Government of **Western Australia**
Radiological Council

INDUSTRIAL RADIOGRAPHY ASSISTANTS TRAINING NOTES

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PREFACE

This manual is for persons wishing to take the Radiological Council of Western Australia's examination for industrial radiography assistants.

The manual was developed by officers of the Radiological Council.

The radiation safety topics are simplified in comparison to those normally presented for persons undergoing the industrial radiographers licence course, but are an acceptable compromise for assistants who are required to work under the direction and immediate personal supervision of licensed industrial radiographers. No person may use radioactive substances or x-ray for industrial radiography unless they are a licensee or an assistant approved by the Radiological Council.

This training manual contains the information required to pass the formal examination for industrial radiography assistants. The syllabus for the examination is available fro the Radiological Council separately.

CONTENTS

RADIATION SAFETY ACT

The use of x-rays and radioactive substances for industrial radiography in Western Australia is controlled under the Radiation Safety Act 1975, its Regulations and any conditions or limitations imposed by the Radiological Council.

The Act provides for the approval of persons working with radiation through the **licensing** of industrial radiographers, the approval of assistants by examination, and the **registration** of the premises and equipment where radiation is used. Registrations, licences and industrial assistant approvals are issued by the Radiological Council, the statutory body created under the Act. Administration of the Act is handled by the Radiation Health Branch, part of the Environmental Health Directorate of the Department of Health, Western Australia.

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REGISTRATION

All x-ray equipment, radioactive substances and prescribed electronic devices must be registered along with the premises where they are used. For industrial radiography, the registrant may be the owners, managers or directors of the company.

The registrant is responsible for ensuring that use of the equipment complies with the –

- Radiation Safety Act,
- Radiation Safety (General) Regulations,
- Any conditions imposed on the registration by the Radiological Council.

The Act provides penalties for failure to comply.

RADIATION SAFETY OFFICER

A Radiation Safety Officer (RSO) must be appointed in writing by the registrant following approval of the appointment by the Radiological Council.

The registrant must appoint the RSO to perform the duties imposed on the registrant by the Act and regulations. Amongst other things, the RSO is responsible for –

- Preparing working rules for safe operation of equipment

- Ensuring safety devices, protective equipment, radiation monitoring and survey devices are available, regularly tested, serviced, repaired or replaced as necessary

- Maintaining all records required by the Act or the regulations

- Ensuring compliance with any conditions, restrictions or limitations imposed on the registration

- Notifying the registrant of any suspected or known contravention of the regulations

- Evaluating the cause of any radiation dose received by any person which exceeds the statutory reporting limits

CONDITIONS, RESTRICTIONS AND LIMITATIONS

Registrations and licences may be subject to a number of conditions, restrictions and limitations imposed under section 36 of the Act. Registration conditions must be displayed in a location accessible to all users of the registered industrial radiography equipment. The registrant is also required to provide a copy of the conditions to the radiation safety officer, to each licensed radiographer and to each approved assistant and assistant in training.

LICENSING

An industrial radiography licence cannot be granted until the Radiological Council is satisfied as to the qualifications, experience and competence of the applicant. Before a licence is issued, a person must –

- have acquired at least three months experience as an industrial radiography assistant

- attend an approved radiation safety course and

- achieve at least 65% in the Council's radiation safety examination (a higher standard examination than that for assistants)

There are separate licences for the use of radioactive substances and x-ray equipment.

APPROVED ASSISTANT

Due to the hazardous nature of industrial radiography, there is a requirement for the licensed radiographer to be assisted by another trained person. The assistant must have a basic knowledge of radiation safety and be able to use the equipment safely. However, because assistants are not licensed, they may only use the equipment under the direction and **immediate personal supervision** of a licensee.

Assistants must pass the Radiological Council's industrial radiography assistants examination to gain approval to work as industrial radiography assistants.

RESPONSIBILITY

The licensee and the registrant (ie. the "owner" of the company) can be prosecuted if assistants are not correctly trained and supervised. A person who acts as an assistant without formal approval, or is an approved assistant but acts without the supervision of a licensee, may also face prosecution. Any radioactive source or x-ray unit issued to a licensee is the responsibility of that person until it is returned to the custodian at the registered premises or transferred to another licensee.

RADIATION MONITORING

Because they are occupationally exposed to radiation, every licensed radiographer and assistant must be issued with individual personal radiation monitoring devices, such as Thermo Luminescent Dosimeters (TLD) or Optically Stimulated Luminescence (OSL) dosimeters, and an audible radiation alarm (see Figures 1 and 2 below).

Figure 1. A type of TLD in common use.

Figure 2. A type of integrating electronic dosimeter

The TLD, the modern replacement of the film badge, records radiation dose in a substance such as lithium fluoride, rather than electronically, and is changed every month. After one month, TLDs are sent to the TLD service provider for processing and from there, the results are sent to your employer. Your employer is required to tell you all your monitoring results whether or not a dose has been recorded.

Regulations require that the TLD, or OSL, is to be worn only by the person to whom it was issued, ie. It must not be shared. You also are required to wear your TLD, or OSL, whenever your work involves the use of ionising radiation.

In addition, each team must have a calibrated radiation survey meter (Figure 3) in good working order to measure the radiation dose rates at their work site. The proper use of this meter can be a vital factor in your safety. The meter must also be used to ensure the radioactive source returns to a fully shielded position.

Figure 3. Examples of survey meters - they measure exposure rate.

The following operational checks should be carried out daily on your survey instrument.

