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**Safety Code 19**

# Recommended Safety Procedures for the Selection, Installation and Use of X-Ray Diffraction Equipment.

EHD--84-111

SAFETY CODE - 19

# RECOMMENDED SAFETY PROCEDURES FOR THE SELECTION, INSTALLATION AND USE OF X-RAY DIFFRACTION EQUIPMENT

Environmental Health Directorate

Health Protection Branch

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# EXPLANATORY NOTES

This document is one of a series of Safety Codes prepared by the Radiation Protection Bureau to set out requirements for the safe use of radiation emitting devices.

The equipment and installation guidelines and safety procedures detailed in this Code are primarily for the instruction and guidance of persons employed in Federal Public Service Departments and Agencies, as well as those coming under the jurisdiction of the Canada Labour Code. This Safety Code is also intended to assist other users of X-ray diffraction equipment to select safe equipment and to install and use it so that the radiation hazard to the operator and other persons in its vicinity is negligible. It should be noted that facilities under provincial jurisdiction may be subject to requirements specified under provincial statutes.

This Code supersedes Safety Code RPD-SC-7, entitled "Requirements For Non-Medical X-Ray Equipment, Use and Installation", insofar as X-ray diffraction equipment is concerned, and it is intended to complement X-ray equipment design, construction and performance standards promulgated under the Radiation Emitting Devices Act.

The words "must" ("shall") and "should" in this Code have been chosen with purpose. The word "must" (or "shall") indicates a recommendation that is essential to meet the currently accepted standards of protection, while "should" indicates an advisory recommendation that is highly desirable and that is to be implemented where feasible.

In a field in which technology is advancing rapidly and where unexpected and unique problems continually occur, the Code cannot cover all possible situations. Blind adherence to rules cannot substitute for the exercise of sound judgement; consequently the recommendations may need to be modified in unusual circumstances, but only after consulting experts with recognized competence in radiation protection. This Code will be reviewed and revised periodically

and a particular requirement may be reconsidered at any time if it becomes necessary to cover an unforeseen situation. Interpretation or elaboration of any point can be obtained by contacting the Radiation Protection Bureau, Health and Welfare Canada, Ottawa, Ontario, K1A 1C1.

The draft of this Code was prepared by Dr. W.M. Zuk and Mr. E. Rabin, and revised by Messrs. P. Dvorak and C. Lavoie.

Appreciation is expressed to all organizations, agencies and individuals whose comments and suggestions helped in preparation of this Code.

# 1. INTRODUCTION

X-ray diffraction equipment is widely used as an analytical tool for material analysis in industry, research laboratories and educational institutions. In common with other types of X-ray machines, X-ray diffraction machines are potential sources of unnecessary X-ray exposure to operators and to other individuals who may be in their vicinity. The intense primary and scattered X-ray beams produced by X-ray diffraction equipment can cause severe burns after only a few seconds exposure. (Primary X-ray beams with exposure rates of more than 0.07 coulomb per kilogram per second (about $10^6$ roentgen per hour) are common.) The very nature of use of X-ray diffraction equipment and its analysis accessories places the eyes and hands particularly at risk.

These high levels of radiation emphasize the need for extreme care in all aspects of the installation, operation and maintenance of X-ray diffraction equipment. However, in spite of this knowledge, reports of serious exposures and injuries to X-ray diffraction workers continue to appear. In each case, the accidental exposure occurs as a result of one or more of the following reasons:

1. Lack of safety features built into the X-ray diffraction equipment.

2. Ineffective or easily defeated safety features incorporated into the X-ray diffraction equipment.

3. Inadequate installation arrangement or facility design.

4. Inadequate instruction to the operator on the proper use of, and hazards associated with, the X-ray diffraction equipment.

Accidents resulting from the first two of these factors can be significantly reduced, if not completely

eliminated, by ensuring that X-ray diffraction equipment conforms to stringent safety standards. The effect of the last two factors can be minimized by insisting on high standards of installation and operator training.

The Radiation Emitting Devices Regulations for X-ray diffraction equipment address themselves to the first two factors, and this Safety Code addresses itself to the last two.

## 2. SCOPE AND PRINCIPAL AIMS OF THE CODE

This Safety Code deals with the protection of all individuals who may be exposed to radiation emitted by X-ray diffraction equipment.

### 2.1 Principal Aims

The principal aims of this Code are:

1. to ensure adequate radiation protection of personnel operating X-ray diffraction equipment; and

2. to ensure adequate radiation protection of workers and the general public in the vicinity of areas where X-ray diffraction equipment is in use.

