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ADDENDUM TO SAFETY CODE 32: Portable, hand-held, x-ray tube based open-beam XRF devices

Healthy Environments and Consumer Safety Branch

Canada

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Appareils FRX portatifs manuels comprenant un tube à rayons X à faisceau ouvert

EXPLANATORY NOTES

This Addendum is intended to include a specific type of analytical x-ray device that has been widely used in industry for non-destructive testing (NDT) in the past several years within the scope of Safety Code 32.

This Addendum consists of several sections, including Appendices and references. It provides regulatory and user requirements, guidance, and information specific to portable, hand-held, x-ray tube based open-beam x-ray fluorescence (XRF) devices as related to NDT applications. The following appendices are also provided:

(i) Appendix I-the permissible radiation dose limits recommended by the International Commission on Radiological Protection (ICRP), revised as of 2011;

(ii) Appendix II-an overview of the radiation risks associated with such XRF devices; and

(iii) Appendix III-a glossary.

Because much of the material in Safety Code 32 is still applicable, this Addendum does not revise Safety Code 32 with the exception of APPENDIX I: ICRP Recommended Dose Limits for Ionizing Radiation. Supplemental information is identified where it is considered appropriate and beneficial for the implementation of Safety Code 32.

The words *must* and *should* in this Addendum and in Safety Code 32 have been chosen with purpose. The word *must* indicates a requirement that is essential to meet the currently accepted standards of protection, while *should* indicates an advisory recommendation that is desirable, and which is to be implemented where feasible.

Safety Code 32 is primarily intended to instruct and guide persons employed in Federal Government departments and agencies, as well as those that fall under the jurisdiction of the Canada Labour Code. Facilities under provincial or territorial jurisdiction may be subject to different requirements; hence, the radiation protection authorities [1] in those jurisdictions should be contacted for details of regulatory requirements in their respective regimes.

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1.0 Scope

This Addendum falls within the scope of Safety Code 32, which is intended to ensure that the radiation risks associated with analytical x-ray equipment remain low.

2.0 Purpose

This Addendum identifies and provides specific regulatory and user requirements, responsibilities, guidance, and information in respect of portable, hand-held, x-ray tube based open-beam x-ray fluorescence (XRF) devices, a special type of analytical x-ray equipment.

3.0 Use

This Addendum is specifically applicable to the portable, hand-held, x-ray tube based open-beam XRF devices as defined in Section 4.0 that are used for elemental or chemical analyses of materials, components, or systems in industrial non-destructive testing (NDT) applications. This Addendum must be used in conjunction with Safety Code 32.

4.0 Overview of Specific X-ray Tube Based XRF Device

Technological innovations that barely existed about a decade ago resulted in the development of specific x-ray tube based XRF devices used for *in situ* elemental or chemical analyses of materials, components, or systems by industry. The defining characteristics of such devices typically include:

i) an x-ray tube as the source of ionizing radiation, capable of operating up to ~50 kV and a few hundred microampere (μA);

ii) an open port from which a collimated primary beam of high intensity emerges (beam port);

iii) inherent filter(s) for modifying the intensity or quality of primary or characteristic radiation;

iv) an internally positioned sensitive radiation detector that picks up, through the open port, fluorescent x-rays created by the irradiated materials;

v) appropriate internal electronics coupled with software that process the detected signals to yield real-time analytical data within short irradiation times (on the order of a few tens of seconds); and

vi) portability and of low enough weight to be hand-held for use utilizing an x-ray on/off switch, which incorporates a failsafe feature in that positive pressure is applied via the operator's finger to generate and sustain x-ray generation for the duration of the test and removal of that pressure promptly stops x-ray generation.

Such devices are defined as portable, hand-held, x-ray tube based open-beam XRF devices and are limited to maximum designed operational ratings of 50 kV and 4 W.

Analyses are performed when the devices, hand-held by the operator, are taken to the location of the test material and activated to provide a high intensity primary beam that bombards the test material at very close range. In the past several years, these devices have been particularly useful to industry while gaining acceptance in a wide array of industrial applications, such as alloy analysis, mining and exploration, lead (Pb) testing in toys, sorting and recycling of scrap metal, and identification of materials. These applications constitute an analytical technique or test method that is not only repetitive or automated, but also falls within the scope of limited industrial NDT [2]; they are referred to in this Addendum as XRF NDT.

