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TECHNICAL GUIDANCE

CODE OF PRACTICE ON RADIATION PROTECTION IN INDUSTRIAL RADIOGRAPHY

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TECHNOLOGY AND INNOVATION
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CODE OF PRACTICE ON RADIATION PROTECTION IN INDUSTRIAL RADIOGRAPHY

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LIST OF ABBREVIATIONS

ADLs	Annual Dose Limits
ALARA	As Low As Reasonable Achievable
CoP	Code of Practice
DDA	Digital Detector Array
HVL	Half-Value Layer
IQI	Image Quality Indicator
JPK	*Jabatan Pembangunan Kemahiran*
OSL	Optically Stimulated Luminescence
P	Operator
PP	Trainee Operator
PY	Supervisor
RT	Radiographic Testing
RT- D	Radiographic Testing- Digital
RPL	Radiophotoluminescence
RPO	Radiation Protection Officer
SKM	*Sijil Kemahiran Malaysia*
TLD	Thermoluminescent Dosimeter
TVL	Tenth-Value Layer

PART I
INTRODUCTION

1. Purpose of Code of Practice (CoP)

The purpose of this Code of Practice (CoP) is to provide minimum requirements and guidance for radiation protection in the use of X-ray and gamma (γ) ray in industrial radiography (film and digital).

2. Specialized meanings for “shall” and “should”

Code of Practice can be prescriptive in style and may be referenced by regulations or conditions of licence. Requirements as stated in the regulations or conditions of licence are expressed in ‘shall’ statements. Practice-specific guidance may recommend good practices, this is expressed in ‘should’ statements, indicating that the measures recommended, or equivalent alternatives on achieving the requirements.

3. Definitions

“accidental exposure” means an unpredictable exposure that results in one or more persons receiving doses exceeding the dose limit;

“Approved Registered Medical Practitioner” means a registered medical practitioner who is approved by the appropriate authority to be responsible for the medical surveillance of workers;

“Act 304” means Atomic Energy Licensing Act 1984;

“Board” means the Board established under section 3 of the Atomic Energy Licensing Act 1984 [Section 3, Act 304];

“calibrated” means an instrument, component or system that has undergone the standard measurement or adjustment that, are performed by an agency recognized and approved by the Board;

“collimator” means a device or mechanism by which the beam is restricted in size and to reduce scattering radiation for safety purposes to radiation workers and the general public;

“controlled area” means any area in which specific protection measures and safety provisions are required for controlling normal exposures or preventing the spread of contamination during normal working conditions, and preventing or limiting the extent of potential exposures; [P.U.(A) 46];

“door interlock” means a mechanical and electrical interlock system that is installed in a shielded enclosure to prevent access to an area of radiation hazard either by preventing entry or by automatically stopping the exposure;

“dose limit” means the value of the effective dose or the equivalent dose to an individual from practice that shall not be exceeded;

“emergency exposure” means a voluntary exposure justified in abnormal conditions for the purpose of bringing help to endangered individuals, preventing exposure to a large number of people or saving a valuable installation including a nuclear installation, where one or more of the dose limits specified for a worker are likely to be exceeded;

“exposure” means either the act or condition of being subject to irradiation, or the amount of ionization produced in the air by ionizing radiation;

“exposure container” means a shield in the form of a container designed to allow controlled use of gamma radiation and employing a source assembly;

“gamma exposure device” means device, including its exposure container and accessories, designed to enable gamma radiation emitted by a sealed

source to be used for industrial radiography that comply to ISO 3999 requirement or equivalent international standard;

“Half-Value Layer (HVL)” means thickness of a certain material required to reduce radiation of a known energy range and intensity, to half of its original intensity. This can also be expressed as the quotient of 0.693 by the linear attenuation coefficient of the material [HVL = $\frac{0.693}{\mu}$ where μ is linear attenuation coefficient];

“industrial radiography” means a non-destructive testing (NDT) method that uses either X-ray or gamma ray to examine materials and components used in industries in the form of radiographic images (film or digital);

“leak test” means a technique for checking the emit of radioactive material from the source capsule;

“leakage radiation” means all radiation emitted from the exposure container or X-ray tube housing other than the useful beam;

“package” means packaging of radioactive contents as presented for transport;

“person” means any individual, partnership, private or public body whether corporate or not, institution or organization, or any international body, institution or organization enjoying legal personality under the law of the Country or the territory of the country where the nuclear installation is situated; [Act 304 Interpretation];

“potential exposure” means prospectively considered exposure that is not expected to be delivered with certainty but that may result from an anticipated operational occurrence or accident at a source or owing to an event or sequence of events of a probabilistic nature, including equipment failures and operating errors;

“public area” means the area which is normally visited or occupied by members of the public;

“qualified expert” means an individual who by virtue of certification by any authority or society or professional licensee, or by virtue of his academic qualifications and experience, is duly recognized by the Board as having the expertise in a relevant field of specialization;

“Radiation Protection Officer” means a technically competent person appointed by the licensee and approved by the appropriate authority to supervise the application of appropriate radiation protection regulations, measures and procedures;

"radiation source" means an equipment capable of emitting ionizing radiation suitable for industrial radiography;

"radiographic equipment" means an exposure device or equipment use for radiography industry activities which includes X-ray equipment, gamma radiography devices and ancillary equipment (control housing, guide tubes, collimator etc.);

“shielded enclosure” means an enclosed space designed and engineered to provide adequate shielding from ionizing radiation to persons in the vicinity;

"shielded enclosure site" means an enclosed space designed and engineered to provide adequate shielding from ionizing radiation to persons in the vicinity to the acceptable dose limit approved by the Board;

"shutter" means a device fixed to the X-ray tube housing or exposure container capable of intercepting the useful beam;

“site radiography” means radiography work performed at the premises of the client (e.g. in a refinery, an offshore location or a construction workshop), in an

urban area (e.g. at a gas pipeline or a building construction site) or in an open field (e.g. a pipeline through a rural or an uninhabited area);

“source changer” means a device designed and used for replacement of sealed source in an exposure container;

“special arrangement” means an arrangement, approved by the Board, under which a consignment which does not fully satisfy the applicable requirements of Radiation Protection (Transport) Regulations 1989 [P.U. (A) 456] may be transported;

“Tenth-Value Layer (TVL)” means the thickness of a certain material required to reduce the radiation of a known energy range and intensity, to one-tenth of its original intensity. This can also be expressed as the quotient of 2.303 by the linear attenuation coefficient of the material [TVL = $\frac{2.303}{\mu}$ where μ is linear attenuation coefficient];

“useful beam” means that part of the radiation which passes through the window, aperture, cone or other collimating device of the X-ray tube or exposure container;

“X-ray radiography equipment” means equipment, including its X-ray tube connected by cable to control panel and its accessories, designed to be used for industrial radiography;

“worker” means any person working under the instruction of the licensee, whether or not employed by the licensee, in the handling or use of, or who will come into contact with any radioactive material, nuclear material, prescribed substance or irradiating apparatus; In the context of this CoP, worker refers to Radiation Protection Officer (RPO), Supervisor (PY), Qualified Expert, Operator (P) and Trainee Operator (PP).

PART II
ADMINISTRATIVE PROCEDURES

4. The Relevant Act and Subsidiary Legislations

4.1 Radiation protection in industrial radiography activities in Malaysia are governed by the following legal instruments:

(a) The Atomic Energy Licensing Act 1984 [Act 304];

(b) The Radiation Protection (Licensing) Regulations 1986 [P.U. (A) 149];

(c) The Radiation Protection (Transport) Regulations 1989 [P.U.(A) 456];

(d) Atomic Energy Licensing (Basic Safety Radiation Protection) Regulations 2010 [P.U. (A) 46]; and

(e) Atomic Energy Licensing (Radioactive Waste Management) Regulations 2011 [P.U. (A) 274].

4.2 The Atomic Energy Licensing Act 1984 is the principle law while the Radiation Protection (Licensing) Regulations 1986, the Radiation Protection (Transport) Regulations 1989 and the Atomic Energy Licensing (Basic Safety Radiation Protection) Regulations 2010 are the subsidiary legislations made under it. The Atomic Energy Licensing (Basic Safety Radiation Protection) Regulations 2010 and the Radiation Protection (Transport) Regulations 1989 specify the operational requirements to ensure safety and security, while the Radiation Protection (Licensing) Regulations 1986 specifies the requirements to obtain a licence and the Atomic Energy Licensing (Radioactive Waste Management) Regulations 2011 specifies the requirement of all aspects related to radioactive waste management from medical, industry and research and any application specified by the Board.