### 2.2 Scope

To assist personnel in achieving these objectives, this Safety Code:

1. specifies minimum standards of safe design, construction and performance for X-ray diffraction equipment;

2. presents recommended correct use and maintenance practices for minimizing X-ray exposures to personnel and ensuring that X-ray diffraction equipment is used in a safe manner;

3. presents recommendations on proper installation layout of X-ray diffraction facilities;

4. sets out the relative responsibilities of the owner, responsible user, operator and other personnel; and

5. describes a program of personnel monitoring and radiation protection surveys which contribute to ensuring the safety of personnel.

## 3. RESPONSIBILITY AND PERSONNEL

The owner is ultimately responsible for radiation safety of an X-ray diffraction facility. It is the responsibility of the owner to ensure that the equipment provided for the responsible user and operators, and the facilities in which such equipment is installed and used, meet all applicable radiation safety standards.

The owner may delegate this responsibility to staff. How this responsibility is delegated will depend upon the size of the staff and on the amount of such equipment owned. In any event, one or more persons must be designated by the owner to carry out the role described as follows:

### 3.1 Responsible User

For each facility, there must be at least one person designated as the responsible user to undertake responsibility for:

1. ensuring that operational procedures pertaining to radiation safety are established and carried out so that the radiation exposure of each worker is kept as low as reasonably achievable;

2. providing instruction in safety practices for all personnel who work with or near X-ray diffraction equipment;

3. maintaining a system of personnel monitoring;

4. investigating any case of abnormal radiation exposure to personnel and taking remedial action if necessary;

5. arranging for radiation safety inspections of X-ray diffraction equipment;

6. reviewing and approving modifications to X-ray apparatus, including X-ray tube housing, cameras, diffractometers, shielding and safety interlocks;

7. arranging for establishment of controlled areas, including placement of appropriate radiation warning signs and/or devices;

8. ensuring that the facility complies with all applicable rules and regulations.

3.2 X-Ray Equipment Operators

All operators of X-ray diffraction equipment must:

1. be familiar with the contents of this Safety Code;

2. have undergone training in the proper use of the equipment and understand the potential hazards involved in the operation of the equipment;

3. have demonstrated competence to use the equipment to the satisfaction of the responsible user;

4. keep radiation exposure to themselves and others as low as reasonably achievable;

5. wear personnel monitoring devices (the appropriate types of monitoring devices are discussed in the section of this Code entitled "PERSONNEL AND EQUIPMENT MONITORING");

6. notify the responsible user of known or suspected abnormal radiation exposure to themselves or others.

3.3 Service or Maintenance Personnel

All personnel responsible for servicing or maintaining X-ray diffraction equipment must:

1. have attended and successfully completed an approved study program on the use, maintenance and repair of the equipment;

2. understand the potential hazards associated with maintenance procedures carried out under conditions where X-rays are being generated by the equipment;

3. demonstrate, to the responsible user, sufficient knowledge of the potential radiation hazards associated with the equipment to ensure that the servicing of the equipment will be carried out in a manner which minimizes any radiation hazard to themselves, to the operators and to other individuals in the vicinity of the equipment; and

4. report, to the responsible user, any anomalous situations which arise with respect to operation or maintenance of the equipment, including any actual or suspected overexposures.

3.4 Students or Operators-in-Training

All students or operators-in-training must:

1. demonstrate, to their instructor, that they understand the contents of this Safety Code (or a similar radiation safety document) before they are permitted to operate the equipment;

2. work only under the direct supervision of an operator as described under 3.2; and

3. wear personnel monitoring devices.

## 4. BUILDING AND INSTALLATION REQUIREMENTS

### 4.1 Design Criteria

The overall safety of an X-ray diffraction facility depends on a combination of factors which include the X-ray equipment itself, the extent and manner of use of the equipment, the qualifications of the operating personnel and the installation in which the equipment is used. A correct installation is of particular importance in ensuring the safety of personnel and individuals of the general public who may be in the vicinity. Thus, in the designing of any X-ray diffraction facility, account must be taken of the expected maximum workload of the equipment, of the types of measurements or experiments to be carried out (e.g. open beam or closed beam) and of the locations and number of persons that will be working with, or in the general vicinity of, the X-ray equipment.

The layout and shielding for a room where X-ray diffraction equipment is installed must be such that its operation does not result in any person exceeding the dose equivalent limits given in Appendix I.

The final plans for an installation should be reviewed by the appropriate agency responsible for radiation protection to ensure that particular aspects of radiation safety applicable to that installation have been considered. (For facilities under federal jurisdiction, the responsible agency is the Radiation Protection Bureau of Health and Welfare Canada.)

