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TRAINING COURSE SERIES

No. 85

Syllabus for the Training of Radiation Protection Officers

Industrial Radiography

SYLLABUS FOR THE TRAINING OF RADIATION PROTECTION OFFICERS

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TRAINING COURSE SERIES No. 85

SYLLABUS FOR THE TRAINING OF RADIATION PROTECTION OFFICERS

INDUSTRIAL RADIOGRAPHY

INTERNATIONAL ATOMIC ENERGY AGENCY
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FOREWORD

This publication has been developed to support training providers in Member States as they design, develop, implement and evaluate training courses for radiation protection officers designated to oversee the safety of industrial radiography sources.

A radiation protection officer is designated by the authorized party to oversee the implementation of its radiation protection programme, a requirement that is rooted in IAEA Safety Standards Series Nos GSR Part 3, Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards, and GSG-7, Occupational Radiation Protection. Many of the duties of the radiation protection officer will be consistent across all Member States, however the practical implementation of those duties will depend on the national arrangements for radiation safety.

Given the very significant number of industrial radiography operators worldwide, it is neither feasible nor sustainable for the IAEA to offer radiation protection officer training directly to operators. However, Member States have, through the IAEA's Steering Committee on Education and Training in Radiation, Transport and Waste Safety and several General Conference resolutions, requested the publication of syllabi for training radiation protection officers for a range of industrial and medical facilities, with the overall objective of supporting Member States as they build their national capacity for education and training.

Within the series of radiation protection officer syllabi, the syllabus for training radiation protection officers in industrial radiography is considered a priority because of the potential for accidents resulting in deterministic effects, and the essential role of the radiation protection officer in maintaining radiation safety, especially when the radiography is undertaken remotely. The syllabi will be supported by and promoted through train the trainer events that are available through the IAEA for individuals who have the appropriate technical knowledge to provide radiation protection officer training in their countries, and who are designated to do so.

The IAEA officers responsible for this publication were A. Cristobal and E. Grindrod of the Division of Radiation, Transport and Waste Safety.

CONTENTS

1. INTRODUCTION

1.1. BACKGROUND

The IAEA has a statutory function to establish standards for the protection of health, life and property against ionizing radiation and to provide for the application of those standards through, inter alia, education and training. IAEA offers a range of activities to support Member States in building competence in radiation, transport and waste safety. These education and training activities are undertaken in line with the resolutions of the General Conference and on the basis of the principles provided in the Strategic Approach to Education and Training in Radiation, Transport and Waste Safety (2021–2030), as approved by the Steering Committee for Education and Training in Radiation Protection and Waste Safety established in 2002.

Paragraph 3.94(e), of IAEA Safety Standards Series No. GSR Part 3, Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards [1], states that "Employers, registrants and licensees, in consultation with workers, or through their representatives where appropriate … [s]hall designate, as appropriate, a radiation protection officer in accordance with criteria established by the regulatory body".

The radiation protection officer (RPO) is defined in GSR Part 3 [1] as "A person technically competent in radiation protection matters relevant for a given type of practice who is designated by the registrant, licensee or employer to oversee the application of regulatory requirements." Requirement 4 of GSR Part 3 [1] states that "**The person or organization responsible for facilities and activities that give rise to radiation risks shall have the prime responsibility for protection and safety.**" While that primary responsibility cannot be delegated, para. 3.66 of IAEA Safety Standards Series No. GSG-7, Occupational Radiation Protection [2] states that "A radiation protection officer should be appointed, when required by the regulatory body, to oversee the application of the relevant regulatory requirements and compliance."

1.2. OBJECTIVE

The objective of this publication is to describe a framework within which training providers can design, develop, implement and evaluate training courses for RPOs designated in relation to industrial radiography. The approach described in this publication is in line with the systematic approach to training, which is described in Safety Reports Series No. 20, Training in Radiation Protection and the Safe Use of Radiation Sources [3].

1.3. SCOPE

In line with the scope of IAEA Safety Standards Series No. SSG-11, Radiation Safety in Industrial Radiography [4], in this syllabus, the term 'industrial radiography' means work that utilizes ionizing radiation for non-destructive testing of objects, either in fixed, shielded enclosures fitted with effective engineered controls (including cabinets) or outside of shielded enclosures (i.e. site radiography[1]). Radiation protection and safety aspects of industrial radiography using computed tomography, real time radiography[2] flash X ray and pulsed X ray are also considered. The term 'radiation generator' includes conventional X ray generators as well as accelerators such as linear

[1] Paragraph 11.1 of SSG-11 [4] states that "When objects to be radiographed cannot be physically moved into a shielded enclosure, the work should be carried out under 'site radiography' conditions. This method of radiography is very common, but it is potentially hazardous because of the absence of engineered safety measures.".

[2] Real time radiography is sometimes referred to as 'fluoroscopy'.

accelerators, betatrons and cyclotrons. The terminology used in this publication is consistent with the definitions given in the IAEA Nuclear Safety and Security Glossary [5].

Underwater radiography and neutron radiography are relatively rare and present some unique radiation protection challenges. While this syllabus does not consider those techniques, it may be a useful basis upon which, with some modifications, a specific syllabus to address the needs of those audiences can be built. The use of radiation for the purpose of inspecting objects such as baggage, cargo and vehicles for security purposes is not within the scope of this publication.

The requirement for the training of workers, including RPOs, is established in para. 3.76 of GSR Part 3 [1], which states:

> "Employers, registrants and licensees shall ensure, for all workers engaged in activities in which they are or could be subject to occupational exposure, that:
>
> …….
>
> (h) Suitable and adequate human resources and appropriate training in protection and safety are provided, as well as periodic retraining as required to ensure the necessary level of competence".

While the responsibility for ensuring that workers receive appropriate training lies with authorized parties[3], such training is often delivered by external training providers. The primary target audience for this publication are training providers i.e. organizations that provide training for RPOs working in industrial radiography. This publication may also be of interest to individual trainers, employers, RPOs, regulators and technical service providers.

Techniques for capturing industrial radiography images are not covered in this publication. Other IAEA publications such as IAEA-TECDOC-628, Training Guidelines in Non-destructive Testing Techniques [6] or IAEA-TECDOC-1931, An Introduction to Practical Industrial Tomography Techniques for Non-destructive Testing (NDT) [7], deal with the techniques and technological aspects of industrial radiography.

1.4. STRUCTURE

Section 2 provides an overview of the syllabus and how it is structured; the overall outcomes of a course based on this syllabus; the relevance of the learning objectives and how exercises can be used to help training providers achieve some of the learning objectives. Section 3 explains how the syllabus can be used to design, develop, implement and evaluate a course, including the assessment of participants. It considers how the syllabus can be customized and the resources needed to organize a course that is based on this syllabus. Section 4 contains the detailed syllabus, arranged under 12 topics.

[3] 'Authorized party' in this context refers to the registrant or licensee, as appropriate.

2. OVERVIEW OF THE SYLLABUS

This publication describes the syllabus for training RPOs who will be overseeing compliance with the relevant regulatory requirements applicable to industrial radiography. In organizations that carry out industrial radiography, the RPO(s) may be industrial radiographers who already have some knowledge and experience of radiation protection and safety. Nevertheless, this syllabus is provided on the basis that course participants do not have any previous knowledge or experience of radiation protection and safety.

The content of this syllabus is based on the requirements of IAEA's safety standards, however, for some topics, training providers will need to expand the content to reflect the national legal and regulatory requirements and how these requirements are implemented in practice. For example in topic 9, training providers may need to include a description of the national arrangements for applying for authorization, and in topic 10 they may need to include a description of the arrangements for transferring disused sources to an authorized facility.

The expected outcomes of a course that is based on this syllabus are that participants will:

— Have a basic understanding of the concepts of ionizing radiation and how it can affect human health, specifically, the risk to health due to radiation exposure from routine work and reasonably foreseeable accidents;
— Have a basic understanding of the fundamental principles of radiation protection and safety;
— Be able to apply proportionate and appropriate precautions during routine industrial radiography and understand the extent to which those precautions can restrict exposures;
— Be able to apply proportionate and appropriate measures in relation to accidents in industrial radiography and understand the extent to which those measures can restrict exposures;
— Have a clear understanding of the relevant requirements of the IAEA safety standards relating to radiation protection and safety in industrial radiography and the relevant national regulations;
— Be able to apply the principles of radiation protection when overseeing the day to day implementation of the radiation protection programme[4] and to carry out the duties of the RPO in relation to industrial radiography, as required by the national regulatory body.

