1.0 INTRODUCTION

This Standard establishes the minimum HSE/SA requirements to be met in respect of potential exposure to radiation unless legislation and/or local regulations impose a higher standard in which case that higher standard shall be followed.

2.0 SCOPE

This Standard applies to all ABB units in all ABB legal entities, including joint ventures/ consortia/ working partnerships with management control.

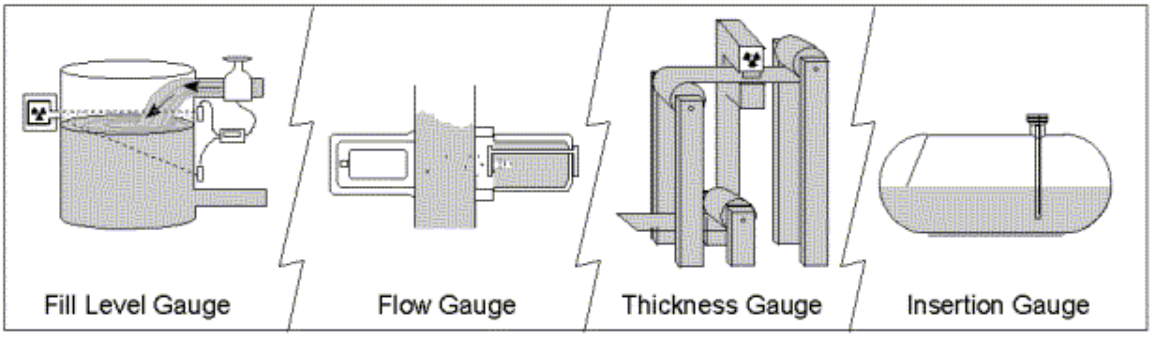
3.0 POTENTIAL SOURCES

3.1 Industrial gauging

ABB produces gauges that use various radiation sources for measuring the properties of sheet processes (e.g. paper, films, metals, etc.). This product line is known as Quality Control Systems (QCS). The sensors in the QCS systems use beta emitting radioactive materials (Kr-85, Pm-147, and Sr-90), x-ray tubes, and lasers to measure various properties of the processes.

Many of ABB's customers also use radiation sources for other industrial gauging applications such as level, density or thickness measurements.

The sources used are designed to be safe to use by end customers with very limited radiation safety training. ABB employees who handle the radiation sources shall be trained in the specific hazards associated with the sources and must be specifically authorized to perform any services on the sensors with the radiation sources.



3.2 Non-destructive testing

Many industrial facilities are required to perform testing on different parts of their facilities (e.g. piping welds) to ensure quality and/or compliance. One way to complete this test is to use a radioactive material with a high energy to produce an image of the target parts, like a medical x-ray image. These sources can only be handled by companies with specific approval by the local nuclear regulatory agency. Additionally, these companies must have an exemplary safety record due to the very serious hazard associated with the radioactive material sources.

4.0 HAZARDS AND RISKS

4.1 Radiation basics

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Radiation comes in many forms. However, it can be most simply divided into two types, radioactive materials and radiation generating equipment. Radioactive materials consist of unstable nuclear atoms that, in an effort to become more stable, give up energy in the form of radiation. This radiation can be electromagnetic photons or particulates. Uncontrolled exposure to radiation represents a significant risk to health and hence it is important to check that all shutters on such equipment are closed before any work is undertaken on the equipment.

1) **Electromagnetic radiation** (photons) includes:
   i. Gamma-rays
   ii. Bremsstrahlung
   iii. X-rays
   iv. Non-ionizing (visible light, microwave, radio, etc.)

   Electromagnetic radiation (photons) differs in frequency, wavelength, and energy. Ionizing radiation has sufficient energy to disrupt the structure of an atom, causing the formation of charged ion pairs. These ions can cause damage in human tissue. Lead, concrete, or steel are the best shielding materials for photons.

