

Australian/New Zealand Standard™

Safety in laboratories

Part 4: Ionizing radiations



AS/NZS 2243.4:2018

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Australian/New Zealand Standard™

Safety in laboratories

Part 4: Ionizing radiations

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PREFACE

This Standard was prepared by the Joint Standards Australia/Standards New Zealand Committee CH-026, Safety in Laboratories, to supersede AS 2243.4—1998.

The objective of this Standard is to promote safe work practices and to prevent unnecessary exposure of persons working in laboratories containing sources of ionizing radiation.

This Standard does not include non-ionizing radiation, which is covered in AS 2243.5, *Safety in laboratories, Part 5: Non-ionizing radiations—Electromagnetic, sound and ultrasound*.

This Standard was prepared after consideration of the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), *Fundamentals for Protection Against Ionising Radiation* RPS F1 (2014) and *Code for Radiation Protection in Planned Exposure Situations* RPS C1 (2016), the most recent recommendations of the International Commission on Radiological Protection (ICRP), and the International Atomic Energy Agency (IAEA). Where necessary, future relevant publications of ARPANSA, the ICRP and the IAEA should be consulted as they become available.

The sections of this Standard dealing with dose limits, accident and emergency procedures and the requirements for radiological laboratories have been further refined since the 1998 edition. For more detailed information, the referenced source documents should be consulted.

This Standard is Part 4 in the AS/NZS 2243 series. The series is as follows:

AS

- 2243 Safety in laboratories
- 2243.1 Part 1: Planning and operational aspects
- 2243.2 Part 2: Chemical aspects
- 2243.3 Part 3: Microbiological safety and containment
- 2243.4 Part 4: Ionizing radiations (this Standard)
- 2243.5 Part 5: Non-ionizing radiations—Electromagnetic, sound and ultrasound
- 2243.6 Part 6: Plant and equipment aspects
- 2243.8 Part 8: Fume cupboards
- 2243.9 Part 9: Recirculating fume cabinets
- 2243.10 Part 10: Storage of chemicals

Statements expressed in mandatory terms in notes to tables are deemed to be requirements of this Standard.

The terms ‘normative’ and ‘informative’ have been used in this Standard to define the application of the appendix to which they apply. A ‘normative’ appendix is an integral part of a Standard, whereas an ‘informative’ appendix is only for information and guidance.

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FOREWORD

Radiation is the emission of energy, in the form of rays, wave motion or particles, from a source. The various kinds of radiation can be subdivided broadly as follows:

- (a) *Ionizing radiations*—radiations that have the potential to cause ionization when interacting with matter. This involves removing or adding electrons from or to the atoms of materials through which the radiations pass, including those that comprise the human organism. Sufficiently energetic radiation may also cause changes in the nuclei of the atoms in the material. Ionizing radiations comprises X-rays, gamma rays, alpha particles, beta particles (i.e. high energy electrons), neutrons, protons and other nuclear particles. Ultraviolet radiation of wavelength less than 100 nm will also cause ionization in air.
- (b) *Non-ionizing radiations*—radiations that do not cause ionization or nuclear changes, but can harm the human body in other ways. Potentially harmful non-ionizing radiations are propagated as electromagnetic waves (in particular, when the wavelength is between about 100 nm and 1 km), and acoustic noise (i.e. unwanted sound).

This Standard does not deal with non-ionizing radiation, which is covered in AS/NZS 2243.5, *Safety in laboratories, Part 5: Non-ionizing radiations*.

NOTES:

- 1 Although referred to in Item (a), ultraviolet radiation is generally classified as non-ionizing radiation and is therefore considered in AS 2243.5.
- 2 Radiation protection is concerned with the protection of individuals, their progeny, the human race as a whole and the environment, while still allowing necessary activities from which radiation exposure may result.
- 3 Various forms of high voltage apparatus may produce ionizing radiations.
- 4 Various chemicals and minerals may be radioactive by virtue of the fact that they contain traces of naturally occurring radioactive elements.

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Australian/New Zealand Standard
Safety in laboratories**Part 4: Ionizing radiations**

SECTION 1 SCOPE AND GENERAL

1.1 SCOPE

This Standard sets out requirements for the protection of people, non-human biota and the environment from the harmful effects of ionizing radiation used in, or as a result of any use within, or in connection with a laboratory.

This Standard also sets out the important characteristics of ionizing radiation-producing materials and apparatus, the nature of the hazards, laboratory design requirements, and other essential radiation protection information.

This Standard applies to the protection against ionizing radiation only, and does not specifically address the control of non-radiological aspects of health, safety and the environment, which are addressed in the relevant Parts of the AS/NZS 2243 series, even though these aspects also need to be considered.

NOTE: The protection from harmful effects of non-ionizing radiation is covered in AS/NZS 2243.5.

This Standard does not apply to exposures incurred during the course of medical or dental diagnosis or treatment and exposure to volunteers as part of a program of biomedical research.

NOTE: See Appendix G, Paragraph G3, [4] and [6].

Where requirements given in this Standard differ from requirements under jurisdictional legislation, the legislation takes precedence.

NOTE: For certain facilities, operations and activities (for example, nuclear installations, transport of radioactive material and radioactive waste management) other requirements apply.

1.2 APPLICATION

This Standard shall be implemented in all laboratories in which—

- (a) radioactive materials are used, processed or stored; or
- (b) ionizing radiation apparatus is used.

