AERB SAFETY STANDARD NO. AERB/SS/2 (Rev. 1)

DESIGN AND CONSTRUCTION OF INDUSTRIAL IONISING RADIATION GAUGING DEVICES

Approved by the Board on October 5, 2001

This document is subject to review, after a period of one year from the date of issue, based on the feedback received.

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FOREWORD

Widespread utilisation of ionising radiations for multifarious applications in medicine, industry, agriculture, research etc. has brought in its wake the need for exercising regulatory controls to ensure safety of the users and members of the public and protection of the environment. The Atomic Energy Regulatory Board (AERB) constituted under the Atomic Energy Act, 1962 by the Government of India, is entrusted with the responsibility of developing and implementing appropriate regulatory measures aimed at ensuring radiation safety in all applications involving ionising radiation. One of the ways to meet these responsibilities is to develop and enforce specific codes and standards dealing with radiation safety aspects of various applications of ionising radiation to cover the entire spectrum of operations, starting from design of radiation equipment, their installation and use, to their ultimate decommissioning/disposal.

In view of the fact that regulatory standards and requirements, techniques of radiation safety engineering and type of equipment change with time, it becomes necessary to review and revise codes and standards from time to time to incorporate these changes.

Among the ionising radiation devices used in industry, gauging devices incorporating radioactive sources or X-ray tube sources are extensively used in the country. Several thousands of these devices are used in manufacturing and construction industries for measuring and monitoring thickness, density, level and other physical parameters, and controlling manufacturing processes. Many types of nucleonic gauges are now manufactured in the country. It is important that the gauges are so designed and constructed as to provide adequate protection to persons handling them.

The first AERB Standard (Specifications) entitled “Radiological Safety in the Design, Construction and Use of Industrial Gauging Devices,” AERB/SS/2 was prepared by a committee and issued in 1990. It specified the essential features of gauging devices that would ensure radiation safety of the users as well as of persons in the vicinity of the gauges.

The above Standard has now been revised by a task group (Task Group VIII) constituted by AERB. The Standing Committee for Review and Revision of AERB's

Radiation Safety Documents, constituted by Chairman, AERB, has subsequently scrutinised and finalised it. This revised Standard, approved for issuance on October 5, 2001 by the Atomic Energy Regulatory Board, is effective from its date of approval and replaces the earlier standard of 1990.

AERB wishes to thank all individuals and organisations who helped in the revision of the Standard. The names of persons who participated in the preparation of the earlier Standard and its present revision are listed, along with their affiliations, for information.

(Suhas P. Sukhatme)
Chairman, AERB

DEFINITIONS

Accessible Surface

Any surface of the source housing that can be readily reached by any part of the human body without the use of tools or without the removal of any part of the housing.

Directional Equivalent Dose Rate (7 mg/cm^2)

The radiation level of X, gamma, charged particles and/or neutrons in mSv/h measured with a detector having a total window and absorber thickness of 7 mg/cm^2 of tissue equivalent material.

Directional Equivalent Dose Rate (300 mg/cm^2)

The radiation level of X, gamma, charged particles and/or neutrons in mSv/h measured with a detector having a total window and absorber thickness of 300 mg/cm^2 of tissue equivalent material.

Gauging Device (Gauge)

A mechanism designed and manufactured for the purpose of determining and/or controlling thickness, density, moisture, level, interface location, and/or qualitative or quantitative chemical composition. It shall include radiation source, radiation shields, useful beam controls and other components, which form an integral part of the device in order to meet the requirements or specifications of this Standard.

Leakage Radiation

Any radiation coming from within the source housing, except the useful beam or primary beam.

Scattered Radiation

Radiation that, during passage through matter, has been deviated in direction. (It may have been modified with resultant decrease in energy).

Sealed Source

The radioactive material suitably encapsulated and intended for use as a source of ionising radiation in the gauge.

Source Holder

A device used to support and retain the source in position.

Source Housing

The shielded container including the source holder, beam control devices and beam status indicators.

Stray Radiation

The sum of leakage and scattered radiation.

Useful Beam or Primary Beam

Radiation which passes through the window, aperture, cone or other collimating device of the source housing, during "BEAM ON" condition.

Useful Beam Controls

The device(s) that affect(s) the quantity, quality, and direction of the useful radiation beam which is emitted from the source.

X-Ray Source

A source producing penetrating electromagnetic radiation having wavelengths shorter than those of ultraviolet light, either emanating from a radioactive source or produced by bombarding a metallic target with fast electrons in high vacuum, constituting an X-ray tube source.

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1. INTRODUCTION

1.1 Purpose and Scope

Devices incorporating radiation sources are used for monitoring several important parameters in industrial processes for quality control. The principle of operation of the device is generally based on the detection of transmitted, scattered or fluorescent radiation from the material of interest. Such devices are referred in this Standard as radiation gauging devices or as "gauges". The term gauging device encompasses radiation source, source housing, detector and the associated controls.

This Standard specifies the features and requirements to be complied with in the design and construction, so as to ensure safety of persons handling them and those in the vicinity of the gauges. The requirements of Radiation Protection Rules, 1971, Notifications issued by competent authority under the Rules, and the safety codes and guides issued by the competent authority from time to time shall be applied in addition to requirements of the Standard. Designers and manufacturers of radiation gauging devices shall demonstrate compliance with this Standard. Gauging devices shall not be marketed or used unless they are approved by the competent authority. This Standard applies to gauges designed and manufactured in India as well as those imported for use in the country. Well-logging devices are not covered in this Standard.

This Standard applies only to radiation safety aspects and does not necessarily imply that the gauge will operate as a measurement system during or after the tests prescribed in this Standard.

Information on radiation safety in installation and use of gauges is provided in Appendix-I.

2. SAFETY FEATURES

2.1 Design Considerations

The gauge shall provide adequate radiation protection to the user and to persons in the vicinity. The gauge shall be designed so that (a) stray radiation levels on and around the gauge do not exceed the limits specified in Table-1; (b) the safety features function throughout its useful life; (c) the reliability of the device and its associated components is assured; and (d) ability to withstand special environmental conditions such as humidity and corrosiveness is ensured. Due consideration shall also be given to ingress of water and dust.