General inspection	Does the instrument look in a good state of repair? Are there any cracks or dents which may interfere with the operation of the instrument ?
Calibration	Is there a sticker on the instrument indicating the calibration is current ?
Battery	Use the "battery check" indicator on instruments with a meter movement, observe that the needle moves freely and does not stick or hesitate at any part of the scale. Replace the battery if there is any gradual drift down from the "battery check" position.
Response	Before carrying out a survey you should check that the instrument responds to radiation. This should be done with a known source so that a known response can be expected. This is the ONLY way of testing the instrument is functioning.

AVAILABILITY OF RECORDS

One disadvantage of TLDs, or OSLs (and previously with film badges), is that you do not know your radiation dose immediately. There is a delay between receiving a dose and the TLD, or OSL, assessment, which can make it difficult to investigate why and when a high reading occurred. (That is a good reason for frequent use of the radiation survey meter).

It is the responsibility of your employer to keep your records on file. Duplicate records are also kept at the Radiation Health Section and by the TLD, or OSL, service provider. If you change employers, a copy of your dose records must be forwarded to your new employer.

Note: A survey meter or Geiger counter does not measure your radiation dose. It measures the radiation exposure rate from which you can **estimate** your dose. With a TLD, OSL or an integrating electronic dosimeter your absorbed dose can be **measured**.

RADIATION UNITS

The units used in radiation measurement are based on the S.I. (metric) system. Many radiation survey meters have scales with outdated units. Familiarity with both systems is thus required.

Because the SI units often involve large numbers, prefixes are used to shorten the length of the numbers used in radiation measurements. Some prefixes are in common daily use, for example, milli in millilitre and kilo in kilometre. The following table lists prefixes encountered in radiation protection.

Prefixes for use with units

p	Pico	10^{-12}	a million-millionth of...
n	Nano	10^{-9}	a thousand-millionth of...
µ	Micro	10^{-6}	a millionth of...
m	Milli	10^{-3}	a thousandth of...
k	Kilo	10^{3}	a thousand times...
M	Mega	10^{6}	a million times...
G	Giga	10^{9}	a thousand-million times...
T	Tera	10^{12}	a million-million times...
P	Peta	10^{15}	a thousand-million-million times...
E	Exa	10^{18}	a million-million-million times...

The prefixes are used with these meanings throughout scientific work.

Isotope Activity

New unit	Old unit
Becquerel (Bq)	curie (Ci)
37 GBq	1 Ci
1200 GBq	32.4 Ci

Dose or Dose Rate

New unit	Old unit
microSievert (µSv)	millirem(mrem)
25 µSv	2.5 mrem
25 µSv/h	2.5 mrem/h

A 1 GBq ^{192}Ir source gives a dose rate in air of 130 µSv/h at 1 metre.

The becquerel is a unit for measuring the activity (the quantity of radioactive material) and is not measured by a survey meter.

Radiation survey meters may have scales marked in counts per second (c/sec), Coulomb per kg per hour (a measure of exposure), mR/h or µSv/h.

TRANSPORT OF RADIOACTIVE SUBSTANCES

The *Code of Practice for the Safe Transport of Radioactive Material (2001)*, issued by the Australian Radiation Protection and Nuclear Safety Agency, has been adopted by WA Regulations under the Radiation Safety Act. Compliance with this Code is mandatory whenever non-exempt radioactive substances are transported.

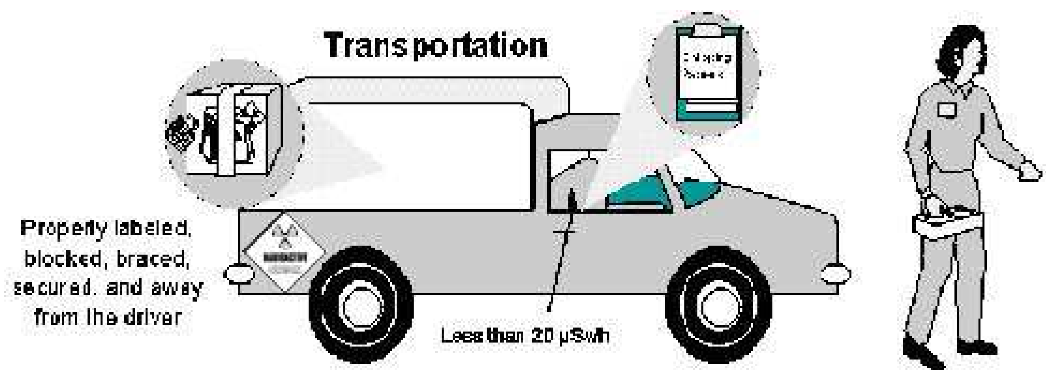


Figure 4. Basic requirements for transportation of sources.

There are two "types" of packages used in industrial radiography that are used for the transport of radioactive substances.

- **Type A Packages** are used to contain the less active sources such as those used for controlling x-ray crawlers.

- **Type B Packages** (which includes industrial radiography source containers) contain the more active sources for which a greater assurance of safety is required. Type B containers must be designed to withstand severe accidents in all modes of transport without loss of containment or shielding. They must be able to pass a comprehensive series of tests intended to produce the type of damage that may be caused by accidents involving severe impacts, fires and immersion in water. Package designs can be classified Type B only when a certificate is issued by the regulatory authority in the country of origin.

The basic requirements for transport of these packages to field sites are –

- Only licensed industrial radiographers and approved assistants may be present in the vehicle during transport by road.
- The vehicle must display a transport label on the outside of each external lateral wall and on the external rear wall of the vehicle. An example of a suitable transport label is depicted in Figure 4 below.
- The radiation level to the driver or passenger must not exceed 20 microsieverts per hour (µSv/h).
- The package must be securely stowed during transport so that it cannot move about.
- Transport may also be undertaken by a person holding a licence for transport of radioactive materials issued under the Radiation Safety Act.

