Australian Government
Australian Radiation Protection and Nuclear Safety Agency

CODE OF PRACTICE & SAFETY GUIDE

Safe Use of Fixed Radiation Gauges

RADIATION PROTECTION SERIES No. 13

Radiation Protection Series

The ***Radiation Protection Series*** is published by the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) to promote practices that protect human health and the environment from the possible harmful effects of radiation. ARPANSA is assisted in this task by its Radiation Health and Safety Advisory Council, which reviews the publication program for the ***Series*** and endorses documents for publication, and by its Radiation Health Committee, which oversees the preparation of draft documents and recommends publication.

There are four categories of publication in the ***Series***:

Radiation Protection Standards set fundamental requirements for safety. They are prescriptive in style and may be referenced by regulatory instruments in State, Territory or Commonwealth jurisdictions. They may contain key procedural requirements regarded as essential for best international practice in radiation protection, and fundamental quantitative requirements, such as exposure limits.

Codes of Practice are also prescriptive in style and may be referenced by regulations or conditions of licence. They contain practice-specific requirements that must be satisfied to ensure an acceptable level of safety in dealings involving exposure to radiation. Requirements are expressed in 'must' statements.

Recommendations provide guidance on fundamental principles for radiation protection. They are written in an explanatory and non-regulatory style and describe the basic concepts and objectives of best international practice. Where there are related **Radiation Protection Standards** and **Codes of Practice,** they are based on the fundamental principles in the **Recommendations**.

Safety Guides provide practice-specific guidance on achieving the requirements set out in **Radiation Protection Standards** and **Codes of Practice**. They are non-prescriptive in style, but may recommend good practices. Guidance is expressed in 'should' statements, indicating that the measures recommended, or equivalent alternatives, are normally necessary in order to comply with the requirements of the **Radiation Protection Standards** and **Codes of Practice**.

In many cases, for practical convenience, prescriptive and guidance documents which are related to each other may be published together. Thus a **Code of Practice** and a corresponding **Safety Guide** may be published within a single set of covers.

All publications in the ***Radiation Protection Series*** are informed by public comment during drafting, and **Radiation Protection Standards** and **Codes of Practice**, which may serve a regulatory function, are subject to a process of regulatory review. Further information on these consultation processes may be obtained by contacting ARPANSA.

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January 2007

This publication was approved by the Radiation Health Committee on 25-26 October 2006, and on 8 December 2006, the Radiation Health & Safety Advisory Council advised the CEO to adopt the Code of Practice and Safety Guide.

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The mission of ARPANSA is to provide the scientific expertise and infrastructure necessary to support the objective of the ARPANS Act — to protect the health and safety of people, and to protect the environment, from the harmful effects of radiation.

Published by the Chief Executive Officer of ARPANSA in January 2007

This publication incorporates the Erratum issued 28 November 2007.

Foreword

Since the early 1980s, the basis of regulation for the use of fixed radiation gauges containing radioactive sources was the requirements of the National Health and Medical Research Council (NHMRC) *Code of Practice for the Safe Use of Radiation Gauges (1982)*. Although few in number, gauges containing X-ray tubes were not covered by the 1982 Code of Practice and neither were gauges incorporating neutron generator tubes.

Since 1982, there have been significant international advances in radiation protection. The International Commission on Radiological Protection (ICRP) has revised its radiation protection limits and the International Atomic Energy Agency (IAEA) has published two major revisions of its international transport regulations. These changes have been reflected in other Australian Recommendations and Codes of Practice since the promulgation of the 1982 Code of Practice.

Australia's system of developing radiation protection guidance is now through the Radiation Health Committee, which was established under the *Australian Radiation Protection and Nuclear Safety Act* 1998. The Radiation Health Committee has agreed to the development of a Radiation Protection Series of publications, which will be formed by progressively reviewing existing publications in the NHMRC Radiation Health Series and publications formulated under the *Environment Protection (Nuclear Codes) Act* 1978, along with consideration of areas for new publications.

Codes of Practice reflect a regulatory style that should facilitate an easier method of adopting them into the legislation of each Australian jurisdiction. This should result in a greater degree of uniformity of application and interpretation of the requirements of Codes of Practice across all Australian jurisdictions.

This Code of Practice and Safety Guide has been developed by a working group of the Radiation Health Committee, which has reviewed the 1982 NHMRC Code of Practice with a view to replacing it. The Code establishes requirements for adoption by Commonwealth, State and Territory jurisdictions that will provide a system for the safe use of fixed radiation gauges that contain radioactive sources, X-ray tubes or neutron generator tubes. The inclusion of the latter two types of radiation generating modes represents a significant change from the earlier NHMRC Code of Practice, but one which was considered necessary in view of the existence of these types of devices.

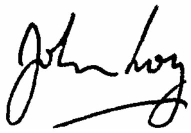
Another significant change from the 1982 Code includes the requirement for Responsible Persons, suppliers and service providers to develop a Radiation Management Plan for use by their practice, thereby generating a safety culture in the workplace. This safety culture will, in turn, give rise to an outcome-based radiation protection program.

The Code of Practice and Safety Guide also reflect the changes to dose limitation and transport mentioned above.

The Code was released for a public comment period from 26 August 2005 to 14 October 2005 with late submissions accepted until 10 January 2006. Also released was a Regulatory Impact Statement, to meet the requirements of the *Principles and Guidelines for National Standard-setting and Regulatory Action by*

Ministerial Councils and Standard-setting Bodies published by the Council of Australian Governments in June 1997. The comments received were reviewed by the working group, and the final document was approved by the Radiation Health Committee on 25-26 October 2006, and the Radiation Health and Safety Advisory Council at their meeting of 8 December 2006 advised the CEO to adopt the Code.

The Code will be revised and updated from time to time to ensure that it continues to provide the highest standards of protection.



John Loy PSM
CEO of ARPANSA

25 January 2007

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Note: Terms that are described in the Glossary appear in **bold type** on their first occurrence in the text. The Glossary is relevant to both the Code of Practice and the Safety Guide.

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CODE OF PRACTICE

Safe Use of Fixed Radiation Gauges

Radiation Protection Series Publication No. 13

January 2007

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Contents

1. Introduction

1.1 CITATION

This *Code of Practice* may be cited as the *Code of Practice for Safe Use of Fixed Radiation Gauges (2007).*

1.2 BACKGROUND

In Australia, the ionizing radiation sources used in **fixed** radiation gauges are regulated by radiation control legislation in the various States, Territories and the Commonwealth. Information on the regulatory authorities that administer the various Acts is provided in Annex 1 of this Code.

Industrial gauges, which include sources of ionizing radiation, are used for a variety of manufacturing process and quality control applications. These applications may include the non-invasive measurement and control of the thickness, level, density, weight, composition (for example, in-stream analysis) or moisture content in an industrial production process. In each case, the principle of operation of the gauge depends on the detection of radiation that is transmitted through, scattered by or emitted as a secondary emission from within, the item or material of interest.

If the radiation sources used in fixed radiation gauges were not adequately shielded, the dose rates near them would generally be of a level that could constitute a significant health hazard.

There are many industrial processes being controlled by fixed radiation gauges and there is a wide range of establishments in which they are used. These gauges may be located in areas that are occupied by, adjacent to or remote from, **employee**s or other individuals. From time to time it may be necessary for maintenance personnel to have access to these gauges or to the equipment on which they are mounted.

Some fixed radiation gauges, due to their specific operation or design features, may be unable to comply with all of the requirements of this Code. It is the responsibility of the **supplier** of the gauge to notify the **Responsible Person** and the **relevant regulatory authority** of any situation where this Code cannot be complied with. The relevant regulatory authority may require the use of further safeguards to ensure that a safety standard is met which is equivalent to that intended by this Code.

Radioactive sources are used in most fixed radiation gauges, although some gauges use X-ray tube and generator assemblies.

A fixed radiation gauge can also incorporate an X-ray tube and external power supply to energise the tube and generate X-rays. The production of X-rays by use of an X-ray tube does not involve the use of a radioactive material.

Neutron generator tubes may also be used in some gauging applications. A neutron generator tube may incorporate both radioactive tritium and an electrically energised tube insert. A neutron generator tube gauge will therefore have aspects of a gauge containing a radioactive source and a gauge containing an electrically energised tube.

This Code supersedes the **NHMRC** *Code of Practice for the Safe Use of Radiation Gauges (1982).*

1.3 PURPOSE

The purpose of this Code is to establish working practices, procedures and protective measures and to ensure the security of radioactive sources. This will ensure that the dose limits specified in Schedule F are not exceeded. In addition, the Code will assist in keeping radiation doses arising from a fixed radiation gauge as low as reasonably achievable, economic and social factors taken into account (the **ALARA principle**).

This Code lays down the requirements for the design, testing, supply, use, storage, transport, disposal and radiation monitoring of fixed radiation gauges. Informed and consistent use of this Code will ensure that fixed radiation gauges are used safely at all times.

1.4 SCOPE

This Code applies to industrial radiation gauges that are designed for installation as a fixed component within an industrial process and are used for the direct or indirect control of any part of that process. They are commonly installed at fixed locations within the industrial production process and will be referred to as *fixed radiation gauges*. Although designed to be installed at fixed locations, this does not preclude them from being mounted on structures which themselves move or have component parts that are designed to move during the normal operation of the gauge.

The term 'fixed radiation gauge' covers the whole of the device and includes the radiation source (radioactive material, energised X-ray tube or neutron generator tube), **source containment** (radioactive source container, **X-ray tube housing** or shielded enclosure or neutron generator tube housing or shielded enclosure), associated exposure controls and detector.

This Code refers, primarily, to fixed radiation gauges that are past the prototype or development stage and are being produced in significant numbers with little or no design variation. Gauges that are under development or test should, as far as practicable, adhere to the requirements of this Code.

1.5 UNITS OF MEASUREMENT

In this Code and Safety Guide, the **ICRP** 60 protection quantities '**effective dose**', '**equivalent dose**', '**ambient dose equivalent**' and '**directional dose equivalent**' are used for protection and operational requirements. These quantities are in the units of sievert (Sv). The terms ‘effective dose’, ‘equivalent dose’, ‘ambient dose equivalent’ and ‘directional dose equivalent’ have the meanings defined in the glossary and can be practically represented by the **ICRU** operational quantities (see *Quantities and units in radiation protection dosimetry*, ICRU Report 51, International Commission on Radiation Units and Measurements, Bethesda, Maryland).

2. Responsibilities

2.1 Responsibilities of the Supplier of a Fixed Radiation Gauge

2.1.1 The supplier of a fixed radiation gauge must ensure that a Radiation Management Plan incorporating the elements listed in Schedule A of this Code is developed, documented, resourced, implemented and regularly reviewed to ensure safety in all applicable dealings involving a fixed radiation gauge.

2.1.2 The supplier of a fixed radiation gauge must ensure that all persons under the supplier's care follow and comply with the Radiation Management Plan formulated under Schedule A.

2.1.3 The supplier must be able to account for all:

(a) fixed radiation gauges within his or her control at all times; and

(b) radioactive sources within his or her control at all times.

2.1.4 A person must not supply a fixed radiation gauge unless:

(a) that person is authorised in accordance with the requirements of the relevant regulatory authority; and

(b) the intended recipient is authorised by the relevant regulatory authority to possess the gauge.

2.1.5 A person who supplies a fixed radiation gauge must advise the intended recipient of the proposed method of disposal of the gauge or source(s) once the gauge or source(s):

(a) has reached the end of its useful life; or

(b) is no longer required.

2.1.6 A person must not supply a fixed radiation gauge unless the type or model of the gauge is approved for use by the relevant regulatory authority.

2.1.7 In order for the relevant regulatory authority to assess a particular type or model of gauge, the supplier must submit to the relevant regulatory authority:

(a) the construction details of the gauge including details of the:

(i) source position or source path[1]; and

(ii) **shielding** included in the gauge,

(b) detailed drawings of the gauge, showing:

(i) the method of its fabrication; and

[1] The source path indicates the intended movement of a source where the source is designed to move within the housing during normal operation.

(ii) the method of holding the source within the housing or containment; and

(iii) the source location or source path within the housing or containment; and

(iv) the materials used in its construction; and

(c) documentation that the source containment, shutter and/or **source control mechanism** are adequate to meet the relevant requirements of Schedule D, by use of the following methods:

(i) testing one or more samples or prototypes using the appropriate methods given in Schedule D of this Code; or

(ii) calculation; or

(iii) reference to other test results; or

(iv) a combination of the methods outlined in 2.1.7(c)(i)-(iii); and

(d) details of the operation of interlocks and external switching associated with the gauge; and

(e) for each radioactive source to be contained in the gauge, details of the:

(i) type of radioactive source;

(ii) maximum **activity** of the radioactive source;

(iii) encapsulation details of the radioactive source; and

(iv) certification for the radioactive source (see Schedule B2.3 of this Code),

(f) the maximum radiation dose rates at distances of 0.05 m and 1 m from the gauge surface when the gauge is:

(i) loaded with the maximum activity of each radioactive source for which the gauge was designed; or

(ii) operated at the maximum kVp and mA for which the tube was designed, and

(g) the radiation dose rate profile around the gauge.

2.1.8 Prior to the transfer or supply of a fixed radiation gauge, the supplier must provide the relevant regulatory authority with:

(a) the name and address of the intended recipient; and

(b) details of the detector intended for use and the position of the detector with respect to the source containment; and

(c) for each fixed radiation gauge, details of:

(i) name and address of the manufacturer; and

(ii) the model; and

(iii) serial number; and

(iv) date of manufacture; and

(d) for each radioactive source to be contained in the gauge, details of the:

(i) type of radioactive source; and

(ii) maximum activity of the radioactive source; and

(iii) the date of measurement of the activity of the source; and

(iv) encapsulation details the radioactive source; and

(v) **test certificate** for the radioactive source; and

(vi) special form certificate, where applicable.

(e) details of all materials (composition, thickness and/or density as appropriate) to be interposed between the source and the detector; and

(f) proposed location of the gauge where known by the supplier; and

(g) confirmation that any shutter or source control mechanism fitted to the gauge operates correctly in its intended manner; and

(h) confirmation, by measurement, that the radiation pattern in the vicinity of the source container, tube housing or shielded enclosure, substantially conforms to the pattern expected for the design or known to be typical of the design, when a radiation source of maximum design intensity is used.

2.1.9 Prior to the transfer of a fixed radiation gauge, the supplier must provide the intended recipient with the:

(a) documentary evidence that the requirements of 2.1.7 and 2.1.8(g) and (h) were met; and

(b) copies of certificates and any other documentation necessary for compliance with 2.2.13 and 2.2.14.

2.1.10 The supplier must maintain a record of the information specified in 2.1.8 and 2.1.9.

2.1.11 The supplier of a radioactive source for use in a fixed radiation gauge, must ensure and be able to demonstrate that any source supplied was:

(a) tested and subsequently certified as being compliant with the requirements of Schedule B1 and B2; and

(b) tested and subsequently certified to show compliance with other standards or specifications that may be required; and

(c) accompanied by appropriate documentation that includes:

(i) the source activity; and

(ii) chemical form of the source; and

(iii) manufacturers' recommendations regarding safe working life of the source; and

(iv) test certificates; and

(v) special form certificates, where applicable; and

(d) not one that contained a radioactive material of high committed effective dose per unit of intake activity, as specified in Table 1 of Schedule B, unless:

(i) the use of the source is necessary for the effective operation of the gauge; and

(ii) the source would be authorised for use in the gauge by the relevant regulatory authority.

2.1.12 The supplier must keep records of initial and ongoing training of employees in relation to radiation safety matters.

2.1.13 The supplier must ensure that all radioactive sources are stored:

(a) in accordance with the requirements detailed in Schedule G; and

(b) with appropriate security.

2.2 RESPONSIBILITIES OF THE RESPONSIBLE PERSON

2.2.1 The Responsible Person must ensure that a Radiation Management Plan incorporating the elements listed in Schedule A of this Code is developed, documented, resourced, implemented and regularly reviewed to ensure safety in all applicable dealings involving a fixed radiation gauge.

2.2.2 The Responsible Person must ensure that all persons under their care follow and comply with the Radiation Management Plan formulated under Schedule A.

