microscopic examinations or analyzing x-ray spectra of matter at the atomic or crystalline level, it is used in this Safety Code to mean those systems that contain an x-ray tube (or sealed demountable tower) as the source of ionizing radiation. X-ray diffraction systems disperse monochromatic radiation and are typically operated in the range of 20-60 kVp. Spectrographic systems disperse polychromatic radiation and are typically operated at potentials in the range of 25-100 kVp.

This Safety Code is prepared under authority of Treasury Board Standards(1) and may be used by facilities subject to Canada Labour Code Part IV.(2) It provides information on regulatory Requirements and guidance necessary to ensure that the risks from analytical x-ray equipment remain low (i.e., the same as the risks from unavoidable natural background radiation). This approach is in accordance with the 1990 International Commission on Radiological Protection (ICRP) objectives(3) to prevent the occurrence of deterministic effects (those for which the severity of a biological effect increases with dose) and to reduce the incidence of stochastic (random) effects (those for which the probability of occurrence increases with dose but the severity does not depend on the magnitude of the absorbed dose) to acceptable levels.

This publication is intended to minimize or avoid the radiation exposures potentially associated with analytical x-ray equipment. It provides information on regulatory requirements and safety procedures, and outlines specific responsibilities for the

- Equipment owner, meaning a person, organization, or institution having title to or administrative control over one or more facilities having source(s) of ionizing radiation;
- Equipment users; maintenance personnel, meaning specifically trained persons employed by the equipment manufacturer or its authorized agent(s) to undertake service functions; and
- Radiation safety specialists (analysts and inspectors as defined in the Radiation Emitting Devices (RED) Act).<sup>(4)</sup>

This document supersedes Safety Code 19 – Recommended safety procedures for the selection, installation and use of x-ray diffraction equipment.<sup>(5)</sup>

This document may be adopted for use elsewhere. Facilities should consult their appropriate regulatory authority provided in Appendix III because of differences in provincial and territorial statutes and requirements.

This publication was prepared by H.P. Maharaj in accordance with the Radiation Protection Bureau internal and external review, and approval criteria. All agencies, organizations and individuals whose comments and suggestions helped in the preparation of this publication are gratefully acknowledged.

Interpretation or elaboration on any point in this Safety Code may be obtained from the X-Ray Section, Radiation Protection Bureau, 775 Brookfield Road, Ottawa, Ontario, K1A 1C1.

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## 1. Introduction

X rays are short-wavelength electromagnetic radiation that can undergo various interactions with matter. Such interactions yield data which, when appropriately analyzed, can provide useful information on the materials irradiated. Machines, typically x-ray diffraction devices and x-ray spectrometers, have been designed to utilize very intense x-ray beams in order to facilitate microscopic examinations or atomic analyses of materials in industry, research laboratories and educational institutions. These machines are generally referred to in this Safety Code as analytical x-ray equipment.

X rays are ionizing radiation that can cause adverse biological effects such as cancer and leukemia. While a brief exposure to the hands in the primary beam of analytical x-ray equipment may not present any clinically observable effects over a short- or long-term period in some individuals, the effect in other individuals may result in mild skin discoloration, which subsequently could develop into a burn, dermatitis and possibly progress to a cancer. Radiation exposures may be considered acute or chronic. Acute exposures are those for which relatively large radiation doses are delivered within short time periods, and the resulting adverse biological effects are manifested in a time frame approximately in an inverse relation to the dose incurred. Chronic exposures are those for which small doses are delivered, more or less uniformly, over long time periods, and the resulting adverse biological effects are more subtle and may develop within years or decades. Recovery from radiation insult depends on many factors including but not limited to, the radiosensitivity of the tissue(s) or organ(s) irradiated, the relative biological effectiveness (RBE) of the radiation, the age and sex of the individual, the dose incurred and the time in which it was delivered. While experimental evidence suggests cellular recovery occurs for low doses incurred over long time periods, such mechanisms may be imperfect, and this could eventually lead to late health effects of radiation such as induction of cancer (carcinogenesis), degenerative diseases (e.g., cataracts), and genetically determined ill-health and developmental abnormalities in the progeny of exposed individuals. Thus, radiation exposure could present immediate and late health effects. In common with other types of man-made ionizing radiation sources used in medicine, industry, research and consumer products, there are potential radiation hazards associated with analytical x-ray equipment.

In recognition of the widespread applications of ionizing radiation to mankind worldwide and the potential adverse human health effects, the International Commission on Radiological Protection (ICRP 1991)(3) has recommended a system of radiological protection which, when followed, would ensure that the risks from ionizing radiation use remain low. The ICRP recommended dose equivalent limits (Appendix I) are based on the prevention of deterministic effects by keeping radiation doses below the relevant threshold, and on the demand that all reasonable steps be taken to reduce the incidence of stochastic effects to acceptable levels. (Deterministic effects are those for which the severity of a biological effect increases with dose; and stochastic effects are those for which the probability of occurrences increases with absorbed dose, but the severity does not depend on the dose.) In this context, analytical x-ray equipment must be designed and constructed to conform with regulatory standards, and persons who install, use and maintain them *must* know the x-ray hazards inherent with such equipment and adhere to recommended procedures.

## 2. Intent of This Safety Code

This Safety Code provides requirements and guidance intended to ensure that the radiation risks from analytical x-ray equipment remain low (i.e., the same as the risks from unavoidable natural background radiation). Specific responsibilities for the equipment owner (defined in the foreword), user and maintenance personnel are outlined. Information on safety procedures, standards, surveillance and monitoring is also provided.

### **3. Radiation Safety Requirements and Responsibilities**

Within the scope of the 1990 ICRP objectives, analytical x-ray equipment must conform with applicable regulatory standards and facility requirements, and persons associated with the equipment ownership, use and maintenance must strictly adhere to their respective responsibilities.

#### **3.1 Regulatory Standards and New Equipment**

All new analytical x-ray equipment sold in Canada *must* conform to the Radiation Emitting Devices (RED) Regulations(6) at the time of sale. Depending on the analytical x-ray equipment design, Part XIV or Part XV of Schedule II of the RED Regulations may apply. These regulations are promulgated under the RED Act,(4) and it is the responsibility of the manufacturer or distributor to ensure that the equipment conforms to the applicable regulations. Since the regulations are subject to amendments in order to reflect changes in technology, information on their current applicability may be obtained by contacting the X-Ray Section, Radiation Protection Bureau, 775 Brookfield Road, Ottawa, Ontario, K1A 1C1.

When selecting or procuring analytical x-ray equipment, the equipment owner is well advised to obtain a copy of the most recent regulations to familiarize oneself with the requirements, and to enquire of the intended manufacturer or importer if the product complies with those current regulations. (These actions may eliminate or minimize the need for modifications to the equipment. Such modifications may be costly and cause considerable inconvenience because of disruption in service.)