### 4.2 General Recommendations

Protection of operating personnel and others working in the vicinity of X-ray diffraction equipment can be achieved by adherence to the following basic recommendations:

1. X-ray diffraction equipment must be installed within a research or industrial facility in such a way as to minimize the number of individuals working in close proximity to the equipment.

2. Wherever practicable, X-ray diffraction equipment should be located in a room that is separate from other work areas and that is dedicated solely to X-ray diffraction work.

3. The room in which X-ray diffraction equipment is used must be lockable.

4. The X-radiation warning sign described in Appendix II of this Code must be affixed to each entrance door to the X-ray diffraction room.

5. A readily discernible and clearly legible warning sign prohibiting unauthorized entry must be placed at each entrance door to the X-ray room.

6. Adequate working space must be provided around the X-ray diffraction equipment to allow for ease of setting up and to permit placing of movable shielding barriers, as required.

7. X-ray diffraction equipment should be positioned in such a way that the direction(s) of the primary beam(s) is(are) toward outside walls or unoccupied areas.

## 4.3 Educational Institutions

1. X-ray diffraction equipment installed in educational institutions for purposes of training students should be located in a separate room that contains no other work stations.

2. The floor space about the X-ray diffraction equipment must be sufficient to enable the students to observe demonstrations from a safe distance.

3. A line indicating a safe viewing perimeter should be painted on the floor of the demonstration room.

**NOTE:** DOSE EQUIVALENT LIMITS FOR STUDENTS UP TO THE AGE OF 18 YEARS ARE GIVEN IN APPENDIX I.

## 5. EQUIPMENT SPECIFICATIONS

### 5.1 New X-Ray Equipment

All new X-ray diffraction equipment and analysis accessories for such equipment must conform to the requirements specified in the Radiation Emitting Devices Regulations for X-Ray Diffraction Equipment. These Regulations specify standards of design, construction and functioning, with respect to radiation safety of the equipment, and are mandatory requirements at the time of sale. It is the responsibility of the manufacturer or seller to ensure that the equipment conforms to the requirements of the regulations.

The Regulations governing X-ray diffraction equipment, in effect at the time of printing of this Safety Code, are reproduced in Appendix III. These Regulations may be amended from time to time to keep abreast with changing technology in the field. Information on the currency of the Regulations and details of any promulgated amendments can be obtained by contacting the Radiation Protection Bureau, Health and Welfare Canada, Ottawa, Ontario, K1A 1C1.

### 5.2 Existing X-Ray Equipment

Inspections of older X-ray diffraction equipment have shown that operators and others can be exposed to hazardous levels of radiation originating from the following sources:

1. the primary X-ray beam;

2. leakage or scatter of the primary X-ray beam through cracks between or in ill-fitting or defective parts;

3. penetration of the primary X-ray beam through the X-ray tube housing, shutters and analysis accessories;

4. secondary emission from the sample or other material exposed to the primary X-ray beam;

5. diffracted X-rays; and

6. radiation generated by rectifiers in the high voltage power supply.

Unnecessary exposure to this radiation can be eliminated or significantly reduced by retrofitting safety features to existing equipment. Thus, whenever possible, and to the extent that it is practical, existing X-ray diffraction equipment should be upgraded to incorporate as many as possible of the safety features required of equipment at the time of sale.

To ensure maximum protection to operators and other workers, all existing X-ray diffraction equipment must meet certain basic requirements. These are as follows:

1. Warning Signs - The external surface of the control panel must bear a permanent and conspicuous sign prohibiting unauthorized use and warning that hazardous X-radiation is emitted when the equipment is in operation.

2. Markings - All controls, meters, lights and other indicators relevant to the operation of the equipment must be readily discernible and clearly labelled or marked as to function.

3. Warning Indicators

(i) There must be readily discernible, separate indicators on the control panel that respectively indicate:

(a) when the control panel is energized and the machine is ready to produce X-rays; and

(b) when X-rays are being produced.

(ii) When more than one X-ray tube is controlled by one control panel, there must be clear and visible indication on or near the tube housing and on the control panel of which tube is connected and ready to be energized. The visible indicators used for these purposes should be lights.

(iii) There must be warning indicators that clearly indicate the open/shut status of each beam port shutter on the X-ray tube housing. Interlock(s) must be included to ensure that X-rays cannot be produced when the port is open and the warning indicator fails simultaneously.

The warning indicators referred to in this section must be readily discernible from a distance of at least two metres.

4. Exposure Control - There must be separate power ON/OFF and X-rays ON/OFF switches on the control panel.

5. Keylock Switch - There must be a keylock switch to secure the X-ray diffraction machine against unauthorized use. The Keylock switch must be of the type which requires the insertion of a key

before X-rays can be generated and where removal of the key causes termination of the production of X-rays.