2.2.3 The Responsible Person must ensure that:

(a) before a new gauge is installed, the relevant regulatory authority is provided with details of the proposed disposal of the gauge or source(s) when it is no longer required; and

(b) before a new gauge is installed or a gauge is relocated to a new location, the relevant regulatory authority is provided with:

(i) detailed plans of the plant or equipment to which the gauge is to be attached; and

(ii) detailed plans of the position of the plant or equipment relative to occupied areas, and

(c) the installation and any subsequent testing, maintenance and repair of the gauge is carried out by a person or company authorised by the relevant regulatory authority to perform the necessary work with due regard to the manufacturer's recommendations; and

(d) a radioactive source used in a fixed radiation gauge meets the relevant requirements of Schedule B; and

(e) the source containment, shutter and/or source control mechanism meet the relevant requirements of Schedule C; and

(f) where a gauge is fitted with safety interlocks that automatically close the shutter, move the source to the safe position or de-energise the tube insert, as appropriate for the particular gauge, these interlocks are connected and regularly tested to confirm their correct operation; and

(g) before using the gauge, and thereafter at intervals not exceeding twelve months[2], it is inspected to ensure that the:

   (i) location of the gauge is verified and recorded; and

   (ii) source containment has all of its component parts, is undamaged and in an acceptable condition; and

   (iii) radiation pattern in the vicinity of the source containment substantially conforms to that expected for the design and installed radiation source; and

   (iv) shutter or source control mechanism, if fitted, and any other safety features operate correctly; and

   (v) labels, as required in Schedule C1, as appropriate for the particular gauge, are intact and legible; and

(h) if functional impairment of a shutter or source control mechanism becomes apparent:

   (i) the relevant regulatory authority is notified immediately; and

   (ii) the gauge is not used until the function of the shutter or source control mechanism is restored to specification; and

   (iii) the gauge is not used until the shutter or source control mechanism is thoroughly tested,

(i) a wipe test[3] is carried out on those gauges that contain one or more radioactive sources at regular intervals not exceeding 36 months[4]; and

(j) if damage to or corrosion of the source containment or an unusual variation in the radiation pattern becomes apparent:

   (i) the relevant regulatory authority is notified; and

   (ii) the fixed radiation gauge is not used until the damage is repaired; and

   (iii) the fixed radiation gauge is tested for proper function; and

   (iv) any problem with the radiation shielding is corrected,

(k) following any catastrophic occurrence, such as fire, flood, earthquake or similar event:

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[2] The relevant regulatory authority may require more frequent inspection.

[3] See Annex F of the Safety Guide for an example of a wipe test procedure.

[4] Wipe testing of radioactive source gauges may need to be carried out more frequently depending on the source type and the environment in which the gauge is located.

(i) the relevant regulatory authority is notified without delay; and

(ii) the gauge is inspected and, if necessary, tested to ensure that neither it nor its radiation source are damaged; and

(iii) the gauge and all of its associated safety features are fully functional before allowing the gauge to be used,

(l) the results of the inspections and tests required in 2.2.3(g)-(k) inclusive are recorded.

2.2.4 The Responsible Person must be able to account for all:

(a) fixed radiation gauges within his or her control at all times; and

(b) radioactive sources within his or her control at all times.

2.2.5 The Responsible Person must ensure that the relevant regulatory authority is notified immediately if a radiation source cannot be accounted for.

2.2.6 The Responsible Person must ensure that radiation doses:

(a) do not exceed the appropriate dose limits specified in Schedule F of this Code; and

(b) are kept as low as reasonably achievable.

2.2.7 The Responsible Person must ensure that permanent physical barriers, locks, safety interlocks, warning notices and other relevant safety features are provided where necessary to ensure that the requirements of 2.2.6 are met.

2.2.8 The Responsible Person must ensure that any equipment provided to measure or limit radiation exposure, is periodically inspected and maintained in good working order.

2.2.9 The Responsible Person must ensure that no person:

(a) removes or in any way interferes with the radiation source(s) in a fixed radiation gauge unless that person is authorised by the relevant regulatory authority; and

(b) carries out any maintenance, adjustment or modification to a fixed radiation gauge unless that person is authorised by the relevant regulatory authority.

2.2.10 The Responsible Person must ensure that each employee engaged to work with or around a fixed radiation gauge:

(a) is properly trained and, at appropriate intervals, re-trained in any:

(i) radiation hazards associated and commensurate with that person's work; and

(ii) precautions necessary to limit personal radiation exposures and to avoid radiation **incident**s and injuries; and

(b) performs their work in accordance with the provisions of this Code.

2.2.11 The Responsible Person must ensure that records are kept of initial and ongoing training of employees in relation to radiation safety matters.

2.2.12 The Responsible Person must ensure that the warning labels and notices of appropriate form and size[5] are:

(a) displayed:

(i) on or adjacent to the gauge; and

(ii) at each entrance to the fixed radiation gauge storage area,

(b) prominently located; and

(c) made of material resistant to weather, dust and fumes likely to be present; and

(d) maintained in a clean, intact and legible condition; and

(e) securely attached; and

(f) rendered illegible or removed from the gauge, store or other location when the radiation source has been permanently removed from the gauge, store or other location.

2.2.13 The Responsible Person must ensure that records are maintained for each fixed radiation gauge within his or her control that show the following details of that gauge:

(a) the location of the gauge within the plant; and

(b) all identification numbers for the gauge; and

(c) name and address of the supplier and/or manufacturer; and

(d) the model; and

(e) serial number; and

(f) date of manufacture; and

(g) where appropriate, the details of the X-ray tube or neutron generator tube including maximum kilovoltage, maximum current, neutron output and tritium content.

2.2.14 The Responsible Person must ensure that records are maintained on each radioactive source within his or her control, including the:

(a) current location; and

(b) name and address of the supplier and/or manufacturer; and

(c) type of radioactive material; and

(d) chemical form of the radioactive material; and

(e) model and serial number; and

[5] Examples of suitable warning labels and notices are given in Annex D of the Safety Guide.

(f) date of manufacture; and

(g) ISO class number; and

(h) test certificate; and

(i) special form certificate, where applicable; and

(j) original activity and date the activity was measured; and

(k) source manufacturers recommended working life expiry date.

2.2.15 The Responsible Person must ensure that:

(a) an annual audit inspection of all radioactive sources and their locations is carried out; and

(b) a copy of the annual audit report, including a list of the sources and their locations, is available for inspection by the relevant regulatory authority; and

(c) the annual audit report identifies any new, replaced, relocated, disposed of or lost sources since the previous audit.

2.2.16 The Responsible Person must ensure that:

(a) the approval of the relevant regulatory authority is obtained before disposing of any radioactive source; and

(b) following disposal of any radioactive source, records, documentation and certificates which are required to be held by the Responsible Person are maintained in a form that is readily available for inspection by the relevant regulatory authority.

2.2.17 The Responsible Person must ensure that all radioactive sources are stored:

(a) in accordance with the requirements detailed in Schedule G; and

(b) with appropriate security.

2.3 RESPONSIBILITIES OF THE SERVICE PROVIDER

2.3.1 The **service provider** must ensure that a Radiation Management Plan incorporating the elements listed in Schedule A of this Code is developed, documented, resourced, implemented and regularly reviewed to ensure safety in all applicable dealings involving a fixed radiation gauge.

2.3.2 The service provider must ensure that all persons under the service provider's care follow and comply with the Radiation Management Plan formulated under Schedule A.

2.3.3 The service provider must be able to account for all fixed radiation gauges within his or her control at all times.

2.3.4 The service provider must be able to account for all radioactive sources within his or her control at all times.

2.3.5 A service provider must ensure that all **service technicians** employed by that person are authorised in accordance with the requirements of the relevant regulatory authority.

2.3.6 Following the provision of a service, the service provider must ensure that a report on the radiation safety status of the gauge is submitted to the Responsible Person.

2.3.7 Upon receiving a gauge for service, the service provider must ensure that the gauge is examined for any damage or wear that may compromise radiation safety.

2.3.8 The service provider must ensure that, while under the care or responsibility of the service provider, the gauge is used, stored, transported or repaired in accordance with the provisions of this Code.

2.3.9 The service provider must ensure that the equipment necessary to implement the Radiation Management Plan, formulated under Schedule A, is available and in good working order.

2.3.10 The service provider must ensure that radiation doses to occupationally exposed persons and members of the public:

(a) are kept as low as reasonably achievable; and

(b) do not exceed the appropriate dose limits specified in Schedule F of this Code.

2.3.11 The service provider must ensure that while the gauge is under the care or responsibility of the service provider, all personnel who work with, service or use the gauge are properly instructed, and reinstructed at appropriate intervals, in:

(a) radiation hazards arising from their work; and

(b) precautions necessary to limit exposures of themselves and of other persons; and

(c) methods to avoid radiation incidents.

2.3.12 The service provider must ensure that all radioactive sources are stored:

(a) in accordance with the requirements detailed in Schedule G; and

(b) with appropriate security.

2.4 RESPONSIBILITIES OF THE EMPLOYEE

2.4.1 An employee must not service, repair or adjust a fixed radiation gauge unless that employee is the holder of an authorisation for that purpose from the relevant regulatory authority.

2.4.2 An employee who may be exposed to radiation from a fixed radiation gauge in the workplace must, to the extent that they are capable:

(a) follow and comply with all requirements of the Radiation Management Plan of their **employer**; and

(b) report all defects in equipment that comes to their notice which they believe may contribute to or represent a radiation hazard; and

(c) acquaint themself with and obey all notices displayed in places they occupy and all instructions issued to them to ensure their safety and the safety of others; and

(d) refrain from any careless or reckless practice or action likely to result in an unexpected radiation hazard to themselves or others;

(e) use any:

(i) personal protective equipment provided to them; and

(ii) devices or equipment provided to them to assess their personal radiation dose.

2.4.3 An employee who may be exposed to radiation from a fixed radiation gauge in the workplace must not:

(a) remove or in any way interfere with the radiation source(s) in a fixed radiation gauge unless that employee is authorised by the relevant regulatory authority; and

(b) carry out any maintenance, adjustment or modification to a fixed radiation gauge unless that employee is authorised by the relevant regulatory authority; and

(c) interfere with, remove, alter, displace or render ineffective any fixed radiation gauge or any associated equipment provided to protect the employee or other persons; and

(d) interfere with any method or working procedure used to reduce radiation exposure, except where necessary for authorised purposes of inspection, maintenance, repair, modification or replacement.

3. Radiation Incidents

3.1 MANAGEMENT OF AN INCIDENT

3.1.1 In formulating the Radiation Management Plan, the Responsible Person, supplier or service provider must develop contingency arrangements detailing the action to be taken following all reasonably foreseeable incidents.

3.1.2 Immediately following an incident, the Responsible Person, supplier or service provider must ensure that the relevant regulatory authority is informed:

(a) that the incident has occurred; and

(b) of the steps that have been taken to rectify the situation; and

(c) of details of any radiation doses known, or suspected to have been received by any person.

3.1.3 Where a **personal monitoring device** is known to have or suspected of having received a radiation dose in excess of 1 mSv as a result of an incident, the Responsible Person, supplier or service provider must:

(a) submit the personal monitoring device of each person concerned for urgent assessment; and

(b) if being returned to a personal radiation monitoring service for assessment, advise the service of the circumstances of the known or suspected radiation dose.

3.1.4 In the event of an incident, the Responsible Person, supplier or service provider must:

(a) investigate the incident; and

(b) submit a complete, written report of the incident, including the preventative action to avoid a recurrence, to the relevant regulatory authority within 7 days.

4. Radiation Monitoring and Radiation Levels

4.1 Personal Monitoring Devices

4.1.1 The Responsible Person, supplier or service provider must provide an appropriate personal monitoring device to determine radiation doses received by each person who:

(a) installs, removes or performs **non-routine maintenance** on a fixed radiation gauge; or

(b) undertakes service or repair of a fixed radiation gauge; or

(c) is likely to be exposed to radiation in excess of one millisievert in any one year.

4.1.2 A person who is involved with the installation, removal, non-routine maintenance, service or repair of a fixed radiation gauge must wear an appropriate personal monitoring device issued to them for their exclusive use at all times while that person may be exposed to radiation from the gauge.

4.1.3 The Responsible Person, supplier or service provider must ensure that the personal monitoring devices provided to each person are capable of measuring the type of radiation emitted by the fixed radiation gauge being used.

4.2 Survey Meters

4.2.1 The Responsible Person, supplier or service provider must ensure that a suitable radiation survey meter that meets the requirements of Schedule E of this Code is readily available or accessible[6] to monitor the X-ray and **gamma radiation** levels.

4.2.2 Where neutron monitoring is required[7] and a neutron survey meter is not available, the Responsible Person must obtain approval from the relevant regulatory authority to estimate neutron levels from gamma measurements[8].

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6 'Readily available or accessible' means that the person can obtain a survey meter within a reasonable time. This may be achieved by borrowing, hiring or sharing a survey meter. Details of how the availability or accessibility of the survey meter are to be achieved are to be included in the Radiation Management Plan. The borrowing, hiring or sharing of a survey meter does not alleviate the Responsible Person, supplier or service provider from the survey monitoring requirements of this Code.

7 Neutron monitoring is required when neutron radiation levels could possibly result in any of the dose rates limits specified in this Code being exceeded. This would include situations where damage to the gauge has or may have occurred.

8 Gamma-neutron ratios can be highly dependent on the shielding material and thickness.

4.2.3 Where beta monitoring is required[9], the Responsible Person, supplier or service provider must ensure that a suitable radiation survey meter is readily available or accessible to monitor the beta radiation levels.

[9] Beta monitoring is required when beta radiation levels could possibly result in any of the dose rates limits specified in this Code being exceeded. This would include situations where damage to the gauge has or may have occurred.

5. Transport of Radioactive Material

5.1 Transport of Fixed Radiation Gauges Containing Radioactive Sources (including nutron generator tubes containing tritium)

5.1.1 A person must not transport radioactive material by road, rail or waterways unless that person does so in accordance with the **Transport Code**.

5.1.2 When a fixed radiation gauge containing one or more radioactive sources is packaged for transport, including transport within the Responsible Person's establishment, the Responsible Person must ensure that:

(a) the source control or shutter mechanism in the source container is locked in the 'beam off' position; and

(b) the package is monitored to ensure that:

(i) the useful beam is properly attenuated with the shutter or source control mechanism in the 'beam off' position before any action is taken to remove the fixing devices that hold the container in its installed location; and

(ii) the radiation exposure pattern is as expected; and

(c) the source container is:

(i) packed in an outer shipping container that is of strong, rigid construction; and

(ii) effectively immobilised within the outer container[10]; and

(d) the outer shipping container is labelled according to the requirements of the Transport Code and the relevant regulatory authority.

5.1.3 During transport of a radioactive source in a vehicle the package must be:

(a) located in the vehicle so that the radiation dose received by any person travelling in the vehicle is minimised; and

(b) stowed securely to prevent it from shifting under normal transport conditions.

5.1.4 If a source container is, or appears to be, damaged in transport:

(a) the persons responsible for the container at the time of the incident or another responsible person must notify the Responsible Person and the relevant regulatory authority; and

[10] For example, in the case of a heavy source container this can be effected by bolting it to the outer container.

(b) the Responsible Person must ensure that the source container is carefully examined to verify that it continues to comply with this Code and if it does not, he or she must ensure that:

(i) all damage is repaired in accordance with Section 6.1; and

(ii) approval to re-use the source container is obtained from the relevant regulatory authority before it is used again.

6. Repairs and Disposal

6.1 Repairs and Maintenance

6.1.1 A person must not carry out **routine maintenance** on a fixed radiation gauge unless that person:

(a) is authorised to do so by the Responsible Person; and

(b) is appropriately trained in the type of maintenance being carried out; and

(c) carries out that maintenance in accordance with the Radiation Management Plan; and

(d) ensures that a radiation survey is conducted after any routine maintenance to confirm that the dose rates do not exceed the expected range.

6.1.2 A person must not carry out repairs or non-routine maintenance on a fixed radiation gauge unless that person:

(a) is authorised with the relevant regulatory authority to perform those repairs or maintenance; and

(b) is appropriately trained in the type of repairs or maintenance being carried out; and

(c) where practicable, carries out that repair or maintenance in a workshop equipped to permit safe repair; and

(d) ensures that a radiation survey is conducted after any repair or maintenance to confirm that the dose rates do not exceed the expected range.

6.1.3 A person must not attempt any repair or alteration to the encapsulation of a radioactive source unless that person is specifically authorised to do so by the relevant regulatory authority.

6.2 Transfer of Ownership

6.2.1 A person must not transfer the ownership of any fixed radiation gauge without the prior approval of the relevant regulatory authority.

6.3 Prohibition of Abandonment or Disposal

6.3.1 A person must not abandon a fixed radiation gauge or the radioactive source from a fixed radiation gauge.

6.3.2 A person must not dispose of any fixed radiation gauge without the prior approval of the relevant regulatory authority.

6.4 RE-USE OR RELOCATION OF SOURCES

6.4.1 A person must not re-use or relocate a radioactive source from any fixed radiation gauge without the prior approval of the relevant regulatory authority.

Schedule A

Radiation Management Plan

A1 FORMULATION OF THE PLAN

A1.1 The Radiation Management Plan[11] must include:

(a) work practices[12]; and

(b) roles and responsibilities; and

(c) radiation monitoring requirements; and

(d) control of an incident involving the gauge; and

(e) storage of the gauge; and

(f) transport of the gauge; and

(g) records of repairs and maintenance of the gauge; and

(h) what to do with the gauge (eg. sale, transfer, disposal) when it is no longer required; and

(i) records and accountability;

(j) mechanisms for implementation and review, including the arrangements for provision of expert advice in radiation protection, of the Radiation Management Plan; and

(k) any other requirement that may have a bearing on safety.

A1.2 Where other documented safety procedures and work practices that exist within the organisation are referred to or utilised, the Responsible Person must have authority over the safety procedures and work practices referred to and the referred to safety procedures and work practices must not be modified without consideration of the effect on the Radiation Management Plan.

[11] The Radiation Management Plan may make reference to and utilise other documented safety procedures and work practices that exist within the organisation.

[12] Guidelines for formulating work practices, including working rules and emergency procedures, are given in Section 2 of the *Safety Guide for Safe Use of Fixed Radiation Gauges (2007)*.

