Radiation Protection Authority

Zambia

SAFETY GUIDE

RPA SG 12

Nuclear Gauges Safety Guide

2024

NOTICE OF APPROVAL

Under the terms of Part II of the Ionising Radiation Protection Act No. 16 of 2005 and Part V of the Statutory Instrument No.98 of 2011, the Radiation Protection Authority (RPA) is authorized to establish or adopt standards of safety for protection of health and minimization of risk to life and the environment, and to provide for the application of these standards.

The Radiation Protection Authority Board (RPAB), has on the 29th/07../ 2024 approved the safety guide on Nuclear Gauges. This guide is approved for the purposes of providing practical guidance with respect to the Ionising Radiation Protection General Regulations No. 98 of 2011.

This guide comes into effect on 29../..07../2024

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BOARD CHAIRPERSON

Radiation Protection Authority Board

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EXECUTIVE DIRECTOR

Radiation Protection Authority

FOREWORD

Radiation Protection Authority (RPA) was established by the Ionising Radiation Protection Act No. 16 of 2005. It is a national regulatory body which implements the policies of the Zambian government relating to the protection of the public, workers and the environment from harmful effects of ionising radiation.

As the utilization of nuclear technology continues to expand globally, it is imperative for Zambia to prioritize the safe and responsible use of nuclear gauges across various industries. The Radiation Protection Authority of Zambia is dedicated to ensuring the highest standards of radiation safety in the use of nuclear gauges within its jurisdiction.

This guide serves as a vital resource for licensee, regulator, and stakeholders involved in the deployment and management of nuclear gauges. RPA is committed to protect the public, the environment, and workers in industries where nuclear gauges are used from the effects of ionising radiation.

The International Atomic Energy Agency (IAEA) Safety Standards Series No. SSG-58, "Radiation Safety in the Use of Nuclear Gauges," provides guidance for the preparation of this guide. This guide encapsulates the best practices, regulatory frameworks, and safety measures essential for the effective implementation of radiation safety protocols when using the Nuclear Gauges. This is to ensure that the use of nuclear gauges in Zambia adheres to the highest standards of safety, reliability, and accountability.

It is envisaged that this guide will serve as a valuable tool for all stakeholders involved in the use of nuclear gauges, fostering a culture of safety, responsibility, and excellence in nuclear technology practices across Zambia.

PREFACE

Radiation Protection Authority (RPA) was established by the Ionising Radiation Protection Act No. 16 of 2005. The structure of the implementation of the protection and safety was established to be compatible with the International Basic Safety Standards.

The structure was commensurate with the number and density and complexity of application and anticipated introduction of practices and sources within practices.

The essential element of the structured approach consisted of the following hierarchy:

- **Legislation** which established the Radiation Protection Authority and its powers and functions;
- **Radiation Safety Regulations** which prescribed the standards for radiation safety, waste safety and transport safety.
- **Radiation Protection and Safety Guides** which provides guidance for regulators, registrant and licensees and all stake holders to comply with the regulation as required by statutory instrument No. 98 of 2011(The Ionising Radiation Protection (General) Regulations, 2011).

This safety guide seeks consistency with the International Atomic Energy Agency (IAEA) Safety Standards Series No. SSG-58, "Radiation Safety in the Use of Nuclear Gauges".

LIST OF ACRONYMS

RPA:	Radiation Protection Authority
RPAB:	Radiation Protection Authority Board
IAEA:	International Atomic Energy Agency
QA/QC:	Quality Assurance/Quality Control
ALARA:	As Low As Reasonably Achievable
DDP:	Device Dose per Measurement
TLD:	Thermoluminescent Dosimeter
GM:	Geiger-Müller (Detector)
DRD:	Direct Reading Dosimeters
NAP:	Nearest Accessible Position
RPO:	Radiation Protection Officer

DEFINITIONS

"Accident" means any unintended event including operating errors, equipment failures or other mishaps, the consequences or potential consequences of which are not negligible from the point of view of protection or safety.

"Act" means the Radiation Protection Act No. 16 of 2005.

"Applicant" This is a company or organisation formally applying for an Ionising Radiation licence.

"Authority" Radiation Protection Authority is the "Authority" in Zambia.

"Client" This is an organisation that hires the employer or licensee to undertake activities with a portable nuclear gauge on the client's site. In the case of installed nuclear gauges, the owner of the site or facility is also normally the licensee. However, the licensee can, in some circumstances, also be a client, for example when installation or maintenance work is performed in the facility by specialist nuclear gauge contractors.

"Controlled area" It means an area in which specific protection measures and safety provisions are required for; controlling normal exposure or preventing the spread of contamination during normal working conditions; and preventing or limiting the extent of potential exposures.

"Dose" means a measure of radiation received or absorbed by a target.

"Emergency plan" means a set of procedures to be implemented in the event of a radiation accident.

"Worker" This is any person who works, whether full time, part time or temporarily, for an employer who has recognized rights and duties in relation to occupational protection, workers are required to fulfill their obligations and perform their duties for protection and safety.

