

Australian Standard™

Safety in laboratories

Part 4: Ionizing radiations

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Australian Council of Trade Unions
CSIRO Manufacturing Science and Technology
Department of Defence, Australia
Department of Labour, New Zealand
Environmental Science and Research, New Zealand
ESR Kenepuru Science Centre, New Zealand
Ministry of Commerce, New Zealand
National Association of Testing Authorities, Australia
New Zealand Chemical Industry Council
New Zealand Microbiological Society
Victorian WorkCover Authority
WorkCover New South Wales

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Australian Standard™

Safety in laboratories

Part 4: Ionizing radiations

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PREFACE

This Standard was prepared by Subcommittee CH/26/4, Ionizing Radiation, on behalf of the Joint Standards Australia/Standards New Zealand Committee CH/26, Safety in Laboratories, to supersede AS 2243.4(Int)—1994.

This Standard is the result of a consensus among representatives on the Joint Committee to produce it as an Australian Standard.

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

This Standard was prepared after consideration of the *Recommendations for limiting exposure to ionizing radiation* (1995) [NOHSC:3022] and *National standard for limiting occupational exposure to ionizing radiation* [NOHSC:1013 (1995)] (Radiation Health Series No. 39) issued by the National Health and Medical Research Council (NHMRC) and Worksafe Australia, and the most recent recommendations of the International Commission on Radiological Protection (ICRP). Where necessary, future relevant publications of the NHMRC and ICRP 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and emergency procedures and the requirements for radiological laboratories have been further refined since the superseded interim edition. Where there is a choice of data, the most restrictive data is presented. For more detailed information, the referenced source documents should be consulted. The previous edition contained some design information for laboratories which has been omitted from this Standard and may now be found in AS/NZS 2982.1, *Laboratory design and construction*, Part 1: *General requirements*.

This Standard is Part 4 in a series aimed at promoting safety in laboratories. The series is as follows:

- Part 1: General
- Part 2: Chemical aspects
- Part 3: Microbiology
- Part 4: Ionizing radiations (this Standard)
- Part 5: Non-ionizing radiations
- Part 6: Mechanical aspects
- Part 7: Electrical aspects
- Part 8: Fume cupboards
- Part 9: Recirculating fume cabinets
- 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 by reason of their nature and energy, interact with matter causing ionization by removing or adding electrons from or to the atoms of substances 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 substance. Ionizing radiation 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 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 might result.
- 3 It should be noted that various forms of high voltage apparatus may produce ionizing radiations. Various chemicals and minerals may be radioactive by virtue of the fact that they contain traces of naturally occurring radioactive elements.

STANDARDS AUSTRALIA

Australian Standard
Safety in laboratories**Part 4: Ionizing radiations**

SECTION 1 SCOPE AND GENERAL

1.1 SCOPE This Standard sets out the precautions needed to prevent unnecessary exposure of persons using sources of ionizing radiation in laboratories and other persons who could be harmed by accidental or planned releases of radioactive substances or external beams of radiation. It also describes the important characteristics of ionizing radiation-producing substances and apparatus, the nature of the hazards, laboratory design requirements, and other essential radiation protection information.

It is recommended that the requirements of this Standard be implemented in all laboratories in which—

- (a) radioactive substances are used or stored; or
- (b) irradiating apparatus is operated.

As a guide to good practice, persons operating with radioactive substances in less than licensable quantities are invited to follow the principles contained in this Standard.

NOTE: The exposure of members of the public is considered in Appendix A.

1.2 REFERENCED DOCUMENTS A list of referenced documents and other related publications is provided in Appendix B.

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

1.3.1 Absorbed dose—the energy absorbed by matter from ionizing radiation per unit mass of irradiated substance. The SI unit of absorbed dose is the joule per kilogram, with the special name gray (Gy). For radiation protection purposes, the absorbed dose is averaged over a tissue or organ.

1.3.2 Activity—the average number of spontaneous nuclear transformations of a radionuclide occurring in unit time. The SI unit of activity is the becquerel (Bq), which is equal to one nuclear transformation per second.

1.3.3 Activity median aerodynamic diameter (AMAD)—The aerodynamic diameter (see Clause 1.3.5) of particles having the median activity of the aerosol of interest. That is, 50% of the aerosol activity is associated with larger particles. For dosimetry purposes, the AMAD can be taken to represent the aerosol.

1.3.4 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 constraints recommended for those sources by the National Health and Medical Research Council (NHMRC) and, in any event, do not exceed the maxima referred to in Section 4.

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

1.3.6 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.

1.3.7 Becquerel (Bq)—the special name for the SI unit of activity.

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

1.3.8 Committed effective dose—the total effective dose, due to the intake of radioactive material into the body, that will be accumulated during the 50 years following its intake.

1.3.9 Constraint—a value of annual dose or dose rate, which is set below the occupational or public limit as appropriate, arising or potentially arising, from a practice involving a single source of ionizing radiation (see Appendix C, Paragraph C7).