Schedule B

Radiation Sources Used in Fixed Radiation Gauges

B1 SELECTION OF RADIOACTIVE MATERIALS FOR FIXED RADIATION GAUGES

B1.1 Radioactive material used in a fixed radiation gauge must:

(a) be appropriate for the particular application, with regard to its activity, **half-life**, energy and type of radiations emitted; and

(b) not be a radioactive material of high committed effective dose per unit of intake activity (**radiotoxicity**) (Sv Bq^{-1}), such as those listed in Table 1, unless:

(i) it is necessary for the production of neutron radiation for the particular gauging use; or

(ii) a radioactive material of low committed effective dose per unit of intake activity, that produces radiation of the required type and energy for the particular gauging application, is unavailable or is otherwise impracticable for use as the source.

(c) be in a chemical and physical form that, throughout the projected useful life of the fixed radiation gauge in which it is used, will minimise:

(i) corrosion and build up of internal pressure; and

(ii) dispersal and solubility of the radioactive material if the source capsule is ruptured.

(d) not have an activity that is greater than necessary to ensure that the fixed radiation gauge operates effectively during its projected useful life and the activity will depend on the:

(i) effective radiation path length between the source and detector; and

(ii) detector sensitivity and the proposed conditions of its use, where an allowance may be made for a 25% loss of detection sensitivity during the lifetime of the gauge; and

(iii) shielding effects of intra-beam material; and

(iv) half-life of the radioactive material used.

Table 1 Radioactive materials of high committed effective dose (radiotoxicity) per unit of intake activity.

Element	Isotopes				
Lead (Pb)	^{210}Pb				
Polonium (Po)	^{210}Po				
Radium (Ra)	^{226}Ra	^{228}Ra			
Actinium (Ac)	^{227}Ac				
Thorium (Th)	^{228}Th	^{230}Th			
Protactinium (Pa)	^{231}Pa				
Uranium (U)	^{232}U	^{233}U	^{234}U		
Neptunium (Np)	^{237}Np				
Plutonium (Pu)	^{238}Pu	^{239}Pu	^{240}Pu	^{241}Pu	^{242}Pu
Americium (Am)	^{241}Am	^{243}Am			
Curium (Cm)	^{242}Cm	^{243}Cm	^{244}Cm	^{245}Cm	^{246}Cm
Californium (Cf)	^{249}Cf	^{250}Cf	^{252}Cf		

B2 RADIOACTIVE SOURCE REQUIREMENTS

B2.1 Each radioactive source used in a fixed radiation gauge must be:

(a) a sealed source of durable design and construction; and

(b) readily identifiable by use of appropriate markings and documentation.

B2.2 The form and working life of each source used in a fixed radiation gauge must be suitable for:

(a) the particular application; and

(b) the useful life of the fixed radiation gauge; and

(c) environmental conditions of its use.

B2.3 The design, construction and markings of each source used in a fixed radiation gauge must satisfy the applicable requirements of ISO (International Standard) 2919-1999(E)[13].

B3 X-RAY TUBE AND GENERATOR ASSEMBLY REQUIREMENTS

B3.1 Any X-ray tube and generator assembly used in a fixed radiation gauge must:

(a) be appropriate for the particular application, with regard to beam intensity and energy spectrum of the radiation emissions; and

(b) be suitably durable and protected so that throughout the projected useful life of the fixed radiation gauge in which it is used, it will

[13] A radioactive source that complies with the 'special form' design and test requirements of the International Atomic Energy Agency (IAEA) would satisfy the ISO test requirements for gauges.

withstand vibration, corrosion and any other adverse affects likely to be encountered; and

(c) not have an operational output intensity that is greater than necessary to ensure that the fixed radiation gauge operates effectively during its projected useful life; and

(d) in relation to the choice of X-ray tube insert, generator and the maximum operational output intensity, depend on the:

(i) effective radiation path length between the tube focus and detector; and

(ii) output intensity reduction due to cathode heater and target degradation as the tube ages, for which an allowance of up to 50% loss may be made; and

(iii) detector selected for the proposed conditions of use, while allowance may be made for a 25% loss of detection sensitivity during the lifetime of the gauge; and

(iv) shielding effects of intra-beam material.

(e) if capable of higher than the required maximum output intensity, have the maximum operational output intensity limited, by the manufacturer or authorised service representative, to that required to comply with B3.1(c); and

(f) where a particular method or device is used to limit the maximum operational output intensity, not allow accessible user control of the output limit.

B4 NEUTRON GENERATOR TUBES

B4.1 Each form of tritium storage used in a neutron generator tube must be:

(a) of durable design and construction; and

(b) readily identifiable by use of appropriate markings and documentation.

B4.2 The form of tritium storage used in a neutron generator tube must be suitable for:

(a) the particular application; and

(b) the useful life of the fixed radiation gauge; and

(c) environmental conditions of its use.

B4.3 The design, construction and markings of each form of tritium storage used in a neutron generator tube must satisfy the applicable requirements of ISO (International Standard) 2919-1999(E)[14].

B4.4 Any neutron generator tube assembly used in a fixed radiation gauge must:

(a) be appropriate for the particular application, with regard to the intensity of the neutron emissions; and

[14] A radioactive source that complies with the 'special form' design and test requirements of the International Atomic Energy Agency (IAEA) would satisfy the ISO test requirements for gauges.

(b) be suitably durable and protected so that throughout the projected useful life of the fixed radiation gauge in which it is used, it will withstand vibration, corrosion and any other adverse affects likely to be encountered; and

(c) not have an operational output intensity that is greater than necessary to ensure that the fixed radiation gauge operates effectively during its projected useful life; and

(d) in relation to the selection of the tube assembly, depend on the:

(i) effective radiation path length between the tube focus and detector; and

(ii) output intensity reduction due to depletion of the tritium or deuterium as the tube ages, for which an allowance of up to 50% loss may be made; and

(iii) detector selected for the proposed conditions of use, while allowance may be made for a 25% loss of detection sensitivity during the lifetime of the gauge; and

(iv) shielding effects of intra-beam material.

(e) if capable of higher than the required maximum output intensity, have the maximum operational output intensity limited, by the manufacturer or authorised service representative, to that required to comply with clause B4.4(c); and

(f) where a particular method or device is used to limit the maximum operational output intensity, not allow accessible user control of the output limit.

Schedule C

Radiation Source Containment

C1 GENERAL REQUIREMENTS FOR RADIATION SOURCE CONTAINMENT

C1.1 Radiation source containment that incorporates depleted uranium in its construction must be **durably marked** to:

(a) warn of the presence of depleted uranium[15]; and

(b) indicate the quantity incorporated; and

(c) provide information on the relevant physical (i.e. may spontaneously catch fire when finely divided) and radiological safety requirements.

C1.2 The useful beam aperture in the shielded container for a radioactive source or the tube housing for a tube insert must be limited to a size no larger than necessary for the effective operation of the gauge.

C1.3 Where a collimator insert or diaphragm is required to limit the size of the useful beam, such a modification must:

(a) only be fitted by the manufacturer or service provider authorised by the relevant regulatory authority; and

(b) not interfere with the effective operation of the gauge; and

(c) not reduce the shielding properties or other safety features of the containment.

C1.4 Unless otherwise authorised by the relevant regulatory authority in accordance with clause C4.1, a fixed radiation gauge must be fitted with:

(a) a shutter; or

(b) a means of moving the source to a safe position; or

(c) a means of de-energising the radiation source.

C1.5 Unless a specific authorisation has been issued by the relevant regulatory for the use of a manual shutter or a manual means of moving the source to a safe position, the operation of the systems required by C1.4 must be **fail safe** and ensure that the primary beam is turned off automatically when:

(a) any safety guard that prevents access to the primary beam is removed; or

(b) internal checks detect a problem with gauge operation that could affect radiation safety; or

(c) there is failure of the power supply to the device.

C1.6 The source container or tube housing must be designed so that whenever the shutter or source control mechanism is in either the 'beam on' or 'beam off' position, the beam condition is clearly and unambiguously indicated.

15 See Figure D.6 of Annex D of the Safety Guide for an example of a warning label.

C1.7 The beam condition indicator must be protected against mechanical damage and:

(a) where the indicator is mechanical, the 'beam on' and 'beam off' markings must be of a type that cannot be readily obscured by dust, precipitation, corrosion or paint; or

(b) where the indicator is electrical, it must:

(i) include separate lamps or signals to indicate the 'beam on' and 'beam off' conditions; and

(ii) be designed to be fail safe in the event of a lamp failure.

C1.8 The gauge must be designed:

(a) to withstand variations of temperature to which it may be subjected in use, without deterioration of either containment or ease of operation of the shutter or source control mechanism that may be fitted; and

(b) so that when any incorporated lifting attachments are used in the intended manner, they do not impose damaging stresses on the structure of the source container, shielded tube housing or shielded enclosure; and

(c) and constructed so that it can withstand the effects of all vibrations, acceleration and vibration resonance likely to arise during its use, without damage, or reduction in ease of operation of the shutter, where fitted, or source control mechanism; and

(d) with due consideration given to brittle fracture of the materials used.

C1.9 Any welded, brazed or similar joint must be in accordance with published standards (AS2205.1 to AS2205.10).

C1.10 The gauge must be constructed of materials that:

(a) are physically and chemically compatible with each other and, where applicable, the materials of the radioactive sources that it is designed to contain; and

(b) can withstand the effects of prolonged irradiation without significant deterioration of any physical properties necessary for the safety of the gauge; and

(c) are resistant to corrosion or other physical or structural damage which may occur during the use, transport and storage of the gauge.

C1.11 The gauge must be provided with features to maintain safe:

(a) manual handling, if it has a gross mass of 10 kilograms to 50 kilograms; or

(b) mechanical handling, if it has a gross mass of greater than 50 kilograms.

C1.12 The gauge must be durably marked with a legibly stamped or engraved label incorporating the trefoil radiation hazard symbol followed by words to the general form of those given in either Figure D.4 or D.5 of Annex D of the Safety Guide.

C1.13 The symbol and markings on the label specified in C1.12 must be black on a yellow background.

C1.14 Each label located on a gauge must be made of a material that can withstand the long-term effects of corrosion and general exposure to the environment in which it is to be used.

C1.15 Locks required in this Code for fitting to fixed radiation gauges must be designed, constructed and mounted so that they resist:

(a) forcible interference using common hand tools; and

(b) key cylinder picking.

C1.16 The gauge must not be modified or altered in any way without the approval of the relevant regulatory authority.

C2 REQUIREMENTS FOR RADIOACTIVE SOURCE CONTAINERS

C2.1 The shutter or source control mechanism and the associated mechanism for its operation, must be designed, constructed and, if necessary, protected by a rugged covering, so that its operation is not adversely affected by corrosive substances, dust, moisture, other contaminants, vibration or heat, to which it may be exposed during its projected useful life.

C2.2 The shutter or source control mechanism must be:

(a) provided with an effective lock so that it can be secured in the 'beam off' position; and

(b) designed so that it cannot be locked in the 'beam on' position.

C2.3 When loaded with a source of the maximum activity for which it was designed and with the shutter or source control mechanism in the 'beam off' position, the radiation levels must not result in an ambient dose equivalent rate or directional dose equivalent rate, as appropriate, exceeding:

(a) 500 μSv h^{-1} at any point 0.05 m from the gauge surface; and

(b) 10 μSv h^{-1} at any point 1 m from the gauge surface.

C2.4 The gauge must be designed so that any primary shielding material, which has a melting point of less than 800^0 C, used in its construction:

(a) is entirely sealed within a durable metal vessel that has a melting point of more than 800^0C; and

(b) maintains the required effectiveness of the primary shield if the shielding material is in a molten state.

C2.5 The gauge must be durably marked with a legibly stamped or engraved label in the general form of that given in Figure D.4 of Annex D of the Safety Guide with the following information:

(a) manufacturer name, model and serial number of the radiation gauge and/or container; and

(b) name and address of the source supplier and/or manufacturer; and

(c) name of the radioactive material; and

(d) model and serial number of the radioactive source; and

(e) ISO class number of the radioactive source; and

(f) original activity of the radioactive source and date the activity was measured; and

(g) maximum radiation dose rate at one metre from the surface of the source container (with all shutters closed) and date this measurement was made.

C2.6 The gauge must not be loaded, reloaded or used with a radioactive source:

(a) for which it was not designed; or

(b) if any of the safety features of the gauge are defective or showing signs of significant deterioration; or

(c) if any of the safety features of the gauge are deactivated unless it is done so by a person who has the appropriate authorisation of the relevant regulatory authority.

C2.7 The condition and safety features of the gauge must be inspected at regular intervals not exceeding 12 months with:

(a) inspection records kept (see Annex E of the Safety Guide); and

(b) any deterioration noted; and

(c) any defects which may have safety implications reported and repaired without delay.

C2.8 Each radioactive source container must be able to comply with the relevant test requirements of Schedule D of this Code.

C3 Requirements for X-ray Tube, Neutron Generator Tube Housings and Shielded Enclosures

C3.1 If primary shielding is provided by a tube housing only, a shutter that is designed to be fail safe, regardless of whether it is manually operated or power operated (i.e. electrical or pneumatic), must be fitted to the tube housing unless otherwise authorised by the relevant regulatory authority under clause C4.1.

C3.2 If primary shielding is provided by a shielded enclosure only, interlocks that are designed to be fail safe and tamper proof must be fitted to the enclosure to ensure that access to the primary beam is prevented by de-energising the X-ray tube or neutron generator tube.

C3.3 If primary shielding is provided by both tube housing and shielded enclosure, the gauge must use tube housing shutters or interlocks or a combination of both to prevent access to the primary beam and provide the level of safety required by this Code.

C3.4 The shutter, if fitted to the tube housing, and the associated mechanism for its manual or power operation must be designed, constructed and, if necessary, protected by a rugged covering, so that:

(a) its operation is not adversely affected by corrosive substances, dust, moisture, other contaminants, vibration or heat, to which it may be exposed during its projected useful life; and

(b) it satisfies the test requirements of Section D5 of Schedule D of this Code.

C3.5 The shutter, if fitted to the tube housing, must be:

(a) provided with an effective lock so that it can be secured in the 'beam off' position; and

(b) designed so that it cannot be locked in the 'beam on' position.

C3.6 When the X-ray tube or neutron generator tube assembly is energised, operating at its maximum output intensity[16] and with the shutter closed, the radiation levels must not result in an ambient dose equivalent rate or directional dose equivalent rate, as appropriate, exceeding:

(a) 500 μSv h^{-1} at any point 0.05 m from the gauge surface; and

(b) 10 μSv h^{-1} at any point 1 m from the gauge surface.

C3.7 Panels, provided for maintenance access or other purposes, which could permit access to the primary beam must:

(a) be secured so that special tools or keys are required to open them; and

(b) be provided with:

(i) at least two safety interlocks; and

(ii) a label that warns of the presence of an X-ray tube or neutron generator tube within.

C3.8 The tube housing or shielded enclosure used to shield an X-ray tube insert must be durably marked with a legibly stamped or engraved label in the general form of that given in Figure D.5 of Annex D of the Safety Guide with the following information:

(a) manufacturer name, model and serial number of the radiation gauge, tube housing and/or shielded enclosure; and

(b) manufacturer name, model and serial number of the tube insert; and

(c) maximum rated tube potential (kVp) and current (mA); and

(d) maximum radiation dose rate at one metre from the surface of the tube housing or shielded enclosure (with all shutters closed); and

(e) date the maximum radiation dose rate measurement was made.

C3.9 In the case of an X-ray tube, the position of the focal spot of the X-ray tube must be clearly marked on the tube housing or shielded enclosure.

C3.10 The tube housing or shielded enclosure used to shield a neutron generator tube insert must be durably marked with a legibly stamped or engraved label in the general form of that given in Figure D.4 of Annex D of the Safety Guide with the following information:

(a) manufacturer name, model and serial number of the radiation gauge, tube housing and/or shielded enclosure; and

(b) manufacturer name, model and serial number of the tube insert; and

(c) name of the radioactive material; and

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[16] The maximum output intensity for the X-ray tube assembly or neutron generator tube is that found when operated at the maximum rated kilovoltage and current of the tube and generator combination, as specified by the manufacturer. Measurements may be made using the maximum rated kilovoltage and at least one half the maximum tube current, and the results scaled accordingly for maximum current.

(d) model and serial number of the radioactive source; and

(e) ISO class number of the radioactive source; and

(f) original activity of the radioactive source and date the activity was measured; and

(g) maximum radiation dose rate at one metre from the surface of the source container (with all shutters closed) and date this measurement was made.

C4 REQUIREMENTS FOR SHUTTERLESS GAUGES

C4.1 A **shutterless gauge** can only be used if:

(a) justification has been made to the relevant regulatory authority for its use in a specified industrial process; and

(b) an authorisation for its use has been issued by the relevant regulatory authority.

C4.2 The radiation source containment for each shutterless gauge must:

(a) for radioactive source containers, be able to meet the design, construction and usage requirements of Section C2 of this Schedule that do not apply specifically to a shutter or source control mechanism; or

(b) for X-ray tube or neutron generator tube housings, be able to meet the design, construction and usage requirements of Section C3 of this Schedule that do not apply specifically to a shutter.

C4.3 Where the requirements of Sections C2 or C3 of this Schedule are not met under the provisions of clauses C4.2(a) or C4.2(b) of this Schedule respectively, those requirements must be replaced by design, construction and/or usage measures which ensure at least the same level of safety as that afforded by the original requirements.

