Petroleum Development Oman L.L.C.

Management of Ionising Radiation

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i Document Authorisation

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ii Revision History

The following is a brief summary of the three most recent revisions to this document. Details of all revisions prior to these are held on file by the issuing department.

IV Related Corporate Management Frame Work (CMF) Documents

The related CMF Documents can be retrieved from the Corporate Business Control Documentation Register *TAXI*

TABLE OF CONTENTS

Introduction

1.1 Purpose

This Specification describes PDO's minimum requirements for managing ionising radiation to protect people and the environment from their harmful effects.

1.2 Scope

This Specification applies to all PDO, Contractors and Sub-Contractors activities involving ionising radiation and outlines the requirements to be fulfilled.

The Specification ***does not apply*** to non-ionising radiation such as, Ultraviolet (UV), Visible Light (VL), Infrared (IR), Radiofrequency and Electromagnetic Field (EMF) .Naturally Occurring Radioactive Materials (NORM) is covered in SP-1170 (October 2019) HSE Specification - Management of Naturally Occurring Radioactive Materials

1.3 Definitions

Accident: Any unintended event, including operating errors, equipment failures and other mishaps, the consequences or potential consequences of which are not negligible from the point of view of protection and safety

Classified worker: Individuals who through the course of their work are likely to receive an annual dose equal or greater than 1mSv/year. Personal monitoring and medical surveillance are mandatory for radiological workers

Collimators: A high-density metallic materials used to reduce the intensity and restrict the size of radiation beam (angle)

Competent Authority: A regulatory authority (such as MECA and ROP in) empowered to authorize and regulated practices and to enforce the legislation and regulations. The Regulatory authority needs to provide for the surveillance, monitoring and inspection of radiation sources and for ensuring adequate plans exist for dealing with radiation hazards

Emergency: A non-routine situation or *event* that necessitates prompt action, primarily to mitigate a hazard or adverse consequences for human life, health, property and the environment

Ionizing Radiation: Radiation that produces ionization in matter. Examples are Alpha particles, Beta Particles, Gamma Rays, X-rays and Neutrons

Leakage Radiation: Any radiation coming from the source housing, other than useful beam or primary beam

Permit: The permission granted to an organization to import, transport, use, Store or disposal of radioactive material

Radioactive materials: are defined in Oman as any material with an activity concentration greater than 100KBq/KG (100Bq/gm)

Radiation monitoring devices: Detection Devices used by classified workers for monitoring Ionization radiation

Radioactive waste: Material, whatever its physical form, remaining from the practices or interventions and for which no further use is foreseen: (a) that contains or is contaminated with radioactive substances and has an activity, i.e. activity concentration, higher than the level for clearance from regulatory requirements; and (b) exposure to which is not excluded from regulatory control

Sealed source: A radioactive source in which the radioactive material is (a) permanently sealed in a capsule or (b) closely bonded and in a solid form

Shielding material: Any material used to absorb radiation and thereby reduce its amount
Of intensity

Transport: The controlled movement of radioactive materials from one location to another.

Transport Index: An Internationally accepted index for classification of packages and how they can be grouped for storage and transport

1.4 Units/ Definition

Becquerel (Bq) is the international System (SI) unit for the quantity of radioactivity defined as equal to one nuclear disintegration per second.

Curie (Ci) is the traditional unit for measurement of radioactivity based on the activity of one gram of radium, i.e. 37 billion disintegrations per second.

- 1 Becquerel, Bq= 27 pCi (27×1^{-12} Ci)
- 1 Curie, Ci = 37 GBq (37×10^{9} Bq)

The Gray is the SI unit of absorbed radiation dose due to ionizing radiation. The gray measures the deposited energy of radiation.

Table 1: Units

Quantity	Units		Relationship
	Old	New	
Radioactivity	Curie Ci	Bequeral Bq	1 Ci = 37×10^{9} Bq
Dose	Rad	Gy	100 Rad = 1 Gy
Equivalent Dose	Rem	Sv	100 Rem = 1 Sv 1 Rem = 10 mSv 1 milliRem = 10 µSv

1.4.1 Legal and Other Requirements

Legal requirements for the import, transport, storage or use of radioactive materials in the Sultanate of Oman are established in Ministerial Decree - *MD 281/2003 "Regulations for the*

Control and Management of Radioactive Materials". The Ministry of Environment and Climate Affairs (MECA) administer this Ministerial Decree.

