Australian Government

Australian Radiation Protection and Nuclear Safety Agency

Code of Practice and Safety Guide

Safe Use of Fixed Radiation Gauges (2005)

Consultation Draft – August 2005

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.

Australian Government

Australian Radiation Protection and Nuclear Safety Agency

CODE OF PRACTICE & SAFETY GUIDE

Safe Use of Fixed Radiation Gauges (200X)

Radiation Protection Series Publication No. ??

Public Consultation Version: 29 August 2005

This publication was approved by the Radiation Health Committee on XX XXXX 2005, and on XX XXXX 2005 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 XXXX 200X

Foreword

Since the early 1980s, the basis of regulation for the use of fixed radiation gauges containing radioactive sources was the requirements of the 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 ICRP has revised its radiation protection limits and the 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*, 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 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 DD MMMMM 200Y to DD MMMM 200Y along with 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 DD MMMMM 200Y, and the Radiation Health and

Safety Advisory Council at their meeting of DD MMMMM 200Y 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.

[signature]

John Loy
CEO of ARPANSA

Date

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Australian Radiation Protection and Nuclear Safety Agency

CODE OF PRACTICE

Safe Use of Fixed Radiation Gauges (2005)

Radiation Protection Series Publication No. ??

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Introduction

1.1 CITATION

This *Code of Practice* may be cited as the *Code of Practice for Safe Use of Fixed Radiation Gauges (2005)*.

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 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, employees 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. 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 energized 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 E 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 having 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. Radiation Management Plan

2.1 Formulation of the Plan

2.1.1 Each Responsible Person, supplier or service provider who deals with a fixed radiation gauge must ensure that a Radiation Management Plan is developed, documented, implemented and regularly reviewed to ensure safety in all applicable dealings with the fixed radiation gauge, including:

(a) work practices[1]; and

(b) roles and responsibilities (Section 3); and

(c) radiation monitoring requirements (Section 4); and

(d) control of an incident involving the gauge (Section 4.3); and

(e) storage of the gauge (Sections 5.1 and 5.2); and

(f) transport of the gauge (Section 5.3); and

(g) repairs and maintenance of the gauge (Section 6.1); and

(h) what to do with the gauge (eg. sale, transfer, disposal) when it is no longer required (Sections 6.2 and 6.3); and

(i) records and accountability (Section 6.5); and

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

[1] Guidelines for formulating work practices, including working rules and emergency procedures, are given in Section 2 of the *Safety Guide for the Safe Use of Fixed Radiation Gauges (2005)*.

3. Responsibilities and Duties

3.1 Responsibilities of the Supplier of a Fixed Radiation Gauge

3.1.1 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 section 2.1.

3.1.2 The supplier must ensure that the Radiation Management Plan is reviewed and updated at appropriate intervals.

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

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

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

3.1.4 The supplier of a fixed radiation gauge must appoint a Radiation Safety Officer where required by the relevant regulatory authority.

3.1.5 A person who supplies a fixed radiation gauge must advise the purchaser of their obligations in relation to 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.

3.1.6 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.

3.1.7 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[2]; and

(ii) shielding included in the gauge,

(b) detailed drawings of the gauge, showing:

(i) the method of its fabrication; and

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

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

(iv) the materials used in its construction; and

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

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

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

(ii) calculation; or

(iii) reference to other test results; or

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

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

(e) details of the composition and construction of the radiation shielding in the housing; and

(f) details of any test result demonstrating that the gauge complies with the requirements of Schedule B of this Code;

(g) 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 A2.4 of this Code),

(h) the maximum radiation dose rates at distances of 0.05 m and 1 m from the gauge surface when the gauge is loaded with the maximum activity of each radioactive source for which the gauge was designed;

(i) the radiation dose rate profile around the gauge including at locations normally occupied by operators during gauge use; and

(j) such other details as may be required by the relevant regulatory authority to assess compliance with the requirements of this Code.

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

(a) the name and address of the proposed Responsible Person; 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 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) special form certificate for the radioactive source,

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

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

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

(g) 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.

3.1.9 Prior to the transfer of a fixed radiation gauge, the supplier must supply the intended Responsible Person with the:

(a) documentary evidence that the requirements of 3.1.7 and 3.1.8(f) and (g) were met; and

(b) copies of certificates and any other documentation necessary for compliance with 3.3.14.

3.2 RESPONSIBILITIES OF THE SUPPLIER OF RADIOACTIVE SOURCES USED IN FIXED RADIATION GAUGES

3.2.1 The supplier of a radioactive source for use in a fixed radiation gauge must ensure that all persons under the supplier's care follow and comply with the Radiation Management Plan formulated under section 2.1.

3.2.2 The supplier must ensure that the Radiation Management Plan is reviewed and updated at appropriate intervals.

3.2.3 The supplier of a radioactive source for use in a fixed radiation gauge must appoint a Radiation Safety Officer where required by the relevant regulatory authority who:

(a) has sufficient professional or technical training to perform the Radiation Safety Officer duties as detailed in the Safety Guide; and

(b) undertakes the measurements, investigations and assessments, makes the reports, keeps the records and performs any other duty required of the Radiation Safety Officer as detailed in the Code, Safety Guide and the Radiation Management Plan; and

(c) has the necessary authorisation, equipment, procedures and employee cooperation so that he/she can undertake the measurements, investigations and assessments, make the reports and keep the records required in this Code, Safety Guide and the Radiation Management Plan; and

(d) ensures that the Supplier is kept informed of the radiation safety status of the practice.

3.2.4 The supplier of a radioactive source for use in a fixed radiation gauge, whether or not they are also the supplier of the gauge, must ensure and, when required to do so by the relevant regulatory authority, demonstrate that any source supplied was:

(a) tested and subsequently certified as being compliant with the requirements of Schedule A1 and A2; and

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

(c) accompanied by appropriate documentation of:

(i) the source activity; and

(ii) chemical form of the source; and

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

(iv) testing certificates; and

(v) special form certificates, where applicable; and

(vi) any additional documentation required by the relevant regulatory authority; 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 A, unless:

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

(ii) prior approval was obtained from the relevant regulatory authority.

3.3 RESPONSIBILITIES OF THE RESPONSIBLE PERSON

3.3.1 The Responsible Person must ensure that all persons under their care follow and comply with the Radiation Management Plan formulated under section 2.1.

3.3.2 The Responsible Person must ensure that the Radiation Management Plan is reviewed and updated at appropriate intervals.