"Employer" This is typically the owner of the facility in which fixed nuclear gauges are installed, or the undertaking activities with portable nuclear gauges. This term may also apply to the original equipment manufacturers and suppliers of nuclear gauges.

"Exposure" means the act or condition of being subjected to irradiation.

"Inspector" means any person appointed under section 35 of the Act to perform radiation inspections and any other duties relating to inspections under the Act.

"Ionising Radiation" Means radiation capable of producing ion pairs in biological materials.

"Licence" It means an authorisation granted by the Authority based on a safety assessment and accompanied by specific requirements and condition to be complied with by the licensee.

"Licensee" Means a holder of a licence granted under the Ionising Radiation Protection Act No 16, of 2005 as amended by Act No 19 of 2011.

"Occupational Exposure" This is all radiation exposure of workers incurred as a result of work.

"Potential exposure" Exposure that is likely to occur from an accident at a source or an event or sequence of events of a probable nature, including an equipment failure or operating error, but is not intended or planned

"Premises" means and includes any land, whether built up or not, including any place underground and any land covered by water.

"Qualified Expert" means an individual who, by virtue of certification by appropriate boards or societies, professional licenses or academic qualifications and experience, is duly recognised as having expertise in a relevant field of specialisation.

"Radiation" means ionising radiation.

"Radiation device" means any equipment capable of generating ionising radiation when energised and it does not contain radioactive material.

"Radiation Protection Officer" This is a person technically competent in radiation protection in relation to the use of nuclear gauges, designated by the employee to oversee the application of relevant requirements, principally the radiation protection and safety programme.

"Radiation Protection" means systems of technical and organization measures to reduce or limit exposure of people and the environment.

"Radiation Safety" means measure intended to minimize the likelihood of accidents with radiation sources and, should such an accident occur, to mitigate its consequences

"Radioactive waste" means some material that contains or is contaminated with radionuclides at concentrations or activities greater than exemption levels as established by the authority and for which no use is foreseen.

"Safety Culture" means the assembly of characteristics and attitudes in organization and individuals which establishes that, an overriding priority, protection and safety issues receive the attention warranted by their significance.

"Source" Means anything that may cause radiation exposure by emitting ionising radiation or releasing radioactive substances or materials.

"Standard Warning" Sign means the radiation signs prescribed by the IAEA.

Table of Contents

1 INTRODUCTION

1.1 General

This guide is dedicated to ensuring the safe and responsible use of nuclear gauges across various industries in Zambia. As Zambia continues to harness the benefits of nuclear technology in sectors such as construction, agriculture, and mining, it is imperative that it prioritises the protection of workers, the public, and the environment from potential radiation hazards.

Nuclear gauges play a crucial role in enhancing productivity, quality control, and efficiency in diverse industrial processes. However, with their inherent ability to emit radiation, it is essential to implement stringent safety measures to mitigate associated risks effectively. This guide aims to provide comprehensive guidance and best practices for the safe handling, operation, and disposal of nuclear gauges in Zambia.

1.2 Scope:

This safety guide applies to all types of nuclear gauges (Fixed or portable); the following are the main categories of nuclear gauges used in the industry:

i. Transmission – It is used to measure density, thickness, and levels of a material. The type of radiation is Beta and Gamma
ii. Backscatter – It is used to measure the thickness of coatings. The type of radiation is Beta, Gamma and Neutron that are from radioactive sources.
iii. Reactive – It is used for elemental analysis. The type of radiation is Beta and Gamma and the source is neutron radioactive sources and radiation generators.

This guide therefore provides guidance on the use, stringency of control measures, conditions to be applied and consequences of loss of control of nuclear gauges. It will show the approach to implementation of safety, the frequency of inspection and also complexity of RPA's inspection.

1.3 Objective

The objective of this safety guide is to outline how RPA and the licensee will effectively implement radiation safety measures in the use of nuclear gauges in Zambia, with the main goal of protecting human health, the environment, and promoting the responsible use of nuclear technology.

2 BACKGROUND-NUCLEAR GAUGES

In the modern world, most industries use various types of equipment to operate effectively, some such equipment incorporate a radioactive source, for example, a nuclear gauge. The nuclear gauge provides inexpensive, yet highly reliable and accurate method of measuring thickness, density, or composition of a wide variety of materials or surfaces. There are two types of nuclear gauges namely fixed and portable nuclear gauges.

2.1 Fixed Nuclear Gauges

2.1.1 Fixed Nuclear Gauges are usually used in factories as a way of monitoring a production process and ensuring quality control (QC). It is often tedious to effectively check and inspect industrial processes by traditional methods requiring direct contact, or a non-destructive measuring technique. In such situations, a nuclear gauge can be incorporated to the process to provide precise measurements of thickness or density.

2.1.2 These fixed nuclear gauges contain a radioactive source that is housed within a holder and placed at a crucial point in the process. When the source is opened, an invisible beam of radiation is directed at the material being processed. A detector mounted opposite the source measures the radiation that passes through the material. A read-out either on the gauge or on a connected computer terminal registers the required information.

