

PETRONAS TECHNICAL STANDARDS
HEALTH, SAFETY AND ENVIRONMENT

IONIZING RADIATION
(GUIDELINE)

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PREFACE

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They are based on the experience acquired during the involvement with the design, construction, operation and maintenance of processing units and facilities. Where appropriate they are based on, or reference is made to, national and international standards and codes of practice.

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GLOSSARY

1. **INTRODUCTION**

This Guide contains recommendations for protective measures against ionizing radiation for use in PETRONAS.

In those countries where matters dealt with in this Guide are governed by statutory regulations or national codes of practice, these must of course be observed. In any case, it is recommended that, where the advice in this Guide and national regulations differ, the more stringent requirements should be adopted.

This Guide covers only those subjects frequently encountered in OPU/JV and does not, for instance, cover the handling of unsealed radioactive substances in detail, although some aspects are discussed in Appendix K. If such radioactive substances are to be handled, certified workers with procedures for this purpose should be in charge of the activities. Transport of radioactive substances is not covered either; information on this can be found in the relevant International Atomic Energy Agency (IAEA) publication.

The Guide is set out in three main sections:

Chapter 2 gives a summary of recommendations and serves as an information brief for Management on the general implications of radiation hazards and the recommendations related to protection against them.

Chapters 3 to 7 are meant for those people in an organization who are actually involved in the implementation of safety measures against radiation hazards, namely the HSE Adviser, the Medical Officer and the Radiation Protection Adviser.

The Appendices give background information and more detail on specific subjects. They should be read selectively depending on the specific task the reader has in the radiation safety organization.

Because of the arrangement in three parts, and the need to satisfy those who wish to read one part only, some duplication occurs. This is considered unavoidable, but acceptable.

The Recommendations of the International Commission on Radiological Protection (ICRP) have been used as the main source for the Guide. One of the later publications (ICRP Publication No. 26, issued in 1977 - ICRP 26, for short) introduces several new concepts with respect to protection against ionizing radiation and these are now being incorporated in most existing legislation on such protection. For example, Euratom have based their standards mainly on the recommendation of ICRP 26 (Publications of the European Community, 17th September 1980), and consequently the member countries of the European Community are committed to adopting these new concepts.

The Atomic Energy Licensing Act – AELA and its addendum regulations is the

umbrella legislation for all radiological related activities in Malaysia. OPU/JV operates to this requirement, local legislation or this guide whichever is deemed to be more stringent. If an OPU/JV needs additional advice on radioactive materials or ionizing radiation, Corporate HSE is the contact to decide whether a person who has received a radiation dose above the recommended limit:

- should be suspended from radiological work
- could resume such work;
- review the state of health of radiological workers when considered necessary, taking into account the nature and extent of exposure and the person's state of health.

CONTRACTORS

Where Contractor employees are engaged in radiological work on OPU/JV premises, they should observe both Statutory and OPU/JV Regulations. This should be stated as a condition in the contract.

STORAGE AND TRANSPORT

Radioactive substances should be kept in specially designed containers with proper shielding, shutters and locks. When not being used radioactive substances should be kept in a specially designed storage place which should be locked. The storage and containers should be clearly marked with the warning sign and the words DANGER-RADIOACTIVE MATERIAL in indelible print.

The dose equivalent rate outside the storage place should not exceed 1 $\mu\text{Sv/h}$ in areas accessible to members of the general public. Inside premises not accessible to the general public a limit of 2.5 $\mu\text{Sv/h}$ can be accepted. The stated limits apply directly outside the fence in cases where special containment with a fence or wall with access under lock and key are used.

The removal and transport of radioactive substances should be done only by authorized personnel. Any change in the location of radioactive substances should be reported to and registered by the RAC.

X-ray equipment should be provided with a lock on the main circuit.

Only authorized personnel should have access to the keys of the various locks.

MAINTENANCE

If damage or corrosion of radiation sources is found or leakage suspected, the Radiation Protection Adviser should be informed immediately.

X-ray equipment should be inspected for radiation leakage and proper functioning of all

safety provisions at least yearly by authorized personnel. In the case of irregularities, the Radiation Protection Adviser should be informed immediately.

2. SUMMARY OF RECOMMENDATIONS

2.1 BASIC RULES

The following basic rules (given in Publication No. 26 of the International Commission on Radiological Protection) should be applied when using ionizing radiation:

Quote:

- No practice shall be adopted unless its introduction produces a positive net benefit. (1)
- All exposures shall be kept As Low As Reasonably Achievable (2), economic and social factors being taken into account.
- The dose equivalent to individuals shall not exceed the recommended limits.
- Unquote.