3.3.3 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 pathway of the gauge or source(s); 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(s) or company approved by the relevant regulatory authority to perform the necessary work with due regard to the manufacturer's recommendations; and

(d) the source containment, shutter and/or source control mechanism meet the relevant requirements of Schedule B at all times; and

(e) 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 must be connected and tested to confirm their correct operation; and

(f) before using the gauge, and thereafter at intervals not exceeding twelve months[3], 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 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 described in Schedule B, as appropriate for the particular gauge, are intact and legible; and

(g) 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,

(h) a periodic wipe test is carried out on those gauges that contain one or more radioactive sources, using the method and the time intervals between tests approved by the relevant regulatory authority; and

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

(i) the relevant regulatory authority is notified; and

[3] The relevant regulatory authority may require more frequent testing.

(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,

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

(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,

(k) the results of the inspections and tests required in 3.3.3(f)-(j) inclusive are recorded.

3.3.4 The Responsible Person must ensure that a Radiation Safety Officer is appointed who:

(a) has sufficient professional and/or technical training to perform the Radiation Safety Officer duties as detailed in the Safety Guide; and

(b) undertakes the measurements, investigations and assessments, makes the reports, keeps the records and performs any other duty required of the Radiation Safety Officer as detailed in the Code, Safety Guide and the Radiation Management Plan; and

(c) has the necessary authorisation, equipment, procedures and employee cooperation so that he/she can undertake the measurements, investigations and assessments, make the reports and keep the records required in this Code, Safety Guide and the Radiation Management Plan; and

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

3.3.5 In order for the Radiation Safety Officer to accomplish his or her prescribed duties, the Responsible Person must not prevent the Radiation Safety Officer using:

(a) outside experts; and

(b) equipment not in the possession of the Responsible Person.

3.3.6 The Responsible Person must ensure that access to all radiation beams emerging from the radiation source(s) are restricted so that:

(a) all radiation doses are kept as low as reasonably achievable; and

(b) no person can receive a radiation dose in excess of the appropriate dose limits specified in Schedule E of this Code.

3.3.7 The Responsible Person must ensure that the doses received by members of the public:

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

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

3.3.8 The Responsible Person must ensure that the necessary permanent physical barriers, locks, safety interlocks, warning notices and other relevant safety features are provided to ensure that the requirements of 3.3.6 and 3.3.7 are met.

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

3.3.10 The Responsible Person must ensure that employees:

(a) do not remove or in any way interfere with the radiation source(s) in a fixed radiation gauge unless they have the training, qualifications and authorisation acceptable to the relevant regulatory authority; and

(b) do not carry out any maintenance, adjustment or modification to a fixed radiation gauge unless they have the training, qualifications and authorisation acceptable to the relevant regulatory authority; and

(c) especially those newly engaged or re-engaged to work with fixed radiation gauges, are properly instructed and, at appropriate intervals, re-instructed in any:

(i) radiation hazards associated with their work; and

(ii) precautions necessary to limit personal radiation exposures and to avoid radiation incidents and injuries; and

(d) perform their work in accordance with the provisions of this Code.

3.3.11 The Responsible Person must ensure that the warning labels and notices of appropriate form and size (examples included Annex D in the Safety Guide) are:

(a) displayed:

(i) on or adjacent to the gauge; and

(ii) at the entrance to the fixed radiation gauge storage area; and

(iii) elsewhere as required by the relevant regulatory,

(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.

3.3.12 The Responsible Person must ensure that records are maintained of the number and location of all the gauges for which the Responsible Person is responsible.

3.3.13 The Responsible Person must ensure that all radioactive sources within his or her control can be accounted for at all times.

3.3.14 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

(f) date of manufacture; and

(g) ISO class number; and

(h) special form certificate, where applicable; and

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

(j) working life expiry date.

3.3.15 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 sent to the relevant regulatory authority; and

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

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

3.3.17 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, for a period determined by the relevant regulatory authority, maintained in a form that is readily available for inspection by the authority.

3.4 RESPONSIBILITIES OF THE SERVICE PROVIDER

3.4.1 The service provider must ensure that all persons under the service provider's care follow and comply with the Radiation Management Plan formulated under clause 2.1.

3.4.2 The service provider must ensure that the Radiation Management Plan is reviewed and updated at appropriate intervals.

3.4.3 A service provider must:

(a) be licensed where required by the relevant regulatory authority; and

(b) ensure that all service technicians employed by that person are licensed in accordance with the requirements of the relevant regulatory authority.

3.4.4 The service provider must ensure that a Radiation Safety Officer is appointed who:

(a) has sufficient professional or technical training to perform the Radiation Safety Officer duties as detailed in the Safety Guide; and

(b) undertakes the measurements, investigations and assessments, makes the reports, keeps the records and performs any other duty required of the Radiation Safety Officer as detailed in the Code, Safety Guide and the Radiation Management Plan; and

(c) has the necessary authorisation, equipment, procedures and employee cooperation so that he/she can undertake the measurements, investigations and assessments, make the reports and keep the records required in this Code, Safety Guide and the Radiation Management Plan; and

(d) ensures that the service provider is kept informed of the radiation safety status of the practice.

3.4.5 In order for the Radiation Safety Officer to accomplish his or her prescribed duties, the service provider must not prevent the Radiation Safety Officer using:

(a) outside experts; and

(b) equipment not in the possession of the service provider.

3.4.6 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:

(a) the Responsible Person; and

(b) if required, the relevant regulatory authority.

3.4.7 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.

3.4.8 The service provider must ensure that, while under the care or responsibility of the service provider, the gauge is used, stored, transported or repaired:

(a) in accordance with the provisions of this Code ; and

(b) only by appropriately qualified and, where required by the relevant regulatory authority, authorised personnel.

3.4.9 Where a service provider carries out a wipe test of the source(s) and source assembly, the test must be carried out in the manner approved by the relevant regulatory authority.

3.4.10 The service provider must ensure that the equipment necessary to implement the Radiation Management Plan, formulated under clause 2.1, is available and in good working order.

3.4.11 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 E of this Code.

3.4.12 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.

3.5 RESPONSIBILITIES OF THE EMPLOYEE

3.5.1 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.

3.5.2 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; and

(e) use, in a manner required by the relevant regulatory authority, devices or equipment furnished to them to assess their personal radiation dose.

3.5.3 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 the employee has the training, qualification and authorisation acceptable to the relevant regulatory authority; and

(b) carry out any maintenance, adjustment or modification to a fixed radiation gauge unless the employee has the training, qualification and authorisation acceptable to 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 adopted to reduce radiation exposure, except where necessary for authorised purposes of inspection, maintenance, repair, modification or replacement.

4. Radiation Monitoring and Radiation Levels

4.1 PERSONAL MONITORING DEVICES

4.1.1 The Responsible Person, supplier or service provider must provide a personal monitoring device approved by the relevant regulatory authority to determine radiation doses received by each person who:

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

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

(c) where required by the relevant regulatory authority, works in an area around a fixed radiation gauge[4].

