# Code of practice for the safe use of industrial radiography equipment (1989)

## RADIATION HEALTH SERIES No. 31



NATIONAL HEALTH AND MEDICAL RESEARCH COUNCIL

# CODE OF PRACTICE
# FOR
# THE SAFE USE OF
# INDUSTRIAL
# RADIOGRAPHY
# EQUIPMENT (1989)

**RADIATION HEALTH SERIES No. 31**

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DEPARTMENT OF COMMUNITY SERVICES AND HEALTH

# PREFACE

This code supersedes the *Code of practice for the control and safe handling of sealed radioactive sources used in industrial radiography,* published by the National Health and Medical Research Council (NHMRC) in 1968. It differs significantly from the former code because radiation protection practice and recommended standards have changed. The code covers the design, construction and requirements for the safe use of X-radiography equipment and gamma-radiography equipment. It provides illustrative working rules, detailed emergency procedures and comprehensive responsibilities and duties for all personnel involved in supplying and using industrial radiography equipment.

The code details those equipment requirements, personnel requirements and work practices that the NHMRC considers necessary to keep exposures to ionizing radiation as low as reasonably achievable.

Some equipment and facilities currently in use may not meet all of the mandatory requirements of this code. These requirements have been included in the code to encourage progress towards future compliance in the expectation that, in the interim, statutory authorities will apply them with discretion.

Prior to publication, the code was extensively reviewed by regulators and users. However, it can be fully evaluated only when it is put into practice. The NHMRC would be grateful for comments and suggestions on the practical application of the code for future review.

# INTRODUCTION

Industrial radiography is a potentially hazardous activity. It makes use of X-ray equipment and sealed radioactive sources of gamma-rays, both of which, if used improperly, could create significant radiological health hazards including potentially lethal radiation doses. Harmful radiation doses have been received in the past by both radiographers and members of the public from a variety of accidents, most of which could have been avoided had appropriate safe working practices been followed. Personal monitoring records show that doses received by operators of industrial radiography equipment are amongst the highest of any group of radiation workers.

The X-rays and gamma-rays used in industrial radiography are highly penetrating and radiation fields are intense. Dose rates of the order of a sievert per second are not uncommon in the radiation beam. Exposure for a few seconds at such dose rates would lead to doses of several sievert, which will cause severe radiation damage to any limbs or tissues exposed. Doses of about 10 Sv or more to the trunk of the body would be fatal.

Industrial radiography is carried out in an industrial environment. At open sites, in particular, radiographs may have to be made in circumstances that involve serious risk of accidental exposure unless site working rules are rigorously followed.

The aim of this code is to promote the protection of persons from possible radiation hazards arising from the use of industrial radiography equipment. To this end the code specifies requirements for the following protective measures:

- allocation of responsibility for safety procedures and for the provision and maintenance of safety equipment;
- design, construction and testing of radioactive sources used in industrial radiography equipment;
- design, construction, testing and maintenance of gamma-radiography equipment;
- design, construction, testing and maintenance of X-radiography equipment;
- siting and installation of industrial radiography equipment and provision of protective barriers, interlocks and other safety features;
- provision of suitable storage areas for radioactive sources;
- provision and maintenance of appropriate radiation monitoring equipment;

- consistent and informed use of personal and other radiation monitoring equipment to measure radiation exposure and to assess potential hazards;
- formulation of comprehensive safety procedures including working rules, emergency procedures and procedures for accounting for radioactive sources;
- the initial and continued instruction of all persons involved in the use and maintenance of industrial radiography equipment;
- use of warning labels, notices, barriers and markings; and
- recording and keeping of all relevant data.

The States and Territories have legislation which controls the possession and use of X-ray equipment and radioactive sources. Information on statutory authorities which administer the various Acts is listed in annexe I.

# SECTION 1 GENERAL

## 1.1 Industrial radiography equipment

Industrial radiography uses the penetrating power of X-rays and gamma-rays to obtain information non-destructively on the internal state of objects and materials. The term industrial radiography equipment is used in this Code to refer to the whole of a device consisting of a source of X- or gamma-radiation (whether generated electronically or derived from the radioactive decay of a material), its housing or container, any associated controls and the radiation detection and imaging apparatus.

## 1.2 Purpose of the code

This code specifies practices designed to ensure that unnecessary exposure of persons to ionizing radiation is avoided, that all exposures are kept as low as reasonably achievable, and that the dose limits specified in the radiation protection standards (1.6) are not exceeded.

## 1.3 Scope of the code

This code applies to industrial radiography equipment, whether using X-rays generated by electronic means or gamma-rays produced by a sealed radioactive source, in which the radiation penetrates an object or material and is subsequently used to form an image of the internal state of the object or material which may be evaluated visually or instrumentally.

This code does not apply to radiation gauges, which rely on detection of radiation rather than formation of an image, and which are the subject of the *Code of practice for the safe use of radiation gauges* (NHMRC, 1952).

This code does not apply to X-ray analysis equipment used in research or in scientific establishments and which is the subject of the NHMRC's *Code of practice for the safe use of X-ray analysis equipment (1984).*

This code does not apply to fully shielded X-ray equipment (sometimes called 'cabinet' X-ray equipment) used for security purposes in screening letters, packages, luggage, etc. These are the subject of the NHMRC's *Statement on cabinet X-ray equipment for examination of letters, packages, baggage, freight and other articles for security, quality control and other purposes (1987).*

Similarly, special purpose enclosed X-ray equipment is covered by the NHMRC's *Statement on enclosed X-ray equipment for special applications (1987).*

## 1.4 Nature of the code

This code has been prepared to supplement legislation controlling X-ray equipment and radioactive sources enacted in Australia and implemented by statutory authorities. The code is intended to serve as a basis for the formulation of detailed equipment specifications and working procedures for the safe use of industrial radiography equipment.

## 1.5 Specialised meanings for 'shall' and 'should'

The words 'shall' and 'should', where used in this code, have specialised meanings. 'Shall' indicates that the particular requirement is considered to be mandatory. 'Should' indicates a requirement that is to be applied as far as practicable in the interests of reducing radiation risks.

NOTE: It is recognised that some existing equipments and facilities may not meet certain of the mandatory requirements of this code. Nevertheless, the word 'shall' has been used where considered necessary to encourage progress towards future compliance with the code, and it is expected that statutory authorities will apply the requirements of this code with appropriate discretion.

## 1.6 Annual dose limits

Radiation protection standards specify annual dose limits for two categories of exposed persons: radiation workers (11.32) and members of the public (11.24). Dose limits are specified in the NHMRC's *Recommended radiation protection standards for individuals exposed to ionising radiation* (NHMRC, 1981) and summarised in annexe IV.

# SECTION 2 GAMMA-RADIOGRAPHY SOURCES AND SOURCE HOLDERS

## 2.1 Selection of suitable sources

The following criteria shall be applied when selecting a radioactive source to be used for industrial radiography.

**2.1.1**

The source shall be appropriate to the applications for which it is intended with regard to the activity of the radioactive substance contained, the types and energies of the radiations emitted and the need to keep the radiation exposure of all persons as low as practicable.

**2.1.2**

The radioactive substance or substances contained in the source shall have a physical and chemical form that will, throughout the intended useful life of the source:

- minimise corrosion of the source and the build up of internal pressure within the source, and
- minimise dispersal of the radioactive substance or substances should the encapsulation be ruptured.

**2.1.3**

Unless prior approval has been obtained from the statutory authority, sources shall be fully sealed and encapsulated as specified in 2.2, and shall not contain radioactive substances other than $^{60}Co$, $^{192}Ir$ or $^{169}Yb$.

## 2.2 Encapsulation of radioactive sources

Sealed radioactive sources used for industrial radiography shall conform to the requirements of International Standard ISO 2919 *Sealed radioactive sources - classification* (see annexe IX). The outermost capsule of a sealed source shall, alone or in combination with one or more inner capsules, satisfy the following requirements.

**2.2.1**

It shall be sealed to prevent the release of radioactive material from the capsule under normal conditions of use.

**2.2.2**

It shall be constructed to withstand the tests specified in 2.3.

### 2.2.3

Its surface shall be free from non-fixed radioactive material.

### 2.2.4

Except when permanently enclosed in a source holder, as in 2.4.4, it shall be durably marked, for example by hard stamping or engraving, with the words 'DANGER RADIOACTIVE' together with a code which allows the unambiguous identification of the source and the following information to be retrieved from records supplied with the source:

- the name of the radioactive substance;
- the activity of the radioactive source and the date of measurement;
- the name and address of the supplier or manufacturer; and
- the identification number of the source.

## 2.3 Tests for structural integrity and endurance of radioactive source capsules

The outermost capsule of a sealed radioactive source that is intended for use in industrial radiography shall satisfy the Tests for Special Form Radioactive Material specified in the *Code of practice for the safe transport of radioactive substances* (see annexe IX).

The statutory authority may, at its discretion, accept certificates of test issued by another authority whether such authority be within Australia or in another country.

## 2.4 Requirements for a source holder

A source holder shall satisfy the following requirements.

### 2.4.1

It shall be constructed so as to be demountable for inspection or removal of the radioactive source by an authorised person.

### 2.4.2

It shall be constructed so as to prevent unintentional release of the radioactive source under the conditions of normal use and of credible misuse. Any screw cap shall be silver soldered, brazed or affixed by another method approved by the statutory authority to prevent the release of the cap and source.

**2.4.3**

If the source holder obscures the marking of the outer capsule of the radioactive source required under 2.2.4, the marking requirement of 2.2.4 shall also apply to the source holder.

**2.4.4**

If the source holder fully encloses the source capsule at all times, except when assembled or disassembled by the supplier, the marking requirement of 2.2.4 shall apply to the source holder.

**2.4.5**

When used in a projection-type container (see 3.1), the source holder shall be secured to a flexible cable or pigtail which meets the requirements of 3.3.

# SECTION 3 SOURCE CONTAINERS AND HANDLING EQUIPMENT

## 3.1 Design and construction of source containers

Each source container shall meet the requirements of International Standard ISO 3999 *Apparatus for gamma radiography - specification* (as amended from time to time) (see annexe IX) and, if used as a transport container, shall comply with the requirements contained in the *Code of practice for the safe transport of radioactive substances* (see annexe IX). It shall also comply with the following design and construction requirements.

A shutter or source control mechanism shall be fitted, or provision made for such fitting, to the source container unless otherwise approved by the statutory authority. It may be either manually operated or power operated (that is, electrically or pneumatically operated) but, if power operated, shall be designed to be fail-safe. That is, if a power failure occurs, the return to the fully shielded condition shall be automatic: for example, the shutter on a shutter-type container should be opened against the pressure of a spring or other positive closing device. For a power operated projection-type container, a mechanical means of returning the source to the fully shielded position shall be provided. The design of the source container should be such that the source cannot be removed through the control connection port.

### 3.1.2

When a source control mechanism is not connected to a source container, the connection port - and for a projection type container, the projection port - shall be closed with an end cap that can be screwed or otherwise firmly fixed into position, and that can be secured with a locking pin or similar device.

### 3.1.3

A shutter or source control mechanism and the associated mechanism for remote manual or power operation shall be designed and constructed or encased in a protective enclosure so that:

- they satisfy the test requirements given in 3.2.1; and
- their operation is not adversely affected by corrosive substances, dust, grit, moisture, vibration or heat that may be present in the immediate environment of the radiography equipment during its projected useful life.

**3.1.4**

The shutter or source control mechanism shall be provided with an effective key-operated lock which can be locked only when the source is in the fully shielded position, and which will secure the source in that position.

**3.1.5**

Source container locks shall be so designed, constructed and mounted that they resist forcible interference using common hand tools and resist key cylinder picking.

**3.1.6**

A projection-type container which is designed to hold the source near the centre of a 'dog-leg' or 'S-bend' conduit in a shielding casing when in the fully shielded position shall incorporate a flexible source holder, or pigtail, which can be secured at its cable-coupling end to the control cable port. A flexible cable, similar to but not mistakable for a pigtail, should also be provided which can be inserted into the projection port and be secured, while the source is not in use, to prevent the source from moving from its fully shielded location.

**3.1.7**

When loaded with the source of greatest activity for which it is approved by the statutory authority, the radiation level shall not exceed 2000 μSv/h at any point 5 cm from the external surface and 100 μSv/h at any point 1 m from its surface. Determinations of these radiation levels are to be made with the shutter or control mechanism in the 'beam off' position, the source in the fully shielded position, and the appropriate port plugs fitted.

**3.1.8**

It shall be so constructed that any primary shielding material, of melting point less than 800°C, shall be entirely enclosed within a metal casing, the melting point of which exceeds 800°C, so that effective shielding is maintained in the event of a fire.

**3.1.9**

It shall be designed to withstand variations of temperature to which it may be subjected in use without deterioration of containment or ease of operation of the shutter or source control mechanism, if fitted. The potential for brittle fracture of materials used shall be taken into account.

**3.1.10**

It shall be so designed that when any incorporated lifting attachments are used in the intended manner, no damaging stresses are imposed on the structure of the source container.

**3.1.11**

Where welded, brazed and other fusion joints are used, they shall be in accordance with relevant published standards and the requirements of the statutory authority.

**3.1.12**

It shall be so designed and constructed that it withstands the effects of all vibrations, acceleration and vibration resonance likely to arise during its transport, handling and use, without damage, deterioration in the effectiveness of closing devices or reduction in ease of operation of the shutter or source control mechanism, if fitted.

**3.1.13**

It shall be constructed of materials that are physically and chemically compatible with each other and with the materials of radioactive source capsules that it is designed to contain. Account shall be taken of the behaviour of the various materials under irradiation.

**3.1.14**

It shall be provided with a handle or handles, lifting lugs or brackets, or other means as appropriate, to facilitate safe handling.

**3.1.15**

It shall be durably marked with a fire resistant label or labels incorporating the radiation hazard symbol (trefoil) and the word 'CAUTION' followed by words to the general form of those given in annexe III. The label or labels shall also incorporate the following information:

- the name of the radioactive substance, and the maximum activity for which the container has been designed;
- the identification number of the container;
- the name and address of the supplier or manufacturer;
- the activity of the enclosed radioactive source and the date of measurement of that activity;
- the maximum radiation level at one metre (with any shutter closed) from the source container and the date this measurement was made; and
- the name, address and telephone number of the owner or emergency contact.

The latter three items may be incorporated in a changeable metal label which shall be firmly fixed to the container by a metal ring or chain or other robust attachment.

#### 3.1.16

The requirements of 3.1.15 shall be met by the use of metal labels legibly stamped or engraved with the required information. When selecting material to be used in the metal label, the long term effects of corrosion and general exposure to the environment should be considered.

## 3.2 Tests for structural integrity and endurance of source containers

A source container housing a radioactive source for use in industrial radiography shall meet the test requirements specified in International Standard ISO 3999 *Apparatus for gamma radiography - specification* (as amended from time to time) (see annexe IX) and, if used as a transport container, shall meet the test requirements specified in the *Code of practice for the safe transport of radioactive substances* (see annexe IX).