XRF devices possessing the above characteristics that are not limited to the maximum operational ratings specified in this section are outside the scope of both the preceding definition and this Addendum, and must not be used in an open-beam or hand-held mode.

5.0 Management of Radiation Protection and Safety: Federal Stakeholders

Clarification of federal stakeholders is necessary. Subsections 5.1 through 5.3 of this Addendum provide supplemental information to Safety Code 32.

5.1 Health Canada

Health Canada is a federal department that is the regulatory authority for radiation emitting devices and is responsible for administering the *Radiation Emitting Devices (RED) Act* [3] and the *Radiation Emitting Devices Regulations*. The *RED Act* governs the sale, lease, or importation of all radiation emitting devices in Canada.

Re-sale, refurbished, or donated analytical x-ray equipment must also comply with the *RED Act* at time of sale or donation. The seller or donor of such radiation-generating equipment must ensure regulatory compliance and bear the associated costs. The seller or donor should also notify the buyer or donor recipient of the safety obligation to contact the appropriate radiation protection authority [1] that has jurisdiction of the facility in which the x-ray equipment will be in use, regarding rules of operation.

5.2 Employment and Social Development Canada

The Employment and Social Development Canada (ESDC) Labour Program is the regulatory authority responsible for administering and directing compliance with the *Canada Labour Code* and associated Regulations [4] in the Public Service of Canada and in the rest of its jurisdiction (i.e., as regulator of both occupational health and occupational safety). As regulator, it can verify compliance with the Safety Codes, make or authorize measurements that would facilitate evaluation for compliance with the requirements of the Safety Codes, or require an operating organization or facility to modify or correct any procedure, practice, system, or component to ensure safety. It can issue directives prohibiting use of radiation generating equipment, depending on the hazards and risks presented by deviations of procedures or by safety violations.

5.3 Natural Resources Canada

Natural Resources Canada (NRCan) is a federal department that implements and manages, through its National Certification Body (NCB), a national certification program in accordance with international rules [5]. For over 50 years, the NCB has been issuing and maintaining NDT certifications for qualified individuals across the country in diverse industries. The NCB has adopted an International Standard [2] with modification to form the basis for the XRF NDT operator certification program.

6.0 Regulatory and Safety Requirements for the XRF Device

XRF devices determine elemental composition or examine the microstructure of materials, are classed as analytical x-ray equipment, and are regulated under the *RED Act* as well as Schedule II, Part XIV Analytical X-ray Equipment of the *Radiation Emitting Devices Regulations* [3]. Since portable, hand-held, x-ray tube based open-beam XRF devices as defined in Section 4.0 of this Addendum, are analytical x-ray equipment, manufacturers, distributors, and importers are responsible for ensuring that portable, hand-held, x-ray tube based open-beam XRF devices comply with the *RED Act* and Schedule II, Part XIV Analytical X-ray Equipment of the regulations before they are sold, leased, or imported in Canada.

In this section, paragraphs or subsections of the applicable *RED Regulations* are indicated along with an interpretation of the requirements. They are followed by best practices (identified by the symbol: ●) that are highly recommended for adding safety precaution to the use of portable, hand-held, x-ray tube based open-beam XRF devices:

1. Paragraph 3(a) requires that the x-ray device be accompanied by instructions from the manufacturer as to the installation, interconnection, testing, operation, and maintenance of the device. These instructions must be embodied in the product specific manual.

   - Moreover, to avoid creating any misleading information or an erroneous or false impression regarding the safety and intended use of such devices, the product manual should also include the following information:

     i) a description of the design of the device, including all of its safety and functional components with labelled pictorial representations of them;

     ii) radiation protection and safety principles associated with the specific device;

     iii) ICRP Publication 103 [6] recommended dose limits;

     iv) where the device design facilitates operation at various filter/beam settings, the measured primary beam dose rate at the window surface of the beam port using appropriate dosimeters and measurement techniques, and the corresponding shallow equivalent dose for each filter/beam setting, the corresponding x-ray tube voltage and current;

     v) measured scattered radiation levels or plots of radiation profiles at several distances (e.g., 0.5, 5.0, 10.0, 25.0 cm) from the external surfaces of the device;

     vi) proper and improper safety techniques when using the device; and

vii) information that reflects XRF-certified operator certification administered by NRCan [7].