2..2 Source Integrity

2.2.1 Radioactive Source

The radioactive material shall be in the form of a sealed source and its encapsulation design shall be of the type approved by competent authority in accordance with the Standard Specifications for the Testing and Classification of Sealed Radioactive Sources, AERB/SS/3.

2.2.2 X-ray Tube Source

Tube source shall not produce radiation except by passage of an electric current through the X-ray tube. In the event of fire or abnormal temperatures, the high voltage shall be automatically cut off before loss of any integral shielding. Therefore, X-ray tube sources are exempted from accident condition test requirements.

2.3 Source Housing

Stray radiation levels external to the housing depend on the material and construction of source housing. External radiation levels at 5 cm from accessible surface and at one metre from the source shown in Table-1 shall be used as the basis for classification of gauge performance in terms of stray radiation.

2.3.1 Source Holder

The source holder shall (a) permit reproducible positioning of radioactive source; (b) have means for immobilising and securing the source in the designated location; and (c) be tamper-proof and shall not permit direct or easy access to the source.

2.3.2 Useful Beam Controls

Gauges for which radiation level exceeds 1 mSv/h at 5 cm from source housing shall be provided with suitable control mechanism to close the primary beam. The beam control mechanism may be operated manually or by application of suitable power. The useful beam control may be achieved by one of the following:

(a) moving shutter;

(b) moving source; or

(c) high voltage power supply control (in case of X-ray tube sources).

Beam control shall be tested through a sufficient number of operational cycles to establish its endurance and performance reliability (refer section 4.6).

2.3.2.1 Manual Useful Beam Control

Manual beam control shall be so designed that when the useful beam is in the "OFF" condition, the measured directional equivalent dose rate in the useful beam space shall not exceed 1 mSv/h at 5 cm from any accessible surface, as measured in accordance with the procedures of section 4.2.2.

In the case of a gauge with a measuring gap not exceeding 10 cm, the radiation level requirements of this sub-section may be met by means of useful beam control alone or by an external shield in addition to the useful beam control system. The external shield shall be designed for easy and secure installation on the device, and shall be supplied by the manufacturer. Means shall also be provided for storing the external shield on the gauge when it is not in use as a shield.

Source housing shall be constructed such that the source can be positioned and kept in the “BEAM-ON” condition or the full “OFF” condition without the need for continuous external manual operation. A locking mechanism shall be provided to physically secure the source in the full “OFF” position and this mechanism shall be designed to be operated only when the source is in the “OFF” position.

2.3.2.2 Powered Useful Beam Control

A powered (non-manual) useful beam control shall be designed such that, in the event of power failure, the source will remain in the “OFF“ condition, and the measured directional equivalent dose rate in the useful beam space shall not exceed 1 mSv/h at 5 cm from any accessible surface, as measured in accordance with procedures of sub-section 4.2.2.

In the case of a gauging device with a measuring gap not exceeding 10 cm, the radiation level requirements of this section may be met by the useful beam control alone or by an external shield in addition to the useful beam control system. The external shield shall be designed for easy and secure installation on the device, and shall be supplied by the manufacturer. Means shall also be provided for storing the external shield on gauging device when it is not in use as a shield.

2.3.3 Status Indicator

A conspicuously visible signal, which positively indicates when the useful beam control is in the “ON” condition, and when it is in the “OFF” condition, shall be located on or adjacent to the radiation source housing. The signal may be electrical, mechanical, or electromechanical, and shall include legible signs describing their meanings. If the radiation level exceeds 0.02 mSv/h at 50 cm from the gauge, the “ON-OFF” indicators shall be located in a manner that is conspicuous to the person approaching the gauge.

2.3.3.1 Indicator for Manual Useful Beam Control

Each gauging device having a manually operated useful beam control shall have a conspicuously visible signal to indicate the “ON” and “OFF” positions of the beam control. Mechanical indicators shall be directly and firmly coupled to the movable beam control system.

2.3.3.2 Indicator for Powered Useful Beam Control

Each indicating system shall consist of at least one “ON” indicating signal and one “OFF” indicating signal. If lights are used, a green signal indicates “OFF”' condition of the useful beam control.

2.3.3.3 Indicator for X-ray Tube Source High Voltage Control

Yellow or amber warning light with the legend "HIGH VOLTAGE ON" shall be located on the control panel and on, or adjacent to, the source housing and shall light up only when power is applied to the X-ray tube high voltage circuit. If the high voltage power supply control is the sole useful beam control, the indicator requirements of sub-sections 2.3.3 and 2.3.3.2 shall apply.

2.4 Detector Housing

The detector housing comprises the following elements:

(a) an ionising radiation detector;

(b) electronic or electromechanical devices associated with detector, if any; and

(c) absorbing shields, if necessary, and measuring instruments which form a rigid assembly with detector housing.

The design of the detector housing shall be such as not to permit direct exposure of persons while handling the detector system. Subject to the category to which the gauge belongs, the detector housing shall be designed to provide, within the class under consideration, compliance with equivalent dose rates laid down in Table-1.

2.5 Source/Detector Housing

In the case of integral devices, where source housing and detector housing are combined, the assembly shall comply with requirements applicable to source housing as well as to those which apply to detector housing.

Examples of integral devices are backscatter gauges and soil moisture gauges.

2.6 Fastening Devices

Devices for fastening or moving source housing and detector housing shall be designed in such a way as to:

(a) facilitate positioning of source housing or detector housing; and

(b) ensure permanent installation in the selected position, taking into account special environmental conditions.

The clear space between source housing and detector housing (in case of thickness gauges), or the clear spaces between the equipment (to which gauge is fixed) and source housing and detector housing, shall not permit persons access to direct radiation beams. If necessary, source housing and detector housing shall be designed so as to accommodate additional protective devices.

2.7 Markings

2.7.1 The following information shall be clearly marked on source housing or source detector housing:

(i) model designation and serial number of the gauge;

(ii) classification designation; and

(iii) name of the manufacturer.