4.1.2 A person who is involved with the installation, removal, routine maintenance, service or repair of a fixed radiation gauge must wear a personal monitoring device approved by the relevant regulatory authority 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 D of this Code is readily available or accessible[5] to monitor the gamma radiation levels.

4.2.2 Where neutron monitoring is required by the relevant regulatory authority and a neutron survey meter is not available, the Responsible Person must ensure that the relevant regulatory authority is consulted for approval to estimate neutron levels from gamma measurements[6].

4.3 MANAGEMENT OF AN INCIDENT

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[4] 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 greater than 0.5 $\mu Sv.h^{-1}$ (see also Section C.1 of Annex C of the Safety Guide).

[5] '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.

[6] Gamma-neutron ratios can be highly dependent on the shielding material and thickness.

4.3.1 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.

4.3.2 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.

4.3.3 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 submit the personal monitoring device of each person concerned for urgent assessment.

4.3.4 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 or in the time specified by the relevant regulatory authority.

5. Storage and Transport

5.1 STORAGE OF FIXED RADIATION GAUGES CONTAINING RADIOACTIVE SOURCES (INCLUDING NEUTRON GENERATOR TUBES CONTAINING TRITIUM)

5.1.1 A fixed radiation gauge containing one or more radioactive sources must be securely stored:

(a) if it is not required for immediate use; or

(b) if it has been removed from service.

5.1.2 When a fixed radiation gauge is placed in storage:

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

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

(c) 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.

5.1.3 A store used for the storage of fixed radiation gauges must:

(a) not be used without the approval of the relevant regulatory authority; and

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

(c) 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 $\mu Sv.h^{-1}$, unless otherwise authorised by the relevant regulatory authority; and

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

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

(d) be under the control of the Radiation Safety Officer or other specified person; and

(e) be kept locked; and

(f) be subject to strict access control; and

(g) not be used for other purposes; and

(h) when radioactive sources are in the store, bear a conspicuous notice bearing a radiation hazard warning symbol the letters and symbol of which must be in black on a yellow background

(an example of a suitable notice is given in Figure D.3 of Annex D of the Safety Guide).

5.1.4 A store for fixed radiation gauges must not be located:

(a) near to explosives, combustible or corrosive materials or photographic or X-ray film[7]; 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.

5.2 STORAGE OF FIXED RADIATION GAUGES CONTAINING X-RAY TUBES OR NEUTRON GENERATOR TUBES

5.2.1 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 the Radiation Safety Officer or other specified person.

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

5.3 TRANSPORT OF FIXED RADIATION GAUGES CONTAINING RADIOACTIVE SOURCES (INCLUDING NEUTRON GENERATOR TUBES CONTAINING TRITIUM)

5.3.1 Fixed radiation gauges containing radioactive sources must be transported so that no person associated with transport is exposed to any risk as a result of inadequate packaging of fixed radiation gauges.

5.3.2 The transport of radioactive materials must comply with the Transport Code, as amended from time to time.

5.3.3 When a fixed radiation gauge containing one or more radioactive sources is packaged for transport:

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

(b) the package must be monitored to ensure that:

(i) the useful beam is properly attenuated with the shutter or source control mechanism in the 'beam off' position; and

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

(c) the source container must be:

[7] See section 5.1 of the Safety Guide for further information.

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

(ii) effectively immobilised within the outer container (for example in the case of a heavy source container this can be achieved by being bolted to the outer container); and

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

5.3.4 Where a radioactive source is transported other than within the Responsible Person's establishment, the 'consignors declaration' and any other required documentation must be provided according to the requirements of the Transport Code and the relevant regulatory authority.

5.3.5 During transport of a radioactive source in a vehicle:

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

(b) the package must be stowed securely to prevent it from shifting under normal transport conditions.

5.3.6 When a fixed radiation gauge containing one or more radioactive sources is transported within the Responsible Person's establishment:

(a) the source control or shutter mechanism must be locked in the 'beam off' position before any action is taken to remove the fixing devices that hold the container in its installed location; and

(b) the container is monitored to ensure that the useful beam is properly attenuated with the shutter or source control mechanism in the 'beam off' position; and

(c) the radiation exposure pattern is as expected.

5.3.7 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

(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. Miscellaneous Requirements

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 maintenance on a fixed radiation gauge unless that person:

(a) is licensed 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 authorised to do so by the relevant regulatory authority.

6.1.4 A person undertaking repairs or maintenance work must keep records in accordance with any instructions that the relevant regulatory authority may issue.

6.2 TRANSFER OF OWNERSHIP

6.2.1 The Responsible Person or the supplier must not transfer the ownership of any fixed radiation gauge unless this is done with the approval of the relevant regulatory authority.

6.3 PROHIBITION OF DISPOSAL

6.3.1 The Responsible Person must not dispose of any fixed radiation gauge without the approval of the relevant regulatory authority.

6.4 RE-USE OR RELOCATION OF SOURCES

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

6.5 ACCOUNTABILITY AND RECORDS

6.5.1 *Accountability:* The Responsible Person must be able to account for all fixed radiation gauges within his or her control at all times.

6.5.2 *Records of fixed radiation gauges:* The Responsible Person must maintain records for each fixed radiation gauge within his or her control that show:

(a) the location and all identification numbers; and

(b) the type of radioactive source, where appropriate; and

(c) the activity and date of measurement of the activity of the radioactive source, where appropriate; and

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

6.5.3 *Transfer of custody:* The Responsible Person or the supplier must not transfer the ownership of any fixed radiation gauge unless this is done with the approval of the relevant regulatory authority.

6.5.4 *Annual audit:* The Responsible Person must:

(a) carry out an annual audit of all radiation sources and their locations; and

(b) send the relevant regulatory authority a copy of the audit required by clause 6.5.4(a).

6.5.5 *Failure to account for a radiation source:* The Responsible Person must immediately notify the relevant regulatory authority if a radiation source cannot be accounted for.

Schedule A

Radiation Sources Used in Fixed Radiation Gauges

A1 SELECTION OF RADIOACTIVE MATERIALS FOR FIXED RADIATION GAUGES

A1.1 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 (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 per unit of intake activity.

Element	Isotope	
Lead (Pb)	^{210}Pb	
Polonium (Po)	^{210}Po	
Radium (Ra)	^{226}Ra	^{228}Ra
Actinium (Ac)	^{227}Ac	
Thorium (Th)	^{228}Th	^{230}Th
Palladium (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		

A1.2 The supplier must obtain prior approval from the relevant regulatory authority where it is considered necessary to use one or more of the radioactive materials listed in Table 1.

A2 RADIOACTIVE SOURCE REQUIREMENTS

A2.1 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.

A2.2 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.

A2.3 Each source used in a fixed radiation gauge must be able to satisfy minimum test conditions as required by the relevant regulatory authority.