2.1.3 Fixed nuclear gauges are commonly used in most types of processing environments such as mills, breweries etc. In a paper mill for instance, fixed gauges can measure the thickness of a sheet of paper as it leaves the press and, in a brewery, a fixed gauge makes sure that each bottle contains the right amount of beer. Regardless of the application, these gauges are mostly used in the quality control processes.

2.2 Portable Nuclear Gauges

Portable nuclear gauges are used in industries such as agriculture, construction, and civil engineering to measure parameters such as moisture of soil, and the density of asphalt in a paving mix. There are two basic methods of measuring material using portable nuclear gauges namely backscatter and direct transmission.

2.2.1 Direct Transmission

It is used for soils and aggregates. For example, in soils, the source is placed in a tube and inserted beneath the surface through a punched access hole. Radiation is then transmitted from the source to a detector on the base of the gauge. The density of the soil is determined by the radiation level at the detector. Less error in measuring composition and compensates for surface roughness.

2.2.2 Backscatter

The backscatter method eliminates the need for the access hole by allowing both the source and the detector to remain on the surface. Radiation is directed beneath the surface, and some radiation is reflected, or scattered, back to the gauge detector by the surface material. This method is less accurate than direct transmission; this is due to the large scattering angle and the shallow depth of measurement. It is also insensitive to density variations beyond a depth of 50mm to 76mm. However, the backscatter method is quicker and easier than direct

transmission, and is useful when measuring uniform material such as asphalt paving.

2.3 Strength of Source

2.3.1 Each nuclear gauge uses one or two radioactive sources containing americium-241, cesium-137, americium-241/beryllium, krypton-85, radium-226, or cobalt-60. The sources strength is measured in terms of how much radioactive energy it gives off. Although these sources are physically quite small, they are often extremely and highly radioactive. However, it is the amount of radiation they emit, that pose a danger to one's health.

2.4 Safety

Nuclear gauges are tools just like a welding torch that may be hazardous unless proper safety precautions are taken. Because the potential harm from radiation is not obvious as that of a blade or flame, the safety precautions are not obvious either. By following the simple rules, you can be assured that working with or around nuclear gauges will pose minimal or no threat to one's health and safety. The three principles of radiation safety are time, distance and shielding. Protection from receiving excess radiation is achieved by the source shielding and by proper handling techniques.

3 ROLES AND RESPONSIBILITIES

3.1 The Licensee

The following are the responsibilities of the licensee;

I. The licensee should possess prime responsibility for protection and safety and is required to implement a radiation protection and safety programme for the nuclear gauges it is responsible for.
II. The licensee should promote safety culture.
III. They licensee should ensure regulatory compliance.

IV. The licensee should develop training programmes that provide the appropriate level of training and information specific to the nuclear gauge.

V. The licensee should make appropriate dosimetry arrangements for its workers and keep records.

VI. The licensee should apply for a licence from RPA and will be regulated and inspected.

3.2 The Worker

The following are the responsibilities of the worker;

I. The worker should follow applicable rules and procedure for protection and safety as specified by licensee.

II. The worker should wear personal radiation monitoring equipment and personal protective equipment.

III. The worker should be responsible for monitoring and controlling both normal and abnormal conditions.

IV. The worker should work with the licensee to develop employee knowledge, skills and attitudes to achieve high levels of radiation safety and protection.

V. The worker should prevent and report the illegal movement of radioactive materials and technologies that could be used for illicit purposes.

VI. The worker should participate in radiation protection training.

VII. The worker should abstain from any willful actions that could compromise radiation protection and safety. They should ensure that illicit diversions of radioactive sources do not occur by increasing oversight.

Note: Other workers and contractors undertaking work close to (but not directly involving) nuclear gauges should cooperate with the licensee to ensure the safety of all persons.

3.3 The Client

The following are the responsibilities of the client;

I. The client should ensure that activities involving nuclear gauges are coordinated with any other work on the site.

II. The client should address the risk from hazards on the site and from the activities involving nuclear gauges.

3.4 The Authority

The following are the responsibilities of the Authority;

I. The Radiation Protection Authority establishes regulations and guidance for radiation sources. This may include design and performance standards and acceptance criteria for nuclear gauges

II. The Radiation Protection Authority issues licenses to applicants using nuclear gauges. RPA should review and assess the applicant's safety assessment.

III. The Radiation Protection Authority should inspect and enforce activities relating to the use of nuclear gauges, to verify that adequate measures are being taken to protect workers, the public and the environment from the harmful effects of ionising radiation.

IV. The Radiation Protection Authority should revoke licenses of licensees that do not comply to the safety standard.

V. The Radiation Protection Authority should keep records of; doses from occupational exposure, facilities and activities, sealed sources and radiation generators, inventories of radioactive waste and events involving radiation.