The statutory authority may, at its discretion, accept certificates of test issued by another authority whether such authority be within Australia or in another country.

### 3.2.1 Shutter and source control mechanism test

To test a shutter or source control mechanism, a sample or prototype mechanism shall be subjected to 50,000 cycles of operation.

A shutter or source control mechanism shall be considered to have complied with this test requirement if it has operated for the specified number of cycles of operation without the component failing to operate in the intended manner, and without showing evidence of undue wear.

## 3.3 Handling equipment

For a projection type source container, equipment used to propel a radioactive source between its shielded position and its exposure position shall meet the requirements specified in International Standard ISO 3999 *Apparatus for gamma radiography - specification* (as amended from time to time) (see annexe IX) and shall comply with the following requirements.

### 3.3.1

A guide tube through which the source can move freely shall be provided. The design of the end cap at the exposure end of the guide tube shall be such as to prevent inadvertent release of the source when fully projected. The guide tube shall be sealed to prevent ingress of dirt, grit and moisture and, if flexible, shall be capable of withstanding repeated flexures without suffering permanent distortion. Recovery from any temporary distortion caused by a compressive load or flexure shall be rapid. The exposure end of the guide tube shall be capable of being clamped in position during exposure without affecting the free movement of the cable and source, and should be capable of being fitted with a collimator.

**3.3.2**

Where a cable is used to move the source, the coupling shall be designed to withstand expected conditions of use such that the source or pigtail does not become detached inadvertently.

**3.3.3**

A control cable shall be not less than 10 m and of sufficient length in relation to the exposure conditions to enable the operator to control the source from a location where the dose rate is as low as practicable. The windout mechanism should incorporate a device to indicate the distance through which the source has been projected from its fully shielded position.

**3.3.4**

Where a source is moved pneumatically, the guide tube shall have damping mechanisms at both ends to protect the source from damage.

**3.3.5**

Where a source is moved by electro-mechanical or pneumatic means, a mechanical device shall be provided that can be used to return the source to its container in the event of an electrical fault or electrical power failure, or pneumatic failure.

## 3.4. Proscription of hand-held devices

Unless prior approval from the statutory authority has been obtained, hand transfer devices (‘torch’ units) shall not be used to move a gamma-radiography source from its container to its exposure position and to return it following exposure.

# SECTION 4 STORAGE AND TRANSPORT OF GAMMA-RADIOGRAPHY SOURCES

## 4.1 Requirements for storage

The following requirements for storage of gamma-radiography equipment shall be met.

Gamma-radiography equipment shall be kept in a store that is not used for any purpose other than for storage of radiography equipment and directly related accessories.

**4.1.2**

Gamma-radiography sources shall not be transferred from one container to another except by procedures approved by the statutory authority.

**4.1.3**

When gamma-radiography equipment is placed in the store, the source control or shutter mechanism shall be locked or otherwise secured in the fully shielded position and all port plugs shall be secured in place. A survey meter shall be used to verify that the source is correctly located in the fully shielded position.

## 4.2 Requirements for a store

The store shall meet the following requirements.

**4.2.1**

It shall be constructed of materials of sufficient durability and strength to resist fire and unauthorised entry.

**4.2.2**

The dose rate outside the store shall not exceed 25 μSv/h and, in occupied areas, shall be as low as reasonably achievable and such that no member of the public will receive a dose exceeding 1 mSv per year.

**4.2.3**

The store shall be under the control of a competent person specified by the owner and shall be kept locked except when removing or replacing sources.

#### 4.2.4

The store shall have a conspicuous notice bearing the word 'CAUTION' and a radiation hazard warning symbol and lettering that makes clear that it is a store for radioactive substances. An example of a suitable notice is given in annexe III. The notice, or a separate but adjacent notice, shall contain instructions for contacting the Radiation Safety Officer, or his or her deputy, in an emergency.

#### 4.2.5

The store shall not be located in proximity to explosives, to combustible or corrosive materials, or to undeveloped photographic or X-ray film.

#### 4.2.6

Apart from any emergency exits normally kept closed, a store should have only one door for access, so that it may not be used as a thoroughfare.

## 4.3 Requirements for transport

This subsection applies to the transport of sources between any of the following: the supplier, the supplier's agent, the owner, the installation and maintenance company or any other organisation; and to transport within the premises where radiography is performed. For transport between any of the former, the requirements of the *Code of practice for the safe transport of radioactive substances* (see annexe IX) shall be met.

### 4.3.1 Preparation for transport

The operator or owner shall ensure the following.

#### 4.3.1.1

The source control or shutter mechanism of the source container shall be locked in the fully shielded position, and all port plugs shall be securely fitted.

#### 4.3.1.2

Monitoring shall be carried out to demonstrate that the useful beam is properly attenuated with the shutter or source control mechanism in the fully shielded position and that the attenuated radiation exposure pattern is as expected, and that dose rates are in compliance with this code.

#### 4.3.1.3

The source container or, if the source container is packed in an otter shipping container, the outer container shall comply with the requirements of the statutory authority and the *Code of practice for the safe transport of radioactive substances* (see annexe IX).

The source container shall be firmly secured within the outer container.

### 4.3.2 Transport

For transport of a radioactive source in a vehicle or aircraft, the operator or owner shall ensure the following.

**4.3.2.1**

The vehicle shall bear appropriate markings or placards, as required by the statutory authority and in accordance with the *Code of practice for the safe transport of radioactive substances* (see annexe IX), which make it clear that radioactive substances are being carried.

**4.3.2.2**

The source container shall be located in the vehicle so that the radiation dose received by any person travelling in the vehicle is as low as practicable. The maximum dose rate at the position of any person in the vehicle shall not exceed 20 μSv/h.

**4.3.2.3**

The source container shall be stowed during transport so as to prevent any shift under conditions normally incidental to transport.

**4.3.2.4**

The storage compartment in which the source container is stowed shall be locked when the vehicle or aircraft is left unattended with the source container still on board. A source container shall not be left unattended in the back of an open vehicle.

### 4.3.3 Movement of a source container within the owner's establishment or within the premises where radiography is performed

The operator or owner shall ensure the following.

**4.3.3.1**

Except for minor adjustment in position for the purposes of further radiography, the source control or shutter mechanism shall be locked in the fully shielded position and all port plugs shall be secured before a source container is moved.

**4.3.3.2**

Monitoring shall be carried out to check that the source is located at its fully shielded position with the shutter or source control mechanism in the fully shielded position and that the external radiation exposure pattern is as expected.

**4.3.3.3**

The source container shall be transported within the establishment in a manner which ensures that the radiation exposure of persons is as low as practicable.

### 4.3.4 Action following loss of or damage to a container during transport

**4.3.4.1**

If a source container is, or appears to be, damaged in transport the following actions shall be taken:

- the person or persons responsible for the container at the time of the incident, or another person if necessary, shall notify the owner and the statutory authority forthwith; and
- the owner shall ensure that the source container is carefully examined to verify that it continues to comply with this code. In particular, a radiation survey shall be carried out to demonstrate that the radiation levels at 5 cm from the surface and at l m from the container meet the specifications of 3.1.7 and that the radiation pattern is as expected. If a source container does not meet the requirements of this code, the owner shall ensure that
  - (i) appropriate steps are taken immediately to limit the exposure of persons who may be consequently exposed to radiation, and
  - (ii) before the source container is used again, all resultant damage is repaired such that it meets the requirements of this code.

**4.3.4.2**

If a source container is lost during transport, the person or persons responsible for the container shall notify the owner or the statutory authority forthwith, and shall provide any relevant information that may facilitate recovery of the source.

# SECTION 5 X-RADIOGRAPHY EQUIPMENT

## 5.1 Selection of X-radiography equipment

Industrial X-radiography equipment shall be appropriate to the application for which it is intended with regard to the maximum X-ray energy and dose rate or maximum tube potential difference (kV(peak)) and maximum current (mA).

## 5.2 Design and construction

### 5.2.1

X-radiography equipment shall comply with the following design and construction requirements.

#### 5.2.1.1

The X-ray tube shall be contained in a housing that provides shielding from radiation in all directions other than the beam direction. The shielding shall be sufficient to ensure that dose rates 1 m from the housing do not exceed 5000 μSv/h under conditions of continuous operation at maximum energy and output.

#### 5.2.1.2

For X-radiography at an open site (see 6.3), the X-ray tube should incorporate filtration to reduce scattered radiation.

#### 5.2.1.3

A key switch shall be fitted to the X-ray control panel to prevent unauthorised use. The key shall be removable only when the switch is in the off position. The function of the key switch and its on and off positions shall be clearly marked on the control panel.

#### 5.2.1.4

X-ray on and off controls shall be physically separate from the key switch. Their function, and the on and off positions, shall be clearly marked on the control panel.

#### 5.2.1.5

A device shall be provided which shall terminate the production of X-rays after a preset interval not exceeding 30 minutes or such maximum time as is required by the statutory authority.

**5.2.1.6**

A red or amber indicator lamp shall be provided on the control panel and shall be automatically illuminated when the X-ray tube is energised. This lamp shall be duplicated on the X-ray tube housing and operate in parallel with its counterpart on the control panel and shall be visible from a distance of at least 10 m. An interlock shall be provided such that if either of the 'beam on' indicator lamps fails, the X-ray tube cannot be energised, and replacement of the lamp will not automatically re-energise the X-ray tube.

**5.2.1.7**

The control panel shall be equipped with a device or devices indicating the X-ray beam energy and output in terms of the X-ray tube potential difference (kV(peak)) and current (mA) or electron energy and dose rate, as appropriate. For equipment that is used at an open site, the values indicated shall be clearly legible in bright sunlight.

**5.2.1.8**

For open site radiography, the control panel shall be fitted with a means of connecting a remote flashing light or a series of remote flashing lights which can be used to define a boundary or provide a visible warning when the equipment is energised.

**5.2.1.9**

The length of cable connecting the control panel with the X-ray tube shall be not less than:

7 m for X-rays less than 100 kV(peak);
10 m for X-rays less than 200 kV(peak);
15 m for X-rays less than 250 kV(peak); and
20 m for X-rays over 250 kV(peak);

unless the X-ray equipment is within, and operated from outside, a fully enclosed or partially enclosed site.

**5.2.1.10**

X-ray equipment that is used for direct-viewing fluoroscopy shall be shielded such that at no time during exposure can the dose rate at any accessible position exceed 25 μSv/h.

**5.2.1.11**

Fluoroscopic imaging devices shall be positioned such that the primary X-ray beam is totally intercepted, and the exposure configuration shall be arranged such that it is not possible for any part of the body of any person to be inserted into the beam.

### 5.2.2 Additional requirements for X-ray crawler equipment

#### 5.2.2.1

Each crawler shall have a klaxon fitted to it. After the crawler has reached the exposure position, this klaxon shall automatically operate continuously for a warning period of 10 seconds immediately prior to the commencement of the exposure. While the exposure is taking place, the klaxon shall continue to operate in a manner distinguishable from the 10 second warning.

#### 5.2.2.2

The klaxon should be loud and distinctive enough to be heard clearly above all other noise sources in the vicinity of the crawler. In most cases, persons in the vicinity will be outside the pipe within which the crawler is operating and therefore the klaxon should be clearly audible through the pipe wall.

#### 5.2.2.3

The width of the useful X-ray beam shall not exceed 200 mm at the circumference of the pipe within which the crawler is operating.

#### 5.2.2.4

An X-ray crawler, for which exposures are initiated by remote control or by an automatic device such as a trip wheel, shall have a safety device fitted to it which prevents the remote control or the automatic device from initiating an exposure unintentionally.

#### 5.2.2.5

An X-ray crawler shall incorporate a safety device which disconnects power from the propulsion unit in the event of a malfunction during operation.

# SECTION 6 INDUSTRIAL RADIOGRAPHY SITES

Industrial radiography may be carried out under a variety of exposure conditions. For the purposes of this code, exposure conditions are classified into one of three types of site: fully enclosed sites (exposure rooms); partially enclosed sites (exposure bays); and open sites (field sites).

## 6.1 Requirements for a fully enclosed site

A fully enclosed site is designed to keep all direct and scattered radiation arising from radiographic exposures within a totally enclosed volume, and to permit operation of the radiography equipment from outside by remote control. No person shall remain inside a fully enclosed site during exposure.

### 6.1.1

A fully enclosed site shall be so constructed that, with access doors or ports closed, the walls, floor and ceiling surrounding the site form a complete shielding enclosure.

### 6.1.2

The shielding associated with a fully enclosed site shall be sufficient to ensure that at no time during exposure does the dose rate outside the enclosure exceed 25 μSv/h measured 5 cm from any accessible surface. The shielding and location of a fully enclosed site shall be such that no member of the public will receive an effective dose equivalent in excess of 1 mSv per year from exposures carried out within it.

### 6.1.3

A fully enclosed site shall be clearly identified as such through the use of warning notices at access points. A warning light shall be provided which is illuminated during exposure and which is clearly visible from outside the enclosure.

### 6.1.4

Interlocks shall be fitted to all access points of a fully enclosed site which will activate a visible and audible alarm if any interlock is opened during exposure. In the case of X-radiography equipment, the opening of an interlock during exposure shall automatically cause the interruption of the power supply to the X-ray equipment or to the X-ray tube, and subsequent closing of this interlock shall not automatically re-energise the X-ray tube.

#### 6.1.5

A fully enclosed site shall be provided with visible and audible warning devices inside the enclosure which shall be activated during exposure, and with a suitable means of exit - which may be the main or only exit-to enable any person who is accidentally shut in to leave the enclosure without delay. Opening of this exit during exposure shall activate an alarm as specified in 6.1.4, and subsequent closing of the exit shall not automatically reset the alarm or re-energise an X-ray tube.

#### 6.1.6

Doors and panels covering access apertures into a fully enclosed site shall overlap those apertures by a sufficient margin to prevent the leakage of scattered radiation from the enclosure. Where a maze is used for access of persons, a lockable door or barrier shall be incorporated and connected to an interlock complying with 6.1.4.

#### 6.1.7

Conduits for feeding cabling, including windout cables, electrical power or other services through the walls of a fully enclosed site, shall incorporate a dog-leg or baffle that leaves no line-of-sight aperture through the walls to the radiation source, so that the radiation shielding integrity of the walls is not impaired.

#### 6.1.8

Before constructing a fully enclosed site, plans and details of construction and of proposed operations shall be provided to the statutory authority for approval.

### 6.2 Requirements for a partially enclosed site

A partially enclosed site is designed to keep all direct radiation arising from radiographic exposures within the area enclosed and to limit any radiation scattered outside the enclosure to a low level. A partially enclosed site is typically an area of a building or room which is partitioned off with shielding walls and floor such that the partitioned area is closed on all sides that adjoin occupied areas, but which may be open at the top or on one side to permit the transfer in and out of the items to be radiographed, and such that the radiography equipment can be operated from outside by remote control. No person shall remain inside a partially enclosed site during exposure.