4.3 A licence issued for industrial radiography is provided with conditions of licence, which shall be complied with Section 17, Act 304.

5. Licence Requirement

Any person who wishes to practice industrial radiography shall obtain a licence for:

(a) Class A;
(b) Class B;
(c) Class C;
(d) Class D;
(e) Class E (if required);
(f) Class G (if required);
(g) Class H (if required).

as applicable to the proposed activities [Subsection 12(1), Act 304].

6. Responsibilities of a Licensee

6.1 Compliance with Relevant Legislations

The licensee shall comply with the relevant provisions of Act 304 and its subsidiary legislations, including conditions in licence made under Act 304 and other related acts such as Occupational Safety and Health Act 1994 [Act 514].

6.2 Protection of Workers and Members of the Public

The licensee shall ensure that the annual dose limits (ADLs) specified in **Table 1** are not exceeded.

Table 1: *Annual Dose Limits (ADLs).*

Types of Exposure	Dose (mSv/ year)
DOSE LIMIT FOR WORKERS	
Limit on the effective dose (Whole Body)	20[1]
Limit on equivalent dose to the lens of the eye	150
Limit on equivalent dose to the skin of a worker, averaged over an area of one square centimetre	500
Limit on equivalent dose to the hands and feet of a worker	500
DOSE LIMIT FOR THE MEMBERS OF THE PUBLIC:	
Limit on the effective dose (Whole Body)	1
Limit on equivalent dose to the lens of the eye	15
Limit on equivalent dose to the skin of a member of the public, averaged over an area of one square centimetre	50

The licensee should establish dose constraints based on their radiography works provided that the ADL for the workers and members of the public are not exceeded.

6.3 Radiation Protection Officer (RPO) and Qualified Expert

The licensee shall employ a Radiation Protection Officer (RPO) or qualified expert to carry out the duties of a RPO [Regulation 16, P.U. (A) 46]. Detailed descriptions of the duties of a RPO are given in *LEM/TEK/18 Pengiktirafan dan Tugas Pegawai Perlindungan Sinaran, LEM/TEK/40 Pengiktirafan dan Tugas Pengendali Perunding, LEM/TEK/68 Pengiktirafan dan Tugas Pengendali Perunding Bebas (PPB)* and *LEM/TEK/50 Panduan bagi Permohonan Pengiktirafan Pengendali Pelatih Radiografi Industri.*

[1] *For a pregnant worker, the dose to the foetus accumulated over a period of between the confirmation of pregnancy and the date of delivery shall not exceed 1 mSv.*

6.4 Establishment and Implementation of a Radiation Protection Programme

The licensee shall establish and implement a radiation protection programme [Subregulation 15(4) & (5), P.U. (A) 46] as approved by the Board. Further details of the organizational structure in the radiation protection program are given in *LEM/TEK/45 Panduan Penyediaan Program Perlindungan Sinaran.*

6.4.1 Medical Surveillance of a Worker

The licensee shall ensure that medical surveillance of a worker is carried out by approved registered medical practitioner as in **Table 2** [Regulation 27, 29, 31, 32, 33, and 34, P.U. (A) 46].

Table 2: *Medical Surveillance of a Worker*

(a) pre-employment medical examinations as specified in Regulation 31;
(b) general health surveillance as specified in Regulation 32;
(c) periodic reviews of health as specified in Regulation 33; and
(d) medical examination at termination of employment or retirement as specified in Regulation 34.

6.4.2 Medical Examinations

Where occupationally related radiation induced diseases are suspected, the licensee shall provide medical examinations, investigations and treatments as appropriate [Regulation 35, P.U. (A) 46].

6.4.3 Personnel Monitoring

The licensee shall be responsible for arranging the assessment of the occupational exposure of workers on the basis of personnel monitoring, where

appropriate, using the dosimetry services as approved by the appropriate authority [Subregulation 22 (1), P.U. (A) 46].

The licensee shall carry out personnel monitoring for all workers who normally work in a controlled area, and workers who occasionally work in a controlled area but may receive significant occupational exposure [Subregulation 22 (2), P.U.(A) 46]. See **Table 3**.

Table 3: *Approved Personnel Monitoring Devices for Assessment of External Exposures*

Monitoring Device	**Requirement of Wearing**
Thermoluminescent Dosimeter (TLD), Optically Stimulated Luminescence (OSL), Radiophotoluminescence (RPL) or other approved dosimeter[2]	Mandatory for workers.
Direct Reading Dosimeters[3]	Optional, subject to requirement for workers if appropriate.
Personal Alarm Monitors[4]	Optional, subject to requirement for workers if appropriate.

[2] The device should be worn visibly at chest or waist level in front of the body. This dosimetry is used to create a formal record of a worker's exposure. TLDs, OSL, RPL are usually used, these dosimeters shall be read monthly in normal conditions. The device should be protected from excessive heat, moisture and pressure. The device should be stored in a suitable low background radiation area and should not be carried home. The device shall not be left at a place where radiation sources are likely to be present.

[3] The device should be worn at chest level in front of the body. These devices give a direct dose reading. Workers should check them during the day to monitor their doses. These dosimeters should be checked for good working order before use and should be handled carefully to avoid mechanical damage, shock or entry of moisture. These dosimeters include quartz fibre electroscopes and electronic direct reading dosimeters.

[4] The device should be worn at chest level in front of the body. It should be kept switched on during radiographic operation. It will give a warning signal when a preset Dose or Dose rate is exceeded and is very useful in alerting workers to unexpected high exposures. The device should be tested daily by holding it close to a source in its shielded position and should be handled carefully to avoid mechanical damage, shock or entry of moisture.

6.4.4 Classification of Working Areas and Setting Up of Barriers.

The licensee shall ensure that classification of working areas and setting up of barriers are carried out as in **Table 4** [Regulation 17, P.U. (A) 46].

Table 4: *The Requirements for Radiographic Sites*

	Shielded Enclosure	**Site Radiography**
Site location	The proposed design, siting and usage of the built shielded enclosure shall be approved by AELB before any radiographic work is undertaken. The proof of approval should be furnished during AELB's inspections.	Should be out of the vicinity of the public whenever possible. Dose limit shall not be exceeded.
Supervision	All radiography activities shall be under supervision of a RPO or a Supervisor or at least an Operator.	All radiography activities shall be under supervision of a RPO or a Supervisor or at least an Operator.
Boundary/Barrier	It shall be constructed of solid building material (e.g. concrete, etc). The dose rate at any point outside the external wall, including doors or adjoining area, should not cause an exposure exceeding 20 mSv/y for the worker or 1 mSv/y for members of the public. The warning signs, notices and signals (lights) shall be installed at all accessible wall. The warning signal should be actuated before and until	Radiography work should be carried out in an area designated as a controlled area. No other work should be permitted in this area until the radiography work has been finished and the controlled area is no longer designated. The boundary of the controlled area should be set to ensure that possible dose to people outside the controlled area are below the relevant reference dose levels.

	Shielded Enclosure	Site Radiography
	completion of the operation.	The boundary of the controlled area shall be defined before radiographic work is undertaken provided that the ADLs for workers and members of the public are not exceeded. The boundary of the controlled area should be demarcated. When reasonably practicable, this should be done by physical means. This should include using existing structures such as walls, using temporary barriers or cordoning off the area with tape. Care should be taken to ensure that unauthorized access to the controlled area is prevented. Particular care should be taken where radiography work is being performed in an industrial plant or on a construction site with several floors that can be occupied by people and where there are ladders, stairways, etc. Operators should ensure that access is prevented to any controlled areas on floors above and below the work area. Operators should place the radiation generator control panel or the gamma wind-out in such a position as to minimize doses to themselves when initiating and ending an exposure.

	Shielded Enclosure	Site Radiography
Door Interlocks	<u>Gamma Radiography</u> Should be fitted with suitable safety systems on the access doors to ensure that people cannot enter while a radiation source is exposed. A mechanical or electrical interlock system should be installed to ensure that the source cannot be exposed unless the door is closed. With some manually operated gamma exposure devices, it may not always be possible to install interlock systems of this nature. In this case, the door should be locked closed by the worker immediately prior to exposing the source. A radiation monitoring system with built-in 'fail-to-safe' features should be installed. Ideally, the radiation monitor should be integrated with the door interlocks to prevent entry to the shielded enclosure when the radiation monitor detects radiation in excess of a preset level. This may not be possible, however, with some manually operated gamma exposure devices with wind-out equipment. The same installed radiation monitor should trigger visible ~~s~~signals when the source is exposed.	