1.3.10 Critical group—that group of the members of the public, having reasonably homogeneous habits, diets, lifestyle and age, which is likely to receive the highest dose.

1.3.11 Derived air concentration (DAC) for occupational exposure—the ALI (of a radionuclide) divided by the volume of air inhaled by Reference Man in a working year (i.e. $2.4 \times 10^3 \text{ m}^3$). The unit of DAC is the becquerel per cubic metre (Bq/m^3).

1.3.12 Derived air concentration for submersion in a cloud of radioactive gas (DAC submersion)—is one two-thousandth of the time integral of the concentration of radionuclide in air which alone over a working year would irradiate a person to the annual effective dose limit for exposure specified in Section 4. The unit of DAC submersion is the becquerel per cubic metre (Bq/m^3).

1.3.13 Designated radiation area (DRA)—an area where the occupational exposure of personnel to radiation or radioactive substances is under the supervision of a radiation protection adviser (RPA) (see Clause 3.3(a)).

NOTE: This includes the ‘controlled’ and ‘supervised’ areas used in publications of the International Commission on Radiological Protection, the International Atomic Energy Agency and the NHMRC.

1.3.14 Deterministic effect—an effect, such as partial loss of function of an organ or tissue, caused by radiation and which 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.

1.3.15 Dose—a generic term which can mean absorbed dose, equivalent dose or effective dose, depending on context.

1.3.16 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. The SI unit is the joule per kilogram, with the special name sievert (Sv).

1.3.17 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. The SI unit of equivalent dose is the joule per kilogram, with the special name sievert (Sv).

1.3.18 External radiation—ionizing radiation received by the body from external sources.

1.3.19 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.

1.3.20 Glove box—a closed box with internal pressure not exceeding ambient, having impermeable gloves (for example rubber gloves) and viewing ports in one or more sides, which is used to completely enclose the radioactive substances and the operations on the substances.

1.3.21 Gray (Gy)—the special name for the SI unit of absorbed dose (see Clause 1.3.1).

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

1.3.22 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.

1.3.23 Internal radiation—ionizing radiation received by the body from radioactive substances taken into the body by injection, ingestion, inhalation or absorption through the skin or a wound.

1.3.24 Intervention—action taken to decrease exposures to radiation which can arise from existing situations.

1.3.25 Ionizing radiation—radiation which is capable of causing ionization, either directly (for example, from radiation in the form of gamma rays and charged particles) or indirectly (for example, from radiation in the form of neutrons).

1.3.26 Irradiating 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.

1.3.27 Leakage radiation—all radiation except the useful beam coming from within a protective housing.

1.3.28 Licensable quantity—that amount of any radionuclide or mixture of radionuclides for which a licence is required by the appropriate regulatory authority.

1.3.29 May—indicates the existence of an option.

1.3.30 Nuclide—a species of atom characterized by the composition of its nucleus, i.e. by the number of protons and neutrons in its nucleus.

1.3.31 Occupationally exposed person—a person who, in the course of his or her work, could be exposed to ionizing radiation arising from direct involvement with sources of such radiation.

1.3.32 Occupied area—an area that can be occupied by one or more persons.

1.3.33 Practice—a type of human activity; in a radiological context, a human activity which could result in exposure to ionizing radiation and to which a system of radiation protection applies.

NOTE: The use of radioactive substances in laboratory experiments provides an example of a practice.

1.3.34 Protective housing—a housing of an X-ray tube, an accelerator or a sealed source, which is intended to reduce the leakage radiation to a specified level.

1.3.35 Radiation laboratory—a laboratory in which irradiating apparatus or sealed radioactive sources are used or stored. It does not contain any unsealed radioactive substances.

1.3.36 Radiation protection adviser (RPA)—a person appointed by the management/employer wherever radioactive substances are used in amounts that require licensing, or wherever irradiating apparatus is used (see Clause 3.2 and Clause 3.3).

1.3.37 Radioactive contamination—the presence of a radioactive substance or substances in or on a material or in a place where it is undesirable or could be harmful. In the specific case of the human body, this contamination includes both external skin contamination and internal contamination.

1.3.38 Radioactive substance—a substance which spontaneously 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.

1.3.39 Radioisotope laboratory—a laboratory in which an unsealed radioactive substance is used or stored. It does not contain any irradiating apparatus.

1.3.40 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 substances within the body.

1.3.41 Radiological laboratory—a laboratory which incorporates the functions of both a radiation laboratory and a radioisotope laboratory.

1.3.42 Radionuclide—a species of atomic nucleus which undergoes radioactive decay.

1.3.43 Radiotoxicity—the toxicity attributable to ionizing radiation emitted by a radionuclide (and its decay products) incorporated in the human body. 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 (see Paragraph C4 of Appendix C).

1.3.44 Reference Man—an adult male whose characteristics correspond to the data published in ICRP Publication 23 (see Reference 1). This model allows generic calculations of derived limits from the primary limits of effective dose or committed effective dose. Where the exposed person differs significantly from Reference Man (for example, a child), it is necessary to take account of the differences in calculating derived limits.