1.3 REFERENCED DOCUMENTS

A list of referenced documents and other related publications is provided in Appendix G.

1.4 DEFINITIONS

For the purpose of this Standard, the definitions below apply.

1.4.1 Absorbed dose

The energy absorbed by matter from ionizing radiation per unit mass of irradiated material.

NOTE: The SI unit of absorbed dose is the joule per kilogram (J/kg), termed the gray (Gy). For radiation protection purposes, the absorbed dose is averaged over a tissue or organ.

1.4.2 Accident

Any unintended event, including operating errors, equipment failures and other mishaps, the consequences or potential consequences of which are not negligible from the point of view of protection and safety.

NOTE: Also known as 'Incident' (although this is usually a broader term also covering regulatory events such as near-misses) in some documents.

1.4.3 Activity

The average number of spontaneous nuclear transformations of a radionuclide occurring in unit time.

NOTE: The SI unit for activity is the reciprocal second (s^{-1}), termed the becquerel (Bq) which is equal to one nuclear transformation per second.

1.4.4 Activity median aerodynamic diameter (AMAD)

The aerodynamic diameter of particles having the median activity of the aerosol of interest, i.e. 50% of the aerosol activity is associated with larger particles.

NOTE: For dosimetry purposes, the AMAD can be taken to represent the aerosol.

1.4.5 Adequate protection

Protection against ionizing radiations so that the radiation doses received by any person from external or internal sources, or both, are as low as is reasonably achievable (the ALARA principle), are below any limits recommended for those sources by the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) or the Office of Radiation Safety (NZ) and, in any event, do not exceed the maxima referred to in Appendix A.

1.4.6 Aerodynamic diameter

The diameter, in μm , of a unit density sphere having the same aerodynamic characteristics as the particle of interest.

1.4.7 ALARA principle

As low as reasonably achievable, taking into account economic and societal factors

1.4.8 Annual dose

The dose from external exposure in a year plus the committed dose from intakes of radionuclides in that year.

1.4.9 Annual limit on intake (ALI)

That quantity of a radionuclide which, if taken into the body during one year, would lead to a committed effective dose equal to the relevant annual limit on effective dose.

1.4.10 Becquerel (Bq)

The number of transformations per second.

NOTE: This is the SI unit of activity.

1.4.11 Bremsstrahlung

Electromagnetic ionizing radiation produced by the deceleration of electrons in the vicinity of nuclei.

1.4.12 Committed dose

The lifetime dose expected to result from an intake.

1.4.13 Committed effective dose $[E(\tau)]$

The sum of the products of the committed dose equivalents for each of the body organs or tissues that are irradiated multiplied by the tissue weighting factors (w_T) applicable to each of those organs or tissues.

NOTE: The quantity $E(\tau)$, defined as—

$$E(\tau) = \sum_{\tau} w_T \times H_T(\tau) \quad \dots 1$$

where

$H_T(\tau)$ = the committed equivalent dose to tissue or organ T over the integration time τ elapsed after an intake of radioactive materials

w_T = the tissue weighting factor for tissue or organ T

When τ is not specified, it will be taken to be 50 years for adults and the time to age 70 years for intakes by children.

1.4.14 Competent person

A person who has acquired through training, qualification and experience, or a combination of these, the knowledge and skills that enable the person to safely and effectively perform the task required.

1.4.15 Constraint

A prospective- and source-related value of individual dose (dose constraint) or of individual risk (risk constraint) that is used in planned exposure situations as a parameter for the optimization of protection and safety for the source, and that serves as a boundary in defining the range of options in optimization.

NOTE: The dose constraint for each particular source is intended, among other things, to ensure that the sum of doses from planned operations for all sources under control remains within the dose limit.

1.4.16 Controlled area

A defined area in which specific protection measures and safety provisions are, or could be, required for controlling normal exposures or preventing the spread of contamination during normal working conditions, and preventing or limiting the extent of potential exposures.

1.4.17 Derived air concentration (DAC) for occupational exposure

The annual limit on intake (ALI) (of a radionuclide) divided by the volume of air inhaled by a reference person in a working year (i.e. $2.4 \times 10^3 \text{ m}^3$).

NOTE: The DAC unit is the becquerel per cubic metre (Bq/m^3).

1.4.18 Designated radiation area (DRA)

An area where radiation producing apparatus or radioactive materials can deliver doses of regulatory concern to radiation workers or the public.

NOTE: This includes the ‘controlled’ and ‘supervised’ areas used in publications of the ICRP, the IAEA and the ARPANSA.

1.4.19 Deterministic effect (non-stochastic)

An effect, such as partial loss of function of an organ or tissue, caused by radiation and which generally occurs only above some threshold of dose, the severity of the effect depending upon the magnitude of the dose received.

NOTE: Examples are non-malignant damage to the skin (radiation burns), cataract formation in the lens of the eye, and damage to blood vessels and connective tissue elements which are common to most organs in the body.

1.4.20 Dose

A generic term which can mean absorbed dose, equivalent dose or effective dose, depending on context.

1.4.21 Dose equivalent

The mean energy deposited per unit mass by the radiation multiplied by a number which reflects the relative biological effectiveness of the radiation.

1.4.22 Effective dose

The product of the equivalent dose (in a tissue or organ) and the tissue weighting factor (w_T), summed over all the tissues and organs of the body.

NOTE: The SI unit is the joule per kilogram (J/kg), known as sievert (Sv).