#### 6.2.1

A partially enclosed site shall be constructed with walls at least 2.1 m high and affording sufficient shielding such that, while exposures are being carried out, the dose rate measured outside the area defined by the enclosure shall not exceed 25 μSv/h measured 5 cm from any accessible surface. The shielding and location of a partially enclosed site shall be such that no member of the public will receive an effective dose equivalent in excess of 1 mSv per year from exposures carried out within the enclosure.

**6.2.2**

A partially enclosed site shall be clearly identified as such through the use of warning notices at its perimeter and at access points. A warning light or lights shall be provided to be illuminated during exposure and to be clearly visible from outside the enclosure.

**6.2.3**

Interlocks shall be fitted to all entrances to a partially enclosed site to activate a visible and audible alarm should any interlock be opened during exposure. In the case of X-radiography equipment, the opening of an interlock during exposure shall automatically cause the interruption of the power supply to the X-ray equipment or X-ray tube, and subsequent closing of this interlock shall not automatically re-energise the X-ray tube.

**6.2.4**

A partially enclosed site shall be provided with visible and audible warning devices which shall be activated during exposure and which can be seen and heard from both inside and outside the enclosure.

**6.2.5**

A partially enclosed site shall be provided with a suitable means of exit - which may be the main or only exit - to enable any person who is accidentally shut in to leave the enclosure without delay. Opening of this exit during exposure shall activate an alarm as specified in 6.2.3, and subsequent closing of the exit shall not automatically reset the alarm or re-energise an X-ray tube.

**6.2.6**

Doors or panels covering access apertures into a partially enclosed site shall overlap those apertures by a sufficient margin to prevent leakage of scattered radiation through the boundary of the partially enclosed site. Where a maze is used for access of persons, a lockable door or barrier shall be incorporated and connected to an interlock complying with 6.2.3.

**6.2.7**

Particular attention shall be given in the design of a partially enclosed site to limit scattered radiation passing through the non-enclosed parts of the site boundary to occupied areas outside. For example, a partially enclosed site that is open at the top shall not be located such that radiation scattered from the roof of the building or room in which it is constructed can present a radiation hazard in occupied areas outside the enclosure.

**6.2.8**

If cabling, including windout cables, electrical power or other services, is taken through the walls of a partially enclosed site, it shall be fed through conduits that incorporate a dog-leg or baffle that leaves no line-of-sight aperture through the walls to the radiation source, so that the radiation shielding integrity of the walls is not impaired.

**6.2.9**

Before constructing a partially enclosed site, plans and details of construction and of proposed operations shall be provided to the statutory authority for approval.

## 6.3 Requirements for an open site

For reasons of economy, convenience or practical necessity, a great deal of industrial radiography takes place without any shielding enclosure. This is especially the case where radiography of structures is required in situ. Particular care shall be exercised at an open site to avoid unnecessary exposure of persons and to keep all radiation exposures as low as reasonably achievable. Collimators should be used to restrict the spread of the beam to the region to be radiographed.

**6.3.1**

Before undertaking any field radiography work, appropriate working rules shall be established. If a general set of open site working rules is available, the operator shall ensure that he or she is familiar with those rules that apply to the planned circumstances of exposure, and that any modifications or additional rules to meet the particular circumstances are developed in cooperation with the Radiation Safety Officer. If no such working rules are available, the Radiation Safety Officer shall ensure that a set that is acceptable to the statutory authority is prepared.

**6.3.2**

Before commencing radiography operations at an open site, a well defined and clearly visible boundary shall be erected using warning signs and devices such as barriers, flagged rope, etc, around, above and below the site as appropriate. An example of a suitable warning sign to be used during exposure is given in annexe III. The boundary shall be located such that the calculated dose rates at the boundary during exposure shall not exceed 25 μSv/h. The actual dose rates at the boundary shall be measured during exposure using a survey meter and the location of the boundary shall be rectified as necessary before subsequent exposures.

**6.3.3**

The boundaries of adjacent sites should not overlap. If overlap is unavoidable, close liaison shall be maintained between operators responsible for the overlapping sites to avoid accidental exposure.

**6.3.4**

The source control position shall be located such that the dose rate there is as low as practicable. During exposure the operator should, whenever possible, move quickly to and remain in a location where the dose rate does not exceed 25 μSv/h. The dose rate at the source control position, if occupied, or at the position taken up by the operator during exposure shall be checked regularly by means of a survey meter.

**6.3.5**

The immediate environment of the exposure position shall be clearly visible from the source control position and from the position taken up by the operator during exposure. The area inside the delineated boundary of an open site shall be inspected prior to exposure to ensure that no person is within it and shall be kept under observation at all times during exposure to ensure that no person enters it.

**6.3.6**

One or more warning lights and an audible alarm located immediately adjacent to the exposure position shall be used to indicate when an exposure is underway.

**6.3.7**

The working rules developed according to 6.3.1 shall be adhered to at all times (see section 9).

# SECTION 7 RESPONSIBILITIES AND DUTIES

## 7.1 Requirements for a supplier of industrial radiography equipment

No person shall offer for sale any X-radiography equipment, gamma-radiography equipment or radioactive source unless authorised to do so under the appropriate legislation.

## 7.2 Responsibilities of a supplier of industrial radiography equipment

Prior to the transfer of industrial radiography equipment to the purchaser, the supplier shall:

**7.2.1**

provide the statutory authority with:

- the name and address of the owner or prospective owner;
- details of the equipment to be supplied, including shielding, and operation of interlocks and shutters;
- details of materials of construction and, where required by the statutory authority, technical drawings and methods of fabrication;
- details of source type, activity and encapsulation of gamma-radiography equipment, including copies of relevant certificates; and
- details of the X-ray generator characteristics of X-radiography equipment, including maximum tube potential difference (kV(peak)) and current (mA), or maximum X-ray energy (keV) and maximum output (dose rate);

**7.2.2**

demonstrate to the statutory authority that the equipment meets the requirements of sections 2 and 3 or section 5, as appropriate. Any one or more of the following methods may be used to demonstrate compliance with the performance criteria specified in sections 2, 3 and 5:

- testing one or more items of the type to be supplied using methods acceptable to the statutory authority;
- calculation; or
- reference to other test results;

**7.2.3**

provide to the owner or prospective owner:

- documentary evidence that the requirements of 7.2.1 and 7.2.2 have been met, together with any certificates required by the statutory authority or in accordance with the *Code of practice for the safe transport of radioactive substances* (see annexe IX);
- details of the equipment to be supplied, including shielding, and operation of interlocks and shutters;
- details of source type, activity and encapsulation of gamma-radiography equipment, including copies of relevant certificates; and
- details of the X-ray generator characteristics of X-radiography equipment, including maximum tube potential difference (kV(peak)) and current (mA), or maximum X-ray energy (keV) and maximum output (dose rate);

**7.2.4**

when supplying a replacement gamma-radiography source in a source container, inspect the pigtail and couplings for wear and replace unacceptably worn, frayed or damaged components; and

**7.2.5**

provide to the purchaser of a sealed radioactive source a dummy source (clearly marked as such), and a source holder, if applicable, of the same appearance, or photographic or other documentation necessary to enable the operator to recognise an accidentally detached source, by size and appearance, in an emergency.

## 7.3 Responsibilities of an owner of industrial radiography equipment

The owner of industrial radiography equipment shall:

**7.3.1**

upon receipt of industrial radiography equipment from a supplier, ensure that the requirements of 7.2 have been met and provide the statutory authority with copies of relevant certificates issued by appropriate authorities, as specified in the *Code* of *practice for the safe transport of radioactive substances* (see annexe IX), such as a certificate of approval for Special Form material, or a certificate of approval for a type B or type B(U) container;

**7.3.2**

prior to construction of a fully enclosed or partially enclosed site, provide plans and details of construction and of proposed operations to the statutory authority for approval (see 6.1.8 and 6.2.9);

**7.3.3**

prior to installation of industrial radiography equipment at fully enclosed or partially enclosed sites, inform the statutory authority of the plans of the location in which the equipment is to be operated, including the position of the equipment relative to occupied areas, and the anticipated dose rates outside the enclosure during exposure;

**7.3.4**

prior to the operation of industrial radiography equipment, supply to the statutory authority for approval a copy of the working rules (see section 9) to be followed during operation of the equipment, including details of the procedures to be adopted to protect persons from radiation during exposure and to keep radiation exposures as low as practicable;

**7.3.5**

prior to the operation of industrial radiography equipment at a site other than the owner's premises, ensure that the person responsible for the site premises is consulted and

- is advised of the nature of the work to be carried out, of any precautions required of persons in the vicinity, and of the identity of the operator responsible for radiographic work at the site, and
- identifies the person nominated as responsible for liaison between the operator and other persons at the site, so that directions given by the operator to maintain radiation safety are followed;

**7.3.6**

ensure that the working rules (see 7.3.4) are followed, and carry out the duties specified in 9.5;

**7.3.7**

ensure that the equipment is inspected prior to its first use and at intervals approved by the statutory authority and tested to ensure that all interlocks, shutters and control mechanisms operate effectively and that no components are unacceptably worn or damaged. Inspection reports shall be kept and shall be made available to the statutory authority upon request (see 10.1);

**7.3.8**

ensure that if damage to the equipment or variation in its radiation pattern comes to his or her attention, the equipment shall not be further used until inspected by a competent person. After repair, as necessary, the equipment shall be tested for proper functioning and, before re-use, shall comply with the requirements of this code to the satisfaction of the statutory authority. Details of repairs shall be kept and shall be made available to the statutory authority upon request (see 10.1);

**7.3.9**

ensure that a second person is immediately available to assist the operator at an open site or a partially enclosed site as specified in 9.2.3;

**7.3.10**

ensure that emergency procedures are prepared such that in the event of an incident personal radiation exposures are as low as practicable. Such procedures should cover all foreseeable, credible incidents and shall be submitted to the statutory authority for approval;

**7.3.11**

ensure that the necessary equipment and facilities are available as specified in section 8 to enable the working rules and emergency procedures to be followed, including the provision of barriers and interlocks where necessary around areas of possible high radiation exposure and the installation or use of appropriate signs for equipment (see annexe III) and for identifying an area as a field site for radiography;

**7.3.12**

ensure that no person receives radiation exposure in excess of the limits specified in 1.6, and that all radiation exposures are kept as low as reasonably achievable;

**7.3.13**

ensure that persons appointed to operate industrial radiography equipment have received adequate training and have appropriate knowledge of the hazards associated with the equipment, and have a demonstrated competence to use the equipment safely;

**7.3.14**

ensure that operators of industrial radiography equipment and personnel who work in conditions under which they may be exposed to radiation are properly instructed in radiation hazards associated with their work, in any precautions necessary to limit radiation exposure of persons in accordance with this code, and in safe working practices to avoid radiation accidents;

**7.3.15**

ensure that the necessary supervision is provided so that personnel who work in conditions under which they may be exposed to radiation arising from operation of radiography equipment for which the owner is responsible are protected from radiation in accordance with the provisions of this code;

**7.3.16**

appoint a Radiation Safety Officer. The person so appointed shall have sufficient professional or technical training to enable him or her to readily comprehend and carry out the duties required (see 7.5). An operator having the necessary qualifications and training may be appointed as the Radiation Safety Officer. One or more assistants to the Radiation Safety Officer having suitable qualifications and training, may be appointed to carry out such duties as are delegated by the Radiation Safety Officer; in particular, an operator may be so appointed;

**7.3.17**

ensure that the measurements, investigations and assessments necessary to properly monitor radiation exposures of persons from industrial radiography equipment are made, and that reports and records are kept in accordance with the requirements of this code (see section 10);

**7.3.18**

ensure that a Radiation Source Movement Record Book is maintained for all gamma-radiography and X-radiography radiation sources under his or her control, so that an up-to-date record of the location of all sources is always available; and

**7.3.19**

notify the appropriate fire authority, and other relevant emergency services of the existence of radioactive sources on the site premises and ensure that information is provided directly, or on attendance of the emergency services, of the location of all radioactive sources for which he or she is responsible.

## 7.4 Responsibilities of an operator and assistant operator of industrial radiography equipment

The operator of industrial radiography equipment shall:

**7.4.1**

be thoroughly familiar with the equipment and its use, the approved working rules and emergency procedures appropriate to his or her work, and the relevant requirements of this code;

**7.4.2**

ensure that the following details of the movement of gamma-radiography and/or X-radiography radiation sources are entered in the Radiation Source Movement Record Book:

- the identification number of the source container or X-ray tube;
- for gamma-radiography equipment, the radioisotope and activity of the source at the time of transfer;
- the location of sites where the source is to be used;
- the date and time of removal;
- the estimated date and time of return;
- the actual date and time of return; and
- the name of the operator;

**7.4.3**

on removing a gamma-radiography source from the store, verify that the source has been transferred to his or her custody by checking the exposure rate from the source container with a survey meter and record this fact by signing the entry in the Radiation Source Movement Record Book;

**7.4.4**

prior to operating the equipment, ensure that all interlocks, shielding, collimators, signs, barriers and other protective devices are properly positioned; that all persons not involved in the operation are at safe locations; and that a suitable radiation survey meter as specified in 8.1.3 and 8.1.5 is available;

**7.4.5**

not operate any industrial radiography equipment without wearing a personal radiation monitoring device and a personal dosemeter;

**7.4.6**

operate the equipment in accordance with the approved working rules (see section 9) appropriate for the circumstances and, in particular, for partially enclosed and open sites, ensure that all persons remain at safe locations during operation;

**7.4.7**

at the completion of each exposure, ensure, by using an appropriate radiation survey meter for gamma-radiography equipment, that the source has been returned to the fully shielded position or, for X-radiography equipment, that the equipment is no longer energised;

**7.4.8**

on returning gamma-radiography equipment to the store, ensure that the source control or shutter mechanism is locked or otherwise secured in the fully shielded position and that all port plugs are firmly secured in place, and check with a survey meter that the source is correctly located in the fully shielded position;

**7.4.9**

not operate any equipment which is known or reasonably suspected to be malfunctioning, to have deteriorated or to be damaged, and to report such circumstances promptly to the owner or Radiation Safety Officer for appropriate investigative action;

**7.4.10**

immediately cease operation of industrial radiography equipment by returning the source to its fully shielded position or by de-energising the X-ray tube, as applicable:

- if a malfunction occurs during operation;
- if any person other than the operator or assistant operator enters an area where the dose rate exceeds or might exceed 25 μSv/h; or
- if the only available survey meter fails to function;

**7.4.11**

be familiar with the nature and physical appearance of any gamma-radiography sources for which he or she has responsibility; and

**7.4.12**

in the event of a radiation incident, promptly take the appropriate measures in accordance with 9.5 to bring the incident under control by rendering the equipment permanently safe, if possible, or otherwise by temporary control combined with removal of all persons to a safe location pending further remedial action. The operator shall inform the Radiation Safety Officer and the owner of the circumstances of the incident forthwith.