A2.4 The design, construction and markings of each source used in fixed radiation gauges must satisfy the applicable requirements of:

(a) ISO (International Standard) 2919-1999(E)[8]; or

(b) any other standard or specification that is considered appropriate by the relevant regulatory authority.

A3 X-RAY TUBE AND GENERATOR ASSEMBLY REQUIREMENTS

A3.1 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 withstand vibration, corrosion and any other adverse affects likely to be encountered; and

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

(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

(c) 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.

(d) 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 A3.1(c); and

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

A4 NEUTRON GENERATOR TUBES

A4.1 Each tritium target 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.

A4.2 The form of each tritium target 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.

A4.3 Each tritium target used in a neutron generator tube must be able to satisfy minimum test conditions as required by the relevant regulatory authority.

A4.4 The design, construction and markings of each tritium target used in a neutron generator tube must satisfy the applicable requirements of:

(a) ISO (International Standard) 2919-1999(E)[9]; or

(b) any other standard or specification that is considered appropriate by the relevant regulatory authority.

A4.5 Any neutron generator tube assembly used in a fixed radiation gauge must:

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

(a) be appropriate for the particular application, with regard to the intensity of the neutron 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 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 target 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 A4.5(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 B

Radiation Source Containment

B1 GENERAL REQUIREMENTS FOR RADIATION SOURCE CONTAINMENT

B1.1 Radiation source containment that incorporates depleted uranium in its construction must be durably marked to:

(a) warn of the presence of depleted uranium (see figure D.5 of Annex D of the Safety Guide); 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.

B1.2 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.

B1.3 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 authorised service representative; 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.

B1.4 Unless otherwise approved by the relevant regulatory authority, an automatic shutter, a means of moving the source to a safe position, or a means of de-energising the radiation source must be provided.

B1.5 The operation of the systems required by B1.4 must:

(a) be fail safe; and

(b) ensure that the primary beam is turned off automatically when:

(i) the process stream on which the gauge is mounted stops; or

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

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

(iv) there is failure of mains power.

B1.6 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.

B1.7 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.

B1.8 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.

B1.9 Any welded, brazed or similar joint must:

(a) be in accordance with published standards (AS2205.1 to AS2205.10); and

(b) meet the requirements of the relevant regulatory authority.

B1.10 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.

B1.11 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.

B1.12 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.4.1 or D.4.2 of Annex D of the Safety Guide.

B1.13 The symbol and markings on the label specified in B1.12 must be black on a yellow background.

B1.14 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.

B1.15 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.

B1.16 The gauge must not be modified or altered in any way without the approval of the relevant regulatory authority.

B2 REQUIREMENTS FOR RADIOACTIVE SOURCE CONTAINERS

B2.1 A shutter or source control mechanism must be fitted to the source container unless otherwise approved by the relevant regulatory authority.

B2.2 The shutter or source control mechanism must be designed so that it is fail safe regardless of whether it is manually operated or power operated (i.e. electrical or pneumatic).

B2.3 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.

B2.4 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.

B2.5 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) 250 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.

B2.6 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 800^0 C; and

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

B2.7 The gauge must be durably marked with a legibly stamped or engraved label in the general form of that given in figure D.4.1 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.

B2.8 The gauge must not be loaded, reloaded or used with a radioactive source:

(a) for which it was not designed, unless this is done with the approval of the relevant regulatory authority; and

(b) if any of the safety features of the gauge are deactivated, defective or showing signs of significant deterioration, unless this is done with the approval of the relevant regulatory authority; and

(c) that has exceeded its recommended working life, unless this is done with the approval of the relevant regulatory authority.

B2.9 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.

B2.10 Each radioactive source container must be able to comply with the relevant test requirements of Schedule C of this Code.

B3 REQUIREMENTS FOR X-RAY TUBE, NEUTRON GENERATOR TUBE HOUSINGS AND SHIELDED ENCLOSURES

B3.1 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 approved by the relevant regulatory authority.

B3.2 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.

B3.3 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.

B3.4 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 C5 of Schedule C of this Code.

B3.5 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.

B3.6 When the X-ray tube or neutron generator tube assembly is energised, operating at its maximum output intensity[10] 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) 250 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.

B3.7 Panels, provided for maintenance access or other purposes, which could permit access to the primary beam must:

(a) be secured so that 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.

B3.8 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.4.2 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.

B3.9 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.

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[10] 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.

B3.10 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.4.1 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

(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.

B4 REQUIREMENTS FOR SHUTTERLESS GAUGES

B4.1 A shutterless gauge[11] must not be used unless it has the approval of the relevant regulatory authority.

B4.2 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 B2 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 B3 of this Schedule that do not apply specifically to a shutter.

B4.3 Where the requirements of Sections B2 or B3 of this Schedule are not met under the provisions of clauses B4.2(a) or B4.2(b) of this Schedule respectively, those requirements must be replaced by design, construction and/or usage measures, approved by the relevant regulatory authority, which ensure at least the same level of safety as that afforded by the original requirements.

B4.4 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) 250 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.

B4.5 If the source is immersed or covered by the material being gauged during the normal operation of the device:

[11] This Code recognises the need for shutterless gauges for certain applications, subject to the approval of the relevant regulatory authority.

(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 B4.4 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.6 of Annex D of the Safety Guide; and

(c) the symbol and markings on the label specified in B4.6(b) must be black on a yellow background.

B4.6 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 either figure D.6 of Annex D of the Safety Guide; and

(c) the symbol and markings on the label specified in B4.6(b) must be black on a yellow background.

B4.7 If any moving part represents a risk of damage to the radiation source[12], a suitable protective guard or stop must be fitted between the source and moving part to prevent damage of the source from occurring.

B4.8 A protective guard or stop required under B4.7 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.

B4.9 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.

B4.10 Each shutterless gauge must comply with any other condition required by the relevant regulatory authority.

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

Schedule C

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 C1-C5 of this Schedule apply to a gauge or prototype gauge designed for use with a radioactive source and, unless otherwise required by the relevant regulatory authority, 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 C4-C5 of this Schedule apply to a gauge or prototype gauge that uses an X-ray tube as the radiation source and are, unless otherwise approved by the relevant regulatory authority, to be carried out with the X-ray tube insert installed in the gauge.

(c) The relevant regulatory authority may approve the use of test methods either similar to or other than those specified here, if satisfied that compliance of the gauge with the requirements of this code will be adequately demonstrated by use of such approved test methods.

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.

The relevant regulatory authority may approve an exemption from any of the test procedures if it is satisfied that such procedures are:

(a) unreasonably severe for a particular use of a gauge; or

(b) unnecessary because the gauge is constructed of materials that will easily withstand the physical and chemical conditions imposed by the particular procedures; or

(c) unnecessary because other engineering or administrative requirements will provide an equivalent level of safety.