2.7.2 For a nucleonic gauge which employs a radionuclide source, there shall be a durable permanent marking indicating radiation symbol, the chemical symbols and mass numbers of radionuclides, the source activity, and the measurement date and a warning legend which shall read as follows:

"CAUTION – RADIOACTIVE MATERIAL"

2.7.3 For an X-ray tube source gauge, there shall be a durable permanent label indicating the maximum operating voltage and current, the radiation symbol, and a warning legend which shall read as follows:-

"CAUTION – RADIATION; THIS EQUIPMENT PRODUCES RADIATION WHEN ENERGISED"

In addition, a placard with the same legend as the label shall be provided by the manufacturer for locating it close to each switch that controls the production of X-rays.

These markings shall remain legible throughout the working life of the gauge.

2.8 Accompanying Documents

A radiation gauge shall be accompanied by documents containing technical information and instruction for installation and operation, servicing and maintenance, emergency procedures and decommissioning and disposal.

Each radionuclide gauge shall have an individual tag giving its characteristics as well as the identification numbers of source(s) which have been incorporated therein, specifying, for each source, the maximum distance between the surface of the gauge and the equivalent dose rate points at 0.5 and 1.5 Sv/h as well as isodose curves for 0.5 and 1.5 Sv/h.

3. TEST REQUIREMENTS

3.1 Device Safety Performance Classification

Gauges shall be subjected to type tests on prototype to demonstrate their compliance with specifications in respect of radiation safety, under normal use and accident conditions.

Safety performance of the gauge shall be assessed based on the following tests:

(i) stray radiation at 5 cm;

(ii) stray radiation at 100 cm;

(iii) high temperature;

(iv) low temperature;

(v) accidental fire;

(vi) accidental drop (applicable to gauges located at heights);

(vii) impact (applicable only for portable gauges);

(vii) vibration; and

(ix) endurance.

When conditions of use dictate, additional criteria may be defined by common agreement between the user and manufacturer, such as resistance to:

- corrosion;
- shear;
- pressure;
- explosion;
- water immersion; and
- special climatic condition.

The test procedures given under section 4 shall be followed.

3.2 Classification Format

1. The performance classification of the device type may also be determined by calculations based on previous tests, or physical characteristics, or field-use feedback, which demonstrate that, if the tests were performed, the device would pass the tests.

2. The order of testing is important only in that stray radiation class must be determined first, and repeated after each mechanical and thermal test.

3.4.2 Classification Designation

The classification of a gauging device shall be designated by a group of digits that identify the tests which the gauge has satisfied and with letters which designate a radioactive or X-ray tube source. The designation is based on digits specified in Table-1 denoting the specified test conditions. Classification of temperature performance and accident condition is not dependent on the source "ON" or "OFF" condition. However, the classification of stray radiation performance is dependent on the source "ON" or "OFF" condition. This Standard recognises this difference and assigns a separate set of digits for the source "ON" and "OFF" conditions for the stray radiation classification. The fire test is not required for X-ray tube sources, provided that conditions of 2.2.2 are met.

Gauge classification shall be encoded as follows:

- AERB (denoting the authority approving the device) followed by a dash, and
- a set of two digits which identifies the performance for stray radiation level in the source "ON" condition - first digit for 5 cm, second digit for 100 cm followed by a dash, and
- a set of two digits which identifies the performance for stray radiation level in the source "OFF" condition - first digit for 5 cm, second digit for 100 cm followed by a dash, and

- a set of two digits which identifies the performance for temperature - first digit for high temperature, second digit for low temperature followed by a dash, and
- the letter R for radioactive source or the letter X for X-ray tube source followed by a dash, and
- a digit, which denotes the temperature of the accident fire condition and a letter D which denotes compliance with accident drop test.

The above classification procedure has been shown below by a typical example.

A TYPICAL EXAMPLE FOR GAMMA LEVEL GAUGE (FIXED INSTALLATION)

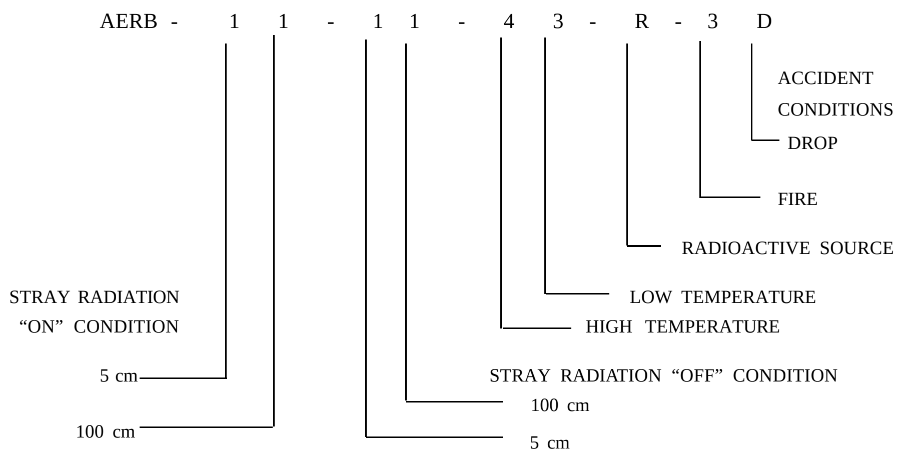

Fig.1. CLASSIFICATION DESIGNATION PROCEDURE FOR A GAUGING DEVICE

4. TEST PROCEDURES

4.1 General

Test procedures given in this section are acceptable for determining the performance classification numbers. The criteria set are the minimum requirements. Procedures which can be demonstrated to be at least equivalent are also acceptable. These tests shall be carried out on source housings. X-ray tube source shall be removed from the housing while source housing is subjected to mechanical and thermal tests.

4.2 Stray Radiation

4.2.1 Test Equipment

The standard instrument shall be an air ionisation chamber survey meter. The gamma and X-ray energy response of the standard meter shall be better than ± 20 per cent over an energy range of 15 keV to 1.3 MeV. Other meters may be used when they are corrected for response against the standard instrument for radiation to be measured. The window thickness of the standard meter shall be 7 mg/cm^2.