An assistant operator of industrial radiography equipment shall:

**7.4.13**

carry out such duties as are delegated by the operator, in accordance with the requirements of 7.4.1 to 7.4.11;

**7.4.14**

only operate industrial radiography equipment whilst under the direct supervision of an operator; and

**7.4.15**

in the event of the operator being unable to carry out the duties specified in 7.4.12, take over these duties insofar as he or she is competent to do so without undue risk to himself or herself or any other persons present.

## 7.5 Responsibilities of a Radiation Safety Officer

The responsibilities of a Radiation Safety Officer are to:

**7.5.1**

obtain and maintain knowledge of the principles and practices of radiation protection and of the potential radiation hazards associated with industrial radiography equipment sufficient to undertake the measurements, investigations and assessments and other duties required of him or her by this code;

**7.5.2**

ensure that, during the installation, removal, maintenance, repair, relocation, translocation and operation of industrial radiography equipment where he or she has responsibility for radiation safety, each radiation worker who may be exposed to radiation in the course of these operations uses appropriate radiation monitoring devices, including a personal radiation monitoring device, a survey meter and a personal dosemeter issued for the worker's exclusive use;

**7.5.3**

be familiar with:

- the requirements of the relevant legislation regarding industrial radiography equipment;
- the provisions of this code;
- the radiation monitoring and protective equipment in use to meet the requirements of this code;
- the nature and physical appearance of any gamma-radiography sources for which he or she has radiation protection responsibility; and

- the detailed working rules and emergency procedures approved for use in accordance with this code, and

participate in the development and revision of working rules and emergency procedures, as necessary;

**7.5.4**

train and instruct the operator of industrial radiography equipment, and the operator's assistants, as necessary, in the safe use of the equipment and in appropriate radiation safety practices;

**7.5.5**

ensure that all necessary personal radiation monitoring devices and radiation survey meters are available and are in good working order, and that the survey meters are calibrated, on a regular basis, for the energy range of the radiation in use;

**7.5.6**

ensure that personal dosemeters are issued, as necessary, used properly, collected and assessed. The Radiation Safety Officer shall seek the advice of the statutory authority regarding detailed conditions for use of such devices;

**7.5.7**

ensure that personal dosemeters are promptly submitted for assessment after use, in accordance with the requirements of the statutory authority, and that reported doses are recorded and kept;

**7.5.8**

ensure that personal dosemeters known or reasonably suspected to have received either a dose in excess of 5 mSv whilst being worn or an unusual dose while not being worn are assessed promptly. If being returned to a personal radiation monitoring service for assessment, the service shall be advised of the circumstances of the exposure;

**7.5.9**

carry out radiation surveys, of a scope and frequency acceptable to the statutory authority, to ensure that safe practices are being followed at the sites for which he or she is responsible;

**7.5.10**

ensure that personal radiation monitoring equipment, survey meters, source containers, shutters and source control mechanisms, X-ray equipment indicators and interlocks, enclosed and partially enclosed site interlocks and area monitors, and other appropriate equipment related to radiation safety are inspected and tested regularly;

**7.5.11**

ensure:

- that the details required by 7.4.2 of the movement of gamma-radiography and/or X-radiography radiation sources are recorded in the Radiation Source Movement Record Book which shall be kept in a safe place; and
- that a copy of the current location of all gamma-radiography sources shall be kept in the store at all times. This latter requirement may be met, for example, by keeping a chart in the store on which is listed each gamma-radiography source, its current location, the date of its removal from the store and the name of the operator responsible for it;

**7.5.12**

ensure that the storage requirements of 4.1 are met;

**7.5.13**

by monitoring at appropriate intervals, ensure that gamma-radiography equipment is correctly stored with the sources located in the fully shielded position and that dose rates within a store do not exceed those permitted in 4.2;

**7.5.14**

ensure that the monitoring requirements of 4.3 for the safe transport of industrial radiography sources are met;

**7.5.15**

select, with the approval of the statutory authority, survey meters to meet the requirements of 8.1; and

**7.5.16**

carry out such extra duties as are necessary to meet the requirements of 9.5 or 4.3.

# SECTION 8 RADIATION MONITORING AND OPERATIONAL EXPOSURE LIMITS

## 8.1 Monitoring equipment

The owner of industrial radiography equipment, after seeking advice from the statutory authority, shall ensure that sufficient radiation monitoring devices in good condition are continually available and that they are used in accordance with the following requirements.

Personal radiation monitoring devices shall be issued to operators, assistant operators and Radiation Safety Officers for whose radiation safety the owner is responsible and who are involved in installing, operating, removing or servicing (if authorised to do so) industrial radiography equipment. Integrating electronic dosemeters (IEDs) which also emit an audible tone and which meet the requirements of 8.1.4 may be used as personal radiation monitoring devices.

### 8.1.2

Film badge dosemeters or thermoluminescent dosemeters (TLDs) which are available from personal radiation monitoring services in Australia (see annexe II), or other approved dosimetry devices (for example, IEDs), shall be used for determination of radiation exposure received by operators, assistant operators and Radiation Safety Officers for whose radiation safety the owner is responsible and who are involved in installing, operating, removing or servicing (if authorised to do so) industrial radiography equipment. These devices will be referred to collectively as personal dosemeters and the user should seek the advice of the statutory authority if he wishes to use monitoring devices other than film badges or TLDs.

### 8.1.3

Portable survey meters, of appropriate energy response, shall be used to monitor the radiation levels in the vicinity of industrial radiography equipment, whenever the equipment is energised in the case of X-radiography equipment, and when in both source exposed and source shielded conditions in the case of gamma-radiography equipment. Portable survey meters should be capable of continuous operation without the need to continuously depress a switch or button.

**8.1.4**

Personal radiation monitoring devices shall:

- be capable of responding to the range of energies of the radiation emitted by the industrial radiography sources for which they are used; and
- continue to give a maximum audible response when exposed to very high radiation dose rates, that is, dose rates in excess of 500 mGy/h in air.

**8.1.5**

Survey meters provided for surveillance of areas and source containers shall meet the following requirements:

- they shall have sufficient measurement range to measure radiation levels at least throughout the ranges of 1 μSv/h or its equivalent to 10 mSv/h or its equivalent for the radiations emitted from the radiation sources under the control of the owner or operator;
- when radiation levels exceed the maximum readings in their measurement ranges, they shall continue to indicate that fact and should provide an audible warning; and
- they shall indicate the measured quantity with a. measurement uncertainty not greater than ±25 per cent, inclusive of uncertainty due to response variation with energy over the range of energies of the radiation to be measured.

**8.1.6**

Radiation survey meters referred to in this section shall be checked and calibrated prior to initial use and at intervals not exceeding twelve months or following damage or repairs. Calibrations shall be made appropriately for the types and energies of the radiations to which the meter will be exposed. Calibration certificates will be acceptable to the statutory authority only when issued by a person or organisation recognised by the statutory authority as competent for the purpose.

## 8.2 Recommended operational limits of dose rate

The dose limits given in the Radiation Protection Standards (1.6) shall not be exceeded in the use of industrial radiography equipment. For purposes of planning in areas near industrial radiography equipment the following dose rates are recommended for application as maximum permitted levels caused by industrial radiography equipment:

**8.2.1**

at places regularly occupied by operators of industrial radiography equipment, or other radiation workers: 25 μSv/h or equivalent, with dose rates being kept as low as practicable; and

**8.2.2**

at places regularly occupied by members of the public exposure levels should be as low as reasonably achievable and shall be such that the dose received by any individual in a year does not exceed 1 mSv.

## 8.3 Accidental and emergency exposures

**8.3.1**

Malfunction of equipment, failure to observe working rules or some cause not within the control of the owner or operator may result in the exposure of one or more persons to radiation. Furthermore, unnecessary exposure of personnel may occur prior to the discovery of an incident. Following any immediate emergency action taken in accordance with 9.5 to isolate the source of radiation from persons who might otherwise be exposed, the statutory authority shall be informed forthwith that an incident has occurred and shall be consulted to determine action following such an occurrence, and planning shall be undertaken to determine appropriate emergency and corrective procedures.

**8.3.2**

It may be necessary for one or more persons to receive a radiation dose in carrying out emergency procedures necessary to bring an incident under control and restore the situation to normal. In most cases it should be possible to bring an incident involving industrial radiography equipment under control in such a way that the following doses are not exceeded during that operation:

- 5 mSv whole body dose; and
- 50 mSv to the hands and forearms, or feet and ankles.

These maximum dose levels are recommended as a guide in planning emergency procedures.

### 8.3.3

The statutory authority shall be informed forthwith of the steps taken to bring an incident under control. Details of any radiation exposures known, or suspected, to have occurred shall also be given. If, following assessment of doses to those involved in the incident, any person is found to have received an effective dose equivalent in excess of 5 mSv, a written report shall be provided to the statutory authority in accordance with its requirements, giving details of the exposure and of the dose assessments made.

# SECTION 9 PROCEDURES

## 9.1 Authorised use of equipment

Industrial radiography operations shall be carried out only by persons licensed to do so by the statutory authority. Under no circumstances shall untrained or inappropriately qualified or unauthorised persons attempt to use, remove, maintain, adjust, modify or in any way interfere with industrial radiography equipment.

## 9.2 Working rules - general

### 9.2.1

Working rules set out detailed and specific procedures for each industrial radiography practice to ensure the safety of all persons from radiation. The owner shall ensure that working rules are prepared for the industrial radiography procedures for which he or she has responsibility, that they are submitted to the statutory authority for approval, and that they are followed by the operator and assistant operator.

### 9.2.2

In preparing working rules for the safe use of industrial radiography equipment, consideration shall be given to all aspects of the planned radiography procedure which require supervision or control, including:

- the use of handling equipment and source containers used in gamma-radiography;
- the operation of source, shutter or X-ray beam activation controls and interlocks;
- the methods for checking the movement and position of a source or the direction of a beam;
- the use of beam collimating and shielding devices;
- the security and control of industrial radiography equipment, including the locking of source containers or X-ray generators when not in use;
- the regular updating of the Radiation Source Movement Record Book;
- the types and occasions for use of radiation monitoring devices, including the steps to be taken in the event of failure of a survey meter;

- the methods of conducting radiation surveys and the occasions on which such surveys will be carried out;
- the regular inspection of all equipment, including source containers, handling devices, interlocks, survey meters, personal radiation alarm monitors, alarms, labels and notices, so as to ensure operational effectiveness;
- arrangements for the safe transport of industrial radiography equipment; and
- steps to be taken in the event of an emergency.

**9.2.3**

A second person, who is capable of promptly taking charge in an emergency, shall be immediately available to assist during industrial radiography exposures at an open site or a partially enclosed site. This person shall be able to:

- ensure that no person remains unnecessarily in an area where the dose rate exceeds or might exceed 25 μSv/h;
- use the source control equipment or any other means at his or her disposal to render the source safe, or to disconnect power from the X-ray tube;
- use a radiation survey meter in order to confirm the situation;
- recognise a loose gamma-radiography source by being familiar with the dummy source (or its photograph) supplied with the gamma-radiography equipment; and
- inform the Radiation Safety Officer and the owner of the circumstances of the emergency without delay.

This person shall not be in charge of operations at an adjacent site unless scheduling arrangements are made such that he or she is not simultaneously responsible for an exposure taking place at the adjacent site.

## 9.3 Working rules - examples

Illustrative working rules for a fully enclosed site, a partially enclosed site, and an open site are given in annexe VII. These should be used only as a guide for developing specific working rules for a particular site.

## 9.4 Radiation monitoring

### 9.4.1

Radiation levels 5 cm from the surface of radioactive source containers shall be measured by the Radiation Safety Officer or another competent person:

- on delivery of the source from the supplier;
- on removal from and return to the store;
- on arrival at the site;
- before and after a source container is moved within the site (except for re-positioning during exposure sequences);
- after each exposure to ensure that the source has returned to its fully shielded position;
- following any emergency incident;
- after source replacement; and
- otherwise at intervals not exceeding three months.

The first of these measurements shall be recorded in the Radiation Source Movement Record Book and any significant change found in subsequent measurements shall be recorded and investigated.

### 9.4.2

Areas which may be occupied by persons during normal operations, maintenance or storage of radioactive source containers shall be surveyed at an appropriate frequency to ensure that no person is exposed to radiation unnecessarily.

## 9.5 Emergency procedures

### 9.5.1

A sufficient number of radiation survey meters and other appropriate equipment shall be available at all times to allow the following emergency procedures to be carried out without delay.

### 9.5.2

In the event of an emergency, any necessary action to allay panic should be taken. The radiation hazard in such situations can be exacerbated by hasty, ill-considered action. It may be prudent, for example, not to rush to the immediate aid of injured parties if the consequence would be an unnecessary over-exposure of the rescuer or rescuers; it may be possible to reduce the hazard first or to limit the number of people who need to risk exposure.

**9.5.3**

A distinction should be made between emergency action necessary to reduce an immediate hazard and remedial action required to return a situation to normal.

A rapid assessment of the nature and scope of the hazard should be made and any persons exposed or thought to be exposed required to leave the area immediately or, in the case of personnel whose continued presence is essential to the safety of other persons from industrial processes which may be in progress in the area, as soon as is practicable. In the latter case, the operator should consult with the personnel responsible for the safety of the industrial process in deciding whether a radiation hazard or an industrial hazard poses the greater threat.

Then the radiation level should be determined, either by direct measurement or by rule-of-thumb. For example, the approximate dose rate 1 m from an exposed source of the types specified in 2.1.3 is given in the table.

| Source | Dose rate at 1 m (mSv/h per TBq) |
|---|---|
| $^{60}Co$ | 350 |
| $^{192}Ir$ | 130 |
| $^{169}Yb$ | 30 |

Then appropriate action should be planned and executed to remedy the situation.

**9.5.4**

In all cases where an incident involving a radiation source has occurred, the Radiation Safety Officer shall be informed forthwith, and the requirements of the statutory authority for the reporting of incidents shall be met.

### 9.5.5 Gamma-radiography

#### 9.5.5.1

In general, the statutory authority should be consulted before any remedial action is taken. If people can be removed from the site of the incident to safe locations, such that no exposure limits will be exceeded, then there should be no urgency for immediate remedial action.

Similarly, if a person experienced in handling radiation emergencies is not available to advise, then, apart from ensuring that no unnecessary exposure of people is occurring, remedial action should be taken only after consultation with the statutory authority.

#### 9.5.5.2

In the event of remedial action being taken, each person shall be thoroughly familiar with his or her own responsibilities, so that no protective measures will be left undone through one person thinking it is another's responsibility. It is also important that there should be a clear line of command and that it should be kept as simple as possible. Each person who is required to manipulate sources during an incident, or who is in any way employed in a process which may involve the use of (or transportation of) sources during an incident, shall receive specific instructions and training from the Radiation Safety Officer.

#### 9.5.5.3

For incidents where the only damage is to the source container, collimator and/or guide tube, the source shall be returned to the container as soon as practicable. This shall be confirmed by monitoring from the source control position. If the damage is such that this is not possible (which shall be confirmed by monitoring), a boundary around the area shall be established in accordance with 6.3.2 and all unauthorised persons excluded.