2) **Particulate Radiation*:***
   i. **Alpha Particles** - Alpha particles are Helium nuclei consisting of two protons and two neutrons. They readily interact with matter, giving them a short range (a few centimeters in air). They are of no concern as an external radiation hazard but can be a hazard if alpha emitting isotopes enter the body through contamination and subsequent ingestion or via inhalation.
   ii. **Beta Particles** - Beta particles are energetic electrons emitted from the atom as a spectrum of energies. The range of a beta particle is dependent on its energy and the material it is traveling in. In general beta particles will not penetrate human tissue more than 1 cm and can be stopped by about 1 cm of Lucite or Plexiglas. Using materials such as lead or steel to shield betas may result in Bremsstrahlung production, replacing the beta hazard with an x-ray hazard.
   iii. **Neutrons** - Neutrons are indirectly ionizing particles with no charge. They are produced mainly in particle accelerators, nuclear reactors, and isotopic neutron generators. The energy of the neutron is dependent on its source, and neutrons may be found as a spectrum of energies. They are shielded with materials such as water or borated polyethylene.

3) **Radiation Generating Devices**

   Radiation can also be generated by man-made devices. Some examples include x-ray machines and lasers. The electromagnetic radiation emitted from these machines is physically similar to electromagnetic radiation emitted from radioactive materials.

4.2 Detection and Measurement

Ionizing radiation is not detectable with the human senses. Radiation survey instruments are therefore used to determine the presence of radiation fields. Geiger Mueller (or GM) detectors are the most common type of survey instrument. They detect the ion pairs formed when beta, gamma or x-ray radiation cause ionizations in the gas in the detector. GM survey meters read out in mR/hr or cpm.

4.3 Units of radiation

The international unit used for radioactivity is the **Becquerel** (Bq) which is equal to 1 dps. The **Curie** (Ci) is also a unit of radioactivity and is equal to 3.7×10^{10} (nuclear) disintegrations per

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second (dps). Because the Ci is so large and the Bq is so small, we often use prefixes to define levels of activity and examples include:

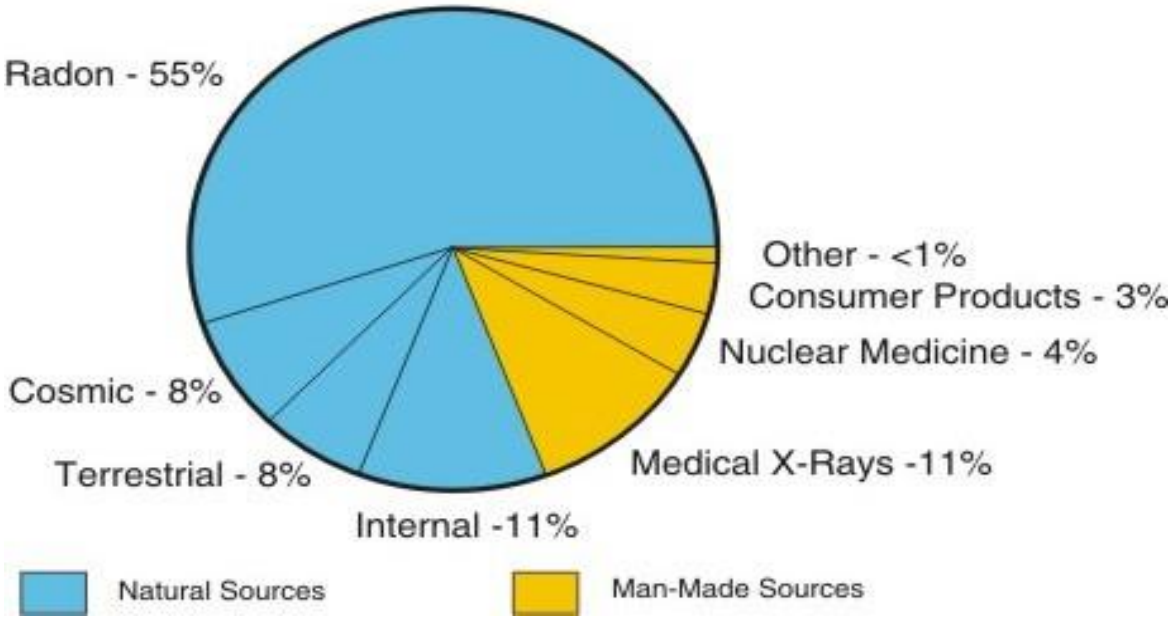
(p) pico (10^{-12}) (n) nano (10^{-9}) (μ) micro (10^{-6}) (m) milli (10^{-3})

(k) kilo (10^{3}) (M) mega (10^{6}) (G) giga (10^{9}) (T) tera (10^{12}).