3.5 Qualified Expert

The following are the responsibilities of the qualified expert;

I. The qualified expert should be trained and formally recognised.

II. The qualified expert may offer consultation on matters to do with radiation safety, such as design of nuclear gauges and associated facilities, radiation shielding calculations, testing and monitoring of workplace instruments.

III. The qualified expert should work in close cooperation with the Radiation Protection Officer to ensure that all the necessary safety measures are performed.

Note: The responsibility for compliance with regulatory requirements should not be delegated to the qualified expert and should remain with the licensee.

3.6 The Radiation Protection Officer (RPO)

The following are the responsibilities of the RPO;

I. The RPO should be in charge of executing the radiation protection and safety program with regard to the nuclear gauge.
II. The RPO should be technically competent in relation to use of nuclear gauges.
III. The RPO should keep establish, keep and maintain a workplace monitoring programme.
IV. The RPO should be the liaison officer between RPA and the licensee.

Note: Selected duties of the RPO may be performed by the qualified expert

4 SAFETY ASSESSMENT

The operation of nuclear gauges must comply with RPA regulations. All gauges must be registered with RPA and approved for use before being put into operation. Once the nuclear gauge is approved for use before being put into operation, RPA will issue a licence to the applicant who will be using it.

4.1 Objectives for Safety Assessment

The objective of the safety assessment is to ensure that protection and safety is optimised, that is, the magnitude of the individual doses, the number of people exposed and the likelihood of incurring potential exposures are as low as reasonably achievable, economic and societal factors being considered.

4.2 Requirements for Safety Assessment

Tests will be conducted regularly by RPA to ensure that the radioactive source is secure within its capsule and is not leaking; the leak test will be conducted by the licensee annually. RPA will conduct a compliance inspection once every year to see if the tests have been performed on schedule, and to make sure that other licence conditions and regulations are adhered to.

The following are the requirements for a safety assessment;

4.2.1 Hazard Identification

The licensee should identify potential hazards associated with the use of nuclear gauges which include: radiation exposure to workers, the public, and the environment.

4.2.2 Risk Analysis

The likelihood and consequences of potential accidents or incidents involving nuclear gauges should be assessed, considering factors such as the type of gauge, its radioactive source, operational conditions, and the surrounding environment.

4.2.3 Training and Education

The licensee should develop and implement training programs to equip users with the necessary knowledge and skills for safe handling, operation, and maintenance of nuclear gauges.

4.2.4 Best Practices

The licensee should ensure best practices for the selection, installation, calibration, and maintenance of nuclear gauges to minimise radiation exposure and maximise operational efficiency.

4.2.5 Facilitate Quality Assurance and Control

The licensee should establish protocols for quality assurance and quality control to ensure the accuracy and reliability of nuclear gauge measurements while maintaining safety standards.

4.2.6 Promote Emergency Preparedness

The licensee should ensure that procedures and protocols for handling emergencies and incidents involving nuclear gauges, including response plans, evacuation procedures, and communication strategies are in place

4.2.7 Collaboration and Communication

The licensee should ensure that collaboration and communication among stakeholders, including government agencies, industry professionals, and community members, are in place to ensure a coordinated approach to radiation safety.

4.3 Safety Assessment Methodology

For nuclear gauges, the safety assessment should include consideration of the following:

4.3.1 The dose rate at the nearest accessible position (NAP) to the gauge must not exceed 7.5 µSv/h (0.75 mR/h). When the area near the gauge has a low occupancy rate, a higher dose rate may be permitted at the NAP, provided that the average dose rate to any person over any 8-hour period does not exceed 2.5 µSv/h (0.25 mR/h). Extra protection may be added, the position of the gauge changed, barriers should be erected or standard warning signs prohibiting loitering in the area should be displayed to ensure that this requirement is met. When necessary, a cage or screen must be erected around the gauge to restrict access to the direct radiation beam of the gauge. Cages or screens, however, must be erected in such a way that source containers are visible and shutter mechanisms easily accessible.

4.3.2 When a gauge is not required to function (e.g. if a line is closed down temporarily, or if a tank is emptied for maintenance) the source container must immediately be secured in the shielded or "beam off" position.

4.3.3 No modification to nuclear gauge assembly should be made without prior assessment of the implications of any proposed modifications for protection and safety. The safety assessment should be reviewed by a qualified expert and, where appropriate, by the Original Equipment Manufacturer or appointed representative.

4.3.4 The safety assessment should be reviewed annually or when any of the following factors apply:

a) Safety is compromised as a result of modifications introduced
b) Use of a new radiation source is planned
c) Current safety measures are invalid or are not fully effective
d) New standards, regulations or guidance come into force or are envisaged

NOTE:

- For nuclear gauges of an identical type, it will be acceptable to conduct a generic safety assessment.
- A new safety assessment might not be necessary when a source has been replaced with a source of identical type, unless there are changes in the working arrangements (for example occupancy of the area around the gauge).