2.1. TOPICS, CONTENT AND LEARNING OBJECTIVES

The syllabus, which is presented in Section 4, is set out in 12 separate topics:

Topic 1: Introduction to the concept of the RPO;
Topic 2: Basic concepts of ionizing radiation;
Topic 3: Quantities and units;
Topic 4: Radiation sources, facilities and equipment used in industrial radiography;
Topic 5: Health effects of ionizing radiation;
Topic 6: Principles of radiation protection;
Topic 7: Control measures and dose reduction techniques;
Topic 8: Framework for radiation protection and safety;
Topic 9: General responsibilities of employers and authorized parties;
Topic 10: Radiation protection programme;

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[4] Radiation protection programme is defined in the IAEA Nuclear Safety and Security Glossary [5] as: "Systematic arrangements that are aimed at providing adequate consideration of radiation protection measures."

Topic 11: Transport safety;
Topic 12: Emergency preparedness and response.

For each topic, the content is accompanied by a number of specific learning objectives. These learning objectives indicate the level of cognitive achievement that training participants might reasonably be expected to achieve on completion of the training. The learning objectives align with one of the five levels of achievement in the cognitive domain, as described in the 2001 revision of Bloom's Taxonomy[5] [8].

Several resources suggest that, when expressing learning objectives, the use of certain verbs indicates participants' expected achievement, as categorised by Bloom [8]. The verbs used in the learning objectives in this publication are intended to align with Bloom's Taxonomy for the cognitive domain as shown in figure 1.

The verbs *to list, to state, to recognize* and *to identify* indicate that participants are expected to remember the content.

The verbs *to explain, to describe, to summarize, to compare* and *to oversee* indicate that participants are expected to understand the content.

The verbs *to use, to demonstrate, to set, to undertake* and *to complete* indicate that participants are expected to be able to apply the content.

The verbs *to verify, to calculate, to convert, to interpret, to select* and *to justify* indicate that participants are expected to be able to evaluate the content.

The verbs *to establish* and *to make* indicate that participants are expected to be able to create the relevant items.

FIG. 1. Relationship between the verbs used in the learning objectives and the expected level of achievement.

2.2. EXERCISES

Exercises introduce an element of 'active learning' into a course and provide participants with an opportunity to apply what has been taught. Exercises are an effective way to reinforce learning and encourage participants to engage with a course, and they can indicate to the trainer whether the material that has been taught through didactic methods has been understood by the participants. Exercises are particularly effective when they are clearly associated with one or more of the stated learning objectives.

Various exercises are suggested in association with many of the topics in Section 4. These suggestions are indicative, and it is understood that training providers will need to adapt these or create new

[5] 'Bloom's Taxonomy hierarchical ordering of cognitive skills' can be of help for trainers and participants. The cognitive domain references the development of intellectual skills.

exercises taking into account the facilities and equipment they have available. The types of exercises suggested in the syllabus are:

— *Demonstrations:* A trainer shows the participants something while the participants observe. Demonstrations may be a good solution if participants cannot undertake an exercise themselves, for example due to safety concerns or where participants need to watch someone complete a task before undertaking it for themselves. Examples in the syllabus are a demonstration of the types and properties of spontaneous radiations and a demonstration of gamma radiography containers, wind-out gear, guide tubes and collimators.
— *Practical work:* Participants are asked to undertake a task by themselves or in groups. By doing so, the participants discover certain concepts in a practical setting and/or practise specific skills. Examples in the syllabus include workplace monitoring and the recovery of a dummy gamma radiography source. Section 5.2.4 of Ref. [3] provides guidance on the use of radiation sources in a training event:

> "If radiation sources are to be used in exercises, care needs to be taken to ensure that the doses to participants are controlled and kept as low as reasonably achievable. Regulations may require that doses to participants be monitored and dose records kept. It is suggested that the participants receive written instructions on the procedures to be followed for radiation protection, and personal dosimeters should be provided when appropriate. In some cases, it may be preferable to use simulated radiation sources. As an introduction to a laboratory exercise or simulation, a demonstration of the correct procedures and operations will assist in controlling doses by avoiding unnecessary exposure and will prevent any damage to equipment."

  Practical work for RPOs in industrial radiography will normally use simulators[6] or very low activity sources to ensure the optimization of protection and safety.
— *Desktop exercises:* Participants, normally working in small groups, are asked to address a specific question or a series of questions. They could be asked, for example, to estimate the dose or dose rate under a given set of circumstances, to review an accident case history and comment on the actions taken by the various parties, to create documents, such as a procedure for monitoring radiation levels around a facility, to consider safety related implications of changing from X ray to gamma radiography, or to identify actions to take in an emergency. Desktop exercises are a particularly effective way for trainers to find out how well the material taught through didactic methods has been understood by the participants.
— *Site visits:* Participants visit a facility with an expert who describes and demonstrates the radiation protection safety features and warning devices. Site visits are an effective way to introduce participants to a facility and show them how a radiation protection programme is applied in practice. For example, on a visit to a shielded industrial radiography enclosure, participants will be able to see the installed safety features and discuss the radiation protection programme with the expert.

[6] 'Simulators' in this context refers to devices that use any technology other than ionizing radiation to simulate the emission and detection of X rays and gamma radiation. Some commercially available systems use simulated detectors that look like popular radiation monitors and include the same operating menu.

3. IMPLEMENTING THE SYLLABUS

Detailed advice on designing, developing, implementing and evaluating training in protection and safety is provided in Ref. [3]. Further specific information related to training courses for RPOs in industrial radiography is given in this Section.

3.1. DESIGNING A COURSE FOR RADIATION PROTECTION OFFICERS

The aim of a training course based on this syllabus is to develop the necessary competences of the RPO in relation to all types of industrial radiography, as described in Section 1.3. The RPO oversees the implementation of the requirements for protection and safety and so supports the employer in achieving the optimization of protection and safety. A training course that is based on this syllabus will therefore contribute to the protection of workers and the public from the effects of exposure to X rays or gamma radiation used in industrial radiography.

To ensure clarity for employers, trainers and course participants, the training provider will need to specify the target audience for each course in terms of:

- Any assumed prior knowledge or experience;
- The types of industrial radiography facilities and activities considered on the course;
- The national laws or regulations that are addressed on the course.

Courses may sometimes be established for RPOs who will oversee radiography in just one type of modality (e.g. cabinet radiography, radiography in a shielded enclosure fitted with effective engineered controls, site radiography) or for RPOs who will supervise industrial radiography using only one type of radiation (e.g. X rays or gamma radiation). In these cases, some elements of the syllabus might not be relevant. For example, if the target audience is RPOs who will only work with X rays, the requirements for the safe transport of radioactive sources, leak testing and source accountancy could be excluded from the course programme. Any such criteria will need to be clearly specified in the scope of the training and stated in any certificate that might be issued on completion of the training.

In some topics, the syllabus content will need to be expanded to include the requirements under applicable national regulations. One such example is topic 9 (general responsibilities of employers and authorized parties), which has a learning objective to ‘describe the notification and authorization processes’; trainers might need to describe the generic requirements and recommendations on notification and authorization in the IAEA safety standards, as well as the specific national requirements for notification and authorization in order to meet the learning objective.

For those topics where it may be necessary to add further content to cover the national requirements, a comment is included in the text in Section 4.

The topics are designed to be delivered in the sequence in which they are presented. An approximate duration for each topic is given in the text above each table in Section 4, however the exact duration of each training course will normally be decided by the training provider based on several factors, including:

— National regulatory requirements and guidance;
— The previous experience of participants;
— The specific type or types of radiography the participants are expected to oversee;
— The number of exercises that are incorporated into the programme;
— Whether the training is being delivered in the mother tongue of the participants.

The duration of a course covering all modalities of industrial radiography for participants with no previous knowledge or experience is likely to be between five and ten days.

3.2. DEVELOPING A COURSE

Training providers will need to pay close attention to the content and learning objectives when developing a training course. Topics with less content, lower order learning objectives, (see Fig. 1) or no exercises, for example topic 6 (principles of radiation protection) can be directly transferred into a programme, as discrete lectures with the same name, content and learning objectives. However, topics with a lot of content and many exercises, for example, topic 7 (control measures and dose reduction techniques) and topic 10 (radiation protection programme) are likely to need several training sessions and exercises to ensure the learning objectives are met. Topics with higher order learning objectives will need a range of different teaching methods to ensure the learning objectives are fully met.

Any training materials that are developed by the IAEA to support RPO training will be made available through IAEA's Occupational Radiation Protection Networks (ORPNET)[7].