The Ministry of Manpower Occupational Health and Safety Regulations in the Private Sector also includes a section on ionising radiation and dose limits, *Regulation of Occupational Safety and Health for Establishments Governed by the Labour Law Ministerial decision No. (286/2008)*

Oman is a Member of the International Atomic Energy Agency (IAEA). The IAEA has developed a comprehensive list of safety standards of which Oman has incorporated the Regulations for the Safe Transport of Radioactive Materials into MD 281/2003.

Any organisation dealing with radioactive materials shall establish an internal radiation management system including staff structure with well-defined responsibilities, written procedures of work, quality assurance procedures, staff training and emergency procedures so as to meet the Ministry's and PDO's requirements.

In addition, PDO will adhere to recommendations of the International Commission on Radiological Protection provided these recommendations meet or exceed the requirements of MD 281/2003.

1.5 Deliverables

1.5.1 Records

Records shall be maintained to document the implementation of this Specification and shall be outlined in the Contractors/ Sub-Contractors Radiation Safety Management System and safe working procedures. Records shall include a register of radiological workers, personal radiation dose rates, site audits and inspection reports, registration of radioactive materials and radiation generators, wipe testing, transportation, storage and inspection measurements and disposal or return to manufacturer.

1.5.2 Reports

Any non-compliance with this Specification shall be notified to the PDO Project Manager, Contract Holder or Principal Contractor in relation to Sub-Contractors and the corporate HSE radiation advisor. Pending the severity of the non-compliance an investigation shall be undertaken and the findings shall be reported. Further information on reporting non-conformances is outlined in *GU 612 Incident investigation and reporting*

1.6 Review and Improvement

Any user of this document who encounters a mistake or confusing entry is requested to immediately notify the Document Custodian using the form provided in CP-122 "HSE Management System Manual". This document shall be reviewed as necessary by the Document Custodian, but no less frequently than every four years.

1.7 Organization Roles and Responsibilities

1.8 Radiation Advisory Committee (RAC)

The PDO Radiation Advisory Committee is responsible for advising PDO Management on all matters related to occupational and environmental radiation protection and safety. The committee reports to the Managing Directors Committee and Internal Assurance Committee quarterly.

The RAC reviews and recommends approval of radiation safety policies, specifications and procedures with respect to operational and administrative management of radiation protection. The RAC is advised by the Radiation Protection Advisor who will be the source of expertise for all matters concerning protection against the hazards of ionising radiation.
The RAC provides a forum to ensure that important radiation safety issues receive appropriate, balanced, and expert review before being acted upon.

The RAC is comprised of:

- Chairman - permanent member
- Corporate Radiation Focal Point (acts as the RAC secretary)-permanent member
- Corporate Environmental Advisor- permanent member
- Directorate HSE TL
- Operation and engineering representative
- Relevant contract holders

1.9 Corporate Radiation focal Point

The Corporate Radiation Focal point is the first source of expertise within PDO for matters concerning the protection against the hazards of ionising radiation. When lacking knowledge or information the corporate advisor may call in the help/advice of the RPA. Further, the radiation advisor:

- Is the RAC secretary
- Communicates with competent authority on PDO matters concerning the protection against the hazards of ionising radiation.
- Monitors the PDO radiation Strategy implementation.
- Is current on all potential ionising radiation issues within PDO.
- Is responsible and accountable for pre-approving radiation safety manuals for contractors utilising radiation sources and generators up on notifications
- Is the contract holder and interface to the external RPA.

1.10 Interior Radiation Protection Supervisors (RPS)

Any contractor or sub-contractor utilising radioactive materials in the PDO Concession area shall appoint a competent Radiation Protection Supervisor (RPS) for each location. The RPS will be the first source of working knowledge within the interior for matters concerning the protection against the hazards of ionising radiation. The RPS shall be experienced in monitoring routine and non-routine situations involving the type of ionising radiation they are handling. The RPS shall be appointed by the Radiation Protection Advisor and endorsed by the company management, and agreed by the operator, that he/she understands his role. In case of lacking knowledge/expertise or doubt RPS may directly call in the help/advice to the contractors Senior Radiation Protection Supervisor or appointed Radiation Protection Advisor.

1.11 Senior Radiation Protection Supervisors (Coastal)

Any contractor or sub-contractor utilising radioactive materials in the PDO Concession area shall appoint a competent Senior Radiation Protection Supervisor (SRPS) who shall be the first source of radiation expertise within the Contractor and/or Sub-Contractor. The Senior RPS is responsible for:

- Monitoring compliance with this Specification for the storage, transport and use of radioactive sources at all worksites.