	Shielded Enclosure	Site Radiography
	Suitable means of exit should be provided if necessary. <u>X-Ray Radiography</u> Should be fitted with suitable interlocks on the access doors, to ensure that no one can access an enclosure while an X-ray generator is generating radiation. The interlock should prevent the generation of X-rays until the door is closed, and it should immediately terminate the production of X-rays if the door is opened. Subsequent closing of the door should not automatically re-energize the X-ray generator. Door interlocks should not hinder people who may be in the enclosure from leaving in an emergency. Interlock systems should be fail-to-safe, so that X-rays cannot be generated if any component of the interlock system has failed or is broken. Suitable means of exit should be provided if necessary.	
Warning signals and notices	<u>Gamma Radiography</u> A pre-warning signal, which may be either visible or audible, should be given immediately prior to	Adequate warning signals should be given that a radiation exposure is about to be made, and that

	Shielded Enclosure	Site Radiography
	exposing a source. This signal should be clear to any person inside or at the entrance to the shielded enclosure. It should last sufficiently long to enable persons to vacate the inside of the enclosure. A second visible or audible warning signal should be given while the source is in the exposed position. Visible notices that clearly explain the significance of the pre-warning and 'source exposed' signals should be posted at appropriate locations in and around the facility. The notices should incorporate the radiation trefoil and other information as required. The text of the notice should be written in a language known by persons likely to be in the areas around the fully enclosed site. <u>X-Ray Radiography</u> A pre-warning signal, which may be either visible or audible, should be given immediately prior to the generation of X-rays. This signal should be clear to any person inside or at the entrance to the shielded enclosure. It should last sufficiently long to enable persons to vacate the inside of the enclosure.	radiation is being generated or a gamma source is exposed. These signals should be distinguishable from each other. They should be either audible or visible. In general, pre-warning signals are audible (a siren, whistle or bell) while 'exposure in progress' signals are visible lights (e.g. flashing beacons). These signals can be operated manually when radioactive sources are being used. They should operate automatically with X-ray equipment. The signals should be clearly audible or visible from all points around the barrier of the controlled area. Supplementary slave signals may need to be incorporated into the warning system. Notices should be displayed at suitable positions on the boundary of the controlled area. The notices should bear the radiation symbol (trefoil), warnings and appropriate instructions in a language known locally. They should also explain the meaning of the 'exposure pre-warning' and 'exposure warning' signals.

	Shielded Enclosure	Site Radiography
	A second visible or audible warning signal should be given while X-rays are being generated. The pre-warning signal and the 'X-rays on' warning signal should be clearly distinguishable from one another, and both should be visible or audible from within the shielded enclosure. The warning signals should be installed so that they operate automatically when an X-ray exposure is initiated. The warning signal system should be designed or installed so that X-rays cannot be generated in the event of the failure of any component of the system (e.g. failure of a light bulb).	It may be appropriate to post additional notices at the entrance to the premises, to inform persons entering the site that radiography work is due to take place. <u>Pipeline Crawler</u> Suitable warning signals (e.g. automatic audible or visible signals located in a box outside the pipe) capable of alerting persons in the vicinity of the crawler, whatever other distractions there might be, should be provided. It should be possible to differentiate between the pre-exposure warnings, (e.g. a steady signal for the first, and an interrupted signal for the second). All associated sources should be provided with suitable storage containers. Except during an exposure, the sum of the dose rates from the exposure container (if any), the tell-tale sources and the control sources should not exceed 100 uSv/h on the accessible surface of the pipe under test. During temporary interruption of use, the apparatus should be cordoned and supervised

	Shielded Enclosure	Site Radiography
		to prevent access the sources. The control sequence designed so that unintended exposures are prevented.
Emergency stop buttons or pull-cords	Emergency stop buttons or pull-cords with manual resets should be installed to enable any person within the shielded enclosure to trigger an alarm immediately and to terminate or prevent radiation exposure, either automatically or by attracting the attention of the operator. The buttons and pull-cords should be so located that they can be reached without passing through the primary radiation beam. They should be labelled with clear instructions on their use. Persons inside the enclosure should be able either to leave rapidly or to shelter behind suitable shielding. The operator should be able to terminate the exposure immediately in an emergency.	
Notes	The source activity used in the exposure room shall not be greater than what has been approved.	

6.4.5 Area Monitoring

Area monitoring for the supervised and controlled areas associated with shielded enclosure and site radiography shall be done for the following cases [Regulation 21, P.U. (A) 46]:

a) Before the operation;

b) During the operation;

c) After the operation;

d) To review the foreseeable types of accidents.

Table 5 indicates recommended methods of area monitoring for external exposures in the shielded enclosure and site radiography industrial radiography and recommended method for recording accumulated dose on the surrounding area of a shielded enclosure.

Table 5: *Recommended method of area monitoring for external exposures.*

Modes of monitoring	Monitoring devices	Objectives
Survey to be carried out before, during and after operations.[5]	Portable survey meter, containing a suitable detector (e.g. compensated Geiger Müller)	To measure and record ambient radiation dose rates.
Continuous monitoring with monthly changes of monitoring device.[6]	Integrating dosimeter, such as TLD, OSL, RPL or other approved personnel monitoring devices	To record accumulated dose in the surrounding areas (i.e. outside the exposure room).

[5] *To be carried out in shielded enclosure and site radiography.*

[6] *To be carried out in the outside area of shielded enclosure of site industrial radiography only and the monitoring device is recommended to be placed on the outside physical barriers.*

In addition, area monitoring for the supervised and controlled areas in a shielded enclosure site, shall also be done for the following cases [Regulation 21, P.U. (A) 46]:

a) Before starting operation in a new facility;
b) Whenever there are, or may have been fundamental changes to the pre-existing facility;
c) When practical changes in the protection system in working process have been made.

6.4.6 Operational Limit

The licensee shall establish an operational limit which is a dose constraint, lower than the ADL that shall not be exceeded during operation [Regulation 6, P.U. (A) 46].

It is recommended that the licensee uses dose constraint as proposed in their Radiation Protection Programme. However, in all cases the licensee shall ensure optimization of protection and safety [Regulation 5, P.U. (A) 46].

In the event the limit being exceeded, the licensee should inform the Board of the occurrence as stated in the Radiation Protection Programme established by the licensee.

6.4.7 Procedures involving Normal or Potential Exposure

The licensee shall establish procedures with respect to the proposed activity to be carried out [Subregulation 15 (10), P.U. (A) 46] as in Part V of this CoP.

6.4.8 Procedures for Transport of Gamma Sources

The licensee shall establish procedures for transportation of a package containing sealed source in accordance with the Radiation Protection (Transport) Regulations 1989 [P.U.(A) 456] and as in Part VI of this CoP.

6.4.9 Procedures involving Accidental Exposure or Emergency Exposure

The licensee should establish procedures to be used in situations involving accidental or emergency exposure as in Part VIII of this CoP.

The licensee shall also establish an emergency plan for responding to and correcting every reasonably foreseeable emergency situation [Regulation 68, P.U. (A) 46].

6.4.10 Prevention of Accidents

The licensee shall make suitable arrangements to prevent as far as possible, any accidents and to limit the consequences of any accident that occurs [Regulation 67, P.U. (A) 46].

6.4.11 Training of Workers

Every worker shall be thoroughly trained and be able to perform industrial radiography according to the procedures set by the licensee while ensuring radiation safety [Subregulation 15 (8), P.U. (A) 46].

The licensee shall give all workers refresher training as stated in the Radiation Protection Programme, it is recommended that workers be given general refresher training once per year, while the licensee should provide emergency response training at least once in year.

The licensee should also provide workers documents, especially the related procedures, in a language they understand and make sure they read and understand them. The licensee should test their understanding by using suitable methods.

6.4.12 Procedures for Keeping and Transferring Records/Documents

All records and documents shall be kept by the licensee according to the requirements stated in the Radiation Protection Programme.

PART III
SAFETY OF INDUSTRIAL RADIOGRAPHY SOURCES AND EXPOSURE DEVICES

7. General Requirements

7.1 Licensee shall only purchase radiography equipment from suppliers that are licensed by the Board as specified in the conditions in licence [Section 17, Act 304].

7.2 For direct procurement from overseas, the licensee shall ensure that the radiography equipment meet the standards recognized by the Board as specified in the conditions in licence [Section 17, Act 304].