2.2 DOSE LIMITS

The recommended occupational dose limits are:

- The whole body annual dose limit should not exceed 50 mSv (14) over one year. This limit is generally referred to as "the dose equivalent limit". (4) and AELA, Radiation Protection (Basic Safety Standards) Regulation
- Individuals below the age of 18 years should not be involved in radiological work. (14)
- The average annual dose equivalent received during employment as a radiological worker should not exceed 5 mSv. (5)

CLASSIFICATION

Any person who may be occupationally exposed to a dose equivalent exceeding 5 mSv over one year should be classified as a radiological worker.

A person classified as a radiological worker should be medically examined before starting such work. (14)

Working conditions should be classified in two categories according to whether a dose equivalent of 15 mSv/a

- might be exceeded (Category A),
- is most unlikely to be exceeded (Category B).

Typical examples of working conditions A are

- well logging operations with radioactive sources or neutron generators;
- non-destructive testing (NDT) with gamma sources or high-voltage X-ray equipment.

EXPOSURE MONITORING

The dose rate received by a radiological worker should be measured using monitoring devices suitable for the type of radiation involved.

- (1) Cost-benefit principle.
- (2) ALARA principle.
- (3) mSv = millisievert: a measure for the ionizing radiation received by the human body.
- (4) These recommendations correspond to those of ICRP 26 and the European Community Publication of September 1980.
- (5) Atomic Energy Licensing Act (Malaysia) and its addendum regulations.

For external irradiation (gamma and X rays) it is recommended that the worker be provided with a radiation monitoring badge which is submitted for read-out every three months, or, if exposure is suspected, immediately thereafter.

Persons working in conditions A should be subject to strict individual monitoring. Personal radiation monitors should be provided in addition to the badges.

ORGANIZATION

Radiation Advisory Committee (RAC)

At OPU/JV where radioactive substances are handled or where equipment is present which may produce ionizing radiation, a Radiation Advisory Committee should be formed. This committee should consist of at least the Medical Officer, the HSE Adviser or Inspector and the Radiation Protection Adviser, who is the focal point on the location for all matters concerning ionizing radiation (see below).

The RAC is in charge of the supervision and control of all matters concerning ionizing radiation. The RAC should maintain records of:

- the names of all radiological workers;

- radioactive substances;
- equipment producing ionizing radiation;
- permits;
- test data and inspection measurements;
- the purchase and disposal of radioactive substances.

Radioactive substances or equipment producing ionizing radiation should be purchased only after approval by the RAC.

The Radiation Protection Officer (RPO)

The Radiation Protection Officer should

- be trained in radiation hygiene and have knowledge of all local regulations on ionizing radiation as well as the recommendations laid down in this Guide;
- advise the RAC on the authorization and training of persons for work involving ionizing radiation;
- advise the RAC which persons should be classified as radiological workers and whether working conditions should be classified as A or B;
- be in charge of the implementation of the safety measures, personal protection devices to be used and selection of appropriate monitoring devices and badges.

The Medical Officer

The Medical Officer should

- carry out medical examinations and keep a record of all previous exposures to ionizing radiation of persons classified as radiological workers;
- decide whether a person who has received a radiation dose above the recommended limit
 - * should be suspended from radiological work
 - * could resume such work;
- review the state of health of radiological workers when he considers necessary, taking into account the nature and extent of exposure and the person's state of health.

CONTRACTORS

Where Contractor employees are engaged in radiological work on OPU/JV premises, they should observe both Statutory and OPU/JV Regulations. This should be stated as a condition in the contract.

STORAGE AND TRANSPORT

Radioactive substances should be kept in specially designed containers with proper shielding, shutters and locks. When not being used radioactive substances should be kept in a specially designed storage place which should be locked. The storage and containers should be clearly marked with the warning sign and the words DANGER-RADIOACTIVE MATERIAL in indelible print.

The dose equivalent rate outside the storage place should not exceed 1 $\mu\text{Sv/h}$ in areas accessible to members of the general public. Inside premises not accessible to the general public a limit of 2.5 $\mu\text{Sv/h}$ can be accepted. The stated limits apply directly outside the fence in cases where special containment with a fence or wall with access under lock and key are used.

The removal and transport of radioactive substances should be done only by authorized personnel. Any change in the location of radioactive substances should be reported to and registered by the RAC.

➤ **X-ray equipment** should be provided with a lock on the main circuit.

Only authorized personnel should have access to the keys of the various locks.