3.3. IMPLEMENTING A COURSE

The criteria for selecting individuals to deliver radiation safety training are addressed in Ref. [3].

Trainers who train RPOs working in industrial radiography will have a broad knowledge of industrial radiography techniques, practical experience of the types of facilities that the participants will be overseeing, and a sound knowledge of radiation protection and safety and the related national and international requirements. Trainers who have the necessary technical knowledge and experience can develop appropriate didactic skills for teaching adult learners, through train the trainer events, such as those run by IAEA.

Courses for RPOs in industrial radiography are sometimes delivered by several trainers, with each trainer delivering discrete training sessions. In these cases, all trainers will need to be familiar with the content and learning objectives of the full programme. It is good practice for trainers to liaise with each other to ensure all aspects of the course are adequately covered and that the training sessions complement each other.

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[7] www.iaea.org/services/networks/orpnet

To ensure the learning objectives are achieved, training providers are expected to have access to, as appropriate:

- A well designed, shielded enclosure fitted with effective engineered controls and X ray and/or gamma ray sources;
- Portable pre-exposure and exposure warning devices, barrier tape, warning signs and an area that can be set up for site radiography;
- Portable source containers, guide tubes, wind-out cables and collimators;
- Non-radioactive (dummy) sources, sometimes known as ‘pigtails’ (see SSG-11 [4]) and photographs or videos of gamma radiography sources (see Section 2.2);
- Calibrated radiation monitoring devices (e.g. dose or dose rate meters, contamination monitors as appropriate) with valid calibration certificates;
- Electronic personal dosemeters (EPDs) and passive individual monitors (e.g. thermoluminescent dosimeter (TLD), optically stimulated luminescence (OSL), radiophotoluminescence (RPL) dosimeter, direct ion storage (DIS) dosimeter);
- Transport containers, vehicle placards and Category I, Category II and Category III labels;
- Equipment for dealing with a radiation emergency in industrial gamma radiography.

3.4. EVALUATING A COURSE

The full evaluation of any training will normally take into account the results of an assessment of participants’ competence, their immediate feedback, an evaluation of the impact of the training and the results of independent audits [3]. Evaluation of the impact of the training and independent audits are not conducted within the course programme and so they are not discussed further in this publication.

In order to implement improvements to a course, training providers can consider participant feedback and the results of assessments. This may help to ensure the training they deliver is of high quality, thereby contributing to high standards of radiation protection and safety. Ultimately, the beneficiaries are the radiographers, other workers and the public.

A formal assessment of the participants, conducted on completion of the course, can:

- Provide feedback to participants on their performance;
- Help employers determine whether an individual is suitable to take on the role of the RPO;
- Indicate to regulatory bodies whether an RPO has passed the course and has therefore accepted the training in accordance with para. 3.83(f) of GSR Part 3 [1];
- Indicate to the training provider whether the learning objectives were met.

The learning objectives of this syllabus describe the specific, expected outcomes of a training course; they are focused on what the participants are expected to know, to do or to apply on completion of the training. It is therefore appropriate to create an assessment that tests whether the learning objectives have been met. The learning objectives are written so that they can readily be turned into assessment questions. For example, in topic 7, the learning objective that participants can ‘calculate the dose rate at 1 m from a gamma radiography source based on the gamma ray constant and the activity of the source’ (see Section 4.7) can be tested by asking participants to calculate the dose rate at 1 m from various gamma sources used for industrial radiography, based on the known activity of the source and the relevant gamma ray constant.

Lower order learning objectives (see Fig. 1), i.e. those where participants are expected to know or understand the content, can normally be tested with carefully written 'true/false' or multiple choice questions.

The higher order learning objectives, i.e. those where participants are expected to apply or evaluate the content or create something new, can normally be tested by asking participants to generate their own solution to a problem, for example by calculating the distance to the controlled area barrier or describing how to safely manage an emergency. These questions, especially open questions, can sometimes test several learning objectives at the same time.

In most cases, it will be impracticable to test all the learning objectives of each topic on a single course. Training providers will need to prioritize the most important learning objectives or build a library of suitable questions and select (randomly or otherwise) questions each time they run an assessment.

Written feedback from participants and from trainers about their experience on the course is also appropriate at the end of the course, normally after the assessment. The primary aim of this feedback is to alert the training provider to issues such as:

— Whether the didactic methods employed by the teaching staff could be improved and, if so, how;
— Whether the structure and content of the programme, including exercises, could be improved.

4. THE SYLLABUS

In this section, the content and learning objectives for each topic are set out in a series of tables. For each topic, some preceding text is provided, including relevant paragraphs from the safety standards, and references to other relevant resources. The text describes how exercises (see Section 2.2) can support the achievement of the learning objectives; indicates the extent to which the course content should be customized; suggests the time that may be needed to deliver the topic; and highlights where topics are interrelated.

The content, which is listed in the first column of the relevant table, reflects what the trainer is expected to include in the training. Trainers can refer to this column to help them structure the training session, and they may choose to use it as a checklist to ensure that all the relevant content is covered.

The learning objectives, listed in the second column of each table, indicate the expected endpoint of the training, that is, what participants are expected to remember, understand, apply, evaluate and/or create on completion of a course that is based on this syllabus, (see Section 2.1).

4.1. TOPIC 1: INTRODUCTION TO THE CONCEPT OF THE RADIATION PROTECTION OFFICER

This topic illustrates how the designation of a competent RPO can support the authorized party in implementing and maintaining a safe working environment. This topic provides a general overview of the role of the RPO in industrial radiography and introduces the relevant interested parties.

At the start of a training course, an overview of the typical occupational doses arising from industrial radiography might help to highlight the need to manage the routine exposure of workers and the public during industrial radiography. In addition, a description of one or more serious accident(s) in industrial radiography, including those where human error was a factor, is helpful in showing the potential for high radiation doses and the need for a strong safety culture in industrial radiography. Appropriate radiological accidents include those that happened in Yanango (Peru) [9], Gilan (Islamic Republic of Iran) [10], Cochabamba (Plurinational State of Bolivia) [11] and Chilca (Peru) [12].

The requirements of GSR Part 3 [1] that are relevant to this topic are:

> "**Requirement 4: Responsibilities for Protection and Safety**
>
> **The person or organization responsible for facilities and activities that give rise to radiation risks shall have the prime responsibility for protection and safety. Other parties shall have specified responsibilities for protection and safety.**
>
> …….
>
> "2.41 Other parties shall have specified responsibilities in relation to protection and safety. These other parties include:
>
> …….
>
> (b) Radiation protection officers".
>
> "**Requirement 24: Arrangements under the radiation protection programme**
>
> **Employers, registrants and licensees shall establish and maintain organizational, procedural and technical arrangements for the designation of controlled areas and supervised areas, for local rules and for monitoring of the workplace, in a radiation protection programme for occupational exposure.**
>
> …….
>
> 3.94. Employers, registrants and licensees, in consultation with workers, or through their representatives where appropriate:
>
> …….
>
> (e) Shall designate, as appropriate, a radiation protection officer in accordance with criteria established by the regulatory body."

If national regulations contain requirements for the designation of the RPO, then it is appropriate to include such arrangements (along with the above requirements of GSR Part 3 [1]) to ensure the learning objectives are fulfilled.

There is potential for overlap with the description of the accidents presented in this topic, in topic 5 (health effects of ionizing radiation) and topic 12 (emergency preparedness and response). Trainers are expected to liaise to ensure the topics complement each other effectively.

The content and learning objectives for topic 1 are given in Table 1. The suggested duration for this topic is one hour for the theoretical part and one hour for the exercise.

TABLE 1. CONTENT AND LEARNING OBJECTIVES OF TOPIC 1: INTRODUCTION TO THE CONCEPT OF THE RPO

Content	Learning objectives
RPO definition, role, responsibilities, designations and duties: - National requirements Role of other relevant interested parties: - Authorized parties, employers - Workers and supervisors - Qualified expert[a] in radiation protection - Regulators - Manufactures, suppliers, installers, technical service providers - First responders	To be able to: - Explain the role, responsibilities and duties of an RPO who is designated to oversee industrial radiography - Describe the difference between the roles of the RPO and the qualified expert - Explain the requirements for the designation of the RPO given in IAEA safety standards and, where appropriate, national regulations - Describe how the relevant interested parties interact to ensure regulatory compliance
Suggested exercise Desktop exercise on duties of the RPO and the qualified expert	

[a] A qualified expert is defined in GSR Part 3 [1] as "An individual who, by virtue of certification by appropriate boards or societies, professional license or academic qualifications and experience, is duly recognized as having expertise in a relevant field of specialization, e.g. medical physics, radiation protection, occupational health, fire safety, quality management or any relevant engineering or safety specialty."