6. Shutters must be retained in situ to open and close all beam ports in the X-ray tube housing.

7. Each beam port shutter must provide the same degree of protection as required by clause 11 of the Radiation Emitting Devices Regulations for X-ray diffraction equipment. (See Appendix III of this Code).

8. The beam port shutters must be connected to the X-ray tube housing in such a way that they normally remain in the fully closed position and positive action is required by the operator to open them.

9. The X-ray tube housing, collimators, and analysis accessories (cameras, goniometers, etc) must be shielded with sufficient material to provide the same degree of protection as required by clauses 11 and 12 of the Radiation Emitting Devices Regulations for X-ray diffraction equipment. (See Appendix III of this Code.)

10. There must be portable or fixed shields to enclose or intercept the X-ray beams as fully as possible without preventing the equipment from functioning.

11. A primary X-ray beam that is transmitted beyond the X-ray detector must be attenuated by a beam stop, beam trap or other permanent shield that is positioned as close as possible to the X-ray tube housing.

12. The shields, beam stop and beam trap referred to in statements 10 and 11 above must provide the same level of protection as required by clauses 11 and 12 of the Radiation Emitting Devices Regulations for X-ray diffraction equipment. (See Appendix III of this Code.)

## 6. RADIATION PROTECTION SURVEYS

A radiation protection survey of a facility is intended to demonstrate not only that the X-ray equipment itself functions properly according to applicable standards but also that the equipment is installed in a safe environment and is used in a way which provides maximum radiation safety for operators and others. It is important, therefore, that X-ray facilities be surveyed at regular intervals.

### 6.1 Performance of Surveys

The responsible user is required to arrange for radiation protection surveys. Surveys must be requested:

1. at the time of installation of X-ray diffraction equipment;

2. after any modification of the equipment which could result in elevated levels of stray radiation emission; and

3. immediately, upon any indication of elevated levels of X-ray emission having occurred during the normal operation of the equipment.

In addition, surveys must be requested on a periodic basis. The frequency of the surveys is a function of the type and extent of use of the equipment and should be determined by the responsible health authority.

It may be permissible in special cases, after consultation with the corresponding radiation protection authority, to operate the equipment for a limited period of time prior to the survey.

Radiation protection surveys of the installation must be performed by an authorized expert (e.g. an inspector of the Radiation Protection Bureau, or the equivalent personnel in a provincial agency for facilities that are under provincial jurisdiction).

## 6.2 Survey Report

The survey report must present, in a clear systematic way, details and results of the measurements carried out, as well as the conditions drawn to the attention of the user and recommendations made by the surveyor. In the report for an existing installation attention must be drawn to any unusual findings with respect to the equipment itself, the installation or operating procedures, which could affect the safety of operators or other persons in the vicinity of the X-ray facility.

The survey report must include at least the following:

1. the identification of the facility and equipment;

2. assessment of the safety features incorporated into the X-ray diffraction equipment, including

    (i) the adequacy of shielding,

    (ii) the proper functioning of shutters, safety interlocks, keylock switch, warning lights and other indicators, and

    (iii) a description of the radiation warning signs and their locations on the equipment;

3. an assessment of the proper functioning of the X-ray controls;

4. an assessment of compliance with Building and Installation requirements;

5. an assessment of the working procedures and conditions;

6. an assessment of the personnel monitoring.

## 7. PERSONNEL AND EQUIPMENT MONITORING

Users of X-ray diffraction equipment must be provided with whole body, and either finger or wrist radiation monitoring devices. The supplier of the monitoring device must be notified of the energy of the monitored radiation.

A monitoring device must be so located that the body part nearest the primary beam is monitored. For example, if the operator sets up an experiment working primarily with his right hand, a wrist or finger monitor must be worn on that hand. Monitoring devices worn on the chest or abdomen may provide an indication of the exposure of the whole body to stray (i.e. leakage and scattered) radiation.

Personnel monitoring data must be maintained as a permanent record and should be available for examination by the users and appropriate health officers.

It is recommended that each installation be equipped with a radiation survey meter to monitor routinely the area around equipment.

## 8. RECOMMENDED WORKING PROCEDURES

A well designed installation and the use of equipment that incorporates good safety features are not by themselves sufficient to ensure safety of personnel. Adherence to comprehensive working procedures that identify and minimize hazards associated with the particular use and maintenance of the X-ray diffraction equipment is an essential requirement for personnel safety.

The following recommendations are basic requirements of good working procedures.