#### **3.2 Requirements for Used Equipment\***

Equipment manufactured prior to the advent of design guidelines presents a number of safety deficiencies when compared to current standards,(7) and some equipment has been decommissioned as a result. Although equipment presented with fewer deficiencies is in general less costly and often practical to upgrade, absolute safety cannot be assured; however, a reasonable level of safety can be achieved by following the operational instructions specified in the equipment manual and the safe working procedures and guidelines outlined in this Code. In addition, operationally used equipment must be equipped with the following minimum requirements:

##### **1. Control panel**

- (i) A keylock control switch or an alternate device must be installed to prevent unauthorized use.
- (ii) A power ON/OFF switch must be installed to energize the equipment.
- (iii) A warning sign that reads “Caution x rays. This equipment produces high intensity x rays when energized. To be used and serviced by qualified personnel only.” and where appropriate, its French equivalent: “ Attention Rayons X. Cet équipement émet un rayonnement X de haute intensité. Il ne doit être utilisé que par du personnel qualifié.” The sign(s) should be placed, preferably, next to the power ON/OFF switch and must be clearly legible at a distance of 2 metres and be clearly visible at any time.
- (iv) An x-ray ON/OFF switch must be installed.
- (v) All lights, meters, controls and other indicators must be properly labelled and marked as to function.
- (vi) Separate fail-safe light indicators must be present to indicate when the x-ray tube is energized and when x rays are being produced. For equipment designed with a single control panel that operates more than one x-ray tube, each tube must be equipped with its separate fail-safe light indicators (of the type just described) to show when it is energized and producing x rays. Tubes

not in use must be disconnected to prevent them from becoming energized or be removed from the equipment.

\* The term 'used equipment' means equipment not under the original manufacturer's warranty issued at the time of initial purchase.

## **2. Shutters and beam ports**

- (i) Warning indicators must be installed to indicate the open/shut status of shutters. Shutter mechanisms must be interlocked with x-ray production. Shutters should normally be in the closed position and positive action required to open them, and unused shutters must be secured to prevent casual opening. Unused beam ports should be permanently blocked-off with lead.

## **3. Shields**

- (i) Primary beams transmitted beyond the detector must be attenuated by a beam stop or trap or other permanent shield that is positioned closest to the equipment to confine the beam, and that does not permit radiation levels to exceed 0.5 mR [ $\sim 4.39$  Gy air kerma] per hour at 5.0 centimetres from its external surface.
- (ii) For any equipment operating under open beam configurations (i.e., where the primary beam may be incident on the extremities or organs in the upper chest and facial regions, and where stray radiation fields are in excess of permissible limits) access to such radiation fields must be restricted. In addition to the facility safeguard requirements in section 3.3, such equipment may need to be placed in a physical enclosure that contains:
  - (a) lead-glass or equivalent material (e.g., lead-acrylic copolymer) of sufficient thickness to attenuate existing radiation levels to 0.5 mR [ $\sim 4.39$  Gy air kerma] per hour at 5.0 centimetres from all externally accessible surfaces of the enclosure, when the equipment is operated at its maximum ratings;
  - (b) sliding door(s) or similar access openings to facilitate safe set-up procedures;
  - (c) an automatic shut-off or appropriate audible alarm to alert personnel of intrusion into a high radiation zone when any sliding door(s) or similar access opening is not in the closed position; and
  - (d) a warning sign of the type described in section 3.2.(1)(iii), that is clearly visible at any time on a part of the sliding door(s) or similar access opening.

## **4. Interlocks**

- (i) Where appropriate and feasible, fail-safe interlocks should be installed on accessories or components for which their removal would cause direct access to the primary beam or to high radiation areas on the equipment.

### **3.3 Facility Safeguards Requirements**

Potential sources of stray radiation have been identified through surveys to be defective parts, poorly fitting accessories causing unshielded gaps, and tube rectifiers on x-ray diffraction devices, especially amongst equipment manufactured before regulatory control was imposed; often the levels are orders of magnitude higher than permissible limits. In a number of cases equipment presented with such problems was improperly secured and/or identified, and this potentially increases the risk of unnecessary radiation exposure.

In order to achieve an acceptable standard of protection, facilities must include the following safeguards:

#### **1. Proper isolation and designation of analytical x-ray equipment**

- (i) Allocate a room, or portion thereof, for the equipment.
- (ii) Permanently affix on the outside of the room, on the door that provides access to the equipment, the appropriate x-ray warning sign shown below. The sign must be clearly legible and visible at a distance of 2 metres to personnel approaching the room door.

#### **2. Restricted access**

Access to rooms in which analytical x-ray equipment is in use must be restricted strictly to the equipment users and other authorized personnel.

### 3.3.1 Pre-operational and Maintenance Measures

The reliability and safety of any physical system decreases with age and use because of component wear or corrosion effects.(8,9) In order to ensure safe and reliable operation of analytical x-ray equipment in every facility, the user must routinely conduct certain preoperational safety checks on components critical to x-ray safety, and the equipment owner or designee must establish and implement a suitable preventive maintenance program. These measures should account for the age and frequency of use of the specific equipment.

#### 3.3.1.1 *Pre-operational Safety Checks*

When analytical x-ray equipment is installed and whenever maintenance functions are performed on it or on its accessory components, the user must consult section 3.4.2 of this Code, and conduct examinations or tests that ensure:

- (i) the proper functioning of all protective and safety devices;
- (ii) the proper assembly and functioning of all radiation shields, beam ports, accessories and fittings;
- (iii) the ambient radiation levels are within the permissible regulatory limit (0.5 mR [ $\sim$  4.39 Gy air kerma] per hour at 5.0 centimetres from all the external surfaces of the equipment) by using an appropriate survey meter (see Appendix II for guidance) provided by the equipment owner or the designee; and
- (iv) any safety by-pass procedures are of the one time actuation and revert back to a fail-safe situation at start-up time of the x-ray generator.

#### 3.3.1.2 *Maintenance Measures*

Hazardous x-ray exposures can be significantly reduced or eliminated when maintenance procedures are in accordance with the manufacturer's guidelines specified in the service manual. Maintenance personnel must observe the following procedures while ensuring that unauthorized individuals are not near the x-ray equipment during servicing:

- (i) test all protective and safety devices and ensure their proper functioning. If by-passing a safety device is deemed essential to facilitate a specific maintenance task, the following requirements are **mandatory**:
  - (a) install a flashing red light or intermittent sound signal that is clearly visible or audible to a person with normal or corrected vision and hearing proximal to that part of the equipment where the safety device was altered,
  - (b) attach, near the flashing red light or intermittent sound signal, a written notice that indicates explicitly what safety device was altered,
  - (c) use an appropriate survey meter if radiation emissions are potentially associated with the intended task, and ensure that the permissible limits are not exceeded (see section 3.4.3 for guidance reference levels for body organs), and
  - (d) ensure that the safety device is re-established and any shielding removed or modified to facilitate the intended task is replaced after the task is completed;
- (ii) examine all radiation shields, beam ports, shutters, accessories and fittings for proper installation and function; and
- (iii) monitor the radiation levels nearest that part of the equipment where maintenance functions will be carried out, before and after the maintenance function(s). Use an appropriate survey meter (either provided by the equipment owner or oneself), and observe the guidance reference limits suggested in section 3.4.3 for body organs and the permissible levels established for the performance of the equipment (see section 3.3.1.1(iii)).