MAINTENANCE

If damage or corrosion of radiation sources is found or leakage suspected, the RPA should be informed immediately.

X-ray equipment should be inspected for radiation leakage and proper functioning of all safety provisions at least yearly by authorized personnel. In the case of irregularities, the RPA should be informed immediately.

DEMARCATATION

An area where radiological work is to be carried out should be fenced off and clearly marked with the proper warning signs. Unauthorized personnel should not be permitted to enter such an area. Outside such an area the radiation dose equivalent rate normally should not exceed 2.5 $\mu\text{Sv/h}$ at the fence. Special approval by the RPA is necessary if a higher limit is required outside the fenced-off area.

EMERGENCIES

The RPA should advise the RAC regarding the regulations and any special equipment to be at hand in case of an emergency.

Emergency regulations should be posted at each place where radioactive substances or equipment producing ionizing radiation are used or stored.

The RPA should be responsible for organizing emergency drills.

If a person has received a radiation dose above the dose limit, or internal or external contamination by radioactive substances has been found or is suspected, the RPA must be notified immediately. He should decide on the action to be taken, in consultation with other members of the RAC as necessary.

UNSEALED RADIOACTIVE SUBSTANCES

Routine use of unsealed radioactive substances should be avoided whenever possible. Handling of such substances should be carried out only by specially equipped and trained personnel specializing in this subject.

In the case of a test with unsealed radioactive substances, the RPA should ensure that no radiation hazard exists for OPU/JV personnel, contractors, or any other persons.

WORK PERMITS

The RAC is responsible for ensuring that all permits needed for radiological work are available and prepared in accordance with PTS 60.154 Permit to Work System. The permits should be signed by the Manager in charge and the RPA or authorized personnel. Copies of the permit should be present at the site and filed at, the RAC.

3. MANAGEMENT OF RADIATION EXPOSURE

3.1 DOSE EQUIVALENT LIMITS

ICRP 26 applies the following three basic rules for the use of ionizing radiation:

- No practice shall be adopted unless its introduction produces a positive net benefit (costbenefit principle).
- All exposures shall be kept As Low As Reasonably Achievable, economic and social factors being taken into account (ALARA principle).
- The dose equivalent to individuals shall not exceed the recommended limits.

Summarizing, it can be said that the third rule indicates that there is an upper limit not to be exceeded, while the other rules reflect the acceptability of dose equivalents in the range from zero to the upper limit.

On this basis the following occupational dose equivalent limits are recommended by the ICRP:

- The whole-body dose equivalent should not exceed 50 mSv over one year. This limit is in general referred to as "the dose equivalent limit".
- Individuals below the age of 18 years should not be involved in radiological work.

It should be realized, however, that the safety of all individuals may not be fully guaranteed by the three rules mentioned above, as a cost-benefit analysis of a particular activity might justify a dose equivalent close to the limit to one or more individuals.

For personnel of OPU/JV it is therefore recommended that:

- the average annual dose equivalent received during employment as a radiological worker should not exceed 5 mSv.

(It has been found in practice that, when the limit of 50 mSv in any one year is applied, the average annual dose equivalent of a group of radiological workers does not exceed 5 mSv, and, over a period of years the average dose equivalent received by individual radiological workers is well below 5 mSv per annum)

Compliance with the above recommendation of 5 mSv/a places radiological work within OPU/JV among the safer occupations even if during one particular year this value is exceeded.

For the application of this recommendation it is necessary to monitor carefully the dose equivalents of every radiological worker to prevent doses close to the limits

during successive years and to keep the average dose equivalent over the years of employment as a radiological worker below 5 mSv/a.

This recommendation should be considered as a reference value to ensure that radiological work within OPU/JV is as safe as any other safe occupation even if during one particular year the reference value may have been exceeded.

The recommendations mentioned above apply to both men and women. If women of reproductive capacity are occupationally exposed at a "regular rate" within the recommended limits, it is most unlikely that an embryo will receive more than 5 mSv during the first two months of pregnancy. ICRP 26 states that if the requirement of "regular rate" is fulfilled there is no need to make any distinction between sexes. However, as soon as a pregnancy is planned or has been established radiological work classified as condition A should be avoided (see next section).

3.2. CLASSIFICATION OF RADIOLOGICAL WORK

In any location where a dose equivalent in excess of 5 mSv/a, i.e. one tenth of the annual limit, cannot be excluded, special precautions should be taken for protection against ionizing radiation. All personnel in such locations should be classified as radiological workers. Depending on the type of radiation and risks involved, special measures should be taken to protect these workers, for example by placing radiation monitors in the location where the radiation occurs or may occur, or by supplying personal monitoring devices such as badges or pen dose meters. The Radiation Protection Adviser should determine which measures should be taken (see Section 4.2).

