IAEA Safety Standards Series No. SSG-57
Radiation Safety in Well Logging
in a nutshell

Nuclear Safety and Security Programme
IAEA Safety Standard General Safety Requirement (GSR) Part 3 on Radiation Protection and Safety of Radiation Sources establish requirements for protection and safety across all facilities and activities involving ionizing radiation and radioactive materials. Use of radiation sources in well-logging practices and in nuclear gauges are ever increasing worldwide and the safety and security of these sources remain a concern. The IAEA has recently published two new Safety Guides on radiation safety in well logging (SSG-57) and radiation safety in the use of nuclear gauges (SSG-58) that provide recommendations and guidance for the protection of workers, public and the environment from these radiation sources. These recommendations combined with the requirements established in GSR Part 3 provide the framework to help regulatory bodies and operating organizations, as well as their employees and radiation protection officers, strengthen radiation safety within these industries.

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Disclaimer: In all cases, the original text of IAEA Safety Standards Series No. SSG-57, Radiation safety in well logging (1) takes precedence over the text in this booklet.
Well logging is used to characterize and evaluate geological formations, boreholes and well constructions. It is used in mining, ground engineering, water industries as well as oil and gas exploration and production. Well logging includes the use of logging tools containing a radioactive source (usually one or more sealed radioactive gamma or neutron sources) or a neutron generator.

The objective of IAEA Safety Standards Series No. SSG-57, Radiation Safety in Well Logging (1) is to provide recommendations on how to meet the relevant requirements of IAEA Safety Standards Series No. GSR Part 3, Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards (2) in relation to well logging involving radiation sources.

Safety culture

Although the radiation sources and associated equipment used in well logging incorporate safety features there is a high reliance on safe working procedures to ensure protection and safety. The operating organization should promote and maintain safety culture by for instance by promoting commitment to safety within the organization, encouraging open communication and a questioning and learning attitude.

Selected main duties and key responsibilities of parties involved in well logging

GSR Part 3 (2) provides the general framework for establishing a robust governmental, legal and regulatory infrastructure for safety of well logging facilities and activities. For more details refer to Section 2 of SSG-57 (1).

The main parties are:

- **Government** establishes legislation that provides the statutory basis for protection and safety.

- **Regulatory body** establishes or adopts regulations and guides for protection and safety and ensures their implementation. It also issues authorizations for well logging, and conducts inspections of well logging.

- **Operating organization** has the prime responsibility for safety of well logging facilities and activities. In order to ensure that protection and safety is optimized it establishes and implements a radiation protection programme. The operating organization is usually a well logging company that employs or contracts workers undertaking well logging operations. It is expected to comply with regulatory requirements.
Well logging is used for recording the geological formations in a borehole.

**Radiation protection officer** oversees the application of the safety requirements, has the authority to intervene to stop an unsafe or non-compliant operation and has other specific responsibilities for protection and safety.

**Qualified expert** is formally recognized as having expertise in radiation protection and the safe operation of well logging tools and is consulted as necessary by the operating organization.

**Workers** are required to fulfil their obligations and perform their duties for protection and safety. Itinerant workers should have the same level of protection and safety as workers employed permanently.

**Clients** if the well logging is undertaken on the site where there are already other radiation sources present it is the client (the operating organization in terms of the site) who is responsible for protection and safety with the regard to the radiation hazard associated with the site, and the well logging company with regard to the use of well logging sources. Their cooperation with other parties is key for protection and safety.
Radioactive sources used in well logging normally fall into Category 3 or Category 4 (in a five categories system, where Category 1 sources are considered to be the most ‘dangerous’) (3). However, the aggregation of sources at a particular well logging site might fall into Category 2. Since many of the radiation sources used in well logging can produce high dose rates they should be subject to a comprehensive safety assessment.

The safety assessment is the primary tool for determining which control measures should be taken, and for confirming that all factors that have a bearing on protection and safety are considered. The associated hazards and control measures should be considered for both normal operating conditions and reasonably foreseeable incidents.

- Prospective users of well logging sources are expected to submit a safety assessment to the regulatory body when applying for an authorization; therefore, the safety assessment should be prepared and documented before any radiation sources are received by the operating organization.

- Suppliers of well logging sources are required to seek an appropriate authorization before selling or delivering them in a State, in accordance with the regulatory requirements of that State.

- For well logging tools containing radiation sources of a similar type, it might be acceptable to conduct a generic safety assessment.

- A new safety assessment might not be necessary when a source is to be replaced with a source of identical type and source strength, unless there are changes in the working arrangements.

- The safety assessment is expected to be independently verified before being submitted to the regulatory body as part of the authorization process.

“The safety assessment should take into account that the magnitude of the individual doses, the number of people exposed and the likelihood of incurring potential exposures are all to be kept as low as reasonably achievable, economic and societal factors being taken into account.