2. Paragraph 5(d) requires the radiation beam to be contained within protective shielding that is equipped with an interlock. These components prohibit any part of the human body from being in the primary beam.
   - In view of the hand-held nature and open-beam design of such XRF devices, one or more of the following is expected to be incorporated at the nose of the device:
     - proximity sensors designed to function as an interlock with the x-ray on switch to ensure that the inanimate material being tested is in direct contact with the nose of the device in order to produce and sustain x-ray generation for the pre-determined time duration specific to the test: or
     - a detection sensor preset by the manufacturer without an inanimate sample at the beam port that prevents x-ray generation below the pre-set threshold.
3. Paragraph 6(a)(ii) requires a key-actuated control that prevents x-ray production when the key is removed. This requirement is a hardware control.
   - It is acknowledged that a software control could provide an equivalent function.
4. Paragraph 6(a)(iii) requires an ON/OFF x-radiation switch for each x-ray tube, equipped with a warning light that indicates when x-radiation is being produced. Part of the function of the ON/OFF switch is that it must be activated manually by the operator.
   - It is acknowledged that an operator-activated x-ray ON/OFF switch can incorporate a failsafe feature that requires positive manual pressure by the operator to generate and sustain x-ray generation for the duration of the preset timed test and stops x-ray generation when that pressure is removed.
   - A separate automatic time-out control should be considered to function so that it prevents x-ray generation after the device is energized and following a period of inactivity, and requires specific user action(s) for re-establishing conditions conducive to x-ray generation.
5. Subsection 10 concerns radiation exposure from the device. The radiation exposure of 0.5 milliroentgen (≈ 4.39 microgray) is interpreted to mean stray radiation rate measurement per hour at 5.0 cm from all accessible external surfaces of the device.
   - The stray radiation dose rate applies when the device is operated at all possible design operational ratings. From the perspective of the ALARA principle and expectation, the measurements should be taken at 0.5 cm from the external surfaces of the device. A low atomic number test material may be used as a scatter medium at the beam port, and appropriate solid state dosimetry may be used to determine such radiation rates.

7.0 XRF NDT Work Practices

Portable hand-held x-ray tube based XRF devices present an "open beam" which means that no part of the human body is prohibited from being in the way of the primary radiation, and the use of engineered safety controls is somewhat limited.

Nevertheless, such devices appear convenient for carrying out *in situ* elemental or chemical analyses of materials, components, or systems by industry. By procedure, the XRF work analyses are performed when the devices, hand-held by the operator, are taken to the location of the test material and activated to provide a high intensity primary beam that bombards the test material at very close range. The latter condition is similar to industrial radiography carried out at a "temporary job site" (where it is not feasible to bring the test material into a radiation shielded facility and the radiation source, being portable, is moved to the test material) for which mitigation of the hazards is necessary. XRF NDT work must not only address radiation safety based on NDT industrial radiography, but administrative measures must be strictly adhered to in order to reduce the likelihood of radiation accidents and unintentional exposures.

Sometimes XRF NDT work can be conducted in a closed beam system (subsection 8.3 in this Addendum).

8.0 XRF NDT User Requirements and Safety Principles

8.1 XRF-certified Operator

An XRF-certified operator is an individual who possesses a valid certification in the XRF NDT method as administered by NRCan [7]. The NRCan XRF certification program consists of radiation safety training and examination components that are based on NDT industrial radiography. There are two levels of NRCan XRF certification (Levels 1 and 2).

Obtaining NRCan XRF-certified operator certification in the XRF NDT method involves passing the mandatory radiation safety examination component, irrespective of whether radiation safety training or equivalent experience was obtained previously.

8.2 XRF NDT Work and Related Purposes Requiring Use of the XRF Device in the Hand-held or Open-Beam Mode

The operator of an XRF device in the hand-held or open-beam mode must be XRF certified as administered by NRCan [7]. To perform XRF NDT work, the NRCan XRF-certified operator must be rated at Level 1. The NRCan XRF-certified operator of an XRF device must be rated at Level 2 when

- (i) training an individual(s) seeking XRF-certified operator certification; or
- (ii) teaching students in an educational or vocational facility where the course curriculum requires hands-on use of the XRF device.

XRF-certified operators are responsible for following and carrying out defined operating and safety procedures that ensure their own protection and that of allied personnel. They should adhere to the safety instructions, procedures and precautions provided in the operating manual specific to the XRF device to be used.