#### 9.5.5.4

If damage to the source capsule, with possible loss of radioactive material is suspected (either through severe damage to the source container or for some other reason), a temporary boundary around the area shall be established in accordance with 6.3.2 and all unauthorised persons excluded. The Radiation Safety Officer shall:

- ensure that any persons who could have been contaminated with radioactive material remain under observation until monitored and cleared;

- not undertake remedial action without consulting the statutory authority and shall advise the statutory authority of the situation forthwith;
- check for contamination outside the temporary boundary and, if necessary, re-locate the boundary to meet the requirements of 6.3.2; and
- by reconstructing events, ascertain whether any persons have received a radiation dose.

**9.5.5.5**

In the event of a source becoming free of its container, collimator or guide tube, but not otherwise damaged, it shall not be left unattended. A boundary around the area shall be established in accordance with 6.3.2 and all unauthorised persons excluded. A rapid assessment of the nature and scope of the radiation hazard shall be made by the Radiation Safety Officer, who shall then decide, after consultation with the statutory authority, if necessary, what procedures shall be adopted to return the source to its container. Until this is done, it may be necessary to:

- erect a temporary radiation shield around the source using whatever material is available to substantially attenuate the radiation;
- remove all persons to an area where the dose rate does not exceed 25 μSv/h, except when the safety of an industrial process may require some personnel to remain on station until the process can be shut down or made safe (see 9.5.3); and
- establish and maintain adequate control over access to the area.

Illustrative emergency procedures are outlined in annexe VIII.

**9.5.5.6**

The operator shall notify the owner forthwith of the occurrence of the incident, giving a clear and concise account of the circumstances of the incident, of the action taken and of any assistance required. A written report shall follow.

**9.5.5.7**

If a source is lost or the radiation dose to any person as a result of an incident may have been greater than 5 mSv, the owner shall:

- immediately report the incident to the statutory authority (a detailed written report shall follow [see 8.3.3]); and

- submit the personal dosemeters of the radiography workers concerned in the incident for immediate assessment.

Illustrative emergency procedures are outlined in annexe VIII.

**9.5.5.8**

The owner or Radiation Safety Officer shall inform the statutory authority forthwith of the circumstances of the incident and of any special course of action which he or she proposes to adopt to restore the situation to normal following an incident. Unless either the owner or the Radiation Safety Officer has been directly informed to the contrary, neither shall assume that the other has notified the statutory authority. In addition, any special medical examinations required by the statutory authority shall be provided at the owner's expense.

**9.5.5.9**

The owner shall take all possible and necessary steps to prevent similar incidents from occurring.

**9.5.5.10**

In the event of a gamma-radiography source being in an area involved in a fire, the following procedures should be followed:

(i) If the fire occurs while the source is exposed during radiography and the control unit can be approached:

  - the source shall be wound back into the container and locked in the fully shielded position. This shall be verified using a survey meter;
  - if conditions permit, the container shall be removed from the immediate area; and
  - the container shall then be placed in a secure location until the emergency is over.

(ii) When the exposed source cannot be returned to the source container and the source will be subject to elevated temperatures, the operator or Radiation Safety Officer shall:

  - ensure that a temporary boundary about the source is identified beyond which entry of unauthorised persons is forbidden and that a boundary is erected in accordance with 6.3.2 as soon as is practicable, and
  - inform firefighters of the hazards involved if close approach to the exposed source is necessary.

(iii) When a source enclosed in a locked container is subjected to fire, the operator or Radiation Safety Officer shall survey the immediate area to establish dose rates and shall advise firefighters accordingly.

When conditions permit safe approach to the container, the operator or Radiation Safety Officer shall:

- survey the immediate area to ensure that dose rates are less than 25 μSv/h;
- survey the source container to ensure that surface dose rates are as expected; and
- inspect the source container for any structural damage or illegible labelling before returning it to a secure location.

Unless advised by the Radiation Safety Officer that it is not necessary, persons required to enter the area shall wear full protective clothing and breathing apparatus. On leaving the area they shall be checked for radioactive contamination and shower if necessary.

No clean-up or salvage operations shall commence until a radiation survey of the area has been made.

### 9.5.6 X-radiography

#### 9.5.6.1

If an incident involving X-radiography equipment occurs while the X-ray tube is energised, the operator or the operator's assistant shall immediately switch off the power to the X-ray tube or otherwise disconnect the power from the X-ray tube: for example, by removing a plug from the control unit.

#### 9.5.6.2

The operator shall notify the owner forthwith of the occurrence of the incident, giving a clear and concise account of the circumstances of the incident, of the action taken and of any assistance required. A written report shall follow.

#### 9.5.6.3

If the radiation dose to any person as a result of an incident may have been greater than 5 mSv, the owner shall:

- immediately report the incident to the statutory authority (a detailed written report shall follow [see 8.3.3]); and
- submit the personal monitoring dosemeters of the radiography workers concerned in the incident for immediate assessment.

**9.5.6.4**

The owner shall take all possible and necessary steps to prevent any similar incident from occurring.

**9.5.6.5**

In the event of a fire occurring in an area which contains operating X-radiography equipment, the operator or the operator's assistant shall immediately switch off or disconnect power to the X-ray tube and convey this fact to the fire officers.

# SECTION 10 RECORDS, ACCOUNTABILITY AND SOURCE DISPOSAL

## 10.1 Records of industrial radiography equipment and accountability

### 10.1.1 Accountability

The owner of industrial radiography equipment shall be able to account for all radiation sources within his or her control at all times by reference to the Radiation Source Movement Record Book (see 7.4.2) and the records required in 10.1.2.

### 10.1.2 Records of industrial radiography equipment

The owner of gamma-radiography equipment shall maintain records which show the following information for all radioactive sources and source containers within his or her control:

- their date of receipt and the name of the supplier;
- their location and identification numbers;
- the type of radioactive substances in the sources;
- the activities and dates of measurement of the radioactive sources;
- the make, model and identification number of the source container;
- inspection reports and details of repairs, if any; and
- on disposal, the date and manner of disposal.

The owner of X-radiography equipment shall maintain records which show the following information for all X-ray generating equipment within his or her control:

- their location and identification numbers;
- maximum tube potential difference (kV(peak)) and current (mA), or maximum X-ray energy (keV) and maximum output (dose rate);
- generator type, for example single-phase, three-phase, capacitor-discharge, linear accelerator;
- inspection reports and details of repairs, if any; and

- on disposal, the date and manner of disposal.

#### 10.1.3 Transfer of custody

The owner or the supplier shall not transfer the ownership of any industrial radiography equipment unless this is done with the prior approval of the statutory authority.

#### 10.1.4 Audit of radiation sources

The owner of gamma-radiography equipment shall carry out a quarterly audit of radioactive sources and of their locations within his or her control. These records shall be available, at all times, for inspection by the statutory authority. The owner shall make an annual compilation of these audits and shall send an annual audit statement to the statutory authority, and shall state whether, to his or her knowledge, any of the radioactive sources has been replaced in the period.

The owner of X-radiography equipment shall inform the statutory authority annually of details of all X-ray generating equipment, and their locations, within his or her control.

#### 10.1.5 Failure to account for a gamma-radiography or X-radiography source

The owner shall immediately notify the statutory authority if a gamma-radiography or X-radiography source cannot be accounted for.

### 10.2 Disposal of radioactive sources

The user of gamma-radiography equipment shall obtain the approval of the statutory authority before disposing of any radioactive source.

### 10.3 Records of exposures

The owner shall maintain records, as required by the statutory authority, of exposures of employees involved in industrial radiography, including personal monitoring results.

# SECTION 11 GLOSSARY

## 11.1 Absorbed dose

The absorbed dose (D) is the quotient of $d\bar{E}$ by dm, where $d\bar{E}$ is the mean energy imparted by ionizing radiation to matter of mass dm.

$$D = \frac{d\overline{E}}{dm}$$

The unit of absorbed dose is one joule per kilogram and is given the name 'gray' (Gy).

$$1 \text{ Gy} = 1 \text{ J kg}^{-1}$$

[This replaces the rad:

$$1 \text{ rad} = 10^{-2} \text{J kg}^{-1}; 1 \text{ Gy} = 100 \text{ rad}].$$

## 11.2 Activity

The activity (A) of an amount of radioactive nuclide in a particular energy state is the quotient of dN by dt, where dN is the expectation value of the number of spontaneous nuclear transitions from that energy state in the time interval dt.

$$A = \frac{dN}{dt}$$

The unit of activity is one disintegration per second and is given the name 'becquerel' (Bq).

$$1 \text{ Bq} = 1 \text{ s}^{-1}$$

[This replaces the curie:

$$1 \text{ Ci} = 3.7 \times 10^{10} \text{ s}^{-1}; 1 \text{ Bq} = 2.7 \times 10^{-11} \text{ Ci}].$$

## 11.3 Assistant industrial radiographer

Assistant operator (see 11.4)

## 11.4 Assistant operator

A person who assists an operator or who operates industrial radiography equipment under the direct supervision of an operator (see 11.26) and who has successfully completed a suitable course of training.

**11.5 Becquerel** (see 11.2)

**11.6 Capsule**

A sealed envelope of metal or other suitable material that may be used to enclose and prevent leakage of a quantity of a radioactive substance (see 11.35). This envelope may incorporate a means of attachment to a source container (see 11.36) or source control mechanism (see 11.37).

**11.7 Control cable**

A component of a mechanical source control mechanism (see 11.37) which, for shutter type source containers (see 11.36), controls the shutter from a location remote from the source or, for a projection type source container (see 11.36) is a windout cable (see 11.41).

**11.8 Crawler equipment**

Industrial radiography equipment designed to travel automatically or by remote control through pipes; and which contains either a sealed radioactive source or X-ray generating equipment, which is used to radiograph pipeline welds through the pipe wall.

**11.9 Dose**

An abbreviation for both absorbed dose (see 11.1) and dose-equivalent (see 11.10).

**11.10 Dose-equivalent**

The dose-equivalent (H), is the product of D, Q and N at the point of interest in tissue where D is the absorbed dose (see 11.1), Q is the quality factor of the radiation and N is the product of all other modifying factors.

$$H = DQN$$

The unit of dose-equivalent is one joule per kilogram and is given the name 'sievert' (Sv).

$$1\ \text{Sv} = 1\ \text{J kg}^{-1}$$

[This replaces the rem:

$$1\ \text{rem} = 10^{-2}\ \text{J kg}^{-1};\ 1\ \text{Sv} = 100\ \text{rem}]$$

**11.11 Durably marked**

So marked that it is likely to retain this marking in a legible condition for the whole period of its use, including during any foreseeable incident (see 10.21).

### 11.12 Exposure bay

Partially enclosed site (see 11.28).

### 11.13 Exposure container

For the purposes of this code, a source container (see 11.36).

### 11.14 Exposure room

Fully enclosed site (see 11.16).

### 11.15 Field site

open site (see 11.25).

### 11.16 Fully enclosed site

An installation used specifically for industrial radiography in which the irradiation area is completely enclosed by shielding, including walls, floor and ceiling, and within which no person is permitted to remain during exposure.

### 11.17 Gamma-radiation

Penetrating electromagnetic radiation emitted spontaneously from the nucleus of an atom in the process of a nuclear transition.

### 11.18 Gamma source

A radioactive source (see 11.34) that emits gamma-radiation.

### 11.19 Guide tube

A tube, typically of flexible construction, designed to provide an enclosed path along which a radioactive source may be moved from its source container to its exposure position and back again.

### 11.20 Half life

For a single radioactive decay process, the time required for the amount of a radioactive substance to decrease to one half of its original value.

### 11.21 Incident

An unintended occurrence involving a radioactive source (see 11.34) or its source container (see 11.36) or an X-radiography source, or the persons or objects surrounding the source that results or may result in one or more persons receiving an accidental dose (see 11.9) of radiation.

### 11.22 Industrial radiographer

Operator (see 11.26).

### 11.23 Ionizing radiation

For the purposes of this code, gamma-radiation (see 11.17) and X-radiation (see 11.41).

### 11.24 Member of the public

A person who, in the course of his or her employment, has no direct involvement with sources of ionizing radiation. (Such persons may be exposed to ionizing radiation as a result of their employment, but as members of the public they have no choice and receive no benefit from such exposure.)

### 11.25 Open site

A radiography site at which, due to operational requirements, the shielding afforded by a fully enclosed site or a partially enclosed site cannot be provided and for which a clearly marked boundary is set up and strict control of access and occupancy is observed.

### 11.26 Operator

A person who operates industrial radiography equipment and who, having successfully completed a suitable course of training, has the approval of the appropriate statutory authority to do so.

### 11.27 Owner

A person who, or an organisation which, owns a particular industrial radiography equipment or, for the purposes of this code, a person who has administrative responsibility for the use of the equipment.

### 11.28 Partially enclosed site

A radiography site at which all objects exposed to direct radiation are completely contained inside a permanent, shielding enclosure having walls at least 2.1 m high but typically open at the top to permit the transfer in and out of the objects to be radiographed, and within which no person is permitted to remain during exposure.

### 11.29 Personal dosemeter

A device designed to be worn on the person which can be used to measure the total radiation dose received by that person over a period.

### 11.30 Personal radiation monitoring device

A device designed to be worn or carried on the person which gives an audible warning when a radiation dose rate above a predetermined level is detected and which gives an indication of the magnitude of the dose rate by the quality, frequency or repetition rate of the tone emitted.

**11.31 Pigtail**

A component of a projection type source container (see 11.36): a short, flexible cable to one end of which is secured the sealed source or source holder (see 11.38); the other end terminating in a connector which can be coupled to the source control cable (see 11.7).

**11.32 Radiation worker**

A person who, in the course of his or her employment, may be exposed to ionizing radiation arising from his or her direct involvement with sources of such radiation.

**11.33 Radioactive decay**

The process by which the nuclei of the atoms in a radioactive material either undergo spontaneous transformation into other atoms or in which there are spontaneous changes in the energy levels of the nuclei.

**11.34 Radioactive source**

For the purpose of this code, a radioactive source is a sealed (radioactive) source, and means radioactive substance sealed in a capsule or having a bonded cover, with the capsule or cover being strong enough to prevent contact with and dispersion of the substance under the conditions of use and wear for which it was designed.

**11.35 Radioactive substance**

Material that undergoes spontaneous transformation of its nucleus with the emission of ionizing radiation and which, for the purposes of this code, exceeds a prescribed concentration or activity as determined by the statutory authority.

**11.36 Source container**

One of three types of container designed to house a radioactive source (see 11.34) and to provide, through shielding, protection of persons from the high levels of radiation close to the source, and to which a source control mechanism (see 11.37) can be attached.

- A shutter type container fully encloses the radioactive source except during exposure, when the shutter is opened, and in some cases the source is moved to a window, to permit the passage of radiation.

- A projection type container retains the radioactive source in a shielded position except during exposure, when it is propelled from the container along a guide tube (see 11.19) to its exposure position.

- A projection-shutter type container combines features of both of the above types.