1. Personnel must not expose any part of their bodies to the useful radiation beams.

2. (i) For short analysis times (a few hours or less) the operator should be in immediate attendance when the equipment is in operation. Deviations from this practice must be cleared with the responsible user.

(ii) For longer analysis times (several hours to several days), if the operator cannot be in immediate attendance when the equipment is in operation, the equipment must be secured so that it is accessible only to authorized personnel who are aware that the equipment is turned on.

(iii) When not in operation, the equipment must be secure so that it is accessible to, or operable by, authorized personnel only.

3. Only trained personnel, approved by the responsible user, must be permitted to install, repair, or make other than routine modifications to the X-ray generating apparatus and accessories.

4. If, for any reason, it is temporarily necessary to alter safety devices, such as to bypass interlocks or remove shielding, such action must be:

(i) specified in writing, and approved by the responsible user; a notice must be posted near the X-ray tube housing so that other persons will know the existing status of the equipment;

(ii) terminated as soon as possible.

5. Wherever practical, alignment of the analysis apparatus should be done by means that do not require working with the open primary beam.

When alignment involves working near the open primary X-ray beam, the X-ray tube current should be reduced in order to lower exposure rates. If a fluorescent alignment tool is used, dimming the room light will permit a significant reduction in tube current. The fluorescent alignment tool must be long enough to permit the operator's hand to be kept a safe distance from the beam. The operator must be familiar with the manufacturer's recommended alignment procedures, and copies of these must be available for reference.

6. All safety devices (interlocks, shutters, warning lights, etc.) must be tested periodically to ensure their proper operation. These tests should be conducted once per week and must be conducted at least once per month. Records of such tests must be maintained.

7. Written emergency procedures pertaining to radiation safety must be established for each facility by the responsible user and must be posted in a conspicuous location near each X-ray diffraction unit. These must list telephone numbers of a physician and the responsible user, and as a minimum, must include instructions for the following actions to be taken in case of a known or suspected accident involving radiation exposure:

   (i) notifying the responsible user; and

   (ii) arranging for a medical examination, being sure to notify the examining physician that exposure to low energy X-rays may have occurred.

# MAXIMUM PERMISSIBLE DOSE EQUIVALENT OF IONIZING RADIATION

For the purpose of radiation protection, individuals are divided into two main categories, namely those exposed to radiation in the course of their work (radiation workers) and others. Maximum permissible levels are given for both categories in the following table. These dose equivalent limits are based on the modified recommendations of the International Commission on Radiation Protection (ICRP) as specified in ICRP Publication 26.

It must be noted that the maximum permissible dose equivalents for radiation workers apply only to exposures resulting directly from their occupation and do not include radiation exposure from any other source, such as medical diagnosis or natural background radiation.

It should also be noted that the ICRP now belives it is sufficient to set annual dose equivalent limits and does not recommend any further restrictions either on the instantaneous rate or on the rate at which the dose equivalent may be accumulated, except in the case of pregnant women. The former age-related formula limiting the dose equivalent at age N years to 50(N-18)mSv is no longer advocated.

Annual Maximum Permissible Dose Equivalent
(Whole Body)

| | |
|---|---|
| Radiation Workers | 50 mSv |
| Other Workers or Members of the Public | 5 mSv |

1 sievert (Sv) is equivalent to 100 rem

**NOTES:**

1. It is emphasized that any exposure may involve some degree of risk and although the levels recommended in this appendix are maximum permitted values, all doses should be kept as low as reasonably achievable and any unnecessary exposures should be avoided.

2. ICRP no longer recommends discrimination in the dose limits between men and women of reproductive capacity if the dose is received at an aproximately regular rate.

3. When pregnancy has been diagnosed the employer must ensure for the remainder of the pregnancy the woman's working conditions are such that the total integrated dose equivalent to the abdomen during the entire pregnancy does not exceed 10mSv, or 15mSv during the year of the pregnancy.

4. For trainee technicians, the dose equivalent limits should be the same as those of the general public.

5. For students up to the age of 18 years who are not radiation worker trainees, the annual whole body dose equivalent limit recommended by the ICRP is 0.5 mSv. It is also recommended that no pupil receive more than one tenth of this annual dose equivalent limit in the course of any one demonstration or experiment.

6. The ICRP no longer recommends different limits for individual organs. The ICRP believes that non-stochastic effects will be prevented by applying a dose-equivalent limit of 0.5Sv in a year to all tissues except the lens of the eye, for which it recommends a limit of 0.15Sv in a year.