1.3.45 Safety 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.

1.3.46 Sealed source—any radioactive substance that is firmly bonded within metals or sealed in a capsule or similar container of adequate mechanical strength to prevent dispersion of the active substance into the surroundings under foreseeable conditions of use and wear.

1.3.47 Shall—indicates that a statement is mandatory.

1.3.48 Should—indicates a recommendation.

1.3.49 Sievert (Sv)—the special name of the SI unit for both equivalent dose and effective dose.

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

1.3.50 Source—any physical entity which can cause radiation exposure.

NOTE: Examples are an X-ray unit or radioactive substance, the use of which constitutes the set of human activities defined as practice.

1.3.51 Stochastic effect—an effect known to occur sometimes as a consequence of exposure to radiation, but which may or may not occur in a particular exposed person, the likelihood of the effect occurring being a function of the dose received.

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

1.3.52 Unsealed source—a source which is not a sealed source and which under normal conditions of use can produce contamination.

1.3.53 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.

1.3.54 Weighting factor

1.3.54.1 Radiation weighting factor (w_R)—a non-dimensional factor used in radiation protection to weight the absorbed dose. It is selected for the type and energy of radiation incident upon the body or, in the case of sources within the body, emitted by the source.

NOTE: The value of each radiation weighting factor (see Table C1) is representative of the relative biological effectiveness of that radiation in inducing stochastic effects at low doses.

1.3.54.2 *Tissue weighting factor* (w_T)—a factor which modifies equivalent dose in an organ or tissue to yield effective dose and which is the partial contribution from the organ or tissue to the total detriment resulting from uniform irradiation of the whole body.

NOTE: The values of tissue weighting factor are given in Table C2.

SECTION 2 HAZARDS AND THEIR CONTROL

2.1 HAZARDS FROM IONIZING RADIATION AND THEIR CONTROL Hazards from ionizing radiation can give rise to biological effects, which are discussed briefly in Appendix C. For radiation protection, they may be conveniently divided into two classes, namely, external and internal, which should be considered together when assessing the total hazard as follows:

- (a) *External hazards* These 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 are to—
 - (i) limit the exposure time;
 - (ii) maximize distance between source and person; and
 - (iii) use suitable shielding.
- (b) *Internal hazards* These arise when radioactive materials enter the body through inhalation, injection, ingestion or absorption through the skin or a wound. An intake of radioactive substance may be rapidly eliminated from the body or some proportion of the intake may become incorporated into particular organ(s) with a slower rate of elimination. The tissue surrounding radioactive atoms will receive a dose of ionizing radiation as the radioactive atoms decay with emission of radiation.

The principles of contamination control are—

- (i) containment; i.e. limit the laboratory area that could become contaminated with radioactive substances by the use of fume cupboards, glove boxes or safe handling techniques;
- (ii) cleanliness; i.e. high quality housekeeping techniques are essential; and
- (iii) use of the least radiotoxic and smallest activity of radioactive substance that is suitable for the task to be undertaken.

Further information is given in Appendix C.

2.2 LEGISLATION Australian States and Territories have enacted legislation controlling the possession, sale and use of radioactive substances and irradiating apparatus.

Legislation generally requires all persons who use radiation in their work to be individually licensed, however exemptions may be granted provided that the work is supervised by a licensee. Each laboratory shall comply with the applicable legislative requirements.

Where recommendations given in this Standard differ from requirements in regulations made under legislation, the latter shall be observed and any more stringent recommendations in this Standard should be used as a guide to good practice.

2.3 TRAINING Before any persons begin work with radiation or radioactive substances, they shall receive training appropriate to the nature of the tasks to be undertaken (see Section 10).

SECTION 3 RESPONSIBILITIES

3.1 GENERAL In laboratories in which ionizing radiations are used, a clearly defined chain of responsibility shall be specified with the duties and responsibilities of individual persons clearly set out in writing. The employer shall be responsible for providing and maintaining services and equipment necessary to implement the radiation protection program given below.

3.2 RESPONSIBILITIES OF THE MANAGEMENT/EMPLOYER The management/employer of an organization having a project using ionizing radiation/radioactive substances shall ensure that—

- (a) a safe place of work, including a high standard of radiation protection, is provided and that all appropriate safety procedures are established and observed;
- (b) there is compliance with the relevant legislation, i.e. the Act and Regulations;
- (c) all recommendations of relevant codes of practice and other written guidance provided by the regulatory authority are observed;
- (d) all persons engaged in work with ionizing radiation or radioactive substances are given the appropriate training in, and advice on, radiation protection before first starting the work, and are retrained at appropriate intervals;
- (e) adequate numbers of persons are engaged on the work to ensure that it can be performed safely and effectively;
- (f) persons working with ionizing radiation are provided with the necessary personal dosimeters and records of their radiation exposure are maintained and made available to each individual and the regulatory authority;
- (g) sufficient numbers of suitable radiation/contamination monitoring instruments are provided and are properly maintained and calibrated;
- (h) all irradiating apparatus and radioactive sources are regularly checked and maintained;
- (i) records are maintained as required by the regulatory authority; and
- (j) an appropriately qualified RPA is appointed.