### 11.37 Source control mechanism

A system or device that operates a shutter and/or projection mechanism on a source container (see 11.36) by remote control. Such a control mechanism may operate mechanically, electrically or pneumatically, and includes a device to lock the shutter in the closed position or to lock the source in its shielded position.

### 11.38 Source holder

A mechanical holder for a sealed radioactive source (see 11.34). When the capsule of a sealed source, as supplied by the manufacturer, is not in a suitable mechanical form for direct manipulation by source handling equipment, a source holder may be required for that purpose (see also 11.31).

### 11.39 Supplier

A person or organisation that transfers industrial radiography equipment or a radioactive source to another person or organisation.

### 11.40 Survey meter

A hand-held instrument which measures radiation dose rate.

### 11.41 Windout cable

A control cable (see 11.7) which can be attached to a projection type source container (see 11.36) to move the radioactive source (see 11.34) through a guide tube (see 11.19) between its fully shielded position and its exposure position, and which can be wound out and in from a location remote from the source.

### 11.42 X-radiation

Penetrating electromagnetic radiation produced by high energy electrons striking matter.

### 11.43 X-ray equipment

Device for producing X-radiation by accelerating electrons through a high potential difference onto a target, and including the high potential generator, the X-ray tube or target assembly and its housing, and associated controls.

# ANNEXE I STATUTORY AUTHORITIES WITHIN AUSTRALIA

Where advice or assistance is required from the relevant statutory authority, it may be obtained from the following officers:

1. AUSTRALIAN CAPITAL TERRITORY

| | |
|---|---|
| Director<br>Radiation Safety Section<br>ACT Board of Health<br>GPO Box 825<br>CANBERRA ACT 2601 | Telephone: (06) 247 2899<br>Fax: (06) 257 3503 |

2. NEW SOUTH WALES

| | |
|---|---|
| Officer-in-Charge<br>Radiation Health Services<br>Department of Health<br>PO Box 163<br>LIDCOMBE NSW 2141 | Telephone: (02) 646 0222<br>Fax: (02) 646 0333 |

3. NORTHERN TERRITORY

| | |
|---|---|
| Director<br>Northern Territory Department<br>of Health and Community Services<br>GPO Box 1701<br>DARWIN NT 5794 | Telephone: (089) 80 2983<br>Fax: (089) 41 0560 |

4. QUEENSLAND

| | |
|---|---|
| Director<br>Division of Health and Medical<br>Physics<br>Department of Health<br>450 Gregory Terrace<br>FORTITUDE VALLEY QLD 4006 | Telephone: (07) 252 5446<br>Fax: (07) 252 9021 |

5. SOUTH AUSTRALIA

| | |
|---|---|
| Director<br>Radiation Protection Branch<br>South Australian Health Commission<br>PO Box 6, Rundle Mall<br>ADELAIDE SA 5000 | Telephone: (08) 226 6520<br>Fax: (08) 226 6255 |

6. TASMANIA

| | |
|---|---|
| Senior Health Physicist<br>Department of Health<br>GPO Box 191B<br>HOBART TAS 7001 | Telephone: (002) 30 6421<br>Fax: (002) 31 0735 |

7. VICTORIA.

| | |
|---|---|
| Chief Radiation Officer | Telephone: (03) 616 7084 |
| Radiation Safety Section | Fax: (03) 616 7147 |
| Health Department Victoria | |
| 555 Collins Street | |
| MELBOURNE VIC 3000 | |

8. WESTERN AUSTRALIA

| | |
|---|---|
| The Director | Telephone: (09) 389 2261 |
| Radiation Health Section | Fax: (09) 381 1423 |
| Health Department of | |
| Western Australia | |
| Verdun Street | |
| NEDLANDS WA 6009 | |

For after hours emergencies only, the Police will provide the appropriate emergency contact number.

# ANNEXE II PERSONAL RADIATION MONITORING SERVICES WITHIN AUSTRALIA

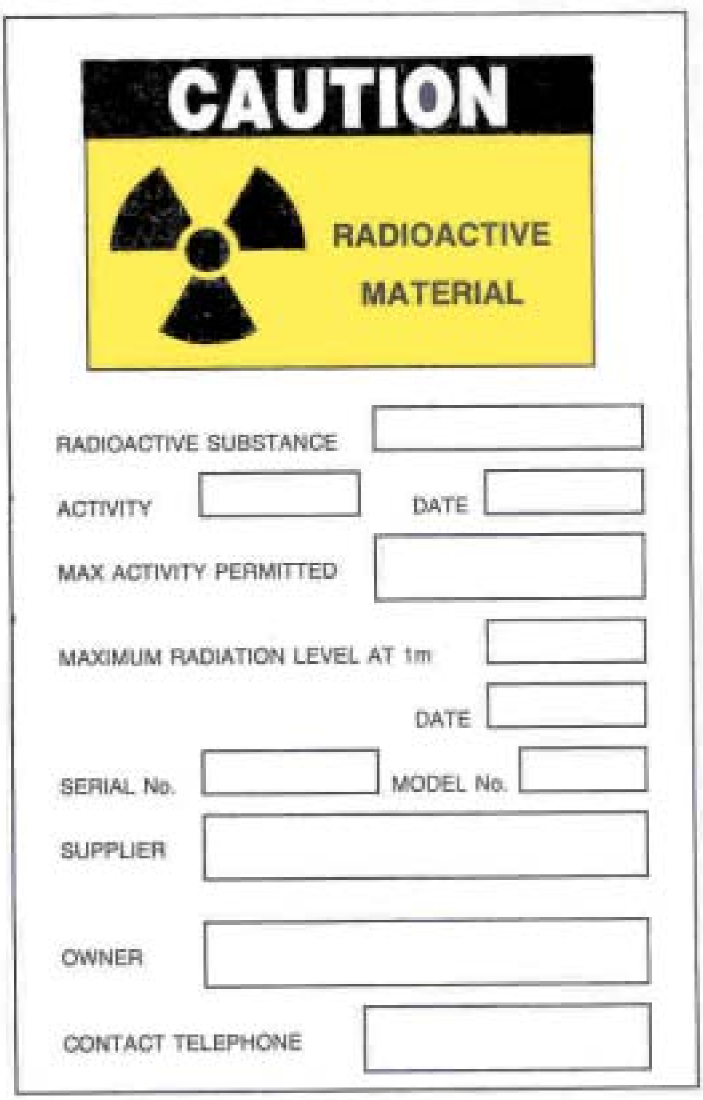
Personal radiation monitoring services within Australia are operated by the following organisations:

| | | |
|---|---|---|
| 1. Australian Radiation Laboratory<br>Lower Plenty Road<br>YALLAMBIE, VIC. 3085 | Telephone:<br>Fax: | (03) 433 2211<br>(03) 432 1835 |
| 2. Radiation Health Services<br>N.S.W. Department of Health<br>P. O. Box 163<br>LIDCOMBE, N.S.W. 2141 | Telephone:<br>Fax: | (02) 646 0222<br>(02) 646 0333 |
| 3. Division of Health and Medical Physics<br>Qld Department of Health<br>450 Gregory Terrace<br>FORTITUDE VALLEY QLD 4006 | Telephone:<br>Fax: | (07) 252 5446<br>(07) 252 9021 |
| 4. Radiation Health Section<br>Health Department of W.A.<br>G P O Box X2307<br>PERTH, W.A. 6001 | Telephone:<br>Fax: | (09) 389 2260<br>(09) 381 1423 |

Users in other States should seek advice from their local statutory authority.

## ANNEXE III RADIATION WARNING LABELS AND NOTICES

III.1 Example of sign suitable for attachment to gamma-radiography equipment containing a radioactive source.

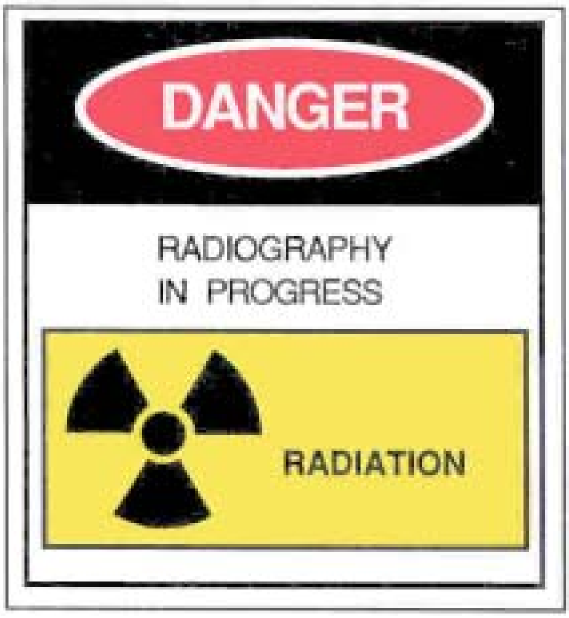



Colours. The panel containing the words "RADIOACTIVE MATERIAL" and the trefoil symbol shall have a yellow background and the lettering and trefoil shall be black. The lower part may be unpainted metal with lettering in black.

III.2 Example of a suitable notice for a store for radioactive sources.


Colours. The lettering and trefoil shall be black on a yellow background.

III.3 Example of a suitable warning sign for display during exposure at an industrial radiography site.




Colours. The sign shall have black lettering on a white background except that:

- the upper panel shall contain the word 'DANGER' in white letters on a red oval and the red oval shall be placed on a black rectangle with a white line surrounding the oval; and
- the lower panel shall contain the word 'RADIATION' and the trefoil symbol in black on a yellow background with a black border.

# ANNEXE IV ANNUAL DOSE-EQUIVALENT LIMITS*

IV.1 Annual dose-equivalent limits: whole body

The annual dose-equivalent limits for the whole body are defined for stochastic effects only.

Radiation worker: 50 mSv
Member of public: 1 mSv

Notes

(a) These limits apply both to uniform irradiation of the whole body and to the weighted mean of the doses to individual tissues. For external irradiation, when the dose distribution is unknown, the limits apply to the deep dose-equivalent index.#

(b) No dose-equivalent limits are recommended for populations but application of the dose-equivalent limits for members of the public, as well as observance of the principles underlying the determination of radiation protection standards*, is likely to ensure that the average dose-equivalent to individuals in a population will not exceed 0.5 mSv per year.

(c) For a member of the public, a subsidiary limit of 5 mSv per year may be used for a number of years provided that the dose averaged over a lifetime does not exceed 1 mSv per year.

IV.2 Derived annual dose-equivalent limits: body organs or tissues when irradiated singly

The derived annual dose-equivalent limit in mSv, for any part of the body listed, is taken as the stochastic or non-stochastic limit, whichever is the lower. The higher value is therefore shown in brackets as a reminder that it should not be used as the limit in practice[a].

---

* For full details refer to the radiation protection standards (IX.1) and to the International Commission on Radiological Protection publication No. 26 (IX.6).

\# The deep dose-equivalent index ($H_{I,d}$) at a point is the maximum dose-equivalent at a depth of 1 cm or more within a 30 cm diameter sphere centred at this point and consisting of material equivalent to soft tissue with a density of 1 g $cm^{-3}$.

| | Radiation worker | | Member of the public | |
|---|---|---|---|---|
| **Part of body** | **Stochastic** | **Non-stochastic** | **Stochastic** | **Non stochastic** |
| gonads | 200 | (500) | 20 | (50) |
| breast | 333 | (500) | 33 | (50) |
| red bone marrow | 417 | (500) | 42 | (50) |
| lung | 417 | (500) | 42 | (50) |
| thyroid | (1670) | 500 | (167) | 50 |
| bone surfaces | (1670) | 500 | (167) | 50 |
| lens | - | 150 | - | 50[(b)] |
| other single organ | (833) | 500 | (83) | 50 |
| skin | - | 500 | - | 50 |
| hands and forearms | - | 500 | - | 50 |
| feet and ankles | - | 500 | - | 50 |

Note

(a) For example, the weighting factor for the thyroid is 0.03, therefore, the implied stochastic limit for the thyroid would be 50/0.03 = 1670 mSv, but as this exceeds 500 mSv, it is discarded and the limit 500 mSv used instead.

(b) This figure appears as 15 mSv in the NHMRC *Recommended radiation protection standards for individuals exposed to ionising radiation,* but was modified to 50 mSv at the 100th Session of Council, November 1985 (see annexe IX).

# ANNEXE V BIOLOGICAL EFFECTS OF IONIZING RADIATIONS AND LIMITS ON EXPOSURE TO SUCH RADIATIONS

Note: This statement provides background information. Not all of it is relevant to this code.

Considerable knowledge has been gained during this century, and particularly during the past three decades, on the possible biological effects of ionizing radiation on man. When such effects manifest themselves in the exposed individual, they are referred to as somatic effects; when they arise in the descendants of the exposed individual, they are referred to as hereditary effects. It is important to recognize, however, that many of the biological effects that can be caused by ionizing radiation may also result from exposure to other agents and it is not always possible to determine the cause of an effect.

Man has always been exposed to radiation from terrestrial sources, from cosmic radiation and from radionuclides deposited in the body. This natural background radiation varies from place to place on the earth, but generally results in individuals receiving about 2 millisievert (mSv)* per year on average, although there are a few places where the terrestrial levels are very much higher than elsewhere. The levels of exposure to this radiation are such that it is not possible to ascribe any of the ill-effects in man specifically to natural background radiation. On the other hand, radiation-induced effects have been observed in man when individuals have been exposed to very large radiation doses and it is from such doses that our knowledge of biological effects from radiation exposure is derived.

Injury to tissue became evident in the past from a number of different sources - for example, as a result of using radium luminous compounds for painting dials on watches and instruments, many workers developed bone sarcoma; some miners working in uranium mines developed lung cancer; some radiologists developed skin erythema and leukaemia when not using adequate protection; and there was a small excess of leukaemia and other malignant diseases above the normally expected incidence rates among survivors of the atomic bombs in Hiroshima and Nagasaki in Japan following exposure to radiation. In all the above examples, and there are many more demonstrated radiation-induced effects, the doses received by individuals were very large - many times the doses arising from natural background radiation.

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* The sievert is the unit used in radiation protection for dose equivalent and is equal to 100 rem. 1 mSv = $10^{-3}$ Sv: 10 mSv = 1 rem.

The effects arising from large radiation doses are well known and many studies have been undertaken in order to correlate radiation-induced effects with smaller doses. However, it has not been possible to confirm that the incidence of effects is directly related to the doses received as the statistics available for such studies have been inadequate. Accordingly, studies have been carried out on animals and plants to determine if there is any correlation with them between effects and dose delivered and dose rate. It has been shown that the incidence of many biological effects produced is related to the total dose delivered, whilst for other effects, there appear to be threshold doses below which those effects may not occur. Whilst it is not possible in all cases to extrapolate the results of these studies to man, they serve a very useful purpose in identifying possible dose-effect relationships.

The effects arising from exposure to ionizing radiation fall into two categories. Stochastic effects are those for which the probability of an effect but not the severity of the effect is regarded as a function of the dose to which the individual is exposed. It is considered that there is no threshold dose below which the probability of such an effect occurring is zero. On the other hand, non-stochastic effects are those for which the severity of the effect varies with the dose to which the individual is exposed and a threshold may occur, below which such an effect does not occur.