5 RADIATION PROTECTION AND SAFETY PROGRAMME

5.1 Guidelines

Working with nuclear gauges is no different from working with other types of industrial equipment. Applicable rules and general guidelines on using, servicing, storing and transporting fixed and portable nuclear gauges should be adhered to. The table below outlines the applicable rules and general guidelines.

Guidelines	Fixed Gauge	Portable Gauge
Before Using the Nuclear Gauge		
Do not use or operate a nuclear gauge without adequate training, knowledge of the instruction manual, and authorisation.	•	•
Read the conditions of the licence	•	•

Post a copy of the licence in accessible and prominent area where all employees can see it.	•	•
Keep a copy of the licence in the gauge storage case		•
Notify other employees when a portable nuclear gauge should be used in the area where they are working.		•
Make sure that the gauge is clearly and durably labeled with the standard radiation warning symbol, details of the source and emergency contact numbers.	•	•
Guidelines	**Fixed Gauge**	**Portable Gauge**
Maintenance and Service		
Only the Original Equipment Manufacturer of the gauge, or a recognised service provider should attempt to repair the source, source holder, or shutter.	•	•
Always lock the shutter in the "off" position until maintenance is completed	•	•

Avoid any physical contact with, or direct exposure to the source and its assembly when performing any maintenance	●	●
Clean the gauge once or twice a week to prevent dirt getting near the shutter where applicable.	●	●
Guidelines	**Fixed Gauges**	**Portable Gauges**
Storage		
Before storing the gauge, make sure the source is in a safe position.		●
Lock the source and shutter in place	●	●
Never modify or change the source holder, shielding or safety interlocks without approval.	●	●
Store the nuclear gauge in a locked container area	●	●

For clear identification purposes in the event of theft, loss or damage, label the storage case with the same details as its corresponding nuclear gauge	•	•
Lock the area where the gauge is being stored. Post a standard radiation warning sign outside the storage area.	•	•
Guidelines	**Fixed Gauges**	**Portable Gauges**
Transportation and Disposal		
When sending gauges anywhere, make proper arrangements for receipt of the package at the delivery point.	•	•
When taking a gauge to and from a job site, place it in its container and keep it in an unoccupied part of the vehicle, such as the locked trunk or secure it to an integral part of the vehicle.		•
Lock the vehicle if the gauge is in it.	•	•

When sending a gauge to a supplier, package it according to the Transport Regulations of Zambia for radioactive materials. Label the package to indicate its contents and affix a standard radiation warning sign below. (Further information on packaging can be obtained by contacting RPA and also the Road Traffic and Safety Agency)	•	•
For disposal, return gauges to the approved supplier, appointed representative, the Original Equipment Manufacturer or to a waste disposal organization that is approved and regulated by RPA.	•	•

5.2 Key elements of radiation protection

5.2.1 Controlled and supervised areas designation.

5.2.1.1 Standard warning signs should be clearly displayed in areas where nuclear gauges are installed.

5.2.1.2 Fixed nuclear gauges should be procured and installed in a way that that they comply with regulations.

5.2.1.3 The controlled areas should be clearly marked during use and maintenance of nuclear gauges.

5.2.2 Local rules and supervision of the work with nuclear gauges

5.2.2.1 The rules describing work with the nuclear gauge should be written in a language that is understood by the employee.

5.2.2.2 Maintenance should never happen if not approved by the radiation protection officer.

5.2.2.3 The supervisor should be trained by the manufacturer on the use of the nuclear gauge and he/she should spearhead.

5.2.2.4 Observers should be at a safe distance from the site of operation

5.2.3 Occupational exposure and workplace monitoring designation

5.2.3.1 Unless you are the primary trained specialist, the nuclear gauge should be avoided when in use. The maximum yearly exposure is 0.05Sv

5.2.3.2 A Thermoluminecent Dosimeter should be worn to keep track of exposure. This dosimeter will then be submitted to RPA and/or licensed service providers at regular intervals of two months but not exceeding three months to keep track of the exposure.

5.3 Radiation Monitoring:

The exposure of workers using nuclear gauges will be assessed by individual monitoring or workplace monitoring.

5.3.1 Individual Monitoring

5.3.1.1 Individual monitoring is limited to certain workers actively involved in using the nuclear gauges. It will be undertaken where appropriate, adequate and feasible.

5.3.1.2 Personal dosimeters should be worn by all workers who are required to regularly enter controlled areas. They might also need to be worn by workers performing maintenance or workers routinely using portable gauges. The dosimeter should be correctly positioned on the body of the employee

5.3.1.3 Active personal dosimeters can help to immediately alert workers to elevated levels of radiation dosage, and hence increase safety measures. However, they should not be used as a replacement for workplace monitoring instruments (survey meters).

5.3.2 Workplace Monitoring

The workplace monitoring will be done in locations where the nuclear gauge is being used and surrounding areas. The frequency of monitoring will be as stipulated by the Radiation Protection Officer and the records are to be kept and presented to RPA whenever need arises.