- Formulation and review of work procedures and contingency plans and training, where necessary to ensure safe working practices and adequate emergency response.
- Implementing a comprehensive system of movement control of all sources of ionising radiation imported into Oman, such that their location is known at all times.
- Monitoring of all workers exposed to ionising radiation, to ensure that they perform their assigned work without endangering themselves, fellow workers, members of the public and the environment.
- Implementing adequate dosimetry control and rigorously reviewing the records.
- Investigating and reporting all incidents involving radioactive materials

1.12 Radiation Protection Advisers (RPA) and/or Health Physicists

All Contractors or Sub-Contractors utilising radioactive materials in the performance of their work for PDO shall appoint (on staff, or under contract) one suitably qualified Radiation Protection Adviser (RPA) or qualified Health Physicist to advise on matters relevant to radiation safety for their operations in Oman. The responsibility for compliance with this Specification is not delegated to the RPA and remains the responsibility of the operating organisation. The RPA provides specialist advice and technical assistance to the organisation and shall be trained such as the IAEA and the ICRP.

The RPA is responsible for:

- Advising management on the implementation of the company's radiation safety management system.
- Monitoring compliance with this Specification for the storage, transport and use of radioactive sources at all worksites through planned inspections and audit programs.
- Formulation of safe working procedures (local rules) and contingency plans, where necessary, to ensure safe working practices and adequate emergency response.
- Training and monitoring of all workers exposed to ionising radiation,
- Peer reviewing investigations of incidents mentioned in section 11.4 of this document

The Contractor shall ensure that the RPA or equivalent holds sufficient competency and formal training in all aspects of the work to meet the requirements of an RPA and approved by PDO. The RPA shall be available at all times through a call-out system, but the permanent presence of the RPA at the worksite is not required.

1.13 Performance monitoring requirement

The responsibility for the importation, transport, storage, emergency response and use of radioactive materials rests with the owner (custodian) referenced on the MECA permit and shall be subjected to performance monitoring in accordance with the owner's radiation safety management system and Contractual requirements. Contractors and sub-contractors who own and utilise radioactive materials and generators shall be pre-approved by the Corporate Radiation Focal Point & CFDH prior to acceptance onto the PDO vendor list. This will include a pre-approval audit and review of the Contractors/ Sub-Contractors Radiation Safety Management System and safe working procedures. **Table 2** demonstrate PDO, Contractor and Subcontract RASCI chart.

Table 2: The RASCI chart Identifies PDO and contractors roles and responsibilities in radiation management

Responsible **(R)**	Accountable **(A)**	Support **(S)**	Consult **(C)**	Inform **(I)**

Monitoring Activity	**Project Managers & Contract Holders**	**Contract Holders**	**CSR**	**Contractors**	**Subcontractors**	**RAC**	**Corporate Radiation Advisor**	**Environmental advisor**	**Others**
Approval of Contractors and Sub-Contractors Radiation Safety Manual (RSM)	S	S				I	R & A		Project HSE S
L2/3 radiation audits of Contractors using radioactive sources & generators	R & A	R & A	S			I	S & I		HSE -TL S
L2/3 radiation audits of Sub-Contractors using radioactive sources & generators				R & A			I		Asset S
Provide audit findings and learning's to CFDH & CRFP for lateral learning	R	R			R	I	C		S
Review monthly Dose reports	I	I		R	R	I	I		
Compile findings to RAC	S	S					R & A		
Initiation and obtaining of environmental and Civil Defense permits	R	R					I	S, C	UIC S
Management of lost in hole sources	R	R		S		I	C,S	S,C	

2 Radiation Safety Management System

Owners of radioactive sources for use for PDO activities shall develop a comprehensive radiation safety management system that incorporates quality assurance and outlines:

- The organisational chart and allocated responsibilities
- Importation, transportation and storage (within Muscat and interior locations) of radioactive materials or generators
- Operations and maintenance activities (including Job HSE Plans to be attached to the PtW)
- Dosimetry and Instrumentation
- Emergency Response plan and drill.
- Training
- Disposal

In addition, the owner shall maintain "Accompanying Documents" which shall include but not limited to;

Description and technical characteristics of the apparatus and sources including suitable photos or drawings to allow identification of the main elements and parts of the apparatus

- Source certificates of the manufacturer to show compliance with the International standard e.g. ISO-2919: 2017- radiological protection- sealed radioactive sources
- Instructions for use including Assembling storage of the container and the use of protective caps, plugs or similar devices on the apparatus while not in use Instructions on the storage of the container
- Inspection, maintenance and repair procedures and records
- Instructions for disposal

2.1 Occupational Dose Limits

The exposure of individuals shall be restricted so that neither the total effective dose nor the total equivalent dose to relevant organs or tissues, caused by the possible combination of exposures from authorized practices, exceeds any relevant dose limits specified in **table 2**. IAEA General Safety Requirements Part 3

It is important to recognize that dose limits are set so that any continued exposure just above the dose limits would result in additional risks that could be reasonably described as "unacceptable" in normal circumstances.