Figure 4. Required transport placard to be placed on each side of the vehicle and one on the rear.

CODE OF PRACTICE FOR THE SAFE USE OF INDUSTRIAL RADIOGRAPHY EQUIPMENT (1989)

The Federal Government through the National Health & Medical Research Council (NHMRC) has published a code of practice to promote the protection of users and the public from radiation hazards associated with the use of industrial radiography equipment. Compliance with this Code by the registrant, licensee and approved assistant is required under the Radiation Safety Act.

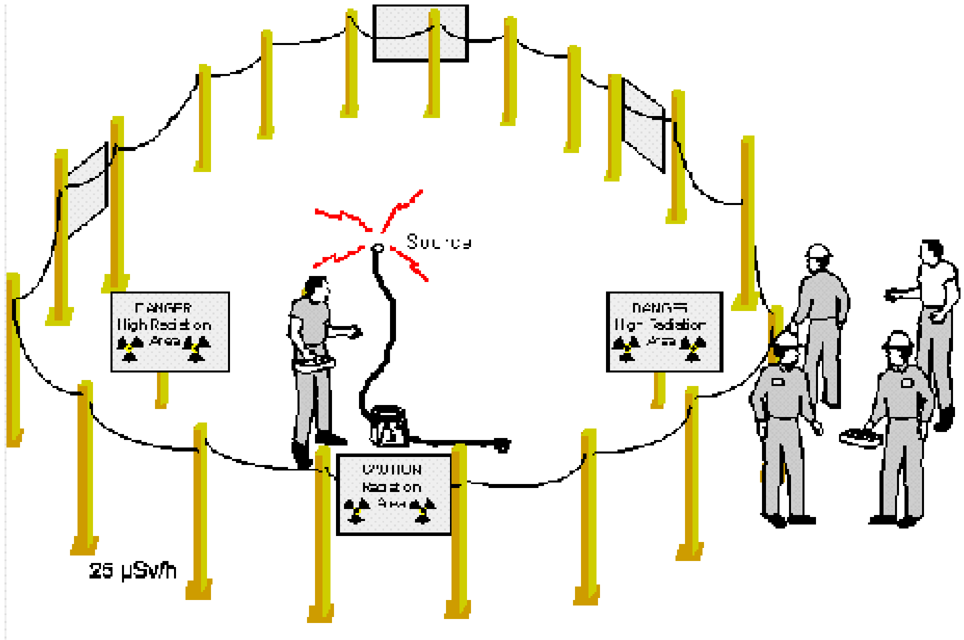


Figure 5. The dose rate at the barriers of a field site must not exceed 25 µSv/h.

Amongst other things, the Code of practice includes the requirements for –

- equipment safety features
- storage
- transport
- establishing and maintaining field sites (see Figures 5 & 6)
- responsibilities and duties
- radiation monitoring
- work procedures

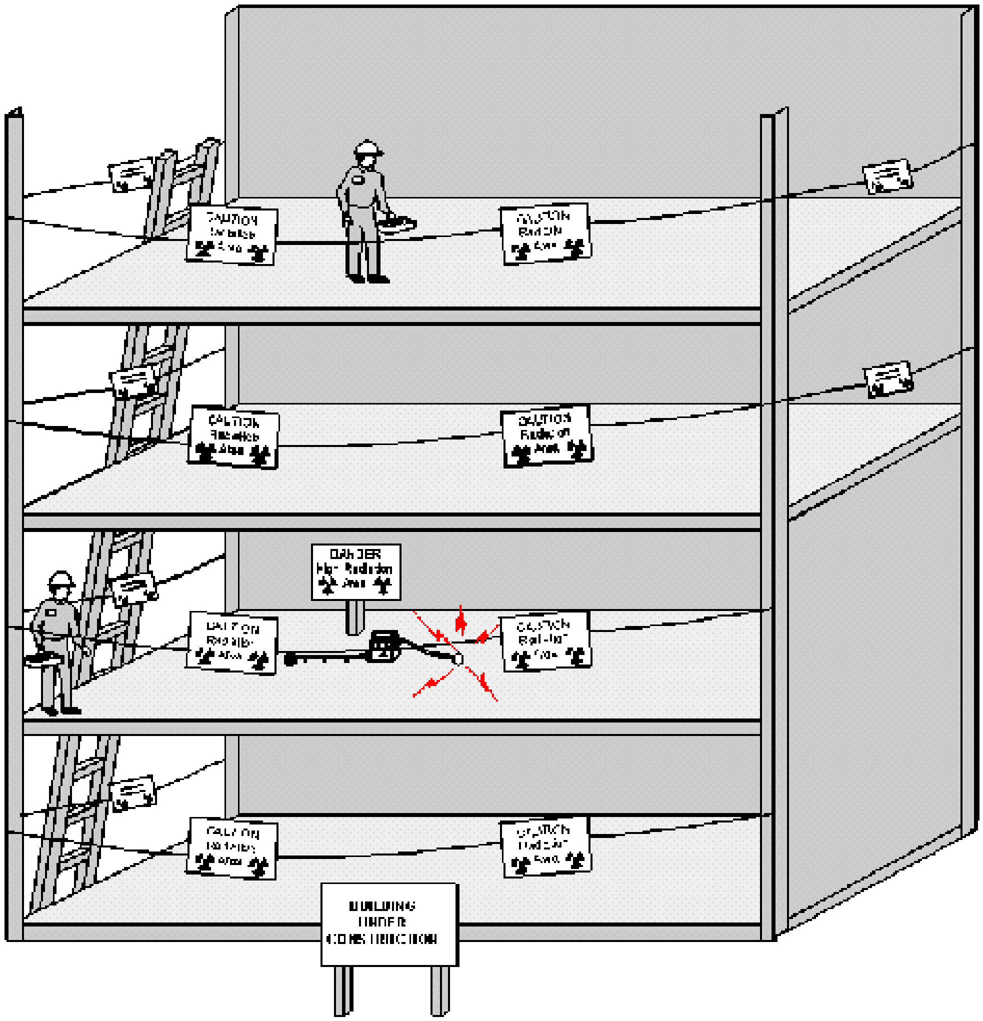


Figure 6. Boundaries in multistorey complexes require special considerations

A company holding a registration for industrial radiography is also required to have a set of working rules and emergency procedures to ensure that workers do not receive radiation doses which exceed the regulatory limits and that all exposures to radiation are kept as low as reasonably achievable (see Figure 7).