5.3.2.1 Dose rate investigation levels will be prescribed for each location after the assessment.

5.3.2.2 Workplace monitoring can be used for indirect estimation of the radiation dose to workers – this is often the case when installed nuclear gauges are used. The programme is supervised by the radiation protection officer or qualified expert.

The measurement of dose rate will be conducted in the following positions:

Around storage facilities	Around nuclear gauges during routine and non-	At the operators positions during use of portable gauges and	At the entrance of the nuclear gauge enclosure	Around package containing portable gauge

	routine maintenance operations	during source loading /uploading operation		and around transport vehicle

5.3.3 Workplace monitoring instruments

5.3.3.1 The workplace monitoring instrument(s) should be suitable for measuring the types and levels of radiation around the nuclear gauge.

5.3.3.2 The licensee should arrange for formal testing or calibration at periodic intervals as guided by the Original Equipment Manufacturer. In addition, routine operational checks programme should be put in place.

5.3.3.3 When selecting a monitoring instrument, the following should be considered; humidity, temperature, radio-frequency interference and noise.

5.3.3.4 The licensee is required to ensure that radioactive sources are kept under proper control at all times - from the time they are first acquired until the end of their useful life.

6 SAFE OPERATIONS

6.1 Acquiring a nuclear gauge

Radiation sources, nuclear gauges and ancillary equipment should be obtained only from authorised suppliers. Import and export of sources should be consistent with the recommendations in the Code of Conduct on the Safety and Security of Radioactive Sources. This implies that an import licence from RPA should be needed to acquire a nuclear gauge. The supplier should provide the licensee with all necessary information on the safe use of the nuclear gauge.

6.2 Installation of Nuclear Gauges

Fixed nuclear gauges should not be mounted or installed unless specifically authorised to do so. The applicant should describe appropriate procedures and employee training provisions. The fixed nuclear gauge should be installed by the original equipment manufacturer or by a licensed service provider.

6.3 Maintenance and record keeping

Nuclear gauges should be subject to a routine preventive maintenance schedule. When performing maintenance on a nuclear gauge, a radiation monitor should always be used to confirm that shutters are fully closed and that the source is adequately shielded. The immediate area around a portable gauge should be cleared of all persons except for the nuclear gauge operator.

Maintaining records of sources and generators helps to ensure their proper control. Accountability checks of sources should take place periodically:

- For fixed nuclear gauges at least once per month;
- For portable gauges every time they are out of the store and once a week when they are in storage

6.4 Radioactive sources

Source capsules for gamma sources and neutron sources used in nuclear gauges should be certified as meeting the requirements for special form radioactive materials. They should be leak tested at least once every year and there should be a valid leak test certificate that is traceable to each individual source.

6.4.1 Restriction of radiation exposure

Nuclear gauges incorporate a radiation source: consequently, there is a potential for radiation exposure, during installation, routine operations, source exchange, and transport of radioactive sources or maintenance.

The main practical measures that can be used to ensure the restriction of radiation exposures are:

- Limiting the exposure time to the shortest possible for any planned work;
- Increasing the distance from the radiation source;
- Use of shielding suitable for a given radiation type and energy;
- Preventing of access to the radiation beam, for example by using shutters (manual or automatic), mechanical guarding and interlock systems. In some cases, designation of controlled areas might be necessary. If using physical barriers is not practicable other means should be used, such as continuous surveillance of the area and/or by using portable barriers and suitable warning notices.

6.5 Radiation generators

6.5.1 X-ray generators used in fixed nuclear gauges

Under normal operating conditions it should not be possible for workers to expose any part of the body to the primary X-ray beam. Attention should be paid to any scattered radiation. The X-ray generator should have safety interlocks, so that any attempt to access the X-ray beam (e.g. by opening an access door) will either cause the X-ray tube to switch off, or cause a shutter to automatically shield the X-ray beam. The shutter should be fitted with safety features such that it cannot be unintentionally opened. Automatic warning signals should be provided to indicate the status of the shutter (open or closed) and an illuminated warning should be activated when the X-ray equipment is energized.

6.5.2 Neutron radiation generators used in nuclear gauges

A neutron generator is a compact linear accelerator that produces high energy neutrons. Gamma radiation is also emitted, both during neutron generation and for some time after the generator is turned off. If the residual dose rate is significant a holding time to allow for the decay of

activation products is necessary. Both gamma and neutron radiation should be considered in shielding consideration. More details as provided for in IAEA Safety Standards Series No. SSG-57, Radiation Safety in Well Logging

6.6 Use of portable nuclear gauges

When a portable nuclear gauge is to be used on client's premises, the client should be consulted on the planning of the work.

This should include:

6.6.1 Agreeing the location and time of work. The client should allow sufficient time for the work to be performed safely

6.6.2 Discussing any specific measures for protection and safety of persons present on site

6.6.3 The client should be made aware of any hazards on site

6.6.4 The client should be provided with a copy of the licensees' local rules and emergency plans and procedures.

6.6.5 The suitable storage facilities should be arranged in advance when it is intended to store the sources at the client's premises.