The **Roentgen** (R) is the unit of radiation exposure (ionization in air). The R (or mR) is the unit usually seen on the meter face of Geiger counters or other survey meters. The Gray (Gy) and the **rad** (Radiation Absorbed Dose) are the units of absorbed energy dose where 1 Gy = 100 rad. The **rem** (Roentgen Equivalent Man) and Sievert (Sv) (1 Sv = 100 rem) are indices of biological harm relating to the damage done by radiation. The rem is also referred to as the unit of risk.

4.4 Radiation effects

1) **Natural Background and Man-made Radiation Doses** - Each of us receives about 300-400 mrem/year from natural sources.



These include solar, cosmic radiation, radon (gases) from soils, and internal dose from Potassium-40 and Carbon-14. We also receive about 70 mrem from man-made sources, primarily from medical applications. Your altitude above sea level and the location and construction materials in your home can also influence your background dose. For example: At higher elevations, the background dose increases. The level of natural background radiation varies depending on location, and in some areas the level is significantly higher than average. Such areas include Ramsar in Iran, Guarapari in Brazil, Kerala in India, the northern Flinders Ranges in Australia and Yangjiang in China

2) **Internal versus External Dose** - External dose is the passage of radiation into tissue from outside the body. Internal dose results from isotopes that have been deposited inside the body. Internal deposition can only result from one of the three entry pathways: ingestion, inhalation, and absorption through the skin or skin punctures.

3) **Acute versus Chronic Doses and Effects** - Chronic radiation doses are received over many years. Acute radiation doses are received in a few hours. The biological effects of chronic doses up to 150 rem over 30 years and acute doses up to 10 rem are not normally detectable. At acute doses of 10 to 75 rem, temporary changes in blood cell

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chromosomes have been observed. At acute doses of 100 to 400 rem biological effects include erythema (skin reddening) and acute radiation syndrome (loss of hair, nausea, dehydration and possible death) have been observed. The LD 50/30 for humans (the lethal dose for 50% of a population exposed within 30 days without medical treatment) is about 500 rem.

4.5 Occupational and non-occupational radiation exposure limits

Whole body (1 cm or 1000 mg/cm^2 external exposure)	2000 mrem/y	20 mSv/y
Lens of the eye (0.3 cm or 300 mg/cm^2)	15,000 mrem/y	150 mSv/y
Extremities (arm below elbow or legs below knee)	50,000 mrem/y	500 mSv/y
Skin (0.007 cm or 7 mg/cm^2)	50,000 mrem/y	500 mSv/y

(NOTE: this will vary by country and must be confirmed for each local region)

5.0 OPERATIONAL CONTROLS

5.1 Risk assessment

As with all work activities there is a requirement to undertake a risk assessment in order to identify the appropriate control measures to mitigate the risks associated with the work. It is essential when applying this to work involving equipment where there is potential for exposure to radiation that the hazard is clearly understood. This will entail identifying the nature of the radiation source, its strength or size and how it is protected. In the case of such equipment being used within ABB facilities the local HSE advisor will advise and there should already be in existence the safe methods of operation and maintenance which should set out how such equipment can be operated, serviced and maintained safely and without risk to health. This information should be available from the manufacturer. It should be possible to carry out the work without receiving any significant radiation dose and well within the occupational exposure limits. There should also be in existence records of maintenance of the equipment including the results of any leak tests.