7.3 Licensee shall ensure that radiography equipment is designed, constructed, operated and maintained in a manner that would minimize the magnitude and likelihood of exposure of workers and members of the public [Regulation 66, P.U. (A) 46].

8. Apparatus for X-Ray Radiography

8.1 General Requirements

8.1.1 Data on the maximum dose rates due to leakage radiation at the surface of the device and at 1 m from the X-ray target should be documented.

8.1.2 Commissioning and test procedures for new X-ray systems shall be conducted according to the Malaysian Standards, or other standards

recognized by the Board, to confirm that the system meets applicable performance requirements before they are put into use [Regulation 66, P.U. (A) 46].

8.2 Inspection and Maintenance of the X-Ray Equipment

In carrying out any regular inspection, reference should be made to the manufacturer's operating and maintenance manuals. The inspection should include, but not limited to the following points:

a) All cables should be checked frequently for cuts or damages;
b) All connections should be correctly and securely coupled;
c) Protective caps on plugs and sockets should be replaced after use to prevent ingress of dust and moisture;
d) Watertight connectors should be used correctly and securely coupled;
e) Regular inspection shall be performed and recorded to verify that all warning signs remain in places and indicators are operating properly.

9. Apparatus for Gamma Radiography

9.1 General Requirements

9.1.1 Apparatus for gamma radiography is classified according to the mobility, *Class P* and *Class M* are respectively portable and mobile, whereas *Class F* is fixed:

a) *Class P*: Portable exposure devices, designed to be carried by one or more persons. The mass of a Class P exposure device does not exceed 50 kg;
b) *Class M*: Mobile, but not portable, exposure devices designed to be moved easily by a suitable means provided for the purpose, such as a trolley or cart;

c) *Class F*: Fixed, installed exposure devices or ones with mobility restricted to the confines of a defined working location, such as a shielded enclosure.

9.1.2 The radiation leakage from an exposure container (when in the locked position and loaded with sealed sources of maximum activity) shall not exceed the dose rate limits shown in **Table 6** [ISO 3999].

Table 6: *Maximum Radiation Leakage from an Exposure Container*

	Maximum Dose Rate (µSv/hr)		
Class	On the external surface of container	50 mm from the external surface of container	1 m from the surface of container
P	2000 or	500	20
M	2000 or	1000	50
F	2000 or	1000	100

If radiation leakage exceeds the values shown in Table 6, the exposure container shall be withdrawn from use and arrangements shall be made immediately for its repair and if necessary, its decontamination.

Table 7 summarizes the general design requirements for apparatus for Gamma Radiography.

Table 7: *General Design Requirements for Apparatus for Gamma Radiography*

Items	**Notes**
Exposure device	The exposure device should comply with the requirements of ISO 3999, an equivalent standard or National requirement. Meeting this standard ensures that a minimum safety standard has been met and that the device and source combination is suitable for use for industrial radiography purposes.
Control cable	Should meet the minimum performance standards given in ISO 3999. Typical lengths are 7–15 m for control

Items	Notes
	cables. The exposure devices should not be operated with control cables that are longer than the manufacturer's recommendations.
Guide tube	Should meet the minimum performance standards given in ISO 3999. Typical lengths are 2–6.5 m for guide tubes. The exposure devices should not be operated with guide tubes that are longer than the manufacturer's recommendations.
Collimator	Collimators are used to reduce the radiation beam in some directions. They should be used whenever possible, to reduce radiation levels and subsequent doses. The collimators should be compatible with the source assembly, so as not to cause the source to jam.

9.2 Inspection and Maintenance of Gamma Radiography Equipment

9.2.1 Gamma Radiography Equipment including accessories should undergo routine inspection, periodic maintenance or as directed by the Board as specified in the conditions in licence [Section 17, Act 304].

Periodic maintenance shall only be performed by a service provider recognised by the Board and no modifications should be performed on the equipment unless approved by the Board as specified in the conditions in licence [Section 17, Act 304].

It is also recommended that Licensees use genuine spare parts or components issued by the manufacturer for the equipment to avoid complications or safety concerns that could lead to malfunction of the equipment.

Workers should carry out routine inspection before the start of radiography work, to detect conditions that could lead to an incident if left uncorrected. Some typical checks should include:

a) Inspection of the exposure device to ensure that:

i Fittings and fasteners are tight;

ii The locking mechanism functions properly;

iii Radiation levels are normal;

iv The connections of the guide tube and the control mechanism are secured;

v The source assembly connection to the drive cable is verified to be secure using a wear gauge, such as a ‘go-no-go’ type check gauge supplied by the manufacturer to check for excessive wear.

b) Inspection of the remote controls to ensure that:

i. Fittings are tight;

ii. There are no indications of crushing, kinks or dents;

iii. The drive cable can move freely.

Workers should inspect any additional ancillary equipment being used (such as magnetic stands, vice grip clamps and collimator attachments) for the following:

a) Freedom of movement;
b) Good working condition;
c) Appropriateness for use.

When performing a source exchange, workers should perform the following pre-operational checks to ensure that:

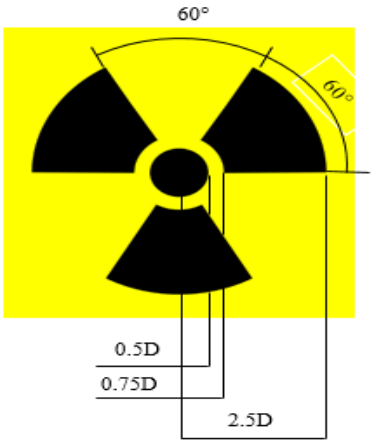
a) Lock assemblies function properly;
b) Guide tube and transfer tube connections are secure;
c) There are no obstructions in the guide tubes or transfer tubes.

Periodic Maintenance

The licensee shall perform maintenance on the Gamma Radiography Equipment at least once a year or as directed by the Board as specified in the conditions in licence [Section 17, Act 304]. The licensee should set up a programme of maintenance of all the equipment used for gamma radiography. The programme should indicate that only the supplier or specially trained operators approved by the Board can perform this maintenance.

An exposure container should be permanently and clearly labelled with the following details:

a) The radiation symbol shall consist of a three-blade design as shown in **Figure 1**;



Note: The following colours shall be used: **BLACK** or other applicable colour used by manufacturer for the design; and **YELLOW** for the background.

Figure 1: *Basic radiation symbol with proportions based on diameter of the central circle, D. The minimum value of D shall be 8 mm [Subregulation 17(6), P.U. (A) 46]*

b) The word “RADIOACTIVE” in letters not less than 10 mm in height;

c) The maximum source activity permitted in the exposure device, quoted for each radionuclide for which the exposure container is suitable;

d) The name of the manufacturer, the model number and the serial number of the exposure container;

e) The mass of the exposure container and details of any depleted uranium shielding if incorporated;

f) The radionuclide, activity, reference date and serial number of the sealed source contained.

10. Pipeline Crawler Equipment

10.1 Pipe crawler equipment is used to radiograph welds on pipelines. The machines carry either an X-ray tube assembly or a gamma source on a mobile carriage that crawls along inside the pipe. They are powered either by batteries on the carriage, by an internal combustion engine or by cables trailing from a generator. The crawler is activated and controlled by the operator from outside the pipe by using a control source. This normally consists of a low activity Cs-137 sealed source mounted in a hand-held device and collimated. Radiation from the control source is received by a detector on the crawler.

10.2 Typically, the control source is moved along the outside of the pipe to prompt the crawler to move in the desired forward or reverse direction. The control source is held against the outside of the pipe to make the crawler stop and wait. An exposure begins automatically about 10 s after the control source is removed from the pipe's surface. Some X-ray crawlers are fitted with a low activity radioactive source, to help to identify the crawler's position inside the pipeline.

10.3 The radiography source does not leave the device during the exposure within a pipeline pipe. Most such pipe crawler equipment is designed to fail-to-safe such that, if power is lost, the source is automatically shielded.

10.4 General radiation safety requirements for apparatus for X-ray and gamma radiography also apply to pipeline crawlers.

PART IV
MONITORING DEVICES, WARNING SIGN AND NOTICE

11. General

As a minimum, the following safety devices shall be made available during any radiographic operation:

a) Approved personnel monitoring devices [Subregulation 22 (4), P.U. (A) 46];

b) Calibrated Area Monitoring Devices (e.g. Survey Meter) [Section 17, Act 304];

c) Warning signs [Subregulation 17 (6), P.U.(A) 46];

d) Warning devices; and

e) Notices [Subregulation 17 (6), P.U.(A) 46].

