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**CODE OF SAFE PRACTICE FOR THE USE OF
X-RAYS AND RADIOACTIVE MATERIAL
IN INDUSTRIAL RADIOGRAPHY**

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1 INTRODUCTION

1.1 This Code of Practice relates to the use of x-rays and radioactive material for the purpose of industrial radiography and covers both site and in-house work.

1.2 This Code **should** be read in conjunction with the *Radiation Protection Act 1965* and the *Radiation Protection Regulations 1982*. It is intended as a guide to safe practice and **should** be applied with sound judgement to any specific situation.

1.3 A copy of this Code is provided to all licensees in industrial radiography. Additional copies are available on request. Each licensee **shall** provide free and convenient access to this Code to all personnel working under his/her supervision.

1.4 Whenever compliance with a requirement in this document is required as a condition to a licence under the *Radiation Protection Act 1965*, the word “**shall**” is used in the clause. The word “**should**” indicates a practice that is recommended but not mandatory. Clauses without either of these words are for information and do not imply obligation for compliance with this Code.

1.5 SI units are used in this Code. Conversion factors to convert from and to the previous units are given in Appendix A.

2 ORGANISATION AND ADMINISTRATION OF RADIATION PROTECTION

2.1 Introduction

This section is primarily based on the statutory requirements of the *Radiation Protection Act 1965* and the *Radiation Protection Regulations 1982*. The Regulations apply to any x-ray equipment that produces a dose equivalent rate of or exceeding 2.5 microsieverts per hour ($\mu\text{Sv h}^{-1}$) at a point which could be reached by a human being and radioactive material with an activity exceeding 3 kilobecquerels (kBq). Any industrial x-ray or gamma-ray equipment is therefore subject to the Regulations.

2.2 Radiation protection legislation

The legislation under which this Code is written, is:

The Radiation Protection Act 1965
The Radiation Protection Regulations 1982.

The Act and Regulations may be amended or replaced before this Code is next revised. If so then references to legislation in the Code **shall** be deemed to refer to the current legislation. In the event of contradiction between the Code and revised legislation, the requirements of the legislation **shall** be paramount.

It must be noted that this Code deals with the requirements of radiation protection legislation only. Other legislation covering occupational safety, protection of the environment, local body planning, transport and other issues may overlap with the radiation protection legislation in some respects, and may impose additional requirements. Compliance with this Code in no way implies that all or any of these other requirements have been satisfied.

2.2.1 The *Radiation Protection Act 1965* and amendments and its Regulations 1982 govern the safe use of irradiating apparatus (ie, x-ray equipment) and radioactive material in New Zealand. The Act is administered in the Ministry of Health by the National Radiation Laboratory. The legislation is compatible with international recommendations such as those of the International Commission on Radiological Protection (ICRP).

2.2.2 The following points arising from the Act and Regulations are noted but the reading of these is neither intended as a substitute for reading of the Act and Regulations themselves nor is it an exhaustive coverage of points of interest for users of industrial radiography apparatus. Copies of the Act and relevant Regulations together with any codes of safe practice (such as this one) are required to be made readily available to industrial radiography personnel by the licensee in any establishment.

2.2.3 No person **shall** use industrial radiography X or gamma equipment unless he/she is the holder of a licence under the Act, or is acting under the supervision or instructions of a licensee (Sections 13 and 15 of the Act). In any company, having a number of licensees may lead to misunderstandings in authority or responsibility. Provision is made in the Regulations for nominating one of the licensees as principal licensee to supervise compliance by the whole group. This is not practical, however, if licensees are working at widely scattered locations.

2.2.4 Licences are issued subject to any conditions that may be prescribed in respect of licences generally as well as those explicit in the Act. Individual licences may additionally be subject to conditions such as restriction to a specified x-ray machine or to specified premises.

2.2.5 Prospective licensees **should** have at least 6 months' work experience and **shall** demonstrate by way of a three hour examination conducted by the National Radiation Laboratory an appreciation of

- (1) The hazards associated with the use of ionising radiation.
- (2) The responsibilities of an industrial radiography licensee.
- (3) Safe working practices.
- (4) The procedures to be followed in an emergency.
- (5) The ability to calculate doses and dose rates, under typical industrial radiography conditions, eg, be able to submit a design and safety assessment of an exposure cell.
- (6) The Act and Regulations (including requirements for the transport of radioactive materials).

2.2.6 Professional degree courses or the holding of a licence from other recognised authorities may be adduced as appropriate evidence of such appreciation.

2.2.7 The granting of a licence places full legal responsibility for the safe use of x-ray equipment and/or radioactive material on the licensee.

The following conditions are placed on licences for industrial radiography:

- (1) The use of radioactive materials is restricted to sealed materials in approved exposure devices.
- (2) Radioactive material and x-ray machines for industrial radiography **shall** be used in accordance with the Code NRL C9.

2.3 Basic principles of radiation protection practice

The New Zealand radiation protection legislation is based on the following five principles, set down by the International Commission on Radiological Protection in *ICRP publication 60*⁵:

- (1) No practice **shall** be adopted unless its introduction produces a positive net benefit to the exposed individuals or to society to offset the radiation detriment it causes. (Justification of the practice.)
- (2) In relation to a particular practice, the magnitude of individual doses, the number of people exposed and the likelihood of incurring exposure where these are not certain to be received **shall** all be kept as low as reasonably achievable (ALARA), economic and social factors being taken into account. This procedure shall be constrained by restrictions on the doses to individuals (dose constraints), or the risks to individuals in the case of potential exposures (risks constraints), so as to limit the inequity likely to result from the inherent economic and social judgements. (Optimisation of protection.)
- (3) The exposure of individuals resulting from the combination of all the relevant practices shall 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 circumstances. Not all sources are susceptible of control by action at the source and it is necessary to specify the sources to be included as relevant before selecting a dose limit. (Limitation of individual dose and risk.)

The two principles in the case of interventions are

- (1) The proposed intervention should do more good than harm, ie, the reduction in detriment resulting from the reduction in dose shall be sufficient to justify the harm and the costs, including social costs, of the intervention.
- (2) The form, scale, and duration of the intervention should be optimised so that the net benefit of the reduction of dose, ie, the benefit of the reduction in radiation detriment, less the detriment associated with the intervention, shall be maximised.