When measuring neutron radiation, the standard instrument shall be a survey meter whose response in equivalent dose rate units (mSv/h) is known over the energy range of 0.025 eV to 10 MeV. Window thickness requirements are not applicable to this type of instrument. The external absorbers specified in 4.2.2.1 shall not be used when measuring neutron radiation.

The survey meter for these tests shall have been calibrated at a laboratory approved by the competent authority for this purpose not more than six months prior to the date of these tests. Beta/gamma survey meters shall be calibrated in directional equivalent dose rate units (mSv/h) to an accuracy of ± 15 per cent of full scale at any point within the rated energy range and neutron survey meters shall be calibrated in equivalent dose rate units (mSv/h) to an accuracy of ± 20 per cent of full scale using an appropriate neutron spectrum.

4.2.2 Procedure

For measurement of stray radiation, appropriate conditions of intended field use shall be simulated to ensure that stray radiation levels represent maximum values. Accordingly, the gauge (source and detector housings) shall be mounted in a physical geometry which will be representative of the actual use condition. The standard conditions are as follows:

• Density gauge	- Gauge mounted on process vessel (or simulation); - Test for all pipe sizes (or worst case); and - Test with no process material in pipe (empty).
• Level gauge	- Source housing mounted 25 mm from a standard 13 mm thick absorber (vessel wall simulator).
• Belt scale gauge	- No belt or process material in the measuring gap (empty air gap); - Test for each measuring gap (or worst case).
• Gamma/X-ray tube transmission gauge	- No product in the measuring gap (empty air gap); - Test for each measuring gap (or worst case); - For X-ray gauge, test for worst case combination of operating kVp and mA available in gauge.
• Beta transmission gauge.	- Same as gamma/X-ray tube transmission gauge
• Neutron transmission gauge.	- Same as gamma/X-ray tube transmission gauge
(a) Gauge used on a belt	- Same as belt scale gauge.
(b) Gauge used for a product in a pipe or chute	- Same as density gauge

- Beta backscatter gauge
  - (a) Gauge used on a roll or other infinite backer
    - Test for all roll diameters (or worst case);
    - Steel plate absorber (roll simulator) at the nominal measuring gap, of sufficient thickness to attenuate all of the useful beam beta particles.
    - No product on roll simulator.
  - (b) Gauge used on product supported or backed up
    - Typical product in the useful beam (or worst case).
- Photon backscatter and fluorescence gauges
  - (a) Gauges used on a roll or other backer
    - Test for all roll diameters (or worst case);
    - For X-ray gauge, test worst case combination of operating kVp and mA available in gauge;
    - Steel plate absorber (roll simulator) at the nominal measuring gap, of sufficient thickness to attenuate 99 percent of useful beam photons;
    - No product on roll simulator.
  - (b) Gauges used on product not supported or backed up
    - Typical product in useful beam (or worst case).
- Neutron backscatter Gauge used on vessels
  - Gauge housing mounted in contact with a standard absorber consisting of a 6 mm thick steel plate backed by a 20 mm thick polyethylene reflector plate;
  - No product in the measuring beam.

If more than one radioisotope source and/or activity is used in a gauge, separate tests shall be performed for each isotope of maximum activity for which it is designed. If a gauge incorporates two or more radiation sources, tests shall be performed with all sources in position. If both neutron and gamma radiation are present, separate measurements shall be made individually and summed up to obtain total directional equivalent dose rate. Measurements shall be made separately for BEAM 'ON' and 'OFF' conditions.

4.2.2.1 Beta and Gamma rays/X-rays Measurement

The location of maximum stray radiation shall be determined by scanning all accessible surfaces of the device with the survey meter at distances specified in the classification table. After the general region of maximum radiation is located, a careful examination shall be made to determine the maximum radiation level. Care must be taken in all measurements to assure that the detector is oriented to obtain a maximum reading through the window and the absorber, and that sufficient time is allowed for meter reading to stabilise. Measurements shall be averaged over an area not less than 30 cm^2 and not more than 100 cm^2, with no linear dimensions of this area to exceed 20 cm.

Distances shall be measured from the surface of the device to the centre of the active volume of the survey meter. Dose rate shall be measured under two conditions: "dose rate (7 mg/cm^2)" and "dose rate (300 mg/cm^2)". The first condition approximates the dose rate to the "skin" of the body. The second condition applies to the dose rate to the "whole body, gonads, active blood-forming organs, head and trunk, or lens of the eye", and assumes that the lens of the eye is not protected by any type of eye shield. For the above measurements the total thickness of the window and the absorber shall not be greater than 7 mg/cm^2 or 300 mg/cm^2 as appropriate. For the external absorbers, a material such as polyethylene with a low effective atomic number (density approximately 1.0) shall be used.

4.2.2.2 Neutron Measurement

Due to the large physical size of the neutron survey meters, measurement at 5 cm shall be eliminated. After locating the general region of maximum radiation, a careful examination shall be made to determine the maximum radiation level. Care shall be taken in all measurements to ensure that the detector is oriented to obtain a maximum reading and that sufficient time is allowed for meter reading to stabilise. Readings shall be interpreted as equivalent dose rates (dose rate 300 mg/cm^2).

4.2.3 Evaluation

All reports on stray radiation measurements shall state the make, model and serial number of the survey meter and the mass per unit area of the total window thickness used in making the measurements.

(a) For devices emitting beta and electromagnetic radiation, the classification number for each distance shall be the number corresponding to the lowest radiation level in the classification table not exceeded by the maximum dose rate (300 mg/cm^2) level measured for that distance. Dose rate (7 mg/cm^2) shall not exceed six times the value in the classification table. If the dose rate (7 mg/cm^2) exceeds six times the value in the classification table determined by the dose rate (300 mg/cm^2) value, the dose rate (7 mg/cm^2) is to be divided by six and classification done based on the resultant.