C4.4 When loaded with a radioactive source of the maximum activity for which it was designed or used with a tube insert operated at the maximum designed output intensity, the radiation levels must not result in an ambient dose equivalent rate or directional dose equivalent rate, as appropriate, exceeding:

(a) 500 μSv h^{-1} at any point 0.05 m from the gauge surface; and

(b) 10 μSv h^{-1} at any point 1 m from the gauge surface.

C4.5 If the source is immersed or covered by the material being gauged during the normal operation of the device:

(a) the containment must be designed so that loss of the material and the shielding that it provided does not result in the radiation levels specified in clause C4.4 of this Schedule being exceeded; and

(b) the gauge must be durably marked with a legibly stamped or engraved label incorporating the trefoil radiation hazard symbol followed by words to the general form of those given in Figure D.7 of Annex D of the Safety Guide; and

(c) the symbol and markings on the label specified in C4.5(b) must be black on a yellow background.

C4.6 If the material being gauged provides shielding for accessible areas:

(a) the loss of the material must not result in the direct radiation beam becoming accessible; and

(b) the gauge must be durably marked with a legibly stamped or engraved label incorporating the trefoil radiation hazard symbol followed by words to the general form of those given in Figure D.7 of Annex D of the Safety Guide; and

(c) the symbol and markings on the label specified in C4.6(b) must be black on a yellow background.

C4.7 If any moving part represents a risk of damage to the radiation source[17], a suitable protective guard or stop must be fitted between the source and moving part to prevent damage of the source from occurring.

C4.8 A protective guard or stop required under C4.7 must be designed so as to:

(a) prevent loss of the source from the containment; and

(b) enable safe retrieval of the source if dislodged from the normal position.

C4.9 In those devices where the source is immersed in a flowing liquid and could be carried away if dislodged, a suitable trap must be fitted to prevent loss of the source downstream.

[17] The radiation source could be a radioactive source, X-ray tube or neutron generator tube depending on the application.

Schedule D

Tests for Source Containers, Shutters and Source Control Mechanisms

Fixed radiation gauges must be tested to ensure that they can withstand harsh working environments and incidents, without compromising safety. Acceptable fixed radiation gauges will be able to comply with the following tests, as appropriate to the type of gauge under examination, as follows:

(a) Tests specified in clauses D1-D5 of this Schedule apply to a gauge or prototype gauge designed for use with a radioactive source are to be carried out with the gauge loaded with a specimen that represents the radioactive source. The specimen must have the same physical dimensions and a similar mass to the radioactive source.

(b) Tests specified in clauses D4-D5 of this Schedule apply to a gauge or prototype gauge that uses an X-ray tube as the radiation source and are to be carried out with the X-ray tube insert installed in the gauge.

On completion of a test procedure, inspect the gauge or prototype gauge for faults in any of its safety features and to determine its compliance. Include in the inspection the use of an appropriate radiation monitor or radiographic method to examine shielding integrity and radiation pattern. In the case of a gauge designed to contain a radioactive source, measurement of the radiation profiles will require the gauge to be loaded with a radioactive source of the maximum activity for which the gauge is designed. The criteria for passing these tests are that:

(a) the radiation source, or specimen that represents a radioactive source, remains captive within the shielded containment; and

(b) the change in effectiveness of either the containment shielding or any other designed safety feature does not result in more than a 20% increase in the radiation level at any external surface of the containment.

D1 THE FREE DROP TEST

D1.1 The requirements of the free drop test are as follows:

(a) The loaded source container must be dropped, free of restraint, onto the target so as to suffer maximum damage with respect to its safety features.

(b) The height of the free drop, measured from the lowest point of the source container to the upper surface of the target, must not be less than nine metres.

(c) The target surface must be flat, horizontal and rigid and must be of such character that any increase in its resistance to displacement or deformation upon impact by the source container would not significantly increase the damage to the source container[18].

[18] A suitable target may be constructed using a reinforced concrete block that is set in firm soil and has a steel plate for the target surface. A concrete block, of at least ten times the mass of the source container under test, would be required. A steel plate of at least 1.25 centimetres thickness and which is wet floated onto the concrete surface to ensure intimate contact, would be required.

D2 The Compression Test

D2.1 The requirements of the compression test are as follows:

(a) The source container is to be subjected, for a period of at least 24 hours, to not less than the greater compressive load of either:

(i) five times the mass of the source container; or

(ii) 1300 kg.m^{-2} multiplied by the vertically projected area of the source container.

(b) The load is to be applied uniformly to two opposite sides of the source container, one of which being the base on which it would normally rest.

D3 The Thermal Test

D3.1 The requirements of the thermal test are that:

(a) the heat input to the loaded source container will be at least that which would result if exposed uniformly, for at least 30 minutes, to a temperature of 800^0 C; and

(b) the average emissivity coefficient of the exposure environment will be at least 0.9[19].

D3.2 In determining the effect of this test, artificial cooling is not permitted or assumed for at least three hours after the heat input, unless it can be shown that the internal temperature has begun or would begin to fall before the end of this period[20].

D4 Corrosion and Vibration Tests

D4.1 Several tests are set out in the Australian Standard series AS 60068 *Environmental Testing*. Refer to this document for further information – in particular to:

(a) AS 60068.2.6-2003 *Environmental testing – Part 2.6: Tests - Test Fc: Vibration (sinusoidal)*;

(b) AS 60068.2.52-2003 *Environmental testing – Part 2.52: Tests—Test Kb: Salt mist, cyclic (sodium chloride solution)*;

(c) AS 60068.2.42-2004 *Environmental testing – Part 2.42: Tests—Test Kc: Sulphur dioxide test for contacts and connections*; and

(d) AS 60068.2.43-2004 *Environmental testing – Part 2.43: Tests—Test Kd: Hydrogen sulphide test for contacts and connections*.

D4.2 Although these tests were primarily intended for electronic component applications, they may be used in other fields of technology as considered appropriate.

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[19] In determining this heat input, an absorption coefficient of 0.8 can be assumed for the surfaces of the source container.

[20] The prescribed duration of heat input, temperature and emissivity coefficient constitute an arbitrary standard to provide a precise criterion rather than a description of a real fire. It is virtually impossible to stage an open fire test that accurately reproduces the furnace conditions specified in this test requirement.

D4.3 Some potential uses may need special consideration but do not lend themselves to a rigid system of testing[21].

D5 SHUTTER AND SOURCE CONTROL MECHANISM TEST

D5.1 Subject to the testing criteria specified in clause D5.2 of this Schedule:

(a) a sample manual operated shutter or source control mechanism must be tested for a minimum of 500 cycles of operation; or

(b) a sample power operated (i.e. electrical or pneumatic) shutter or source control mechanism must be tested for a minimum of 5000 cycles of operation.

D5.2 A shutter or source control mechanism will be considered to comply with this test requirement if it operates for the specified number of cycles without the component either failing to operate in the intended manner or showing undue signs of deterioration.

[21] This applies, in particular, to corrosion and vibration.

Schedule E

Survey Meters

E1 GENERAL REQUIREMENTS OF THE SURVEY METER

E1.1 A radiation survey meter required by clause 4.2.1 used for the surveillance of areas and source containment must:

(a) have sufficient range to measure radiation levels at least throughout the range 1 μSv.h^{-1} to 1000 μSv.h^{-1}, or equivalent, for the radiations emitted from the radiation sources under the control of the Responsible Person; and

(b) continue to indicate, either visibly or audibly, when radiation levels exceed the maximum readings in their measurement ranges; and

(c) indicate the measured quantity with a measurement uncertainty not greater than ±25%, including uncertainty due to energy response variation over the range of radiation energies to be measured.

E2 CALIBRATION OF THE SURVEY METER

E2.1 Radiation survey meters must have an operational and calibration check:

(a) before initial use; and

(b) at intervals not exceeding twelve months; and

(c) following damage or repairs; and

(d) when otherwise indicated by their performance.

E2.2 The calibration of a radiation survey meter must be, in the case of electromagnetic radiation[22], traceable to:

(a) the Australian National Standard of air **kerma**; or

(b) a foreign reference Standard of air kerma recognised by the Chief Metrologist[23]; or

(c) a National Standard of a country with which Australia has an arrangement for that Standard.

E2.3 Where a neutron survey meter has been obtained, the calibration of that survey meter must be traceable to:

(a) the Australian National Standard for neutron radiation; or

(b) a foreign reference Standard for neutron radiation recognised by the Chief Metrologist; or

(c) a National Standard of a country with which Australia has an arrangement for that Standard.

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[22] X-ray and gamma radiation.

[23] The Chief Metrologist is defined under section 18A of the *National Measurement Act 1960*.

Schedule F

ARPANSA's *Recommendations for Limiting Exposure to Ionizing Radiation* (2002) – Dose Limits

Application	Dose Limits[1]	
	Occupational	Public
Effective dose	20 mSv per year, averaged over a period of 5 consecutive calendar years[2,3]	1 mSv in a year[4]
Annual equivalent dose in:		
the lens of the eye	150 mSv	15 mSv
the skin[5]	500 mSv	50 mSv
the hands and feet	500 mSv	–

1. The limits shall apply to the sum of the relevant doses from external exposure in the specified period and the 50-year committed dose (to age 70 years for children) from intakes in the same period.
2. With the further provision that the effective dose shall not exceed 50 mSv in any single year. In addition, when a pregnancy is declared by a female employee, the embryo or fetus should be afforded the same level of protection as required for members of the public.
3. (DELETED)
4. In special circumstances, a higher value of effective dose could be allowed in a single year, provided that the average over 5 years does not exceed 1 mSv per year.
5. The equivalent dose limit for the skin applies to the dose averaged over any 1 cm^2 area of skin, regardless of the total area exposed.

NOTE 1: The above dose limits table has been directly extracted from ARPANSA's *Recommendations for limiting exposure to ionizing radiation (1995)*, [republished as RPS 1 in 2002]. However, as the Radiation Health Committee now advises that the exceptional circumstances clause is not recommended for use in Australia, note 3 of the table in RPS 1 has been deleted from this Code.

NOTE 2: Exposure to radiation from natural sources is generally excluded from occupational or public exposure, except when the exposure is a direct consequence of a practice or is specifically identified by the appropriate authority as requiring control through the implementation of a program of radiation protection. Medical exposure includes doses received by patients undergoing medical diagnosis or therapy, doses received by volunteers in medical research, and doses received knowingly and willingly by persons other than health care workers as a consequence of their proximity to an exposed patient. Dose limits do not apply to exposures from natural sources, except as described above, or to medical exposures.

Schedule G

Storage of Fixed Radiation Gauges

G1 Storage of Fixed Radiation Gauges Containing Radioactive Sources (including neutron generator tubes containing tritium)

G1.1 A fixed radiation gauge containing one or more radioactive sources must be securely stored if it:

(a) is not required for immediate use; or

(b) has been removed from service.

G1.2 When a fixed radiation gauge containing one or more radioactive sources is placed in storage:

(a) the gauge must be clearly labelled as containing a radioactive source; and

(b) the gauge must be stored so that the likelihood of damage[24] to the gauge is minimised; and

(c) the source control or shutter mechanism must be locked or otherwise secured in the 'beam off' position; and

(d) the gauge must be monitored to ensure that the useful beam is properly attenuated with the shutter or source control mechanism in the 'beam off' position.

G1.3 A store used for the storage of a fixed radiation gauge containing one or more radioactive sources must:

(a) be of solid construction and made of durable materials; and

(b) be designed, located, constructed and, if necessary, shielded so that:

(i) the radiation levels at any accessible place outside the store do not result in an ambient dose equivalent rate or directional dose equivalent rate, as appropriate, exceeding 10 $\mu Sv.h^{-1}$; and

(ii) no person will receive a radiation dose in excess of the appropriate limit specified in Schedule F of this Code; and

(iii) the resultant radiation dose rate in any occupied area is as low as reasonably achievable; and

(c) be under the control of a person nominated by the Responsible Person; and

(d) be kept locked; and

(e) be subject to strict access control; and

(f) not be used for other purposes; and

(g) when a radioactive source is in the store, display a conspicuous notice bearing the radiation hazard warning symbol, the letters and symbol of which must be in black on a yellow background[25].

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[24] Damage to a gauge in storage could result from a fall, collision, corrosion etc.

[25] An example of a suitable notice is given in Figure D.3 of Annex D of the Safety Guide.

G1.4 A store for fixed radiation gauges must not be located:

(a) near to explosives, combustible or corrosive materials or photographic or X-ray film[26]; or

(b) in an area prone to flooding or other potential hazard that may damage the store and/or its contents; or

(c) in an area that allows unrestricted access to the public.

G2 Storage of a Fixed Radiation Gauge Source Container Incorporating Depleted Uranium in its Construction

G2.1 A fixed radiation gauge that contains depleted uranium must be stored in accordance with the requirements specified in part G1 of this Schedule.

G3 Storage of Fixed Radiation Gauges Containing X-Ray Tubes or Neutron Generator Tubes

G3.1 A fixed radiation gauge that contains an X-ray tube or neutron generator tube must be stored:

(a) so that the tube cannot be energised; and

(b) in an area or room that can be kept locked; and

(c) under the control of a person nominated by the Responsible Person.

G3.2 Strict access control must be exercised over a store that contains a fixed radiation gauge containing an X-ray tube or neutron generator tube.

[26] See Section 5.1 of the Safety Guide for further information.

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Standards Australia AS 2205.2.1-2003 *Methods for destructive testing of welds in metal – Transverse butt tensile tests*.

Standards Australia AS 2205.2.2-2003 *Methods for destructive testing of welds in metal – All-weld-metal tensile test*.

Standards Australia AS 2205.2.3-2003 *Methods for destructive testing of welds in metal – Transverse joggle-butt tensile test*.

Standards Australia AS 2205.3.1-2003 *Methods for destructive testing of welds in metal – Transverse guided bend test*.

Standards Australia AS 2205.3.2-2003 *Methods for destructive testing of welds in metal – Transverse free bend test*.

Standards Australia AS 2205.3.3-2003 *Methods for destructive testing of welds in metal – Longitudinal guided bend test*.

Standards Australia AS 2205.3.4-2003 *Methods for destructive testing of welds in metal – Transverse joggle-butt wrap-around bend test*.

Standards Australia AS 2205.3.5-2003 *Methods for destructive testing of welds in metal – Tongue bend test.*

Standards Australia AS 2205.4.1-2003 *Methods for destructive testing of welds in metal – Nick-break test.*

Standards Australia AS 2205.4.2-2003 *Methods for destructive testing of welds in metal – Fillet break test.*

Standards Australia AS 2205.5.1-2003 *Methods for destructive testing of welds in metal – Macro metallographic test for cross-section examination.*

Standards Australia AS 2205.6.1-2003 *Methods for destructive testing of welds in metal – Weld joint hardness test.*

Standards Australia AS 2205.7.1-2003 *Methods for destructive testing of welds in metal – Charpy V-notch impact fracture toughness test.*

Standards Australia AS 2205.7.2-2003 *Methods for destructive testing of welds in metal – Dropweight fracture toughness test for nil-ductility transition temperature.*

Standards Australia AS 2205.7.3-2003 *Methods for destructive testing of welds in metal – Fracture mechanics toughness tests (K(sub)lc(/sub), critical CTOD and critical J values).*

Standards Australia AS 2205.8.1-2003 *Methods for destructive testing of welds in metal – Longitudinal fillet shear test.*

Standards Australia AS 2205.8.2-2003 *Methods for destructive testing of welds in metal – Transverse fillet shear test.*

Standards Australia AS 2205.9.1-2003 *Methods for destructive testing of welds in metal – Hot cracking test.*

Standards Australia AS 2205.10.1-2003 *Methods for destructive testing of welds in metal – Corrosion test for welded austenitic stainless steel.*

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Standards Australia AS 60068.2.42-2004 *Environmental testing – Tests – Test Kc: Sulphur dioxide test for contacts and connections.*

Standards Australia AS 60068.2.43-2004 *Environmental testing – Tests – Test Kd: Hydrogen sulphide test for contacts and connections.*

Glossary

Activity

the measure of quantity of radioactive materials, except when used in the term 'human activity'. Activity, A, is a measure of the amount of a radioactive material given by:

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

where *dN* is the expectation value of the number of spontaneous nuclear transitions which take place in the time interval *dt*.

The unit of activity is s^{-1} with the special name becquerel (Bq).

ALARA Principle, the

an acronym for 'as low as reasonably achievable', used in the context of optimisation.

Ambient dose equivalent, H*(d)

at a point in a radiation field, is the dose equivalent that would be produced by the corresponding expanded and aligned field, in the ICRU sphere at a depth, d, on the radius opposing the direction of the aligned field.

Unit: J kg^{-1}. The special name for the unit of ambient dose equivalent is sievert (Sv).

Contamination

the presence of a **radioactive substance** on a surface in quantities in excess of 0.4 Bq cm^{-2} for beta and gamma emitters and low toxicity alpha emitters, or 0.04 Bq cm^{-2} for all other alpha emitters.

Directional dose equivalent, H'(d,Ω)

at a point in a radiation field, is the dose equivalent that would be produced by the corresponding expanded field, in the ICRU sphere at a depth, d, on a radius in a specified direction, Ω.

Unit: J kg^{-1}. The special name for the unit of directional dose equivalent is sievert (Sv).

A depth d=0.07 mm is recommended for weakly penetrating radiation.

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.