1.4.23 Emergency exposure situation

An unexpected situation of exposure that arises as a result of an accident, a malicious act, or any other unexpected event, and requires prompt action in order to avoid or to reduce adverse consequences.

1.4.24 Environmental exposure

The exposure of wildlife to ionizing radiation.

NOTE: This includes exposure of animals, plants and other organisms in the natural environment.

1.4.25 Environmental monitoring

The measurement of external dose rates due to sources in the environment or of radionuclide concentrations in environmental media.

1.4.26 Equivalent dose

The product of the absorbed dose (averaged over a tissue or organ) and the radiation weighting factor (w_R) for the radiation that is of interest.

NOTE: The SI unit is the joule per kilogram (J/kg) known as sievert (Sv).

1.4.27 External radiation

Ionizing radiation received by the body from external sources.

1.4.28 Flushing sink

A funnel-shaped sink for the disposal of aqueous liquid waste, which during its operation has a curtain of water flowing smoothly down its sides to dilute the waste and reduce the contamination of both the sink and the drainage pipe.

1.4.29 Glove box

A closed box with internal pressure not exceeding ambient, having impermeable gloves (e.g. rubber gloves) and viewing ports in one or more sides, which is used to completely enclose the radioactive materials and the operations on the materials.

1.4.30 Gray (Gy)

The SI unit of absorbed dose.

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

1.4.31 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.

1.4.32 Hazard

A source or a situation with a potential for harm in terms of human injury or ill-health, damage to property, damage to the environment, or a combination of these.

NOTE: Refer to AS/NZS 4801.

1.4.33 Intervention

Any action intended to reduce or avert exposure or the likelihood of exposure to sources that are not part of a controlled practice or that are out of control as a consequence of an accident.

1.4.34 Ionizing radiation

Radiation which is capable of causing ionization, either directly (e.g. from radiation in the form of gamma rays and charged particles) or indirectly (e.g. from radiation in the form of neutrons).

1.4.35 Ionizing radiation apparatus

Apparatus that is capable of producing ionizing radiation, or of accelerating atomic particles, for which a registration/licence is required from the appropriate regulatory authority.

1.4.36 Justification

The process of determining whether a practice (or intervention) is, overall, beneficial, as required by the ICRP's System of Radiological Protection, i.e. whether the benefits to individuals and to society from introducing or continuing the practice outweigh the harm (including radiation detriment) resulting from the practice.

1.4.37 Leakage radiation

All radiation except the useful beam coming from within a protective housing.

1.4.38 May

Indicates the existence of an option.

1.4.39 Monitoring

The measurement of dose, dose rate or activity for reasons relating to the assessment or control of exposure to radiation or exposure due to radioactive materials, and the interpretation of the results.

1.4.40 Nuclide

A species of atom characterized by the number of protons and neutrons in its nucleus.

1.4.41 Occupationally exposed worker

A person who, in the course of their work, could be exposed to ionizing radiation arising from direct involvement with sources of such radiation.

1.4.42 Occupied area

An area that can be occupied by one or more persons.

1.4.43 Optimization of protection (and safety)

The process of determining what level of protection and safety makes exposures, and the probability and magnitude of potential exposures, as low as reasonably achievable under the prevailing circumstances, with economic and social factors being taken into account, as required by the ICRP's System of Radiological Protection.

1.4.44 Planned exposure situation

A situation involving the deliberate introduction and operation of sources.

NOTE: This may give rise both to exposures that are anticipated to occur (normal exposures) and to exposures that are not anticipated to occur (potential exposures).

1.4.45 Protective housing

An enclosure of an X-ray tube, an accelerator or a sealed source, which is intended to reduce the radiation exposure to a specified level.

1.4.46 Radiation laboratory

A laboratory in which ionizing radiation apparatus or sealed radioactive sources are used or stored. It does not contain any unsealed radioactive materials.

1.4.47 Radiation protection adviser (RPA)

A person appointed by the responsible person to oversee the application of relevant radiation safety requirements..

NOTE: See Appendix C, Paragraph C3 for a more detailed definition.

1.4.48 Radiation weighting factor (w_R)

A number by which the absorbed dose in a tissue or organ is multiplied to reflect the relative biological effectiveness of the radiation in inducing stochastic effects at low doses, the result being the equivalent dose.

1.4.49 Radioactive contamination

The presence of a radioactive material(s) in or on a material or in a place where it is undesirable or could be harmful.

NOTE: In the specific case of the human body, this contamination includes both external skin contamination and internal contamination.

1.4.50 Radioactive material

A material which emits ionizing radiation as a consequence of radioactive decay.

NOTE: Under legislation, each regulatory authority defines the lower limits of radioactivity which are subject to control.

1.4.51 Radioisotope laboratory

A laboratory in which an unsealed radioactive material is used or stored. It does not contain any ionizing radiation apparatus.

1.4.52 Radiological hazard

The potential danger to health arising from exposure to ionizing radiation; it can arise from external radiation or from radiation emitted by radioactive materials within the body.

1.4.53 Radiological laboratory

A laboratory which incorporates the functions of both a radiation laboratory and a radioisotope laboratory.

1.4.54 Radionuclide

A species of atomic nucleus which undergoes radioactive decay.

1.4.55 Radiotoxicity

The toxicity attributable to ionizing radiation emitted by a radionuclide (and its decay products) incorporated in the human body.