At any job site or facility where the XRF device is hand-held or presents an open-beam for the intended application, an XRF-certified operator must:

1) Carry an appropriate proof of identification and XRF operator certification whenever XRF NDT work is being conducted.
2) Provide the owner of the XRF device appropriate evidence affirming identification and certification.
3) Perform, prior to use, safety and functional checks of the XRF device and survey meter (where the latter is necessary at the job site as per paragraph 8.1.6 below). If the XRF device and survey meter are defective, the operator is not to use them.
4) Keep unauthorized personnel away from the immediate vicinity of the XRF NDT work area while taking measurements (a minimum distance of one metre is recommended).
5) Wear extremity dosimeters appropriately on the hand(s) and finger(s) that are likely to incur the highest risk, where required by a regulatory authority or specified in operational procedures. The operator must ensure that the worker permissible limits regarding these tissues or organs as indicated in Appendix I, Table 2 in this Addendum are not exceeded (such dosimeters must be supplied by a dosimetry service provider [8] that is approved by the Canadian Nuclear Safety Commission in accordance with its regulations [9]).
6) Use an appropriately calibrated and functional survey meter, when necessary, to ascertain, establish, or confirm that radiation levels are within 20 per cent of those provided by the manufacturer of the XRF device, in situations where

    (a) the radiation shielding or performance of the XRF device is suspect for reasons related to design, damage, or malfunction; or

    (b) during XRF measurements, when radiation levels in the immediate work area are in question.

    The operator must ensure that relevant documentation of the preceding actions and following conditions is retained:

    (i) the survey meter photon detection threshold should be 5 keV;

    (ii) the survey meter must be calibrated by a national standards calibration ionizing radiation laboratory (e.g., National Research Council, Ottawa, Canada; NIST, USA) or a laboratory that has been accredited by a national standards calibration ionizing radiation laboratory to perform such calibrations;

    (iii) calibrations are to be done at several photon energies to cover the range of photon energies generated by the XRF device;

(iv) frequency of calibration is once a year or after the survey meter has been serviced or repaired;

(v) records of survey meter calibrations must be kept at the facility; and

(vi) additional information on survey meters is provided as in Appendix II of Safety Code 32).

7) Keep personal radiation exposure and exposure to allied personnel ALARA.

8) Notify the owner of the XRF device of any known or suspected abnormal radiation exposure to any person, provide the necessary details, and maintain a record of such notification.

9) Supervise, as delegated by the owner of the XRF device, any individual in training for XRF operator certification.

10) Supervise students in an educational or vocational institution who are required to use the device as part of a course curriculum after they have received safety training specific to the device intended for use, when necessary and as delegated by the owner of the XRF device.

11) Follow all protection and safety rules established by the owner of the XRF device for the XRF NDT work and for the device itself.

12) Secure the XRF device when it is in their custody, and not allow any unauthorized individual to use it.

13) Brief the client appropriately with respect of the safety issues relevant to such work and ensure that the work is carried out safely, where applicable and when XRF NDT work is to be carried out at a client's facility.

Students assigned XRF NDT work at a facility or job site (i.e., field work) must have NRCan XRF-certified operator certification, before using the XRF device for such work when

(i) the XRF device must be in the hand-held or open-beam mode for the application; and

(ii) direct supervision by an XRF-certified operator is neither practical nor warranted.

8.3 XRF NDT Work Using a Closed Beam System

There are situations in which a portable, hand-held, x-ray tube based open-beam XRF device as defined in Section 4.0 of this Addendum is manufactured, assembled or integrated by the manufacturer into a closed beam system to carry out XRF NDT work. A closed beam system consisting of such an XRF device as the ionizing radiation source must comply with the requirements specified in Schedule II, Part XIV Analytical X-ray Equipment of the *RED Regulations*.

Where such an XRF device is configured and operated in a closed beam system, the user would not require NRCan XRF-certified operator certification, since the XRF NDT work does not require the XRF device to be in the hand-held or open-beam mode for the application.

8.4 Safety Principles

8.4.1 Owner of an XRF Device

The owner of a portable, hand-held, x-ray tube based open-beam XRF device is directly and ultimately responsible for its management, control, and application. Any delegation to another individual does not relieve the XRF device owner of these responsibilities. In addition, the owner must follow the guidance provided in Section 3.4.1 of Safety Code 32 to implement safety precautions and measures to eliminate or mitigate the radiation risks associated with the portable, hand-held, x-ray tube based open-beam XRF device, where considered necessary or appropriate.