12. Warning Sign

The licensee shall ensure that supervised areas and controlled areas are clearly demarcated and appropriate legible notices and warning signs bearing the radiation symbol are posted conspicuously in strategic places [Subregulation 17 (6), P.U. (A) 46].

Examples of warning sign are given in **Annex I**.

a) Warning sign shall incorporate radiation symbol as shown in **Figure 1** and the words "BAHAN RADIOAKTIF" or “SINAR-X” or other appropriate descriptions to indicate the source [Subregulation17 (6), P.U. (A) 46].

b) The warning sign should preferably be fire resistant. Examples of the most widely used warning signs are shown in **Annex I**.

13. **Notices**

The notices shall be in Bahasa Malaysia and, if necessary, in any other languages [Subregulation 17 (7), P.U. (A) 46].

Examples of notice are given in **Annex II**.

PART V
PROCEDURES INVOLVING NORMAL OR POTENTIAL EXPOSURE

14. General

Licensee shall ensure that a minimum of two workers consist of at least one operator and one trainee operator are available for each radiography job. [Section 17, Act 304].

The competency of a certified trainee operator is as outlined in LEM/TEK/50.

Radiography jobs should not be carried out in public area. However, if a radiography job has to be carried out in public area, the licensee shall obtain written approval from the Board as required in the conditions of licence [Section 17, Act 304].

Licensee shall submit notice of site radiography work to the Board not later than 24 hours before the work begins [Section 17, Act 304].

15. Prior to Radiographic Operation

The following factors shall be considered when planning a working procedure prior to radiographic operation [Subregulation 15 (10), P.U. (A)46]:

a) Permission to work: Shall be obtained from the person responsible for the site;

b) Radiographic site: Unauthorized person shall not be permitted to enter the controlled area;

c) Radiographic technique: Should be that which involves the least exposures consistent with the needs of an acceptable radiograph;

d) Radiographic parameters: Should be consistent with good technique and practice using appropriate film, qualified DDA, appropriate Imaging Plate, IQI, screen, suitable exposure time, whichever practicable;

e) Radiographic and non-radiographic works: Should be segregated whenever practicable;

f) Collimator and local shielding: Should be made available and used whenever possible;

g) Approved personnel monitoring device: Shall be available to all workers involved. Radiographic operation shall not proceed without this equipment;

h) Calibrated area monitoring devices: Shall have a valid calibration sticker. Radiographic operation shall not proceed if the calibrated area monitoring device is not available or is not in good working order or is damaged;

i) Warning signs, notices and barriers: Shall be used to identify, define and barricade a controlled area;

j) Warning devices: Should be provided in the form of lamps or audible signals or both;

k) A storage facility: Shall be provided and approved by the Board to store gamma radiography sources. [Section 17, Act 304];

l) Source activity or output of X-ray equipment: Should be selected to give reasonable exposure times whilst minimising the dose to workers. The work should be organised to comply with the ALARA principle by taking one or more of the following courses of action:

i. Collimator should be used when practicable;

ii. Use the accessories which provide more shielding for the worker;

iii. Use a source with optimum activity or optimum power of X-ray equipment;

iv. Reduce the time for exposure, for example by:

a) Use Radiographic Testing – Digital technique;

b) Use fast film, if appropriate;

c) Reduce the source to film distance (SFD);

d) Reduce the worker's workload by evenly distributes the work that need to be done.

m) Allowable working time: Should be calculated and determined by the licensee based on their radiography works. See example in Annex III.

n) The position of control panel (in the case of X-ray) or winding cable (in the case of gamma ray) shall be carefully chosen. If possible, it should be outside the controlled area. If this is not possible, the distance from the control panel/winding cable to the radiation source shall be maximized by straightening control panel/winding cable and the guide tube. The control panel/winding cable should be placed behind any convenient shielding which will provide further protection. The worker should not remain inside the controlled area during the exposure. The route taken to and from the control panel/winding cable should not cross the useful beam;

o) Barriers for controlled areas: Shall be established before starting radiographic operation and NOT during the operation, when there may already be people in the areas.

p) Provision of Shielding - Dense materials such as lead, concrete or iron should be used as shielding materials for X and gamma rays.

16. During Radiographic Operation

The following factors shall be considered during radiographic operation [Regulation 18, P.U. (A) 46]:

a) RPO/Supervisor/Operator and Trainee Operator shall ensure safety of workers and avoid unauthorized usage of radiographic equipment and ensure compliance with legislation;

b) RPO/Supervisor/Operator and Trainee Operator shall be constantly alert and stay in positions where they can ensure the effectiveness of the barrier. Should the barrier break for any reasons or any member of the public enters the controlled area, the source shall be returned immediately to its shielded position or the X-ray equipment be switched off.

17. After Radiographic Operation

The RPO/Supervisor/Operator and Trainee Operator shall ensure that all radiographic equipment including the source, warning sign and notices have been removed from the site. A final area monitoring shall be made before the site is vacated on completion of work. He should then inform the person responsible for the site, when this has been completed.

18. Storage of Apparatus for X-radiography

With X-ray equipment, no special storage facility is required other than protection against theft, vandalism or unauthorized usage. A small lockable storeroom or cupboard will suffice. Keys to the X-ray control panel and storeroom should be kept by the RPO/Supervisor/Operator.

19. Storage of a Sealed Source

19.1 General

When not in use, exposure containers shall be stored in a facility such as a storage pit, a storage room or a storage enclosure [Section 17, Act 304].

a) Prior approval for the proposed design, siting of a storage facility shall be obtained from the Board before it is put into use;

b) In selecting a location for a storage facility, the licensee shall take into account the presence of any hazard including risks due to fire and flood. Radioactive sources should be separated from other hazardous substances such as combustible, corrosive and explosive materials;

c) The storage facility should be at a place that will avoid the need to transport a package containing a sealed source, over great distances;

d) The storage facility should:

i. Resistant to fire, to minimize the potential for loss of shielding and containment in the event of a fire in the vicinity;
ii. Located at a remote distance from any corrosion and explosion hazards;

iii. Made of materials that provide sufficient shielding to reduce dose rates outside the room or store to below the relevant levels specified by the regular body.

e) A storage pit can be constructed to provide storage either at the company's premises or remote locations where the requirement may be temporary. An example of the storage pit is shown in **Figure 2**, the pit should be prepared before the sealed source is brought to the site [Section 17, Act 304].

f) The dose rate at any point outside the storage facility should not cause an exposure exceeding 1 mSv/y for members of the public [Regulation 9, P.U. (A) 46].

g) Embossed type warning signs and notices shall be clearly posted [Subregulation 17 (6), P.U. (A) 46] on the lid of the storage pit and on the four walls of the fence as shown in **Figure 2**.

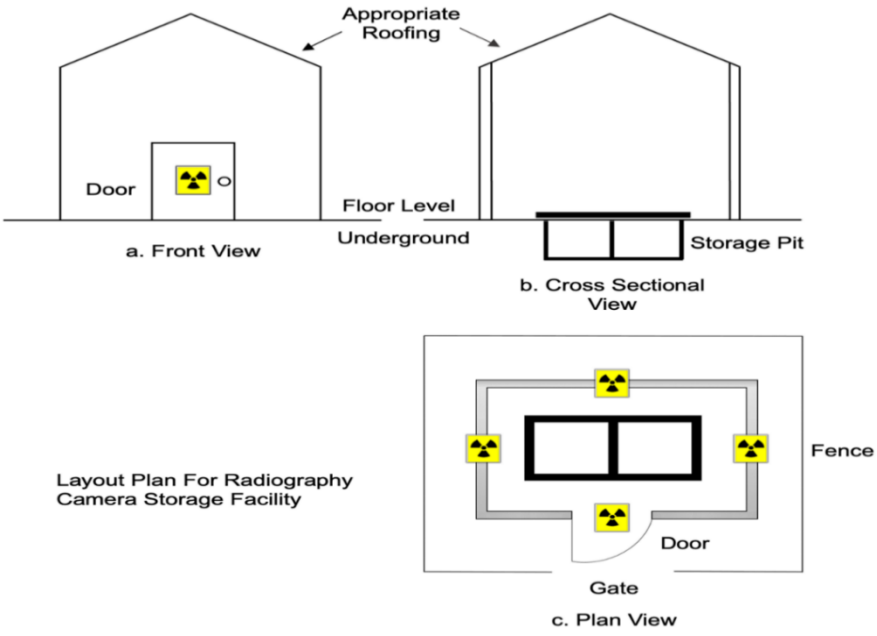


Figure 2: *Example of a Storage Pit*

19.2 Storage Room

a) The licensee should store exposure containers in a storage room [Section 17, Act 304];

b) The storage room should be provided with adequate illumination and ventilation. Provision should be made to switch off all the electrical services from the outside of the storage room;

c) The dose rate at any point outside the external wall, including doors or adjoining area, should not cause an exposure exceeding 20 mSv/y for the worker or 1 mSv/y for the public

d) The boundary of the controlled area shall be defined before radiographic work is undertaken provided that the annual dose limit is not exceeded.

e) The dose rate outside the adjoining walls of the storage room should not cause an exposure exceeding 1 mSv/y for members of the public. [Regulation 9, P.U. (A) 46].

f) The storage room shall be lockable and access to the room shall be restricted. The key of the storage room should be kept by the RPO/Supervisor/Operator.

g) Warning signs and notice shall be clearly posted at four walls as well as at the entrance of the storage room [Subregulation 17 (6), P.U. (A) 46].