NOTE: The RPA may be appointed from within or outside the organization.

3.3 RADIATION PROTECTION ADVISER (RPA) In this Standard the term RPA applies to a person appointed by the employer to supervise radiation safety activities. In some legislations, provision may be made for the formal appointment of a radiation safety officer (RSO), having responsibilities similar to those of the RPA. The responsibilities and duties of the RPA listed below may be carried out by the licensee or any other suitably qualified responsible person on behalf of the management/employer.

The RPA's responsibilities shall be to—

- (a) supervise the radiation protection in designated radiation areas (DRAs) in order to minimize personal doses (see Clause 4.2.2);
- (b) advise on safe working practices in accordance with regulations and codes of practice;
- (c) consult and liaise with the relevant regulatory authority;
- (d) ensure that all necessary licensing and registration matters are processed;

- (e) liaise with occupationally exposed persons and their supervisors to ensure that the proposed work with radioactive substances or irradiating apparatus is properly planned;
- (f) arrange that areas, equipment and operations are monitored as considered necessary and upon request;
- (g) ensure that suitable personal and other monitoring devices are provided where required, kept in good working order, properly used, and calibrated at least once each year (see Clause 9.2);
- (h) arrange that, where measured for individuals, records of effective doses are kept for 50 years or such period as required by legislation;
- (i) arrange for any required medical services to be provided and for medical records to be kept for 50 years or such period as required by legislation;
- (j) inspect areas and installations where ionizing radiations are used or are proposed to be used and make reports and recommendations to management on radiation safety;
- (k) record and report to management and the appropriate authorities any unsafe practices or accidents;
- (l) notify station officers of the local fire brigade of the locations of any radioactive substances and radiation apparatus;
- (m) prepare local rules for dealing with any foreseeable radiological accidents (see Clause 10.2);
- (n) ensure that current records of all stocks and locations of radioactive substances and irradiating apparatus are maintained and kept for two years after the date of disposal;
- (o) arrange for the safe storage of radioactive substances and for the safe disposal of any radioactive waste;
- (p) provide advice to radiation workers, as well as instruction and local rules on radiation safety in an easily understandable form and on an adequate scale for occupationally exposed persons; and
- (q) perform any other tasks as may be necessary to maintain a high standard of radiation safety.

3.4 OCCUPATIONALLY EXPOSED PERSONS At common law, employers are responsible for the actions of their employees, but this does not absolve the individual workers from responsibility towards their colleagues and the general public. Occupational Health and Safety Acts generally require the employer to provide a safe place of work and safe systems of work; also, employees are required to observe local safe working instructions and to use the safety equipment provided. These criteria also apply to tertiary institutions in respect of paid employees, unpaid students and research workers who could be considered to be occupationally exposed and legally entitled to be on the institution's premises.

In particular, all persons working with ionizing radiation shall not expose themselves or others to radiations to an extent greater than is absolutely necessary for the purposes of the work, and shall ensure that any doses received do not exceed the limits specified in Section 4 of this Standard.

In addition, occupationally exposed persons shall be responsible for the following:

- (a) Using the personal monitoring devices issued and returning them at the end of the prescribed period. They shall also take every precaution to ensure that personal dosimetry devices are exposed only to those ionizing radiations that impact on the wearer during the normal course of work.

- (b) Reporting immediately to the RPA any instance of known or suspected unsafe practice or other hazardous situation or contingency.
- (c) Becoming familiar with the main chemical and physical properties, and biological effects, of the radiations or radioactive materials being used.
- (d) Reducing to a minimum the radiation hazards in the workplace.
- (e) Knowing what to do in case of an accident.
- (f) Being familiar with relevant parts of the appropriate regulations and codes of practice, and with local management instructions.

The safety of each worker ultimately depends on the safety consciousness of each individual and of co-workers.

SECTION 4 PRIMARY DOSE LIMITS

4.1 GENERAL The doses of ionizing radiation received by persons as a result of work with radioactive substances or irradiating apparatus shall not exceed the dose limits recommended by the NHMRC and shall be in accordance with Clause 4.2.2. The NHMRC recommendations (see Reference 2) are based on the recommendations of the International Commission on Radiological Protection (ICRP) and are summarized in Clause 4.2.1 to Clause 4.2.6.

The total annual dose to any organ or tissue is the sum of the annual dose it receives from external sources of radiation and the committed effective dose received from internal sources taken into the body in that year. The integration period for the committed effective dose is 50 years for adults. Non-occupational irradiation, such as that from natural background ionizing radiation and personal exposure from medical or dental procedures, is not to be included in the assessment of annual dose.

4.2 NHMRC RECOMMENDATIONS

4.2.1 Classes of persons In the application of primary dose limits, the two classes of persons considered are—

- (a) occupationally exposed persons; and
- (b) members of the public (this group consists of all persons not included in Item (a) above).