8.4.2 User of XRF Device

The user of a portable, hand-held, x-ray tube based open-beam XRF device, whether the XRF device is used in the hand-held mode, open-beam mode, or in a closed beam system, must also follow the guidance provided in Section 3.4.2 of Safety Code 32 to take safety precautions and measures to eliminate or mitigate the radiation risks to himself or herself and to allied personnel, where considered appropriate and necessary.

For the safety of operators and that of allied personnel, users of a portable, hand-held, x-ray tube based open-beam XRF device are advised

(i) to exercise prudence and ensure that the XRF device intended for use meets the regulatory requirements; and

(ii) to contact the radiation protection authority that has jurisdiction of the facility in which the XRF device will be in use in order to comply with the appropriate federal, provincial, or territorial rules of operation given that rules of operation may differ from one jurisdiction to the other [1].

8.4.3 Service Personnel for an XRF Device

Personnel responsible for servicing portable, hand-held, x-ray tube based open-beam XRF devices must follow the guidance in Section 3.4.3 of Safety Code 32 and take safety precautions and measures to eliminate or mitigate the radiation risks to himself or herself and to allied personnel, where considered appropriate and necessary.

9.0 Additional Guidance

Subsections 9.1 through 9.2 provide supplemental information to Safety Code 32.

9.1 Resale or Donated XRF Device

An XRF device intended for sale or donation must comply with the *RED Act* as well as Schedule II, Part XIV Analytical X-ray Equipment of the *RED Regulations* [3] at time of sale or donation. The seller or donor must

(i) ensure regulatory compliance of the product, retain the relevant documentation and test reports in support of regulatory compliance, and bear the associated costs; and

(ii) notify the purchaser or donor recipient that it is the purchaser's or donor recipient's responsibility to make certain that the following requirements are met:

   (a) The work must be performed only by an XRF-certified operator in the case where the XRF NDT work requires the XRF device to be used in the hand-held or open-beam mode; and

   (b) the appropriate radiation protection authority [1] must be contacted to determine the applicable operational requirements for the XRF device.

9.2 Disposal of an XRF Device

When disposing of an XRF device, the device owner must observe the instructions provided by the manufacturer in the product manual or contact the manufacturer for information and guidance. When a manufacturer is no longer in the business of manufacturing, selling, or servicing such devices, the following procedures must be followed:

i) the vacuum in the x-ray tube must be breached;

ii) the x-ray tube window should be investigated to determine whether it contains beryllium and, if it does, apply special disposal procedures since beryllium presents a toxic ingestion or inhalation hazard;

iii) the transformer oil, if this exists, must be disposed of in accordance with pertinent environmental legislation; and

iv) the lead (Pb) must be recycled accordingly.

APPENDIX I: ICRP Recommended Dose Limits for Ionizing Radiation

Recently, the International Commission on Radiological Protection (ICRP) revised the recommended dose limits for the eye and the fetus, including the radiation and tissue weighting factors. They are reflected in this Appendix I.

Supplemental Information: Appendix I of this Addendum applies to all analytical x-ray equipment and, therefore, replaces Appendix I in Safety Code 32.

The ICRP recommended dose limits for ionizing radiation in its 2007 Publication 103 [6] and subsequent bulletins are stated below. The dose limits do not include medical and natural background ionizing radiation exposures.

Table 1: Effective Dose Limits

Person	Period	Effective Dose (mSv)
Radiation worker[1]	(a) One year (b) five-year period	(a) **20 (average)** 50 (special circumstances) (b) **100**
Pregnant radiation worker[2]	Remainder of pregnancy	**1**
Member of Public[3]	One year	**1**

1 A radiation worker is defined by the ICRP as any person who is employed, whether full time, part time, or temporarily, by an employer and who has recognized rights and duties related to occupational radiological protection. A self-employed person is regarded as having the duties of both an employer and a radiation worker.

2 In the case of a female radiation worker who is pregnant, the fetus must be protected from radiation exposure for the remainder of the pregnancy once pregnancy has been diagnosed. **An effective dose limit of 4 mSv, which takes into account all sources of ionizing radiation consistent with CNSC regulatory requirements [9], is adopted for purposes of this Addendum and Safety Code 32.**

3 A member of the public is defined by the ICRP as any individual who receives an exposure that is neither occupational nor medical.