Effective dose

the quantity *E*, defined as a summation of the tissue equivalent doses, each multiplied by the appropriate tissue weighting factor:

$$E = \sum_{T} w_T \cdot H_T$$

where H_T is the equivalent dose in tissue T and
w_T is the tissue weighting factor for tissue T.

From the definition of equivalent dose, it follows that:

$$E = \sum_{T} w_T \cdot \sum_{R} w_R \cdot D_{T,R}$$

where w_R is the radiation weighting factor for radiation R and
$D_{T,R}$ is the average absorbed dose in the organ or tissue T.

The unit of effective dose is J kg^{-1}, termed the sievert (Sv).

Employee

a person who works for an employer within an operation or an external contractor to that employer.

Employer

an operator who or which engages people to work within an operation; the term employer includes a self-employed person.

Equivalent dose

a measure of dose in organs and tissues which takes into account the type of radiation involved.

Equivalent dose, *H*, is a weighted dose in an organ or tissue, with the radiation weighting factor(s) determined by the type and energy of the radiation to which the organ or tissue is exposed. The equivalent dose H_T in organ or tissue T is given by the expression:

$$H_T = \sum_{T} w_R \cdot D_{T,R}$$

where $D_{T,R}$ is the absorbed dose averaged over the organ or tissue T due to radiation R and
w_R is the radiation weighting factor for that radiation.

The unit of equivalent dose is the same as for absorbed dose, J kg^{-1}, with the special name sievert (Sv).

Fail safe

for the purpose of this Code, fail safe refers to the design of a safety device that ensures that the failure of a component part of the device or of the power supply to the device, does not result in the failure of the safety function of the device or of the system to which it may be attached.

Fixed

can only be removed by the use of tools.

Gamma radiation

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

Half-life

in relation to radioactive decay, the time required for the quantity of a radionuclide to decrease to one half of its initial value.

ICRP

the International Commission on Radiological Protection. It is an independent organisation that provides general guidance on radiation protection. The recommendations of the ICRP are not legally binding, but are generally followed by countries framing national regulatory requirements.

ICRU

the International Commission on Radiation Units and Measurement.

Incident

an event which causes, or has the potential to cause, abnormal exposure of employees or of members of the public and which requires investigation of its causes and consequences and may require corrective action within the program for control of radiation.

Kerma, K

the quotient of dE_{tr} by dm, where dE_{tr} is the sum of the initial kinetic energies of all the charged particles liberated by uncharged particles in a mass dm of material, thus

$$K = \frac{dE_{tr}}{dm}$$

Unit: J kg^{-1}. The special name for the unit of kerma is gray (Gy).

Neutron

an elementary particle of mass 1.675×10^{-27} kg having some properties similar to the proton but carrying no charge; neutrons are constituents of all nuclei except for the most common isotope of hydrogen.

NHMRC

the National Health and Medical Research Council. Its principal function is to advise the Australian community on matters relating to the achievement and maintenance of high standards of individual and public health through appropriate legislation, administration and practices, and to encourage health and medical research to achieve those standards.

Non-routine maintenance

work intended by the manufacturer of a fixed radiation gauge to be performed by a service technician or other person authorised by the relevant regulatory authority.

Personal monitoring device

a device worn by an individual to monitor the ionizing radiation dose to which that person is exposed.

Radioactive source

any quantity of radioactive material which is intended for use as a source of ionizing radiation.

Radioactive substance

material that undergoes spontaneous transformation of its nucleus with the emission of ionizing radiation and which, for the purposes of this Code and Safety Guide, exceeds a prescribed concentration or activity as determined by the relevant regulatory authority.

Radiotoxicity

the potential of radioactive material when introduced into the body to cause damage to living tissue by absorption of energy from the radiation it emits. This is measured as the committed effective dose per unit of intake activity in units of Sv Bq^{-1}.

Relevant regulatory authority

the radiation protection authority or authorities designated, or otherwise recognised, for regulatory purposes in connection with protection and safety relating to a fixed radiation gauge. A list of radiation protection authorities in Australia is included as Annex 1 of the Code of Practice.

Responsible Person

in relation to any radioactive source, radiation apparatus, prescribed radiation facility, or premises on which unsealed radioactive sources are stored or used, means the person:

(a) having overall management responsibility including responsibility for the security and maintenance of the source, apparatus, or facility; and

(b) having overall control over who may use the source or apparatus, or facility; and

(c) in whose name the source, apparatus, or facility, would be registered if this is required.

Routine maintenance

work intended by the manufacturer of a fixed radiation gauge to be performed by the Responsible Person.

Service provider

a person who is, or who employs, a service technician.

Service technician

a person, being a natural person, who repairs, performs non-routine maintenance or calibrates a fixed radiation gauge.

Shielding

the component of the equipment, transport or storage container used to absorb or limit the external radiation when the source is in the shielded position or container. The shielding material may be lead, depleted uranium, or steel for gamma radiation shielding, and may be special plastics, water, or wax for neutron shielding.

Shutterless gauge

for the purpose of this Code, a shutterless gauge refers to those gauges with:

(a) radioactive source containers but without the shutter or source control mechanism required in Clause C2.1 of Schedule C of the Code; or

(b) X-ray tube housings but without the shutter required in Clause C3.1 of Schedule C of the Code.

Source assembly

the component into which the radioactive source(s) are permanently fixed. The source assembly may be movable or may itself be permanently fixed.

Source containment

a component of a fixed radiation gauge that encloses a radiation source and provides, by attenuation and by distance, some protection of individuals from the high radiation levels close to the radiation source.

Source control mechanism

a system or device that operates a shutter, energises and de-energises an X-ray tube or moves a radioactive source between the shielded and unshielded positions inside the source containment. Such a control mechanism may operate mechanically, electrically or pneumatically in order to perform this function.

Supplier

any legal person to whom a registrant or licensee delegates duties, totally or partially, in relation to the supply, design, manufacture, production or construction of a source or fixed radiation gauge. An importer of a source or fixed radiation gauge is considered to be a supplier.

Test certificate

a certificate issued by the manufacturer of a radioactive source that includes details of the isotope, measured activity, date of measurement of the activity, date of manufacture of the source, ISO classification, details of leak tests carried out on the source and other relevant information.

Transport Code, the

the *Code of Practice for the Safe Transport of Radioactive Material 2001* published by the Chief Executive Officer of ARPANSA in September 2001. Radiation Protection Series No. 2.

X-ray tube housing

the X-ray tube housing is the shielded containment for an X-ray tube insert. The housing may be so designed that it can be dismantled to gain access to the tube insert for its repair or replacement.

Annex 1

Regulatory Authorities

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

COMMONWEALTH, STATE / TERRITORY	CONTACT	
Commonwealth	Chief Executive Officer ARPANSA PO Box 655 Miranda NSW 1490 Email: info@arpansa.gov.au	 Tel: (02) 9541 8333 Fax: (02) 9541 8314
Australian Capital Territory	Manager Radiation Safety Radiation Safety Section ACT Health Locked Bag 5 Weston Creek ACT 2611 Email: radiation.safety@act.gov.au	 Tel: (02) 6207 6946 Fax: (02) 6207 6966
New South Wales	Director Radiation Control Department of Environment and Conservation PO Box A290 Sydney South NSW 1232 Email: radiation@environment.nsw.gov.au	 Tel: (02) 9995 5000 Fax: (02) 9995 6603
Northern Territory	Manager Radiation Protection Radiation Protection Section Department of Health and Community Services GPO Box 40596 Casuarina NT 0811 Email: envirohealth@nt.gov.au	 Tel: (08) 8922 7152 Fax: (08) 8922 7334
Queensland	Director, Radiation Health Department of Health 450 Gregory Terrace Fortitude Valley QLD 4006 Email: radiation_health@health.qld.gov.au	 Tel: (07) 3406 8000 Fax: (07) 3406 8030
South Australia	Director, Radiation Protection Division Environment Protection Authority PO Box 721 Kent Town SA 5071 Email: radiationprotection@state.sa.gov.au	 Tel: (08) 8130 0700 Fax: (08) 8130 0777
Tasmania	Senior Health Physicist Health Physics Branch Department of Health and Human Services GPO Box 125 Hobart TAS 7001 Email: health.physics@dhhs.tas.gov.au	 Tel: (03) 6222 7256 Fax: (03) 6222 7257
Victoria	Manager, Radiation Safety Section Department of Human Services GPO Box 4057 Melbourne VIC 3001 Email: radiation.safety@dhs.vic.gov.au	 Tel: 1300 767 469 Fax: 1300 790 733
Western Australia	Secretary, Radiological Council Locked Bag 2006 PO Nedlands WA 6009 Email: radiation.health@health.wa.gov.au	 Tel: (08) 9346 2260 Fax: (08) 9381 1423

Please note: This table was correct at the time of printing but is subject to change from time to time. For the most up-to-date list, the reader is advised to consult the ARPANSA web site (www.arpansa.gov.au). For after hours emergencies only, the police will provide the appropriate emergency contact number.

Australian Government

Australian Radiation Protection and Nuclear Safety Agency

SAFETY GUIDE

Safe Use of Fixed Radiation Gauges

Radiation Protection Series Publication No. 13

January 2007

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Contents

1. Introduction

1.1 Citation

This Safety Guide may be cited as the *Safety Guide for Safe Use of Fixed Radiation Gauges (2007).*

1.2 Background

The information contained in this Safety Guide is used to provide practice-specific guidance on achieving the requirements set out in the accompanying Code of Practice for Fixed Radiation Gauges (2007) (hereafter 'the Code').

This Safety Guide provides general information on the working rules and emergency procedures that need to be considered for the mandatory requirements of the Code. General duties to ensure radiation protection are also given, as is information on personal monitoring devices, survey meters, transport and storage of gauges, auditing requirements and details of warning signs.

The guidance contained in the Safety Guide is not mandatory, however, it is recommended that the measures included in the Safety Guide should be implemented in the interests of reducing radiation exposure and risks.

1.3 Purpose

The purpose of this Safety Guide is:

(a) to assist in the development of a Radiation Management Plan that complies with the requirements of Section 2 of the Code; and

(b) to provide other general safety guidance to assist compliance with the Code.

1.4 Scope

The scope of this Safety Guide is the same as that given in Section 1.4 of the Code.

2. Work Practices

Section 2 of the Code requires that work practices be included in the Radiation Management Plan. Work practices will include working rules that need to be followed to ensure a high standard of radiation safety and procedures that need to be followed in the event of an incident or emergency. In addition to general incident or emergency procedures, some specific scenarios should be considered, eg. fire, flood, loss of control of a gauge or source(s) or unintended human exposure.

It is necessary to develop, document, implement and regularly update procedures to ensure the safe use of a fixed radiation gauge. Advice from the relevant regulatory authority and the manufacturer of the gauge should be obtained when developing and reviewing these procedures.

2.1 Working Rules

Working rules incorporated in the Radiation Management Plan should be clear and easy-to-understand and should include details of:

(a) the expected radiation levels around each fixed radiation gauge under the control of the Responsible Person;

(b) where appropriate, tests for non-fixed surface **contamination**;

(c) the occasions on which radiation surveys and contamination tests will be carried out;

(d) the methods for conducting the radiation surveys, wipe tests and any other examination required by the Code, and for reporting and recording results;

(e) information relating to:

    (i) the operation of source or shutter controls;

    (ii) locking of source containers;

    (iii) de-energising X-ray or neutron generator tubes;

(f) the arrangements of locks and safety procedures and equipment for preventing exposure of persons to a radiation beam;

(g) the arrangements for preventing or minimising occupational and public radiation exposure;

(h) the methods of ensuring that no part of any person can enter the item of equipment to which the gauge is attached while the gauge is in the 'beam on' condition;

(i) any licence/registration requirements and conditions of the relevant regulatory authority;

(j) any special instructions from, or requirements of, the relevant regulatory authority;

(k) the arrangements for security of a gauge when it is in storage or being transported within the establishment;

(l) the regular inspection of all equipment including:

(i) source containers or housings;

(ii) survey meters;

(iii) personal monitoring devices;

(iv) labels;

(v) markings;

(vi) notices;

(m) the types and occasions for use of personal monitoring devices;

(n) the steps to be taken in the event of an emergency (see Section 2.2 of this Safety Guide);

(o) the arrangements for the calibration, repair and maintenance of a fixed radiation gauge;

(p) instructions concerning the posting of radiation warning signs in the vicinity of the gauge (see Annex D Figures D.2 and D.3 for examples);

(q) the contact addresses and telephone numbers, including the after hours emergency number, where relevant, for:

(i) the Responsible Person;

(ii) relevant regulatory authority;

(iii) the service provider;

(iv) the provider of the personal monitoring service,

(r) the arrangements for disposal of a radioactive source, X-ray tube or neutron generator tube from a fixed radiation gauge, which need to be in accordance with the requirements of the relevant regulatory authority; and

(s) any other site specific information that may have a bearing on safety.

Where necessary, the working rules should also include details of a radiation isolation procedure for the gauge. When work is required in the vicinity of a gauge, the Responsible Person will need to consider the radiation exposure that could occur as a result of the work and due to any other unforseen circumstances. Consideration should be given to the following:

(a) the radiation levels around the gauge;

(b) the locations where work is required;

(c) the duration of the work; and

(d) the possibility of unauthorised interference with the gauge.

If there is any risk of exposure to the primary beam during maintenance work, the Responsible Person should ensure that the radiation isolation procedure is followed before allowing work near the gauge. The recommendations of the gauge manufacturer should be followed when developing the procedure. However, a typical procedure would include the following:

(a) close the shutter, retract the source, or remove power from the radiation source;

(b) apply a lock so that the radiation beam cannot be turned on;

(c) verify with a radiation survey meter that the radiation beam has actually been turned off;

(d) measure radiation levels in areas where the employees will be working;

(e) advise employees that the gauge has been isolated; and

(f) advise employees of their responsibilities when working near the gauge.

If a significant amount of work is required on or near the gauge, the Responsible Person may decide that the gauge should be removed from its fixed location for the duration of the work. The gauge containing the radiation source will need to be securely stored in the Responsible Person's radiation store subject to the requirements of the Code (see Section 5 of the Code).

2.2 Emergency Procedures

Written emergency procedures for inclusion in the Radiation Management Plan should include:

(a) instructions on the immediate actions that need to be taken to protect human life, limit injury and provide first aid where required;

(b) instructions for the Responsible Person to be notified immediately:

  (i) if a radioactive source is lost or damaged; or

  (ii) if the radiation dose to any person, as a result of an incident, exceeded or may have exceeded limits set by the relevant regulatory authority;

(c) instructions for any employee involved in an incident to immediately report the incident to the Responsible Person, and to the relevant regulatory authority;

(d) instructions on the immediate procedures needed to bring the incident under control, including details on the action necessary to:

  (i) allay panic;

  (ii) assess the nature and scope of the radiation incident;

  (iii) assess whether any physical damage has occurred to a radioactive source. Such an incident could have serious consequences in relation to contamination of persons and property;

  (iv) adequately shield the radiation source, where safe to do so;

  (v) secure an area of at least 3 metres[27] around any unsecured source(s). It is important to ensure that while securing an area, the source(s) is not lost or carried away by a conveyor belt, vehicle, the process stream or other means;

  (vi) establish adequate access control over the area;

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27 It should be noted that for relatively high activity sources, this distance might need to be considerably larger.

(vii) move persons to a safe distance and prevent unauthorised and unnecessary access to the secured area;

(viii) secure the gauge or sources and to prevent any further damage;

(ix) remove a radioactive source if necessary and safe to do so;

(x) de-energise an X-ray tube or turn the gauge off in the case of an electrically energised device;

(xi) monitor persons and equipment leaving the area. A dislodged source could become entangled in clothing or other equipment;

(xii) prevent the further spread of contamination (if this possibility arises);

(xiii) implement any further action required to bring the incident under control;

(xiv) investigate the circumstances of the incident, including the undertaking of assessments, measurements and calculations needed to:

- determine the optimum corrective action plan; and
- estimate the doses to the operators and members of the public involved in the incident;

(xv) assemble the necessary resources and implementation of the required corrective action, taking into account instructions from the Responsible Person and the relevant regulatory authority;

(xvi) prepare a detailed report of the incident as soon as possible after the incident and submission of this report to the relevant regulatory authority through the Responsible Person; and

(xvii) advise the Responsible Person and the relevant regulatory authority on changes required to prevent the recurrence of a similar incident.

(e) names, addresses and telephone numbers required in the event of an emergency (these should be checked and updated at least once every 12 months and when changes in arrangements are made);

(f) any other instructions to cover possible emergencies, such as:

(i) observed or suspected damage to a gauge, eg. crushing by a forklift or other vehicle, heavy object dropped on the gauge etc.;

(ii) observed or suspected malfunction of the gauge or the **source assembly**;

(iii) suspected or actual loss of the gauge or of a source;

(iv) failure of safety procedures or a breach of the working rules; and

(v) fire, flood, explosion or other disaster.

2.3 PROCEDURES TO AVOID LOSS OF A SOURCE

There have been several instances around the world, including Australia, where radioactive sources have been lost with serious consequences. Some of these involved a gauge containing a radioactive source being discarded with steel scrap and being melted down in a furnace, resulting in many tonnes of contaminated steel requiring disposal at significant cost to the former owner. In other cases, people have received significant radiation exposure from inadvertently handling a lost source.