The working conditions may be subdivided into two categories, as shown in Table 3-1.

WORKING CONDITIONS A:
CONDITIONS WHERE THE ANNUAL EXPOSURES MIGHT EXCEED THREE TENTHS OF THE DOSE EQUIVALENT LIMITS;
WORKING CONDITIONS B:
CONDITIONS WHERE IT IS MOST UNLIKELY THAT THE ANNUAL EXPOSURES WILL EXCEED THREE TENTHS OF THE DOSE EQUIVALENT LIMITS.

The objective of classifying working conditions as A or B is to simplify the safety requirements in locations where the possibility of exposure to significant levels of radiation is negligible and consequently condition B applies. Under conditions classified as A there is a real possibility of exposure to radiation and radiation safety requires more elaborate measures.

A difficulty in this subdivision is the interpretation of "might exceed" and "most unlikely". The RPO should decide which condition is appropriate. The Euratom norms of 1980 give some guidance. Working conditions A may be found in establishments and plants where sealed sources are used in radiotherapy, gammagraphy and industrial irradiators. High-activity laboratories and plants should also be included in this category. Appendix J gives additional guidance. In practice only very few activities in OPU/JV would be classified as constituting condition A.

3.3. DERIVED DOSE EQUIVALENT LIMITS

From the 50 mSv/a limit derived limits of 1 mSv/week or 25 μ Sv/h can be used for practical applications. The limits of exposure of individuals not registered as radiological workers and of the public at large should be considerably lower. In these cases a dose equivalent limit of 5 mSv/a and derived limits of 0.1 mSv/week or 2.5 μ Sv/h should not be exceeded. This last derived limit is generally applied for the outside of fenced-off areas on sites where radiological work has to be carried out (see Chapter 5).

One of the assumptions made in the calculations of derived limits (i.e. dose equivalent on an hourly basis) is a working time of 2000 hours per annum. This implies the assumption that a person is continuously exposed to radiation during this time. Only if it is certain that a person is partly involved in radiological work is it permitted to introduce an occupancy factor.

For non-destructive testing purposes a value of 7.5 μ Sv/h (instead of 2.5 μ Sv/h) at the outside of the fenced-off area is frequently considered acceptable. For most practical applications of non-destructive testing it is realistic to take an occupancy factor of less than 30% which justifies the above increase. Special approval by the Radiation Protection Officer is necessary if a higher limit is required.

3.4. MEDICAL SURVEILLANCE

Medical surveillance of the workers shall be carried out on the workers by an approved medical practitioner. This shall include:

- a) pre-employment medical examination
- b) general health surveillance
- c) periodic reviews of health
- d) medical examination at termination of employment

Nobody found to be medically unfit shall be employed as a worker for any period.

A medical record of each worker shall be kept for as long as the incumbent

remains a worker.

4. ORGANIZATION

A Radiation Advisory Committee (RAC) should be set up consisting of at least the Radiation Protection Officer, the Medical Officer and the HSE Adviser. The task of this Committee is to advise Management on measures and precautions necessary to ensure safe working conditions during radiological activities on the site.

This Committee should decide on the duties and responsibilities of each of its members. As the organizational structure will differ between the various locations, only general recommendations are given in this Guide.

4.1 RADIATION ADVISORY COMMITTEE - RAC

The RAC is in charge of the supervision and control of all matters concerning ionizing radiation. The RAC should take all measures required by Statutory Regulations and the recommendations of this Guide concerning the acquisition, storage, use and management of radioactive substances and X-ray equipment. The Committee can delegate specific duties and responsibilities to its individual members or to other authorized personnel.

Specific duties and responsibilities are:

- To maintain records of all personnel, material and activities concerning radiological work.
- To provide instructions concerning radiation hazards and safe working practices for all personnel whose duties necessitate the handling of radioactive substances and X-ray equipment, and for all other personnel who are not regularly employed on such work, but who may be exposed to radiation.
- -To ensure beyond reasonable doubt that all personnel working with radioactive substances and X-ray equipment are adequately instructed in the use of all necessary safeguards and procedures and are supplied with such auxiliary devices as may be necessary.
- -To decide whether a person should be classified as a radiological worker and whether working conditions should be classified as A or B.
- -To ensure that Statutory Regulations are complied with and that the necessary working procedures, emergency procedures and procedures for registration and record-keeping are set up and adhered to.
- To set up personal monitoring procedures and to ensure that radiological workers wear radiation badges, pen dose meters or similar devices as necessary.
- To make arrangements for exposure assessments of radiation badges at approved centres, at intervals required by local legislation but not longer than

three calendar months of continuous or discontinuous exposure. Results of these assessments should be recorded on personal radiation dose records. When an employee is transferred, his radiation dose record should be forwarded to his next employer or location.