4.2. TOPIC 2: BASIC CONCEPTS OF IONIZING RADIATION

The aim of this topic is to provide the participants with sufficient knowledge and understanding of the nature and origins of X rays and gamma radiation used in industrial radiography, so that topics 3 to 12 can be easily understood.

Trainers are expected to take care to use language that the participants will understand, and all new terms will need to be carefully defined. It will not normally be necessary to teach the scientific concepts in detail.

A demonstration of alpha, beta and gamma radiation and their properties, using a radiation detector and test sources, will help the participants to understand the properties of the three main types of radiation. If this cannot be demonstrated safely, a video could be used.

The full content and learning objectives for topic 2 are given in Table 2. The specific content of topic 2 will need to be tailored to the needs of the target audience, whether this is for RPOs supervising gamma radiography, X ray radiography or both. Nevertheless, the suggested duration for this full topic is two hours for the theoretical part and one hour for the exercises.

TABLE 2. CONTENT AND LEARNING OBJECTIVES OF TOPIC 2: BASIC CONCEPTS OF IONIZING RADIATION

Content	Learning objectives
Atomic and nuclear structure: - Protons, neutrons, electrons - Stable atoms, unstable atoms Radioactivity: - Isotopes, radioisotopes (nuclides, radionuclides) Radioactive decay: - Emitted energy (i.e. radiation) - Types and properties of alpha, beta, gamma and neutron radiation - Radioactive half-life Sealed sources: - Source construction - Categorization of sources Radioactive contamination X ray production: - Accelerating voltage, current and beam filtration - Bremsstrahlung effect and characteristic X rays - X ray spectrum Components of a generator Primary beam and scattered radiation	To be able to: - Describe the difference between ionizing and non-ionizing radiation - Explain the terms 'ionizing radiation' 'sealed source' and 'radioactive contamination' - Explain, in practical terms, the difference between radioactive sources and radiation generators - Describe the important features of gamma sources and X ray generators used in industrial radiography - Explain how the accelerating voltage, current and beam filtration affects the quality of the X ray beam generated - Explain for an X ray generator, in general terms, the relationship between applied voltage and radiation energy - Compare the penetrating powers of different types of radiation and of radiations of the same type but of different energies - Explain the categories of the radioactive sources used in industrial radiography - Explain the difference between the primary beam and scattered radiation
Suggested exercise Demonstration of the types and properties of spontaneous radiations including their penetrating power	

4.3. TOPIC 3: QUANTITIES AND UNITS

The aim of this topic is to familiarize participants with the relevant quantities and units used in the IAEA safety standards, national regulations and other official documents, so that they can use these quantities and units appropriately.

In this topic, it will be appropriate for trainers to explain the difference between:

- Physical quantities;
- Radiation protection quantities (i.e. quantities that describe the risk to health);
- Operational quantities (i.e. quantities that are measurable, using radiation detectors).

Trainers should be aware, however, that the effects of radiation on human health are not covered until topic 5.

A desktop exercise on the use of the different quantities, units and prefixes would support the achievement of the learning objectives. Such an exercise might ask participants to convert activity from curie to becquerel and then estimate the activity taking into account radioactive decay. Simple estimates of effective and equivalent dose using radiation and tissue weighting factors might also help participants to fully understand the concepts. Some training providers might choose to coordinate this exercise with that suggested for topic 7.

The full content and learning objectives s for topic 3 are given in Table 3. The content will need to be tailored to the interests of the audience. The suggested duration for the full topic is one hour for the theoretical part and one hour for the exercise.

TABLE 3. CONTENT AND LEARNING OBJECTIVES OF TOPIC 3: QUANTITIES AND UNITS

Content	Learning objectives
Definition of ‘quantity’ and ‘unit’ Relevant prefixes and abbreviations: T, G, M, k, m, μ Exposure pathways: - External - Internal Physical quantities and associated units: - Activity: becquerel, curie (Bq, Ci) - Radiation energy: (eV, keV, MeV) - Absorbed dose: gray (Gy) Radiation and tissue weighting factors Relative biological effectiveness (RBE): - RBE-weighted absorbed dose Radiation protection quantities and associated units: - Equivalent dose (extremities) sievert (Sv) - Effective dose (Sv) - Committed equivalent and committed effective dose (Sv) Operational quantities and associated units: - Ambient dose equivalent – H*(10) (Sv) - Personal dose equivalent – Hp(10) (Sv), Hp(0.07) (Sv), Hp(3) (Sv) Dose rate: (Sv/h)	To be able to: - Explain the need for physical, radiation protection and operational quantities - Describe the relevant exposure pathways in industrial radiography - Use appropriate quantities and units, including prefixes and abbreviations, when: • Describing the activity of a radioactive source • Describing any radiation dose to the body, skin or lens of the eye, including doses high enough to cause deterministic effects • Describing the energy of radiation • Making records of workplace monitoring • Keeping records of individual monitoring - Convert activity from curies to becquerels - Explain the different dose quantities used in personal dose records - Describe, in quantitative terms, the relationship between applied voltage and radiation energy for X ray generating systems
Suggested exercise Desktop exercise on the use of radiation quantities, units, their prefixes and abbreviations	

4.4. TOPIC 4: RADIATION SOURCES, FACILITIES AND EQUIPMENT USED IN INDUSTRIAL RADIOGRAPHY

The aim of this topic is to provide the participants with an overview of the radiation sources, facilities and equipment used for industrial X ray and gamma radiography.

Topic 4 is associated with topics 7, 10 and 12. Topic 4 introduces the equipment used in industrial radiography and describes how it works.

Continuity between these four topics will be easier to achieve if the same trainer is assigned to them all.

One of the learning objectives specified in Table 4 is that participants can identify a gamma radiography source (‘pigtail’). However, because of the very high dose rates generated by industrial radiography sources, it is impracticable to show real radiography pigtails during a training course. Alternatives would be to show non-radioactive (dummy) pigtails or to include photographs provided by source manufacturers in the presentations, indicating the size of the pigtail, for example by including dimensions.

A visit to see a shielded enclosure and to a location where site radiography is in progress, videos and photographs of different types of equipment or real equipment (provided there is no risk of radiation exposure) will help participants to understand the topic and fulfil the learning objectives.

The full content and learning objectives for topic 4 are given in Table 4. The content of this topic will need to be tailored to the specific needs of the target audience. The suggested duration for this topic is two hours for the theoretical part and two hours for the exercises.

TABLE 4. CONTENT AND LEARNING OBJECTIVES OF TOPIC 4: RADIATION SOURCES, FACILITIES AND EQUIPMENT USED IN INDUSTRIAL RADIOGRAPHY

<table>
<tr><th>Content</th><th>Learning objectives</th></tr>
<tr><td>Overview of radiography equipment:
- Gamma sources:
• Typical radionuclides and activities
• Sealed radioactive sources:
- Capsule design, recommended working life[a], special form
• Exposure devices
• Ancillary equipment (wind-out gear, guide tubes and collimators)
• Source changers and storage containers
• Shielding material (depleted uranium/tungsten)
- Radiation generators (features and typical parameters):
• X ray generators
• Accelerators (linear accelerators, betatrons and cyclotrons)
• Real time radiography
• Flash or pulsed X ray
Radiography in shielded enclosures
Radiography in cabinets
Site radiography</td><td>To be able to:
- Summarize the important characteristics of typical radionuclides used in gamma radiography: their half-lives, the energies of the gamma emissions and the radiation dose rates at 1 m
- Describe the various components of the equipment used for gamma radiography
- Describe the important components of industrial radiography X ray generators, typical operating parameters (kV and keV, mA, filtration) and the radiation dose rate at 1 m from the anode
- Identify a radioactive source (‘pigtail’) used for gamma radiography
- Identify source containers that contain depleted uranium shielding
- Explain how radioactive sources and radiation generators are used in industrial radiography</td></tr>
<tr><td colspan="2">Suggested exercises
A demonstration of the equipment used in X ray and gamma radiography
Site visits to a shielded enclosure and to a location where site radiography is in progress
Demonstration of gamma radiography containers, wind-out gear, guide tubes and collimators</td></tr>
</table>

[a] Guidance on the recommended working life of sealed radioactive sources can be found in ISO standard 2919:2012 [13].