The following guidance should be followed in order to reduce the possibility of a source being lost:

(a) When a new gauge is installed, the supplier should be asked what situations could result in loss of a source and whether the supplier has ever had this situation occur.

(b) The supplier's recommendations for maintenance and service of the gauge should be followed.

(c) Installed gauges should be regularly inspected for security of mounting and deterioration of the source containment. Particular attention should be paid to fasteners that hold the source containment together.

(d) As far as practicable, the gauge should not be placed at risk of damage from any nearby equipment and where this cannot be avoided, the gauge should be inspected more frequently.

(e) Regular records of dose rates around the source containment should be made. Any change in dose rates could indicate damage to the source containment or loss of a source and should be investigated.

(f) The Responsible Person should consider all possible scenarios for loss of a source. Plans should be made for recovery of a lost source.

(g) The Responsible Person should maintain good records of the location of all radioactive sources under his or her control and is, in fact, obligated to do so under Section 2.3 of the Code. Turnover of employees however, may result in records being lost or responsibilities becoming confused. The Responsible Person should make sure that all new employees are advised of their responsibilities. Furthermore, consideration should be given to the possibility of the future changing ownership of the company including the transfer of ownership of the gauges to the new owner.

(h) Gauges or sources that are not in use should be securely stored and clearly labelled as containing radioactive material. Experience has shown that gauges that have been removed from service, even for a short time, have a greater chance of being lost or discarded with scrap material.

2.4 PROCEDURES FOR EMPLOYEE TRAINING

Adequate training is essential to ensure that work practices are followed. Training also has the benefit of reducing any unnecessary fear that people may have about the use of radiation in the work environment.

The following procedures are recommended for training:

(a) All employees who need training should be identified. Various levels of training will generally be required to suit the particular needs and responsibilities of each employee.

(b) Basic training information may be provided to employees in the form of a radiation safety manual.

(c) The training records, required under Sections 2.1.12 and 2.2.11 of the Code, should include the following information:

   (i) The name of each person trained;

   (ii) The date on which the training took place;

   (iii) Specific details of the training material delivered.

(d) The need for training should be included in the induction procedures for new employees.

(e) Training should be repeated regularly, as deemed necessary by the Responsible Person.

3. Responsibilities and Duties

Section 2 of the Code requires that roles and responsibilities of Responsible Persons, suppliers, service providers, service technicians and employees involved with the use of fixed radiation gauges be included in the Radiation Management Plan. In addition to the mandatory responsibilities and duties specified in the Code, the following responsibilities and duties for Responsible Persons should be considered for inclusion in the Radiation Management Plan.

3.1 Responsibilities of the Responsible Person

The Responsible Person should ensure that the appropriate fire authority is informed of the location of all radiation sources under the control of the Responsible Person and the relevant regulatory authority is notified that this has been done. This will be of particular importance where the gauge or gauges are stored at semi-permanent or permanent locations.

3.2 General Duties to Ensure Radiation Protection in an Organisation

The Code requires that the supplier of a gauge, the Responsible Person and a service provider prepare and implement a Radiation Management Plan, which should include the following elements:

(a) The procedures for undertaking the measurements, investigations and assessments detailed in the Code and this Safety Guide;

(b) The methods for determining that all radiation survey meters, protective equipment and personal monitoring devices in use meet the requirements of the Code and this Safety Guide;

(c) The methods for determining that all personal monitoring devices and radiation survey meters are in good working order;

(d) Procedures for ensuring that any personal monitoring devices used are issued and collected at the appropriate times;

(e) Procedures for ensuring that personal monitoring devices are promptly submitted for assessment after use;

(f) Details of any extra duties necessary to meet the requirements of the Code in relation to storage, emergencies and transport.

3.3 Radiation Safety Officer

A person with the legal responsibility for dealing with a radiation device such as a fixed radiation gauge may decide to delegate certain duties to a person such as a Radiation Safety Officer (RSO). Delegating duties to an RSO does not absolve that person from their legal responsibility for ensuring that those duties are carried out. In some Australian jurisdictions, the appointment of an RSO is, in fact, mandatory following the issue of an authorisation by the relevant regulatory authority. Typically, an RSO will:

(a) have sufficient professional and/or technical training to perform the RSO duties as detailed in Annex G; and

(b) undertake the measurements, investigations and assessments, make the reports, keep the records and perform any or all of the duties specified in Annex G;

(c) have the necessary authorisation, equipment, procedures and employee cooperation to undertake the measurements, investigations and assessments, make the reports and keep the records required specified in Annex G; and

(d) ensure that the Responsible Person is kept informed of the radiation safety status of the practice.

The RSO can be an employee of the organisation that deals with the fixed radiation gauge and the duties can, for example, be added as an extra level of duties for the Occupational Health and Safety Officer. An external provider of such services or a radiation protection consultant could also be used to perform the RSO functions. Where the appointment of an RSO is mandated by a given jurisdiction however, such an appointment will be subject to the requirements of the relevant regulatory authority.

4. Radiation Monitoring and Radiation Levels

In addition to the mandatory requirements for radiation monitoring specified in the Code, the following information should also be considered for inclusion in the Radiation Management Plan.

4.1 Monitoring Devices to be Available

The Responsible Person, supplier or service provider, after seeking advice from the relevant regulatory authority, should ensure that enough radiation survey meters, in working order, are available and used in accordance with the requirements specified in the Code.

4.2 Survey Meters

Radiation survey meters that are primarily sensitive to gamma radiation will not accurately indicate the total dose rate near a fixed radiation gauge that also produces neutron radiation. The radiation dose rate around a fixed radiation gauge that contains both a neutron and gamma ray source should be determined by measuring the neutron and gamma ray dose rates separately using appropriate survey meters. The dose rates may then be added together to give the total dose rate. In certain specific cases the dose rate measured by a gamma survey meter may be used to estimate the total dose rate. It is important to note though, that the gamma reading might not indicate the total neutron and gamma dose rate unless the conversion factor used has been shown to be correct for the specific case. The relevant regulatory authority should be consulted in relation to such estimations.

The regulatory authority might also approve the use of gamma ray measurements for checking whether the radiation pattern around a radiation gauge has changed. A change of gamma ray pattern could indicate damage to the shielding. If other types of radiation are present though, it should be noted that the true dose rate could be several times higher than that indicated by the gamma ray survey meter.

The radiation survey meter should be checked against a known radiation source prior to each use to ensure that it is operating in the correct manner[28]. Failure to do so may result in personnel being inadvertently exposed to elevated radiation levels where a monitor is malfunctioning or not calibrated.

It should be noted that due to the generally lower energy spectrum of X-radiation, a specialised survey meter might be needed to measure the radiation levels around a fixed radiation gauge that incorporates an X-ray tube. A specialised survey meter will also be needed to measure alpha or beta radiation.

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[28] It should be noted that such a check does not substitute for an instrument calibration.

The instrument's batteries should be checked regularly to ensure that they are sufficiently charged and they should be replaced or recharged if not so. The power level of the batteries should also be checked in the survey meter before each use.

5. Storage and Transport

In addition to the mandatory requirements for storage and transport specified in the Code, the following information should also be considered for inclusion in the Radiation Management Plan.

5.1 Storage of Gauges

When one or more fixed radiation gauges are placed in the store, the warning notice outside the store should also contain instructions for contacting the Responsible Person.

A radioactive source might need to be removed from a large fixed radiation gauge while a major service was being carried out on that gauge. This would be done to minimise the radiation dose to the service personnel. The removal of a radioactive source from a fixed radiation gauge is normally only carried out with the approval of the relevant regulatory authority.

As far as practicable, and taking into account the ALARA principle, a fixed radiation gauge containing a radioactive source should not be stored near regularly occupied or frequented areas nor should it be stored in the same storage area as dangerous goods of the following classes:

1.	Explosives
2.1	Flammable gas
3	Flammable liquid
4.1	Flammable solid
4.2	Spontaneously combustible
4.3	Dangerous when wet
5.1	Oxidising agent
5.2	Organic peroxide
8	Corrosive

Consideration should be given to separation of these classes when designing a store from the 'ground up' or, as is more often the case, when designating an existing store as a storage area for a fixed radiation gauge containing a radioactive source.

In addition, fixed radiation gauges containing radioactive sources should not be stored near undeveloped X-ray or photographic film or foodstuffs.

5.2 Transport of Gauges

Where a gauge containing a radioactive source needs to be relocated within the Responsible Person, supplier or service provider's establishment, lifting devices should be used to remove the source container from its installed location. An appropriate vehicle should be used to transport the gauge to its new location. These procedures will minimise manual handling with a view to keeping the radiation exposure of persons to a level as low as reasonably achievable.

The source container should be moved within the establishment in such a manner as to ensure a similar level of safety to that intended by the *Code of Practice for the Safe Transport of Radioactive Material (2001)*.

When transported on public roads, a gauge containing a radioactive source, wherever possible, should be fixed in location within the vehicle with the shutter mechanism facing away from the vehicle occupants or facing downwards.

Loading restrictions also exist for the transport of fixed radiation gauges containing radioactive sources with other classes of dangerous goods. These classes are the same as those given for storage as outlined above.

The Australian Dangerous Goods Code (ADGC) specifies the criteria for the transport of mixed dangerous goods on the one conveyance. The ADGC should be checked before a fixed radiation gauge containing a radioactive source is transported with any other dangerous goods on the one conveyance. In general though, mixing incompatible classes of dangerous goods on the one conveyance would not be permitted unless there is segregation of at least 12 metres and for some mixed classes, 24 metres.

Where other compatible dangerous goods are being transported on or in a vehicle, it may be necessary to have two sets of placards indicating that the vehicle is carrying a fixed radiation gauge containing radioactive sources and another class of dangerous goods.

6. Licensing Issues

The following information should also be considered for inclusion in the Radiation Management Plan.

6.1 Cross Border Licensing Issues

While the packaging, labelling and paperwork required for the transport of radioactive material is uniform throughout Australia, the licensing requirements for transport across the jurisdictions may not be. Further, the registration/licence requirements for the possession and use of fixed radiation gauges may differ between jurisdictions. Licences or other types of authorisations granted in one jurisdiction only apply within that jurisdiction.

If re-locating a fixed radiation gauge across a jurisdictional boundary, the relevant regulatory authorities in each jurisdiction should be consulted to ascertain the licensing and registration requirements.

Annex A

Radiation Sources Used in Fixed Radiation Gauges

A1 SELECTION OF RADIOACTIVE MATERIALS FOR FIXED RADIATION GAUGES

The radioactive sources used in fixed radiation gauges should:

(a) only incorporate radioactive substances that have the minimum activity and half-life, consistent with the projected useful life of the gauge; and

(b) emit radiation of the type and energy appropriate for the particular application.

If the use of a short half-life radioactive material is not practicable, consultation with the relevant regulatory authority is recommended.

Radioactive substances that are very highly radiotoxic should not be used for a fixed radiation gauge unless:

(a) no other suitable lower radiotoxicity substance is available; or

(b) the radioactive substance is being used to produce neutrons.

Some manufacturers of radioactive sources do not specify working life but advise that a source is within its working life provided the source complies with test requirements, such as wipe testing. The relevant regulatory authority may assign a recommended working life of a radioactive source if the manufacturer does not specify it.

A radioactive source nearing the end of its working life may undergo inspections, testing and/or other processes approved by the relevant regulatory authority to determine and/or assure the safe condition of the source and its fitness for continued use. If satisfied that the source is in acceptable condition, the relevant regulatory authority may approve extensions to the working life of the source.

A2 TESTING OF SEALED SOURCE ENCAPSULATION

The International Organization for Standardization (ISO) has developed a system of classification of sealed sources which is based upon safety requirements for those sources in typical uses (such as bore-hole logging, gauging, industrial radiography etc.)

This system provides a manufacturer of sealed radioactive sources with a set of tests to evaluate the safety of their products under working conditions. It also assists the user of such sealed sources to select types which suit the particular application, especially where protection against the release of radioactive material is required.

The tests to which prototype sources are subjected to are listed in Table A.1. Each test can be applied in several classes of severity. Sealed sources are issued with a five figure ISO code that indicates the level of performance passed by a particular source in each of the five tests. For example, a source with the ISO classification C66646 meets all of the tests to the highest level.

Table A1 Classification of sealed source performance standards[29].

Test	Class 1	Class 2	Class 3	Class 4	Class 5	Class 6
Temperature	No Test	-40°C (20 min.) +80°C (1hour)	-40°C (20 min.) +80°C (1hour)	-40°C (20 min.) +400°C (1hour) and thermal shock 400°C to 20°C	-40°C (20 min.) +600°C (1hour) and thermal shock 600°C to 20°C	-40°C (20 min.) +800°C (1hour) and thermal shock 800°C to 20°C
External Pressure	No Test	25kPa absolute to atmospheric pressure	25kPa absolute to 2MPa absolute	25kPa absolute to 7MPa absolute	25kPa absolute to 70MPa absolute	25kPa absolute to 170MPa absolute
Impact	No Test	50g from 1m	200g from 1m	2kg from 1m	5kg from 1m	20kg from 1m
Vibrations	No Test	30 min 25 Hz to 500Hz at $5g_n$ peak amplitude	30 min 25 Hz to 50Hz at $5g_n$ peak amplitude and 50Hz to 90Hz at 0.635 mm amplitude peak to peak and 90Hz to 500Hz at $10g_n$	90 min 25 Hz to 80Hz at 1.5mm amplitude peak to peak and 80Hz to 2000Hz at $20g_n$		
Puncture	No Test	1g from 1m	10g from 1m	50g from 1m	300g from 1m	1kg from 1m

Some sealed radioactive sources may also be classified as special form. Special form radioactive material is defined by the International Atomic Energy Agency (IAEA) in their Regulations for the Safe Transport of Radioactive Materials as being:

> 'either an indispersible solid radioactive material or a sealed capsule containing radioactive material.'

The sealed capsule needs to be so constructed that it can be opened only by destroying the capsule.

For a particular source to be classified as special form, a prototype source must have passed impact, percussion, bending and heat tests, with immersion tests for leakage being done after each of the four mentioned tests. Special form certification indicates that the source capsule is exceptionally rugged and is capable of withstanding significant abuse without release of the radioactive contents. Special form certification has important implications for the transport of radioactive material and special form certificates are issued by the government transport authorities in some countries. The certificate specifies the capsule type as well as the maximum activities of the specific isotopes which are permitted. Special form certificates expire after a time period, which is usually 5 years or less. For most types of sources new certificates are issued, however some sources may lose their special form certification if the manufacturer does not apply for re-certification, or if test requirements change.

Before reuse of any radioactive source, the source should be inspected by the manufacturer or agent of the manufacturer and, if necessary, re-encapsulated to ensure compliance with the relevant ISO specifications (ISO (International Standard) 2919-1999(E)) (see Table A1).

Re-encapsulation of a used radioactive source may be an alternative to purchasing a new source. However, the encapsulation must be done by an organisation with appropriate facilities and the encapsulation must be certified to comply with the relevant ISO specifications.

[29] This table is based on International Standard ISO 2919, Table 2. Permission to reproduce this material was granted by Standards Australia.

A3 X-RAY TUBE AND GENERATOR ASSEMBLY REQUIREMENTS

An X-ray tube and generator assembly used in a fixed radiation gauge should include either user or automatic controls to maintain the minimum output intensity necessary for effective operation throughout the anticipated useful life of the gauge. This feature is intended to ensure minimum output intensities while allowing compensation for tube and detector aging.

A4 NEUTRON GENERATOR TUBES

Most (but not all) neutron generator tubes, where the neutron generator device is contained within a hermetically sealed vessel, rely on the deuterium-tritium (DT) fission reaction to produce fast neutrons. In some cases the deuterium-deuterium (DD) reaction may be used to produce lower energy neutrons. A tritium-tritium (TT) reaction may be used to produce a broad spectrum of neutron energies.

In a common type of neutron generator, deuterons are accelerated by an electric field, focused into a beam by a magnetic field, and impact a target that contains either radioactive tritium or non-radioactive deuterium. The applied voltage may typically be up to 120 kV. High probability nuclear fusion reactions take place which produce fusion neutrons. Solid tritium impregnated targets may contain of the order of 100 GBq of tritium. The total inventory of tritium within a sealed tube assembly, which stores the tritium in a solid solution form, can be up to 400 GBq which is a limit value imposed by IAEA transport vessel classification (Class 7 UN2910 0r UN2911).

Some neutron generators may use tritium and/or deuterium in a gaseous form such as the Inertial Electrostatic Confinement type which has no solid target. The reactant gas (D or T) is stored in solid solution within a getter pump sintered alloy component. At elevated temperatures of around 500°C, the partial pressure of the hydrogen isotopes will be in the 10^{-2} mbar (10^{-4} Pa) range. This is suitable for glow discharge operation whereby ions are accelerated and decelerated within a concentric electrostatic field. The cathode is at a negative voltage typically in the range of 20 to 100 kV. The anode is at ground potential and usually forms the vacuum vessel wall. The cathode is not a target for fusion grade particle collisions.

Neutron generator tubes, particularly those that contain radioactive tritium, have characteristics of both X-ray tubes and sealed sources in that:

(a) turning off the electrical supply can stop the ionizing radiation output;

(b) the intensity of the neutron radiation output depends on the voltage and current applied to the tube; and

(c) radioactive material is contained in the sealed assembly; and

(d) X-ray Bremsstrahlung radiation is also produced when the high voltage is applied during operation.