- To investigate and report any incident with X-ray equipment or radioactive substances and the circumstances of any excessive exposure to radiation.
- To take measures to ensure beyond reasonable doubt that the radiation level outside and inside a controlled area is such that no one will receive a radiation dose in excess of the recommended limits.
- To ensure that radioactivity discharged into the environment is maintained at an average concentration below the recommended levels, by appropriate surveying or monitoring procedures.
- To appoint and discharge authorized personnel and radiological workers.
- To consider for approval, before its being submitted to Management, any order for the purchase of X-ray equipment and radioactive substances to be used on site.
- To ensure that, if contractors are carrying out radiological work, their responsibilities are clearly stated in the contract (see Section 4.8).

4.2 THE RADIATION PROTECTION OFFICER – RPO

The Radiation Protection Officer is the focal point on the location for all matters concerning ionizing radiation. It is essential that he should have been suitably trained in radiation hygiene by an authorized institution; for examples of these see Appendix F. It is recommended that the Radiation Protection Officer has a responsible position in the OPU/JV.

The Radiation Protection Officer should have knowledge of all local regulations on ionizing radiation as well as the recommendations laid down in this Guide and should advise the RAC accordingly.

He should be fully acquainted with local conditions with respect to the potential hazards of radiological work on site and during transportation, storage and waste handling of radioactive substances.

He should notify the HSE Adviser or the RAC of the existence of any condition or situation which may not normally be considered a radiation hazard, but may become a hazard under special or unusual circumstances.

He should ensure that, before radiological work is carried out, the required permit is obtained and signed and that the written precautions are followed.

He should advise the RAC on the authorization and training of persons for work involving ionizing radiation.

He should advise the RAC which persons should be classified as radiological workers and whether working conditions should be classified as A or B.

He should be in charge of the implementation of the safety measures and personal protection devices to be used and he decides on the selection of appropriate monitoring devices and badges.

He should advise the RAC with respect to the regulations and special equipment to be at hand in case of an emergency.

He is in charge of organizing emergency drills.

If tests are being carried out the Radiation Protection Officer should ensure that no radiation hazard exists for any person involved.

He is responsible for all keys related to the storage and use of radioactive substances and radiation equipment.

4.3 THE HSE ADVISER

The HSE Adviser's position may be a full-time one, as is usually the case at more complex installations, or, on smaller sites, the duty of safety supervision may be vested in a technical employee as part of his regular duties, indeed, on some smaller locations the Radiation Protection Adviser and the HSE Adviser may be one and the same person.

The HSE Adviser should be informed without delay when an accident occurs or a dangerous situation develops in order that, after consultation with Management, the appropriate authorities be informed when necessary.

He should advise the RAC on the implementation of the Statutory Regulations and on registration, and sees to a proper investigation and reporting of any incident with X-ray equipment or a radioactive substance which has or could have resulted in over-exposure to radiation.

4.4 THE MEDICAL OFFICER – MO

A Medical Officer should be available when radiological work, according to the criteria in Section 3.2, is going to be carried out. For his duties see Appendix G.

4.4 AUTHORIZED PERSON – AP

An Authorized Person is so authorized by the RAC on the recommendation of the RPO for a special job. He should be instructed and trained by the RPO and will assist him as required.

4.5 RADIOLOGICAL WORKER

Any person who may be occupationally exposed to an annual dose equivalent of more than 5 mSv, i.e. one tenth of the whole-body annual dose equivalent limit, should be considered a radiological worker. Persons under the age of 18 years should not be permitted to be occupationally exposed.

All radiological workers should be fully acquainted with Statutory Regulations and with the OPU/JV rules and regulations. They should also be aware of the potential hazards resulting from the presence of radiation at the storage site, during transportation or on the working site, and from the equipment in use. Radiological workers, from both OPU/JV and contractors, should wear the proper radiation badge when carrying out radiological work (see Section 5.3). A radiological worker should notify the RPO of the existence of any condition or situation which, while not normally being considered a radiation hazard, may become a hazard in special or unusual circumstances.