19.3 Storage Enclosure

a) The use of storage enclosure is allowed only where the construction of storage room or storage pit is not possible (e.g.: at barges or offshore) [Regulation 12(b), P.U.(A)149].

b) The boundary of storage enclosure shall be formed by a physical barrier to prevent access [Regulation 18, P.U.(A)46].

c) The dose rate at accessible places outside a physical barrier should not cause an exposure.

d) Warning signs and notices shall be conspicuously posted in strategic places (refer Figure 2) [Regulations 17(6), P.U.(A)46].

e) The storage enclosure shall be under the supervision of the Operator or RPO or the supervisor [Regulation 12(b), P.U.(A)149 and Regulations 15 and 21, P.U.(A)46].

20. Source Changing

20.1 Source changing should be performed only with the use of an appropriate source changer and by a person specifically trained and authorized to do so.

20.2 The precautions for radiographic operations shall also be applied when changing a source [Regulation 15, P.U. (A) 46].:

a) Making sure prior to the operation, that approved personnel monitoring devices and all necessary equipment, including any special tool and shielding materials are available;

b) Obtaining and following source changing manuals from the manufacturer. The manuals should include a complete diagram of the device;

c) Establishing of a controlled area;

d) The operations should be carried out at a flat, hard and dry surface;

e) When the new (replacement) source has been transferred to the exposure container, make survey by using a survey meter to ensure that both sources have been returned to their shielded positions. Radiation

leakage shall not exceed any of the leakage limits. Transport label outside the container should be changed to indicate the new sources;

f) Lock both the exposure container and source changer;

g) Return both the exposure container and source changer to a storage facility.

PART VI
TRANSPORTATION OF GAMMA RADIOGRAPHY SOURCES

21. General Procedures

21.1 Gamma radiography sources can be moved within the worksite or to another site.

21.2 Transport of gamma radiography sources from one site to another site shall be carried out in accordance with the Radiation Protection (Transport) Regulation 1989 [P.U. (A) 456].

21.3 Guidance on transport of radioactive sources are given in *LEM/TEK/51 Tugas dan Tanggungjawab Pembawa Bahan Radioaktif*.

PART VII
SECURITY OF RADIATION SOURCE

22. General Requirements

22.1 Radioactive sources used in industrial radiography are generally considered to be Category 2 sources under the IAEA Categorization of Radioactive Sources [Categorization of Radioactive Sources, IAEA Safety Standards Series No. RS-G-1.9, IAEA, Vienna 2005].

22.2 The licensee shall ensure the security and protection of all radiation sources in his possession or under his control to prevent theft, loss or sabotage [Regulation 70, P.U. (A) 46].

22.3 The Licensee shall establish a security plan which is subject to the Board's endorsement, implement, review and revise the security plan if necessary [Section 17, Act 304].

22.4 The licensee shall maintain an accountability system for all radiation sources in his possession or under his control e.g. inventory record of each radiation source [Regulation 69, P.U. (A) 46]. The licensee shall also conduct weekly accounting of all radiation sources by physical inspection [Section 17, Act 304].

22.5 The licensee shall notify the Board of any theft, loss or sabotage within twenty-four (24) hours upon discovering the theft, loss or sabotage and submit a complete written report of the theft, loss or sabotage to the Board within thirty (30) days after the notification to the Board [Regulation 71, P.U. (A) 46].

PART VIII
PROCEDURES INVOLVING ACCIDENTAL EXPOSURE OR EMERGENCY EXPOSURE

23. General Requirements

The licensee shall notify the Board of any accidental exposure or emergency exposure within twenty-four (24) hours after the occurrence of such accidental exposure or emergency exposure. The licensee shall submit to the Board a written report of such accidental exposure or emergency exposure within thirty (30) days [Regulation 26, P.U. (A) 46].

24. Types of Emergency

24.1 Gamma Radiography

a) A source becomes stuck in the guide tube or the collimator, or near the entrance to the exposure device;

b) Physical damage is caused that affects the shielding;

c) A source becomes disconnected from its drive cable and remains in the guide tube;

d) A source is projected out of the end of the guide tube;

e) A pipeline crawler becomes stuck in a pipe with the source exposed;

f) A source is lost;

g) There is a fire;

h) Unauthorized persons are present in the controlled area during an exposure.

24.2 X-ray Equipment

a) Generation of radiation fails to terminate after the intended time period;

b) An X-ray generator is unintentionally energized;

c) An operator fails to terminate a manually controlled generation of radiation;

d) A safety system or warning system malfunctions, including deliberate action to override a system;

e) Another malfunction causes X-rays to be generated other than in a controlled manner;

f) Physical damage is caused that affects the shielding or filtration;

g) Unauthorized persons are present in the controlled area during an exposure.

25. Emergency Equipment

The licensee should ensure that all necessary emergency equipment for dealing with all reasonably foreseeable emergencies is readily available e.g.

a) Appropriate and functional survey meters to measure both high and low dose rates;
b) Personal alarm dosimeters and direct reading dosimeters (preferably electronic personal dosimeters rather than quartz fibre electroscopes);
c) Additional personal dosimeters (TLD, OSL, RPL or film badges);
d) Barrier materials and notices;
e) Bags of lead shot, and extra lead sheet;
f) Suitable tool kit and source recovery equipment (long handling tongs, pliers, screwdrivers, bolt cutters, adjustable spanner, hacksaw and torch);
g) Spare shielded container for emergency use;
h) Communication equipment (e.g. mobile phones, radio transmitters and receivers);
i) Spare batteries for survey meters, electronic personal dosimeters, mobile phones and torches;
j) Pens, paper, calculator and an incident log book;
k) Equipment manuals

26. Specific Emergency Procedures

26.1 Gamma Radiography

The worker *(response initiator)* should:

a) Recognize that an abnormal situation has arisen that might constitute an emergency;

b) Remain calm and move away from the exposed source. Ensure that any other workers in the vicinity are aware that there may be a problem;

c) Measure the radiation dose rates and record any doses measured by direct reading dosimeters;

d) Establish or re-establish controlled area barriers on the basis of dose rate reference levels consistent with regulatory requirements and guidance;

e) Prevent access to the new controlled area;

f) Do not leave the controlled area unattended; and

g) Inform the RPO of the operating organization and the radiography client and seek assistance.

The RPO should:

a) Plan a specific course of action on the basis of previously established emergency procedures, taking care to minimize doses that may be received as a result of this course of action;

b) Move to an area away from the controlled area and rehearse the planned course of action before entering the controlled area to implement the emergency plan;

c) Implement the planned course of action to the extent that training, equipment and authorizations allow; under no circumstances allow the source to come into contact with the hands or other parts of the body;

d) If the course of action taken is unsuccessful, leave the controlled area and consider the next course of action while maintaining surveillance of the controlled area;

e) Call for technical assistance, if necessary, from a qualified expert or from the manufacturer;

f) When the emergency is over and the source has been made safe, assess the doses received and prepare a report;

g) Return personal dosimeters to the dosimetry service for the purpose of accurate assessment of exposures;

h) Send damaged or malfunctioning equipment to the manufacturer or to a qualified expert for detailed examination and repair prior to any reuse; and

i) Prepare an accident report and notify the regulatory body as required.

26.2 X-ray Generators

The following steps should be taken in an abnormal situation involving an X ray generator.