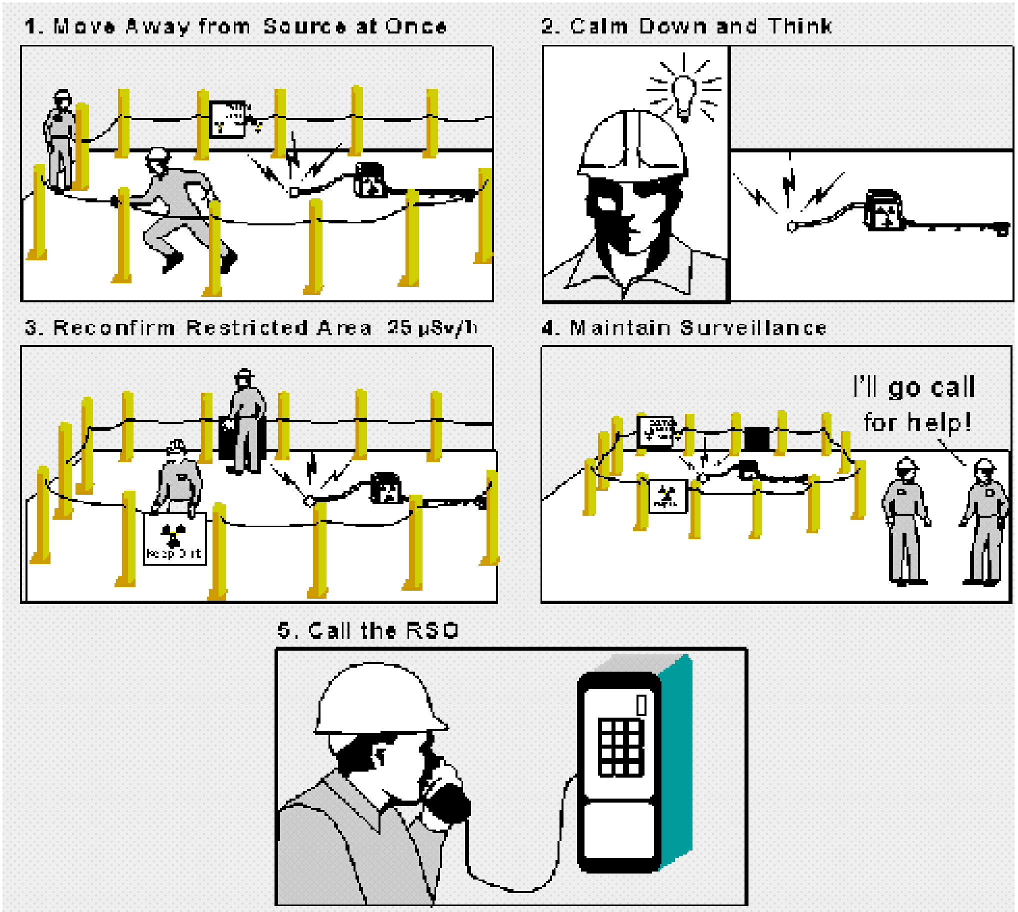


Figure 7. The registrant must have formulated emergency procedures and working rules. A copy of which should be available to all workers using industrial radiography equipment.

DOSE LIMITS

The annual effective radiation dose limits stipulated in the regulations are as follows –

- 20 000 µSv (20 mSv) per year for radiation workers averaged over 5 consecutive years and not more than 50 000 µSv (50 mSv) in any one year.
- 1 000 µSv (1 mSv) per year for the general public. A higher value of 5 000 µSv (5 mSv) in one single year is permitted provided the average over 5 years does not exceed 1 000 µSv (1 mSv) per year.

The basic radiation protection principles should be utilised throughout your work with radiation producing equipment such that the radiation exposure to you and the public is kept to the minimum, ie minimal exposure time, maximum distance, maximised shielding. When using good working practices, no one should receive doses approaching the maximum dose limits.

VARIATIONS FROM THE CODE

Although the Code (Section 3.1.7) requires that the radiation leakage from a gamma camera shall not exceed 2 000 µSv/h, the Radiological Council has stipulated 1 000 µSv/h as a limit. The Code and the Regulations require the dose rate at radiography site boundaries to be less than 25 µSv/h.

However, be aware that the following additional dose limits apply to members of the public who may be in the vicinity during industrial radiography:

- 20 µSv in any 1 hour
- 250 µSv in any 7 consecutive days
- 5 000 µSv in one year *

* With the average over 5 years not to exceed 1 000 µSv per year.

SAFETY EQUIPMENT

Annexe VIII of the Code recommends the minimum emergency equipment that a registrant should have available. Certain safety equipment must also be available at each field site, especially if you are working in a remote location where the full range of emergency equipment is not available.