4.5. TOPIC 5: HEALTH EFFECTS OF IONIZING RADIATION

The aim of this topic is for participants to understand the effects of radiation on the human body at the molecular and cellular levels and how these can result in stochastic effects and, at higher doses, tissue reactions. A good understanding of the basic principles of the health effects of ionizing radiation is necessary to understand the principle of optimization of protection and safety. It is therefore important that participants know that the risk to health associated with radiation exposure is based on the linear no-threshold relationship, that deterministic effects are subject to a threshold dose, and that radiation sources used in industrial radiography have the potential to cause both types of effect.

When discussing the potential for radiation exposure in industrial radiography, trainers will need to emphasize that an intake of radioactive material during routine work is not a realistic hazard, but that any intake, for example due to accidents or leaking radiography sources, could be extremely serious and need immediate advice from a qualified expert.

Photos of tissue reactions resulting from accidents involving industrial radiography sources, such as the accident at Yanango (Peru) [9], will help to illustrate the potential for deterministic effects in industrial radiography. Accidents in gamma radiography are also described in topic 1 (introduction to the concept of the RPO) and topic 12 (emergency preparedness and response) and trainers are expected to liaise to ensure the various discussions of case histories throughout the course are complementary.

The content and learning objectives for topic 5 are given in Table 5 and the suggested duration is two hours.

TABLE 5. CONTENT AND LEARNING OBJECTIVES OF TOPIC 5: HEALTH EFFECTS OF IONIZING RADIATION

Content	Learning objectives
Basic interactions: - Ionization: breakage of molecular bonds - Significance of breakage in DNA - Chromosome damage Cell damage: cell sensitivity Stochastic effects: - Definition - Manifestation of stochastic effects (cancer, effects on embryo/fetus, probability of hereditary effects) - Available scientific data on radiation risk: • Atomic bomb survivors • Uranium miners • Medical exposures Deterministic effects: - Definition - Manifestation of deterministic effects (cataracts, erythema, hair loss, acute radiation syndrome) Relationship between dose and health risk Appropriate examples to illustrate the potential for exposure in industrial radiography Examples of conventional risk	To be able to: - Compare the two types of radiation effect: • Deterministic effects • Stochastic effects and provide examples - Recognize that the risk of inducing stochastic effects increases with increasing effective dose, according to current scientific consensus; - Compare the risk of developing stochastic effects with other (conventional) risks - Describe the magnitude of effective and equivalent (extremity) doses that could be received by workers and the public under normal conditions and reasonably foreseeable accidents in industrial radiography - Explain the general circumstances that could lead to a dose significant enough to cause deterministic effects - Explain the general circumstances in industrial radiography that could lead to an intake of radioactive material

4.6. TOPIC 6: PRINCIPLES OF RADIATION PROTECTION

This topic provides participants with an understanding of the principles of radiation protection: justification, optimization and dose limitation. Following the presentation on the health effects of ionizing radiation, this topic explains the need for a system of radiation protection that allows ionizing radiation to be used for many beneficial purposes while ensuring the harmful effects of radiation are minimized.

The requirement of GSR Part 3 [1] that is relevant to this topic is:

> “**Requirement 1: Application of the principles of radiation protection**
>
> **Parties with responsibilities for protection and safety shall ensure that the principles of radiation protection are applied for all exposure situations.**”

The content and learning objectives for topic 6 are given in Table 6 and the suggested duration is two hours.

TABLE 6. CONTENT AND LEARNING OBJECTIVES OF TOPIC 6: PRINCIPLES OF RADIATION PROTECTION

Content	Learning objectives

Justification
Optimization of protection and safety:
- As low as reasonably achievable (ALARA)
- Dose constraints
- Reference levels
Dose limitation:
- Basis for dose limits:
  • Prevention of deterministic effects
  • Tolerability of risk of development of stochastic effects
- Annual dose limits:
  • Occupationally exposed workers
  • Members of the public
  • Apprentices of 16–18 years of age
Restrictions related to pregnant female workers
	To be able to:
	- Explain the three basic principles of radiation protection: justification; optimization of protection and safety; and dose limitation
	- Describe what optimization of protection and safety is and why it is important
	- Describe appropriate action to take in the event that a worker receives a dose in excess of a dose reference level
	- State the dose limits for effective dose and equivalent dose to the extremities for workers over 18, apprentices aged 16–18, and female workers who have notified pregnancy
	- Explain the circumstances under which, in relation to industrial radiography, workers and the public could receive a dose in excess of a dose limit
	- Describe the dose limitation arrangements for pregnant female workers

4.7. TOPIC 7: CONTROL MEASURES AND DOSE REDUCTION TECHNIQUES

The aim of this topic is to develop participants’ skills in applying the principles of radiation protection and provide them with an understanding of the control measures and dose reduction techniques that can restrict exposures during industrial radiography.

Topic 7 is associated with topics 4, 10 and 12. Topic 7 goes into detail on the safety features of equipment and shielded enclosures used for industrial radiography and describes how they are expected to be maintained. Continuity between these four topics will be easier to achieve if the same trainer is assigned to deliver them all.

Training providers might choose to deliver this topic in two sessions, one covering the factors affecting radiation dose (output, time, distance and shielding), and another teaching the design and safety features of the facilities and equipment used in industrial radiography.

A presentation on the factors affecting dose will normally be supported by desktop exercises in which participants are asked to undertake calculations, for example to estimate the output of specified gamma and X ray sources, and, by applying the factors of time, distance and shielding, to estimate doses. These exercises could be a continuation of the desktop exercise described in topic 3 (quantities and units). Calculations that are focused on exposure of extremities can help to clarify the difference between physical quantities and radiation protection quantities and the relevance of tissue weighting factors.

A presentation on the design and safety features of the equipment and facilities will normally be supported by a site visit to see the industrial radiography equipment in use. This could be combined with the site visit described under topic 4 (radiation sources, facilities and equipment used in industrial radiography). Videos and photographs of some of these aspects would also help to fulfil the learning objectives.

The content and learning objectives s for topic 7 are given in Table 7. The content of this topic will need to be tailored to the specific needs of the target audience. The suggested duration for the full topic is four hours for the theoretical part and three hours for the exercise.

TABLE 7. CONTENT AND LEARNING OBJECTIVES OF TOPIC 7: CONTROL MEASURES AND DOSE REDUCTION TECHNIQUES

Content	**Learning objectives**
Hierarchy of control measures: - Engineered controls, administrative controls, personal protective equipment Factors affecting personal dose in industrial radiography: - Output, time, distance, shielding - Primary beam and scattered radiation - Air scattering of radiation above an enclosure	To be able to: - Explain the basis for the hierarchy of control measures - State the factors that determine radiation dose resulting from exposure to X ray and gamma ray sources used in industrial radiography - Calculate the dose rate at 1 m from a gamma radiography source based on the gamma ray constant and the activity of the source - Calculate the dose rate at 1 m from an X ray generator for a range of mA settings, based on manufacturer's data - Calculate the dose rate at any working distance from a gamma source and a radiation generator, based on a known dose rate at any other distance, using the inverse square law - Calculate on the basis of a given dose rate: • The dose that would be received in a specified exposure time • The exposure time that will result in a specified dose
Suggested exercise Desktop exercise on estimating the effects of output, time, distance and shielding on dose	

TABLE 7. CONTENT AND LEARNING OBJECTIVES OF TOPIC 7: CONTROL MEASURES AND DOSE REDUCTION TECHNIQUES (CONT.)

Content	**Learning objectives**
Concept of ‘fail-to-safe’ Safety features of gamma radiography equipment: - Exposure devices - Ancillary equipment - Source changers and storage containers Safety features of radiation generators: - Tube head - Cable length - Collimators and beam filters Design features of shielded enclosures: - Primary and secondary barriers - Maze entrances - Operator positions - Cable ducts Safety and warning features for shielded enclosures: - ‘Search and lock up’ systems - Interlocks: doors, overhead cranes, etc. - Emergency cut-off switches - Pre-exposure and exposure warning signals - ‘Fail-to-safe’ in practice (for shielded enclosures) - Warning notices Site radiography: - Demarcation of the area - Pre-exposure and exposure warning signals - ‘Fail-to-safe’ in practice (for site radiography) - Radiation monitoring of the area - Warning notices - Completion of work and removal of sources from site Exchange of information with site owner	To be able to: - Identify and describe: • The safety and design features of shielded enclosures • The safety and design features of the radiation equipment, including ancillary equipment • The safety features of a store for radiography sources • The administrative controls used in site radiography that ensure protection and safety - Explain what ‘fail-to-safe’ means, recognize when this is appropriate and safely identify whether a given safety feature meets this criterion - Describe an appropriate methodology for checking that source containers, portable warning devices and the safety features associated with shielded enclosures, are functioning - Describe the action to take in the event that a safety feature is not functioning as expected - Compare the safety of industrial radiography carried out in a shielded enclosure, with site radiography - Explain the procedures for ensuring the source is always under control
Suggested exercises Site visit to a shielded industrial radiography enclosure fitted with effective engineering controls Demonstration of a site radiography set-up and the associated safety equipment	

4.8. TOPIC 8: FRAMEWORK FOR RADIATION PROTECTION AND SAFETY

This topic aims to provide an awareness of the role of international organizations in radiation protection and the significance of their main publications. These publications include United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) reports, International Commission on Radiological Protection (ICRP) recommendations on the international system of radiological protection, IAEA safety standards and International Labour Organization (ILO) Labour Standards.