The relevant regulatory authority may, at its discretion, accept certificates of tests issued by another authority whether such authority is within Australia or in another country.

C1 THE FREE DROP TEST

C1.1 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[13].

C2 THE COMPRESSION TEST

C2.1 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.

C3 THE THERMAL TEST

C3.1 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[14].

C3.2 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[15].

C4 CORROSION AND VIBRATION TEST

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[13] 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.

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

[15] 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.

C4.1 Several tests are set out in Australian Standard AS 1099 *Basic Environmental Testing Procedures for Electrotechnology* and the International Electrotechnical Commission IEC Publication 68. Refer to these documents for further information - in particular to AS 1099 and IEC 68.2.47-1982 Fc (Vibrations), IEC 68.2.52-1996 Kb (Salt mist), IEC 68.2.42-1982 & IEC 68.2.49-1983 Kc (Sulphur dioxide), and IEC 68.2.43-1976 Kd (Hydrogen sulphide).

C4.2 Although these tests were primarily intended for electronic component applications, AS 1099 indicates that they may be used in other fields of technology as considered appropriate.

C4.3 Some potential uses may need special consideration but do not lend themselves to a rigid system of testing[16].

C5 SHUTTER AND SOURCE CONTROL MECHANISM TEST

C5.1 Subject to the testing criteria specified in clause C5.2 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 5,000 cycles of operation.

C5.2 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.

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

Schedule D

Survey Meters

D1 GENERAL REQUIREMENTS OF THE SURVEY METER

D1.1 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 $\mu Sv.h^{-1}$ to 1000 $\mu Sv.h^{-1}$, 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.

D2 CALIBRATION OF THE SURVEY METER

D2.1 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.

D2.2 The calibration of a radiation survey meter must be, in the case of electromagnetic radiation, traceable to:

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

(b) an equivalent overseas National Standard of air kerma recognised by the relevant regulatory authority.

D2.3 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) an equivalent overseas National Standard for neutron radiation recognised by the relevant regulatory authority.

Schedule E

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.

References

(To be completed)

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 labelled, marked or engraved

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.

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).

gamma radiation

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

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.

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 stable 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.

personal monitoring device

a device worn by an individual to monitor the ionising 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.

Recommendations* and *National Standard

the Recommendations for Limiting Exposure to Ionizing Radiation (1995) and National Standard for Limiting Occupational Exposure to Ionizing Radiation (republished 2002) published by the Chief Executive Officer of ARPANSA in March 2002. Radiation Protection Series No. 1.

relevant regulatory authority

the radiation protection authority or authorities designated, or otherwise recognized, 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 maintenance other than routine maintenance or calibrates a fixed radiation gauge.

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 B2.1 of Schedule B of the Code; or

(b) X-ray tube housings but without the shutter required in Clause B3.1 of Schedule B 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.

source 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.

supplier

any legal person to whom a registrant or licensee delegates duties, totally or partially, in relation to the 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.

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 gauge

a fixed radiation gauge that incorporates 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.

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	Director, Regulatory Branch ARPANSA PO Box 655 Tel: (02) 9541 8333 Miranda NSW 1490 Fax: (02) 9541 8348 Email: info@arpansa.gov.au
Australian Capital Territory	Manager Radiation Safety Radiation Safety Section ACT Health Locked Bag 5 Tel: (02) 6207 6946 Weston Creek ACT 2611 Fax: (02) 6207 6966 Email: radiation.safety@act.gov.au
New South Wales	Director Radiation Control Department of Environment and Conservation PO Box A290 Tel: (02) 9995 5000 Sydney South NSW 1232 Fax: (02) 9995 6603 Email: radiation@environment. nsw.gov.au
Northern Territory	Manager Radiation Protection Radiation Protection Section Department of Health and Community Services GPO Box 40596 Tel: (08) 8922 7152 Casuarina NT 0811 Fax: (08) 8922 7334 Email: envirohealth@nt.gov.au
Queensland	Director, Radiation Health Department of Health 450 Gregory Terrace Tel: (07) 3406 8000 Fortitude Valley QLD 4006 Fax: (07) 3406 8030 Email: radiation_health@health.qld.gov.au
South Australia	Director, Radiation Protection Division Environment Protection Authority PO Box 721 Tel: (08) 8130 0700 Kent Town SA 5071 Fax: (08) 8130 0777 Email: radiationprotection@state.sa.gov.au
Tasmania	Senior Health Physicist Health Physics Branch Department of Health and Human Services GPO Box 125B Tel: (03) 6222 7256 Hobart TAS 7001 Fax: (03) 6222 7257 Email: health.physics@dhhs.tas.gov.au
Victoria	Manager, Radiation Safety Program Department of Human Services GPO Box 4057 Tel: (03) 9637 4167 Melbourne VIC 3001 Fax: (03) 9637 4508 Email: radiation.safety@dhs.vic.gov.au
Western Australia	Secretary, Radiological Council Locked Bag 2006 PO Tel: (08) 9346 2260 Nedlands WA 6009 Fax: (08) 9381 1423 Email: radiation.health@health.wa.gov.au

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.

1888
1889

Code of Practice
Fixed Radiation Gauges

Australian Government

Australian Radiation Protection and Nuclear Safety Agency

SAFETY GUIDE

Safe Use of Fixed Radiation Gauges (2005)

Radiation Protection Series Publication No. ??

Public Consultation Version: 29 August 2005

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1. Introduction

1.1 CITATION

This Safety Guide may be cited as the *Safety Guide for the Safe Use of Fixed Radiation Gauges (2005).*

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 (2005) (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 of the Radiation Safety Officer are also given, as is general 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 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) the methods of conducting radiation surveys;

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

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

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

(f) 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;

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

(h) arrangements for preventing or minimizing occupational and public radiation exposure;

(i) 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;

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

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

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

(m) 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;

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

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

(p) the arrangements for maintenance and repair of fixed radiation gauges;

(q) arrangements for the calibration, repair and maintenance of the gauge;

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

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

- (i) the Radiation Safety Officer;
- (ii) relevant regulatory authority;
- (iii) the service provider;
- (iv) the provider of the personal monitoring service,

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

(u) 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. This may need to be done by the Radiation Safety Officer;

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

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

(f) advise staff 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 the following items:

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

- (i) allay panic;
- (ii) shield the radiation source;
- (iii) secure an area of at least 3 metres[17] around any unsecured source(s);
- (iv) establish adequate access control over the area;
- (v) move persons to a safe distance and prevent unauthorised and unnecessary access to the secured area;
- (vi) secure the gauge or sources and to prevent any further damage;
- (vii) remove a radioactive source if safe to do so;
- (viii) de-energise an X-ray tube or turn the gauge off in the case of an electrically energised device;
- (ix) monitor persons and equipment leaving the area. A dislodged source could become entangled in clothing or other equipment; and