NOTE: Radiotoxicity is related not only to the radioactive characteristics of the radionuclide but also to its chemical and physical state and to the metabolism of the radioactive elements in the body or in an organ of the body.

1.4.56 Reference person

An individual whose characteristics correspond to the data published in the International Commission on Radiological Protection (ICRP) Publication 89.

NOTES:

- 1 See Appendix G, Paragraph G4.
- 2 This model allows generic calculations of derived limits from the primary limits of effective dose or committed effective dose.

1.4.57 Representative person

An individual receiving a dose that is representative of the doses to the more highly exposed individuals in a population.

1.4.58 Responsible person

The person bearing the legal responsibility for setting up and implementing the technical and organizational measures that are required for ensuring protection and safety for the ionizing radiation sources within an authorized organization.

NOTE: See Appendix C, Paragraph C2.

1.4.59 Risk

The likelihood and consequence of injury or harm occurring.

NOTE: Refer to AS/NZS 4801.

1.4.60 Risk assessment

An assessment of those aspects of a proposed procedure and its associated equipment which are relevant to the safety of persons, including the analysis of risks associated with normal conditions, abnormal conditions and accident situations.

NOTE: Refer to AS/NZS 4801.

1.4.61 Sealed source

Any radioactive material that is firmly bonded to prevent dispersion of the active material into the surroundings under foreseeable conditions of use and wear, such as within metals or sealed in a capsule or similar container of adequate mechanical strength.

1.4.62 Shall

Indicates that a statement is mandatory.

1.4.63 Should

Indicates a recommendation.

1.4.64 Sievert (Sv)

The SI unit for both equivalent dose and effective dose.

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

1.4.65 Source

Any physical entity which can cause radiation exposure.

1.4.66 Stochastic effect

A radiation induced health effect, the probability of occurrence of which is greater for a higher radiation dose and the severity of which (if it occurs) is independent of dose.

NOTE: Examples of this are carcinogenesis in exposed individuals and hereditary effects.

1.4.67 Supervised area

A defined area not designated a controlled area but for which occupational exposure conditions are kept under review, even though no specific protection measures or safety provisions are needed.

1.4.68 Tissue weighting factor (w_T)

Multiplier of the equivalent dose to an organ or tissue used for radiation protection purposes to account for the different sensitivities of different organs and tissues to the induction of stochastic effects of radiation.

1.4.69 Unsealed source

A source which is not a sealed source and which, under normal conditions of use, can produce radioactive contamination.

1.4.70 Useful beam

That part of the primary and secondary radiation which passes through the aperture, cone or other device for collimating a beam of ionizing radiation.

1.4.71 Waste stream

A waste stream is the flow or movement of wastes from the point of generation (e.g. a laboratory or veterinary practice) to final disposal (e.g. incineration, landfill, sewer).

SECTION 2 HAZARDS AND THEIR CONTROL

2.1 HAZARDS FROM IONIZING RADIATION

2.1.1 General

Hazards from ionizing radiation can give rise to biological effects.

For further information on the effects of radiation on health and the environment please see Fundamentals for Protection Against Ionising Radiation, RPS F1, (Appendix G, Paragraph G3, [8]).

For radiation protection purposes, ionizing radiation hazards may be divided into two classes: external and internal. These should be considered together when assessing the total hazard.

2.1.2 External hazards

External hazards arise from sources of ionizing radiation outside the body that can irradiate all or part of the body with sufficient energy to affect the skin or underlying tissues.

Practical control measures to protect the body from such hazards shall include the following:

- (a) Limit the exposure time.
- (b) Maximize the distance between source and person.
- (c) Use suitable shielding.

2.1.3 Internal hazards

Internal hazards arise when radioactive materials enter the body through inhalation, ingestion, injection or absorption through the skin or a wound.

Practical control measures to protect the body from such hazards shall include the following:

- (a) Use of the least radiotoxic and smallest activity of radioactive material that is suitable for the task to be undertaken.
- (b) Containment, i.e. limit the laboratory area that could become contaminated with radioactive materials by the use of fume cupboards, glove boxes or safe handling techniques.
- (c) Cleanliness, i.e. high quality housekeeping techniques are essential.

2.2 LEGISLATION

Legislation requires all persons who deal with ionizing radiation in their work shall do so under a licence. As the licensing requirements vary among the jurisdictions, each laboratory shall determine their obligations and comply with the applicable legislative requirements.

NOTE: All jurisdictions (Australian Commonwealth, States and Territories and New Zealand) have enacted legislation controlling the importation, sale, possession, use, transport and disposal of radioactive materials and ionizing radiation apparatus (for further details see Appendix C).

2.3 RISK ASSESSMENT

Risk assessments of all radiation operations in the laboratory shall be carried out. As part of the risk assessment, the information contained in various regulations and accompanying codes of practice and the other Parts of the AS/NZS 2243 series shall be incorporated where appropriate.

Tasks shall be assessed for performance during normal working hours, outside of normal working hours, and working in isolation. Risks associated with normal and foreseeable deviations in operations shall be included in the assessment. The laboratory's activities shall also be in accordance with security requirements.

NOTE: See also Sections 4 and 5.