It would be appropriate to include the relevant national framework for radiation protection under this topic. This will include a summary of the national legislative instruments and regulations related to radiation safety that are in place or under development, together with a brief description of the regulatory body and its regulatory functions (e.g. authorization, review, assessment, inspection, enforcement), and the national provisions for technical services.

The relevant requirements of GSR Part 3 [1] are:

> "**Requirement 2: Establishment of a legal and regulatory framework**
>
> **The government shall establish and maintain a legal and regulatory framework for protection and safety and shall establish an effectively independent regulatory body with specified responsibilities and functions.**"

and

> "**Requirement 3: Responsibilities of the regulatory body**
>
> **The regulatory body shall establish or adopt regulations and guides for protection and safety and shall establish a system to ensure their implementation.**"

Requirements on the governmental, legal and regulatory framework for safety for all the facilities and activities in a country are established in IAEA Safety Standards Series No. GSR Part 1, Governmental, Legal and Regulatory Framework for Safety [14].

The content and learning objectives for topic 8 are given in Table 8 and the suggested duration is one hour.

TABLE 8. CONTENT AND LEARNING OBJECTIVES OF TOPIC 8: FRAMEWORK FOR RADIATION PROTECTION AND SAFETY.

Content	Learning objectives
International framework: - Overview of relevant organizations: • UNSCEAR, ICRP, IAEA, ILO • Relevant regional organizations • IAEA safeguards National framework: - Government bodies - Legal and regulatory framework - Competent authorities - Occupational health and safety authorities - Technical and scientific support organisations - Associations Professional networks, e.g. regional ALARA (as low as reasonably achievable) networks	To be able to: - Explain the role, function and status of the key international organizations - State that depleted uranium is included under the IAEA safeguards regime - Explain in general terms, the national framework for radiation protection and safety

4.9. TOPIC 9: GENERAL RESPONSIBILITIES OF EMPLOYERS AND AUTHORIZED PARTIES

This topic provides the participants with an awareness of the responsibilities of employers and authorized parties for radiation safety. This topic also aims to provide participants with a basic understanding of the purpose, structure and content of the safety assessment for facilities and activities.

The relevant requirements of GSR Part 3 [1] are:

“**Requirement 4: Responsibilities for protection and safety**

The person or organization responsible for facilities and activities that give rise to radiation risks shall have the prime responsibility for protection and safety. Other parties shall have specified responsibilities for protection and safety.”

…….

“2.44. The relevant principal parties and other parties having specified responsibilities in relation to protection and safety shall ensure that all personnel engaged in activities relevant to protection and safety have appropriate education, training and qualification so that they understand their responsibilities and can perform their duties competently, with appropriate judgement and in accordance with procedures.”

“**Requirement 7: Notification and authorization**

Any person or organization intending to operate a facility or to conduct an activity shall submit to the regulatory body a notification and, as appropriate, an application for authorization.”

“**Requirement 9: Responsibilities of registrants and licensees in planned exposure situations**

Registrants and licensees shall be responsible for protection and safety in planned exposure situations.

“3.13. Registrants and licensees shall bear the responsibility for setting up and implementing the technical and organizational measures that are necessary for protection and safety for the practices and sources for which they are authorized. Registrants and licensees may designate suitably qualified persons to carry out tasks relating to these responsibilities, but they shall retain the prime responsibility for protection and safety.

…….

“3.15. Registrants and licensees:

…….

(c) Shall, for the sources for which they are authorized and for which a safety assessment is required …, conduct such a safety assessment and keep it up to date”.

“**Requirement 13: Safety assessment**

The regulatory body shall establish and enforce requirements for safety assessment, and the person or organization responsible for a facility or activity that gives rise to radiation risks shall conduct an appropriate safety assessment of this facility or activity.”

“**Requirement 23: Cooperation between employers and registrants and licensees**

Employers and registrants and licensees shall cooperate to the extent necessary for compliance by all responsible parties with the requirements for protection and safety.”

As well as teaching the relevant requirements of GSR Part 3 [1], a brief description of the national process of notification and authorization for facilities and activities involving industrial radiography will need to be given to complete the topic and fulfil the learning objectives.

Paragraph 1.2 of IAEA Safety Standards Series No. GSR Part 4 (Rev.1), Safety Assessment for Facilities and Activities [15] states that "The safety assessments are to be carried out and documented by the organization responsible for operating the facility or conducting the activity, are to be independently verified and are to be submitted to the regulatory body as part of the licensing or authorization process." Requirement 24 of GSR Part 4 (Rev. 1) states that "**The safety assessment shall be periodically reviewed and updated.**"

To ensure the requirements quoted in the previous para. are met, the applicant will normally consult with a qualified expert. For that reason, this syllabus does not include a detailed coverage of the safety assessment process. However, once the initial safety assessment(s) has (have) been accepted by the regulatory body as part of the authorization process, the RPO may be in a position to recognize when the design basis or the operational limits and conditions of the safety assessment have been breached. The RPO may also be involved in the periodic review and update of the safety assessment.

A desktop exercise on the licensing process for industrial radiography, with an emphasis on safety assessment and safety culture, will help to ensure the learning objectives are met.

The content and learning objectives for topic 9 are given in Table 9. The suggested duration for topic 9 is two hours for the theoretical part and one hour for the exercises.

TABLE 9. CONTENT AND LEARNING OBJECTIVES OF TOPIC 9: GENERAL RESPONSIBILITIES OF EMPLOYERS AND AUTHORIZED PARTIES

Content	**Learning objectives**
Definition of registrant, licensee, authorized party, employer and employee Consultation with the qualified expert Notification Licensing of facilities: - Shielded enclosures Authorization of activities: - Site radiography - Transport of radioactive material - Use of depleted uranium - Import and export of radioactive sources (Code of Conduct on the Safety and Security of Radioactive Sources) Safety assessment: - Objective and purpose - Content - Safety culture Training and qualification: - The need to use personnel with appropriate qualifications - National regulatory requirements for training RPOs and workers Cooperation between employers and authorized parties	To be able to: - List the topics that a qualified expert could advise the authorized party on - Describe the notification and authorization processes - State the objectives and purpose of the safety assessment - Identify changes in the work for which a review of the safety assessment would be necessary - Describe the implications of the conditions specified in the authorization - Describe the need for, and actively participate in, implementing a strong safety culture - Explain the obligations of the employer and the authorized party to employ personnel with appropriate qualifications, and ensure provision of appropriate training for the RPO and occupationally exposed workers - Describe appropriate arrangements for the exchange of information between employers and authorized parties to ensure compliance with the requirements for protection and safety

TABLE 9. CONTENT AND LEARNING OBJECTIVES OF TOPIC 9: GENERAL RESPONSIBILITIES OF EMPLOYERS AND AUTHORIZED PARTIES (CONT.)

Content	Learning objectives
Related content of national regulations	To be able to: - Describe the national requirements for notification, licensing of facilities and activities and authorization for import and export of radioactive sources involved in industrial radiography
Suggested exercise Desktop exercise on the licensing process for industrial radiography, with emphasis on the safety assessment	

4.10. TOPIC 10: RADIATION PROTECTION PROGRAMME

Paragraph 3.49 of GSG-7 [2] states:

> "The general objective of the radiation protection programme is to fulfil the management's responsibility for protection and safety through the adoption of management structures, policies, procedures and organizational arrangements that are commensurate with the nature and extent of the risks. The radiation protection programme should cover all the main elements contributing to protection and safety. The radiation protection programme could relate to all phases of a practice or to the lifetime of a facility (i.e. from design through commissioning and operation or process control to decommissioning)."

This topic provides the participants with the knowledge and skills to be able to oversee the day to day implementation of the radiation protection programme and to carry out the duties required by the programme.