Apart from the TLDs or OSLs, personal monitor, survey meter, and a collimator, additional safety equipment for each field site should consist of:

- bags of lead shot
- a hacksaw or bolt cutters
- a pair of 1 metre handling tongs

In addition your company will have available a portable source container or "pig" for transporting damaged sources from the field site back to the registered premises if required.

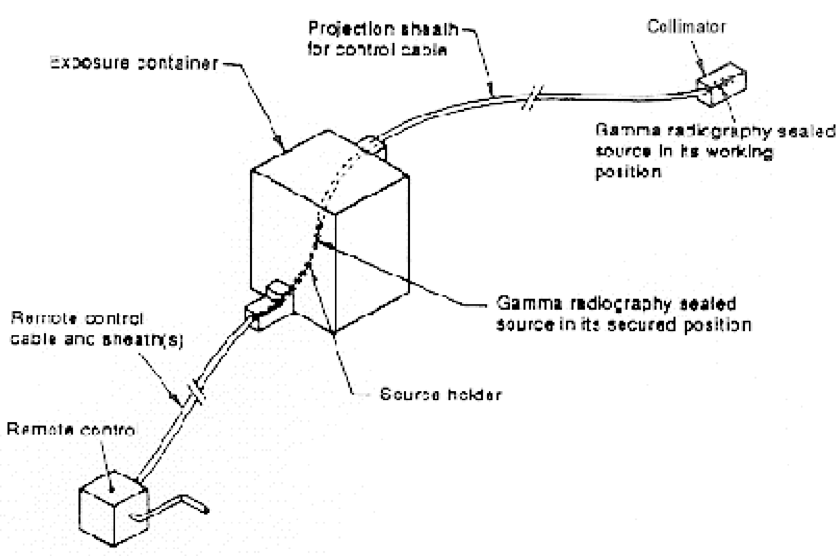


Figure 8. Typical components of gamma equipment used for industrial radiography. Note the collimator in place. Use of this device is essential in minimising your dose.

MINIMISING YOUR RISK

Ionising Radiation is known to cause harmful biological effects. A number of serious accidents involving industrial radiography sources have resulted in deaths and severe injuries to industrial radiographers and members of the public in other countries.

Ionising radiation refers to radiation possessing sufficient energy to remove an electron from a neutral atom when struck, thus causing the atom to become electrically charged or "ionised". The presence of such ions in living tissues may disrupt normal biochemical processes. The biological effects of ionising radiation begin with the absorption of radiation in single living cells. The effects which occur depend on the types of cells which absorb the radiation, the total radiation dose, the length of time over which the exposure occurred, and whether the body is able to effect any repair of the damage. Differences in biological effects are the result of differences in these factors. A large dose administered over a short period may cause sufficient damage to the cell or organism to result in severe injury or death.

Injuries or death from industrial radiography radiation sources are rare but are inevitably the result of human error, predominantly a failure to use a functioning survey meter. Of more significance is the increased risk of cancer.

The effects of low doses of radiation are not so apparent and the relationship between small doses and possible radiation induced effects is uncertain.

The International Commission on Radiological Protection (ICRP), the acknowledged authority on radiation safety, recommends that in the light of present knowledge it is prudent to **assume** that a linear relationship for low doses of radiation exists and that even small doses of radiation may be associated with a small risk of increased incidence of disease.

The ICRP estimates that the risk of fatal cancer to the whole population is 5×10^{-2} per Sv, from which an incidence of 5 fatal cancers for every 100 persons exposed to 1 Sievert can be derived.

The mean radiation dose to the Australian population of 17 500 000 from the medical uses of ionising radiation (diagnostic x-rays and nuclear medicine) has been estimated as perhaps 1 000 µSv per year. The number of fatal cancers in the population from this average dose can then be estimated using the risk factor.

i.e. 5 fatal cancers in a population of 100 exposed to 1 Sv; or 50 fatal cancers in a population of 1 000 000 exposed to 1 000 µSv; or 875 fatal cancers in a population of 17 500 000 exposed to 1 000 µSv.

Accepting the ICRP risk factor and the assumption that the risk exists regardless of the dose, the implication is that the medical uses of ionising radiation in Australia may be responsible for some 875 cancer deaths each year. For comparison, the average annual effective dose per measurably exposed industrial radiographer in Australia was around 1 520 µSv for the period 1985 - 1989 (UNSCEAR 1993).

A comparison of the risk for various causes of death is given in the following table.

Comparative Risk

Cause of death	Risk per year	Data source
All natural causes (age 40)	1.2 in 1 000	1982 (Carruthers 1987)
Run over by vehicle	1 in 10 000	NSW 1985 (Carruthers 1987)
Theoretical fatal cancers arising from 2 mSv per year from background radiation	**1 in 10 000**	**Based on the whole population risk factor of 5 x 10^{-2} Sv^{-1} ICRP 60 (1990)**
Suicide	1.1 in 10 000	1983 (Carruthers 1987)
Homicide	1.9 in 100 000	1983 (Carruthers 1987)
Fire	4 in 100 000	NSW 1985 (Carruthers 1987)
Electric shock	4 in 1 000 000	VIC 1985 (Technica 1987b)
Struck by meteorite	1 in 1 000 000 000	Carruthers 1987

As well as the effects which may act on the individual exposed to ionising radiation, there is the possibility of inducing hereditary effects. Hereditary (or genetic) effects are those which may be passed on by parents to future generations.

The information necessary to produce a new individual is carried in chemically coded form in a single sperm cell from the father and a single egg cell from the mother. The information is stored in genes in the chromosomes in the nuclei of the cells.

An error in the coded information may give rise to a defect in the new individual. Such defects occur naturally in the population and may be caused by a variety of agents in the environment both of natural origin and man made.