SECTION 3 DESIGN REQUIREMENTS FOR RADIATION, RADIOISOTOPE AND RADIOLOGICAL LABORATORIES

3.1 GENERAL

This Section provides requirements and guidance for the design of the following:

- (a) *Radiation laboratories*—in which ionizing radiation from ionizing radiation apparatus or sealed radioactive sources are used or stored. (It does not contain any unsealed radioactive materials.) Such laboratories may need radiation shielding, warning provisions and limitations on access.
- (b) *Radioisotope laboratories*—in which unsealed radioactive materials are used or stored. (It does not contain any irradiation apparatus.) Such laboratories may need additional design features to minimize the potential for spread of radioactive contamination and its ingestion or inhalation.
- (c) *Radiological laboratories*—in which ionizing radiation apparatus, sealed radioactive materials and unsealed radioactive materials are used. Such laboratories may need the design features for both radiation and radioisotope laboratories.

When a new laboratory is being planned or an existing laboratory is being modified, the advice of the radiation protection adviser (RPA) shall be sought at an early stage, taking into consideration any guidance and requirements of the regulatory authorities. This is particularly important for medium level and high level laboratory proposals or modifications (see Clause 3.5 on grading of laboratory).

3.2 PLANNING BRIEF

A written planning brief shall be prepared early in the planning stage for a new or modified laboratory. This brief shall provide essential information on specifications and regulatory requirements to the consultant engineers and architects commissioned to design the laboratory and should be prepared in accordance with AS/NZS 2982, AS/NZS 2243.1 and this Standard. The RPA and users shall be consulted to ensure the proposed laboratory is fit for purpose.

The planning brief should include, at a minimum, the following information:

- (a) Whether the proposed new or modified laboratory will be a radiation laboratory, radioisotope laboratory or a radiological laboratory.
- (b) Any future needs or changes of functions or processes, i.e. any future expansion needs.
- (c) Type, grading and function of the laboratory (see Clause 3.5).
- (d) A description of the procedures (now and envisaged for the future) to be carried out as these may affect building requirements, including laboratory layout.
- (e) Details of the hazards associated with the work (see Clause 3.3).
- (f) Fittings (such as benches, sinks, and fume cupboards) and apparatus to be installed including relevant operational details (e.g. heat loads, electrical power requirements, cooling, floor loading, etc.).
- (g) Storage requirements for stocks of radioactive materials, including security (see Appendix G, Paragraph G3, [7] or [29]), radiation shielding, temperature control and exhaust ventilation.

- (h) Proposed waste disposal and management techniques, including—
 - (i) packaging, storage and transport for solid wastes;
 - (ii) treatment (if any) for aqueous liquid wastes and their packaging;
 - (iii) scrubbing or filtration (if any) for airborne contaminants and their safe dispersal above the building; and
 - (iv) procedures for management and disposal of other wastes including solvents, chemical and biological wastes.
- NOTE: See also Section 8 and Appendix F.
- (i) Areas to be regarded as designated radiation/radioactive areas (DRAs) (see also Clause 4.2).

3.3 TYPES OF HAZARDS

The following types of hazards may be encountered in radiation, radioisotope and radiological laboratories and shall be taken into account in the planning brief:

- (a) Mechanical and physical.
- (b) Electrical.
- (c) Fire.
- (d) Explosion.
- (e) Chemical (including solvents, cytotoxics, carcinogens and teratogens).
- (f) Gases and cryogenics (including flammable and toxic).
- (g) Biological (including microbial pathogens).
- (h) Ionizing radiation.
- (i) Non-ionizing radiation.
- (j) Potential surface or airborne contamination arising from—
 - (i) chemical, biological or radioactive operations; and
 - (ii) operations where flammable liquids and toxic, radioactive, microbial pathogens or genetically modified organisms materials may contaminate ventilation air, particularly in the event of an accident or spillage.
- (k) Types of flammable or non-flammable gases and vapours likely to be produced by particular laboratory processes or to arise from flammable liquid stores or cabinets, and the tendency of those gases or vapours to ascend or descend in air.
- (l) Hot and cold objects.
- (m) Creation of dusts.

3.4 DESIGN AND CONSTRUCTION REQUIREMENTS

The design and construction requirements for radiation, radioisotope and radiological laboratories shall be in accordance with the National Construction Code of Australia and the New Zealand Building Code respectively (see Appendix G, Paragraph G3, [2] and [32]), AS/NZS 2982 and this Standard.

3.5 RADIOISOTOPE LABORATORY GRADING

Radioisotope laboratories shall be graded according to the factors in Tables 3.1 to 3.4.

Using the radiotoxicity groups in Table 3.1 (see Appendix G, Paragraph G3, [12]), a grading system (see Appendix G, Paragraph G3, [13] and [33]) shall be utilized that designates the features, standards of finish and facilities in a laboratory according to the quantities of unsealed radioactive materials that can be used safely in it.