4.2.2 System of radiological protection The NHMRC has endorsed the ICRP system of dose limitation, the main features of which are as follows:

- (a) *The system of protection in practices* The system of radiological protection recommended by the Commission for proposed and continuing practices is based on the following general principles:
 - (i) No practice involving exposures to radiation should be adopted unless it produces sufficient benefit to the exposed individuals or to society to offset the radiation detriment it causes. (The justification of a practice.)
 - (ii) In relation to any particular source within a practice, the magnitude of individual doses, the number of people exposed, and the likelihood of incurring exposures where these are not certain to be received, should all be kept as low as is reasonably achievable, economic and social factors being taken into account. This procedure should be constrained by restrictions on the doses to individuals (dose constraints), or the risks to individuals in the case of potential exposures (risk constraints), so as to limit the inequity likely to result from the inherent economic and social judgements (the optimization of protection).
 - (iii) The exposure of individuals resulting from the combination of all of the relevant practices should be subject to dose limits, or to some control of risk in the case of potential exposures. These are aimed at ensuring that no individual is exposed to radiation risks that are judged to be unacceptable from these practices in any normal circumstance. Not all sources (of radiation) can be controlled by action at the source (origin) and it is necessary to specify the sources (of radiation) to be included as relevant before selecting a dose limit (individual dose and risk limits).
- (b) *The system of protection in intervention* The system of radiological protection recommended by the ICRP for intervention is based on the following general principles:
 - (i) The proposed intervention should do more good than harm, i.e. the reduction in detriment resulting from the reduction in dose should be sufficient to justify the harm and the costs, including social costs, of the intervention.

- (ii) The form, scale, and duration of the intervention should be optimized so that the net benefit of the reduction of dose, i.e. the benefit of the reduction in radiation detriment, less the detriment associated with the intervention, should be maximized.

Dose limits do not apply in the case of intervention or emergency situations. Information on the application of intervention is given in Reference 3.

Any system of protection shall include an overall assessment of its effectiveness in practice. This shall be based on the distribution of doses achieved and on any appraisal of the steps taken to limit the probability of potential exposures. It is important that the basic principles shall be treated as a coherent system. No one part shall be taken in isolation.

The NHMRC and ICRP recommendations do not restrict the rate at which any occupational radiation dose is received, provided that the annual dose limits given in Clauses 4.2.3 and 4.2.4 are not exceeded. The limits apply to the source of the relevant doses from external exposure in the specified period and the 50-year committed dose from intakes in the same period for adults.

4.2.3 Occupationally exposed persons The dose limits for adult persons exposed to ionizing radiation in the course of their work shall be as follows:

- (a) *For the prevention of deterministic (threshold) effects*—an equivalent dose limit of 500 mSv per year for the skin (averaged over 1 cm²) and for all tissues in the hands and feet, and 150 mSv per year for the lens of the eye.
- (b) *To limit the occurrence to an acceptable level of stochastic (non-threshold) effects*—an effective dose limit of 20 mSv per year averaged over 5 years. The effective dose shall not exceed 50 mSv in any single year.

For the limitation of stochastic effects, the annual effective dose received shall satisfy the following relationship:

$$\sum_T w_T \sum_R w_R D_{T,R} \leq 20 \text{ mSv}$$

where

w_T = tissue weighting factor (see Clause 1.3.54.2)

w_R = the radiation weighting factor, (see Clause 1.3.54.1)

$D_{T,R}$ = absorbed dose averaged over the tissue or organ T , due to radiation R .

The values of the radiation and tissue weighting factors are given in Tables C1 and C2, respectively, of Appendix C.

For internal exposure, ALIs are based on a committed effective dose of 20 mSv.

For occupationally exposed females of reproductive capacity, separate effective dose limits are not considered necessary on the assumption that the dose is received at an approximately even rate and that it is unlikely that a pregnancy would go unrecognized for more than two months. Where a pregnancy is confirmed, it is recommended that during the remainder of the pregnancy, the dose to the surface of the abdomen will not exceed 2 mSv, and that the intake of radionuclides will not exceed 1/20th of the ALI. The absorption of external radiation by the tissue of the pregnant female and the limited transfer of nuclide, reduce the dose to the embryo or foetus and ensure that it is less than the public effective dose limit of 1 mSv.

The occupational effective dose limits are summarized in Table 4.1. These do not include natural background radiation and personal exposure for medical purposes.