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

(x) prevent the further spread of contamination (if this possibility arises),

(c) instructions for any employee involved to report the incident to the Radiation Safety Officer or the Responsible Person;

(d) instructions for the Radiation Safety Officer to:

(i) immediately notify the Responsible Person:

- if a radioactive source is lost or damaged; or
- 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;

(ii) assess the nature and scope of any radiation hazard;

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

(iv) immediately report the incident to the Responsible Person, and to the relevant regulatory authority;

(v) investigate the circumstances of the incident and undertake assessments, measurements and calculations, in order to:

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

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

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

(viii) 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. 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 housing. Particular attention should be paid to fasteners that hold the source housing 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 housing should be made. Any change in dose rates could indicate damage to the source housing, 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 Sections 3.3 and 6.5 of the Code. Turnover of staff however, may result in records being lost or responsibilities becoming confused. The Responsible Person should make sure that all new staff 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 have a greater chance of being lost or discarded with scrap material.

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 and duly appointed Radiation Safety Officers 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 Duties of the Radiation Safety Officer

The Code requires that the supplier of a gauge, the Responsible Person and a service provider appoint a Radiation Safety Officer. The person appointed as the Radiation Safety Officer will 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 monitor(s) for the exclusive use of the 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, with the approval of the relevant regulatory authority, 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.

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.

The Responsible Person, supplier or service provider should seek the advice of the relevant regulatory authority concerning the use of personal dosimeters other than film badges or thermoluminescent dosimeters.

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 and adding these together. The dose rate measured by a gamma survey meter may be used to estimate the total dose rate if a suitable conversion factor has been provided by the survey meter supplier. It is important to note though, that the gamma reading might not indicate the total neutron and gamma dose rate unless the conversion factor supplied specifies that this is the 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 would most likely be 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[18]. Failure to do so may result in personnel being inadvertently exposed to elevated radiation levels where a monitor is malfunctioning or not calibrated.

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.

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

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 radioactive sources are placed in the store, the warning notice outside the store should also contain instructions for contacting the Radiation Safety Officer or his or her deputy.

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 with 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 dangerous goods with the class restriction. These 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. Miscellaneous

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 fixed radiation gauges may differ between jurisdictions.

If re-locating a fixed radiation gauge across a jurisdictional boundary, it is highly recommended to ascertain the relevant licensing and registration requirements of each jurisdiction.

Annex A

Radiation Sources Used in Fixed Radiation Gauges

A.1 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.

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 Tables A.1 and A.2 below).

Table A.1 Classification of sealed source performance covering the class ranges appropriate for radiation gauges (see also Table)[19].

Test	Class		
	2	3	4
Temperature	- 40° C (20 min) + 80° C (1 h)	- 40° C (20 min) +180° C (1 h)	- 40° C (20 min) + 400° C (1 h) and thermal shock to about 20° C
External pressure	25 kPa absolute to atmospheric	25 kPa absolute to 2 MPa absolute	25 kPa absolute to 7 MPa absolute

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

Test	Class		
	2	3	4
Impact	50 gm from 1 m or equivalent imparted energy	200 gm from 1 m or equivalent imparted energy	2 kg from 1 m or equivalent imparted energy
Vibration	3 times 10 min 25 to 500 Hz at 49 $m.s^{-2}$ max.	3 times 10 min 25 to 50 Hz at 49 $m.s^{-2}$ max. and 50 to 90 Hz at 0.635 mm amplitude peak to peak and 90 to 500 Hz 98 $m.s^{-2}$ max.	3 times 30 min 25 to 80 Hz at 1.5 mm amplitude peak to peak and 80 to 2000 Hz 196 $m.s^{-2}$ max.
Puncture	1 g from 1 m or equivalent imparted energy	10 g from 1 m or equivalent imparted energy	50 g from 1 m or equivalent imparted energy

Table A.2 Sealed source performance requirements for typical usage of radiation gauges (see also Table A.1)[20].

Sealed source usage	Sealed source test class				
	Temperature	Pressure	Impact	Vibration	Puncture
Gamma gauges (medium and high energy[21]) Unprotected source	4	3	3	3	3
Gamma gauges (medium and high energy) Source in device	4	3	2	3	2
Beta gauges and sources for low-energy gamma gauges	3	3	2	2	2
General neutron source applications	4	3	3	2	3

A.2 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.

A.3 NEUTRON GENERATOR TUBES

Most (but not all) neutron generator tubes rely on the deuterium-tritium (DT) reaction to produce fast neutrons. Deuterons are accelerated by an electric field and impact a target that contains either radioactive tritium or non-radioactive deuterium that, in turn, produces a beam of monoenergetic neutrons. Solid tritium targets may contain of the order of 100 GBq of tritium. Some neutron generators may use tritium in a gaseous form.

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

[20] This table is based on International Standard ISO 2919, Table 4. Permission to reproduce this material was granted by Standards Australia.

[21] High energy gamma radiation has an energy of above approximately 1 MeV, medium energy gamma radiation has an energy of the order of 100s of keV, low energy gamma radiation has an energy of below about 100 keV.

(a) turning off the electrical supply can stop the neutron 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 source.

As such, criteria for determining the suitability of neutron generator tubes involve elements of both section A.1 and section A.2 above.

Annex B

Radiation Source Containment

B.1 REQUIREMENTS FOR RADIOACTIVE SOURCE CONTAINERS

The radioactive sources should be either permanently mounted within the source housing of the gauge or permanently fixed in the moveable assembly.

The gauge 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 800^0 C melting point limit should be made in the selection of brazing alloys and other bonding materials.

B.2 REQUIREMENTS FOR X-RAY TUBE HOUSINGS AND SHIELDED ENCLOSURES

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.

B.3 AUTOMATIC SHUTTERS AND INTERLOCKS

In situations where the primary beam is not fully enclosed, an automatic shutter, a means of moving the source to a safe position or a means of de-energising the radiation source is normally required.

A gauge that has an automatic shutter will normally be provided with electrical inputs and outputs to permit interlocking with plant control systems.

A method of manually 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 staff, to ensure that staff is not unnecessarily exposed to radiation.

B.4 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 to which the requirements of the Code apply is an instream analyser that immerses a probe containing a radioactive source into a slurry stream.

If the material being gauged provides substantial shielding for accessible areas and there is a loss of the material being gauged that results in increased radiation levels, a suitable warning light should indicate that loss.

Annex C

Radiation Monitoring and Radiation Levels

C.1 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 $\mu Sv.h^{-1}$. 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 $\mu Sv.h^{-1}$.