From the studies undertaken it is known that the induction of malignancies, including leukaemia, is a stochastic effect of radiation, although such malignancies may not become manifest until many years after the radiation exposure. Mutagenic effects are also stochastic effects and these may be propagated through the population for many generations. Defects arising from such mutations are only likely to become apparent in the first or second generation following irradiation of an individual. A defect causing slight physical or functional impairment, and which may not even be detectable, will tend to continue in the descendants, whereas a severe defect will be eliminated rapidly through the early death of the zygote or of the individual carrying the defective gene. The risk of mutagenic effects arising will decrease with increasing age of the irradiated individuals due to their decreasing child expectancies with age.

Non-stochastic effects are specific to particular tissues, for example, non-malignant damage to the skin, cataract of the eye, gonadal cell damage leading to impaired fertility etc. For many of these effects a minimum or threshold dose may be required for the effect to be manifest. If an individual receives a dose greatly in excess of the threshold dose, the manifestation of the effect will occur in a relatively short period after the irradiation. However, if the dose is not greatly in excess of the threshold dose, many of the resulting effects will be of a temporary nature and reversion to normal conditions usually occurs.

From our knowledge of biological effects arising from exposure to radiation, it is possible to identify the risks of stochastic effects occurring with the doses received by the various organs and tissues of the body. These risks are derived from exposure of persons to very high doses and from studies on animals etc. As there is very little information on the effects of exposure to low doses, it is cautiously assumed that risk is directly proportional to dose, right down to zero dose and that there is no threshold below which these effects do not occur. These assumptions may lead to overestimates of the risks associated with exposure to low doses of radiation. Although the risks derived from such assumptions may be very small, it is important that they are kept As Low As Reasonably Achievable (referred to as the ALARA principle) and that there be a demonstrated net benefit for each exposure.

Radiation protection is concerned with the protection of individuals involved in various radiation practices as well as with the protection of members of the public. It recognises that various practices involving radiation exposure are necessary for the well-being of individuals and for the good of mankind. In undertaking such practices individuals, as radiation workers or as members of the public, may be irradiated and the exposure resulting from those practices must be minimised in accordance with the ALARA principle. Good radiation protection practice requires the setting of standards for occupational exposure and these arc such that the risk of fatalities arising from radiation-induced malignancies from the average doses received in such exposure is no greater than the risk of fatalities arising in other occupations that have high standards of safety. Radiation protection standards have been prepared for the National Health and Medical Research Council (IX.1, IX.2) for use in Australia and are based on the recommendations of the International Commission on Radiological Protection (IX.6, IX.7). They assume for stochastic effects a linear relationship between risk and dose and that there is no threshold dose below which effects do not occur. For non-stochastic effects relating to specific organs, the standards set a limit on the dose received, below which such effects would not be manifest. The limit given in the radiation protection standards for an organ is the lower limit of that derived for stochastic effects and that derived for non-stochastic effects when that organ is the only irradiated organ.

For purposes of radiation protection, the limits given in the standards are specified in terms of annual dose-equivalent limits. For whole body exposure, the annual limit for radiation workers is 50 mSv (or 50,000 μSv). In certain circumstances, it is possible that only partial exposure of the body occurs or that single organ exposure occurs. In these circumstances, limits are prescribed such that the risks associated with partial body exposure or with single organ exposure are the same as the risk with uniform whole body exposure. Accordingly higher limits are prescribed for these circumstances.

When exposure is from external sources only, the doses received can be determined by the use of personal dosemeters which give the doses received by the body at the point of wearing them. From the everyday point of view, it is not convenient to determine from the dosemeter reading the dose to the whole body or to specific organs. In practice if the annual dose for an individual, as determined from the dosemeter results, does not exceed 50 mSv, then the dose-equivalent limits for the whole body and for the various organs will not be exceeded provided the dosemeter has been worn on the body such that it would most likely have received the highest dose to the body.

Although the standards prescribe limits on an annual basis only, it is useful to ensure that doses reported for personal dosemeters do not exceed 1000 μSv per week (or 4000 μSv per four-weekly period). By this means it will become obvious during a year if there is any real likelihood of the annual limits either being approached or exceeded.

In determining the total dose-equivalent received from occupational exposure, exposures from normal natural background radiation or from radiological procedures to the individual (including radiodiagnosis, dentistry, radiotherapy and nuclear medicine) are not to be included. The standards make provision for special limits in circumstances involving planned special exposures. They recognise that limits cannot be set for emergency or accidental exposures, but that attempts must be made to assess as carefully and as quickly as possible the dose-equivalents received in those situations so that any necessary remedial action can be taken.

The radiation protection standards do not make any special provisions for females of reproductive capacity. However, they state that when a pregnancy is confirmed (and this would normally be within a period of two months), arrangements should be made to ensure that the woman works only under such conditions that it is most unlikely that doses received during the remainder of the pregnancy would exceed three-tenths of the pro-rata annual dose-equivalent limits for occupationally exposed persons.

For members of the public, the principal limit is that the annual dose-equivalent to an individual member of the public shall not exceed 1 mSv, not counting natural background radiation or radiation received as a patient undergoing radiological procedures. A subsidiary limit of 5 mSv in a year is permissible for some years, provided that the average annual dose-equivalent over a lifetime does not exceed 1 mSv. The non-stochastic dose-equivalent limit for each of the skin and the lens of the eye is 50 mSv in a year for members of the public (IX.2, IX.7).

# ANNEXE VI GUIDE TO LIMITING THE RADIATION EXPOSURE OF INDIVIDUALS

Note: This statement provides background information.

The code specifies practices designed to ensure that unnecessary exposure of persons to ionizing radiation is avoided and that all exposures are kept as low as reasonably achievable. In general there are three basic methods to limit radiation doses to persons:

- increase the distance between the source of radiation and the persons exposed:
- provide suitable shields between the source of radiation and the persons exposed; and
- restrict the time of exposure of the persons.

These methods are briefly discussed below with some supplementary control methods outlined in clauses VI.4 and VI.5.

## VI.1 Increase of distance from a radioactive source

The radiation level adjacent to a radioactive source decreases as the distance from the source increases. When sources of radiation are small in physical dimensions, as is often the case, the decrease in radiation level follows an inverse square law with distance. That is, if $I_1$ and $I_2$ are the radiation levels at distance $d_1$ and $d_2$ from the. radioactive source,

$$I_1 = I_2 \times \frac{{d_2}^2}{{d_1}^2}$$

If the radiation level at 1 metre is 100 mGy/h, by this formula it will be 1 mGy/h at 10 metres and 25 μSv/h at about 60 metres from the radioactive source. The application of this principle is of great utility in reducing radiation doses from radioactive sources. Thus the external dimensions of a housing or source container, whether or not it incorporates shielding material, are significant in determining the radiation level at all accessible points.

In general, staying a sufficient distance from the radioactive source is often the most economical and practical method of limiting radiation exposure.

## VI.2 Shielding

For each type of radiation, materials are available that provide shielding against such radiation (that is, significant absorption or attenuation of it), leading to reduction of the radiation levels beyond the shield. For gamma and X-radiation, materials of high atomic number are most useful and efficient. Thus lead, tungsten and depleted uranium are often of the most use in the construction of source containers for gamma sources. Where space and weight considerations do not apply, materials of lower atomic number, such as concrete and brick, may be used. The thickness required will be very much greater than for the metals listed above. The statutory authority should be consulted concerning appropriate shielding thicknesses and materials. Some information is given inside the back cover.

## VI.3 Restriction of time of exposure

If the radiation level at an occupied place is too high to meet, under conditions of continuous occupancy, the occupational dose limits laid down in this code, the time of exposure of persons to that radiation level may be so limited that the doses received by each person in a year are not in excess of those limits.

## VI.4 Supplementary methods of control

Supplementing the general methods of limiting radiation doses described in VI.1, VI.2 and VI.3 of this annexe are the following methods:

- the display of signs warning of the presence of radioactive sources (see annexe III); and
- restriction on movement of radioactive material.

## VI.5 Radiation monitoring

The methods of control outlined refer to supervised conditions of work but it is often desirable to check the dose received by employees over a period. Such checks may be regarded as routine control measures to be exercised over an extended period.

Such routine control measures include:

- the regular monitoring of radiation levels in areas of interest; and
- the use of personal dosemeters such as film badges, thermoluminescent monitors and direct-reading personal radiation monitoring devices (direct reading electronic devices) as appropriate, to assess the dose received by an operator under actual conditions of work.

It is important that any radiation monitor used be of the correct design for the type of radiation to be measured and be calibrated at appropriate intervals to ensure reliable results.

# ANNEXE VII ILLUSTRATIVE WORKING RULES

## VII.1 Working rules (example) for a fully enclosed site (exposure room)

The inherent safety of a fully enclosed site affords adequate protection of persons outside during an exposure, provided the following conditions are met.

(a) Only operations for which the fully enclosed site provides adequate shielding shall be carried out. The dose rate shall be periodically measured by the operator and shall not exceed 25 μSv/h in any accessible area outside the fully enclosed site.

(b) Before commencing an exposure, the operator shall ensure, by inspection that the fully enclosed site is unoccupied.

(c) All entrances to the fully enclosed site shall be locked, or interlocked to an audible and visible alarm, during radiographic exposure.

(d) A personal radiation monitoring device and a personal dosemeter shall be worn by the operator and the operator's assistants at all times during industrial radiography operations.

(e) At the completion of an exposure, the operator shall ensure, using a radiation survey meter, that the X-ray generator has been switched off or the gamma-ray source returned to its fully shielded position within its container.

(f) The operator shall, according to appropriate advice prepared by the Radiation Safety Officer, ensure that dose rates in occupied areas are such that no member of the public will receive a dose exceeding 1 mSv per year from radiography performed within the site.

## VII.2 Working rules (example) for a partially enclosed site (exposure bay)

(a) A second person, who is capable of promptly taking charge in an emergency, shall be immediately available to assist during industrial radiographic exposures. This second person shall be able to:

- ensure that no person remains unnecessarily in an area where the dose rate exceeds or might exceed 25 μSv/h;
- use the source control equipment or any other means at his or her disposal to render the radiography equipment safe, if necessary;

- use a radiation survey meter in order to confirm the situation;
- recognise a loose gamma-radiography source by being familiar with the dummy source (or its photograph) supplied with the gamma-radiography equipment; and
- inform the Radiation Safety Officer and the owner of the circumstances of the emergency without delay.

This person shall not be in charge of operations at an adjacent site, unless scheduling arrangements are made such that he or she is not simultaneously responsible for an exposure taking place at the adjacent site.

(b) Before commencing an exposure, the operator shall ensure by inspection that the partially enclosed site is unoccupied.

(c) All openings into the partially enclosed site shall be closed during exposure and when 'radiation on' indicators are activated.

(d) The dose rate shall be periodically measured by the operator particularly when radiographic exposure configurations are changed and shall not exceed 25 μSv/h in any accessible area outside the partially enclosed site.

(e) Unnecessary occupation of the area immediately adjacent to the partially enclosed site should be avoided during exposure, unless measurement shows that dose rates there are negligible. In particular, the area above a partially enclosed site shall be kept under surveillance during exposure to ensure that no persons (for example, gantry drivers, personnel on a higher floor or roof) stray into a position where the dose rate exceeds or might exceed 25 μSv/h.

(f) A personal radiation monitoring device and a personal dosemeter shall be worn by the operator and assistant operators at all times during industrial radiography operations.

(g) At the completion of an exposure, the operator shall ensure, using a radiation survey meter, that the X-ray generator has been switched off or the gamma-ray source returned to its fully shielded position within its container.

(h) The operator shall, according to appropriate advice prepared by the Radiation Safety Officer, ensure that dose rates in occupied areas are such that no member of the public will receive a dose exceeding 1 mSv per year from radiography performed within the site.

### VII.3 Working rules (example) for an open site (field site)

(a) General

(i) On first arriving at the site, the operator shall:

- advise the person responsible for the area in which the radiography site will be set up of the intended operations and the estimated amount of time required to complete the work: and

- ascertain the nature, duration and location of all other work to be performed in the vicinity of the site and the possible points of entry to the site.

(ii) Before commencing exposures, a well defined and clearly visible boundary shall be erected (using, for example, flagged rope) around the site, including above and below as necessary, such that the dose rate at the boundary shall not exceed 25 μGy/h during exposures. This shall be checked periodically by the operator by means of a survey meter. The boundary shall be marked with radiation warning signs. An example of a suitable warning sign to be used during exposure is given in annexe III. Warning lights shall be used to indicate that an exposure is underway. The area within the boundary shall be kept under surveillance at all times during exposures to ensure that no person enters it or remains within it. Unnecessary occupation of areas near the boundary should be avoided.

(iii) The boundaries of adjacent exposure sites should not overlap. If an overlap is unavoidable, close liaison shall be maintained between operators responsible for the overlapping sites to avoid accidental exposures.

(iv) The operator shall, according to appropriate advice prepared by the Radiation Safety Officer, ensure that dose rates in occupied areas are such that no member of the public will receive a dose exceeding 1 mSv per year from radiography performed within the site.

(v) A radiation source shall not be partially or wholly exposed outside its shielding container nor an X-ray equipment switched on except when it is within the site boundary.

(vi) The immediate surroundings of the exposure position shall be clearly visible from the control position. The control position shall be in an appropriately safe place, as far as practicable from the exposure position. The dose rate at the source control position, if occupied, or at the position taken up by the operator during exposure shall be checked regularly by means of a monitor.

(vii) A second person, who is capable of promptly taking charge in an emergency, shall be immediately available to assist during industrial radiographic exposures. This person shall be able to:

- ensure that no person remains unnecessarily in an area where the dose rate exceeds or might exceed 25 μSv/h;
- use the source control equipment or any other means at his or her disposal to render the radiography equipment safe, if necessary;
- use a radiation survey meter in order to confirm the situation;
- recognise a loose gamma-radiography source by being familiar with the dummy source (or its photograph) supplied with the gamma-radiography equipment; and
- inform the Radiation Safety Officer and the owner of the circumstances of the emergency without delay.

This person shall not be in charge of operations at an adjacent site, unless scheduling arrangements are made such that he or she is not simultaneously responsible for an exposure taking place at the adjacent site.

(viii) Where applicable, collimators shall be used to restrict the area of the primary radiation beam to the minimum necessary for radiography. The beam should be directed towards the ground, but if this is not possible, a back shield should be used. Shielding should also be used to reduce stray radiation, when practicable.

(ix) Radiography equipment and the item to be radiographed shall be set up so that each of the components, particularly the X-ray tube or the source, are stable and therefore will not move during the exposure.

(x) Before commencing an exposure, the operator shall ensure by inspection that all unauthorised persons are outside the boundary and that the assistant operators are in an area where the dose rate is as low as, or lower than, where he or she is.

(xi) Just prior to commencing an exposure, a warning signal shall be given to warn persons within a reasonable distance that an exposure is about to take place.