2.4 Obligations of industrial radiography companies and owners of industrial radiography X and gamma ray equipment

The ALARA principle requires that owners of industrial radiography X and gamma ray equipment take all reasonable practical steps to restrict the extent to which all persons are exposed to ionising radiation. To that end the owners **shall** ensure that there is a suitably licensed person (see 2.2.3) responsible for the safe care of the radioactive material and/or x-ray equipment.

The owner **shall** provide adequate equipment, materials, and manpower to ensure the use, transportation, storage and disposal of radioactive material and/or x-ray equipment is carried out safely at all times.

If there is no suitable licensed person the radioactive material and x-ray equipment **shall not** be used. They **shall** be stored to the satisfaction of the National Radiation Laboratory or disposed of in accordance with the Regulations.

2.4.1 Contract notification

Prior to the commencement of any industrial radiography contract involving site radiography that is expected to last for at least 4 months, the principal licensee involved **shall** inform NRL of the contract, giving details of the following:

- (1) Location of contract.
- (2) Proposed starting date.
- (3) Proposed completion date.
- (4) Licence holders undertaking the contract.
- (5) Equipment to be used.

2.4.2 Education and training of radiation workers

2.4.2.1 General requirement

Persons engaged in industrial radiography **shall** be educated and trained appropriately for the work so that they may use ionising radiations efficiently and safely. They **shall** be fully conversant with the hazards of ionising radiations, and the working procedures and emergency procedures adopted by the Company (see sections 6 and 7).

2.4.2.2 Continuing education

Industrial radiographers **should** endeavour to keep abreast of technical improvements, especially those which affect the efficiency of use of radiation or radiation safety. Appropriate advanced courses, refresher courses, and seminars, **should** be attended.

2.5 Obligations of the licensee

2.5.1 Every licensee is responsible for the safe care of any radioactive material or x-ray equipment under his/her control and **shall** retain that responsibility until it is assumed by another suitably licensed person or the radioactive material or x-ray equipment is stored or disposed of according to the Regulations.

2.5.2 Every licensee **shall** ensure that every person using the radioactive material or x-ray equipment under his/her control complies with the provisions of the Regulations and to any further conditions of the licence.

2.5.3 Every licensee **shall** ensure that every person working with radioactive material or x-ray equipment under that licence has been fully instructed in the hazards of ionising radiation associated with the equipment and is fully conversant with the company's working procedures and emergency procedures in the event of an incident. (Note that this precludes the practice of using a licensed radiographer assisted by someone from the shop floor with no background in radiation protection.)

2.5.4 The licensee **shall** ensure that all the necessary safety equipment is on hand and is being used correctly to comply with the Regulations.

2.5.5 The licensee **shall** ensure all practical steps are taken to prevent unauthorised tampering with the industrial radiography apparatus under the licensee's control.

2.5.6 The licensee **shall** take all practical steps to prevent the loss of industrial radiography apparatus under his/her control.

2.5.7 The licensee **shall** in the event of the loss of radioactive material take all reasonable steps to recover that radioactive material, and to estimate the dose equivalent that any person might receive as a consequence of that loss. The licensee **shall** inform the National Radiation Laboratory as soon as practicable of that loss and the course of action taken.

Refer to 2.8 for action following the overexposure of any person.

2.6 Personal monitoring

2.6.1 The Regulations require that all personnel working in conditions where the annual dose from ionising radiation might exceed three-tenths of the effective dose limit be subject to individual monitoring.

For the purpose of this Code it will be deemed that all persons actively engaged in industrial radiography fall in the above category and **shall** be continuously monitored by a dosimeter of a type approved by the National Radiation Laboratory.

2.6.2 Film monitors are available from the National Radiation Laboratory. Films are changed at monthly intervals. The use of old films and the wearing of films for longer than one month result in a significant loss of sensitivity and accuracy in the measurement of personal dose. Regardless of any reduction in workload, the film in each monitor must be returned to the National Radiation Laboratory not more than one month after issue, and replaced with a newly issued film, to ensure reliable measurements.

2.6.3 Other personal monitors that record accumulated dose may be used if approved by the National Radiation Laboratory. These are to be calibrated annually.

2.6.4 Standard wearing position for personal dosimeters is at waist level.

2.7 Individual dose limits

For the purpose of this Code of Safe Practice the radiation dose limits are:

2.7.1 Limits for persons exposed to radiation as a normal condition of employment

- (1) an effective dose of 20 mSv per year averaged over any five-year period and 50 mSv in any one year;
- (2) an equivalent dose of 500 mSv to the skin at the nominal depth of 7 mg cm^{-2} averaged over 1 cm^2 , regardless of the total area exposed, in any one year;

- (3) an equivalent dose of 150 mSv to the lens of either eye in any one year;
- (4) an equivalent dose of 500 mSv to the hands and feet in any one year;
- (5) for women who declare themselves pregnant an equivalent dose of 2 mSv at the surface of the abdomen over the remainder of the pregnancy.

2.7.2 Limits for members of the public

- (1) an effective dose of 1 mSv in any one year;
- (2) an equivalent dose to the lens of the eye of 15 mSv in any one year;
- (3) an equivalent dose to the skin of 50 mSv over any 1 cm² regardless of the area exposed, in any one year.

2.7.3 The effective dose limit is to be used only as a guide. The object in radiation protection is that radiation doses **should** be as low as reasonably achievable, economic and social factors being taken into account (ALARA). This usually means that personnel working with ionising radiation very seldom get doses near the effective dose limit.

2.7.4 The terms “dose” or “radiation dose” are commonly used. In the context of dose limits, the precisely defined terms “effective dose” and “equivalent dose” are required. (See the Glossary.)

2.8 Radiation dose records

2.8.1 All companies **shall** maintain up-to-date records of the radiation doses received by all personnel working in industrial radiography. It is important that these records are kept up to date. They can be used to detect unsatisfactory working habits.