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/yr)
= 1 mSv/yr ÷ (1 × 2000 hours/yr)
= 1/2000 mSv/h
= 0.5 µSv/h

The receptionist should not be exposed to an ambient dose equivalent rate or directional dose equivalent rate greater than 0.5 µSv/h 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/yr)
= 1 mSv/yr ÷ (0.3 × 2000 hours/yr)
= 1/600 mSv/h
= 1.7 µSv/h

The factor of 0.3 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 without the annual dose limit for a member of the public being exceeded.

C.2 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) 15000 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.

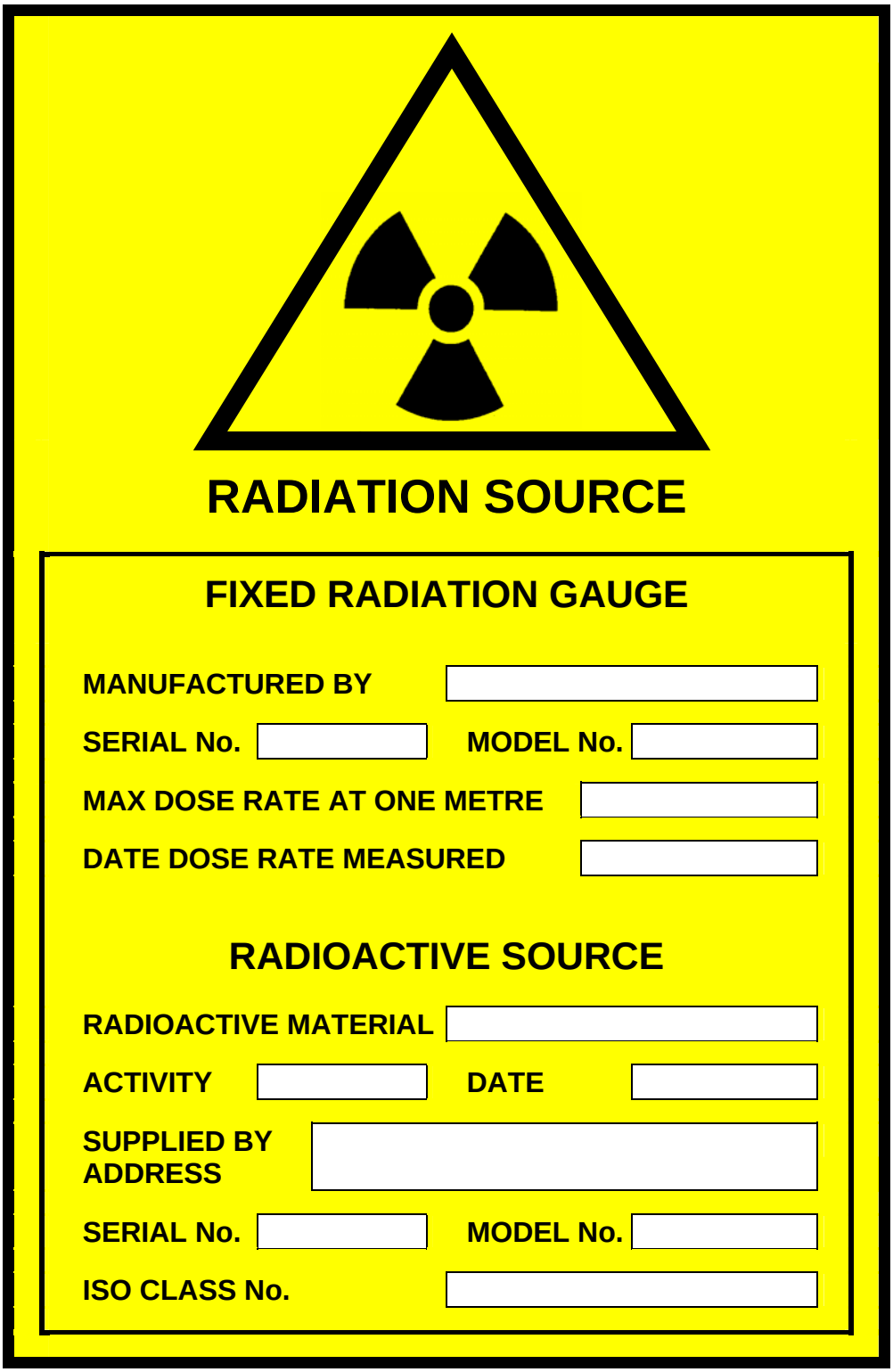
D.1 COLOURS FOR RADIATION WARNING LABELS AND NOTICES

Background: yellow
Marking and trefoil: black
(NOTE: lower part of labels D.4.1 and D.4.2 may be unpainted metal with black lettering).