Any interaction between these various factors should be taken into account.”

Paragraph 3.12 of SSG-57 (1)
SAFETY ASSESSMENT

Safety assessment methodology

For well logging, the safety assessment should include consideration of the following:

Normal operating conditions:
• Storage of the well logging sources;
• Calibration and operation of the well logging tools;
• Transport of the sources;
• Work at the site with the well logging tools;
• Maintenance of the tools;
• Disposal of disused sources.

Reasonably foreseeable incidents – selected examples:
• Source becoming detached from the logging tool;
• Source stuck in the tool or container;
• Tool stuck down the well or borehole;
• Neutron generator failing to de-energize;
• High dose rates present in an area that is not designated as a controlled area;
• Suspected or actual overexposure of individuals to ionizing radiation;
• A missing, lost or stolen source;
• A damaged or leaking source, for example due to mechanical damage, fire or explosion in a work or storage area;
• Events involving rupture of well logging source;
• An accident during the transport of radioactive sources.

For each of the above scenarios, following elements should be assessed:

1. External radiation hazards
2. Internal radiation hazards
3. Who would be exposed to these hazards?

Control measures

Engineered controls, for instance:
• Shielding, design and use of storage facilities, logging tool containers, transport packages, the use of appropriate handling tools, temporary containers.
Administrative controls, including:

- Safe working procedures, including local rules;
- Transport package labelling and documentation;
- Designation of controlled areas and delineation with barriers and warning signs;
- Staff training and appointment of a radiation protection officer;
- Advice from a qualified expert;
- Workplace monitoring, individual monitoring and health surveillance;
- A preventive maintenance programme;
- Periodic safety audits of operations;
- Leak testing of sealed radioactive sources;
- Records of source accountancy and source movements.
The radiation protection programme includes organizational, procedural and technical arrangements for the measures to control radiation hazards and to optimize protection and safety. This includes:

• Management policies for protection and safety, supported by an organizational structure that assigns responsibilities for safety
• A training programme for protection and safety
• Local rules and supervision to ensure safe working
• Arrangements for:
  – The safety and security of radioactive sources
  – The designation of controlled and supervised areas
  – Radiation monitoring and for health surveillance
• Emergency arrangement for responding to incidents involving radiation sources.

A radiation safety committee should be established in larger companies that have a significant number of well logging tools and well logging applications, for the purpose of regularly reviewing the implementation of the radiation protection programme.

A suggested structure of well logging local rules is presented in Annex V of SSG-57 (1). For more details refer to Section 3 of SSG-57 (1).
Individual monitoring

For work involving the assembly, calibration and use of well logging tools containing radiation sources, it will normally be appropriate for workers to wear personal dosimeters to directly assess their occupational exposure. Personal dosimeters are required to be worn by all workers who usually work in controlled areas. The dose limits for occupational exposure are defined in Schedule III of GSR Part 3 (2).

Passive dosimeters

There are various types of passive dosimeters available for measuring individual doses from gamma well logging sources. These include thermoluminescent dosimeters, optically stimulated luminescent dosimeters and film dosimeters. Some of these dosimeters also offer a neutron dose measurement capability.

Alternatively, separate neutron dosimeters (for example, track etch detectors) may be worn. All these types of dosimeters incorporate one or more passive elements to record radiation exposure. The dosimeters are supplied by and returned to an accredited dosimetry service that then processes the dosimeters to assess the dose received.

Active dosimeters

Active personal dosimeters are a useful tool to warn of high dose rates or to prevent overexposures. The operating organization should provide them to any well logging personnel who regularly undertake well logging work with radiation sources.

Active personal dosimeters should not replace passive dosimeters unless they have been specially approved (for example by the regulatory body) for this purpose. In most cases, active personal dosimeters will supplement the passive dosimeters worn by well logging personnel. However, in any case they should not be used as a replacement for workplace monitoring instruments.

Workplace monitoring

Workplace monitoring should be carried out during well logging operations. The workplace monitoring programme should describe the locations to be monitored, the frequency of monitoring and the records to be kept. This information should be included in the local rules and should also be described in the radiation protection programme. Dose rate investigation levels should be prescribed for each location.

“Records of occupational exposure for each worker shall be maintained during and after the worker’s working life, at least until the former worker attains or would have attained the age of 75 years, and for not less than 30 years after cessation of the work in which the worker was subject to occupational exposure.”

Paragraph 3.104 of GSR Part 3 (2)
Workplace monitoring can be used for indirect estimation of the radiation dose to workers – this is often the case for workers who are not directly involved in well logging with radiation sources.

Well logging uses sealed radioactive sources and surface contamination is not normally present. However:

- It might be necessary to perform periodic checks for radioactive contamination on accessible surfaces of the logging tool at time intervals specified by the regulatory body. Monitoring for radioactive contamination within the well logging area, on the surface of the transport package or on well logging workers is not normally necessary.