TABLE 4.1
OCCUPATIONAL AND PUBLIC DOSE LIMITS

Application	Dose limit (Note 1)	
	Occupational	Public
Effective dose	20 mSv per year, averaged over a period of 5 consecutive calendar years (Note 2 & 3)	1 mSv in a year (Note 4)
Annual equivalent dose to— the lens of the eye the skin (Note 5) the hands and feet	150 mSv 500 mSv 500 mSv	15 mSv 50 mSv (Note 6)

NOTES:

- 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 foetus should be afforded the same level of protection as required for members of the public.
- 3 When, in exceptional circumstances, a temporary change in the dose limitation requirements is approved by the appropriate authority, one only of the following conditions shall apply:
 - (a) The effective dose limit shall not exceed 50 mSv per year for the period, which shall not exceed 5 years, for which the temporary change is approved.
 - (b) The period for which the 20 mSv per year average applies shall not exceed 10 consecutive years and the effective dose shall not exceed 50 mSv in any single year.
- 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 cm² area of skin, regardless of the total area exposed.
- 6 NHMRC makes no specific recommendation.

4.2.4 Members of the public The control of public exposure is usually exercised by the application of controls at the source rather than in the environment. The controls are achieved by the procedures of optimization and the use of constrained limits. The NHMRC recommends an effective dose limit for public exposure of 1 mSv in a year. However, in special circumstances, a higher value of effective dose could be allowed in a single year, provided that the average over five years does not exceed 1 mSv per year. The NHMRC also recommends annual limits of 15 mSv for the lens of the eye and 50 mSv for the skin averaged over any 1 cm², regardless of the area exposed.

The public effective dose limits are summarized in Table 4.1. These do not include natural background and personal exposure for medical purposes.

4.2.5 Radiation dose constraints Actual radiation doses incurred from well-managed operations will be below the dose limits in Table 4.1. As part of the process of reduction of radiation doses, regulatory authorities may specify a dose constraint below the dose limit for particular classes or types of operations or occupations. Constraints, if they are required, should take account of dose contributions from other sources and practices.

4.2.6 Emergency exposures While it might not be appropriate to apply occupational dose limits to emergency actions to save lives or to bring an accident under control, some restriction of exposure of emergency teams will be necessary, in particular to ensure that doses are kept below the thresholds for deterministic effects. Doses received during emergency actions shall be treated separately from normal occupational exposures. Once the emergency has been brought under control, doses received by employees during subsequent remedial action shall be limited as for practices.

In the event of an accident which causes or which could lead to high doses of radiation, or persons being severely contaminated with radioactive substances, and following any immediate first aid and medical assistance, the appropriate authority shall be consulted without delay for advice on the medical management of those persons. Counselling services may need to be provided, whether or not large doses were actually received.

SECTION 5 CLASSIFICATION AND MONITORING OF PERSONS EXPOSED TO IONIZING RADIATIONS

5.1 OCCUPATIONALLY EXPOSED PERSONS Employers are responsible for ensuring that a radiation monitoring program is developed and maintained, as required by the appropriate regulatory authority. The purpose of the radiation monitoring program is to identify all sources of radiation exposure within a practice in order to—

- (a) enable assessments to be made of the exposure to ionizing radiation of persons working in the laboratory (and members of the public, if appropriate);
- (b) permit timely detection of changes in radiation parameters which could lead to increased exposures; and
- (c) produce sufficient information for optimization purposes, i.e. to ensure that exposures are as low as reasonably achievable, economic and social factors being taken into account.

The radiation monitoring program shall be reviewed periodically and amended in the light of operational experience.

The type and degree of monitoring required depends on the circumstances and the level of exposure. When assessed doses are well below the dose limits, group or area monitoring strategies may suffice.

Individual personal monitoring shall be implemented when required by the regulatory authority. When doses could be a significant fraction (for example, 50%) of the limits, personal monitoring should be considered.

The total annual dose to any organ or tissue shall be the sum of the annual dose it receives from external sources of ionizing radiation and the committed effective dose it receives from internal sources taken into the body in that year. For adults, the integration period for the committed effective dose shall be 50 years. Non-occupational irradiation, such as that from natural background ionizing radiation and personal exposure from medical and dental procedures, shall not be included in the assessment of annual dose.

The RPA shall ensure that all assessed doses are recorded for all occupationally exposed persons, and review these doses at least annually. The RPA shall also review any individual dose which, pro-rata for the wearing period of the monitor, exceeds 25% of the annual limit.

5.2 MEMBERS OF THE PUBLIC Employers are responsible for ensuring that members of the public (including employees who are not occupationally exposed) do not receive doses from laboratory operations in excess of the recommended public dose limits. These limits are given in Table 4.1. Protection procedures shall be optimized so that any doses they do receive are as low as reasonably achievable (ALARA).

NOTE: Control of radiation exposure of the public is covered in Appendix A.

SECTION 6 IONIZING RADIATION PROTECTION

6.1 GENERAL The provisions of this Section apply to the protection of persons from the hazards of ionizing radiations from any source, i.e. from apparatus producing ionizing radiation, or from radioactive substances, whether sealed or unsealed.

Control of exposure to radiation is based on a hierarchy of procedures including the following:

- (a) Avoidance of exposure, where practicable.
- (b) Isolation of sources and the provision of engineering controls, involving shielding, containment, remote handling techniques and local exhaust ventilation.
- (c) Adoption of safe work practices, including work methods that make appropriate use of time, distance, shielding and containment to minimize exposure.
- (d) The use of approved personal protective equipment where other means of controlling exposure are not practicable.