### 3.4 Human Considerations

If radiation risks are to remain low in conformity with the ICRP objectives, personnel in every facility at which analytical x-ray equipment is installed for use must strictly adhere to the responsibilities charged to them. The respective responsibilities affecting equipment ownership, use and maintenance are indicated below.

#### 3.4.1 Equipment Owner Responsibilities

The ultimate responsibility for the radiation safety of analytical x-ray equipment rests with the equipment owner. **The equipment owner is defined as a person, organization, or institution having title to or administrative control over one or more facilities having source(s) of ionizing radiation.** The equipment owner must ensure that the analytical x-ray equipment meets all applicable radiation safety standards. For some applications, this responsibility may be delegated to staff (e.g., a senior user or the facility health and safety officer, henceforth, called the equipment owner designee). In every facility where analytical x-ray equipment is in use, the equipment owner or designee is responsible for:

1. ensuring that the equipment is installed in accordance with the requirements set out in section 3.3 of this Safety Code;
2. ensuring that all users have received training on the proper operation and x-ray hazards appropriate to the analytical x-ray equipment installed;
3. prescribing and posting prominently near the x-ray equipment radiation safety rules, and safe operating and emergency procedures which shall include address information and contact details of a hospital or clinic where medical treatment can be administered;
4. making readily available a copy of this Safety Code for reference by users and maintenance personnel;
5. implementing a system of verification, supervision and periodic review to ensure that all users and maintenance personnel have received adequate training, and have read and understood the relevant parts of this Safety Code, the applicable radiation safety rules, safe operating and emergency procedures before using and servicing the analytical x-ray equipment;
6. establishing a maintenance program, taking into account the age and frequency of use, that ensures all safety devices and components critical to both x-ray production and shielding, are routinely checked and defective parts replaced or repaired;
7. providing an appropriate survey meter, and ensuring that it is in a working and functional condition at all times for use by users and maintenance personnel;
8. conducting prompt investigations of all radiation overexposures and accidents, and submitting appropriate reports to the equipment owner or designee and to the appropriate radiation protection regulatory authority within 5 calendar days;
9. ensuring that victims of radiation overexposures receive specialized medical attention (e.g., consultation with a radiation oncologist or physician knowledgeable in human biological effects of ionizing radiation);
10. determining the appropriate corrective measures following radiation overexposures, unsafe events and accidents, and ensuring that such measures are implemented effectively; and
11. ensuring that, during a radiation protection survey, a copy of the most recent survey report including summaries of corrective measures recommended and instituted on the equipment, is readily available to the radiation inspector.

#### 3.4.2 User Responsibilities

All users of analytical x-ray equipment must:

1. receive training, authorized or approved by the equipment owner or designee, on the operation and x-ray hazards relevant to the particular analytical x-ray equipment intended for use;

2. have read, understood and follow all applicable radiation safety rules and emergency procedures that are prescribed by the equipment owner or designee and by the appropriate radiation protection regulatory authority, before operating the analytical x-ray equipment;
3. wear personal radiation monitors consistent with the equipment design and operation (see section 3.7 of this Code) and as recommended by the regulatory radiation protection authority;
4. perform regular reviews of their own personal dosimetry data and identify unexpected radiation exposures, investigate them as to root cause(s) and implement appropriate corrective action(s);
5. use an appropriate survey meter to identify and monitor radiation levels at critical areas (tube housing, beam ports, shutters, analysis accessories, etc.) of the equipment during set up and beam alignment procedures, and following modifications and alterations to the device or its accessories, and to ensure that compliance with the regulatory limit (0.5 mR [ $\sim$  4.39 Gy air kerma] per hour at 5.0 cm from any external surface of the equipment) is maintained, and that the guidance levels (indicated in section 3.6) including the permissible dose limits (Appendix I) would not be exceeded under routine operational conditions of the equipment;
6. conduct the pre-operational safety checks indicated in section 3.3.1.1 of this Code; and
6. stop the operation of the analytical x-ray equipment if any unsafe operational conditions arise, and immediately notify the equipment owner or designee of such conditions.

### **3.4.3 Maintenance Personnel Responsibilities**

All personnel responsible for the maintenance of analytical x-ray equipment must:

1. be adequately trained in the proper maintenance and repair of the various analytical x-ray equipment for which they are responsible, with emphasis on maintenance operations that may require x-ray production;
2. have read, understood and follow all radiation safety rules, requirements and emergency procedures applicable to the analytical x-ray equipment and the facility, including sections 3.6 and 3.7 of this Code;
3. wear personal radiation dosimeters to monitor separately whole body and extremity doses as deemed appropriate for the operation(s) being undertaken;
4. use a properly functioning radiation survey meter (supplied by the equipment owner or oneself) to identify and monitor the radiation levels at critical areas (tube housing, beam ports, shutters, analysis accessories, etc.) of the equipment during set up, beam alignment and maintenance procedures, and following modifications and alterations to the device or its accessories;
5. undertake precautionary measures to eliminate or reduce radiation levels (measured according to clause 3.4.3.4) to ensure that the regulatory limit (0.5 mR [ $\sim$  4.39 Gy air kerma] per hour at 5.0 cm from any external surface of the equipment) is met, and that the guidance levels (indicated in section 3.6) including the permissible dose limits (Appendix I) would not be exceeded during routine operational conditions of the equipment;
6. perform regular reviews of their own personal dosimetry data and identify unexpected radiation exposures, investigate them as to root cause(s) and implement appropriate corrective action(s) as may be necessary;
7. provide the user and the equipment owner or designee with a written report that specifies explicitly any user procedure or action that could lead to an x-ray safety hazard, as soon as such a procedure or action is identified;
8. consult and adhere to the maintenance procedures indicated in section 3.3.1.2 of this Code;
9. supervise the work of maintenance personnel in training; and prevent the operation of the analytical x-ray equipment if any unsafe operational conditions arise, and immediately notify the equipment owner or designee of such conditions.