2.8.2 All personnel **shall** have access to their personal dose records.

2.8.3 All dose records **shall** be kept for 10 years after the last entry.

2.9 Investigation and notification of exposures

2.9.1 Investigation

Any exposure to radiation or intakes of radioactive material may warrant investigation, but all exposures or intakes which may exceed the investigation level **shall** be reported to the responsible licensee. The investigation levels for this purpose are 2 mSv in a period of one month, or 6 mSv in a period of three months.

If anyone suspects that a person may have received a radiation exposure exceeding the investigation level and is unable to report to the responsible licensee, he or she **shall** as soon as practicable inform the Director of NRL.

Any licensee who has become aware that a person may have received an exposure exceeding the investigation level **shall** investigate the circumstances and take all reasonable steps to ensure that there is no continuing risk of over limit exposure to any person.

2.9.2 Notifications

As soon as is practicable after becoming aware of any exposure over 20 mSv, the licensee **shall** notify the Director of NRL. If the exposure is an acute exposure then the notification **shall** be within 24 hours of discovery.

Within one week of the over limit exposure, the licensee **shall** provide a written report of the circumstances and measures taken to prevent recurrence to the Director NRL.

2.9.3 If the licensee has reason to believe that the dose exceeds 200 mSv then the licensee **shall** as soon as possible make provision for that person to have a medical examination by an approved medical practitioner.

2.9.4 Action by the National Radiation Laboratory

Depending on the dose received the National Radiation Laboratory may direct that the person exposed undergo a medical examination.

The National Radiation Laboratory may instigate an investigation into the circumstances of the exposure and make recommendations to prevent any recurrence.

2.10 Control of radioactive material

2.10.1 Records

2.10.1.1 Section 16 of the Regulations requires that every person who has any radioactive material under his/her control **shall** keep a record sufficient to ensure that at all times the location of that radioactive material is known.

To meet this requirement a daily log of source movements **shall** be kept.

2.10.1.2 Section 16 also requires that in addition to the above, any purchaser of radioactive material **shall** keep full and accurate records specifying the purposes to which those materials are put.

2.10.1.3 These records are to be kept for a minimum period of 10 years unless the National Radiation Laboratory approves earlier disposal.

For industrial radiography, Ir-192 source records need not be kept for longer than one year after disposal of the source.

2.10.1.4 For radioactive material with a half-life greater than five years the records **shall** state the age of the encapsulation of the radioactive material.

2.10.1.5 As provided for by Regulation 17.1 of the *Radiation Protection Regulations 1982* the National Radiation Laboratory may periodically request a copy of the records. The records **shall** show by identification number or code all sources currently held and their location, together with a list of all sources received, transferred or exported since the previous request.

2.10.2 Storage

2.10.2.1 Radioactive material **shall** be stored in a locked source container, ie, a gamma camera or transport package, in a locked storage area. The storage area can be a building, a locker, or in the case of some field operations a vehicle compartment.

2.10.2.2 The principal requirement for the storage of radioactive material in a locked source container is that there **shall** be adequate security.

2.10.2.3 The source containers **shall** be stored locked without their keys.

2.10.2.4 The storage area **shall** be prominently labelled as containing radioactive material. The labels **shall** comply with the requirements of Clause 4 of the Second Schedule of the *Radiation Protection Regulations 1982*.

2.10.2.5 The dose rate in any area accessible to the general public, immediately surrounding the storage area, **shall** be such that no member of the general public will receive in one year an effective dose of 0.3 mSv. This value is derived from the application of dose constraints to a single practice.

2.10.3 Source integrity testing

2.10.3.1 For all caesium-137 sources the source encapsulation **shall** be wipe tested at intervals not exceeding two years and a record is to be kept of the test results.

3 EQUIPMENT

3.1 Introduction

Well designed, well maintained equipment is essential to the safety of any industrial radiography operation. But good design and a thorough maintenance programme are of no consequence if the operator of the equipment is poorly trained and unable to recognise the symptoms of a malfunction.

All equipment **shall** be maintained in good working condition as recommended by the manufacturer.

All equipment **should** be provided with means to prevent unauthorised use of that equipment.

3.2 X-ray equipment

3.2.1 Control panels **shall** be marked with a suitable warning to the effect that the equipment will produce x-rays when energised.

3.2.2 Control panels **shall** indicate when x-rays are being produced.

3.2.3 The tube housing **shall** protect personnel from leakage radiation at the maximum specified rating.

Leakage **shall not** exceed 5.0 mSv h^{-1} at 1 m.

3.2.4 The tube head **shall** have a warning light indicating that x-rays are being produced.

3.2.5 A remote warning light and/or audible alarm, interlocked with the x-ray equipment so that if the warning devices malfunction the x-ray tube cannot be energised, **should** be used.

3.3 Gamma ray equipment

3.3.1 All industrial radiography sources **shall** meet the sealed source performance requirements of *ISO 2919:1980*⁸.

3.3.2 All gamma ray equipment **should** meet the requirements of *ISO 3999:1977*⁷ and if it is to double as a transport package it **shall** conform to transport package specifications.

3.3.3 The general requirements for these devices, condensed from *ISO 3999:1977*, are as follows:

- (1) All components and surface finishes **shall** be durable and corrosion resistant. This particularly applies to controls or moving parts. Mud, sand, water, etc **should not** be able to get into the controls or other moving parts. Alternatively, the apparatus **should** be so designed that these parts can be safely cleaned out using, for example, a hose and water.
- (2) The unit **should** operate over a wide temperature range. Non-metallic materials, plastics, sealing compounds, etc **should not** be used close to the source if they are prone to radiation damage.
- (3) There **should** be available appropriate accessories for mounting the exposure device or exposure head in different positions of use. Source holders and other replacement parts **should** be interchangeable. Instructions for use, periodic inspection, and maintenance, **should** be available.
- (4) Where depleted uranium is used as shielding material it **shall** be clad with a non-radioactive material of sufficient thickness to attenuate or absorb the beta radiation. If the cladding is liable to react with the depleted uranium at elevated temperatures then the uranium **shall** be given a suitable surface treatment to inhibit this effect.
- (5) Leakage radiation from a fully loaded device **should not** exceed 2 mSv h^{-1} at 50 mm from the external surface of the container, or $20 \text{ } \mu\text{Sv h}^{-1}$ at 1 m from the external surface of the container (but see 8.2 for transport package dose rate limits).