The effective dose received by occupationally exposed persons shall not exceed the limits specified in Clause 4.2.3. All exposures shall be kept as low as is reasonably achievable, economic and social factors being taken into account (see Clause 4.2.2).

The accumulated dose in areas continuously accessible to members of the public shall not exceed the public limit of 1.0 mSv in one year. Where appropriate, this condition may be relaxed by the application of the occupancy factors shown in Table C5. This Table takes account of exposure from the source of radiation.

For design purposes, the effective doses for both occupationally exposed persons and members of the public should be constrained to one half of the effective dose limits given in Table 4.1. During the design process the occupancy factors given in Table C5 may be applied. The design should be checked by—

- (i) undertaking a safety assessment; and
- (ii) ensuring that the dose rate does not exceed the values given in Column 4 of Table C5, when averaged over one week.

Ionizing radiation protection that is permanently built into any installation shall be used in preference to the provision of personal protective measures for the occupationally exposed person. Protective devices and appliances shall be suitable for their purpose, shall provide adequate protection, and shall be convenient to use. They shall be examined by the RPA before being put into use, at regular intervals of time during use and whenever changes are made.

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

Unsealed radioactive substances selected for a given purpose should be the least radiotoxic and possess the minimum activity (consistent with the ALARA principle) for the work undertaken. They shall also be manipulated and used in such a way that their potential for entry into the body is minimized.

All areas likely to have an ionizing radiation hazard shall be monitored with appropriate instruments at regular intervals, as decided by the RPA, and the results shall be recorded (see Section 9 and Appendix D).

Where radiation doses to persons are likely to approach or exceed relevant dose limits, from either personal or equipment failure, a second person shall be present to act solely as an observer to ensure that all relevant safety precautions are taken.

6.2 DESIGNATED RADIATION AREAS (DRAS) DRAs and the operations within them shall be inspected by the RPA at least annually or whenever changes are made. More frequent inspections should be carried out by appropriate persons. Only authorized persons should be allowed to enter such areas. These areas contain, permanently, or temporarily, radioactive materials in excess of quantities specified as licensable quantities under State legislation or are areas in which irradiating apparatus is operated.

The RPA shall be kept informed of the locations and nature of the work being done in each DRA. The RPA shall also ensure that a register is kept of the receipt, location, use and disposal of radioactive substances in each DRA (see Clause 3.2).

6.3 RADIATION WARNING SIGNS Radiation warning signs shall be displayed at the entrances to each DRA (see Appendix E).

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

6.4 SHIELDING The purpose of shielding is to ensure that the dose received by any person is below the dose limits specified in Section 4 and is as low as is reasonably achievable.

Sealed and unsealed sources and apparatus which emit penetrating ionizing radiation (for example, X-, gamma, beta or neutron radiation) may need to be shielded. The level of shielding required depends on the type and energy of the radiation emitted and its intensity.

For shielding X-radiation and gamma radiation, high atomic number material is often used (for example, lead). Lower atomic number material (for example, steel, concrete) can be used but in correspondingly greater thickness.

For shielding beta radiation, low atomic number material (for example, perspex, aluminium) is preferable to minimize production of bremsstrahlung.

NOTE: Bremsstrahlung is electromagnetic ionizing radiation produced by the deceleration of electrons in the vicinity of nuclei.

Neutron radiation shielding requires the use of materials which contain significant amounts of hydrogen (for example, paraffin wax, concrete, water).

6.5 PERSONS WORKING IN ISOLATION Working alone should be avoided whenever practicable. When unavoidable, all practicable means shall be taken to minimize the risk to persons working alone.

All tasks to be carried out while working alone shall be subject to a safety assessment. This assessment shall consider the experience and training of the person involved in the proposed work. Additional instruction and training may be necessary before working alone is approved by the person's supervisor.

Where the safety assessment shows that significant risk(s) may occur, such work shall not be undertaken by a person working alone.

A person who has a medical condition that may give rise to dangerous or life threatening situations when working alone, should notify his/her supervisor of that condition.

A person who must work alone in a laboratory after normal working hours, or work in an isolated or hazardous area, shall be provided with a method for summoning help. In addition, the person working alone shall be required to respond to regular monitoring calls from a designated person. It shall be the responsibility of the supervisor of the person working alone to arrange these monitoring calls.

6.6 IONIZING RADIATION PROTECTION—SEALED SOURCES AND RADIATION-PRODUCING APPARATUS

6.6.1 General The provisions of this Clause apply to protection of persons from the hazards of ionizing radiations from sealed sources (such as are used in the study of radiation-induced changes in materials), apparatus that produces ionizing radiations (such as X-ray generators and particle accelerators), and apparatus that produces ionizing radiations incidentally (such as electron microscopes, cathode-ray tubes and high-voltage electronic rectifiers). Such sources or apparatus may be used in either an enclosed or an open installation.