(b) For devices emitting neutron radiation, classification number at 100 cm shall be the number corresponding to the lowest radiation levels in the classification table which are not exceeded by the maximum neutron radiation levels measured at that distance. If beta and gamma radiation are present, the beta and gamma dose rate values are to be added to the neutron dose rates (in mSv/h). The maximum total value shall be used for the classification. When the dose rate (7 mg/cm^2) value resulting from beta and electromagnetic radiation, added to neutron radiation, exceeds six times the value in the classification determined by the

(300 mg/cm^2) value, the dose rate (7 mg/cm^2) is to be divided by six, this value is added to the neutron dose rate, and the classification done based on the resultant.

4.3 Use Condition Temperature Test

4.3.1 Test Equipment

The test shall be performed in a temperature chamber capable of achieving and maintaining the minimum and maximum temperatures in the classification table when the device is operating with its heat load. Two chambers may be used, if necessary, to provide the temperature values. The device may be transferred, at room temperature, from the low temperature chamber following the low temperature portion of the cycle to the high temperature chamber. Means shall be provided for monitoring the performance of the safety of the device during the temperature test.

4.3.2 Preparation

The time required for temperature stabilisation of the entire device at the temperature extremes shall be determined by experiment or by computation. Stray radiation from the device (source in 'OFF' position) shall be measured and recorded prior to starting the test.

4.3.3 Procedure

The device shall be placed in the chamber at room temperature and checked for proper operation of safety features. The ambient air temperature shall be decreased to the low value shown in the classification table and shall be maintained at that value for stabilisation time plus one hour. After achieving stabilisation and allowing one more hour, the operation of safety devices shall be verified. Then the temperature in the chamber shall be raised to room temperature. After stabilisation time, the operation of safety features shall be checked.

The ambient air temperature shall be increased to the high value shown in the classification table and maintained at that value for stabilisation time plus one hour. It is necessary that the entire mass of gauge (source housing) shall attain the required temperature. Presence of any temperature-retarding or insulating material in contact with the body of the gauge shall be avoided. The operation of safety features shall then be checked. The temperature shall be decreased to room temperature and maintained for stabilisation time. At the conclusion of that portion of the temperature cycle, the operation of safety features shall again be verified. The device shall be removed from the chamber and examined visually for defects. Stray radiation levels of the source housing (source in “OFF” condition) shall then be measured and recorded and the integrity of the source verified.

4.3.4 Evaluation

During the temperature cycle there shall be no failure causing loss of function of safety features. Visual examination shall reveal no defect which could result in loss of function of safety features. Stray radiation at the conclusion of temperature test shall not exceed the value recorded prior to the test. X-ray tube shall continue to operate within the design specifications.

4.4 Impact Test

The test requires demonstration that gauging device will withstand horizontal and vertical impacts it is likely to experience during use. This test is not required for gauges which are not of portable type.

4.4.1 Horizontal Impact Test

The target shall consist of a flat vertical face of 50 mm diameter cylindrical steel bar, 30 cm long, fixed or welded horizontally to a rigid mass at least 10 times the mass of the gauge. The gauge shall be suspended without causing rotation around a vertical axis.

While performing the test, the gauge shall be locked in "Beam-OFF" position. The gauge shall be suspended from a fixed point so that when at rest one of the fragile areas just touches the target. The gauge shall be moved from its resting position until the height of its centre of gravity is raised by 10 cm and the gauge shall then be allowed to swing in a pendulum movement to hit the target. The test shall be repeated 20 times on each of the areas of the device regarded as fragile.

4.4.2 Vertical Impact Test

The rigid target (such as steel or concrete) shall have a mass of at least 10 times the mass of the gauge and shall have a flat horizontal surface covered with a sheet of 25 mm thick plywood or equivalent. The gauge device shall be allowed to fall 100 times from a height of 15 cm on to the rigid target.

4.4.3 Evaluation

The integral safety features of the gauge shall remain operational after the tests and there shall not be loss of shielding integrity after impact tests.

4.5 Vibration Test

The test shall be carried out by fastening the gauge, after locking it in "Beam-OFF" position, on a vibrating table whose vibration frequency can be varied.

The main inherent frequency of gauging device shall be determined by scanning in a low amplitude frequency between 5 and 80 Hz. This inherent frequency is defined as the frequency for which the ratio of energising force to platform speed is equal to or less than one-tenth of the largest value measured during scanning. Then the device shall be vibrated at this main inherent frequency for 8 hours and with a maximum acceleration equal to 9.8 m/s^2. If, during initial scanning, it is noted that the gauging device has several main inherent frequencies, the gauging device shall be energised at each of these frequencies for 8 hours with maximum acceleration equal to 9.8 m/s^2. If no inherent frequency is detected in the range of 5 to 80 Hz the device shall be vibrated for 70 minutes with a maximum acceleration of 9.8 m/s^2 at each of the following frequencies: 5, 8, 12, 20, 32, and 80 Hz.

4.5.1 Evaluation

The integral safety features of the gauge shall remain operational after the test and there shall not be loss of shielding integrity after the test.

4.6 Endurance Test

The purpose of endurance test is to verify the resistance-to-wear of ejection devices, shutters, useful beam controls and position indicator devices of the gauge. For manual shielding control devices, the test (opening and closing the shutter, moving the source holder from the storage position to its extreme operating position) may be carried out manually or by an automatic device. The drive mechanism is then adjusted to exert, in each direction, the force specified by the manufacturer for normal operation.

In remote or servo-controlled devices, endurance tests shall be carried out in the following order:

- opening and closing cycles of the shutter; and
- ejection and repositioning cycles of the source holder.

The number of operating cycles for endurance test shall be 25,000 for gauges having source ejection mechanism. For all other types of gauges the minimum number of operating cycles shall be 2,00,000. However, if the shutter is used only during servicing/maintenance or shutdown, the number of operating cycles shall be limited to 1000.

4.6.1 Evaluation

Safety features of the gauge shall remain operational and there shall be no loss of shielding integrity after the test.

4.7 Accident Condition Test

4.7.1 Fire Test

The furnace used shall have the capacity to heat the air around the source housing to provide the time-temperature profile shown in the following Table:

TIME-TEMPERATURE PROFILE

Time (minutes)	Temperature (°C)
0	Room temperature
5	550
10	660
15	710
30	820
60	925
90	990
120	1030
180	1090
240	1130
360	1200

The fire test on lead-filled gauges may also be carried out in an open hydrocarbon fuel/air fire, fully engulfed except for the support system.