As such, criteria for determining the suitability of neutron generator tubes involve elements of both section A1 and section A3 above.

Annex B

Radiation Source Containment

B1 Requirements for Radioactive Source Containers

The radioactive sources should be either permanently mounted within the source containment or permanently fixed in a moveable assembly.

The source container should be robust and easy to use.

Radiation levels should be determined with the shutter or source control mechanism in the 'beam off' position.

Any component subject to the heat test requirements of the Code may require re-testing if it is welded or brazed subsequent to testing and certification. Due consideration of the 800°C melting point limit should be made in the selection of brazing alloys and other bonding materials.

B2 Shutters and Interlocks

In situations where the primary beam is not fully enclosed, a means of turning off the primary beam is required. This may be a shutter, a means of moving the source to a safe position or a means of de-energising the radiation source.

A manual method of turning off the primary beam may be permitted providing it can be shown that this does not pose an unacceptable risk of radiation exposure. Justification for a manual shutter should be based on the following considerations:

(a) the radiation intensity in the primary beam is low enough not to present a significant hazard;

(b) securely fixed guards are in place to prevent access to the primary beam; and

(c) the above features are backed up by working rules, and supervision and training of employees, to ensure that employees are not unnecessarily exposed to radiation.

When an automatic method for turning off the primary beam is fitted, it will normally be provided with electrical inputs and outputs to permit interlocking with plant control systems.

B3 Requirements for Shutterless Gauges

In special cases it may be possible to justify the use of a gauge that has no shutter. Some shutterless gauges require special containment measures to protect the source from damage or loss while the gauge is in use.

One example of a shutterless gauge is an instream analyser that immerses a probe containing a radioactive source into a slurry stream. The slurry provides sufficient shielding to meet the requirements of the code without the need for a shutter.

If the material being gauged provides substantial shielding for accessible areas a failsafe method for indicating the loss of that material should be provided.

Shutterless gauges may also be approved if low activity sources are used or if the design of the gauge prevents access to the primary beam during use or routine service work.

Annex C

Radiation Monitoring and Radiation Levels

C1 GENERAL RADIATION LEVELS

When planning for regularly occupied areas near to fixed radiation gauges, the radiation levels at any accessible location should not result in an ambient dose equivalent rate or directional dose equivalent rate greater than 0.5 μSv.h^{-1}. Similarly, a store for fixed radiation gauges that is located near regularly occupied areas should not have radiation levels that result in an ambient dose equivalent rate or directional dose equivalent rate greater than 0.5 μSv.h^{-1}.

Acceptable radiation levels may be estimated for compliance with the appropriate dose limits and dose constraints by assuming the maximum exposure period (i.e. 2000 hours per year, if a 40 hour working week is assumed) and worst case occupancy factors of 1, 0.3 and 0.1 (i.e. estimate the occupancy factor and use the next higher worst case factor to ensure an acceptable safety margin).

If, for example, a receptionist were required to sit on the opposite side of a wall adjacent to the location of a radiation gauge, the following calculation could be made:

Annual dose limit ÷ (occupancy factor × hours.y^{-1})
= 1 mSv.y^{-1} ÷ (1 × 2000 hours.y^{-1})
= 1/2000 mSv.h^{-1}
= 0.5 μSv.h^{-1}

The receptionist should not be exposed to an ambient dose equivalent rate or directional dose equivalent rate greater than 0.5 μSv.h^{-1} while working at his or her desk. Even then, he or she may receive their maximum permissible annual dose of 1 mSv and ALARA considerations may need to be taken into account.

If, however, the gauge needed to be located adjacent to a storeroom with an occupancy factor of 0.1, the dose rate would be:

Annual dose limit ÷ (occupancy factor × hours.y^{-1})
= 1 mSv.y^{-1} ÷ (0.3 × 2000 hours.y^{-1})
= 1/600 mSv.h^{-1}
= 1.7 μSv.h^{-1}

The factor of 0.3 (the next higher worst case factor) has been used to ensure an acceptable safety margin. The ambient dose equivalent rate or directional dose equivalent rate in the storeroom could therefore be up to 1.7 μSv.h^{-1} without the annual dose limit for a member of the public being exceeded.

C2 RADIATION EXPOSURE AS A RESULT OF AN INCIDENT

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 a fixed radiation gauge under control in such a way that the following doses are not exceeded during that operation:

(a) 1000 μSv to the whole body from gamma or neutron radiation;

(b) 5000 μSv to the hands and forearms, feet and ankles; and

(c) 6000 μSv to the skin from low energy radiation.

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

Annex D

Radiation Warning Labels and Notices

Radiation warning signs and notices, must conform to AS 1319 - 1994 Safety signs for the occupational environment, and AS 2342 - 1992 Development, testing and implementation of information and safety symbols and symbolic signs. Examples of suitable warning notices are given below.

In the selection of the material to be used for a metal label, the long-term effects of corrosion and general exposure to the environment in which it is to be used should be considered. Ideally, the label should be manufactured from 316 Stainless Steel or of material with at least similar strength and corrosion resistance.

The text and trefoil should be acid etched and filled with an epoxy paint. The data should be put on using impact stamps or rotary tool engraving. Diamond, laser or burr engraving are not generally deep enough to withstand the rigors of aggressive environments.

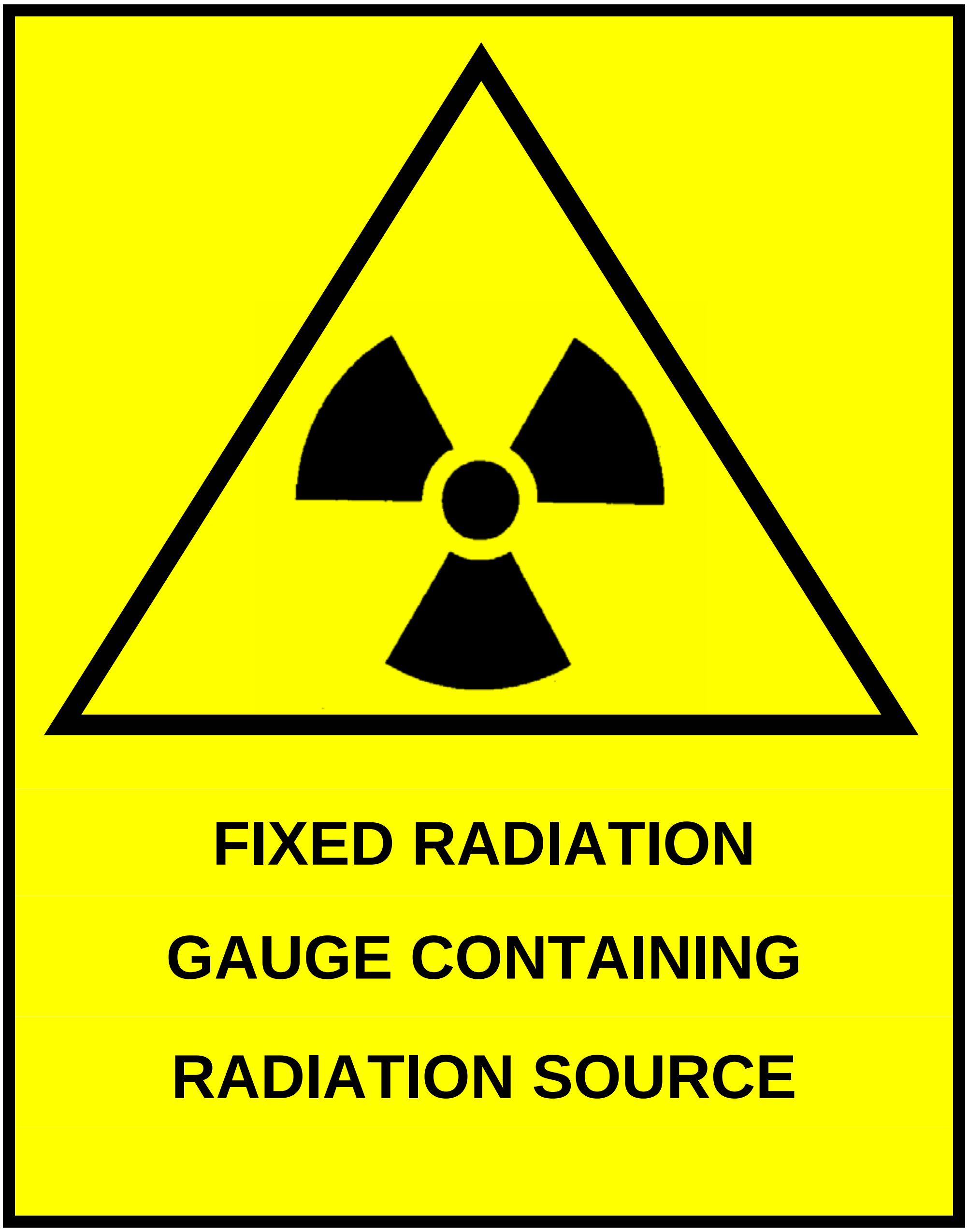
The method of fixing the label to the gauge should be robust and reliable enough to ensure that it remains affixed securely for the estimated life of the gauge.

D1 Colours for Radiation Warning Labels and Notices

Background:	yellow
Marking and trefoil:	black

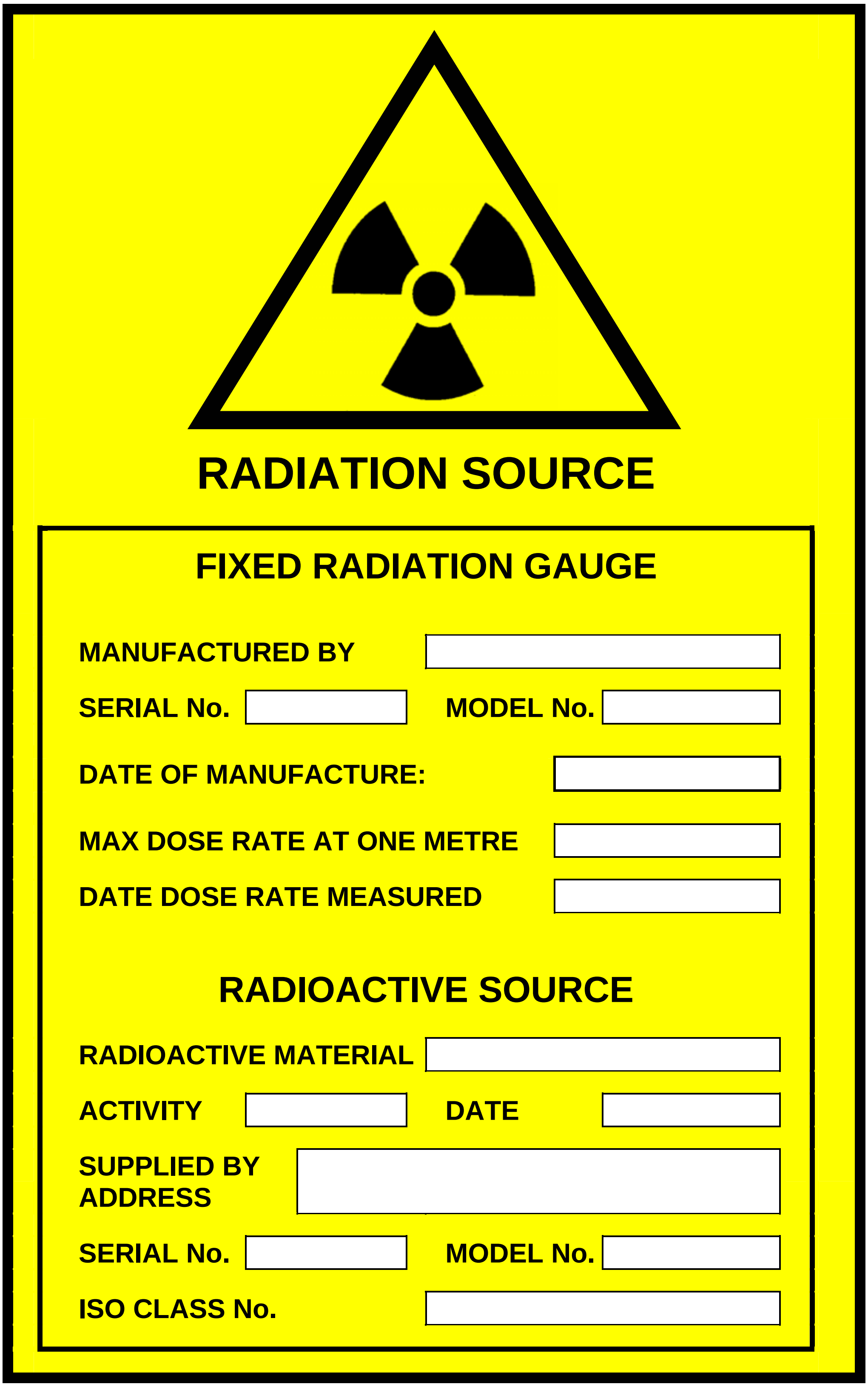
(NOTE: lower part of labels D4 and D5 may be unpainted metal with black lettering).

D2 EXAMPLE OF SUITABLE WARNING NOTICE FOR AREA ADJACENT TO GAUGE



D3 EXAMPLE OF A SUITABLE WARNING NOTICE FOR A STORE

D4 EXAMPLE OF A SUITABLE WARNING LABEL FOR ATTACHMENT TO A FIXED RADIATION GAUGE CONTAINING A RADIOACTIVE SOURCE



D5 EXAMPLE OF A SUITABLE WARNING LABEL FOR ATTACHMENT TO A FIXED RADIATION GAUGE CONTAINING AN X-RAY TUBE INSERT

RADIATION SOURCE

FIXED RADIATION GAUGE

MANUFACTURED BY			
SERIAL No.		MODEL No.	
MAX DOSE RATE AT ONE METRE			
DATE DOSE RATE MEASURED			

X-RAY TUBE INSERT

MANUFACTURED BY			
SERIAL No.		MODEL No.	
MAXIMUM RATINGS			
kVp		mA	

D6 Example of a Suitable Warning Label for Attachment to a Fixed Radiation Gauge Containing Depleted Uranium Shielding Material

D7 Example of a Suitable Warning Label for Attachment to a Shutterless Fixed Radiation Gauge

Annex E

Inspection Proforma

The following is a guide to the information that should be included in an inspection proforma used for inspecting a fixed radiation gauge:

(a) the date and time of the inspection;

(b) the name of the person carrying out the inspection;

(c) the details of the fixed radiation gauge including:
  (i) manufacturer;
  (ii) model (or type); and
  (iii) serial number or other identifying insignia.

(d) the details of the radiation source including:
  (i) manufacturer;
  (ii) model (or type);
  (iii) serial number;
  (iv) operating factors of the X-ray equipment, if appropriate;
  (v) the activity and date of measurement of the radioactive source, if appropriate.

(e) a comment or grading (e.g. 'good, average and poor', 'acceptable and unacceptable', 'satisfactory and unsatisfactory' etc) of each of the following aspects relating to the gauge:
  (i) the general condition of the gauge (all parts of the gauge should be considered including the gauge mounting);
  (ii) a shutter operation check;
  (iii) operation of the beam indicators relating to the gauge;
  (iv) condition (e.g. clarity and legibility) of the labels located on the gauge; and
  (v) condition (e.g. clarity and legibility) of the warning signs located near the gauge.

(f) radiation measurements at suitable locations around the gauge (e.g. front, back, top, bottom and each side). Measurements should be made at 0.05 m and 1 m from the surface of the gauge[30]. Measurements should also be made at any nearby workstations. The background radiation dose rate should also be noted;

(g) the details of the radiation survey meter used to take radiation measurements including:
  (i) manufacturer;
  (ii) model (or type);
  (iii) serial number; and
  (iv) date of last calibration.

(h) any other comments, observations or suggested remedial actions, if required, by the inspecting person relating to the safety of the gauge or its installation.

[30] It would be prudent to compare the radiation measurements with the expected radiation profile for the gauge being investigated.

Annex F

Example Wipe Test Procedure

F1 OBJECTIVE

A wipe test on the exterior of a fixed radiation is used to indicate whether any radioactive material has leaked from the radioactive source contained within the gauge. Analysis of a wipe test swab in a specialised laboratory allows very small level of radioactive contamination to be detected. By conducting wipe tests at regular intervals it may be possible to detect a ruptured source before significant levels of radioactive material have been released.

It is important to note that a negative wipe test does not necessarily confirm that there is no leakage from the source capsule. Leakage may have occurred and been contained within the source housing of the fixed radiation gauge. To confirm that the source is not leaking it is necessary to remove the source capsule from the gauge and conduct a wipe test on the capsule itself. Removal of the source capsule from the gauge requires specialised procedures and training and is not covered by the procedure described here. Dismantling a source housing and removing the source capsule should be undertaken with careful consideration of the risks involved.

F2 MINIMISING RADIATION EXPOSURE

All persons using radioactive materials are required to ensure that exposure to radiation follows the ALARA principle, viz., exposure is kept As Low As Reasonably Achievable. This philosophy should always be borne in mind when working with radiation and fundamentally involves the considerations of time, distance and shielding:

TIME:
Prepare wipe test equipment and relevant paperwork before approaching the source housing. While not actually making a wipe test, keep at a distance where dose rate is not measurably above background.