4.7 REGISTRATION AND REGISTERS

4.7.1 Registers

- **Register of radiological workers**

The names of all company personnel designated as radiological workers should be entered in a "Radiation Dose Register" kept by the RAC. Likewise contractors should maintain their own register.

- **Personal radiation dose records**

Results of exposure assessments of badges of all radiological workers should be entered into personal radiation dose records which should be inspected by the MO on a regular basis. These records should be kept by the MO with the medical records. They should be kept permanently; copies should be forwarded to the next employer or location when the person concerned is transferred.

- **Registration of radioactive substances**

All radioactive substances, with the exception of certain small sources (see Appendix B), should be registered. The register should contain the following data

- type of radioactive substances;
- sealed or unsealed source;
- nuclide;

- activity;
- date of receipt;
- location when not in storage;
- date and method of disposal (if appropriate).

Every source should have a separate number and registration card (see Appendix H). At regular intervals, but at least every three calendar months, the presence of all radioactive substances on site should be checked against the register.

- **Register of X-ray equipment In use**

This register should contain the following data

- mark and type of equipment;
- maximum tube voltage of the equipment;
- location where equipment is in use.

- **Records of wipe-testing and inspection measurements**

These records should contain

- date and results of wipe testing of the sealed sources and a description of the method used;
- date and results of inspection measurements of X-ray equipment.

See also Section 5.4.

➤ **Records of work permits**

Copies of all work permits relating to radiological work should be filed at the RAC.

➤ **Records of disposal**

Radioactive substances should be disposed of in accordance with the requirements of local legislation and records should be kept.

4.7.2 Purchase and disposal

In order to control the use of X-ray equipment and radioactive substances on site, such equipment or substances should be purchased only with the RAC's prior approval.

Records should be kept of the transfer of radioactive waste to third parties.

For a definition of what constitutes radioactive waste and for recommendations on the handling of radioactive waste see Section 5.6 and Appendix B.

4.8 CONTRACTORS' RESPONSIBILITIES

When OPU/JV employ contractors for radiological work, the contractor's responsibilities should be stated in the contract, according to PTS 60.139 "Management of Contractor HSE". Additionally, the contractor should supply and have available all emergency tools and other equipment as necessary.

5. WORKING PROCEDURES

Two sources of ionizing radiation are used

- radioactive substances and
- X-ray equipment.

The radioactive substances can be divided into 'sealed' and 'unsealed'. Most applications of ionizing radiation involve either sealed sources or X-ray equipment.

The use of unsealed sources is primarily limited to tracer experiments. Appendix K should be considered as indicative only of the special precautions to be taken for these experiments. In view of the complications involved, specialist advice and guidance should always be obtained when using unsealed sources.

5.1 RECOMMENDED MAXIMUM ACTIVITY FOR SOURCES FOR OWN USE

The first step towards safety is to limit the number and total activity of the available ionizing radiation sources on the location. The maximum allowed activities of individual radiation sources and their total activity is often laid down in local regulations.

a. Sealed radioactive sources

In the absence of Statutory Regulations, recommendations as given in Table 5-1 should be adopted. For those incidental cases where higher activity radioactive sources are required, the services of a specialized contractor should be obtained. This is allowed only after a positive recommendation has been given by the RPO and/or the RAC.

Toxicity group (see App. B)	Recommended maximum activity		Exceptions		
				Recommended maximum activity	
	GBq	Ci(1)			GBq
1	5	0.1	Am-241 e.g. sulphur analyser Am-241/Be well logging	50 1000	1 20
2	50	1	For NDT purposes: Co-60 Cs-137 Ir-192 (2)	 1000 500 1500	 20 10 30
3	500	10			
4	Rarely applied as sealed sources.				
Note (1) The curie values are approximate figures.					
(2) Because of the relatively short half-life of Ir-192, the recommended activity should be considered as an onsite value. Purchasing activity may therefore be higher.					

b. X-ray equipment

Sealed radioactive substances have taken over a large proportion of non-destructive testing (NDT) activities at site that were originally covered by X-ray equipment only. A better image quality, however, can be obtained with X-ray exposures. In addition, storage of the equipment does not create the problems encountered with radioactive substances. Hence, X-ray equipment is advantageously applied where accessibility is sufficient. In view of the availability of radioactive substances with deep-penetrating radiation, it is normal practice to limit the use of X-ray equipment to thinner specimens. At present X-ray equipment with voltages up to 300 kV is commonly used for routine radiographic purposes.

5.2 SHIELDING, STORAGE AND TRANSPORT

An accurate update of registration of all radioactive substances should be done at regular intervals (see Section 4.7).