The worker *(response initiator)* should:

a) Recognize that an abnormal situation has arisen that might constitute an emergency;

b) Turn off the electrical power to the radiography equipment;

c) Perform a radiation survey to confirm that the tube is de-energized;

d) Do not move the radiography equipment until details such as position, beam direction and exposure settings (tube voltage, current and time) have been recorded;

e) Inform the RPO of what has happened; and

f) Do not use the X-ray generator until it has been examined and repaired by the manufacturer or by a qualified expert.

The RPO should:

a) Assess the possible doses that could have been received and prepare a report;

b) Return personal dosimeters to the dosimetry service for the purpose of accurate assessment of exposures; and

c) Prepare an accident report and notify the regulatory body as required.

27. Investigation of Over Exposure

Upon suspicion of an overdose, the licensee shall carry out an investigation to determine the circumstances and the consequences in which the over exposure took place and submit the report to the Board [Regulation 25 & 26 P.U. (A) 46].

28. DOCUMENT RECORD:

<table>
<tr><th>Effective Date</th><th>Revision</th><th>Drafter</th></tr>
<tr><td>22 June 1995</td><td>0</td><td>AELB</td></tr>
<tr><td>2 Dec 2008</td><td>1</td><td>AELB</td></tr>
<tr><td>1 Sept 2020</td><td>2</td><td>This Code of Practice was reviewed by Jawatankuasa Kecil Keselamatan (Keselamatan Sinaran) and AELB Secretariat as follows;
<table>
<tr><td>1. Pn. Hjh. Noraishah Pungut</td><td>AELB</td></tr>
<tr><td>2. Dr. Shukri Mohd</td><td>Agensi Nuklear Malaysia</td></tr>
<tr><td>3. En. Zunaide Kayun</td><td>Kementerian Kesihatan Malaysia</td></tr>
<tr><td>4. Dr. Wan Saffiey Hj. Wan Abdullah</td><td>Malaysian Radiation Protection Association, MARPA</td></tr>
<tr><td>5. En. Mohd Radzi Rozihad</td><td>Jabatan Keselamatan dan Kesihatan pekerjaan</td></tr>
<tr><td>6. En. Saharudin Kambari</td><td>Malaysian Society for Non- Destructive Testing (MSNT)</td></tr>
<tr><td>7. Pn. Salbiah Husein</td><td>Jabatan Pembangunan Kemahiran</td></tr>
<tr><td>8. Cik Gan Pek Yen</td><td>AELB</td></tr>
<tr><td>9. En. Bryan bin Gindana</td><td>Secretariat</td></tr>
<tr><td>10. Pn. Nor Faezah Rabani</td><td>Secretariat</td></tr>
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<tr><td>10 Dec 2021</td><td>3</td><td>This Code of Practice was reviewed by Jawatankuasa Kecil Keselamatan (Keselamatan Sinaran) and AELB Secretariat as follows;
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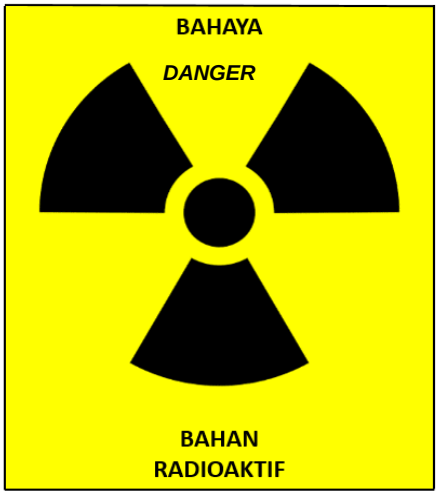
<tr><td>9. Pn. Siti Kamalia Mokhtar</td><td>Secretariat</td></tr>
</table></td></tr>
</table>

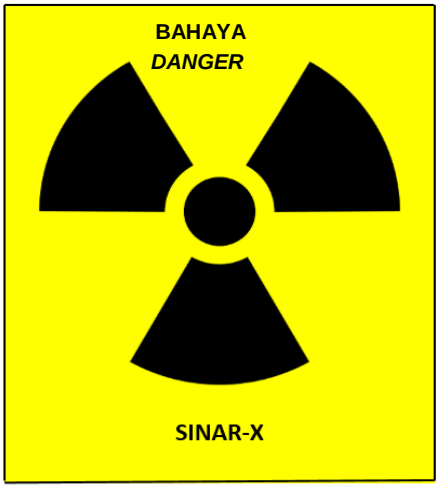
29. REFERENCES

1. Atomic Energy Licensing Act 1984 (Act 304)
2. Occupational Safety and Health Act 1994 (Act 514)
3. The Radiation Protection (Licensing) Regulations 1986 (P.U. (A) 149)
4. The Radiation Protection (Transport) Regulations 1989 (P.U. (A) 456)
5. Atomic Energy Licensing (Basic Safety Radiation Protection) Regulations 2010 (P.U. (A) 46)
6. Atomic Energy Licensing (Radioactive Waste Management) Regulations 2011 (P.U. (A) 274)
7. Categorization of Radioactive Sources, IAEA Safety Standards Series No. RS-G-1.9, IAEA, Vienna 2005
8. Radiation Safety in Industrial Radiography, IAEA Safety Standards Specific Safety Guide No. SSG-11, Vienna 2011
9. ISO 3999:2004 Radiation protection — Apparatus for industrial gamma radiography — Specifications for performance, design and tests, 2004
10. Radiation Safety for Industrial Radiography, Malaysian Nuclear Agency (Nuclear Malaysia), 2004
11. *LEM/TEK/18 Pengiktirafan dan Tugas Pegawai Perlindungan Sinaran*
12. *LEM/TEK/40 Pengiktirafan & Tugas Pengendali Perunding*
13. *LEM/TEK/45 Panduan Penyediaan Program Perlindungan Sinaran*
14. *LEM/TEK/50 Panduan Bagi Permohonan Pengiktirafan Pengendali Pelatih Radiografi Industri*
15. *LEM/TEK/68 Pengiktirafan dan Tugas Pengendali Perunding Bebas*

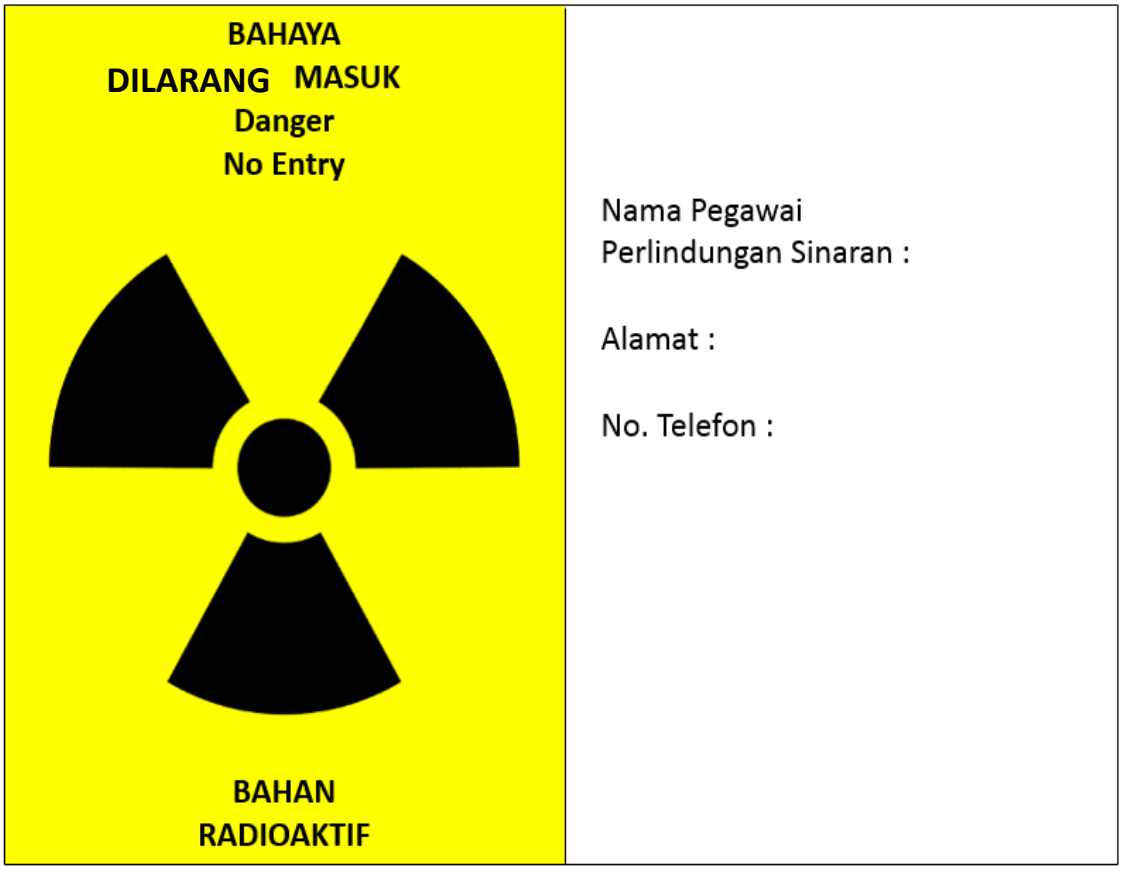
ANNEXES

Annex I





Annex II



Annex III

CALCULATION GUIDELINES

1. Calculation for allowable working time:

$$\text{Allowable working time (h/year)} = \frac{\text{ADL } (\frac{\text{mSv}}{\text{year}})}{\text{dose rate } (\frac{\text{mSv}}{\text{h}})}$$