### **3.5 Radiation Protection Surveys**

A radiation protection survey of analytical x-ray equipment is intended to determine whether the equipment functions according to applicable design and performance standards and is used and maintained in a way that provides maximum x-ray safety to all persons. In order to achieve these objectives, the following requirements apply to all facilities:

1. Analytical x-ray equipment must be surveyed when it is initially installed, and when maintenance, modification, damage and overexposure accidents have occurred on it.
2. Surveys must be performed by the appropriate radiation protection regulatory agency. However, authorized equivalents may be permitted provided that prior approval has been obtained from the appropriate regulatory authority.
3. Routine surveys of analytical x-ray equipment should be conducted at a frequency that depends on the particular equipment design, conditions of use, and performance history. The survey frequency may be based on consultation with the appropriate radiation protection regulatory authority.
4. Surveys of analytical x-ray equipment must include:
  - (i) a thorough inspection of all safety devices and radiation shields;
  - (ii) stray radiation measurements carried out under worst-case (if feasible) user conditions around the system;
  - (iii) proper quantification of stray radiation levels above the regulatory limit and their exact distance specification of the area or location on the x-ray equipment where they were found;
  - (iv) an assessment of occupational and public exposures when radiation levels have exceeded the regulatory limit;
  - (v) audits on: the availability of a copy of this Safety code, applicable radiation safety rules, safe operating and emergency procedures at or near the analytical x-ray equipment, the maintenance program established and followed by the equipment owner or designee, reports of unsafe operational conditions, overexposure incidents and accidents; and
  - (vi) review and assessment of personal dosimetry records.
5. Survey reports must state the following:
  - (i) an identification of the analytical x-ray equipment that sets out the manufacturer, brand name, model number, serial number and the date of manufacture;
  - (ii) an assessment of the safety devices, radiation shields, occupational exposures, and personal dosimetry records and the deficiencies observed;
  - (iii) specific corrective actions necessary for compliance with this Safety Code and RED Regulations, including the completion deadlines; and
  - (iv) safety recommendations (if any).
6. After analytical x-ray equipment has been decommissioned, all survey reports pertaining to that equipment must be retained for a period of five years by the last responsible user.

### **3.6 Guidance on Operational Safety**

Unattended x-ray equipment is not considered a potential hazard unless there is human intervention. In order to reduce the probability and severity of radiation accidents and overexposures, strict adherence to operating and maintenance procedures recommended by the analytical x-ray equipment manufacturer must be observed in addition to those indicated in this Code. The following general guidance should also be observed and incorporated where feasible:

1. For operations not requiring constant user supervision or surveillance, the analytical x-ray equipment must be adequately secured to prevent access by unauthorized individuals.
2. Personnel must not expose any part of the body in the primary beam. If and when alignment of analysis accessories requires the use of an open x-ray beam, specific precautions must be exercised to reduce or eliminate radiation exposures to the extremities and other parts of the body. Long-handle forceps or remote handling devices, low x-ray tube current, and fluorescent beamdefiners of higher radiation sensitivity should be employed.

3. While it may be necessary, under some circumstances, for maintenance operations to be performed with stray radiation fields above the regulatory limit (0.5 mR [ $\sim 4.39$  Gy air kerma] per hour), every effort must be made to minimize exposures to organs or parts of the body that could be affected, so as to minimize the likelihood of long-term risks. The ICRP recommended maximum permissible dose equivalent limits (Appendix I) must not be exceeded by any maintenance personnel. A practical guide, based on a busy maintenance worker performing, on average, one job per week under such conditions, would be to assume 1/50th of the annual permissible dose limit for each individual maintenance worker per week. This translates to a weekly working reference level of 10 mSv(1000 mrem) for the hands and other organs in the chest and upper facial regions, except the lens of the eye for which the limit would be 3 mSv(300 mrem). **Nonetheless, all efforts must be made to reduce radiation exposure.**
4. All protective apparel and safeguards, including the radiation survey meter(s), must be tested regularly to ensure that they are in proper working and functional condition and are not defective; and proper documentation that such tests were carried out should be maintained.

### 3.7 Personal Exposure Monitoring

Personal dosimeters are intended to monitor occupational doses thereby providing a mechanism for restricting future radiation exposures to an individual, so that the recommended maximum permissible limits indicated in Appendix I are not exceeded. For the general application of this Safety Code, users and maintenance personnel are considered radiation workers and the applicable limits are indicated in column 2, Appendix I.

Depending on the analytical x-ray system design, monitoring the extremity doses as well as the whole body doses may be required. For extremity measurements, which typically would be the case for alignment procedures that involve open x-ray beams and systems potentially capable of irradiating the extremities, at least two finger monitors should be worn on the hand nearest the beam; one monitor should be worn on the dorsal surface of the finger and the other on the palmar surface, so as to detect exposures from narrow beams. For whole body monitoring, the monitor should be worn at chest level for work situations above bench height, enabling estimates of the dose to the breast and possibly facial organs; otherwise, wearing the monitor at waist level is satisfactory. Dosimetry records must reflect separate extremity and whole-body cumulative doses, where applicable, in order to facilitate better control on doses approaching the respective permissible limits.

The need for personal dosimeters should be determined by the appropriate radiation protection regulatory authority on the basis of survey results and the particular analytical x-ray equipment in use. Given the historic injuries, effective lines of defense against radiation exposure to the body are the application of shielding and the proper use of a survey meter in the work area of the equipment, during beam alignment and set up procedures, as well as following modifications and alterations to the equipment or its accessories; personal monitoring should be used as confirmation rather than control.

Dosimetry records should be maintained at the facility for at least 5 years after a user has terminated working with such equipment.

### References

1. Treasury Board of Canada. *Handbook of Occupational Safety and Health*. Ottawa: Government Publishing Centre. 1989.
2. Department of Labour. *Canada Occupational Health and Safety Regulations*. Ottawa: Queen's Printer; Canada Gazette; Revised Statutes of Canada, Chapter L-1; (SOR/86-304); 1984.
3. International Commission on Radiological Protection. *1990 Recommendations of the International Commission on Radiological Protection*. Oxford: Pergamon Press; ICRP Publications 60; 1991.

4. Department of National Health and Welfare. *Radiation Emitting Devices Act*. Ottawa: Queen's Printer; Revised Statutes of Canada, Chapter 34, Supplement 1; 1984.
5. Department of National Health and Welfare. *Recommended Safety Procedures for the Selection, Installation and Use of X-ray Diffraction Equipment*. Ottawa, Ontario: Environmental Health Directorate; Safety Code-19; 84-EHD-111; 1984.
6. Department of National Health and Welfare. *Radiation Emitting Devices Regulations*. Ottawa: Queen's Printer; Canada Gazette; Schedule I and II; 1981.
7. Maharaj, H.P. Safety considerations and recommendations for analytical x-ray equipment based on a review of survey data. *Health Physics*. **66**:463-471; 1994.
8. Masse, F.X., Contu-Reilly, J., Galanek, M., Ducatman, A. The need for additional warning in x-ray diffraction equipment: a shutter failure incident. *Health Physics*. **58**:219; 1990.
9. More, T.M., Britain, R.G. Corrective action program for a malfunctioning commercial x-ray diffraction shutter system. *Health Physics*. **22**: 107-108; 1972.
9. Maharaj, H.P. Response of the Victoreen 440 RF/C and the Rad Owl RO-1 survey meters to low energy photons (<66 keV) for narrow beam geometries. *Radiat. Prot. Dosimetry*. **30**: 129-133; 1990.