The test shall be carried out in air. The temperature of the device under test shall be determined by thermocouples evenly distributed over all exterior parts of the device.

The accident condition fire test shall be carried out until the specified time and temperature requirements are met.

4.7.2 Drop Test

The target for drop test shall be a flat, horizontal surface of such a character that any increase in its resistance to displacement or deformation upon impact by the specimen would not significantly increase the damage to specimen.

The device under test shall drop on to the target so as to suffer the maximum damage in respect of its safety features. The height of drop measured from the lowest part of the gauge to the upper surface of the target shall be 9 metres.

4.7.3 Evaluation

Compliance with accident condition tests shall be determined by the ability of the gauge to maintain a level of radiological safety as specified subsequently. Safety features may not be operational or perform as originally intended. A dummy source or a sealed source of low activity may be used in place of sealed radioactive source during tests.

The necessary criteria for passing each accident test is that the source capsule shall remain captive in the protective source housing and the radiation level at one metre shall not exceed ten times the radiation level at 5 cm from the surface prior to the test. The above condition on radiation level is not applicable for neutron gauges.

4.8 Other Requirements

Gauging devices designed for installation and use at elevated locations and in uncovered areas shall be subjected to special tests in addition to the tests mentioned above. Special tests include water immersion test. Procedures applicable to packages for transport of radioactive materials and described in AERB Safety Code on Transport of Radioactive Materials (AERB/SC/TR-1) shall be used to carry out special tests and other relevant tests for Type A or Type B transport package as appropriate for the individual gauging device.

5. PERFORMANCE REQUIREMENTS

The minimum requirements of performance in terms of stray radiation, normal use conditions and accident conditions depend on the type of gauge. The classification of gauge performance standard is given in Table-1. The minimum requirements based on classification designation for different types of gauges are given in Table-2.

The classification of sealed source performance standards and the corresponding requirements of sealed source classification are given in Tables 3 and 4 respectively.

The manufacturer shall specify the classification designation of the gauge after verification of performance as per relevant test procedures. The manufacturer shall make a written application to the competent authority along with detailed reports on the tests performed to demonstrate compliance for issue of type approval, viz. format of application is given in Appendix-II. The competent authority may stipulate terms and conditions of the type approval, which may include the period of validity.

6. QUALITY ASSURANCE

A quality assurance (QA) and quality control (QC) programme shall be established to ensure that the gauging devices manufactured according to quality assurance programme will have the performance at least equal to that of the prototypes tested as per this Standard. An important aspect of the quality assurance programme is the documentation covering design review, use of revised drawings for construction, establishment of audit procedures, inspection, record of traceability of materials and components, as well as records of installation, servicing and maintenance.

The authority and responsibility of the organisational unit or individuals performing the quality assurance function shall be stated clearly in writing.

TABLE-1: CLASSIFICATION OF GAUGE PERFORMANCE STANDARDS

TEST	CLASS						
	0	1	2	3	4	5	6
External Radiation Level:							
Maximum stray radiation at 5 cm	No test	1000 µSV/h	200 µSV/h	50 µSV/h	20 µSV/h	1.5 µSV/h	Special
Maximum stray radiation at 100 cm	No test	20 µSV/h	10 µSV/h	2.5 µSV/h	1.5 µSV/h	0.5 µSV/h	Special
Normal Use Condition:							
High temperature Low temperature	No test No test	50°C 10°C	100°C 0°C	200°C -40°C	400°C -100°C	600°C -196°C	Special Special
Accident Condition:							
Fire Temperature	No test	538°C	800°C	945°C	1050°C	1150°C	Special
Duration		5 min	20min	60min	120min	240min	Special

TABLE-2: GAUGE CLASSIFICATION DESIGNATION – MINIMUM REQUIREMENTS

[Refer to section 3.2.1 and Table-1 for explanation of symbols]

Gauging devices	Stray radiation		Temperature		Source	Accident condition
	ON	OFF	High	Low		
Gamma gauge Portable/dolly mounted	24	24	2	2	R	1
Fixed installation	11	11	4	3	R	3D
Beta gauge	14	34	2	2	R	1
Betascope using kBq (µCi) sources	00	00	1	1	R	0
Neutron gauge	23	23	4	3	R	2
X-ray tube gauge	23	NA	4	3	X	NA
XRF gauges	24	34	2	2	R	0

NA : Not applicable

TABLE-3: CLASSIFICATION OF SEALED SOURCE PERFORMANCE STANDARDS

TEST	CLASS						
	1	2	3	4	5	6	X
Temperature	No test	-40°C (20 min) + 80°C (1h)	-40°C (20 min) +180°C (1 h)	-40°C (20 (20 min), +400°C (1 h) and thermal shock 400°C to 20°C	-40°C (20 min), +600°C (1 h) and thermal shock 600°C to 20°C	-40°C (20 min), +800°C (1 h) and thermal shock 800°C to 20°C	Special test
External Pressure	No test	25 kPa absolute to atmospheric	25 kPa absolute to 2 Mpa absolute	25 kPa absolute to 7 MPa absolute	25 kPa absolute to 70 MPa absolute	25 kPa absolute to 170 MPa absolute	Special test
Impact	No test	50g from 1 m	250 g from 1 m	2 kg from 1 m	5 kg from 1 m	20 kg from 1m	Special test
Vibration	No test	3 times 10 min 25 to 500 Hz at 49 m/s^2 (5 g)[1)]	3 times 10 min 25 to 500 Hz at 0.634 mm amplitude peak-to-peak and 90 to 500 Hz at (10 g)*	3 times 30 min 25 to 80 Hz at 1.5 mm amplitude peak-to-peak and 80 to 200 2000 Hz at 196 m/s^2 (20 g)[1]			Special test
Puncture	No test	1 gram from 1 m	10 gram from 1m	50 gram from 1 m	300 gram from 1 m	1kg from from 1 m	Special

* Peak acceleration amplitude.