Radioactive substances not in use should always be kept in a dedicated storage place, especially designed for this purpose, as the shielding afforded by the exposure containers does not provide sufficient long-term protection.

5.2.1 Shielding

The radioactive substances, usually in the form of pellets (for example Co-60, Ir-192) or ceramic beads (such as Cs-137, Am-241), are encased in seal-welded stainless steel capsules. The capsules should be checked for leakage at regular intervals (see Section 5.4.2). Radioactive substances emitting alpha particles, and

sources of toxicity group 1, should be doubly encapsulated.
Capsules are located inside exposure containers:

- for gamma radiation they may be of lead, tungsten alloy or depleted uranium, or,
- for sources emitting neutrons, a medium containing hydrogen.

The containers should be provided with a shutter security lock. For NDT activities a suitable remote control should also be provided. On the outside of the exposure container the wording: RADIOACTIVE, in clear and indelible print, should be shown together with the warning sign for radioactivity (see Appendix I). In addition, the nature of the radioactive substance and its activity should be indicated. The construction of the exposure container should be such as to provide a fire-resistance of at least one hour.

The recommended maximum dose equivalent rate on the surface of the container is 2 mSv/h, while at a distance of 1 m from the centre of the container a maximum of 0.1 mSv/h is recommended.

Appendix A gives some examples of calculations with respect to shielding of gamma-ray sources and X-ray equipment.

5.2.2 Storage

a. Radioactive substances

All radioactive substances not in use should be kept securely in a dedicated store. The construction of the store should be such that it is fire-resistant for at least one hour and should be approved by the RAC and fire-fighting department. The storage place should be clearly marked with the warning sign and the wording:

DANGER - RADIOACTIVE MATERIAL in clear and indelible print (see Appendix I).

Its access hatch or door should be provided with a lock, the keys of which should be kept by the Radiation Protection Officer or authorized personnel.

The dose equivalent rate at a distance of 10 cm from any point on the outside of the store should not exceed 1 μ Sv/h in areas accessible to the general public.

Inside premises not accessible to the general public a rate of 2.5 μ Sv/h can be accepted. In many cases the storage place may be a pit in the ground with a "dog kennel" over the pit.

The stated limits then apply for the outside of the "kennel" if the access is provided with a lock.

Only authorized personnel should introduce sources into, or remove them from, the store.

The store should be located in a room, provided with an exit, which can be operated from the inside. The door of the storage room should be provided on the outside with a warning sign and the wording: STORAGE RADIOACTIVE MATERIALS. The room should be locked if no one is present. Inside the room, which should be used only for storage of radioactive substances, the furniture should be limited to a bare minimum. Suitable calibrated dose meters should always be available.

It is strongly recommended that the storage room and examination area for radiography are combined in one building to limit the transport of sources and to enhance supervision. In this case, additional to the standard warning signs at access points, lights and/or audible alarms should be provided to give adequate warning before and during irradiation operations.

Sources used for permanent process measurements normally fall under the instrumentation department's responsibility. At each location where these sources are used a simple display should indicate where the sources are located, whether the shutter is in an open or closed position and whether the source has been (temporarily) removed. An obvious location for this display is the control room of the location concerned.

b. X-ray equipment

X-ray equipment should never be left unattended, if still operable. If the equipment is left on site for a short period, the electricity supply should be disconnected, the equipment locked and the key kept by authorized personnel. To prevent tampering with the equipment, it should be kept in a locked storage room.

Separate storage rooms for radioactive substances and X-ray equipment are advisable. Responsibility for the keys of these storage rooms rests with the RPO

5.2.3 Transport

a. Outside the premises

The IAEA and or Malaysian "Radiation Protection (TRANSPORT) Regulations", whichever is appropriate, for the Safe Transport of Radioactive Materials should be followed. They are specified in the Radiation Protection (TRANSPORT) Regulation and IAEA Safety Series Nos. 6 and 7 (see Chapter 7). Compliance with these regulations is the responsibility of the consignor of the materials.

IAEA makes a distinction between A and B containers. The B type is for high-activity radioactive substances and should be certified to meet IAEA specifications for resistance to damage.

Transport vehicles should be provided with at least one portable fire extinguisher of the halon type, one portable orange-coloured flashlight and fireproof warning notices in front and rear. The warning notices should be clearly displayed, showing the telephone number(s) of the Radiation Protection Officer and authorities to be notified, and the steps to be taken in the case of an accident.

Transport routes should be short and safe. Written instructions on action to be taken in the event of accidents should be present in the vehicle. During the transport of radioactive substances the vehicle should never be left unattended. In the case of a defect to the vehicle, measures should be taken immediately to safeguard the transport of the radioactive material.