**Appendix I**  
**Recommended Maximum Permissible**  
**Dose Equivalent Limits for**  
**Ionizing Radiation**

For the purpose of radiation protection, individuals may be classified in one of two groups: radiation worker\* or member of the public. The former group refers to individuals exposed to ionizing radiation during the course of their work, excluding medical and natural background ionizing radiation exposures. The latter group refers to those individuals who are not radiation workers. The following table summarizes the 1990 ICRP **recommended** dose equivalent limits for ionizing radiation.(3)

Applicable body organ or tissue	Maximum permissible dose equivalent Limits in a year <sup>a</sup>	
	Radiation worker <sup>b</sup>	Member of the public
Whole body	20 mSv	1 mSv
Lens of the eye	150 mSv	15 mSv
Skin (1 cm <sup>2</sup> )	500 mSv	50 mSv
All organs	500 mSv	

- a These limits are intended to prevent deterministic effects by keeping doses below the relevant threshold, and to reduce the incidence of stochastic effects to acceptable levels by demanding that all reasonable steps be taken to lower doses. For further details, consult the source, ICRP 1991.(3)
- b For women who are or may be pregnant, the fetus must be protected from radiation exposure once pregnancy has been diagnosed. For the remainder of the pregnancy, the dose equivalent limit from radiation sources external to the body is 2 mSv applied to the surface of the abdomen, and the limit for radionuclides taken internally by the body is 1/20th of the allowable annual intake. If a woman is exposed to both internal and external sources, both limits apply separately and the total limit shall not exceed 1 mSv (since the fetus is considered a member of the public).

c While dose equivalents up to 50 mSv may be permitted in a single year for special circumstances, a total limit of 100 mSv over a five-year period is recommended by the ICRP. This translates into an average annual limit of 20 mSv y<sup>-1</sup>.

\* For purposes of this Safety Code, users and maintenance personnel of analytical x-ray equipment are considered radiation workers.

## **Appendix II**

### **Guidance on Survey Instrumentation**

Survey meters that utilize ionization in a gas remain one of the most common instruments used for determining radiation levels around analytical x-ray equipment. General guidance information is provided below and is intended to assist in choosing instruments and interpreting their measurements.

1. In order to be detected or measured, the ionizing radiation must enter the sensitive volume of the detector. Alpha, beta, gamma and x rays, and neutrons are ionizing radiations with different penetration characteristics. This means that an instrument designed for detecting and measuring alpha particles, for example, will not be appropriate for gamma and x rays. For instruments that are not intentionally designed to measure x rays but are designed to measure alpha, beta and gamma radiation, the user should obtain the manufacturer's specifications to see if the instrument will measure x rays used in analytical x-ray equipment.
2. A given instrument intended for performing quantitative measurements will respond differently to various energies of a given radiation. That is, the energy dependence of the instrument must be known and accounted for in order to make accurate quantitative measurements. Two instruments of the same model may not necessarily yield identical results (because of internal variations in electrodes, electric fields, noise, internal components, etc.); the difference would be much larger if they were of different designs. Thus, to compare the measured exposure rates at a particular point using differently designed detectors, both detectors must be calibrated at the radiation energy at which the measurements are being made.
3. The instrument should be calibrated for the energy range intended if the readings are to be relied upon. This means, if quantification of the radiation is intended, that the instrument reading must be corrected for the corresponding energy calibration factor.
4. The range of the instruments must be compatible with the range of radiation exposures to be measured. This means the instrument must be capable of measuring sufficiently low levels to establish whether or not the analytical x-ray equipment meets the regulatory limit (0.5 mR [ $\sim 4.39$  Gy air kerma] per hour at 5.0 cm from any external surface of the equipment).
5. While instrument calibration is done under well defined and highly reproducible conditions in a standardization laboratory, or one accredited by or traceable to such a laboratory, the radiation encountered in the field may come from different and often unknown directions. Therefore, an instrument with a low directional dependence should be used.
6. Extreme care should be exercised if a large detector is used for measuring narrow beams of radiation because of differences in areal response of the detectors.(10) A practical approach would be to determine the distance from the source where the field is wide enough to encompass the detection volume, measure the exposure rate there, and then use the inverse square law to estimate the exposure rate at the source (it should be higher). The result so obtained would be satisfactory for making relative comparisons that would alert or warn of the existence of a radiation hazard; that is, the instrument is used in a qualitative sense. Alternatively, a detector that is small enough to make field variations over its own dimensions negligible, may be used to quantify the radiation exposure, provided that the appropriate calibration factor corresponding to the radiation energy of the measurement is applied.
7. Geiger Mueller (GM) survey meters may be sensitive to daylight, uv radiation, radiofrequency fields, and may undergo paralysis of response (read zero) at high exposure or count rates. Therefore, when a reading is obtained it should be ascertained that it is not affected by these factors. GM meters used in surveys should be turned on before entry into the zone to be checked, in case the radiation field is so

high that it causes the detector to undergo paralysis and indicate zero reading (i.e., a false indication of a radiation field). GM meters used for x rays and gamma radiation <100 keV are highly energy dependent and unless a calibration is available for the energy spectrum present, their use should be restricted to only the detection of radiation. An endwindow GM detector, because of its small size and increased x-ray sensitivity compared to an ion chamber, is very useful in detecting high radiation areas close to, or on, the equipment; a pancake type GM probe has the advantage of allowing the user to keep the hands out of the beam while placing the probe head into an x-ray beam. In addition, GM detectors should not be used for the measurement of short high intensity pulsed radiation because the level during pulsation may be sufficiently high to cause the instrument to respond in its non-linear range, thereby causing readings that are too low.

8. The instrument(s) must be in good working condition, and constancy performance and functional tests should be conducted periodically

### **Appendix III Provincial and Territorial Agencies**

#### ***Responsible for Radiation Safety***

##### **Alberta**

Alberta Radiation Health Service  
Occupational Health & Safety  
4th Floor, Donsdale Place  
10709 Jasper Avenue  
Edmonton, Alberta  
T5J 3N3  
Tel: (403) 427-2691  
FAX: (403) 427-5698

##### **British Columbia**

Worker's Compensation Board of British Columbia  
P.O. Box 5350 Stn Terminal  
Vancouver, British Columbia  
V6B 5L5  
Tel: (604) 231-8374 (toll free within B.C. 1-888-621-7233)  
FAX: (604) 279-7410

##### **Newfoundland**

Medical and Hygiene Services  
Employment and Labour Relations  
Fall River Plaza  
P.O. Box 8700  
St. John's, Newfoundland  
A1B 4J6  
Tel: (709) 729-2644  
FAX: (709) 729-2142

##### **Northwest Territories**

Occupational Health and Safety Division  
Safety and Public Services  
Government of the Northwest Territories  
P.O. Box 1320