TABLE 3.1
RADIOTOXICITY GROUPINGS

Group 1	Ac-225, Am-241, Ac-227, Bk-249, Ce-144, Cf-246, Cf-248, Cf-249, Cf-250, Cf-251, Cf-252, Cm-240, Cm-242, Cm-243, Cm-244, Fm-255, In-115, Pa-230, Pb-210, Po-210, Pu-236, Pu-238, Pu-241, Ra-223, Ra-224, Ra-225, Ra-228, Sr-90, Th-227, Th-228, Th-229, U-230, U-232 U-240
Group 2	Ag-105, Ag-110m, Ag-111, Am-243, Am-244, As-73, As-74, As-76, At-207, At-211, Au-195, Au-198, Ba-128, Ba-133, Ba-140, Bi-210, Bi-212, Bi-206, Bi-207, Bi-213, Bk-245, Bk-250, Ca-45, Ca-47, Cd-109, Cd-115, Cd-115m, Ce-134, Ce-139, Ce-141, Ce-143, Cf-244, Cm-238, Cm-241, Cm-245, Cm-246, Cm-248, Co-55, Co-56, Co-57, Co-58, Co-60, Cs-134, Cs-136, Cs-137, Dy-166, Er-169, Es-251, Eu-152, Eu-154, Eu-155, Fe-52, Fe-55, Fe-59, Gd-153, Ge-68, Hf-175, Hf-181, Hg-195m, Hg-197, Hg-197m, Hg-203, Ho-166, I-124, I-125, I-126, I-130, I-131, I-133, In-114m, Ir-190, Ir-192, Ir-194, La-140, Lu-177, Pa-227, Mg-28, Mn-52, Mn-54, Mo-93, Mo-99, Na-22, Nb-90, Nb-93m, Nb-95, Nb-95m, Nb-96, Nd-147, Np-239, Os-185, Os-191, P-32, P-33, Pa-231, Pa-233, Pb-212, Pm-147, Pm-149, Pr-142, Pr-143, Pu-234, Pu-239, Pu-240, Pu-242, Pu-246, Ra-226, Rb-86, Rb-87, Re-186, Re-188, Ru-103, S-35, Sb-122, Sb-124, Sb-125, Sc-46, Sc-47, Sc-48, Se-75, Sm-153, Sn-113, Sn-125, Sr-85, Sr-89, Ta-182, Ta-183, Tb-149, Tb-160, Tc-96, Te-121m, Te-123m, Te-125m, Te-127m, Te-129m, Te-131m, Te-132, Th-226, Th-230, Th-234, Tm-170, Tm-171, U-237, V-48, Y-88, Y-90, Y-91 Yb-169, Zn-65, Zr-88, Zr-89, Zr-95, Zr-97
Group 3	Am-237, Am-238, Am-239, Am-240, Am-244m, Am-245, Am-246, Am-246m, As-77, Be-7, Br-75, Br-76, Br-77, Br-82, C-14, Ce-135, Ce-137m, Cl-38, Cm-247, Co-61, Cr-51, Cs-129, Cs-131, Cs-132, Cs-134m, Cs-135m, Cs-138, Cu-64, Cu-67, Dy-165, Er-161, Er-171, Eu-152m, F-18, Ga-67, Ga-68, Ga-72, Gd-159, Ge-67, Ge-71, H-3 I-120, I-120m, I-123, I-128, I-132, I-132m, I-134, I-135, In-111, In-113m, In-115m, K-42, K-43, Mn-51, Mn-56, Mo-90, Mo-93m, Mo-101, Na-24, Nb-88, Nb-94, Nb-97, Nd-149, Ni-63, Ni-65, Np-237, Os-191m, Os-193, Pb-203, Pd-103, Pd-109, Po-203, Pt-191, Pt-193m, Pt-195m, Pt-197, Pt-197m, Pu-237, Pu-243, Pu-245, Ra-227, Rb-81, Rh-105, Ru-106, Ru-97, Se-83, Si-31, Sm-151, Sn-121, Sr-80, Sr-87m, Sr-91, Sr-92, Tc-99m, Te-116, Te-121, Te-123, Te-127, Te-129, Te-131, Te-133m, Th-231, Tl-197, Tl-200, Tl-201, Tl-202, Tl-204, U-231, U-233, U-234, U-239, W-181, W-185, W-187, Y-87, Y-90m, Y-91m, Y-92, Y-93, Yb-175, Zn-62, Zn-69, Zn-69m, Zr-86
Group 4	Al-26, C-11, Cl-36, Cs-135, I-129, Mn-53, Ni-59, Pt-193, Pu-244, Re-187, Rh-103m, Sm-147, Sr-85m, Tc-97, Tc-99, Th-nat, Th-232, U-nat, U-235, U-236, U-238, Zr-93

NOTES:

- 1 A radioisotope listed in Table 3.1 is considered to be unsupported by a longer lived parent when determining its radiotoxicity group. In cases where a radioisotope is supported by a longer-lived parent, the group of the mixture shall be that of the longer-lived parent. For example, unsupported Po-210 is in group 1. If the Po-210 is associated with Ra-226, the appropriate group for the chain of radioisotopes is group 2. Similarly, unsupported Pb-210 is in group 1, but if the Pb-210 is associated with natural uranium, the appropriate group of the chain of radioisotopes is group 4.
- 2 For isotopes not listed, please refer to the methodology outlined in Carter M.W. et al, (see Appendix G, Paragraph G3, [12]).

Table 3.2 shows laboratory gradings that shall be applied for normal, wet chemical operations.

TABLE 3.2
GRADING OF RADIOISOTOPE LABORATORIES

Radiotoxicity group	Grade of laboratory for specified levels of activity		
	Low level laboratory	Medium level laboratory	High level laboratory
1	<0.2 MBq	0.2 MBq to 20 MBq	>20 MBq
2	<20 MBq	20 MBq to 2 GBq	>2 GBq
3	<2 GBq	2 GBq to 0.2 TBq	>0.2 TBq
4	<0.2 TBq	0.2 TBq to 20 TBq	>20 TBq

Because the potential for radioactive contamination is largely determined by the nature of the work (e.g. storage presents a reduced risk, whereas dusty operations increase the inhalation hazard), the factors shown in Table 3.3 shall be applied to modify the grading according to the operations performed in the laboratory.