- (6) On all exposure devices the source **shall** only be exposed after a manual unlocking operation.
- (7) The exposure device **shall** be provided with either an integral lock or hasps through which a padlock can be fitted. The lock **shall** be of a safety type, ie, lockable without a key or an integral lock from which the key cannot be withdrawn when the container is in a workable position. The lock **shall** retain the source in the secured position and **shall not**, if damaged, prevent the source returning to the secure position from a working position. If a separate padlock is used there **shall** be an additional device to provide a positive means of retaining the source in the secured position.
- (8) Apparatus for gamma radiography **shall** clearly indicate when the source is in the secured or working position. If colours are used, green **shall** indicate that the source is secured, red not secured. However, colours **shall not** be the sole means of indication.
- (9) A remote control system that is manually operated **shall** be designed so that it is impossible for the sealed source to be withdrawn from the rear of the exposure container whilst operating, connecting or disconnecting the remote control cable.
- (10) Each exposure container, or a metal plate permanently fixed to the container, **shall** be permanently and indelibly marked by engraving, stamping, or by some other means with the trefoil sign, the word “Radioactive” in letters not less than 10 mm in height, and the maximum rating for the container, plus the manufacturer’s type and serial number.

There is a testing programme to which the exposure container is subjected by the manufacturer, designed to check the device’s shielding efficiency, ability to withstand horizontal and vertical shock vibration and accidental dropping. In mechanically remotely controlled devices the control cable is subjected to kinking, crushing and tensile tests.

3.4 Pipeline crawlers

As well as complying with the requirements for x-ray or gamma ray equipment, crawlers **shall** have some means of warning the operators when an exposure is being made.

3.5 Safety equipment

3.5.1 Survey meter

3.5.1.1 The survey meter is the most important single item of radiation safety and **shall** be used every time an industrial radiography apparatus is used. Ideally the survey meter **should** be portable, rugged, sensitive, simple in construction, and reliable.

3.5.1.2 Survey meters **shall** be checked prior to use. Gamma cameras have a characteristic surface dose rate and this can be used to check the response of the survey meter.

3.5.1.3 The instrument **shall** be calibrated for the energies of radiation used. That calibration is to be checked yearly. The accuracy required is $\pm 10\%$.

3.5.1.4 Calibration check can be carried out with an Ir-192 source of known activity and a suitable quantity of steel or lead to attenuate the radiation intensity to an appropriate level. Using inverse square law to obtain a range of dose rates a calibration curve of calculated dose rate vs meter reading can be constructed.

The survey meter **should** be at least 30 cm from the Ir-192 source to ensure that the sensitive volume of the instrument is fully covered by the radiation beam.

3.5.1.5 The instrument **shall** at least cover the range 0 - 5 mGy h⁻¹ (dose rate to air).

The instrument **shall** be well maintained.

3.5.2 Personal audible monitors

3.5.2.1 All personnel actively engaged in industrial radiography **shall** wear at all times when using industrial radiography apparatus a good quality audible personal monitor.

3.5.2.2 These monitors **shall** be capable of responding to a radiation dose rate of 0.25 mGy h^{-1} .

3.5.2.3 It is preferable that the audible alarm also measure accumulated dose.

3.5.3 Warning signs

3.5.3.1 Warning signs **shall** be readily visible and **shall** incorporate the internationally recognised warning sign and wording similar to that described in Clauses 4 and 5 of the Second Schedule of the Regulations.

3.5.3.2 These signs **shall** be maintained in a legible condition.

4 REQUIREMENTS FOR AN IN-HOUSE RADIOGRAPHY OPERATION

4.1 Introduction

An in-house radiography operation is taken to mean industrial radiography in a room or area entirely devoted to that purpose.

4.2 General requirements

4.2.1 The walls and, if necessary, the floor and ceiling, of this room **shall** provide sufficient shielding to ensure that the radiation dose rates outside the room do not subject non-radiation workers, or the general public, to more than $6 \mu\text{Gy wk}^{-1}$ and radiation workers to more than $100 \mu\text{Gy wk}^{-1}$ for all anticipated x-ray and gamma-ray use of the room. (These values derive from the application of dose constraints to a single practice.)

4.2.2 All access into the room **shall** be either through a door with shielding equivalent to that of the walls, or through a maze of appropriate wall thickness which prevents the primary beam from being aimed directly at the entrance.

4.2.3 All access into the room **shall** be arranged so that no one can enter the room during an exposure without the operator's knowledge.

4.2.4 All radiography equipment used **shall** be capable of being operated remotely from outside the room.

4.2.5 All x-ray equipment **should** be interlocked with the access to the radiography room to prevent personnel access to the room while the x-ray unit is on. This can take the form of electrical interlocks on the door or light beam control of maze entrances.

4.2.6 Remote warning lights **should** also be used with x-ray equipment to indicate that x-rays are being produced. These warning lights **should** be of the fail-safe type.

4.2.7 Warning lights and/or audible alarms **should** be provided outside all entrances to the room to indicate that ionising radiation is being produced.

This can be achieved with portable gamma equipment by using a gamma alarm.

4.2.8 All fixed installations **shall** display suitable warning notices that comply with Clause 5 of the Second Schedule of the *Radiation Protection Regulations 1982*.

5 REQUIREMENTS FOR SITE RADIOGRAPHY

5.1 Introduction

5.1.1 Site radiography is radiography undertaken outside any area detailed in 4.1, at a construction site, or on a shop floor, etc where it is not practicable to do the work in a walled enclosure. Here the radiographer **shall** define a barrier to restrict entry by unauthorised personnel to the work area and to ensure doses received by personnel outside that barrier are well within the prescribed limits.

5.2 General requirements

5.2.1 The boundary of an open site radiography operation **shall** be so defined that the maximum dose any person could receive outside that boundary would not be greater than 0.1 mSv in any one quarter. Most people outside the boundary would receive much less than this. A maximum permissible dose rate is not defined, but if equipment is operated continuously or at regular intervals, an appropriate dose rate limit can be calculated. All operators **shall** determine the boundary dose rates taking into account the workload undertaken, beam orientation, and the occupancy of the area outside the boundary to ensure the above condition.