For work on project or customer sites, suitable enquiries will need to be made at the pre-contract stage to establish the range of equipment used on site which may contain sealed sources and their strength or size and what protection measures are currently provided. It should also be possible establish the manufacturers' recommended method for servicing and maintaining the equipment safely and without risk to health. All this information must be available to the LBU/PGU before any work starts on site.

As with all HSE risks, the hierarchy of control shall be applied where risk avoidance and elimination are the preferred options over risk reduction and control. In terms of exposure to radiation this principle becomes very important and in all cases no ABB employees or any contractors working on ABB's behalf shall be exposed to radiation as a result of a non-naturally occurring radiation activity where such exposure is avoidable. Thereafter, exposure shall be both limited and monitored so that the person's dose is monitored over time so that it is kept within the relevant occupational exposure limit.

No persons (ABB or contractors' employees) shall undertake any work on plant or equipment where there is involving potential exposure to radiation from sealed sources unless they have received the appropriate training and are competent to undertake the work safely and without risk to health.

5.2 Limiting External Radiation Exposure

There are three basic elements to be considered in minimizing exposure or dose. These are time, distance, and shielding or protection.

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1) **Time** - Radiation field measurements are always expressed as a rate, i.e. mrem/hr (or cpm). The amount of time spent in a radiation field should be kept to the minimum required to perform the task.
2) **Distance** - Radiation follows the inverse square law. The intensity of the radiation field decreases with the inverse square of the distance from the source. For example, standing twice as far from a source will reduce the radiation field intensity to ¼ of the original intensity.
3) **Shielding** - Shielding is used to reduce field intensity by attenuating the intensity of the radiation. Always use the appropriate shielding for the isotope being used.

In all cases the risk assessment shall be carried out to determine the level of risk and identify the appropriate control measures. In all cases, the equipment should be isolated and the manufacturers' instructions followed.

5.3 ALARA

Most experts and regulators agree that a linear dose-to-risk model (risk increases as dose increases) presents the safest assumption of the risk relationship for radiation exposure. This view drives the ALARA concept, which aims at keeping radiation exposures **A**s **L**ow **A**s **R**easonably **A**chievable (or in some countries ALARP - **A**s **L**ow **A**s **R**easonably **P**racticable) consistent with the state of the technology, the economics of the situation, and other societal and socioeconomic considerations. This means making every reasonable effort to maintain exposures to ionizing radiation as far below the dose limits as is practical, consistent with the purpose for which the licensed activity is undertaken, and taking into account the state of technology, the economics of improvements in relation to state of technology, the economics of improvements in relation to benefits to the public health and safety, and other societal and socioeconomic considerations, and in relation to utilization of nuclear energy and licensed materials in the public interest. LBU/PGUs shall see guidance from their local HSE advisor and/or the ABB Radiation Safety Officer as what is "as low as is reasonably achievable".

5.4 Marking and Labeling

An essential contamination control measure.
ALL RADIATION AREAS, RADIOACTIVE MATERIAL USE AREAS, EQUIPMENT AND STORAGE CONTAINERS MUST BE MARKED WITH THE RADIATION TREFOIL SYMBOL.

5.5 Emergencies

Report any incidents involving radioactive materials and radiation generating devices to ABB Radiation Safety Officer immediately on tel. +1-614-818-6300 or the Radiation Safety Officer in country, if applicable. Keep all involved personnel near the area until radiation safety staff responds to assist you.

THE MOST IMPORTANT THING TO REMEMBER ABOUT AN EMERGENCY IS TO STAY CALM, PROTECT YOURSELF AND OTHERS, AND CALL RADIOLOGICAL OPERATIONS AS SOON AS POSSIBLE.

5.6 Dosimetry

Dosimeters are small wearable devices that monitor and record your radiation dose. Your work assignment may or may not require dosimetry to be worn during work with radiation sources. Store the dosimeters, not in use, in an uncontaminated area free from any radiation. Dosimeters must be exchanged on a timely basis. Report lost or contaminated dosimeters to the Radiological Operations Center as soon as possible.