DISTANCE:
Use tongs or forceps and an extended arm to keep the distance between your body and the source as large as possible while making a swab. Remember the Inverse Square Law applies; twice the distance means on quarter the dose rate.

SHIELDING:
The exposure rates around the source housing of a fixed radiation gauge should be low enough that for the time required to make the wipe test, no significant radiation will be received during the wipe test procedures. In some cases, shielding may be used to reduce exposure. Dose rates measurable around the source housing shall dictate the necessity for shielding.

F3 CONTROL OF RADIOACTIVE CONTAMINATION

Radioactive contamination refers to radioactive material that has escaped from the source encapsulation. Contamination is generally not visible, so all devices that have come into contact with the source housing must be assumed to be contaminated until a negative wipe test result is received. Because of the risk of contamination the following rules apply to personnel conducting a wipe test:

(a) Personnel with hand wounds must not conduct wipe tests unless wounds are suitably covered with waterproof dressing.

(b) No smoking, eating or drinking is permitted during the wipe test procedure.

(c) Disposable gloves are to be worn while performing wipe tests. These are to be removed in the correct manner so as to reduce the risk of personal contamination.

(d) Tissues should be used instead of personal handkerchiefs should the need arise.

F4 Items Required to Conduct a Wipe Test

(a) Wipe test swab (a commercially available wipe test swab or a piece of filter paper, or other material of high wet strength and absorbent capacity).

(b) Distilled water or other liquid (for example methylated spirits) which will not attack the material of the gauge housing and which is known to be effective in removing the radioactive substance involved.

(c) Surgical gloves.

(d) Forceps or tongs. These should have rounded edges to prevent any damage to the wipe test swab.

(e) Plastic bags made of thin tough material for covering the forceps or tongs during use. Freezer bags are generally suitable.

(f) Sealable plastic bags.

(g) Identification labels or marking pen.

(h) Extendable arm mirror device.

(i) A contamination meter capable of detecting alpha, beta and gamma radiation. An end window GM tube or pancake GM tube would generally be suitable. This could also be used for making approximate gamma dose rate measurements near the source housing.

(j) A wipe test report sheet for recording swab details and a precise description of the areas wiped.

F5 Method for Making the Wipe Tests:

(a) Ensure the survey meter is functioning before checking radiation levels around the source with the meter. Examine the source housing (without touching it) for likely areas of contamination such as welds, joints, corroded shielding, shutter linkage areas, etc.

(b) Leave the operating contamination meter in a convenient location near the source housing. It should be positioned with the detector window accessible.

(c) Retire to a suitable working distance (where dose rates are not measurably above background) to prepare for making the wipe test.

(d) Prepare paperwork.

(e) Prepare two polythene bags to receive swab(s).

(f) Wear a pair of gloves.

(g) Moisten the wipe test swab.

(h) Place plastic bag over tongs to be used for swabbing and picking up swab.

(i) Gently wipe outer surfaces of source housing. Ensure that at least 100 square centimetres of surface area is wiped. Try and work from areas of least likely contamination toward areas most likely to be contaminated. For example, where a gauge has an accessible shutter, work from labels to around welds and finish with the shutter linkage. Swab thoroughly and efficiently.

(j) Check the swab for gross contamination by bringing it carefully to within 10 mm of the contamination meter window. There should be no discernible change in count rate. If a consistent increase in count rate is observed when the swab approaches the window then contamination is likely to be present and steps must be taken to prevent spreading of contamination.

If swab material and/or plastic bag becomes snagged then:

Use tongs and/or forceps to recover any snagged materials. Complete swabbing with reclaimed material before placing into one of the waiting bags. Since the tongs may now be contaminated place tongs and/or forceps into second bag to prevent spread of possible contamination. Seal first bag with swabs while gently removing air (with the open end of the bag directed away from face). Seal this bag and label clearly.

Otherwise:

Pull bag inside out over the swab, and with open end of bag away from face, gently remove air as you seal bag. Label bag containing swab clearly.

Take additional wipe tests if required.

Note:

- Before moving onto other sources housings, take swab of tongs and forceps. Bag, seal and label as before.
- Gloves must also be changed, bagged, sealed and labelled between swabbing different source housings and must be removed correctly to prevent the spread of contamination.
- Gloves should be peeled off inside out from the wrist.

(k) On completion of all wipe tests, take a final swab of the tongs and forceps. Remove gloves and bag, seal and label with the swabs from the tongs.

(l) Double bag all swabs taken of sources housing(s) prior to packaging and contact Health Physics section to arrange for analysis.

(m) Double bag tongs, forceps and bagged gloves. Seal, label and store in a suitable location until negative wipe test results have been received. This will avoid dispersal of any contamination which may be present on the equipment used.

F6 PACKAGING PROCEDURES:

(a) Make a final check of all sealed wipe test bags with the contamination meter in a location away from any radioactive materials. If there is any consistent change in meter reading when the bagged swabs are brought up to the measurement window there is likely to be contamination and the regulatory authority will need to be contacted for further advice.

(b) All swabs to be sent for analysis need to be placed in a suitable container, eg: a cardboard or plastic box of at least 10cm length per side.

(c) The appropriate paperwork will need to be placed in an envelope attached to the outside of the package.

(d) Cautionary labels, detailing approximate contents of plastic bag(s) (containing the swabs), viz.,

> **Caution**: Contents may contain radioactive materials.
>
> To be opened by suitably authorised persons only.

Will need to be affixed to these plastic bag(s).

(e) Warnings are not required to be visible on the outside of the container (cardboard box or plastic box of at least 10 cm length per side) providing there is no radiation detectable from the bagged swabs with the survey instrument. The cautionary labels must, however, be visible to someone opening the outermost layer of the package.

(f) The package should be sealed securely (with tape) on the outer surfaces.

(g) Under Australia Post requirements, radioactive material cannot be sent through the normal mail. The package will therefore need to be couriered to a laboratory with facilities for analysing wipe tests.

Annex G

Radiation Safety Officer

A person appointed as the Radiation Safety Officer could typically have the following duties:

(a) obtain and maintain a knowledge of the principles and practices of radiation protection and of the potential radiation hazards associated with fixed radiation gauges, sufficient to undertake the measurements, investigations and assessments as detailed in the Code and this Safety Guide;

(b) be thoroughly familiar with the:

  (i) requirements of the relevant radiation safety legislation;

  (ii) provisions of the Code and this Safety Guide;

  (iii) Radiation Management Plan of the organisation;

  (iv) detailed working rules and emergency procedures adopted for use in accordance with the Code and this Safety Guide; and

  (v) radiation survey meters, protective equipment and personal monitoring devices in use to meet the requirements of the Code and this Safety Guide;

(c) ensure that each person who may be exposed to radiation in the course of the installation, removal, dismantling, maintenance, repair or relocation of a fixed radiation gauge is issued with an appropriate personal monitoring device for the exclusive use of that person;

(d) ensure that all personal monitoring devices and radiation survey meters are in good working order;

(e) issue and collect any personal monitoring devices that may be used;

(f) seek the advice of the relevant regulatory authority regarding any detailed conditions for use of personal monitoring devices;

(g) ensure that personal monitoring devices are promptly submitted for assessment after use;

(h) ensure that where an individual personal monitoring device is known or reasonably suspected to have received a dose in excess of 1 mSv while being worn:

  (i) it is assessed promptly; and

  (ii) if being returned to a personal radiation monitoring service for assessment, that the service is advised of the circumstances;

(i) select survey meters to meet the requirements of the Code and the Safety Guide; and

(j) carry out such extra duties as are necessary to meet the requirements of the Code in relation to storage, emergencies and transport.

Annex H

Health Effects of Ionizing Radiation and Standards for Control of Exposure

It is well known that high doses of ionizing radiation can cause harm, but there is continuing scientific uncertainty about effects at low doses. At levels of dose routinely encountered by members of the public and occupationally exposed persons, there is little or no epidemiological evidence of health effects. Radiation protection standards recognise that it is not possible to eliminate all radiation exposure, but they do provide for a system of control to avoid unnecessary exposure and to keep doses in the low dose range.

Extreme doses of radiation to the whole body (around 10 sievert[31] and above), received in a short period, cause so much damage to internal organs and tissues of the body that vital systems cease to function and death may result within days or weeks. Very high doses (between about 1 sievert and 10 sievert), received in a short period, kill large numbers of cells, which can impair the function of vital organs and systems. Acute health effects, such as nausea, vomiting, skin and deep tissue burns, and impairment of the body's ability to fight infection may result within hours, days or weeks. The extent of the damage increases with dose. However, 'deterministic' effects such as these are not observed at doses below certain thresholds. By limiting doses to levels below the thresholds, deterministic effects can be prevented entirely.

Doses below the thresholds for deterministic effects may cause cellular damage, but this does not necessarily lead to harm to the individual: the effects are probabilistic or 'stochastic' in nature. It is known that doses above about 100 millisievert, received in a short period, lead to an increased risk of developing cancer later in life. There is good epidemiological evidence – especially from studies of the survivors of the atomic bombings – that, for several types of cancer, the risk increases roughly linearly with dose, and that the risk factor averaged over all ages and cancer types is about 1 in 100 for every 100 millisievert of dose (i.e. 1 in 10 000 per millisievert).

At doses below about 100 millisievert, the evidence of harm is not clear-cut. While some studies indicate evidence of radiation-induced effects, epidemiological research has been unable to establish unequivocally that there are effects of statistical significance at doses below a few tens of millisieverts. Nevertheless, given that no threshold for stochastic effects has been demonstrated, and in order to be cautious in establishing health standards, the proportionality between risk and dose observed at higher doses is presumed to continue through all lower levels of dose to zero. This is called the linear, no-threshold (LNT) hypothesis and it is made for radiation protection purposes only.

There is evidence that a dose accumulated over a long period carries less risk than the same dose received over a short period. Except for accidents and medical exposures, doses are not normally received over short periods, so that it is appropriate in determining standards for the control of exposure to use a risk factor that takes this into account. While not well quantified, a reduction of the high-dose risk factor by a factor of two has been adopted internationally, so that for radiation protection purposes the risk of radiation-induced fatal cancer (the risk factor) is taken to be about 1 in 20 000 per millisievert of dose for the population as a whole.

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[31] The sievert (Sv) is a unit of measurement of radiation dose (see ARPANSA's *Recommendations for limiting exposure to ionizing radiation (2002)*).

If the LNT hypothesis is correct, any dose carries some risk. Therefore, measures for control of exposure for stochastic effects seek to avoid all reasonably avoidable risk. This is called optimising protection. However, risk in this sense may often be assessed in terms of risk to a population, and may not ensure sufficient protection of the individual. Consequently, the optimisation approach is underpinned by applying dose limits that restrict the risk to individuals to an acceptable level. The fundamental regulatory philosophy is expressed in three principles, based on the recommendations of the International Commission on Radiological Protection (ICRP), which may be summarised as follows:

> *Justification*: human activities that cause exposure to radiation may be permitted only if they do more good than harm;
>
> *Optimisation of protection*: exposure to radiation from justified activities should be kept as low as reasonably achievable, social and economic factors being taken into account; and
>
> *Limitation of individual dose*: doses must not exceed the prescribed dose limits.

Determining what is an acceptable risk for regulatory purposes is a complex value judgement. The ICRP reviewed a number of factors in developing its recommendations, which have in general been internationally endorsed, including by the World Health Organization, the International Labour Organisation and the International Atomic Energy Agency. Australia's Radiation Health Committee, now established under the ARPANS Act[32], has recommended that the international standards be adopted in Australia. The recommended dose limits are summarised as follows:

Limit on effective dose*

	For occupational exposure	For members of the public
To limit individual risk	20 mSv per year, averaged over 5 years*	1 mSv in a year*

*for details, see *ARPANSA's Recommendations for limiting exposure to ionizing radiation* (2002)

In most situations, the requirements for limiting individual risk ensure that doses are below deterministic thresholds, but for cases where this does not apply, the recommended limits are as follows:

Annual limit on equivalent dose*

	For occupational exposure	For members of the public
To prevent deterministic effects		
in the lens of the eye	150 mSv	15 mSv
in the skin	500 mSv	50 mSv
in the hands and feet	500 mSv	–

*for details, see *ARPANSA's Recommendations for limiting exposure to ionizing radiation* (2002)

32 The *Australian Radiation Protection and Nuclear Safety Act (1998)*

In the case of occupational exposure during pregnancy, the general principle is that the embryo or fetus should be afforded the same level of protection as is required for a member of the public. For medical workers, the ICRP recommends that there should be a reasonable assurance that fetal dose can be kept below 1 mGy[33] during the course of the pregnancy. This guidance may be generalised to cover all occupationally exposed pregnant workers by keeping the fetal dose below 1 mSv. A full explanation of radiation protection principles and of the recommended standards for Australia is given in ARPANSA/NOHSC Radiation Protection Series No. 1: *Recommendations for limiting exposure to ionizing radiation (1995)* and *National standard for limiting occupational exposure to ionizing radiation (both republished 2002).*

[33] The gray (Gy) is a unit of radiation dose. For X-rays and gamma radiation, it is essentially equivalent to the sievert.

Annex I

ARPANSA Radiation Protection Series Publications

ARPANSA has taken over responsibility for the administration of the former NHMRC Radiation Health Series of publications and for the codes developed under the *Environment Protection (Nuclear Codes) Act 1978*. The publications are being progressively reviewed and republished as part of the *Radiation Protection Series*. All of the Nuclear Codes have now been republished in the Radiation Protection Series.

All publications listed below are available in electronic format, and can be downloaded free of charge by visiting ARPANSA's website at **www.arpansa.gov.au/codes.htm**.

Radiation Protection Series publications are available for purchase directly from ARPANSA. Further information can be obtained by telephoning ARPANSA on 1800 022 333 (freecall within Australia) or (03) 9433 2211.

Radiation Protection Series

RPS 1. Recommendations for Limiting Exposure to Ionizing Radiation (1995) and National Standard for Limiting Occupational Exposure to Ionizing Radiation (republished 2002)

RPS 2. Code of Practice for the Safe Transport of Radioactive Material (2001)

RPS 3. Radiation Protection Standard for Maximum Exposure Levels to Radiofrequency Fields – 3 kHz to 300 GHz (2002)

RPS 4. Recommendations on the Discharge of Patients undergoing Treatment with Radioactive Substances (2002)

RPS 5. Code of Practice and Safety Guide for Portable Density/Moisture Gauges Containing Radioactive Sources (2004)

RPS 6. National Directory for Radiation Protection, Edition 1.0 (2004)

RPS 7. Recommendations for Intervention in Emergency situations Involving Radiation Exposure (2004)

RPS 8. Code of Practice for the Exposure of Humans to Ionizing Radiation for Medical Research Purposes (2005)

RPS 9. Code of Practice and Safety Guide for Radiation Protection and Radioactive Waste Management in Mining and Mineral Processing (2005)

RPS 10. Code of Practice and Safety Guide for Radiation Protection in Dentistry (2005)

RPS 11. Code of Practice for the Security of Radioactive Sources (2007)

RPS 12. Radiation Protection Standard for Occupational Exposure to Ultraviolet Radiation (2006)

RPS 13. Code of Practice and Safety Guide for Safe Use of Fixed Radiation Gauges (2007)

Those publications from the NHMRC Radiation Health Series that are still current are:

RADIATION HEALTH SERIES

RHS 3. Code of practice for the safe use of ionizing radiation in veterinary radiology: Parts 1 and 2 (1982)

RHS 8. Code of nursing practice for staff exposed to ionizing radiation (1984)

RHS 9. Code of practice for protection against ionizing radiation emitted from X-ray analysis equipment (1984)

RHS 10. Code of practice for safe use of ionizing radiation in veterinary radiology: part 3-radiotherapy (1984)

RHS 13. Code of practice for the disposal of radioactive wastes by the user (1985)

RHS 14. Recommendations for minimising radiological hazards to patients (1985)

RHS 15. Code of practice for the safe use of microwave diathermy units (1985)

RHS 16. Code of practice for the safe use of short wave (radiofrequency) diathermy units (1985)

RHS 18. Code of practice for the safe handling of corpses containing radioactive materials (1986)

RHS 19. Code of practice for the safe use of ionizing radiation in secondary schools (1986)

RHS 21. Revised statement on cabinet X-ray equipment for examination of letters, packages, baggage, freight and other articles for security, quality control and other purposes (1987)

RHS 22. Statement on enclosed X-ray equipment for special applications (1987)

RHS 23. Code of practice for the control and safe handling of radioactive sources used for therapeutic purposes (1988)

RHS 24. Code of practice for the design and safe operation of non-medical irradiation facilities (1988)

RHS 25. Recommendations for ionization chamber smoke detectors for commercial and industrial fire protection systems (1988)

RHS 28. Code of practice for the safe use of sealed radioactive sources in borehole logging (1989)

RHS 30. Interim guidelines on limits of exposure to 50/60Hz electric and magnetic fields (1989)

RHS 31. Code of practice for the safe use of industrial radiography equipment (1989)

RHS 34. Safety guidelines for magnetic resonance diagnostic facilities (1991)

RHS 35. Code of practice for the near-surface disposal of radioactive waste in Australia (1992)

RHS 36. Code of practice for the safe use of lasers in schools (1995)

RHS 37. Code of practice for the safe use of lasers in the entertainment industry (1995)

RHS 38. Recommended limits on radioactive contamination on surfaces in laboratories (1995)

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