5.2.2 All boundary dose rate calculations **shall** be confirmed by measurement of the actual dose rate at the boundary with a suitably calibrated survey meter.

Any change in working condition, **shall** require verification that the above condition still holds.

5.2.3 The area determined by the requirement that persons outside the barrier be subject to no more than 0.1 mSv in any one quarter, **shall** be demarcated by the use of suitably labelled hazard tape or rope barrier, or appropriate warning signs.

5.2.4 The warning signs **shall** comply with the requirements of 3.5.3 of this Code.

5.2.5 Sufficient warning signs **shall** be used to ensure the boundary is adequately signposted.

5.2.6 The boundary demarcation is not intended to physically prevent access to the radiography site. This will be achieved by supervision of the site.

5.2.7 The site safety officer and all personnel working in the vicinity of the site operation **shall** be made aware of the radiography operation.

5.2.8 The dose constraint for radiographers **shall** be 1.5 mGy in any one quarter.

6 GENERAL WORKING PROCEDURES

Any company actively engaged in industrial radiography **shall** produce a set of working procedures for those personnel working with ionising radiation. To ensure radiation safety everyone working with ionising radiation **shall** be thoroughly familiar with the company's working rules. This section outlines the general requirements which **shall** be taken into account when formulating those working procedures.

General requirements

6.1 The act requires that industrial radiography **shall** only be undertaken by a licensed radiographer or by someone under the supervision or instruction of a licensee.

6.2 The hazards associated with industrial radiography are such that absentee licensees cannot adequately supervise safety, eg, a licensee **shall not** sit at a desk and be responsible for the safety of radiography operations 30 km away. This means that every gang on a pipeline operation is required to be under the control of a licensed radiographer.

6.3 With site radiography the licensee **shall** always be present and available when radiography operations are being undertaken.

6.4 In the interests of safety it is strongly recommended that at least two persons are employed on every job involving site radiography. Further to this if gamma radiation is involved on-site then two persons **shall** be employed. One of these persons will be a licensed radiographer and the other will have appropriate training in the hazards of ionising radiation, the operation of the equipment, the company's working procedures, and be able to recognise an emergency situation if one occurs. That person **shall** then be able to take the appropriate action as laid down in the company's emergency procedures manual.

6.5 For an in-house operation, one competent radiographer **should** be sufficient to undertake the work safely provided all entrances to the exposure bay can be visually observed by the operator.

6.6 Prior to starting work all equipment to be used **shall** be checked to ensure that it is in good working condition and adequate for the job in hand.

6.7 If site radiography is involved boundaries as required in section 5 **shall** be erected on the basis of calculation to be later verified by measurement.

6.8 On setting up work whenever practicable the beam of radiation **should** be collimated and directed downwards towards the ground. Failing this the beam **should** be directed towards the area with the least occupancy.

6.9 The operator's position **shall** be, as far as practicable, removed from the source of radiation and the operator **shall** utilise any available shielding to reduce dose rate.

6.10 No person **shall** approach an industrial radiography apparatus in a working situation without a properly functioning survey meter being used.

6.11 When using a gamma camera, after each exposure the gamma camera **shall** be surveyed with the survey meter to ensure that the source has returned safely and the source is made secure.

6.12 At no time must an exposed gamma source or energised x-ray unit be left unattended. If leaving the radiography area for a short period of time, eg, tea breaks, the equipment must be locked to prevent its unauthorised use.

6.13 The changing of the source in a gamma camera **shall** only be carried out with the use of an approved source changer, by persons trained and authorised to do so.

6.14 If the survey meter malfunctions then all radiography operations **shall** cease until the survey meter has been replaced by a properly functioning survey meter or alternatively the survey meter is repaired and checked.

7 EMERGENCY PROCEDURES

7.1 Introduction

7.1.1 Any company engaged in industrial radiography **shall** produce and maintain a set of emergency procedures to deal with emergency situations that might arise in the course of working with ionising radiation.

7.1.2 All personnel **shall** be familiar with these procedures and practise them regularly.

7.1.3 These emergency procedures **shall** be made available to all site safety officers.

7.1.4 It must be borne in mind that any set of emergency procedures will not indicate exactly how to handle a particular emergency situation but they will serve as a basis on which a plan of action can be formulated.

7.1.5 This section outlines the general requirements to be considered when formulating emergency procedures.

7.2 Emergency recognition

7.2.1 Before the emergency situation can be rectified it first must be recognised as an emergency. Gross physical damage to a guide tube preventing return of a source can be easily recognised, but a detached source in all probability would not be recognised if the radiographer fails to use his/her survey meter and is without a personal audible alarm. Correct working procedures are vital.

7.3 X-ray emergencies

7.3.1 The most likely emergency with x-ray equipment is when someone is unintentionally exposed, eg, whilst changing films, or setting up the x-ray unit, or after getting past the barriers unnoticed.

Switch off the x-ray plant and follow the directions in section 2.8 of this Code, “Action in the event of overexposure”.

7.4 Gamma equipment emergencies

7.4.1 With gamma equipment most emergencies arise from the failure of the source to return to the camera after exposure.

7.4.2 Because working procedures are being followed, barriers, etc will be in place, and the emergency has been recognised immediately. The radiographer **shall** retire to outside the barrier to consider his/her plan of action.

7.4.3 If help is needed contact the company and/or the National Radiation Laboratory.

7.4.4 Under no circumstances **shall** anyone attempt a source recovery without a working survey meter, personal monitor and an approved personal dosimeter.

7.4.5 Under no circumstances **shall** anyone directly handle a source.

7.4.6 The plan of action **shall** be thought out carefully. Use time, distance, shielding and manpower to minimise individual doses.

7.4.7 A dummy run can establish the expected doses to personnel.

7.4.8 The general approach to the problem involves locating the source’s position with a survey meter, and shielding the source with sand or lead shot bags.

If the guide tube or control cable needs cutting use bolt cutters.

If the source needs picking up use long-handled tongs (too long a pair of tongs will be cumbersome).

Secure the source in an emergency container or, if possible, in its original camera.