## RADIATION WARNING SIGN SPECIFICATIONS

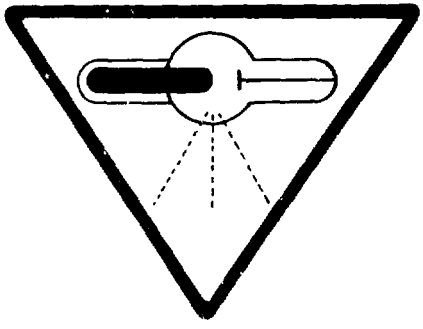
The X-radiation warning sign referred to in Section 4.2 of this Code is a sign that:

(a) is shown in two contrasting colours;

(b) is clearly visible and identifiable from a distance of 1 metre;

(c) bears the words "CAUTION, X-RAYS" and "ATTENTION, RAYONS X," and

(d) is designed in accordance with the following diagram:



# RADIATION EMITTING DEVICES REGULATIONS FOR X-RAY DIFFRACTION EQUIPMENT

The *Radiation Emitting Devices Regulations* establishing standards of design, construction and functioning for X-ray diffraction equipment were passed by Governor-in-Council on July 2, 1981, and were published in the Canada Gazette, Part II, of July 22, 1981. These Regulations define X-ray diffraction equipment as:

> being any X-ray machine that utilizes the scattering of X-rays by atoms of a specimen for the purpose of the examination of the microstructure of the specimen, including the X-ray generator, X-ray tube, tube housing, cabinet and analysis accessories."

The specific requirements of the Regulations are reproduced below.

## PART XIV

## X-RAY DIFFRACTION EQUIPMENT

**Interpretation**

1. In this Part,

"analysis accessory" means any diffraction camera, goniometer, X-ray detector or any other component that is used in association with X-ray diffraction equipment, and that can affect the radiation safety of the equipment; (accessoire d'analyse);

"beam port" means an opening in the tube housing expressly designed to permit an X-ray beam to exit from the tube housing; (fenêtre);

"beam trap" means a shielded device for intercepting and absorbing an X-ray beam; (piège à faisceau);

"collimator" means a device that limits the dimensions of the useful beam to a required cross-sectional area; (collimateur);

"leakage radiation" means X-radiation, other than the useful beam, emerging from the tube housing, collimators or analysis accessories; (rayonnement de fuite);

"primary beam" means the unscattered or undeflected X-ray beam emerging from a beam port; (faisceau primaire);

"tube housing" means the enclosure surrounding the X-ray tube that is constructed to shield the user from X-radiation and incorporates beam ports to permit the emergence of useful beams in desired directions; (logement du tube);

"shutter" means a shielded cover or barrier that, in the closed position, completely intercepts the primary beam and prevents its emergence from the tube housing; (obturateur);

"useful beam" means an X-ray beam that is necessary for the diffraction machine or analysis accessory to provide analytical information and includes the primary beam and X-ray beams scattered or deflected by the specimen before interception by the detector. (faisceau utile)

## STANDARDS OF DESIGN AND CONSTRUCTION

2. X-ray diffraction equipment shall be designed and constructed in such a manner that when installed maintained in accordance with the instructions referred to in section 3, it functions in accordance with section 11 for as long as it has its original components or any replacement components recommended by the manufacturer.

3. X-ray diffraction equipment shall be equipped with installation and maintenance instructions supplied by the manufacturer of the device that, if followed, will enable the device to comply with the requirements of these Regulations.

4. X-ray diffraction equipment shall bear on the external surface of the X-ray control panel

(a) a warning sign located next to any switch that turns on an X-ray tube, bearing the words "CAUTION-X-RAYS -- ATTENTION-RAYONS X. This Equipment Produces High Intensity X-Ray Beams When Energized - To be Operated Only by Qualified Personnel -- Cet appareil produit des faisceaux de rayons X à haute intensité lorsqu'il est activé - son utilisation est réservée au personnel compétent.";

(b) the X-radiation warning sign described in section 13; and

(c) a readily discernible and clearly visible permanent mark or label that sets out, with respect to the combination of the X-ray generator and tube housing,

(i) the name of the manufacturer,

(ii) the model designation,

(iii) the serial number,

(iv) the date of manufacture, and

(v) the city and county of manufacture.

5. X-ray diffraction equipment shall be designed and constructed in such a manner that

(a) all marks, labels and signs required by these Regulations are securely affixed to the device and clearly visible; and

(b) all controls, meters, lights or other indicators required by these Regulations are

(i) readily discernible, and

(ii) clearly labelled or marked as to function.