6.7 Storage

6.7.1 Containers used for storing or exchanging radioactive sources from nuclear gauges should be designed to meet the applicable international/national safety standards. When in storage the source assembly of a nuclear gauge must be secured in the "beam off" position

6.7.2 No radioactive material or instrument or apparatus containing such material may be stored on any premises zoned for domestic purposes.

6.7.3 Each radioactive source container should have a lock designed to prevent unauthorized or accidental removal of the source.

6.7.4 Storage facilities should also be kept locked, unless under direct surveillance of operating personnel.

6.7.5 The storage facility should be built of materials providing sufficient shielding and designated as a controlled area or supervised area

6.7.6 Environmental conditions of the storage facility to be considered include, but are not limited to weatherproof and resistant to fire. The storage facilities should consist of a lockable room, purpose-built store or storage pit to which access is controlled. The safety and security level of such storage should be the same as at the licensee's premises

6.7.7 Dose rates outside the store must not exceed 2.5 μSv/h (0.25 mR/h)

6.7.8 No radioactive material may be stored with, or near any corrosive, combustible or explosive material.

6.8 Transport

6.8.1 The transport of radioactive sources used in nuclear gauges should conform to national and international transport regulations.

6.8.2 Portable gauges should be kept in the storage facility until they are to be moved to a new location. This applies also to any movement planned within the worksite. The gauge should be moved only in the original container, locked, with keys removed

6.8.3 An enclosed vehicle must be used for transporting the gauge by road. If an open van is used, a lockable canopy must be installed, or the gauge must be secured in the vehicle. The vehicle containing the nuclear gauge should be labeled with the standard radiation warning sign.

6.8.4 The vehicle should not be left unattended with the gauge in (or on) it. The nuclear gauge must be secured in the shielded ("beam off") position.

6.8.5 The gauge should be positioned as far as possible from the driver of the vehicle and should be so stowed as to prevent any shift under normal conditions of transport.

6.8.6 The maximum radiation level at the position of any person in the vehicle should not exceed 20 µSv/h (2 mR/h)

6.8.7 Nuclear gauges may be dispatched by public transport (i.e. by ship, air freight or road) provided that the following additional requirements are met:

6.8.7.1 The source container should be packed in an outer shipping container/package which is of strong, rigid construction. The source container should be effectively immobilized within the outer container.

6.8.7.2 The outer shipping container should bear approved transport labels in accordance with the radiation levels associated with the gauge.

6.8.7.3 The gauge should be accompanied by properly completed transport documents specifying the radioactive content

6.9 Disposal of radioactive sources and radiation generators

The recommended working life is an indication of the period of time over which a radioactive source is expected to retain its integrity. The source should be replaced when it reaches the end of its recommended working life. The regulatory body may agree to the extended use of a source beyond its recommended working life if the source is subjected to more frequent or more detailed leakage tests.

Agreements should be made with manufacture or supplier for disused radioactive sources to be returned to the original supplier or transferred to another authorised

body. A gauge containing a disused source should never be disposed of as a scrap and should remain part of the source inventory until transferred to a suitably authorised organisation.

Nuclear gauges that are no longer in use:

6.9.1 Should be formally removed from the point of use/installation and removed from the site. The regulatory body should be informed about the source removal. Radioactive sources and radiation generators should be transferred to an authorised organisation for safe disposal. If possible, they should be returned to original supplier. If it is not possible the regulatory body should authorize another action.

6.9.2 The relevant records should be maintained as specified by regulatory body.

6.9.3 All standard radiation warning signs and other notices should be removed from the facility and a workplace monitoring survey should be conducted by the RPO or qualified expert, to confirm that the sources have been removed from the site.

6.9.4 A final decommissioning plan including the final radiation survey and the details of storage, transfer or disposal of sources of radiation should be prepared in advance.

7 EMERGENCY PREPAREDNESS AND RESPONSE

In many cases, incidents involving nuclear gauges can be prevented or their consequences can be mitigated if the appropriate precautions are taken.

Incidents involving nuclear gauges include:

a) Jammed or broken shutters;
b) Other mechanical damage to gauges (e.g. crushing);
c) Higher than expected dose rates;
d) Missing sources;

e) Leaking sources due to mechanical impact, fire or corrosion;

f) Malicious acts such as theft of nuclear gauges (especially portable gauges).