Topic 10 is associated with topics 4, 7 and 12. Topic 10 goes into detail on the radiation protection programme. Continuity between these four topics will be easier to achieve if the same trainer is assigned to deliver them all.

This is one of the key topics for RPOs and there is a lot of content and many learning objectives. Training providers may, therefore, choose to present this topic over a series of presentations with each one supported by exercises.

The related requirements of GSR Part 3 [1] are:

> "**Requirement 23: Cooperation between employers and registrants and licensees**
>
> **Employers and registrants and licensees shall cooperate to the extent necessary for compliance by all responsible parties with the requirements for protection and safety.**"

> "**Requirement 24: Arrangements under the radiation protection programme**
>
> **Employers, registrants and licensees shall establish and maintain organizational, procedural and technical arrangements for the designation of controlled areas and supervised areas, for local rules and for monitoring of the workplace, in a radiation protection programme for occupational exposure.**"

In line with Requirement 24 of GSR Part 3 [1] and para. 3.60 of GSG-7 [2] the scope of the radiation protection programme includes: classification of areas; monitoring of the workplace; individual monitoring and the assessment of occupational exposure; records of occupational exposure; workers' health surveillance; local rules and procedures and personal protective equipment; accountability for radiation generators and radioactive sources; information, instruction and training; emergency plan; and periodic reviews of the performance of the radiation protection programme.

The emergency plan is covered in topic 12 of this syllabus (emergency preparedness and response).

Practical work on workplace monitoring is essential to fulfil the learning objectives and it would be appropriate to include practical work covering the measurements described in para. 7.1 of SSG-11 [4].

> "The operating organization should establish a programme of monitoring of radiation levels in and around the workplace. The adequacy of the arrangements in place for protection in radiography work should be assessed in the programme, which should include measurements of radiation levels at the following positions:
>
> (a) For radiography in shielded enclosures:
> - (i) Around the walls and doors (and other openings) of the enclosure under a range of operating conditions, to ensure that an adequate level of shielding is maintained;
> - (ii) At the entrance to the enclosure after completion of each gamma radiography exposure, to confirm that the gamma source has been satisfactorily returned to the exposure device or that X ray emission has stopped;
> - (iii) Around the gamma source store, to ensure that an adequate level of shielding is provided.
>
> (b) For site radiography work:
> - (i) Around barriers during a test exposure (or first exposure, depending on the circumstances) to confirm that the barriers are correctly positioned;
> - (ii) At the operator position during wind-out of a gamma source or when an X ray generator is energized, to confirm that radiation levels are not unacceptable;
> - (iii) Around the barriers during routine exposures, to confirm that dose rates remain below any values specified in national regulations or guidance or by the operating organization;
> - (iv) At the operator position during wind-in of a gamma source or termination of exposure of an X ray generator;
> - (v) Around the exposure device after each exposure, to ensure that the source has been fully returned to the shielded position;
> - (vi) Around any source store used on-site, to ensure that an adequate level of shielding is provided;
> - (vii) Around the site on completion of the radiography work, to confirm that no gamma sources have been left on the site;
> - (viii) Around vehicles used to transport gamma sources prior to departure to and from the site."

To ensure the learning objectives are fully met, it will be appropriate for these exercises to include:

- — Making a physical inspection of the radiation monitor including checking the battery;
- — Measuring the radiation dose rate;
- — Interpreting the results and keeping records;
- — Taking appropriate action, based on the results.

Before this topic is covered, a desktop exercise could be organized, with the objective of participants considering what elements they expect to be included in the radiation protection programme. A further desktop exercise at the end of this topic, on the role of the RPO, based on the preparation for a regulatory inspection might also be helpful.

The content and learning objectives s for topic 10 are given in Table 10. This content will need to be tailored to the specific needs of the target audience, for example a brief description of the national requirements related to the radiation protection programme will need to be included to fulfil the learning objectives. The suggested duration for the full topic is five hours for the theoretical part and five hours for exercises.

TABLE 10. CONTENT AND LEARNING OBJECTIVES OF TOPIC 10: RADIATION PROTECTION PROGRAMME

Content	Learning objectives
Objective of a radiation protection programme Basis for a radiation protection programme Core elements of the programme Classification of areas: - Criteria for designating controlled and supervised areas: • Shielded enclosures • Site radiography - Associated arrangements: • Delineation by physical means • Restriction of access • Area monitoring • Assessment of occupational exposure • Supervision of work Workplace monitoring: - The objective of a workplace monitoring programme - Dose rate monitoring: • Appropriate use of portable monitors • Care of, including calibration and testing of, monitoring devices • Monitoring techniques • Appropriate monitoring programme • Interpretation of measurement results • Measurement of the actual dose rate in a narrow beam - Measurement of flash or pulsed beams[a]	To be able to: - Describe the criteria for developing the radiation protection programme, based on a prior radiological evaluation - Explain the key elements of the radiation protection programme - Compare the working arrangements in controlled, supervised and undesignated areas - Explain the criteria for accessing the controlled areas - Establish controlled and supervised areas, in relation to: • Radiography in a shielded enclosure • Site radiography • Source storage - Select appropriate monitoring equipment to measure dose rates around radiation sources used for industrial radiography - Verify that radiation monitoring equipment is tested and is in working order - Take and interpret dose rate measurements around industrial radiography sources, including the dose rate in a narrow beam - Establish and justify an appropriate dose rate monitoring programme that includes: • When and how often monitoring is carried out • Which monitoring equipment to use • Where to take the measurements • Who can undertake the monitoring • How to record the results - Describe appropriate actions to take based on the results of workplace monitoring

TABLE 10. CONTENT AND LEARNING OBJECTIVES OF TOPIC 10: RADIATION PROTECTION PROGRAMME (CONT.)

Content	Learning objectives
Individual monitoring Assessment of occupational exposure: - Passive and active dosimeters (TLD, OSL, EPD) - Whole body, eye and extremity dosimeters - Use and care of dosimeters Health surveillance Care of facilities and equipment: - Maintenance and servicing regimes - Routine testing of safety features: • Installed safety features • Portable safety features • Gamma source containers and ancillary equipment • X ray generators - Appropriate frequency of checks and maintenance Care of radioactive sources (including disused sources): - Marking and labelling of sources and their containers - Safe movement of radioactive sources within the work site - Safe storage of radioactive sources - Source inventory - Accounting for radioactive sources during site radiography and in the facility - Practical arrangement for leak testing of sealed radioactive sources - Safeguards reporting The conditions and restrictions in relation to the transfer of disused sources and radioactive waste to an authorized facility	To be able to: - Demonstrate the constituent parts of passive dosimeters - Set dose and dose rate alarms on active dosimeters - Demonstrate suitable arrangements for the care, storage, use and return of dosimeters - Explain appropriate arrangements for: • Dosimetry and health surveillance for workers • The provision of information, instruction and training to workers • Maintenance and servicing of equipment - Establish and justify an appropriate schedule of routine safety feature checks - Establish an appropriate accountancy regime for gamma sources, taking into account storage, use, movement off-site and temporary storage away from the facility - Complete safeguards reports - Describe the requirements for leak testing of sealed sources, including the frequency of tests, methodology and recording of results - To undertake the leak test of an industrial radiography source - Establish and justify safe and secure arrangements for the: • Movement of gamma sources and their containers around the workplace • Storage of gamma sources, disused sources and depleted uranium - Explain the conditions and restrictions that apply in relation to the transfer of disused sources to authorized facilities

[a] The measurement of pulsed or flash X ray may be undertaken by the qualified expert. Nevertheless, the radiation protection officer will need to be aware of the need to take measurements and to retain records of the results.

TABLE 10. CONTENT AND LEARNING OBJECTIVES OF TOPIC 10: RADIATION PROTECTION PROGRAMME (CONT.)

Content	Learning objectives
Local rules and procedures: - Purpose - Essential content: • Radiography work in shielded enclosures • Source exchange and transport • Site radiography work Training for workers Provision of information Periodic review of the performance of the radiation protection programme by a radiation safety committee Record keeping: - Individual monitoring - Assessment of exposure - Health surveillance - Workplace monitoring - Maintenance, servicing and routine testing of the equipment - Source accountancy - Leak testing - Training - Calibration certificates of monitoring equipment and sealed sources	To be able to: - Describe the essential content of local rules - Explain the role of the RPO in ensuring compliance with the local rules - Explain the need for and the process of reviewing the performance of the radiation protection programme - Describe the records that need to be maintained to demonstrate compliance with the radiation protection programme, specifically: • How frequently such records need to be updated • How long they need to be kept for
Suggested exercises Desktop exercise on the content of the radiation protection programme, including record keeping (e.g. preparing for a regulatory inspection) Practical work on workplace monitoring	

4.11. TOPIC 11: TRANSPORT SAFETY

This topic provides the participants with a basic understanding of the requirements for the safe transport of gamma radiography sources and devices. The provisions for the movement of radioactive sources within a facility are addressed under topic 10 (radiation protection programme).