There are two objectives in limiting the dose. The first is to keep doses below the threshold level for deterministic effects and the second is to keep the risk of stochastic effects at a tolerable level. The stochastic effects occur at considerably lower doses and are therefore the basis for dose limitation. Ionising radiation doses for individuals shall not exceed the levels stipulated in **Table 3 &4.**

Table 3: Dose Limit

Classification	Dose Limit
Annual effective dose received from occupational exposure as a radiological worker	20 mSv/yr
Equivalent dose received from occupational exposure	
Eye lens	150 mSv in a year
Skin	500 mSv in a year
Hands and feet	500 mSv in a year
Declared pregnant radiological workers	1 mSv during entire term of pregnancy
Effective dose received by members of the Public	1 mSv/yr

Table 4: Dose Action Limits

Classification	Dose reference (mSv)	Action
Annual effective dose received from occupational exposure at any time of a calendar year	20 mSv/yr	Employer undertakes internal investigation (auditable by PDO, Contractor or Regulator)
Three (3) monthly average effective dose received from occupational exposure	5 mSv / 3 months	Managers shall be notified and precautionary action to be taken
Monthly effective dose received from occupational exposure	1.6 mSv/month	Managers shall be notified and take action to improve work condition

2.2 Dosimetry Control

During work, all radiological workers shall continuously wear a personal cumulative dosimetry (TLD or Film) badges sensitive to the type of ionising radiation to which they are exposed. Such badges shall be controlled by a recognised and competent dosimetry service, which shall provide the employer with reports on the dose received during the period of use of the badge and the cumulative annual and lifetime dose of the wearer.
Personal cumulative dosimetry badges shall be analysed monthly where the work environment is shown to expose workers to an average effective dose in excess of 1 mSv per year.
Any step out requirement on monitoring frequency shall be approved by the corporate Radiation advisor and in accordance *with Safety Guide No. RS-G-1.3, Assessment of Occupational Exposure Due to External Sources of Radiation.* For any work where the cumulative exposure is likely to exceed 100 µSv in one day, radiological workers conducting the work shall carry, in addition to the cumulative dosimeter badge (TLD or Film), a personal cumulative audible alarming dose rate meter, which shall be controlled and reset after each work period. The readings for each day shall be recorded and kept on file.

2.3 Work Area Classification and Entry Restriction

Principles of area classification shall be in accordance with Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards, *IAEA General Safety Requirements Part 3*

Controlled Areas: An area where immediate dose rate can exceed 7.5 µSv/h (0.75mrem/h). Controlled areas shall be physically demarcated by means of a physical barrier with appropriate warning signs. Only classified radiation worker shall enter into a controlled area, unless the work is assessed and can be performed safely.

Supervised Areas: An area where the immediate dose rates exceed 2.5 µSv / h (0.25mrem/h) but not exceeding 7.5 µSv/h (0.75mrem/h). Entry into supervised areas may be permitted to non-classified workers in the work is assessed and can be performed safely.

3 Training

MD 249/97 requires that all classified radiological workers and drivers of radioactive sources must be adequately trained for the job to which they are assigned and include refresher training as a minimum every three years. This training shall be recorded and maintained in the HSE matrix.

Specific training to a recognised standard by the RPA or equivalent shall be given to all persons whose work involves the handling of unshielded sources and the operation of X-ray or neutron generators.

Radiological workers shall be fully acquainted with the requirements of this specification and should be fully aware of the potential hazards arising from the presence of radiation at the storage site, during transportation or at the work site. Such workers include, but are not limited to NDT radiographers (Gamma and X-ray), Multiphase, profiler instrument technicians and well logging engineers

4 Import

All imports of radioactive materials, shipping and permits shall be in accordance to *MD 281/2003 for the Control and Management of Radioactive Materials* .