Table 2: Equivalent Dose Limits

Tissue or Organ	Person	Period	Equivalent dose (mSv)
Skin	(a) Radiation worker (b) Public	One year One year	**500** **50**
Lens of the eye[4]	(a) Radiation worker (b) Public	One year One year	**20** **15**
Hands and feet	(a) Radiation worker (b) Public	One year One year	**500** **50**

[4] ICRP Statement on Tissue Reactions, April 2011. For the lens of the eye, the depth of interest is 3 mm, at which the equivalent dose applies.

Table 3: ICRP Recommended Tissue Weighting Factors

Tissue	Weighting Factor, w_T	Sum of w_T values
Red bone marrow, colon, lung, stomach, breast, remainder tissues[5]	0.12	0.72
Gonads	0.08	0.08
Bladder , oesophagus, liver, thyroid	0.04	0.16
Bone surface, brain, salivary glands, skin	0.01	0.04
		Total = 1.00

[5] Remainder tissues include: Adrenals, extrathoracic (ET) region, and gall bladder, heart, kidneys, lymphatic nodes, muscle, oral mucosa, pancreas, prostate, small intestine, spleen, thymus, and uterus/cervix [6].

Table 4: ICRP Recommended Radiation Weighting Factors

Radiation type	Radiation weighting factor, w_R
Photons	1
Electrons and muons	1
Protons and charged pions	2
Alpha particles, fission fragments, heavy ions	20
Neutrons	A function of neutron energy[6]

[6] Refer to the source, ICRP 2007 Publication 103 [6] for relevant information.

APPENDIX II: Overview of Radiation Risks

Potential for adverse effects

Measured exposures at the window surface of beam ports of portable, hand-held, x-ray tube based open-beam XRF devices yield effective dose rates that can be significant. At a typical intensity of 5.0 mSv/minute, the ICRP recommended hand and skin dose limits (500 mSv in a year, Table 2, Appendix I of this Addendum) to a radiation worker can be exceeded in 100 minutes or on average two minutes per week (based on 50 work weeks a year). This translates to 24 seconds per day or to a few tests! It is apparent that the public dose limit would be exceeded in a matter of 10 minutes.

While the ICRP recommended limits are conservatively determined so as not to cause significant risks, small areas of the hands are likely to be exposed to the primary beam when such XRF devices are used in an unsafe manner repeatedly and for extended periods. This has the potential to cause acute or chronic radiation-induced adverse effects. The adverse effects would be exacerbated at the x-ray energies (20-50 keV) associated with such devices, since the radiation interactions result in 3 to 5 times more energy absorption (i.e., higher absorbed dose) in bone than in soft tissue [10].

Improper procedures

Conceivably, in operational settings, XRF device operators tasked with a large number of daily routine tests could possibly place their hands in the primary beam at the beam port of the device for a few tests per day. They may do this without realizing that, cumulatively over a year, the permissible radiation limits to the skin and hands could be exceeded and the underlying bone could incur a much higher dose than soft tissue, thereby increasing personal risks. Other users or persons in training who observe an individual operating the device in this manner are likely to adopt the same habit(s), which over time and extended use manifests into a complacent attitude towards radiation protection and safety when working with such XRF devices.

In the past several years, such XRF devices have been particularly useful to industry while gaining acceptance in an expanding array of industrial applications, such as alloy analysis, mining and exploration, lead (Pb) testing in toys, sorting and recycling of scrap metal, and identification of materials to name a few. This increase in application ought to be considered within the context of improper procedures potentially being followed.

Risk Management Strategy

Collectively, all the preceding factors suggest radiation risks are a concern. Therefore, a combination of device design and use warrant consideration; these are addressed in Sections 6.0, 7.0, and 8.0 of this Addendum.

APPENDIX III: Glossary

The terms defined below apply to this Addendum. **In addition, this glossary is considered supplemental information to Safety Code 32.**

ALARA. An acronym for As Low As Reasonably Achievable. This concept means that the design and use of radiation sources and the practices associated with them must ensure that exposures to radiation are kept as low as reasonably achievable with social and economic factors taken into account.

Allied personnel. Personnel or other staff in the vicinity of work areas where radiation generating equipment is used.