Certain labelled organic and biological compounds may be metabolized in a different way from the elemental radionuclides and may, therefore, present a greater hazard. This particularly applies to those compounds containing—

- (a) hydrogen;
- (b) carbon;
- (c) sulphur;
- (d) phosphorus; and
- (e) iodine.

In most cases, the additional risk is small, but an additional modifying factor of 0.1 should be applied, since the intact molecule may be used in important metabolic pathways and synthesis.

The following are examples of why the biological modifying factor should be applied:

- (i) When thymidine labelled with H-3 or C-14 is used, the molecule may be used intact in the synthesis within the body of DNA.
- (ii) When even a simple molecule such as P-32 labelled KH_2PO_3 (a simple biological buffer) is introduced into the cells it will be utilized in the Krebs Cycle as well as carbohydrate, protein and DNA synthesis.

TABLE 3.3
MODIFYING FACTORS

Procedure	Factor
Simple storage	×100
Very simple wet operations (e.g. using aliquots of stock solutions)	×10
Very simple wet operations incorporating biological or organic compounds	×1
Normal chemical operations (e.g. analysis of simple chemical preparations)	×1
Normal chemical operations incorporating biological or organic compounds	×0.1
Complex wet operations (e.g. multiple operations, or operations with complex glass apparatus)	×0.1
Complex wet operations incorporating biological or organic compounds	×0.01
Simple dry operations (e.g. for example manipulations of powders) and work with volatile radioactive compounds	×0.01
Simple dry operations incorporating biological or organic compounds	×0.001
Complex dry operations (e.g. where powders are likely to become airborne) and work with radioactive gases	×0.001

Requirements for laboratory design and construction shall be in accordance with Table 3.4.

TABLE 3.4
SUMMARY OF LABORATORY REQUIREMENTS

	Low	Medium	High	Comments
Structural shielding	Nil	Required depending on radioisotopes and activities		Facility shielding shall prevent non-occupationally exposed persons from exceeding the public exposure limit
Flooring	Continuous and cleanable Building expansion joints shall not pass through the floor area of radioisotope laboratories or laboratory store rooms	As for Low but covered up the wall to 150 mm		Welded seam vinyl preferable The finished flooring shall be smooth and watertight
Floor penetrations	Minimized			
Bench tops	Cleanable Materials impervious to the common materials used	As for Low and, capable of supporting any shielding and lipped so as to form a shallow basin; stainless steel preferable		For example, melamine, PVC, stainless steel are acceptable
Joins	Bench joins shall be designed and constructed so as to not leak or trap contamination			
Sinks	Stainless steel			
Drainage	Isolated from all other waste systems internal to the building			To prevent contamination and overflow into other areas

(continued)

TABLE 3.4 (continued)

	Low	Medium	High	Comments
Walls	Smooth and cleanable finish with minimum fittings to prevent dust accumulation			
Ventilation (refer to AS 1668)	Minimum of exhaust fan provided it is negative pressure with flow of 3 to 6 L/s per m ² floor area	Installed ventilation of negative pressure with flow of 6 to 9 L/s per m ² floor area	Installed ventilation of negative pressure with flow of >9 L/s per m ² floor area, may require filtration and 'scrubbing'	The negative pressure shall be capable of scavenging any atmospheric contaminants from the laboratory
Fume cupboard	May not be required, depending on processes	Mandatory		In accordance with AS/NZS 2243.8 Some processes may require additional containment such as glove boxes, biosafety cabinets, etc.
Handwashing basin	A hands-free or automated hand-washing facility	A dedicated hands-free or automated hand-washing facility near all exits	A dedicated hands-free or automated hand-washing facility near all exits and similar in change room	
First-aid	The handwashing facility may be appropriate	Wash basin		First aid facilities as appropriate for the risks associated with the tasks and materials
Radioactive materials storage	Shielded and secure			ARPANSA RPS 11 (see Appendix G, Paragraph G3, [5]) requirements to be incorporated into storage design
Access	Restricted to laboratory staff	Entry only to authorized occupationally exposed persons		
Coat hooks	Sufficient number located near entryway		Sufficient number located in change room	To ensure lab coats are specific for the DRA
Write-up area	Small area of bench space specifically for documentation, etc. To be kept free of contamination		No write-up areas in a high-level laboratory	Refer to AS/NZS 2243.1 for definition if write-up areas

(continued)

TABLE 3.4 (continued)

	Low	Medium	High	Comments
Emergency shower and eyewash	Dedicated eyewash and emergency shower to be in or in close proximity to the DRA			A deluge shower may not be appropriate for radioactive decontamination
General comments	Criteria as itemized in AS/NZS 2982 RPA to review design and organization for conformance	Criteria as itemized in AS/NZS 2982 RPA to be consulted at the design stages for conformance Conformance with appropriate parts of <i>ARP/ANSA RPS 14</i> (see Appendix G, Paragraph G3, [6]), <i>IAEA Pub1207</i> (see Appendix G, Paragraph G3, [15]) and <i>IAEA Pub1342</i> (see Appendix G, Paragraph G3, [18]) Laboratory is solely dedicated to radiation work Overshoes may be required Uniquely identifiable laboratory coats	Refer to AS/NZS 2982 RPA to be consulted at the design stages for conformance Access will be via change room. See Recommendations of the Nuclear Industry Safety Directors Forum (UK), 'Changeroom Design, Operation and Maintenance' for further detail. Conformance with appropriate parts of <i>IAEA Pub1207</i> (see Appendix G, Paragraph G3, [15]) and <i>IAEA Pub1342</i> (see Appendix G, Paragraph G3, [18]) Overshoes may be required Uniquely identifiable laboratory coats	Other requirements may be specified by local radiological regulators, such as the New Zealand Ministry of Health, and non-radiological regulators, such as the Office of the Gene Technology Regulator, WorkSafe New Zealand, etc.