8 TRANSPORT

8.1 Regulations

Regulation 3 of the *Radiation Protection Regulations 1982* requires that all transport of radioactive material in New Zealand shall comply with the current edition of the IAEA *Regulations for the safe transport of radioactive materials*³ and any amendments thereof. The current edition is the 1996 revision.

Compliance with the compatible regulations of IMO (International Maritime Organisation) and IATA (International Air Transport Association) covering the transport of radioactive material by sea and air respectively, satisfies Regulation 3 of the *Radiation Protection Regulations*.

Radioactive material may not be carried with more than limited quantities of the following classes of hazardous substances.

Class 1	Explosives
2.1	Flammable Gases
3	Flammable Liquids
4.1	Flammable Solids
4.2	Spontaneously combustible
4.3	Dangerous when wet
5.1	Oxidising Agents
5.2	Organic Peroxides
8.0	Corrosives

*NZS 5433:1988*¹⁷ and Land Transport Safety Authority *Rule 45001*¹³ should be consulted to ensure compliance.

8.2 Permissible dose rate

The gamma radiation emitted by radiography sources cannot be switched off, and shielding must be provided to reduce the radiation to safe levels while the source is not in use, including during transport. The regulations require that shielding be incorporated within the packaging to reduce the external radiation

to less than specified levels. Three “categories” are defined for this purpose. The maximum permissible dose rates at the surface of the package and at one metre from any point on the surface are those in the following table.

Table 8.1. Package Category dose rate limits

	Maximum dose rate on surface	Maximum dose rate at 1 m
Category I	5 $\mu\text{Sv h}^{-1}$	-
Category II	500 $\mu\text{Sv h}^{-1}$	10 $\mu\text{Sv h}^{-1}$
Category III	2 mSv h^{-1}	100 $\mu\text{Sv h}^{-1}$

Obviously very much more shielding must be provided if it is to qualify as a Category II package rather than a Category III, and even more if it is to qualify as a Category I. As heavy materials such as lead or uranium are used for shielding purposes, the economics of air freight led to Category III being preferred. However, a decayed iridium-192 source being sent to the manufacturer for replacement by a much higher activity source will often be sent in a package with sufficient shielding for the higher activity. In such a case the radiation dose rates may qualify as Category II with the decayed source but Category III with the higher activity source. The Transport Index is defined as the maximum radiation dose rate at one metre from the external surface of the package (in microsieverts per hour divided by 10). This must be shown in the appropriate places in documentation and on labels. The regulations limit the number of packages of any Category stored in one place or transported on one aircraft by requiring that the total of the transport indices of all packages **shall not** exceed 50.

8.3 Packaging standards

Hazards from internal radiation (radiation from radioactive material taken into the human body) can only be effectively controlled by preventing the entry of radioactive material into the body. In the transport scene this requires the use of transport packaging designed to prevent any serious release or dispersal of radioactive material.

Type A packaging must be designed to withstand normal conditions of transport, including rough handling such as dropping from waist height. It must be able to withstand specified tests, including a water spray test, a free drop of 1.2 metres, a compression test and a penetration test. Type A packaging is not designed to withstand accident conditions. Because the radioactive contents could be released in an accident, the total activity permitted in a Type A package is restricted. In the case of iridium-192 no more than 1 TBq is permitted in a Type A package.

If activities above the Type A limits (more than 1 TBq of iridium-192) are to be transported, a Type B packaging is required. Type B packaging must be able to withstand normal conditions of transport and accident conditions. Test conditions specified for Type B packaging are therefore much more severe and include an additional drop test of 9 metres, a fire test of exposure to an environment of 800°C for 30 minutes, and a water immersion test.

For the air transport of more than 1 TBq of iridium-192, a Type B(U) package is required. This requires certification by the competent authority, the official agency entrusted with administering transport of radioactive material legislation, in the country where the package was designed. Any industrial radiographer in New Zealand wishing to design his own package must have it certified by the National Radiation Laboratory before it is used for more than 1 TBq of iridium-192. A stringent engineering assessment, perhaps including tests on a prototype, will be required before a certificate is issued. Most commercially available gamma ray projectors, or cameras, also serve as transport packages and have been certified by overseas competent authorities. Both New Zealand and Australia have accepted these certificates. Airlines may require to sight a copy of the certificate before accepting a loaded package for transport. Any radiographer contemplating purchasing new equipment in which new iridium-192 sources may be transported **should** require an up-to-date Type B(U) certificate with the equipment. Many such certificates have expiry dates specified, and a renewal certificate **should** be requested before that expiry date. Transport of radioactive materials regulations are frequently changing, and an unexpired certificate may certify compliance of a package with an earlier edition of the IAEA or IATA regulations. This would generally be accepted for transport within New Zealand.

8.4 Procedure for dispatch, for air transport

The following is the procedure to be followed when an iridium-192 source is being returned to the manufacturer for replacement.

- (1) The source **shall** be packed in the package strictly according to the instructions of the package manufacturer. The package **shall** comply strictly with specifications and any drawings quoted in the certificate. Any screw-on retaining caps or other appendages which have been lost **shall** be replaced with identical replacements if the certificate is to remain valid, and if there is to be no risk of movement of the sources within the package.
- (2) A reliable radiation monitor **shall** be used to check that the radiation dose rate on the surface of the package is within the limits allowed in Table 8.1, and that there are no beams of excessive dose rate at any point. A reasonably accurate measurement of the maximum dose rate at one metre from the surface **shall** be made. This measurement will determine the “Transport Index” on labels and transport documents.
- (3) The package **shall** be labelled. (Labels are available from airlines.) The appropriate Category I, II or III label will be determined by the radiation dose rate measured above and by reference to Table 8.1. Labels **shall** be fixed to the package on opposite faces. The “principal radioactive content” **shall** be filled in, eg, “Ir-192”; the “activity of contents” **shall** be filled in as the number of becquerels at date of dispatch; and the Transport Index **shall** be filled in with the measurements as determined above. If the activity exceeds the Type A limit a prominent label saying “Type B” **shall** be shown. If it is less than the Type A limit “Type A” **shall** be shown on this label, unless, as is often the case, the package is a certified Type B package, when it is optional which Type is shown on the label. (Note that when it is being returned with a source greater than the Type A limit a Type A label will require changing to a Type B label.) Other labels required for freight and customs purposes **shall** then be fixed without obscuring any of the dangerous goods labels.
- (4) All necessary documentation **shall** be prepared. In the normal freight and Customs documents, the cargo **shall** be described as “radioactive material”. In addition, the “Shippers Declaration for Radioactive Materials” required by the IATA regulations **shall** be completed. (Pads of blank forms are available from airlines at main centres.) For a Type

B package, the competent authority's identification mark will be shown on the certificate.