A defect may be slight or lethal or somewhere in between. If not lethal, the error in the coded information will be passed on to future generations. It will not necessarily appear in the first generation, but may occur later.

Changes in genes are called mutations. They are difficult to study in humans because of the long time between generations but a great deal of information on the subject of hereditary effects following radiation exposure has been gained from studies using insects and small animals.

As an indication of the genetic risk to humans, the ICRP has stated that –

> *'Radiation has not been identified as a cause of such (hereditary) effects in man, but experimental studies on plants and animals suggest that such effects will occur and that the consequences may range from the undetectably trivial, through gross malformations or loss of function, to premature death.'*
>
> *ICRP 60 (Publication 87)*

To minimise the risk from radiation it is therefore essential that all procedures using radiation be carried out with strict adherence to work practices which encompass radiation safety principles.

While ensuring the dose limits are not exceeded is a regulatory requirement, it is recommended that in practice, doses should be kept

***A**S*
***L**OW*
***A**S*
***R**EASONABLY*
***A**CHIEVABLE*

– the ALARA principle

ENVIRONMENTAL RADIATION

Ionising radiation is not a new feature of our environment but rather something that has always existed since the formation of the earth. What is new is the additional exposure that the population receives from man made sources.

Natural or background ionising radiation comes from cosmic radiation - the sun, naturally occurring radioactive materials which can be found in the food we eat and the ground we walk on.

Annual effective doses to adults from natural sources

Source of exposure	*Annual effective dose (mSv)*	
	Typical	*Elevated* [a]
Cosmic rays	0.39	2.0
Terrestrial gamma rays	0.46	4.3
Radionuclides in the body (except radon)	0.23	0.6
Radon and its decay products	1.3	10
Total	2.4	-

Source: UNSCEAR 1993

[a] Elevated values are representative of larger regions. Even higher values occur locally.

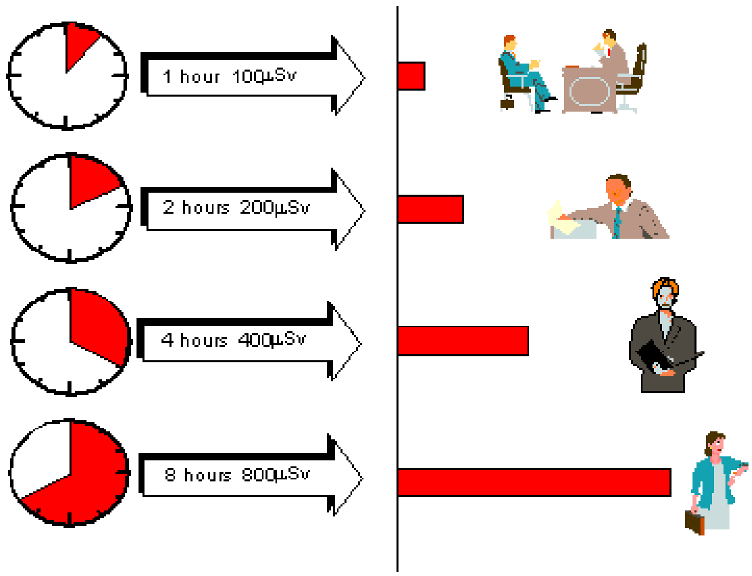
The annual effective dose for a person living in the Perth metropolitan area is about 2 mSv per year.

RADIATION SAFETY PRINCIPLES

The application of the following three principles of radiation protection is the basis for ensuring that industrial radiography work is carried out safely.

- *Minimise exposure **time***
- *Maximise **distance** to the source*
- *Maximise **shielding***

Time



Effect of time in a constant radiation field to the total radiation dose received

Radiation survey meters give readings in exposure rate per hour. You need to be able to calculate what the approximate dose will be after being exposed for some period of time.

Dose = dose rate x time

Example calculations

1. You need to carry out 10 exposures. Suppose you will be standing in an area where the dose rate will be 50 µSv/h. If each exposure is 4 minutes, what do you expect your radiation dose to be following the 10 exposures?

4 min x 10 exposures	= 40 mins total
50 µSv/h	= 50 ÷ 60 µSv/min
	= 0.83 µSv/min
40 min x 0.83 µSv/min	= 33 µSv

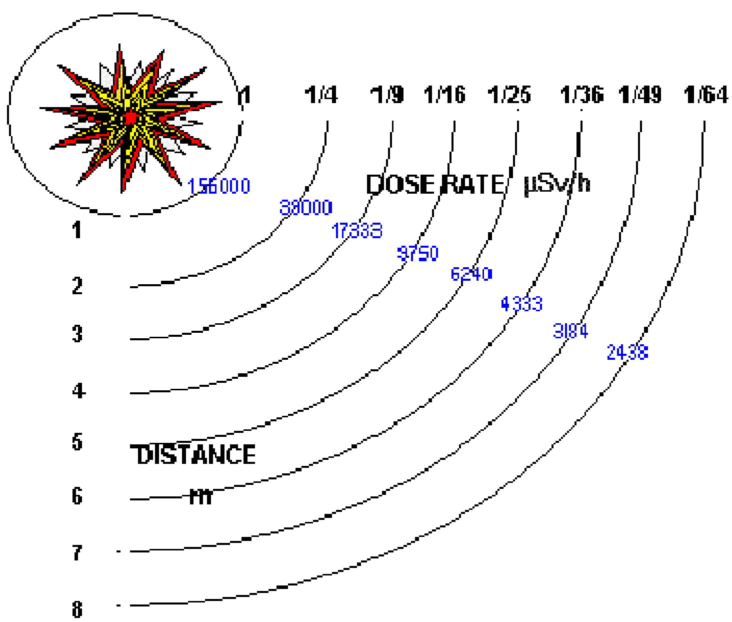
2. The annual dose limit for radiation workers is 20 mSv per year which, assuming a 50 week working year, corresponds to 400 µSv per week. How many hours could a worker spend each week in an area in which the dose rate is 15 µSv/h?