Yellowknife, N.W.T.  
X1A 2L9  
Tel: (403) 920-8616  
FAX: (403) 873-7706

**Saskatchewan**

Radiation Safety Unit  
Department of Human Resources,  
Labour and Employment  
Saskatchewan Place  
1870 Albert Street  
Regina, Saskatchewan  
S4P 3V7  
Tel: (306) 787-4486  
FAX: (306) 787-2208

**New Brunswick**

Radiation Protection Services  
Department of Health and Community Services  
2nd Floor, Carleton Place  
King Street  
P.O. Box 5100  
Fredericton, New Brunswick  
E3B 5G8  
Tel: (506) 453-2360  
FAX: (506) 453-2726

**Ontario**

Radiation Protection Service  
Ontario Ministry of Labour  
81 Resources Road  
Weston, Ontario  
M9P 3T1  
Tel: (416) 235-5922  
FAX: (416) 235-5926

**Yukon**

Consumer, Corporate and Labour Affairs Branch  
Department of Justice  
P.O. Box 2703  
Whitehorse, Yukon  
Y1A 2C6  
Tel: (403) 667-5450  
FAX: (403) 667-3609

## 4.2.3 X-ray Safety Regulation 861

# Occupational Health and Safety Act Loi sur la santé et la sécurité au travail

## REGULATION 861

### *No Amendments*

### **X-RAY SAFETY**

*This Regulation is made in English only.*

1. In this Regulation,

“absorbed dose” means the mean energy per unit mass imparted by ionizing radiation to matter;

“air kerma” means the sum of the initial kinetic energies per unit mass of all the charged particles liberated by uncharged ionizing radiation in air;

“Director” means the Director of the Health and Safety Support Services Branch of the Ministry of Labour;

“dose equivalent” means the product of absorbed dose and a quality factor where the quality factor is a measure of the biological effectiveness of the radiation, and is assigned the value 1.0 for X-rays;

“failsafe design” means a design in which any failure of safety indicators or components that can reasonably be anticipated causes the production or emission of X-rays to cease;

“gray” means,

(a) a unit of absorbed dose, and is realized when one joule of energy has been imparted per kilogram of material, or

(b) a unit of air kerma, and is realized when one joule of energy has been liberated per kilogram of air;

“redundant”, when used with reference to a light, means a light with two or more separate and equivalent bulbs so designed that the failure of one bulb will not affect the operation of the other bulb or bulbs;

“shield” or “shielding” means radiation absorbing material or materials used to reduce the absorbed dose or absorbed dose rate imparted to an object;

“sievert” means a unit of dose equivalent, and for X-rays the dose equivalent measured in sieverts is numerically equal to the absorbed dose measured in grays;

“X-ray machine” means an electrically powered device, the principal purpose of which is the production of X-rays;

“X-ray source” means any device, or that portion of any device, that emits X-rays, whether or not the device is an X-ray machine;

“X-ray worker” means a worker who, as a necessary part of the worker’s employment, may be exposed to X-rays and may receive a dose equivalent in excess of the annual limits set forth in Column 4 of the Schedule;

“X-rays” means electrically-generated electromagnetic radiation of maximum photon energy not less than 5,000 electron volts. R.R.O. 1990, Reg. 861, s. 1.

2. Subject to section 3, this Regulation applies to every owner, employer, supervisor and worker at a workplace where,

(a) an X-ray machine is present or used; or

(b) an X-ray source that is not an X-ray machine is present or used, if the X-ray source is capable of producing an air kerma rate greater than 1.0 microgray per hour at any accessible point outside its surface. R.R.O. 1990, Reg. 861, s. 2.

3. (1) This Regulation does not apply to an X-ray source that is licensable under the *Atomic Energy Control Act* (Canada).

(2) Sections 5, 6, 7 and 8 of this Regulation do not apply in respect of an X-ray machine the installation, registration or operation of which is subject to the *Healing Arts Radiation Protection Act*. R.R.O. 1990, Reg. 861, s. 3.

4. Except as permitted under the *Healing Arts Radiation Protection Act*, an X-ray source shall not be operated for the irradiation of a worker. R.R.O. 1990, Reg. 861, s. 4.

5. (1) An X-ray source shall not be used at a workplace unless the employer who has possession of the X-ray source is registered with the Director.

(2) An application for registration under this section shall be in Form 1 and shall be filed with the Director.

(3) An employer who was registered under Ontario Regulation 263/84 or Regulation 855 of the Revised Regulations of Ontario, 1980 or a predecessor thereof shall be deemed to be registered under this section if the registration was subsisting at the end of the 29th day of October, 1986.

(4) If an employer who is registered under this section ceases to have possession of an X-ray source, the employer shall forthwith give a notice to the Director advising the Director of that fact.

(5) An employer's registration under this section terminates when the employer notifies the Director that the employer no longer has possession of any X-ray sources. R.R.O. 1990, Reg. 861, s. 5.

**6.** (1) An X-ray source shall not be installed or used in a permanent location and an X-ray source that is designed for portable or mobile use shall not be installed or used regularly in one location unless an application for review, together with plan location drawings, of the installation have been reviewed by and are acceptable to an inspector.

(2) Subsection (1) does not apply to an X-ray source that,

(a) was in use in a permanent location before the 27th day of April, 1984, if it has remained continuously in that location since that time and so long as it remains in that location; or

(b) was installed after the 26th day of April, 1984, if the installation was made in compliance with Ontario Regulation 263/84 and there was compliance with that Regulation until the end of the 29th day of October, 1986.

(3) An application mentioned in subsection (1) shall be in Form 2 and shall be accompanied by the plan location drawings mentioned in that subsection, in duplicate.

(4) Plan location drawings mentioned in subsection (1),

(a) shall bear the name of the applicant and the address of the location;

(b) shall be on a legible scale that is not less than 1:100 and that is suitable for microfilming;

(c) shall indicate the direction north;

(d) shall show the proposed location of the X-ray source and, where applicable, the range of its motion;

(e) shall show the proposed location of the X-ray control panel, if the location of the control panel is different from that of the X-ray source;

(f) shall indicate the use of rooms or areas that are adjacent, both horizontally and vertically, to the proposed location;

(g) shall indicate the type and thickness of the shielding installed or to be installed on the boundaries of the proposed location; and

(h) shall indicate the type and location of the safety devices such as warning lights, interlocks and cut-off switches.

(5) An application under this section shall be filed with the Director.

(6) Where an application under this section or a predecessor of this section has been found acceptable by an inspector, the X-ray source to which the application relates shall not be installed except in accordance with the application and the plan location drawings as accepted by the inspector.

(7) An X-ray source to which subsection (1) applies or that is described in subsection (2) shall not be used, if after the installation of the X-ray source there is a change in,

(a) the installation or use of the X-ray source;

(b) the use of rooms or areas adjacent, horizontally or vertically, to the X-ray source; or

(c) any shielding of the X-ray source,

that may result in an increase in the exposure of a worker to X-rays unless the change has been reviewed by and is acceptable to an inspector.