Example 1: How many hours could an operator spend each month in an area, in which the dose rate is 0.05 mSv/h with an ADL of 20 mSv/ year?

Solution:

$$\text{Allowable working time (h/year)} = \frac{\text{ADL } (\frac{\text{mSv}}{\text{year}})}{\text{dose rate } (\frac{\text{mSv}}{\text{h}})}$$

$$= \frac{20\ (\frac{\text{mSv}}{\text{year}})}{0.05\ (\frac{\text{mSv}}{\text{h}})}$$

$$= 400\ \text{h/year}$$

Therefore, the allowable time is 400 h/year.
If the allowable working time (hours in a week is required), a proper calculation must be made, but it shall not correspond to a figure exceeding 20 mSv/year.

2. Calculation for barrier distance:

A preliminary estimate of distance from the working position to the barrier position can be made using one of the following methods:

i. Using the Inverse Square Law

The maximum distance from the working position to the barrier can be calculated using inverse square law which is expressed as:

$$\frac{I_1}{I_2} = \frac{(d_2)^2}{(d_1)^2} \text{ : where}$$

d_1 and d_2 are the distances

I_1 and I_2 are the dose rates at distances d_1 and d_2 respectively from the source

Example 2: The dose rate at 1 m from a particular sealed source is 0.2 mSv/h. At what distance will it be at dose rate of 7.5 µSv/h?

Solution:

$$\frac{I_1}{I_2} = \frac{(d_2)^2}{(d_1)^2}$$

$$\frac{(d_2)^2}{(1\ \text{m})^2} = \frac{0.2\ \text{mSv/h}}{7.5\ \mu\text{Sv/h}}$$

$$(d_2)^2 = \frac{0.2\ \text{mSv/h} \times (1\text{m})^2}{0.0075\ \text{mSv/h}}$$

$$d_2 = 5.16\ \text{m}$$

Therefore, a dose rate of 7.5 uSv/h will be at a distance of 5.16 m.

ii. Using Gamma Constant

To calculate barrier distances from a sealed source, the Gamma constant can be used by using the following mathematical expression:

$$I/d^2 = \Gamma A; \quad \text{where}$$

I = dose rate (mSv/h)

Γ = specific gamma ray constant (mSv/h/GBq) at a distance of 1 m from the source (see **Table I**).

A = the activity (GBq)

d = the distance (m)

Example 3: What is the dose rate from 1 GBq Co-60 source at 2 m?

Solution:

1 GBq of Co-60 gives a dose rate of 0.306 mSv/h at 1 m. If the dose rate at 2 m = I_2, then by inverse square law:

$$I_1(d_1)^2 = I_2(d_2)^2$$

$$I_1 \text{ x } 2^2 = 0.306 \text{ x } 1^2$$

$$I_2 = 0.306 \text{ mSv/h}$$

$$= 0.0765 \text{ mSv/h}$$

Therefore, the dose rate at 2 m is 76.5 uSv/h.

Note: The above method can also be applied for X-rays by replacing "activity (GBq)" with "tube current – (mA-min)"
Licensee or user should obtain the dose rate constant for X-ray radiography from the manufacturer however **Table II** is provided as a guidance for the example provided).

Table I: *Radionuclides Most Commonly Used in Industrial Radiography and their Characteristics*

Radionuclides	Energy	Source output at 1 m ($mSv \cdot h^{-1}$ per 37 GBq)	Half-life	Thickness of steel for which this is typically used (mm)
Co-60	1.17 and 1.33 Mev	13.0	5.3 y	50 - 120
Ir-192	206-612 keV	4.8	74 d	12-70
Se-75	97-401 keV	2.03	120 d	8-30
Yb-169	63-308 keV	1.25	32 d	4-20
Tm-170	51-84 keV	0.25	128 d	2.5-12.5

**Reference IAEA Safety Standard Specific Safety Guide Radiation Safety in Industrial Radiography (SSG 11)*

Table II: *Example of dose rate constant (k-Factor) for various kilo voltages after passing through a copper filter.*

Tube Voltage (kV)	"k – Factor" (mSv/mA-min at 1 m)		
	0.07 mm Cu	0.10 mm Cu	0.5 mm Cu
50	3.2	1.8	-
75	7.0	5.0	0.5
100	12.0	8.5	1.6
150	23.0	17.5	6.0
200	36.0	29.0	12.5
250			19.0
300			28.0
400			56.0
500			80.0
1000			330.0

**Reference Radiation Safety for Industrial Radiography Malaysian Nuclear Agency (Nuclear Malaysia)*

Example 4: What is the dose rate at 5 m from an X-ray machine operated at the following conditions: tube voltage :150 kV; tube current (A): 10 mA; filter: 0.1 mm Cu?

Solution:

$$I = \frac{(k)A}{d^2}$$

$$= \frac{17.5 \times 10}{5^2} \text{ mSv/min}$$

$$= \frac{17.5 \times 600}{25} \text{ mSv/h}$$

$$= 420 \text{ mSv/h}$$

Therefore, dose rate at 5 m in is 420 mSv/h.

3. Calculation for shielding thickness

The thickness of a required shielding material can be calculated by:

i. Using Half-Value Layers (HVL) or Tenth-Value Layers (TVL):

The thickness of a required shielding material can be calculated by using so-called HVL and TVL which are mathematically expressed as:

$I = I_o / 2^n$ (for HVL) n = Thickness/HVL

$I = I_o / 10^n$ (for TVL) n = Thickness/ TVL

Where

n = the number HVL or TVL required respectively

I_o = the initial dose rate.

I = the dose rate after penetrating n HVL or n TVL thickness of the materials

The example approximate values of TVL and HVL for various materials for different sources are shown in **Table III**.

Example 5: A 200kV x-ray equipment is operating at 10mA by using 0.5 mm Copper filter. Calculate the thickness of concrete wall required to reduce the dose rate at 1 m to a limit of 2.5 µSv/h.

Solution:

k-factor with 0.5 mm Copper = 12.5 mSv/mA - min (from **Table III**)

$$I = I_o / 2^n$$

Number of HVL required

$$2^n = I_o / I$$

$$= \frac{12.5 \text{ x } 600}{2.5 \text{ x } 10^{-3}}$$

$$= 300 \text{ x } 104$$

$$n = 22$$

From **Table III**, HVL of concrete at 200 kVp = 26 mm;
26 mm x 22 = 572 mm thick of concrete is required as a barrier.

Table III: *Approximate value of TVL and HVL for various materials of different sources (Thickness in mm)*

Sources	Lead		Steel		Concrete	
	TVL (mm)	HVL(mm)	TVL(mm)	HVL(mm)	TVL(mm)	HVL(mm)
X-rays						
50 kVp	0.25	0.07	1.5	0.5	14	9
100 kVp	1.0	0.3	5.5	2	54	17
150 kVp	1.0	0.3	13	4	70	22
200 kVp	1.4	0.45	19	6	86	26
250 kVp	3.2	1.0	36	12	90	28
300 kVp	4.9	1.5	45	15	102	30
Co-60	41.2	12.4	73.7	22.1	218.4	66
Ir-192	16.3	4.8	50.8	15.5	157.5	48.3

**Reference Radiation Safety for Industrial Radiography Malaysian Nuclear Agency (Nuclear Malaysia)*