(xii) A personal radiation monitoring device and a personal dosemeter shall be worn by the operator and assistant operators at all times during industrial radiography operations.

(xiii) The operator shall continually check the radiation level at his or her location during exposure using a survey meter.

(xiv) The operator alone shall exercise control over:

- the radiation source during exposures; and
- the occupancy of the site during the period of exposure of the source by continuous and competent supervision of the site.

(xv) Care shall be taken at all times to ensure that unauthorised persons cannot operate the equipment.

(xvi) Industrial radiography equipment should not be left unattended. If it is necessary to leave equipment unattended for a short period, a radiation source shall be returned to its fully shielded condition or switched off, as appropriate, and locked. The operator shall retain the key in his possession and before re-inserting the key, confirm that the equipment has not been tampered with in any way. If the equipment has been tampered with, this fact shall be reported immediately to the owner. For long periods without use the radiation source shall be returned to an appropriate storage location.

(xvii) Before a site is vacated, the operator shall ensure, by monitoring, that all radiation sources are locked in the fully shielded condition or switched off, as appropriate, and returned to the source container store or to the transport vehicle and that all boundary-defining equipment has been removed. The operator shall inform the person responsible for the area when this has been carried out.

(b) Additional working rules for X-radiography equipment

(i) X-ray equipment shall be transported or relocated only with the power supply disconnected.

(ii) When setting up, the power cable shall be laid out to ensure as large a distance as possible between the X-ray tube and the control box and in such a way that the cable is unlikely to be damaged, for example, by falling objects or by being run over by cars or trucks.

(iii) The window on the X-ray tube shall be completely shielded during warm-up procedures.

(iv) Immediately after each exposure, the operator shall use the survey meter to confirm that the X-ray equipment is de-energised and shall first turn the kV control back to its lowest setting, if it does not automatically reset, before other controls are changed.

(v) The X-ray equipment shall be properly earthed.

(c) Additional working rules for X-ray crawler equipment

(i) Where a right of way is situated adjacent to the pipeline in which a crawler is operating; the boundary that is established in accordance with 6.3.2 of this code shall restrict the passage of vehicles and personnel along that right of way while the crawler is activated.

(ii) In a very noisy industrial environment in which the crawler's klaxon may not be readily audible to all those who should be warned by it, particular attention shall be given to competent and continuous supervision of access to the site and to the possible use of a high-intensity flashing (strobe) light or an ancilliary klaxon outside the pipe.

(iii) While a crawler is not in operation in a pipeline and prior to its transfer into or out of a pipeline, the exposure control shall be made safe so that it is not possible for an exposure to be initiated by unintentional tripping of the exposure initiation device. Where there is no exposure control safety device, the power supply shall be disconnected.

(iv) When a fault condition causes a battery-operated crawler X-ray tube to be continually energised, with the consequence that the battery voltage falls, the energy of the X-rays produced may be below the range of the survey meter. If such a fault occurs, it shall be assumed that the tube is energised and emitting radiation until the battery supply has been disconnected.

(v) A crawler unit shall not be handled manually unless the power supply is disconnected or the equipment is otherwise made safe.

(d) Additional working rules for gamma-radiography equipment

(i) Only radiation workers, who are wearing personal dosemeters, shall travel in road vehicles which transport sources around or between industrial radiography sites or between such sites and the owner's premises or the radiography equipment store. There shall be at least one functional survey meter and one audible alarm dosemeter also in the vehicle, and the latter should be left operating during the journey.

(ii) When setting up source control cables, collimators and containers for exposure, the equipment shall be laid out to ensure as large a distance as possible between the source container and the control mechanism and in such a way that the cable is unlikely to be damaged, for example, by falling objects or by being run over by cars or trucks. Control cables and guide tubes shall be laid out such that they do not contain sharp bends or kinks which might cause the cable or source to jam or which cause excessive wear of the cable.

(iii) Radiography equipment and the item to be radiographed shall be set up so that each of the components, particularly the source or source holder in its exposure position, are stable and therefore will not move during the exposure.

(iv) Before exposure, the correct operation of the windout equipment shall be verified - the mechanism should be wound out through two revolutions and back through two revolutions, and a survey meter used to confirm movement of the source.

(v) Wind-out and wind-in operations should be performed quickly but carefully.

(vi) A correctly operating survey meter shall be placed adjacent to the windout mechanism during winding so as to confirm the status of the source. In particular, the survey meter shall be used to confirm that the source has been returned to its container at the completion of the exposure. The operator shall use this monitor when approaching the source, irrespective of its operating status.

# ANNEXE VIII ILLUSTRATION OF PROCEDURES WHICH MIGHT BE ADOPTED IN AN EMERGENCY INVOLVING A LOOSE OR LOST GAMM-RADIOGRAPHY SOURCE

## VIII.1 Administration

The operator and the Radiation Safety Officer shall be fully trained and equipped to take immediate action in an emergency to ensure that no person is exposed to radiation unnecessarily. They shall have the skill and knowledge to formulate contingency plans and have suitable equipment available, and shall also carry out regular checks of the emergency equipment to ensure that it is complete and in working order. Unless urgent, practical considerations dictate otherwise, emergency procedures should not be carried out without consultation with the statutory authority.

These emergency procedures will normally apply when a radioactive source becomes separated from its control cable or lost on a site. Most radiation incidents in industrial radiography ate due either to a source failing to return to a projection type container at the end of an exposure, or to a source becoming separated from a shutter or manual extraction type container during or after use. Because the work will be isolated within a suitably marked area, there will already be barriers in position and since radiation monitors are being used, the presence of an unshielded source should be apparent immediately. Experience has shown that when this happens, highly radioactive sources can be brought into a safe condition without anyone receiving an excessive exposure. Grossly excessive exposures have been received when monitors or survey meters have not been used. If a sufficient number of persons are available, it is desirable that one of them take notes during the procedure to facilitate subsequent reconstruction of events and estimation of doses that may have been received.

## VIII.2 Emergency equipment

The recommended minimum requirements are:

- dummy source or photograph (incorporating an indication of the physical dimensions) of the dummy source;
- personal radiation monitoring device;
- two survey meters (one of them suitable for high dose rates);
- tongs (one metre and two metre lengths);
- pliers;
- screwdriver;
- adjustable spanner or wrench;
- other hand tools which are appropriate for the particular equipment;

- bags of lead shot (2 kg per bag), at least two of which are required for $^{192}$Ir sources; and
- a lead pot with wall thickness greater than 4 cm and/or lead sheet.

## VIII.3 Action if the source has become separated from its control cable

The operator shall:

(a) inform the Radiation Safety Officer immediately of what has happened, the action proposed and the help required;

(b) measure the dose rate with a survey meter to ensure that no person remains unnecessarily in an area where the dose rate exceeds 25 μSv/h. If the meter has developed a fault or is not immediately available, it should be assumed that the source is completely unshielded and appropriate action taken to remove all persons to a safe location;

(c) restrict access to the area by erecting a barrier at a location where the dose rate does not exceed 25 μSv/h. (Barriers may also be required to restrict access to areas above and/or below the source location.) If barrier materials are not available, 'sentries' shall be posted where the barrier should be, allowing each to remain in position for not more than a total of 8 hours. If possible, however, people should be kept even further away so that sentries may be posted at locations where the dose rates are much less than 25 μSv/h. Radiation warning notices and flashing lights shall be displayed at the barrier position. No person shall be allowed to pass the barrier except those engaged in recovery or rescue operations. Any person who may have been inside the restricted area shall be identified;

(d) plan a course of action outside the barriers. If possible, practise the proposed operations on similar equipment. Collect long handling tongs, shielding materials, hand lamps (flashlights), etc. in readiness;

(e) ensure that the time spent by each person in the emergency action is kept to a minimum and that any time spent in an exposed position is noted. In high dose fields, substantial doses can be received when approaching and leaving an exposed source. If at all practicable the emergency action should be limited to one approach. This is why planning is essential;

(f) if possible, replace the source into the container. Use the long handling tongs and work quickly, keeping all parts of the body at arm's length from the source. DO NOT PICK UP THE SOURCE WITH BARE HANDS. Check with a survey meter that the source is back in the container;

(g) ensure that a second person stands at the barrier to time the work and indicate when the permitted time has expired. This person shall also continuously monitor the dose rate at the boundary during the recovery procedure; and

(h) ensure that, if a gamma source cannot be replaced in its container, then lead bricks or layers of sheet lead, or bags of lead shot are placed around the source to completely enclose it. If these materials are not available, then sand or similar materials can be used though they are not as effective. If possible, mark the exact location of the source before obscuring it with the temporary shielding. At all times, care shall be taken to keep all parts of the body at arm's length from the source. Barriers, warning signals and notices shall be kept in position until assistance arrives, allowing no person, except those engaged in recovery or rescue operations, to enter the controlled area.

### VIII.4 Action when the source has been returned to the container

The operator or, if present, the Radiation Safety Officer, shall immediately:

(a) check by monitoring that the source has been returned to its fully shielded position; and

(b) check the fastenings of the container, especially if the source has accidentally become separated from its container.

The Radiation Safety Officer shall, as soon as practicable:

(a) inform the statutory authority and the owner of the circumstances of the incident and the action taken;

(b) ensure that those involved in the recovery operation do no further radiation work until their doses have been estimated;

(c) send the personal dosemeters worn by all workers involved to the relevant personal radiation monitoring service (annexe II) for urgent assessment, explaining the reasons; and

(d) make a full investigation of the circumstances, taking written statements from the employees involved, including details of where they were in relation to the source and for how long. Obtain similar information from any other persons who may have been exposed.

### VIII.5 Action if the source is still outside the container

The operator or, if present, the Radiation Safety Officer, shall:

(a) ensure that barriers, warning signals and notices are satisfactory and that no unauthorised persons are in the controlled area and that persons supervising the barriers are not receiving excessive radiation exposure;

(b) unless it is likely that excessive exposures may be incurred, make a further planned attempt, if it seems possible that another attempt may be successful, to return the source to its container using the same precautions as before. If this attempt fails, it may be possible to place the source in another container. If so, the recovery procedure shall be repeated using the alternative container as below. If not, the contingency plans described in VIII.3 (h) shall be initiated and assistance called from the statutory authority;

(c) place the source in the alternative container and decide, as soon as practicable, whether the source can be returned to normal use with the aid of appropriate handling facilities, or whether disposal action is necessary; and

(d) initiate the series of actions in VIII.4.

### VIII.6 Source lost or irretrievable

This could give rise to serious problems on a site but adherence to these procedures, particularly with respect to regular monitoring, should minimise the possibility. If a source is lost or cannot be returned to its container, the operator shall:

(a) immediately report the loss to the Radiation Safety Officer, who shall then immediately inform the statutory authority (if the operator cannot contact the Radiation Safety Officer, he or she shall immediately inform the statutory authority); and

(b) take urgent action to monitor and establish safe areas where personnel can assemble.

The operator or, if present, the Radiation Safety Officer, shall:

(a) describe the source, or display the dummy source (or its photograph), to all personnel in order to ascertain whether any person has seen it; and

(b) monitor all personnel coming into a safe area to establish whether or not the source has become lodged in their clothing. Priorities in the monitoring of personnel shall be established with those most likely to have been in contact with the source being monitored first.

Once the monitoring has been carried out, the search shall be continued by the operator or the Radiation Safety Officer. Safe areas should be established as the search proceeds.

If the source is located reasonably quickly, then the emergency procedures detailed earlier shall be adopted. If the source cannot be located, then the search shall be continued, paying particular attention to drains, pipes, etc. which may shield the radiation.

If the location or recovery of the source is not possible or too hazardous with the facilities available, assistance from the statutory authority shall be obtained.

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6. International Commission on Radiological Protection, *Recommendations* of *the International Commission on Radiological Protection,* ICRP Publication 26 (Annals of the ICRP, Vol. I No.3), Pergamon Press, Oxford, 1977.

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8. International Organisation for Standardisation, *Sealed radioactive sources - classification,* ISO 2919, 1980.

9. International Organisation for Standardisation, *Apparatus for gamma radiography - specification,* ISO 3999, 1977.

## SYMBOLS, UNITS AND CONVERSION FACTORS

| QUANTITY | SYMBOL | NAME OF UNIT | DEFINITION OF UNIT | CONVERSION FACTOR |
|---|---|---|---|---|
| Absorbed dose (see 11.1) | D | gray | 1 Gy = 1 J $kg^{-1}$ | 1 Gy = 100 rad |
| Activity (see 11.2) | A | becquerel | 1 Bq = 1 $s^{-1}$ | 1 Bq = 2.7 × $10^{-11}$Ci (Ci: curies) |
| Exposure | X | coulomb per kilogram | 1 C $kg^{-1}$ | 1 C $kg^{-1}$ = 3876 R (R: roentgen) |
| Dose-equivalent (see 11.10) | H (H=DQN) | sievert | 1 Sv = 1 J $kg^{-1}$ | 1 Sv = 100 rem |

## HALF-VALUE THICKNESSES[1] IN VARIOUS SHIELDIKNG MATERIALS FOR INDUSTRIAL GAMMA-RADIOGRAPHY SOURCES

| | Half-value thicknesses in mm | | |
|---|---|---|---|
| Material | $^{60}$Co | $^{192}$Ir[2] | $^{169}$Yb |
| Lead | 12 | 6.4 | 2.6 |
| Mild steel | 20 | 13 | 9.5 |
| Concrete | 66 | 46 | - |

## APPROXIMATE DOSE RATE AT VARIOUS DISTANCES FOR INDUSTRIAL GAMMA RADIOGRAPHY SOURCES

| | Dose rate in mSv $h^{-1}$ per TBq | | | |
|---|---|---|---|---|
| Source | 1 m | 2 m | 5 m | 10 m |
| $^{60}$Co | 350 | 88 | 14 | 3.5 |
| $^{192}$Ir | 130 | 33 | 5.2 | 1.3 |
| $^{169}$Yb | 30 | 7.5 | 1.2 | 0.3 |

## PREFIXES

| | | | | | |
|---|---|---|---|---|---|
| milli (m) | : | $10^{-3}$ | kilo (k) | : | $10^{3}$ |
| micro (μ) | : | $10^{-6}$ | mega (M) | : | $10^{6}$ |
| nano (n) | : | $10^{-9}$ | giga (G) | : | $10^{9}$ |
| pico (p) | : | $10^{-12}$ | tera (T) | : | $10^{12}$ |
| femto (f) | : | $10^{-15}$ | peta (P) | : | $10^{15}$ |

[1] The values given refer to absorption of heavily filtered radiation by lead (density 11.3 g $cm^{-3}$). mild steel (density 7.85 g $cm^{-3}$) and concrete (density 2.35 g $cm^{-3}$). Approximate values for materials of similar composition but different density may be obtained from the given values on the basis that attenuation of gamma-radiation is proportional to density.

[2] Because $^{192}Ir$ emits gamma-rays having a wide range of energies, the thicknesses given in these columns differ considerably from the corresponding thicknesses for unfiltered or slightly filtered radiation.

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