NOTE: Any apparatus in the laboratory that utilizes electrons accelerated by voltages greater than 5 kV is considered capable of producing inadvertent X-rays.

Whenever practicable, special enclosures, such as cabinets or rooms, shall be used to house ionizing radiation sources and apparatus producing ionizing radiations in such a way that, under all operating conditions, persons outside the enclosures are adequately protected from the useful beam and from leakage and scattered radiation.

An area where sources or apparatus could cause an external ionizing radiation hazard shall be a DRA and shall be identified by an appropriate and readily recognizable warning sign (see Appendix E). Visible or audible signals, or both, shall be provided inside and outside enclosures and in the vicinity of installations, to provide warning before and during irradiations.

Section 11 contains information on the design of radiation, radioisotope and radiological laboratories.

6.6.2 Enclosed installations An enclosed installation for any source of ionizing radiation and the materials being irradiated is a permanent enclosure designed so that—

- (a) no person shall be permitted to be within the enclosure during an irradiation;
- (b) persons shall be prevented from entering the enclosure during an irradiation by the provision of interlocks;
- (c) for large enclosures, a warning alarm will sound automatically for a period of at least 20 s before irradiation begins;
- (d) any person accidentally shut in a large enclosure shall be able either to leave by a suitable exit or be able to enter an adequately shielded refuge without delay;
- (e) where an irradiation takes place in a large enclosure it shall be capable of being stopped or quickly interrupted from within the enclosure; the means of so doing shall not be capable of being reset from outside the enclosure;
- (f) under all practical operating conditions, persons outside the enclosure shall be adequately protected;
- (g) during operation, the dose at any accessible outside surface of any large enclosure shall not, in any one hour, exceed 200 μSv or, if non-occupationally exposed persons have access to the outside area, the values given in Column 4 of Table C5;
- (h) when not in use, sealed sources shall be capable of being housed, by remote control, within suitable shielding inside the enclosure; and
- (i) all interlocks and control systems shall be ‘fail-safe’ and, if electrically operated, shall ‘fail to safe’ in the event of loss of electrical power.

6.6.3 Open installations An open installation, because of operational requirements such as the use of a portable apparatus, cannot be provided with the safeguards specified in Clause 6.6.2 for enclosed installations. In an open installation, the source of ionizing radiation and the materials being irradiated shall, as far as is practicable, be confined within an area that is isolated from other areas and delineated by suitable barriers and warning signs so that—

- (a) only authorized persons shall have access to the area;

- (b) all persons outside the area shall be protected under all practical operating conditions, so as to fulfil the requirements of Clause 6.6.2;
- (c) authorized persons shall enter the area only for the minimum time needed to make essential adjustments to the apparatus; and
- (d) the apparatus shall be capable of remote operation.

6.6.4 Sealed sources To minimize the dose to the operator, sealed sources shall be manipulated only by remote means such as forceps, long tongs, drive cables or similar devices.

Shielding shall be set up as close as is practicable to the source. Precautions shall be taken to protect workers and persons in adjacent areas from direct and scattered ionizing radiations. Unshielded sources shall be manipulated remotely and for the minimum possible time. Any new or unfamiliar operation with a high activity source should be preceded by a practice run using a non-radioactive mock source.

Each sealed source or its containment shall be clearly labelled to show the source activity and nature, and shall be serially numbered or otherwise identified to distinguish it from others in the same establishment.

A record for each sealed source shall be kept by a responsible person in the establishment and these records shall be reviewed at least annually or when changes are made. The record shall include the following:

- (a) The serial number or other identification of each source.
- (b) The physical nature of the source, the radionuclide, its date of receipt and its activity upon receipt.
- (c) All movements of the source in the establishment.
- (d) The date and manner of disposal of the source when it leaves the establishment.

The record for each source should be kept for two years after the disposal of that source. The RPA, licensee or responsible person, shall be satisfied that each sealed source is satisfactorily accounted for by means of a periodic audit, and entries to this effect shall also be made in the record.

The RPA should arrange for each sealed source or its housing to be examined for contamination and for the integrity of its sealing, i.e. by wipe or smear testing each source or its housing at annual intervals. Leak testing shall be performed at 10-year intervals (see ISO 9978) and whenever leakage is suspected. Particulars of these examinations shall also be entered into the record.

If a sealed source becomes corroded or damaged, or if for any reason it is suspected of causing radioactive contamination, it shall be sealed in a leak-proof container and the appropriate statutory authority shall be informed without delay.

If a sealed source is believed to be lost or mislaid, the RPA shall be informed without delay. If the loss is confirmed, the appropriate regulatory authority shall be informed without delay.

When not in use, sealed sources shall be stored in a secure and adequately shielded containment, which shall bear the appropriate distinguishing markings as specified in Appendix E. The storage facilities shall comply with the requirements of Clause 7.1.

If a source has the potential to release a radioactive gas, the storage place shall be provided with an efficient mechanical method of ventilation to the open air before the storage space is opened. The RPA shall determine the need for air monitoring.