7.1 Emergency plan and procedures

The licensee must have a set of emergency procedures and a plan of action in case of an accident or in the event of damage to the gauge. If uncertain about what to do during a malfunction, accident or damage, the following steps should be taken:

a) Cease work immediately

b) If the gauge has been partially damaged or destroyed, keep people at least 10 meters away.

c) Have leak tests performed after any incident that may result in source damage.

d) In case of accident or fire, do not use the gauge until any danger from or damage to the source is assessed.

e) Inform RPA within 24 hours of any theft, accident or incident involving the nuclear gauge

7.2 Emergency Equipment

For emergencies involving nuclear gauges, consideration should be given to the need for the following equipment, as appropriate:

a. Appropriate workplace monitoring instruments to measure both high and low dose rates;

b. Active personal dosimeters;

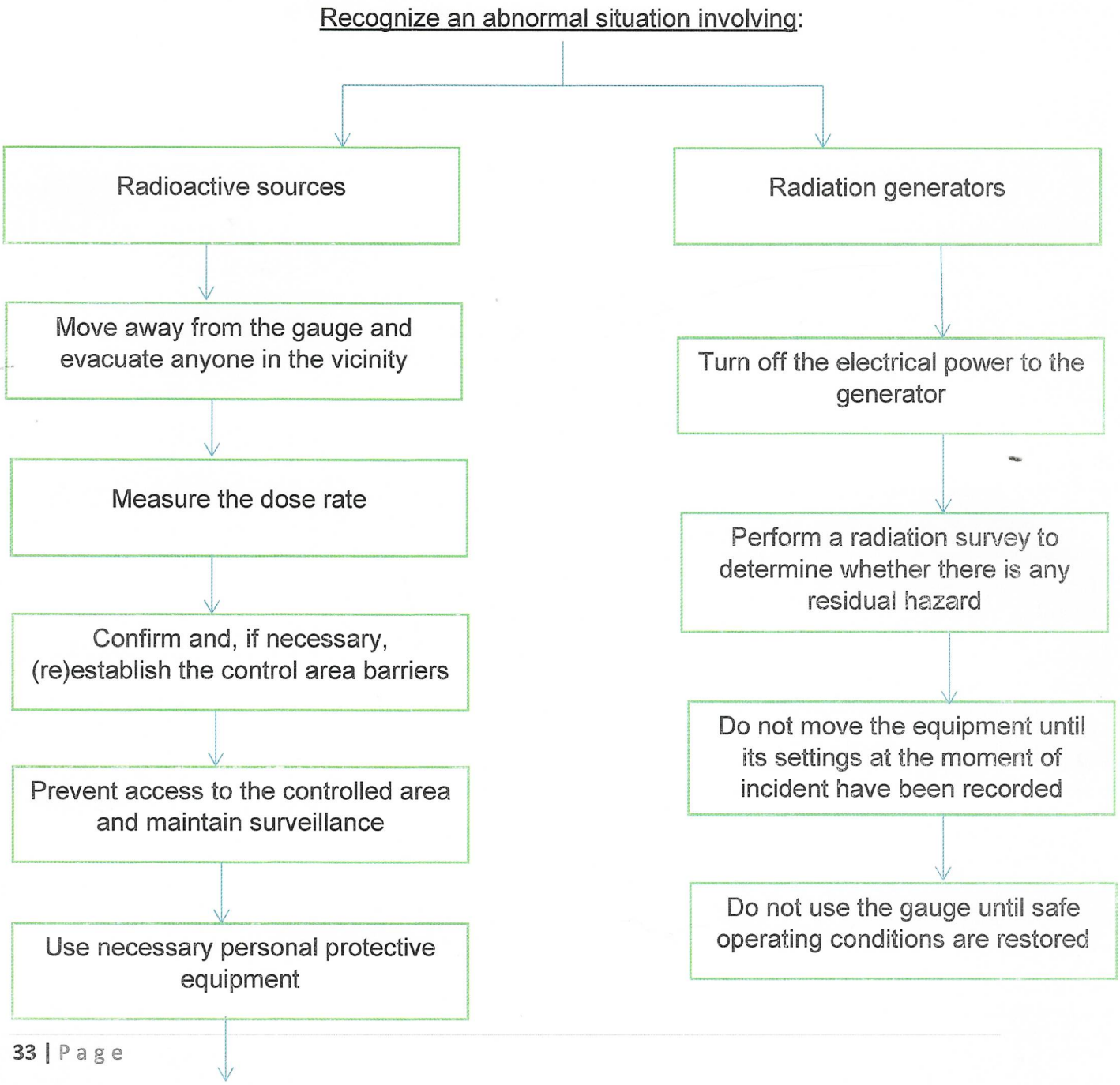
c. Barrier materials and warning notices for the temporary designation of a controlled area; Emergency preparedness and response

d. If appropriate, suitable local shielding, such as blanking plates to shield the primary beam in the event of the shutter being stuck in the open position;

e. Forceps or remote handling tongs, and a spare source container with adequate shielding;

f. Wipe test kit for leak testing sources and for other surface contamination checks;
g. Communication equipment (e.g. portable phones);
h. Spare batteries and torches. if it is known or suspected that a source capsule has ruptured the operating organization should promptly seek advice from a qualified expert

7.3 Response procedures for incidents involving nuclear gauges



Inform relevant authorities, including client

health dangers if basic precautions are taken.

es and the principles of radiation protection and

by helping others do likewise the nuclear gauge can be used safely.

8. REFERENCES

INTERNATIONAL ATOMIC ENERGY AGENCY, Radiation Safety in the use of Nuclear Gauges, IAEA Safety Standards Series No. SSG-58, IAEA, Vienna (2022).

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