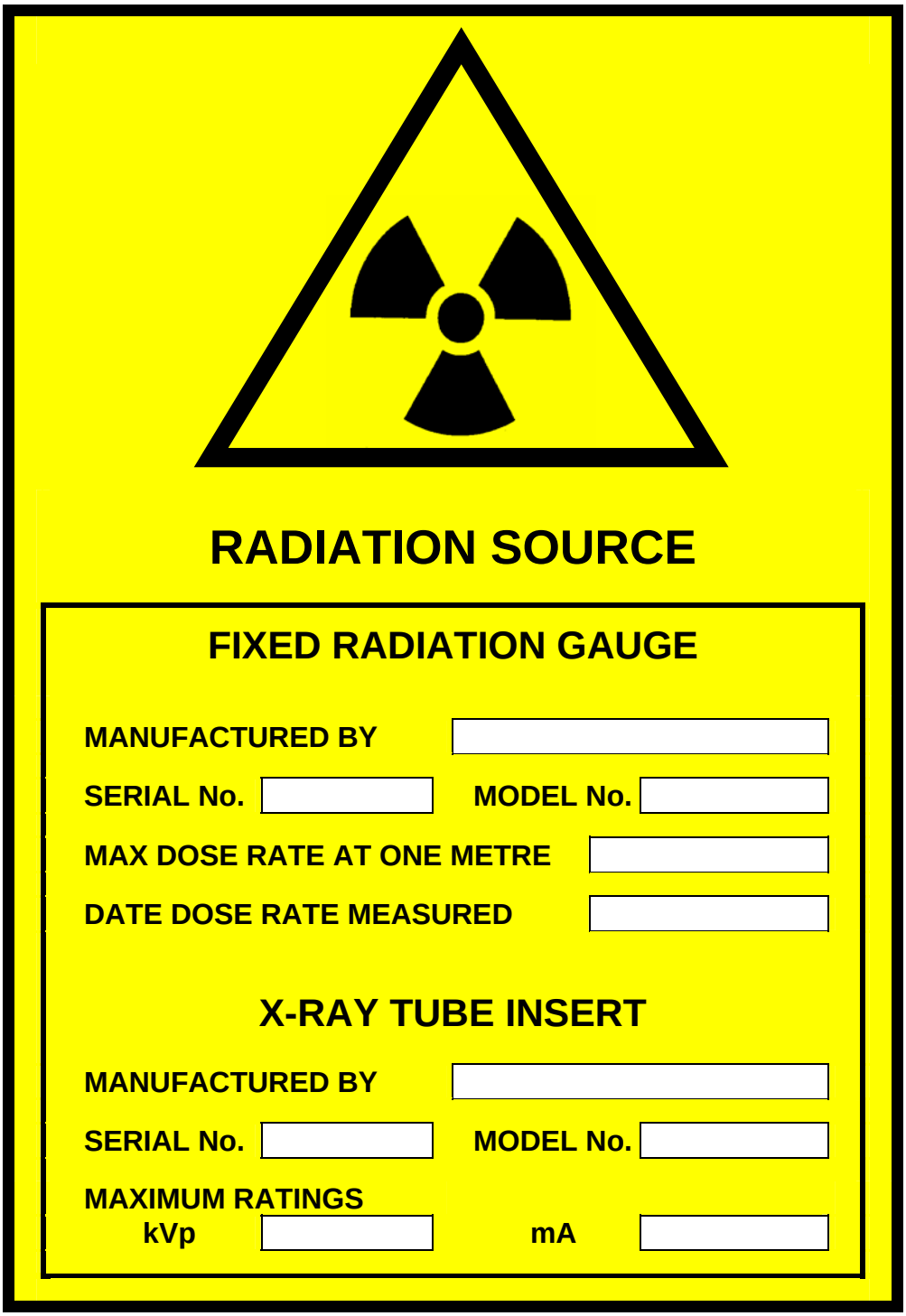
D.2 EXAMPLE OF SUITABLE WARNING NOTICE FOR AREA ADJACENT TO GAUGE

D.3 EXAMPLE OF A SUITABLE WARNING NOTICE FOR A STORE

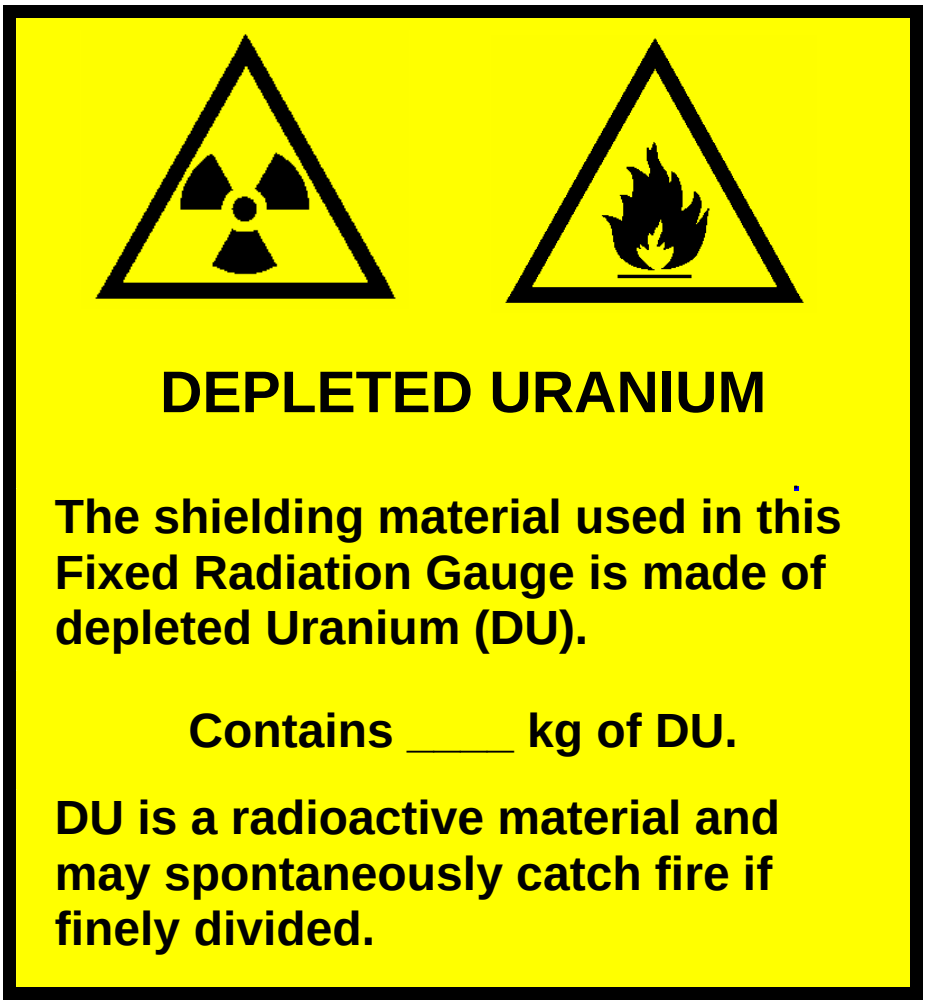
D.4.1 EXAMPLE OF A SUITABLE WARNING LABEL FOR ATTACHMENT TO A FIXED RADIATION GAUGE CONTAINING A RADIOACTIVE SOURCE



D.4.2 EXAMPLE OF A SUITABLE WARNING LABEL FOR ATTACHMENT TO A FIXED RADIATION GAUGE CONTAINING AN X-RAY TUBE INSERT



D.5 EXAMPLE OF A SUITABLE WARNING LABEL FOR ATTACHMENT TO A FIXED RADIATION GAUGE CONTAINING DEPLETED URANIUM SHIELDING MATERIAL



D.6 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 approximately 5 cm and 30 cm from the surface of the gauge[22]. 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.

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

Annex F

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 most present-day radiation workers, there is little or no epidemiological evidence of health effects. Radiation protection standards recognize 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* 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.

* 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 optimizing 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 optimization 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 summarized as follows:

> *Justification*: human activities that cause exposure to radiation may be permitted only if they do more good than harm;
>
> *Optimization 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[†], has recommended that the international standards be adopted in Australia. The recommended dose limits are summarized 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)*

[†] 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[‡] 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).*

[‡] The gray (Gy) is a unit of radiation dose. For X-rays and gamma radiation, it is essentially equivalent to the sievert.

Annex G

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 #. Code of Practice and Safety for the Safe Use of Fixed Radiation Gauges (2005)

Those publications from the NHMRC Radiation Health Series that are still current are:

RADIATION HEALTH SERIES

RHS 2. Code of practice for the design of laboratories using radioactive substances for medical purposes (1980)

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 20.	Code of practice for radiation protection in dentistry (1987)
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 29.	Occupational standard for exposure to ultraviolet radiation (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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