Freight Offices are entitled to sight the Type B certificate, and it will simplify matters if a photocopy of the certificate is included with the other documentation.

From the point of view of transport of radioactive materials regulations, the package is now ready for dispatch.

The National Radiation Laboratory requires industrial radiography companies to nominate a licensed radiographer to be responsible for all shipments of radioactive material out of their offices. The nominated radiographer **shall** check that the packages comply with the Regulations and it will be his/her signature on the Shippers Declaration for Radioactive Material.

The National Radiation Laboratory **shall** be notified of the nominated radiographer and that radiographer **shall** assume full legal responsibility for the transport of radioactive material until NRL receives notification of his/her replacement.

8.5 Surface transport

If the radioactive material is to be transported by commercial freight operators or privately then regardless of the mode of transport the above procedures **shall** be followed.

The IATA Shippers Declaration will be accepted by most transport operators and is acceptable to NRL for road delivery of radioactive material to or from an airport.

NRL has Shippers Declaration forms for road transport available to all users of radioactive material.

Industrial radiographers **shall** carry a copy of the Shippers Declaration in the cab of their vehicle when carrying radioactive material.

The Shippers Declaration may be used for up to three months.

The package **shall** be stowed securely so as to prevent injury should the vehicle have to stop suddenly.

The package **shall** be stowed as far as practicable away from persons occupying the vehicle.

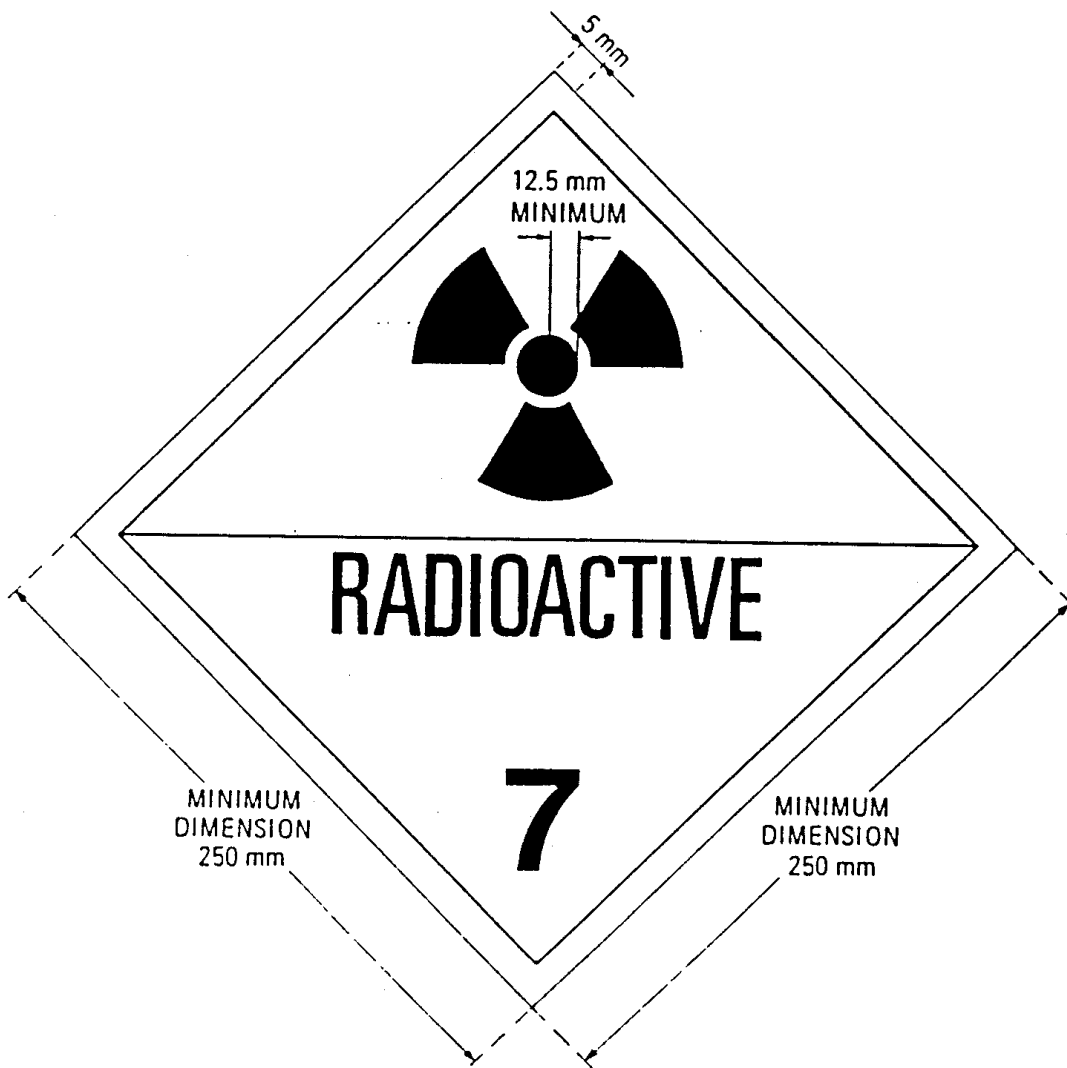
The maximum dose rate at any occupied position in the vehicle **shall not** exceed $20 \mu\text{Sv h}^{-1}$.

The storage compartment in which the package is stowed **shall** be locked when the vehicle is left unattended. No packages **shall** be left unattended in the back of an open vehicle.