- The operating organization should consider the need to monitor logging tools for contamination due to naturally occurring radioactive material (NORM). If such contamination is detected, the operating organization should ensure that the tool is decontaminated and the resulting waste is disposed of in an appropriate manner. More details may be found in IAEA Safety Report Series No. 34 Radiation Protection and the Management of Radioactive Waste in the Oil and Gas Industry (4). If it is known that NORM is present in areas where well logging operations are to be performed, the suitable arrangements to prevent the spread of radioactive contamination, to protect well logging personnel and to dispose of any waste arising should be undertaken.

**Workplace monitoring instruments**

Workplace monitoring instruments should be selected to accurately measure the types of radiation emitted by the radiation sources used in well logging. The operating organization should arrange for formal testing or calibrating of these instruments at periodic intervals by a specialized testing laboratory. In addition, the operating organization should implement a programme of routine operational checks.

When selecting a monitoring instrument, account should be also taken of the environmental conditions, such as humidity, temperature, radio-frequency interference or noise. In many oil and gas facilities, only instruments that are designed to minimize the likelihood of accidental ignition of flammable fumes or vapours (‘intrinsically safe monitoring instruments’) are allowed to be used.
The operating organization 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 lifetime. The manufacturers and suppliers of radioactive sources and radiation generators should provide all necessary information on their safe use to the operating organization.

**Sealed radioactive sources**

Well logging equipment utilizes sealed radioactive sources that emit gamma radiation or neutron radiation. They are installed into logging tools using special source handling tools. The radioactive sources (or in some cases, the pre-loaded logging tools) are housed in shielded containers when not in use. The part of the tool containing the radioactive source is attached to the main logging tool string, to be transferred to the borehole or well (or else to a calibration facility).

Sealed radioactive sources used for well logging purposes should be compatible with the tool and any ancillary equipment (such as handling tools) with which they are used. Such sources should also meet international or equivalent national standards, for example:

- Sources should comply with the relevant requirements set out in ISO 2919 (5).
- Sources should be certified as meeting the requirements for special form radioactive material, as established in IAEA Safety Standard Series No. SSR-6 (Rev. 1), Regulations for the Safe Transport of Radioactive Material, 2018 Edition (6).
- Sources should be leak tested in accordance with ISO 9978 (7) or an equivalent national standard, and there should be a valid leak test certificate that is traceable to each individual source.
- Sources should be marked in accordance with ISO 2919 or an equivalent national standard, or, at a minimum, marked with the radiation symbol (trefoil) and the word ‘RADIOACTIVE’.

**Neutron generators**

A neutron generator used for well logging is a compact linear accelerator of deuterium nuclei, which produces high energy neutrons. There is also gamma radiation emitted both during neutron generation and for some time after the generator is turned off. The neutron generator components also often include a target containing radioactive material (tritium).
The neutron generator should be kept switched off until the well logging tool is underground, typically at a depth of 20 to 50 meters. Equally, when raising a generator from a well it should be switched off and remain down the hole at this depth to allow for the decay of short lived activation products. The dose rate at 0.1 m from the tube target should normally be below 1 μSv/h, or else below a value established by the regulatory body, before personnel can be permitted to directly handle the generator.

See Annex III of SSG-57 (1) for more detailed information on radiation safety of neutron generators used in well logging.

Safety of neutron generators in calibration operations
Shielding materials of low atomic number are normally the most cost effective and practical approach for reducing dose rates around neutron generators during calibration operations. Information on shielding calculations for neutron radiation is provided in Annex IV of SSG-57 (1). The geometry of the shielding should be designed to restrict the exposure of the workers undertaking the calibrations, with due account for scattered neutron radiation.

Storage of sources
The well logging company should have a source storage facility at its main base and on-site storage facilities, as necessary. Such stores should be built of materials that provide sufficient shielding and should be designated as a controlled area or supervised area, as appropriate. The environmental conditions should be taken into account, for instance stores should be weatherproof and resistant to fire. Each container for a radioactive source should have a lock (or outer locked container or enclosure) designed to prevent unauthorized or accidental removal of the source.

Storage facilities are required to be kept locked when containing radioactive sources except when under the direct surveillance of operating personnel.

Preparation for site operation
As well logging work is generally performed on the premises of a client rather than on the premises of the operating organization, the client should be consulted on the preparation and planning including the location and time for the well logging work to be performed. The designation of areas and the use of signs, warning signals and alarms during the well logging work should be discussed between the parties, to avoid possible confusion on the site, while remaining consistent with regulatory requirements.

• It is useful to prepare a written agreement between the operating organization and the client clearly specifying the outcomes of the planning and preparation, and the associated roles and responsibilities of each party.
• The well logging personnel should be made aware of any hazards on the site in the locations where the work is planned.