Upon arrival, radioactive material should remain in its transport container and the RPO notified. Only after receipt of a duly signed and completed permit should the material be allowed to be transported to the relevant department, in the packing and container as specified on the permit.

For disposal of radioactive substances it is suggested that the services of a contractor specialized in this type of transport be obtained. Liability in case of accident or damage should be properly covered.

b. On the premises

During transport, radioactive substances should be kept in adequately shielded and closed containers. Scaled sources for radiography with their exposure container should be kept inside a lead-lined box which has the radiation warning sign on the outside. The transport container should be properly strapped to prevent movement or loss, and be as far away as possible from the personnel involved. During transport the shielding should be such that the dose equivalent rate does not exceed 0.1 mSv/h at a distance of one metre from the centre.

A portable fire extinguisher of the halon type should be at hand and fireproof warning signs should be provided.

Any loss of radioactive material should be reported at once to the RPO and, if applicable, to the authorities.

Suitably trained workers should be in charge of all transportation of radioactive material.

5.3 HANDLING PROCEDURES AND PERSONAL PROTECTION

Regulations for the safe handling of ionizing radiation sources should be compiled by the RAC. It is the responsibility of all radiological workers and personnel carrying out work on equipment containing a radioactive substance or on X-ray equipment, or giving orders to do so, to familiarize themselves with, and adhere to, these regulations. Errors or deficiencies in instructions or working conditions should be reported to the RAC. The regulations should be clearly exhibited at those locations where regular handling of ionizing radiation sources takes place.

5.3.1 The Three Golden Rules

Every effort should be made to limit unnecessary exposure to radiation. The three golden rules for the use of ionizing radiation sources for NDT purposes should be observed:

- **Keep maximum distance to the source**

A good way to reduce the radiation level is to increase the distance from the radiation source, as the dose rate diminishes with the square of the distance. Only remote controlled equipment should, therefore, be used for radiography purposes. The typical length of X-ray equipment cables or flexible cables of isotope sets should not be considered as adequate to provide a safe distance.

Direct contact between source and body should be prevented under all circumstances.

- **Provide maximum shielding**

For sealed sources collimators should be used. In order to limit scattered radiation, additional shielding should be considered, for example by means of mobile protective lead screens.

Direct radiation from X-ray tubes should be limited by the use of diaphragms.

When working on site, all available radiation obstructions such as pipes and concrete walls should be used to the maximum extent to reduce the dose rates received by radiological workers.

- **Keep exposure time down**

The time during which personnel are exposed to radiation should be minimized. Radiological workers should move fast if they are in the radiation zone.

The practice of applying a shift system in order to distribute the received radiation dose evenly over the radiological workers involved is not an adequate alternative to shielding and is therefore not recommended for this purpose.

5.3.2 Guidelines

As general guidelines for the handling of sealed ionizing radiation sources the following recommendations are given:

- **Permits**

No work should be carried out without the applicable work permit(s) (see Chapter 4 and Appendix E). The instructions mentioned in work permits should be strictly adhered to.

- **Location**

Whenever practicable radiography should be carried out inside a walled enclosure especially designed for this purpose. If this is not possible, the responsible person in charge of the area where radiation work is to be carried out should be notified prior to and after completion of the radiological activities.

The radiological work should be isolated from other work and all non-authorized persons should be excluded from the area concerned.

- **Radiation monitoring**

There is a large variety of measuring devices for the monitoring of ionizing radiation. The RPO is trained in the use of such devices, in general referred to as dose meters. The most commonly used detection device is the radiation badge which is worn on the body of the worker. Different types of badge are used for different types of radiation. For gamma and X rays in general a badge containing X-ray film is used, although thermoluminescence dose meters (TLD) are gradually replacing the film badge. For simplicity, in this Guide these devices are referred to as "radiation badges".

All radiological workers engaged in the handling of ionizing radiation sources should be so authorized and, if applicable, wear a radiation badge. The recommended minimum frequency for changing radiation badges is once every three months. If a radiation exposure is suspected the badge should be read out as soon as possible. During handling of radiation sources a proper radiation monitor should be at hand.

Persons employed in working conditions A should be monitored more closely than others. The RPO should decide which additional personal monitoring devices should be used. In work with X-ray, gamma and neutron radiation, badges should always be worn and changed at least on a monthly basis. The RPO should establish rules with respect to the additional use of personal dose meters which can be read out directly after the work has been completed but at least on a daily basis.