5 Transport

PDO's HSE Specification – Road Transport SP2000 describes PDO's minimum requirements for managing road transport safety. It describes the minimum requirements for driver qualifications, vehicle standards, and Journey management including the route of delivery. It is the consignor's responsibility to comply with the transportation rules. Transportation, labelling, packing and storage of radioactive materials shall be in accordance with *MD 281/2003 for the Control and Management of Radioactive Materials* and *IAEA Regulation for the Safe Transport of Radioactive Material, 2012 Edition, No. SSR-6*

6 Radioactive Source Movement Control

Source owners shall track and maintain reports of source movements within the PDO Concession area and shall at any time be able to advise the Contract Holder, PDO Radiation Focal Point or Ministry officials of the source location. A Radioactive Source Consignment Note shall be completed for each movement of radioactive materials from Muscat to interior locations and return of sources moved from one interior storage location to another for use will also require completion of the Source Consignment Note e.g. Fahud to Yibal.

The following information shall be maintained:

- Contract Number working under and contractor/sub-contractor details
- MECA Permit Number
- Approved storage location
- Date of arrival on PDO site
- Source serial number, radionuclide(s),activity (Ci & Bq)
- Date of last wipe test and next due

7 Storage

Storage facilities for radioactive sources shall be in accordance to *MD 281/2003 for the Control and Management of Radioactive Materials*, approved by MECA and with a valid permit. The process of applying for new storage or renewal permit is detailed in the *SOP for Radioactive Storage Approval Process*

Additional Requirements for the Storage of Radioactive Sources

Permanent storage of radioactive sources shall comply with the following:

- Emergency contact details of the source owner and nominated person (RPS / SIC)
- The level of radiation at the exterior of the store shall not exceed 2.5 µSv when fully loaded with all assigned radioactive sources.
- At the perimeter of the security fence the radiation level shall not exceed 1µSv.
- Every radioactive source storage facility shall have a nominated supervisor. This person shall be a radiological worker and shall be responsible for managing the storage facility, including access control, and tracking the movements of sources into and out of the store.

- The storage facility supervisor shall also be responsible for keeping a log of all sources normally stored at the facility, including the source type and serial number, decay chart, a list of key holders and ensure valid permit is available.
- Contractors and sub-contractors shall not be permitted to store their radioactive sources within the store or pit of another contractor / sub-contractor unless MECA approval is granted

Radioactive materials used for well logging must remain in their shield in an exclusive store or "dog kennel" and shall be located in a designated area in clear view of the driller or logging engineer until being loaded. The container shall be locked, labelled and cordoned with barrier tape. Additional precautions such as securing to a pipe wracking should be considered. Preferably, the sources will be stored in a dedicated sea container whilst on-site.

8 Instruments

8.1 Portable Survey Meters

Portable exposure rate meters shall be provided suitable for the type of radiation used. They shall be light, robust and capable of being used in all-weather under arduous conditions. The exposure rate meter can be scaled in millirem (mR) per hour or micro Sieverts (µSv) or millisieverts (mSv) per hour; however, preference is given to SI units. Ordinary detectors that are suitable for X-rays, gamma rays and even beta particles must not be used to detect neutrons. In the event of an incident involving a neutron emitting source, to enable calculation of the permitted exposure time, a neutron survey meter shall accompany all neutron emitters e.g. Am/Be-241. Calibration of instruments shall be conducted by a qualified service provider every 12 months or as per the manufacture recommendation and include a test certificate from the date of the test. The employer is responsible for ensuring that sufficient numbers of meters are provided for the work to enable calibration servicing and repair to meters and increased workload.

Note: ***not all meters are intrinsically safe and may require a Hot Work permit in facilities or working around hydrocarbons***.

8.2 Audible Alarms (Bleepers)

Audible alarms are small light weight, designed to be carried in the top pocket of a coverall. They must be kept switched on during the entire period that the wearer may be exposed to high output sources. These shall be able to indicate the presence of radiation by an audible signal immediate warning of a high dose rate. They shall also be capable or emitting a recognizable signal at a dose rate of 100 µSv/h.

9 Practices involving sealed sources, radiation generators and tracers

9.1 General Requirements

The following requirements shall apply when using ionising radiation:

- No practice shall be adopted unless its introduction produces a positive net benefit.
- All exposures shall be kept As Low As Reasonably Achievable (ALARA), economic and social factors being taken into account.
- Individuals below the age of 18 years shall not be involved in radiological work.
- Any work utilising radioactive sources carried out on behalf of PDO, or within PDO's concession area shall be carried out under an approved Permit to Work System (PR-1172, Permit to Work Procedure).