IAEA Safety Standards Series No. SSR-6 (Rev. 1), Regulations for the Safe Transport of Radioactive Material, 2018 Edition [16] establishes standards of safety which provide an acceptable level of control of the radiation, criticality and thermal hazards to people, property and the environment that are associated with the transport of radioactive material.

This topic focuses on the responsibilities of the consignor, the carrier, the driver and the consignee as set out in SSR-6 (Rev. 1) [16], for the correct packaging and labelling of the transport container, placarding of the vehicle and documentation. Trainers will be aware that in many cases in industrial radiography the responsibilities of these four parties are met by the same person or group of people.

Exercises could include a desktop exercise in which participants develop a series of check sheets for the transport of radioactive sources and a practical exercise in which participants prepare a source and a vehicle for transport.

The content and learning objectives s for topic 11 are given in Table 11 and the suggested duration for this topic is one hour for the theoretical part and two hours for the exercises.

TABLE 11. CONTENT AND LEARNING OBJECTIVES OF TOPIC 11: TRANSPORT SAFETY

Content	**Learning objectives**
The need to seek advice from a qualified expert Introduction to the relevant requirements of SSR- 6 (Rev.1): - Responsibilities of the consignor, consignee, carrier and driver - Packaging - Labelling - Marking - Transport index - Placarding - Transport documents - Radiation protection programme - Emergency response - Management system - Training	To be able to: - Identify circumstances when the authorized party should seek advice from a qualified expert - Summarize the relevant requirements of SSR-6 (Rev.1) applicable to the transport of sources for site radiography work - Oversee the safe preparation, transport and receipt of radioactive sources and their packages and overpacks, specifically, ensuring the responsibilities of consignors, carriers and consignees are met, as appropriate - Describe appropriate regimes of checks and measurements for the transport of packages containing radioactive sources
Suggested exercises Practical work on preparing a package and vehicle for transport Desktop exercise on developing checklists to support the verification of the requirements before, during and after transport	

4.12. TOPIC 12: EMERGENCY PREPAREDNESS AND RESPONSE

The aim of this topic is to teach participants how to mitigate accidents, that is, how to plan for and, if necessary, safely deal with, reasonably foreseeable radiological emergencies during industrial radiography.

The related requirements of the GSR Part 3 [1] are:

> "**Requirement 15: Prevention and mitigation of accidents**
>
> **Registrants and licensees shall apply good engineering practice and shall take all practicable measures to prevent accidents and to mitigate the consequences of those accidents that do occur.**

and

> "3.44. Registrants and licensees shall be responsible for the implementation of their emergency plans and shall be prepared to take any necessary action for effective response."

Paragraph 4.16 of IAEA Safety Standards Series No. GSR Part 7, Preparedness and Response for a Nuclear or Radiological Emergency [17] states that “The operating organization shall establish and maintain arrangements for on-site preparedness and response for a nuclear or radiological emergency for facilities or activities under its responsibility, in accordance with the applicable requirements”[8].

The national requirements relating to emergency plans for industrial radiography facilities and activities will need to be taught to fulfil the learning objectives.

Accounts of various accidents in industrial radiography (e.g. Yanango (Peru) [9], Gilan (Islamic Republic of Iran) [10], Cochabamba (Plurinational State of Bolivia) [11] and Chilca (Peru) [12]) or those described in Ref. [18] will help to illustrate the range of possible serious accidents in industrial radiography. Any description of such accidents will need to include a consideration of the primary causes (often inadequate training, failure to implement monitoring or lack of safety culture) and lessons learned from the accidents. There is potential for overlap with the description of the accidents in topic 1 and topic 5; trainers are expected to liaise with one another to ensure these topics complement each other effectively.

Participants who are experienced industrial radiographers may already have some knowledge, skills and experience, in implementing emergency response actions. Nevertheless, appropriate practical work will enable participants to further develop the skills needed to deal with emergency situations. As well as using the case studies of the events described above, training providers might include a practical exercise on implementing protective actions, for example searching for a ‘lost’ radioactive source, the use of remote handling tongs and the use of wire cutters to cut through guide tubes.

Paragraph 5.7 of SSG-11 [4], states that “The training should provide practical exercises, including the rehearsal of emergency plans… such as plans for retrieving a jammed source. However, radioactive sources should never be used in such rehearsals.” Where available, simulators will enable trainers to conduct the practical exercises without the risk of radiation exposure and dummy pigtails, pens or similar objects can be used instead of real pigtails.

Topic 12 is associated with topics 4, 7 and 10. Topic 12 goes into detail on the procedures to follow in case of an emergency. Continuity between these four topics will be easier to achieve if the same trainer is assigned to deliver them all.

The content and learning objectives for topic 12 are given in Table 12. This topic will need to be tailored to the needs of the target audience. The suggested duration for the full topic is two hours for the theoretical part and three hours for the exercises.

[8] Operating organization is defined in GSR Part 7 [17] as: “Any organization or person applying for authorization or authorized to operate an authorized facility or to conduct an authorized activity and responsible for its safety”.

TABLE 12. CONTENT AND LEARNING OBJECTIVES OF TOPIC 12: EMERGENCY PREPAREDNESS AND RESPONSE

Content	**Learning objectives**
Examples of reasonably foreseeable emergencies in industrial radiography: - Radioactive source stuck in the exposed position, detaches from the wind-out gear or does not fully return to the shielded position - Lost or stolen radioactive source - Radiation generator fails to terminate - Physical damage to a facility that affects the shielding (including fire) - Transport accident involving a radioactive source - Unauthorized persons are present in the controlled area during an exposure - Safety system or warning system malfunctions, including deliberate action to override a system Emergency preparedness: - The national provisions for emergency preparedness and response (EPR) - Emergency plan for a facility or activity - Identification of an emergency: operational criteria - Equipment to be used in emergencies involving gamma radiography sources Training and exercises for EPR Emergency response: - Identifying and notifying a radiological emergency - Activating the emergency plan - Calling for technical assistance, if necessary, from a qualified expert or manufacturer - Taking response actions - Protecting emergency workers	To be able to: - Identify reasonably foreseeable emergencies in industrial radiography and explain the potential health consequences - State the roles and responsibilities for EPR within the operating organization - Describe the content of an emergency plan and the procedures for implementing it - Describe how an emergency can be identified - List the emergency equipment relevant to industrial radiography - Describe the arrangements for training, drills and exercises - In the event of a reasonably foreseeable emergency: • Explain how to activate the emergency response • Implement appropriate response actions, applying the principles of the optimization of protection and safety (time, distance and shielding) - Demonstrate the steps to be taken to safely recover a gamma radiography source in the event that: • It becomes detached from the wind-out mechanism, inside the guide tube • It becomes detached from the wind-out mechanism, outside the guide tube • It becomes stuck in the guide tube, while attached to the wind-out gear - Explain how the exposure of emergency workers is managed

TABLE 12. EMERGENCY PREPAREDNESS AND RESPONSE (CONT.)

Content	**Learning objectives**
Confirming that an emergency is over Follow up actions: - Estimation of doses - Reporting format and criteria - Evaluation of emergency response - Quality management programme for EPR	To be able to: - Explain the actions to be taken once a source is brought under control - Explain the arrangements for estimating the doses received during the emergency, including the recovery: • Prompt return of dosimeters • Dose reconstruction techniques • Chromosome aberration analysis that may be arranged by the qualified expert - Describe how and when the relevant authorities have to be notified in the event of: • Abnormally high dose including overexposure • Loss of control of a source including loss or theft • Damage to a source - Describe the content of the operating organization's reports of the emergency - Oversee the quality management programme of the operating organization for EPR
Suggested exercises	
Desktop exercise: Case study on any significant accident in industrial radiography, for instance Yanango [9] Gilan (Islamic Republic of Iran) [10], Cochabamba (Plurinational State of Bolivia)[11] or Chilca (Peru) [12], focusing on primary causes and on lessons learned Practical work: cordoning off an area around an unshielded source Practical work: searching for a lost (dummy) source (using a radiation simulator if available) Practical work: recovery of a dummy gamma radiography source	

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