6. X-ray diffraction equipment shall be designed and constructed of such materials and in such a manner that,

(a) under normal conditions of use, the tube housing, shutters, collimators, couplings, shields and barriers required by or referred to in these Regulations will not deform or deteriorate in their shielding properties in such a way as to permit leakage radiation in excess of the maximum exposure rate specified in section 11;

(b) with the device fully assembled for use and analysis accessories in place,

(i) the tube housing, collimator and analysis accessories are fully contained within an enclosure that

a. contains sufficient shielding to enable the device to comply with the standard of functioning specified in section 11, and

b. is interlocked in such a way that opening or removal of the enclosure prevents X-rays from being produced by the X-ray tube or causes distinct audible warning; or

(ii) the useful beam, passing between the beam ports, collimators and analysis accessories, is completely enclosed and shielded so that the device functions in accordance with section 11; and

(c) where the setting up or alignment procedures for the device require direct access to the useful beam, a mechanism to override the interlocks described in paragraph (b) is provided, that

(i) is clearly marked as to function, and

(ii) provides a conspicuously displayed indication of the operating condition of the interlocks.

7. X-ray diffraction equipment shall be designed and constructed to include

(a) a control panel having the following safety features, namely,

(i) a power "ON/OFF" switch,

(ii) a lock of a kind that requires the insertion of a key before X-rays can be produced and where removal of the key causes termination of the production of X-rays,

(iii) an X-ray tube "ON/OFF" switch,

(iv) electrical meters or other indicators that show the operating tube potential in kilovolts and the tube current in milliamperes,

(v) a warning light, in close proximity to the power "ON/OFF" switch, that indicates when the control panel is energized and the device is ready to produce X-rays,

(vi) a warning light, in close proximity to the X-ray tube "ON/OFF" switch, that indicates when X-rays are being produced in the X-ray tube,

(vii) a warning light that indicates when any of the beam port shutters are open and any X-ray beam is emerging from the tube housing,

(viii) where more than one X-ray tube is controlled from the control panel,

a. a separate X-ray tube "ON/OFF" switch for each such tube, and

b. a warning light or other visual indicator to indicate which tube is energized and is producing X-rays, and

(ix) a timer that

a. automatically terminates the production of X-rays or, after a preset time interval, automatically prevents X-rays from emerging from the tube housing.

b. prevents the initiation of an X-ray exposure if the timer is set on the zero or off position, and

c. has a clearly marked indefinite time setting where an intended use of the device requires continuous operation of a duration greater than 24 hours;

(b) for equipment designed and constructed in accordance with subparagraph 6(b) (ii), a warning light on the tube housing that indicates when the X-ray tube is energized and producing X-rays and that is clearly visible at a distance of 2 metres from all accessible sides of the device;

(c) for equipment designed and constructed in accordance with subparagraph 6(b) (ii), a separate warning light for each beam port on the tube housing that

(i) indicates when the shutter on the beam port is open,

(ii) is clearly visible at a distance of 2 metres from the port, and

(iii) is so connected that failure of the light either causes the shutter to close or terminates production of X-rays by the X-ray tube;

(d) a shutter, covering each beam port, that is constructed and connected in such a way that

(i) the shutter normally remains fully closed,

(ii) a positive action by the operator is required to open the shutter,

(iii) an interlock is incorporated in the shutter mechanism that, unless there is an alignment device or analysis accessory connected to the beam port prevents X-ray production when the shutter is open,

(iv) it is not possible to remove the shutter or its operating mechanism without the use of tools,

(v) the shutter and its operating mechanism are interlocked so that removal of the shutter inactivates the X-ray tube, and

(vi) the shutter contains sufficient shielding to enable it to comply with the standard of functioning specified in section 11;

(e) labyrinth-type joints, couplings or interfaces between beam ports, collimators and analysis accessories that ensure that radiation leakage rates in excess of the maximum specified in section 11 cannot occur as a result of incomplete connections;

(f) where the machine is designed to be used with interchangeable filters,

(i) interlocks or other means to ensure that the filters can only be inserted into or removed from the filter holder when the X-ray beam is off, and

(ii) sufficient shielding of the filter slots or access openings to ensure compliance with the X-ray leakage requirements of section 11; and

(g) provisions for the connection of one or more remote warning lights that automatically indicate when the X-ray tube is activated and X-rays are being produced.

8. Every analysis accessory shall be equipped with information, supplied by the manufacturer, that

(a) sets out in respect of that accessory either

(i) the X-ray diffraction equipment for which the accessory is specifically designed, or

(ii) the X-ray diffraction equipment with which the accessory is not designed to be used; and

(b) indicates the design and dimensions of the coupling surfaces of the accessory.

9. Every analysis accessory shall bear on its external surface a permanent mark or label that sets out in respect of that accessory

(a) the name of the manufacturer;

(b) the model designation;

(c) the serial number;

(d) the date of manufacture; and

(e) the city and country of manufacture.