5.7 Naturally Occurring Radioactive Materials (NORM)

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Many industrial facilities that process natural materials (e.g. oil and gas, mining, ores processing) will find low levels of naturally occurring radioactive materials in their processes. Over time, however, these radioactive materials can get trapped within the process handling equipment, be consolidated, and accumulate in larger quantities. Thus, the radiation levels from these materials can become a significant hazard, particularly when dismantling the process handling equipment for repair, maintenance, or decommissioning. These are often referred to as unsealed sources and hence they pose a significant risk to health and there is the potential for such material to enter the body through ingestion or inhalation. When working on any of these types of processes, ABB employees and contractors must be aware of the potential for exposure and need to consult with the customer and the local radiation safety professional to properly assess this hazard.

6.0 TRAINING AND COMPETENCE

6.1 All persons (employees and contractors) shall be suitably instructed and trained so that they are competent to undertake the work activities for which they have been assigned including the application of any specific HSE measures identified by the risk assessment to prevent or mitigate any possible personal injury or incidence of ill health.

6.2 All persons who are required to carry out servicing and maintenance work on devices containing sealed sources shall be instructed and trained in respect of the safe method of working and in particular with any radiation safety rules and shall include:

1) **Initial Training:** Prior to job assignment, ABB shall provide training to ensure that the hazards associated with radiation are understood by workers and that the knowledge, skills and personal protective equipment required are provided to workers. The training shall as a minimum include the following:
    i. Each authorized worker shall receive training in the recognition of applicable hazards involved with a particular job. The methods and means necessary for safe work.
    ii. The applicable regulatory requirements –ensuring the most stringent is applied.
    iii. The specific nature of the operation which could result in exposure to radiation.
    iv. The purpose, proper selection, fitting, use and limitation of respirators or other protective equipment as applicable.
    v. The engineering controls and work practices associated with the worker's job assignment, including training of workers to follow relevant good work practices.
    vi. The rights and responsibilities of workers with regards to exposures to radioactive materials or radiation.
2) **Refresher Training:** Scheduled refresher training will be conducted on an as needed basis.
    i. Retraining shall be provided for all authorized and affected workers whenever there is a change in their job assignments, a change in personal protective equipment, equipment or processes that present a new hazard, when their work takes them into hazardous areas, or when there is a change in the safety procedures. Retraining will also be provided whenever a safety procedure fails resulting in a near-miss, illness, or injury.
    ii. Additional retraining shall also be conducted whenever a periodic inspection reveals, or whenever ABB has reason to believe, that there are deviations from or inadequacies in the worker's knowledge of known hazards, use of equipment or procedures.

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iii. The retraining shall re-establish worker proficiency and introduce new equipment, or revised control methods and procedures, as necessary.

3) ABB shall validate when workers are competent to complete certain radiological tasks or an outside competent vendor shall validate that training has been accomplished and is being kept current. The training document shall contain a synopsis of the training conducted, each worker's name, and dates of training.

7.0 MONITORING AND CHECKING

7.1 All ABB owned sealed sources that contain radioactive substances that emit ionizing radiation, or those owned and operated by ABB's customers and serviced by ABB shall be accounted for at all times in terms of the location and the quantity of radioactive substance contained. The source shall be contained to prevent any leakage of radiation and shall be secured.

7.2 Each device shall be tested for leaks at suitable intervals and in any event once per year to ensure that any shielding or shutter mechanisms are in good working order.

7.3 Employees who undertake such work on a regular shall be subject to health surveillance as recommended by the ABB occupational health physician and the LBU/PGU shall maintain a register of all ABB employees who are authorized and are required to work on equipment that contains sealed source of radiation.

8.0 DOCUMENTATION AND RECORDS

8.1 A record shall be kept in respect of any leak tests or other maintenance carried out and retained for 2 years from the date of the test.

8.2 All ABB personnel who carry out servicing and maintenance work on devices containing sealed sources shall have their dose monitored and a record shall be kept for 40 years.

8.3 Records shall also be maintained in respect of training including any refresher training provided in respect of radiation safety. Records shall be maintained for 5 years from the last day of employment with ABB.

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