The PtW shall include:

- Details and planning of the work (pre-inspection is recommended)
- Completed Job HSE Plan i.e. a written risk assessment
- Radiation protection arrangements i.e. control
- Emergency and recovery provisions in the event of an incident
- The *radiography certificate* for NDT work
- A sketch of the controlled area is required for NDT work
- An atmospheric test using a multigas detector shall be conducted as per the PtW requirements for entrance into a confined space in case of entering the pipe to retrieve the crawler

In addition, a number of simple methods are to be employed and shall be covered in general radiation protection training and site-specific briefs to employees as follows:

- Minimising **time** spent in the vicinity of the source of radiation or in areas where radiation levels are higher;
- Maximizing **distance** from the source;
- Use of **shielding** where reasonably practicable.
- Dose sharing is not to be used as a primary means of restricting exposure to individuals. Rather, priority is to be given to improving engineering controls and other means of restricting exposure, including changing the methods of work.

9.2 Industrial radiography applications

9.2.1 Gamma sources

The use of Gamma sources in PDO shall be in accordance with *IAEA Radiation Safety in Industrial Radiography - Specific Safety Guide No. SSG-11*. The sources in use shall not exceed the strengths stipulated in **Table5** for any PDO job without written approval from the PDO quality team and the Corporate Radiation Focal Point. In the event of heavy wall thickness where there is no other alternate NDT method such Advance Ultrasonic Testing (AUT), the Contract Holder or Project/construction manager shall submit a *step out request* including a risk assessment and any additional controls for approval prior to source mobilisation to site.

Table 5: Gamma sources and strength

Isotope	Half life	Optimum steel thickness of object material in (mm)	Maximum Strength (Ci) allowed in PDO
Selenium (Se) 75	120 days	4-28	70
Iridium (Ir)192	74 days	10-70	40
***Cobalt (Co) 60**	5.3 years	50-150	10

Shall be approved by the quality team and Corporate Radiation Focal Point prior to site mobilisation
***All Co 60 jobs shall be performed in approved enclosure/ banker**

Local rules

- Radiation workers shall have sufficient time to plan the work and conduct a site visit (Emergency work shall give sufficient time for planning)
- All operations involving the use of ionising radiation shall be carried out by a minimum of two qualified radiological workers. Radiography crews (RT and X-ray) shall consist of two ASNT level II radiographers, one of which must be competent Radiation Protection Supervisor appointed by the RPA and contractor management. An ASNT Level I radiographer may assist the Level II provided the latter has RPS qualifications.

9.2.2 Crawlers and X-ray Equipment

X-ray equipment shall not be left unattended in a condition where it may be operated and shall be provided with a lock on the main circuit. If the equipment is left on site for a short period, the electricity supply should be disconnected and the equipment left locked. For a longer period, the equipment should be transported to the dedicated lockable storage room to prevent unauthorised use and shall not be stored with other radiography equipment. Only authorised radiological workers shall keep keys.

The register of X-Ray equipment must contain the:

- Mark and type of equipment
- Maximum tube voltage of the equipment
- Location where the equipment is in use
- Dates and results of inspection measurements of X-ray equipment.

The radiation safety manual shall contain the drawings and maintenance procedures for X-ray equipment for both crawlers and external X-ray equipment as used by the contractor. Where radiography is not conducted in a shielded enclosure, cable lengths shall be no less than 20 m for x-ray generators up to 300 kV and longer for equipment with higher tube potentials. All metallic items including casings, interconnecting cables, power supply unit (transformer/generator), X-ray control equipment, tube assembly, warning signals, other safety devices and the irradiated object are bonded together and grounded (connected to earth). Advice on electrical matters, as well as inspection and testing, should be provided by a qualified expert.

9.2.3 Design and Use of Shielded Enclosures (Fixed Facilities)

For permanent radiography locations e.g. workshops and major projects with site spool fabrication, it is strongly recommended that a purpose built enclosure to be constructed to enable radiography (gamma and x-ray) be performed safely outside of the contractors workshop without interruption. A properly designed and operated shielded enclosure will help keep radiation exposures of radiographers to ALARP. In other cases, local shielding is to be used as far as reasonably practicable. The general design is similar for all enclosures, although different characteristics are incorporated depending on whether the enclosure is to be suitable for X-ray, accelerators or gamma radiation equipment. Designs to shielded enclosures require guidance in terms of anticipated doses, dose rates and exposure times. Design considerations for these installations include: (a) shielding considerations, (b) personnel access door interlocks, (c) fixed radiation monitors, (d) warning signs and symbols and (e) emergency stops.