10. Every analysis accessory shall be designed and constructed in such a manner that

(a) all joints, couplings or interfaces by which the accessory connects to a beam port or collimator are of the labyrinth-type and are compatible with those used on the X-ray diffraction equipment for which the accessory is designed;

(b) subject to paragraph (c), it is fully enclosed and shielded so that

(i) during normal operation access by any part of the body of the operator of the X-ray diffraction equipment to the useful beams traversing the accessory is precluded,

(ii) the shielding is sufficient to enable the accessory to comply with the requirements of section 12, and

(iii) the shielding is connected or interlocked so that

a. it cannot be removed, or

b. removal of any part of the shielding results either in termination of X-ray production by the X-ray tube or closure of the shutter of the beam port to which the accessory is connected; and

(c) where the intended purpose of the accessory or alignment of the useful beam traversing the accessory requires that the useful beam be transmitted through an opening in the enclosure,

(i) there is, on the external surface of the accessory in close proximity to the opening, a permanent mark or label bearing a warning statement to the effect that an intense X-ray beam is present at the opening, and

(ii) appropriate shielding barriers or beam traps are provided so that

a. when positioned on the X-ray diffraction machine they fully intercept the transmitted X-ray beam, and

b. they contain sufficient shielding to comply with the requirements of section 12.

## STANDARDS OF FUNCTIONING

11. X-ray diffraction equipment when fully assembled for use shall function in such a way that, for any setting of the X-ray tube operating potential in kilovolts and current in milliamperes within the range of settings specified by the manufacturer,

(a) the transmission of the useful beam through any closed beam port shutter results in a radiation exposure rate that does not exceed 2.5 millircentgen per hour at a distance of 5 centimetres from any accessible external surface of the shutter, when averaged over a detection area of 1 square centimetre and of circular cross-section;

(b) the exposure rate from leakage radiation from

(i) the tube housing,

(ii) any joint, coupling or interface between beam ports, collimators and analysis accessories,

(iii) filter slots or access openings, or

(iv) the X-ray beam enclosure systems referred to in paragraph 6(b),

does not exceed 2.5 milliroentgen per hour at a distance of 5 centimetres from any accessible external surface of any of the devices mentioned in subparagraphs (i) to (iv), when averaged over a detection area of 1 square centimetre and of circulator cross-section; and

(c) the emission of ionizing radiation by the high voltage power supply for the X-ray tube does not exceed a rate of 0.5 milliroentgen per hour at a distance of 5 centimetres from any point of the housing of the power supply, when averaged over a detection area of 10 square centimetres and of circular cross-section.

12. Every analysis accessory when fully assembled for use and connected to X-ray diffraction equipment for which it is designed shall function in such a way that, under the conditions of operation referred to in section 11,

(a) the transmission of the useful beam through the shielding barriers or beam traps referred to in paragraph 10(c) results in a radiation exposure rate that does not exceed 2.5 milliroentgen per hour at a distance of 5 centimetres from any accessible external surface of the barrier or trap, when averaged over a detection area of 1 square centimetre and of circular cross-section; and

(b) the exposure rate from leakage radiation does not exceed 2.5 milliroentgen per hour at a distance of 5 centimetres from any accessible external surface of the accessory, when averaged over a detection area of 1 square centimetre and of circular cross-section.

## WARNING SIGN SPECIFICATIONS

13. The X-radiation warning sign referred to in Section 4.2 (1)(ii) of this Code is a sign that

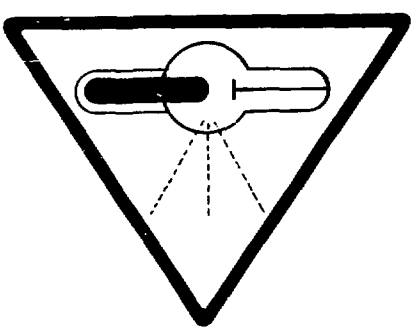
(a) is shown in two contrasting colours;

(b) is clearly visible and identifiable from a distance of 1 metre;

(c) has no outer dimensions of less than 2 centimetres;

(d) bears the words "CAUTION, X-RAYS" and "ATTENTION", RAYONS X", and

(e) is designed in accordance with the following diagram:



## BIBLIOGRAPHY

Further details on the topics covered in this Safety Code may be obtained from the references listed below.


1. "Recommendations of the International Commission on Radiological Protection," ICRP Publication 26, Annals of the ICRP, Volume 1, No. 3, (1977).

2. "Radiation Protection In Educational Institutions," NCRP Report No. 32, (1966).

3. "Radiation Hazard Control In Industry," RPB-TM-3, National Health and Welfare, (1973).