TABLE-4: SEALED SOURCE PERFORMANCE REQUIREMENTS

<table>
<tr><th colspan="2" rowspan="2">Type of gauge</th><th colspan="5">Sealed source test and class</th></tr>
<tr><th>Temp-erature</th><th>Pressure</th><th>Impact</th><th>Vibration</th><th>Puncture</th></tr>
<tr><td rowspan="2">Gamma gauge (medium and high energy)</td><td>Unprotected source</td><td>4</td><td>3</td><td>3</td><td>3</td><td>3</td></tr>
<tr><td>Source in device</td><td>4</td><td>3</td><td>2</td><td>3</td><td>2</td></tr>
<tr><td colspan="2">Beta gauge and source for low energy gamma gauge or for X-ray fluorescence analysis (excluding gas-filled sources)</td><td>3</td><td>3</td><td>2</td><td>2</td><td>2</td></tr>
<tr><td colspan="2">Gas filled source</td><td>3</td><td>3</td><td>2</td><td>2</td><td>2</td></tr>
<tr><td colspan="2">Portable moisture and density gauge (including hand-held and dolly-transported)</td><td>4</td><td>3</td><td>3</td><td>3</td><td>3</td></tr>
</table>

(Refer to section 3.2.1 and Table-3 for explanation of symbols)

APPENDIX-I

INSTALLATION AND USE OF GAUGES

Radiation gauging devices should normally be installed and/or used in an environment free from excessive humidity or temperature, presence of corrosive gases and vapours, dust or particulate matter and other corrosive materials. Where gauging devices have to be used in such an atmosphere, the users should ensure that gauges are adequately protected form direct contact with or influence of these physical and chemical agents which would cause progressive deterioration of the device and impair its safety performance. Users are advised to consult the manufacturers whether the materials of gauging devices would withstand the influence of adverse environmental conditions. Where necessary, users should ensure that appropriate tests are carried out by manufacturers, or otherwise satisfy themselves that the gauging device would function with adequate radiation safety in the environment. The sole responsibility for ensuring the continued safe performance of gauging device and the radiation safety of occupational workers and others in the vicinity of the gauging device rests with the user. Tests that may be carried out to verify the safe performance of the device under adverse conditions of use include special tests for corrosion, ingress of water, dust, etc.

Fastening devices or mounting devices provided for gauging device should be able to withstand adverse environmental conditions, and under no condition, lead to a situation which would damage the integrity of the gauging device. It is the user's responsibility (with the help of the supplier of the gauging device) to ensure that the gauging system is mounted such that the source and the detector in the gauging device are properly aligned.

Interlocks

Under normal conditions of use, when there is immediate occupancy around the gauge installation, there shall be interlocks or barricades to prevent a person from access to the radiation field to a major portion of the body in excess of 10 μSv/h. For conditions of infrequent use, or where such interlocks or barricades are physically impossible or impractical, appropriate instructions, auxiliary shielding, or administrative controls may be stipulated.

On X-ray gauges, interlocks (e.g., access covers, etc.) shall be incorporated to prevent accidental exposures to X-rays as well as high voltages associated with the X-ray tube.

Auxiliary Shielding

Auxiliary shielding or barriers around the source housing may be installed whenever the gauging device is located in occupied areas. Any such auxiliary shield or barrier should be permanently installed and be of rugged construction. The shield or barrier should reduce stray radiation in occupied areas to levels consistent with good radiation protection practice or restrict access to excessive levels of radiation exposure. Temporary shielding or barriers may be necessary during servicing or maintenance of the gauging device or nearby equipment.

Servicing/Maintenance

Radiation source, its encapsulation, and shielding shall be serviced and maintained only by individuals who are properly trained and authorised by the competent authority. Gauging device shall be so designed and installed that when the manufacturer's instructions are followed, servicing and maintenance in the field can be carried out without exceeding applicable dose limits.

Safe Work Practice

Users of gauging device should establish a radiation protection programme aimed at protecting persons handling and working in the vicinity of the gauging device. Generally, the built-in features incorporated by manufacturers are adequate enough to assure safety, provided that these are used as prescribed by the manufacturer.

Rule 12 of Radiation Protection Rules, 1971 requires the availability of a Radiation Safety Officer (RSO) to ensure that the work practices are adequately safe. RSO will periodically monitor the radiation levels, instruct the workers and train them on safety matters, maintain the instruments and calibrate them periodically, ensure proper use of personnel monitoring devices and maintain dose records, ensure that servicing and maintenance, on and around the device, are carried out in a safe manner.

APPENDIX-II

Government of India
Atomic Energy Regulatory Board
Niyamak Bhavan, Anushaktinagar,
Mumbai-400094

APPLICATION FOR TYPE APPROVAL OF
INDUSTRIAL IONISING RADIATION GAUGING DEVICE

To be submitted by the manufacturer/vendor of Industrial Ionising Gauging Devices to the Chairman, Atomic Energy Regulatory Board, Niyamak Bhavan, Anushaktinagar, Mumbai-400094, with a copy to the Head, Radiological Physics and Advisory Division, Bhabha Atomic Research Centre, CT&CRS Building, Anushaktinagar, Mumbai-400094.

(Separate application should be submitted for each Model of Ionising Radiation Gauging Device)

A. Details of Manufacturer/Vendor

1. Name and address of applicant :

2. Name and address of manufacturer/ vendor :

3. Person(s) to be contacted regarding this application :

4. Number of devices to be manufactured/ supplied/per annum :

5. (i) Place where the device will be demonstrated for type approval :

   (ii) Details of test facilities available at the site :

NOTE : In case of imported equipment the documents pertaining to the safety evaluation of the device should be submitted. These include results of tests performed on the device.