(8) An employer shall request a review of a change described in subsection (7) by giving the request to the Director. R.R.O. 1990, Reg. 861, s. 6.

**7.** (1) Where an employer comes into possession of an X-ray source that is designed for portable or mobile use and that is so used, notice thereof shall be given to the Director.

(2) The notice required by subsection (1) shall be in writing and shall include,

(a) the name and address of the employer;

(b) the employer's registration number, if any, under section 5;

(c) the location where the X-ray source will normally be stored;

(d) the purpose for which the X-ray source will be used;

(e) the make, model and serial number of the X-ray source; and

(f) the maximum operating voltage and current of the X-ray source. R.R.O. 1990, Reg. 861, s. 7.

**8.** An employer shall designate a person, for each X-ray source, who is competent because of knowledge, training or experience in the use and operation of X-ray sources and in radiation safety practices, to exercise direction over the safe use and operation of the X-ray source, and shall advise the Director in writing of the name of the person designated. R.R.O. 1990, Reg. 861, s. 8.

**9.** (1) An employer who employs a person as an X-ray worker shall, at the time that employment begins,

(a) inform the worker in writing that the worker is employed as an X-ray worker;

(b) inform the worker of the limits imposed by subsection 10 (1) on the dose equivalent that may be received by the worker; and

(c) if the worker is female, inform her of the dose equivalent limit mentioned in subsection 10 (2) applicable to a pregnant X-ray worker.

(2) An employer shall maintain a list of all X-ray workers in the employment of the employer. R.R.O. 1990, Reg. 861, s. 9.

- 10.** (1) The dose equivalent received or that may be received by a worker shall be as low as is reasonably achievable, and in any case,
- (a) an X-ray worker shall not receive a dose equivalent in excess of the annual limits set out in Column 3 of the Schedule; and
  - (b) a worker who is not an X-ray worker shall not receive a dose equivalent in excess of the annual limits set out in Column 4 of the Schedule.
- (2) Despite subsection (1), an employer shall take every precaution reasonable in the circumstances to ensure that the mean dose equivalent received by the abdomen of a pregnant X-ray worker does not exceed 5 millisieverts during the pregnancy. R.R.O. 1990, Reg. 861, s. 10.
- 11.** The following measures and procedures shall be carried out in a workplace where an X-ray source is used:
- 1. X-ray warning signs or warning devices shall be posted or installed in conspicuous locations.
  - 2. Every X-ray source 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. Where the air kerma in an area may exceed 100 micrograys in any one hour, access to the area shall be controlled by,
    - i. locks or interlocks if the X-ray source is one to which subsection 6 (1) applies or is described in subsection 6 (2), and
    - ii. barriers and X-ray warning signs if the X-ray source is portable or mobile and is being so used.
  - 4. To ensure that the dose equivalent limits mentioned in section 10 are not exceeded,
    - i. structural or other shielding shall be installed as is necessary, and
    - ii. diaphragms, cones and adjustable collimators or other suitable devices shall be provided and used as are necessary to limit the dimensions of the useful X-ray beam. R.R.O. 1990, Reg. 861, s. 11.
- 12.** (1) An employer shall provide to each X-ray worker a suitable personal dosimeter that will provide an accurate measure of the dose equivalent received by the X-ray worker.
- (2) An X-ray worker shall use the personal dosimeter as instructed by the employer.
  - (3) An employer shall ensure that the personal dosimeter provided to an X-ray worker is read accurately to give a measure of the dose equivalent received by the worker and shall furnish to the worker the record of the worker's radiation exposure.
  - (4) An employer shall verify that the dose equivalent mentioned in subsection (3) is reasonable and appropriate in the circumstances, and shall notify an inspector of any dose equivalent that does not appear reasonable and appropriate.
  - (5) An employer shall retain an X-ray worker's personal dosimeter records for a period of at least three years. R.R.O. 1990, Reg. 861, s. 12.
- 13.** Where a worker has received a dose equivalent in excess of the annual limits set out in Column 4 of the Schedule in a period of three months, the employer shall forthwith investigate the cause of the exposure and shall provide a report in writing of the findings of the investigation and of the corrective action taken to the Director and to the joint health and safety committee or health and safety representative, if any. R.R.O. 1990, Reg. 861, s. 13.
- 14.** Where an accident, failure of any equipment or other incident occurs that may have resulted in a worker receiving a dose equivalent in excess of the annual limits set out in Column 3 of the Schedule, the employer shall notify immediately by telephone, telegram or other direct means the Director and the joint health and safety committee or health and safety representative, if any, of the accident or failure and the employer shall, within forty-eight hours after the accident or failure, send to the Director a written report of the circumstances of the accident or failure. R.R.O. 1990, Reg. 861, s. 14.
- 15.** (1) This section applies only to X-ray machines used for industrial radiography or industrial fluoroscopy but does not apply to an X-ray machine to which section 17 applies.
- (2) No X-ray machine to which this section applies shall be used except by or under the supervision of a competent person.
  - (3) In addition to any other requirements of this Regulation, the following requirements apply with respect to every X-ray machine to which this section applies:
    - 1. The control panel of the X-ray machine shall have a plainly visible warning light to indicate when X-rays are being produced in the X-ray tube.
    - 2. The X-ray machine, if installed in a permanent location or if designed for portable or mobile operation but used regularly in one location, shall be contained in an enclosure.
    - 3. No person shall be permitted in the enclosure required by paragraph 2 while X-rays are being produced.
    - 4. The enclosure required by paragraph 2 shall be provided with,
      - i. reliable locks or interlocks to prevent any person from entering a radiation enclosure during an exposure and, where an exposure is terminated by an interlock, it shall only be possible to restart the exposure from the control panel, and
      - ii. conspicuous warning lights of failsafe or redundant design near each entrance to the enclosure that indicate when X-rays are being produced, and paragraph 3 of section 11 does not apply.
    - 5. If the enclosure required by paragraph 2 is of such a size or is so arranged that the operator cannot readily determine whether it is unoccupied, it shall be provided with,
      - i. suitable audible or visible pre-exposure warning signals within the enclosure that shall be actuated for not less than ten or more than thirty seconds immediately before the initiation of an X-ray exposure,
      - ii. suitable audible or visible warning signals within the enclosure that shall be actuated during the X-ray exposure, and