Collimator. A shield placed in the path of a primary beam to restrict the size of that radiation beam.

Distributor. A person engaged in the business of selling or leasing radiation emitting devices. This includes an importer.

Dose or absorbed dose. Defined as the quotient of $d\varepsilon_T$ by dm :

$$D = d\varepsilon_T / dm$$

where $d\varepsilon_T$ is the total energy imparted to matter of mass element dm. The International System of Units (SI) of absorbed dose is $J\ kg^{-1}$ which has the special name gray (Gy). (1 gray = 100 rad.)

Dose limit. Applies in relation to persons and refers to the limit on effective dose or equivalent dose specified in Appendix I.

Effective dose. The summation of the tissue equivalent doses, H_T, each multiplied by the appropriate tissue weighting factor w_T :

$$E = \Sigma\, w_T\, H_T$$

The w_T values in Appendix I Table 3 represent the contributions of individual organs and tissues to overall radiation detriment from stochastic effects. The unit of effective dose is $J\ kg^{-1}$ and its special name is seivert (Sv). The rem, equal to 0.01 Sv, is sometimes used as a unit of equivalent dose and effective dose.

Ensure. To make certain.

Equivalent dose. A radiation protection quantity defined by

$$H_{T,R} = w_R\, D_{T,R}$$

where w_R is the radiation weighting factor for radiation type R, and $D_{T,R}$ is the absorbed dose delivered by radiation R in an organ or tissue T. When the radiation field is composed of different radiation types with different values of w_R , the equivalent dose is

$$H_T = \Sigma\, w_R\, D_{T,R}$$

where the sum, Σ, is performed for all radiations, R. The unit of equivalent dose is $J\ kg^{-1}$ which has the special name sievert (Sv).

Facility. A general term meaning a site in which radiation generating equipment is manufactured, produced, installed, used, serviced, stored, or disposed of with respect to industrial, medical, educational, research or development purposes, and where people may be exposed to radiation. A site includes a property, building, plant, structure, or land, and may be of a commercial, permanent or temporary nature or any combinations thereof.

Failsafe. Having the property that any failure causes an action or actions that always result in a safe situation.

Gray. International System of Units (SI) for dose or absorbed dose. 1 gray (Gy) = 100 rad.

ICRP. International Commission on Radiological Protection. An independent group of experts from a wide range of scientific disciplines that have been publishing recommendations for the protection of radiation workers and the public against ionizing radiation for more than 50 years.

Industrial radiography. Examination of the structure of materials by non-destructive test (NDT) methods in which ionizing radiation is used to make radiographic images.

Interlock. A device that precludes radiation exposure to an individual by preventing entry to a hazardous area or by automatically removing the hazard.

Leakage radiation. All radiation, except the primary radiation, coming from an ionizing radiation source.

Non-destructive testing (NDT) or Non-destructive examination (NDE). A wide group of analysis techniques used in science and industry to evaluate the properties of a material, component, or system without causing damage or permanent alteration. Common NDT/NDE techniques include ultrasonic, radiographic, magnetic particle, liquid penetrant, remote visual inspection, eddy current testing, low coherence interferometry, and x-ray fluorescence (XRF).

Primary beam or primary radiation. Radiation that emanates directly from a radiation source or target and passes through the radiation shielded assembly via a collimator or other beam shaping device.

Secondary radiation. Ionizing radiation emitted by matter as a result of the interaction of primary radiation with that matter.

Shallow equivalent dose. A radiation protection operational quantity that is a measure of external exposure from low-penetrating ionizing radiation (e.g., x-rays, gamma rays, electrons) to the extremities or skin and, is the equivalent dose at a depth of 0.07 mm.

Stray radiation. The sum of secondary and leakage radiations.

Watt. A unit of power. One watt (W) is the rate at which work is done when one ampere (A) of current flows through an electrical potential difference of one volt (V). 1 W = 1 A x 1 V.

X-ray fluorescence (XRF). An industrial non-destructive testing technique that employs low energy photons for detecting and quantifying elements in substances, where the term “industrial” implies the exclusion of medical applications.

XRF-certified operator. A person who possesses a valid NRCan XRF-certified operator certification as defined in Section 8.1 of this Addendum with respect to portable, hand-held, x-ray tube based open-beam XRF devices for industrial NDT purposes, where the term "industrial" implies the exclusion of medical applications.

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