B. Details of the Gauging Device

1.	Model and type designation	:	
2.	Gross weight of the gauge	:	
3.1	Source holder (detailed drawing and design description)	:	
3.2.	Source housing (detailed drawing and design description)	:	
4.1	Maximum source rating	:	....................Bq (.....................Ci) of.......................... (radionuclide)
4.2	Number of sources in the device (specify radionuclide and maximum activity of each source)	:	
4.3	Radiation shielding material (maximum and minimum thickness in mm and IS designation of the material)	:	
4.4	Source location from external reference points	:	

C. Radiation Source

1.	Radioactive material	:	
2.	Chemical and physical form of radionuclide	:	
3.	Overall dimensions of the source	:	
4.	Active dimensions of the source	:	
5.	Material and thickness of encapsulation or protective covering	:	
6.	Sealed source classification (Please attach the source certification)	:	
7.	X-ray tube source (if applicable)	:	
	(a) Tube voltage	:	....kV
	(b) Tube current	:	.... mA
	(c) Anode material	:	
	(d) Radiation output at 10 cm (specify kVp and mA)	:	

8. Source access control (sketch or drawing to describe the physical protection of the source and description of control) :

D. Useful Beam Controls

1. Type of useful beam control (moving shutter/ moving source in case of radionuclide device, and electrical controls in case of X-ray tube device) :

2. Useful beam control mechanism :

   (a) pneumatic (b) electrical
   (c) mechanical (d) electromechanical

3. Description of useful beam control mechanism with detailed drawings showing material and thickness of the shutter or useful beam absorber/shield :

4. Dimensions of measuring gap :

5. Size and shape of useful beam :

6. Automatic source 'OFF' mechanism for radionuclide device :

7. Description of beam 'ON/OFF' mechanism for X-ray source :

8. Useful beam status indicators (visual/other) :

9. Location of status indicators :

10. Distance from device up to which status indication is observable in clear daylight :

11. Markings and labels affixed on the gauge :

12. Anticipated useful life of the gauging device :

13. Maximum number of operational cycles for which device is designed :

E. Results of Type Tests

1. Maximum stray radiation level at : 5cm..................ON.........................OFF

   100cm.................ON......................OFF

2. Normal use condition

   High temperature :

   Low temperature :

3. Accident condition

   Fire :

4. Any other test :

5. Gauge Classification Designation :

F. Quality Assurance Programme

(Please furnish a copy of the quality assurance manual giving details of QA organisation, material control, document control, internal and external audit etc.)

G. Description of Packaging for Transport:

(Furnish information on the design of the packages and tests carried out for compliance with AERB Safety Code for Transport of Radioactive Materials, AERB/SC/TR-1)

H. Radiation Safety Requirements in Installation and Use

1. Nature and description of interlocks :
2. Nature and description of auxiliary shielding :
3. Recommended procedures for in-service maintenance and repairs :

4. Organisation responsible for servicing and maintenance :

5. Recommendations on decommissioning, dismantling and disposal of gauging devices :

6. Recommended procedures for removal and disposal of radiation source :

7. Organisation responsible for decommissioning, dismantling and disposal of radiation source :

I. Emergency Provisions

1. Provision in case the device gets stuck in the 'ON" position :

2. Provision for physical security of the source from tampering, theft or unauthorised use. :

3. Other safety provisions to protect the device from

   (a) chemical corrosion :

   (b) ingress of water, mud, dust :

   (c) protection from fire and flood :

J. Standards to which Gauging Device Conforms

AERB/SS-2 or any other (if the device is designed and built in accordance with a Standard, please furnish a copy of the Standard or its authentic English translation if the Standard is in any other language)

K. Documents to be Furnished with This Application

1. Design drawings of the radiation source holder, source housing, useful beam controls, useful beam status indicators, interlock and control circuits

2. Installation and operation manual

3. Special instructions to user on radiation safety in installation and use of gauging devices

4. Instructions for servicing, maintenance, dismantling, decommissioning and disposal, and

5. Copy of the Standard which the device complies with (if other than AERB/SS/2)

6. Detailed test report with description of each test, and the sequence in which the tests are carried out. Furnish certificates from the laboratory where tests were carried out, along with signatures of persons witnessing the test and high clarity good contrast photographs as pictorial evidence of the method adopted for carrying out the test.

I certify that the information furnished by me is correct to the best of my knowledge and belief.

Place:....................................... Signature:....................................

Date:....................................... Name:...

Designation:.................................

(Seal of the institution)

BIBLIOGRAPHY

1. Classification of Industrial Ionising Radiation Gauging Devices; American National Standard N538 - 1979.

2. Radionuclide Gauges - Gauges Designed for Permanent Installation, International Standards Organisation, ISO-7205-1986.

3. Testing and Classification of Sealed Radioactive Sources; Atomic Energy Regulatory Board, AERB Standard Specification, AERB/SS/3.

4. Code for Safety in Transport of Radioactive Materials; Atomic Energy Regulatory Board, AERB/SC/TR-1

LIST OF PARTICIPANTS

COMMITTEE FOR PREPARATION OF AERB STANDARD SPECIFICATIONS FOR RADIOLOGICAL SAFETY IN THE DESIGN, CONSTRUCTION AND USE OF INDUSTRIAL IONISING RADIATION DEVICES

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Shri S.P. Agarwal	:	Bhabha Atomic Research Centre Mumbai.

Note: Smt. R.N. Vadiwala, AERB, also associated and rendered assistance to the above Committee.

TASK GROUP VIII

TASK GROUP FOR REVISION OF AERB STANDARD SPECIFICATIONS FOR RADIOLOGICAL SAFETY IN THE DESIGN, CONSTRUCTION AND USE OF INDUSTRIAL GAUGING DEVICES

Members of the Task Group:

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Shri R. Kannan	:	Bhabha Atomic Research Centre Mumbai
Dr. Pushparaja	:	Bhabha Atomic Research Centre Mumbai
Shri G.D. Rehani	:	Defence Laboratory, Jodhpur
Shri K.D. Pushpangadan	:	Atomic Energy Regulatory Board Mumbai
Smt. R.N. Vadiwala (Secretary)	:	Atomic Energy Regulatory Board Mumbai

STANDING COMMITTEE FOR REVIEW AND REVISION OF AERB'S RADIATION SAFETY DOCUMENTS (SCRCG)

Members participating in the meeting:

Shri A. Nagaratnam (Chairman)	: Consultant, Defence Research and Development Organisation, Hyderabad (Formerly)
Shri E.B. Ardhanari	: Walchandnagar Industries Limited, Walchandnagar (Formerly)
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