- iii. a suitable exit to enable any person to leave the enclosure without delay and without having to pass through the primary X-ray beam or an effective means, within the enclosure, that,
    - A. prevents or interrupts an X-ray exposure,
    - B. cannot be reset from outside the enclosure, and
    - C. can be reached without having to pass through the primary X-ray beam.
6. An X-ray machine shall be operated, and, where an enclosure is required by paragraph 2, the enclosure shall be shielded in such a manner that,
    - i. an X-ray worker is not likely to receive an effective dose equivalent in excess of 1 millisievert per week, and
    - ii. a worker who is not an X-ray worker is not likely to receive an effective dose equivalent in excess of 100 microsieverts per week.
  7. The employer shall ensure that a direct reading dosimeter of a suitable type is provided to each X-ray worker who in the course of his or her work may be exposed to an air kerma rate in excess of 100 micrograys per hour.
  8. An X-ray worker provided with a direct reading dosimeter shall use it and shall determine the amount by which its reading has increased during each work day and record that amount at the end of the work day.
  9. The employer shall retain the direct reading dosimeter records of each X-ray worker provided with such a dosimeter for a period of at least three years.
  10. At least one radiation survey meter of a suitable type shall be provided for each portable or mobile X-ray machine and it shall be calibrated at least once every twelve months and kept in good working order. R.R.O. 1990, Reg. 861, s. 15.
- 16.** In addition to any other requirement of this Regulation, the following requirements apply to every X-ray machine used for the diagnostic examination of animals:
1. Where practicable, radiographic procedures shall be performed in a room designed for the purpose of performing X-ray examinations of animals.
  2. The air kerma due to leakage radiation from the X-ray tube housing or from an attached beam-limiting device shall not exceed 1 milligray in one hour at a distance of 1 metre from the focal spot of the X-ray tube.
  3. Exposure duration shall be controlled by a preset timing mechanism and shall be initiated by a switch that requires positive action by the operator to continue the exposure and that allows the operator to remain at least 2 metres from the tube housing.
  4. To the extent practicable, the dimensions of the useful beam shall be restricted to not more than those of the film.
  5. The film cassette shall not be held by hand during an exposure.
  6. The animal being X-rayed shall be restrained or supported by mechanical means where practicable.
  7. If an animal is required to be restrained or supported by hand, a protective apron and gloves, providing shielding equivalent to at least 0.5 millimetre of lead, shall be worn by any person providing the restraint or support.
  8. A record of radiographic exposures, including the date, kilovoltage, tube current and duration of each exposure, shall be maintained and kept for at least one year. R.R.O. 1990, Reg. 861, s. 16.
- 17.** In addition to any other requirements of this Regulation, where an employer is in possession of an X-ray source in which the X-ray source, the object or the portion of the object being exposed to X-rays and the detection device are enclosed in a cabinet that, independent of existing structures, provides radiation attenuation and prevents access to the X-ray beam, the employer shall comply with the following requirements:
1. 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. Access doors and sample ports shall be interlocked with the X-ray source or with an adequately shielded shutter of failsafe design and, where operation has been interrupted by an interlock, it shall be possible to resume operation only from the control panel after the interlock has been reset.
  3. The cabinet shall be so arranged and shielded as to prevent the air kerma rate from exceeding 5 micrograys per hour at any accessible point 5 centimetres from the external surface, under all possible operating conditions.
  4. Cabinet X-ray equipment that is intended to permit the entry of a person shall also be provided with,
    - i. suitable audible or visible warning signals within the cabinet that shall be actuated for at least ten seconds immediately prior to the initiation of X-ray production after the closing of any door that is designed to permit human access into the cabinet,
    - ii. suitable audible or visible warning signals within the cabinet that shall be actuated during X-ray production, and
    - iii. effective means within the enclosure to prevent or interrupt the production of X-rays, that cannot be reset from outside the enclosure and that can be reached without having to pass through the primary X-ray beam. R.R.O. 1990, Reg. 861, s. 17.
- 18.** In addition to any other requirements of this Regulation, where an employer is in possession of an X-ray source that consists of analytic X-ray equipment to which section 17 does not apply and that is primarily used to determine the structure or composition of a sample of a material, the employer shall comply with the following requirements:
1. The control panel shall have an indicator, in close proximity to the X-ray "ON/OFF" switch, that clearly indicates when X-rays are being produced in the X-ray tube.
  2. A warning light shall be mounted near each X-ray tube in such a way as to be clearly visible from any direction from which the tube can be approached, that indicates when X-rays are being produced.

3. The condition of each shutter, open or closed, shall be clearly indicated at or near the X-ray tube.
4. Each port shall be designed in such a way that the X-ray beam can emerge only when a camera or other recording device is in its proper position, wherever practicable.
5. At least one of the warning or safety devices mentioned in paragraphs 1 to 4 shall be of failsafe design.
6. A guard or interlock which prevents entry of any part of the body into the primary beam path shall be used, wherever practicable.
7. A shield shall be provided to absorb the primary beam at the nearest practicable position beyond the point of intersection of the beam and the sample that it is intended to irradiate.
8. All unused ports shall be secured in such a way as to prevent inadvertent opening. R.R.O. 1990, Reg. 861, s. 18.

19. In applying this Regulation, a procedure or device may vary from the procedure or device prescribed in this Regulation if the protection afforded thereby is equal to or greater than the protection afforded by the procedure or device prescribed. R.R.O. 1990, Reg. 861, s. 19.

#### Schedule

PART OF BODY IRRADIATED	EXPOSURE CONDITIONS AND COMMENTS	DOSE EQUIVALENT ANNUAL LIMIT (MILLISIEVERTS)	
		X-RAY WORKERS	OTHER WORKERS
COLUMN 1	COLUMN 2	COLUMN 3	COLUMN 4
Whole body or trunk of body	Uniform irradiation	50	5
Partial or non-uniform irradiation of body	The limit applies to the EFFECTIVE DOSE EQUIVALENT defined in Note (a)	50	5
Lens of eye	Irradiated either 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

Notes to the Schedule:

- (a) The EFFECTIVE DOSE EQUIVALENT,  $H_E$ , is determined by the following formula:

$$H_E = \sum W_T H_T$$

where:

- (i) T is an index for tissue type;
  - (ii)  $H_T$  is the annual dose equivalent in tissue T;
  - (iii)  $W_T$  is a weighting factor which has the following values:
    - 0.25 for the gonads,
    - 0.15 for the breast,
    - 0.12 for the red bone marrow,
    - 0.12 for the lungs,
    - 0.03 for the bone surfaces,
    - 0.03 for the thyroid,
    - 0.06 for each of the five other organs or tissues receiving the highest dose equivalents, but excluding the skin, extremities and eye lenses. The exposure of all other remaining tissues can be neglected. When the gastro-intestinal tract is irradiated, the stomach, small intestine, upper large intestine and lower large intestine shall be considered as four separate organs; and
  - (iv)  $\sum W_T H_T$  is the sum of the  $W_T H_T$  values for all irradiated tissues which receive more than 1 millisievert in a given year.
- (b) The annual limits do not include any dose equivalent received by a worker from background sources or received as a patient undergoing medical diagnostic or therapeutic procedures.
- (c) The annual limits include any dose equivalent received by a worker, as a consequence of his or her occupation, from all sources of ionizing radiation.

R.R.O. 1990, Reg. 861, Sched.