8.5.1 Vehicle placarding

Any vehicle carrying radioactive materials which require a dangerous goods label (that is, all Type A and Type B packages) must be placarded. The IAEA Regulations specify that the placards be placed according to international practice, that is, at the rear and both sides of the vehicle. New Zealand law allows an alternative placement in line with standard dangerous goods placarding in New Zealand, that is, at the front and the rear of the vehicle.

The placards shall be at least 250 millimetres square, and be of the design reproduced below. The upper half of the diamond shall be yellow, and the lower half white.



8.6 Accidents

Accidents are unpredictable and the degree and type of damage they cause is also unpredictable. However, it is possible to state that the maximum impact conceivable in a transport accident and the maximum temperature attained in a transport fire would never shatter, melt, or in any way disperse iridium metal. Therefore there is no risk of dispersal of iridium-192 from an industrial radiography source. It is quite conceivable that the shielding could be severely damaged in an accident to a Type A package (and it could happen to a Type B package in an accident of extreme severity) giving rise to high external radiation dose rates from an effectively unshielded source. Commonsense use of radiation monitoring instruments, long-handled tools and shielding blocks can cope with any conceivable situation of this type. There are large numbers of transport movements throughout the world annually involving Type B transport packages. At the time of printing there has been no recorded accident involving a Type B package which has resulted in exposure of the source, or release of the radioactive material.

8.7 Transport of other nuclides

Minor variations to the above rules may apply in some instances when nuclides other than iridium-192 are to be transported. On the rare occasions that this may occur, the National Radiation Laboratory will supply relevant information.

8.8 Import and export of radioactive material

Section 12 of the *Radiation Protection Act 1965* prohibits the import and export of radioactive materials without authorisation. Agreements have been entered into with the major suppliers of radioactive materials to New Zealand and their local agents, allowing automatic approval of orders from licensed persons for imports from these suppliers. In particular, industrial radiography iridium-192 sources from the Australian Nuclear Science and Technology Organisation (ANSTO) are authorised in this way. No such automatic procedure has been instituted for the export of radioactive materials. Customs will require an "Authorisation to Export Radioactive Materials" from the National Radiation Laboratory on each occasion sources are exported. This authorisation will be issued automatically upon application by licensed radiographers.

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APPENDIX A

Units

In 1982 New Zealand adopted the Système International d'Unités (SI system) of units for ionising radiations. However, there are still a number of instruments using non-SI units. Therefore in order to work within this Code it may be required to convert from SI to the previous units. The conversions are as follows.

Quantity	Previous unit	Multiply by	To give SI unit
Exposure	roentgen (R)	2.58×10^{-4}	coulomb per kilogram (C kg ⁻¹)
		8.7×10^{-3}	gray to air (Gy)
Absorbed Dose	rad	10^{-2} (0.01)	gray (Gy)
Dose Equivalent	rem	10^{-2} (0.01)	sievert (Sv)
Activity	curie (Ci)	3.7×10^{10}	becquerel (Bq)

Quantity	SI unit	Multiply by	To give previous unit
Exposure	coulomb per kilogram (C kg ⁻¹)	3.876×10^3	roentgen (R)
Absorbed Dose	gray	10^2 (100)	rad
		1.15×10^2	roentgen (R)
Dose Equivalent	sievert	10^2 (100)	rem
Activity	becquerel (Bq)	2.7×10^{-11}	curie (Ci)

GLOSSARY

Absorbed dose: *See* Gray

Activity (A): The number of nuclear transformations or disintegrations occurring in a quantity of radioactive material per unit time. The SI unit of radioactivity is the becquerel (Bq) (1 disintegration per second).

ALARA: An acronym for the optimisation principle – as low as reasonably achievable, social and economic factors being taken into account.

Dose equivalent: The product of the absorbed dose at a point in time and a quality factor which takes into account the relative effectiveness of different types of radiation for causing damage. The unit is the sievert (Sv).

Effective dose: This is the sum of the equivalent doses in all tissues of the body from a particular exposure, each weighted according to the risk associated with that tissue. It represents the uniform whole body dose that would have the same radiation detriment as the actual dose distribution arising from a given irradiation. The units are sieverts (Sv). (*See ICRP publication 60*⁵.)

Equivalent dose: The product of the absorbed dose with a radiation weighting factor to allow for the biological effectiveness of the type of radiation. The radiation weighting factors for X and gamma radiation are equal to 1.0. In this case the equivalent dose is numerically equal to the absorbed dose. The units are sieverts (Sv). (*See ICRP publication 60*⁵.)

Gray (Gy): The SI unit of absorbed dose being equal to 1 Joule per kilogram of the material being irradiated.

IAEA: International Atomic Energy Agency.

IATA: International Air Transport Association.

ICRP: International Commission on Radiological Protection. Internationally recognised body established to make recommendations on matters of radiation protection.

IMO: International Maritime Organisation.

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

Justification: The justification of a practice is a fundamental principle of the ICRP radiation protection system. No practice involving exposures to ionising radiation **should** be adopted unless it produces sufficient benefit to the exposed individuals or to society to offset the radiation detriment it causes.

Licensee: Person licensed to use radioactive material, or irradiating apparatus under the *Radiation Protection Act 1965*.

Limitation: A principle of the ICRP approach to radiation protection where a limit is placed on doses and risks that may be received by persons from ionising radiation. Doses or risks over these limits are not acceptable.

Practice: Any human activity that introduces additional sources of exposure or exposure pathways or extends exposure to additional people or modifies the network of exposure pathways from existing sources, so as to increase the exposure or the likelihood of exposure of people or the number of people exposed.

Principal licensee: The licensee appointed, when there are several in overlapping areas of work, to take responsibility for radiation safety when this becomes ambiguous. (*See Section 2.2.3.*)

Radiation dose: This is a general term denoting the quantity of radiation. If unqualified it refers to absorbed dose.

Radioactive material: Any material containing radionuclides with an activity concentration greater than 100 kBq per kg, and a total radioactivity greater than 3 kBq.

Radionuclide: An isotope of an element that is unstable and transformed into another, emitting radiation.

Sievert (Sv): The SI unit of dose equivalent, effective dose, and equivalent dose, being equal to an absorbed dose of one Gray multiplied by the appropriate weighting factor to represent the amount of risk associated with the absorbed dose.