SECTION 4 IONIZING RADIATION PROTECTION

4.1 GENERAL

The requirements of this Section apply to protection from the hazards of ionizing radiations from any source, i.e. from apparatus producing ionizing radiation, or from radioactive materials, whether sealed or unsealed.

All planned exposures shall be justified and optimized. Optimization of exposure to radiation shall be based on a hierarchy of controls including the following (see also Appendix A, Paragraph A2.3):

- (a) Elimination of exposure, where practicable.
- (b) Use of sources with the minimum of activity and least radiotoxicity necessary.
- (c) Isolation of sources
- (d) Engineering controls, including shielding, containment, remote handling techniques and local exhaust ventilation.
- (e) Administrative controls, including documented work methods that make appropriate use of time, distance, shielding and containment to minimize exposure.
- (f) Use of approved personal protective equipment where other means of controlling exposure are not practicable.

The effective dose received by occupationally exposed workers and members of the public shall not exceed the limits specified in Appendix A, Table A1.

The effective dose in areas continuously accessible to members of the public shall not exceed the public limit given in Appendix A, Table A1.

For areas not continuously occupied by members of the public, the occupancy factors and maximum dose rates shown in Appendix B, Table B3 may be used.

For design and management purposes, the effective doses for occupationally exposed workers and members of the public should be constrained to values lower than the doses in Appendix A, Table A1, in accordance with operational requirements.

NOTE: This does not override the requirement to justify and optimize exposures to radiation.

The design should be checked by—

- (i) undertaking a radiation risk assessment; and
- (ii) ensuring that the dose rate does not exceed the values given in Column 3 of Appendix B, Table B3, when averaged over 40 working hours.

Ionizing radiation protection that is permanently built into the engineered design of any installation should be used in preference to administrative controls or the provision of personal protective measures for the occupationally exposed worker. Protective devices and appliances shall be suitable for their purpose, provide adequate protection, and be convenient to use. They should be examined by the RPA before being put into use, at regular intervals of time during use and whenever changes are made to ensure that they are, and remain, suitable for use and have been properly maintained.

All useful beams of ionizing radiation should be confined to the smallest practicable cross-section. They should be directed away from any adjacent unshielded occupied areas.

Unsealed radioactive materials selected for a given purpose should be the least radiotoxic and possess the minimum activity for the work undertaken. They should also be manipulated and used in such a way that their potential for entry into the body is minimized (e.g. containing the materials within a fume cabinet or ventilated glove box).

All areas likely to have an ionizing radiation hazard shall be monitored with appropriate instruments at regular intervals, in consultation with the RPA, and the results recorded (see Section 6 and Appendix D). Where there is a significant risk from a planned operation that radiation doses to persons are likely to approach or exceed relevant dose limits, due to either personal or equipment failure, a competent person should be present to act solely as an observer to ensure that all relevant safety precautions, as described in the risk assessment, are taken. The observer should be positioned such that they are exposed to a minimum radiation dose (e.g. protected by additional shielding or perhaps by viewing via electronic means from a remote location).

4.2 DESIGNATED RADIATION AREA (DRA)

4.2.1 Controlled area

Controlled areas and the operations within them should be inspected by the RPA at least annually or whenever changes are made to the laboratory or operations within it. More frequent inspections should be carried out by appropriate persons, as appointed by the responsible person (see Appendix C, Paragraph C2). Only authorized persons should be allowed to enter such areas.

The RPA should be kept informed of the locations and activities undertaken in each controlled area. The responsible person should also ensure that a register is kept of the receipt, location; use and disposal of radioactive materials in each controlled area (see Appendix C, Paragraph C2). The RPA, or other competent person, may be appointed by the responsible person to do this.

NOTE: Controlled areas, whether permanent, or temporary, contain radioactive materials in excess of quantities specified as licensable quantities under legislation or are areas in which ionizing radiation apparatus is operated. In these areas there is the potential for significant internal or external exposure from radiation or contamination.

4.2.2 Supervised area

If exposure conditions in a supervised area could lead to an effective dose of greater than 1 mSv/year or an equivalent dose greater than 10% of any other relevant dose limit, the area shall be designated a controlled area.

NOTES:

- 1 These supervised areas may, on rare occasions, be subject to increased radiation or radioactive contamination but in which specific protection measures are not needed.
- 2 An example of a supervised area would be a change room at the exit from a radiation controlled area (see Clause 4.8.6).

4.3 RADIATION WARNING SIGNS

Radiation warning signs shall be displayed at the entrances to each designated radiation area (DRA). The sign shall state if the hazard is radiation or contamination or both (see Appendix E, Paragraph E4). The sign shall also indicate the appropriate requirements for entry (e.g. list the required personal protective equipment and dosimetry to be worn in the area plus appropriate training or supervision).

These signs may also be incorporated into the general hazard laboratory sign. Statutory regulations may require the use of specific wording.