9.3 Fixed Gauges or Profilers applications

Radiation source owners and applicants for fixed gauges or profilers to be installed in PDO facilities shall ensure the following:

- All work is conducted safely, in adherence to the conditions of the license, and with resultant exposures to personnel to as low as reasonably practicable (ALARP)
- Perform, or cause to be performed (e.g., by manufacturer, consultant, or qualified employee), appropriate surveys, using operable and, calibrated instruments.
- Perform leak tests on time.
- Establish and maintain record systems for leak tests, shutter tests, surveys, receipt, inventory and use records, and (if personnel dosimetry is required) for personnel dosimetry reports.
- Provide a personnel dosimetry program when required. Advise individual radiation workers of each high exposure report, and conduct an investigation to determine the cause of all overexposures to preclude a reoccurrence. Perform a quarterly review of occupational exposure to authorized users and workers to determine that the exposures are within the limits established by the ALARP program. Annually advise each user of their accrued dose.
- Maintain a current inventory of the types, quantities, and locations of all radioactive material possessed, making sure the activity and types possessed never exceed license limits.
- Make sure radioactive shipments are properly packaged and labelled according to IATA requirements and that shipment are accompanied by proper shipping documents.
- Instruct workers, who work or may work in or about the vicinity of the fixed gauge or gauges, of all applicable radiation safety rules and procedures 1) initially, 2) with every addition of new personnel, and 3) with each change in the radiation safety program.
- Apprise management of the status of the radiation safety program and management's responsibility for maintaining an adequate radiation safety program.
- Take charge in all emergencies (loss, theft, fire, explosion, etc.) to make sure correct emergency procedures are carried out, including notification. Also, evaluate the situation that led to the emergency to reduce the chance of further problems.
- Assure that radioactive materials are only used by, or under the supervision of individuals authorized by the license.
- Assure that radioactive materials are properly secured against unauthorized removal.
- Maintain current operating and emergency procedures, including maintenance and procedures for work in and around fixed gauges.

9.4 Well logging applications

Well Engineering requirements for managing risks associated with transporting, storing and using radioactive sources in the drilling rig activities of PDO and Contractor staff (particularly well logging) are described in *PDO SP-1218 Well Engineering Specification for Radioactive Sources.*

In the event of a lost in hole (LIH) radioactive source, the ultimate decision to abandon a radioactive material rests with the Asset Manager after consultation with the Senior Well Engineer and Corporate Radiation and Environment Focal Points. Abandonment of radioactive materials down hole shall be performed in accordance with HSE Well Engineering Specification for Radioactive Sources Specification SP-1218.

The abandonment of the radioactive material shall be reported to the authorities via the environmental advisor, who shall provide advice about the information required. A letter by the Asset Owner, accompanied by the completed “Abandoned Source Template”, shall be sent to the Ministry for Environment and Climate Affairs (MECA). The management and reporting of stuck and lost radioactive sources is detailed in the Standard Operation Procedure *(SOP) for radioactive source incident reporting and management.*

9.5 Unsealed Radioactive Material and Tracers

Radiotracers are used during completion, stimulation and recovery enhancements to determine that procedures have been carried out satisfactorily. Some examples of radiotracers include but not limited to Scandium 46 (Sc-46), Antimony 124 (Sb-124) or Iridium 192 (Ir-192).

- Tracer work creates radioactive waste that must be stored and disposed of in accordance with the requirements of the regulatory body.
- The service companies must maintain inventories of all radioactive materials received, used, stored, decayed and disposed of.
- All radioactive material declared, as waste must be managed in accordance with the requirements of the regulatory body.

10 Medical Control

Pre-employment medical examinations of all radiological workers shall include, in addition to the standard Visa requirements a detailed medical examination in accordance with SP-1230 "Medical Examination, Treatment and Facilities" It is now accepted that medical surveillance of radiation workers should follow the same general principles of occupational medicine as applied to other groups of workers.
In most cases, the actual exposure to Ionising Radiation is small that it will have little influence on decisions regarding medical suitability for employment.