$$
\begin{aligned}
\text{Dose} &= \text{dose rate x time} \\
400\ \mu\text{Sv/week} &= 15\ \mu\text{Sv/h x time} \\
\text{time} &= 400\ \mu\text{Sv/week} \div 15\ \mu\text{Sv/h} \\
&= \text{just under 27 hours in the area in one week}
\end{aligned}
$$

Distance and the Inverse Square Law

Like light rays, gamma and x-rays travel in straight lines and spread outwards from their source as they travel. As they spread out, the intensity diminishes, falling off in accordance with the **inverse square law**. The intensity of the radiation is inversely proportional to the square of the distance from the source of radiation (see the following example).

$$\text{Old intensity x (Old distance)}^2 = \text{New intensity x (new distance)}^2$$



Effect of distance to the dose rate from a 1200 GBq Iridium-192 source

Example calculations

1. You are standing 20 metres from a source where the dose rate is 25 µSv/h. What would be the dose rate 1 metre from the source?

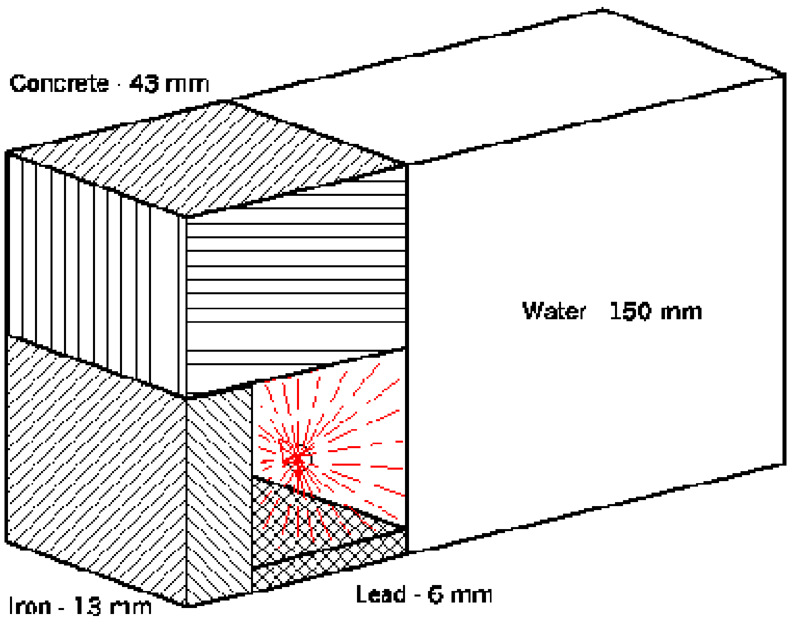
$$
\begin{aligned}
\text{OI x (OD)}^2 &= \text{NI x (ND)}^2 \\
25\ \mu\text{Sv/h x (20 m)}^2 &= \text{NI x (1 m)}^2 \\
\text{NI} &= \frac{25\ \mu\text{Sv/h x 20 m x 20 m}}{\text{1 m x 1 m}} \\
\text{New intensity} &= 10\ 000\ \mu\text{Sv/h (= 10 mSv/h)}
\end{aligned}
$$

2. If you picked up a source by the pigtail, what would be the dose rate (say 20 cm from the source)?

$$
\begin{aligned}
\text{OI x (OD)}^2 &= \text{NI x (ND)}^2 \\
10\ \text{mSv/h x } (100\ \text{cm})^2 &= \text{NI x } (20\ \text{cm})^2 \\
\text{NI} &= \frac{10\ \text{mSv/h x 100 cm x 100 cm}}{20\ \text{cm x 20 cm}} \\
\text{New intensity} &= 250\ \text{mSv/h } (= 250\,000\ \mu\text{Sv/h})
\end{aligned}
$$

Shielding and Transmission Factors

A range of materials can be used to provide shielding from radiation.



Shown is the HVL of different materials for Iridium-192.

Lead is a common shielding material used for x and gamma radiation but uranium is more effective due to its higher atomic number and density. Hence, uranium is commonly the material used for shielding in radiography source containers.

Note: As uranium is slightly radioactive, your survey meter may respond to radiation from a gamma camera even when there is no radiography source inside.

The transmission factor of a barrier (or shield) to radiation is described by the following.

$$T = \frac{\text{Intensity of beam tranmitted through barrier}}{\text{Intensity of beam without barrier}}$$

The half thickness or half-value layer (HVL) for a particular shielding material is the thickness required to reduce the intensity to one half its unshielded value.

Example calculations

1. If a radiation beam produces a dose rate of 20 mSv/h at a given point and this is reduced to 1 mSv/h by inserting a sheet of lead between that point and the source, what is the transmission factor of the sheet of lead?

   T = 1/20 = 0.05 (5%)

2. If the half value layer of lead for Iridium-192 (^{192}Ir - an isotope commonly used for industrial radiography) is 6 mm, how many layers of 6 mm lead sheet should be used to reduce the dose rate from 100 µSv/h to 25 µSv/h?

HVL	Doserate (µSv/h)
0	100
1	50
2	25

   i.e. 2 x 6 = 12 mm lead.

Half Life

Half life is used to describe the time taken for a quantity of a particular radioisotope to decay to half the original activity. ^{192}Ir has a half life of 74 days while Cobalt-60 (^{60}Co) has a half life close to 5 years.