• Any permit-to-work systems or other site safety procedures implemented by the client should be followed.

• The client should be provided with a copy of the operating organization’s local rules and emergency plans and procedures.

**Designation of controlled areas on site**

On-site well logging work should be performed in an area designated as a controlled area. No other work should be permitted in this area until the well logging work has been completed.

• The typical values for the maximum dose rate at the controlled area boundary are in the range 2.5-20 μSv/h. However, it is often practicable to achieve a dose rate of less than 1 μSv/h.

• Transient dose rates outside the controlled area during source loading and unloading will be much higher than the dose rates during the actual well logging operation when the source is in the borehole. Additional care should be taken during these operations, to ensure that there is no significant risk to persons standing at the boundary of the controlled area.

• In order to prevent unauthorized access to the controlled area its boundary should be demarcated by physical means such as walls, using temporary barriers or cordonning off the area with tape and clearly displayed warning signs.

• The well logging work should be arranged in such a way that there is no need to designate controlled area outside the operational area. The extent of the controlled area may be limited by using additional shielding, while its surroundings might be designated as supervised area depending on the dose rate outside.

**Transport of radioactive sources**

The transport of radioactive sources (including neutron generators containing tritium) used in well logging should conform to national regulations and the requirements of IAEA Safety Standards Series No. SSR-6 (Rev.1) (6).

The radioactive sources should be kept in the storage facility until they are to be moved to the new location, including any movement planned within the worksite. They should be moved only in shielded containers, locked, with keys removed.
Disposal of sources

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 it is subjected to more frequent or more detailed leakage tests.

When a well logging facility or radiation sources are no longer used, and there are no plans to use them again in the foreseeable future, the facility should be formally decommissioned. All radiation symbols and other notices should be removed from the facility and a workplace monitoring survey should be conducted by the radiation protection officer or qualified expert, to confirm that the sources have been removed from the site.

Radioactive sources should be disposed of in a manner consistent with the national regulatory framework.

- Disused sources and neutron generators should be transferred to an authorized organization for safe disposal. If possible, they should be returned to original supplier. If it is not possible the regulatory body should authorize another action.

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

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.
Incidents involving well logging radiation sources may compromise both safety and security. Such incidents can be prevented or their consequences can be mitigated if the appropriate precautions are taken.

The requirements for an adequate level of preparedness and response for a nuclear or radiological emergency are established in IAEA Safety Standards Series No. GSR Part 7, Preparedness and Response for a Nuclear or Radiological Emergency (8). Radioactive sources used in well logging generally are in emergency preparedness category IV.

Incidents involving well logging sources include:

- Mechanical damage to well logging equipment;
- Loss of shielding resulting in higher dose rates than expected;
- Missing radioactive sources;
- Dropped or detached sources;
- Sources stuck in a well or borehole;
- Leaking sources due to mechanical impact, corrosion or fire;
- Natural disasters (e.g. a hurricane, flooding);
- Malicious acts such as theft of sources.

See Annex VI of SSG-57 (1) for some examples of recorded incidents involving radiation sources in well logging.

Potential emergencies that could affect workers, members of public or the environment should be identified in the operating organization’s safety assessment.

Emergency plans and procedures

The operating organization is required to have an emergency plan and procedures prepared in advance. When well logging work is to be performed on a client’s premises, the plan and procedures should be discussed with the client. Emergency procedures for a well logging facility should include the following:

- A clear statement of roles and responsibilities;
- A concept of operations;
- Communication and coordination arrangements;
- Protocols for notification of an emergency;
- Instructions to site personnel;
- Instructions for delineation of the affected area and access control;
- Measures to protect emergency workers, as appropriate.
It should be taken into account that the implementation of the on-site emergency plan and procedures may require off-site support.

**Emergency equipment**

For emergencies involving well logging sources, 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 alarm dosimeters;

(c) Additional personal dosimeters;

(d) Barrier materials and warning notices for the temporary designation of a controlled area;

(e) Local shielding, such as bags of lead shot or lead sheets;

(f) Suitable tool kits and source recovery equipment (long handled tongs, pliers, screwdrivers, bolt cutters, adjustable spanner);

(g) A spare shielded container;

(h) Wipe test kit for leak testing sources and for other surface contamination checks;

(i) Communication equipment (e.g. mobile phones);

(j) Spare batteries and torches;

(k) Necessary personal protective equipment.

If it is known or suspected that a source capsule has ruptured, the operating organization should promptly seek advice from a qualified expert.

**Response procedures for incidents involving radiation sources in well logging**

Paragraphs 13.17–13.20 of SSG-57 (1) provide recommendations on the immediate actions to be taken by workers and by the radiation protection officer when an incident involving a well logging source occurs, as summarized below.