The requirements for adequate medical surveillance comprise of;

- A pre-employment medical examination before first being designated as a classified radiological worker;
- A complete occupational history, including all previous exposures to ionising radiation and a review of the previous exposure (TLD/Film) records;
- An assessment whether the radiation is electrically generated or from sealed or unsealed radioactive materials and Type (alpha/beta/gamma/neutrons/X-rays)
- Special medical surveillance of an employee when a relevant dose limit has been exceeded (based on advice from the RPA);
- Any test specifically recommended for radiological workers by PDO's Medical Officer or Company approved physician
- A review of health after cessation of work where this is necessary to safeguard the health of the individual

All radiological workers shall undergo an annual medical examination at the employer’s expense in a PDO approved clinic. The employer shall provide the examining medical practitioner with the worker's occupational dose history since the previous medical examination. Women of child reproductive capacity should receive advice about the risks to the fetus and nursing infant arising from exposure to ionising radiation and the need to notify the employer in writing and immediately if they become pregnant.

11 Emergency Response

The emergency equipment has to be obtained to adequately respond to an emergency. It is suggested that the following minimum resources be made available by the operating organization

11.1 Radiation survey instruments

- Long range high level gamma survey instrument measuring dose rates up to several Sieverts per hour (teletector)
- Low range survey instrument
- Contamination monitor or probe in
- Self-reading dosimeters for each team member

11.2 Communication equipment

Portable radio communications

11.3 Supplies

- shielded container (old source shield or source transfer shield)
- Appropriate shielding (sufficient to attenuate the radiation significantly, for example, at least two bags of lead shot, i.e. 2 kg each for 192Ir and 10 kg each for 60Co
- Tongs at least 1.5 m long, suitable for safely handling the source assembly
- appropriate hand tools (e.g. Long-handled pliers / Cutter, angle wrenches)
- extra radiation warning labels and signage
- metal tray (could be lead, aluminum, steel)
- log book, rope, and stop watch
- plastic for preventing contamination of instruments

11.4 Supporting documentation

- Equipment operations manuals
- Response co-ordination procedures
- Procedures for conducting monitoring
- Procedures for personal radiation protection

The following occurrences shall be reported to MECA and PDO in accordance with *GU 612 - Incident Investigation and Reporting Guideline* by the Project Manager, Contract Holder or Main Contractor in the case of sub-contractors.

- Any loss of radioactive material (including temporary loss or stuck logging tools).
- Loss or theft of a source of ionising radiation
- Vehicular accident involving transport of sources of ionising radiation
- Accidental separation of a source from its shielding
- Physical damage to a sealed source, causing leakage of radioactive material
- Contamination of the environment with radioactive material
- If any worker receives exposures greater than the allowable occupational exposure limit

Formal Contingency Plans shall be prepared to respond to any emergency that might arise from the storage and handling radioactive materials including incidents outlined above. Written emergency procedures shall be documented in the Radiation Safety Manual of the contractor and shall align with PDO's emergency response and preparedness and IAEA Response for Radiological Emergency General Safety Requirement *GSR Part 3.*
Contractors shall have planned emergency mock drills to demonstrate that radiological workers and others such as the ROP, first aid responders or fire and emergency crews have sufficient experience and confidence to handle emergencies.

12 Disposal

Waste shall be classified as radioactive waste material if its activity is higher than 100 Bq/g.
Radioactive waste differs from all other types of waste. Its radioactivity decreases only with time, and its radioactive properties cannot be altered or destroyed by any physical, chemical or biological treatment.
Sealed sources and tracer applications account for most of the industrial use of radioactive substances. There is almost no waste disposal required in the use of sealed sources, except for disposal of the source upon decay of its radioactivity to levels at which it can no longer be used. Damage to the sealed source may result in radioactive waste in the form of contaminated equipment, packing, clothing and other accessories.
Radioactive waste material shall be classified as hazardous waste, and shall be handled and disposed of in accordance with the requirements of SP-1009 “Waste Management" and MD249/97.
The owner or custodian of the source shall maintain records to demonstrate safe return and disposal of the radioactive source once beyond the effective use of the source or contract expiry. No sources shall remain in the PDO location beyond the completion of an existing contract with PDO. The Project Manager, Contract Holder or nominated Company Site Representative is responsible for ensuring all sources are removed and properly disposed.

References

International Atomic Energy Authority (IAEA) Safety Series TS-R-1 Regulations for the Safe Transportation of Radioactive Materials 2009

International Atomic Energy Authority (IAEA) Safety Glossary Terminology Used in Nuclear Safety and Radiation Protection 2018 Edition

Ministry of Environment and Climate Affairs MD249/97 and Supplement 2003

Ministry of Manpower Occupational Health and Safety Regulations in the Private Sector 286/2008

PDO GU612 – HSE Guideline Incident Investigation and Reporting

PDO PR1712 - Permit to Work System Manual

PDO SP1218 - Well Engineering Specification for Radioactive Sources