Example calculation

^{60}Co has a nominal half life of 5 years. It is used in a source container for 15 years after which time the activity is 20 GBq. What was the initial activity?

15 years divided by 5 years = 3 half lives

Half Lives	Time	Activity
0	Now	20 GBq
1	5 years ago	40 GBq
2	10 years ago	80 GBq
3	15 years ago	160 GBq

Therefore, the initial activity was approximately 160 GBq.

DEFINITIONS

Radiation Dose

All radiation output measurements should be recorded as absorbed dose or dose rate in air. The unit for absorbed dose is the gray (Gy). Commonly used sub-multiples of this are milligray (mGy = 10^{-3} Gy) and microgray (µGy = 10^{-6} Gy). For X and γ radiation, an exposure of 1 R = 8.73 mGy in air and 1 mR = 8.73 µGy in air.

The following table compares SI and non-SI units for radiation dose.

Quantity	SI unit	Old unit	Conversion
Exposure	C kg^{-1}	Roentgen (R)	1 C kg^{-1} = 3876 R
Absorbed Dose	gray (Gy)	rad (rad)	1 Gy = 100 rad
Equivalent Dose	sievert (Sv)	rem (rem)	1 Sv = 100 rem
Effective Dose	sievert (Sv)	rem (rem)	1 Sv = 100 rem

Absorbed Dose (Gy)

Is the energy absorbed per unit mass in a nominated medium. Because the amount of energy deposited in a material from a beam of radiation will depend on the material being irradiated, it is common for the medium to be stated. For example, in air, in soft tissue, etc. The unit of absorbed dose gray (Gy) is equal to deposition of energy of 1 joule in a mass of 1 kg of the nominated material.

Biologically, the amount of radiation is not the only important consideration but also the type (eg. Alpha, Beta, Gamma, Neutrons). Equal doses of different types of radiation do not necessarily have equal biological effects.

Equivalent Dose (Sv)

This quantity takes into consideration the type of radiation being measured. The unit of equivalent dose is the sievert (Sv).

Equivalent Dose (Sv) = Σ (Absorbed Dose x W_R)

> where W_R is the Radiation Weighting Factor and Absorbed Dose refers to the average dose over a tissue or organ.

The Radiation Weighting Factor relates to the biological effects that result from the various types of radiation. For x and γ-rays, the weighting factor equals 1 and thus an absorbed dose of 1 gray (Gy) of x or γ radiation gives an equivalent dose of 1 sievert (Sv).

Effective Dose (Sv)

The quantity of effective dose is perhaps the most meaningful quantity to be used in radiation protection because it relates the equivalent dose against a Tissue Weighting Factor to certain tissues or organs to a whole body dose of radiation.

Effective Dose = Σ (Equivalent Dose x W_T)

> where W_T is the Tissue Weighting Factor.

Gamma & X-rays

Gamma rays and x-rays are penetrating electromagnetic radiation with short wavelengths. They can be considered as packets of energy which travel at the speed of light and have no electric charge. While gamma and x-rays are produced in different ways, their properties are the same.

Material through which gamma or x-rays pass does not become radioactive. There are three other types of ionising radiation ; alpha particles, beta particles and neutrons. These three forms of ionising radiation play no part in industrial radiography in this State.

(Note: microwaves are also a form of electromagnetic radiation but, like radiowaves and light, they are not ionising.)

Gamma constant

Radioactive materials which emit gamma radiation do so uniquely in respect of the number and energy of the gamma ray photons. Calculations and measurements have been undertaken of the gamma radiations to establish a gamma constant for each radioactive isotope. These constants are expressed in terms of the absorbed dose rate in air at 1 metre from an unshielded gamma source with a specified activity, eg. 130 μGy/h at 1 m from 1 GBq of ^{192}Ir.

SPECTRUM OF ACUTE EFFECTS OF WHOLE BODY EXTERNAL RADIATION

Dose (mSv) (x 1000 for μSv)	**Effect**
20 000	Small area -serious burns, ulcers, boils from infections
10 000	If in a short period to whole body – death
10 000	Finger tip - severe burns and loss of fingers
3 000 – 5 000	To the testis - permanent sterility
3 000	If received in a short period to whole body, 50% of people may die
2 000	Sunburn effect, loss of hair. To the eye - cataracts
1 000	Symptoms of 'radiation sickness' appear, vomiting, diarrhoea
300	Temporary sterility
200	Changes in blood can be detected
156	Dose in 1 hour from a 1200 GBq ^{192}Ir source at 1 m
150	Earliest acute exposure effects shown by chromosome analysis
50	Maximum limit for radiation workers in any 1 year of a 5 year period
20	Annual limit for radiation workers averaged over 5 years
5	Maximum limit for the public in any one year
2	Approximate annual background dose for persons in the Perth area
1	Annual limit for the public (above background)
0.05	Effective dose per chest x-ray

REFERENCES

1990 Recommendations of the International Commission on Radiological Protection
Annals of the ICRP Publication 60 Vol 27 No 1-3
Pergamon Press 1991

Radiation Safety Act 1975
Western Australia
State Law Publisher
William Street Perth W A

Radiation Safety (General) Regulations 1983
Western Australia
State Law Publisher
William Street Perth W A

Recommendations for Limiting Exposure to Ionizing Radiation (1995)
National Health and Medical Research Council
Radiation Health Series No 39
June 1995
Australian Government Publishing Service

Code of practice for the safe use of industrial radiography equipment (1989)
National Health and Medical Research Council
Radiation Health Series No 31
December 1989
Australian Government Publishing Service

Sources and Effects of Ionising Radiation
United Nations Scientific Committee on the Effects of Atomic Radiation
UNSCEAR 1993 Report to the General Assembly
United Nations
New York 1993