GOVERNMENT OF INDIA

AERB SAFETY CODE

RADIOLOGICAL SAFETY IN THE DESIGN AND MANUFACTURE OF X-RAY ANALYSIS EQUIPMENT

ATOMIC ENERGY REGULATORY BOARD

AERB-SS-5 (1992)

AERB STANDARD SPECIFICATION No. 5

RADIOLOGICAL SAFETY IN THE DESIGN AND MANUFACTURE OF X-RAY ANALYSIS EQUIPMENTS

Approved by the Board on May 4, 1992

Atomic Energy Regulatory Board
Vikram Sarabhai Bhavan,
IV Floor,North Wing,
Anushaktinagar,
Bombay - 400 094.
India.

Price :

Orders for this standard should be addressed to:

The Administrative Officer,
Atomic Energy Regulatory Board
Vikram Sarabhai Bhavan,
IV Floor, North Wing,
Anushaktinagar
Bombay 400 094.

RADIOLOGICAL SAFETY STANDARD SPECIFICATION FOR THE DESIGN AND MANUFACTURE OF X-RAY ANALYSIS EQUIPMENTS

FOREWORD

X-ray analysis is an important tool in science and engineering. Fluorescence and diffraction techniques are used in scientific investigations including criminology and in industrial processes. These techniques involve the use of X-ray equipment in various configurations and experimental conditions. Operations with these X-ray equipments include mounting, alignment and adjustments of the specimen, recording devices and other experimental systems. Some of the operations need to be carried out in close proximity to the primary beam subjecting fingers and forearm of the user to intense radiation. There have been several instances of acute radiation injuries to hands and face of users of these equipments. In order to prevent such accidental situations, the equipment should incorporate safety provisions such as interlocks, shielded barriers, and access control devices.

This standard specifies that such features shall be provided in the design and construction of the equipment. This standard also specifies what tests should be carried out to verify the effectiveness of such safety provisions.

This standard is intended for the designer and manufacturers of X-ray analysis equipment so that compliance with this standard ensures adequacy of built-in safety of the equipment.

The first draft of this standard was prepared by Miss. Manisha G. Kusurkar and Dr. I. S. Sundara Rao of AERB.

S.D.Soman 7/5/92

(S.D.Soman)
Chairman , AERB

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RADIOLOGICAL SAFETY STANDARD SPECIFICATION FOR THE DESIGN AND MANUFACTURE OF X-RAY ANALYSIS EQUIPMENTS

1. INTRODUCTION

The X-ray diffraction and fluorescence techniques find a wide range of scientific and industrial applications related to material research and analysis. For the purpose of this standard such equipments are referred to as "X-ray Analysis Equipments". The typical acceleration potentials encountered for these applications are in the range of 25-100 kV. The X-ray analysis equipments make use of a collimated intense X-ray beam, improper use of which leads to acute exposures of skin, eyes, hands and fingers.

2. SCOPE AND OBJECTIVE OF THIS STANDARD

This standard provides guidelines specific to the radiation safety aspects in the design of X-ray analysis equipments for diffraction and fluorescence applications. The objective of the standard is to specify adequate built-in safety features in the design and manufacture of such equipments so that when equipments are designed and constructed in accordance with this standard, they can be accepted with reasonable confidence that users are adequately protected from unacceptable radiation exposures. The standard does not cater to the safety requirements related to electrical or mechanical aspects of the equipments. The standard does not deal with the radiological safety aspects related with the use of X-ray analysis equipments using radionuclides as X-ray sources.

The following documents are consulted in the preparation of this standard :-

1. IEC Publication 601-2-1 (1981)

2. "American National Standard N43.2 Radiation Safety for X-ray Diffraction And Fluorescence Analysis Equipment" ANSI 43.2-1977.

3. "Code of Practice for Protection Against Ionising Radiation Emitted from X-ray Analysis Equipments (1984) ", National Health And Medical Research Council,Australia.

3. TERMS USED IN THIS STANDARD

3.1 Accessory : An optional component part intended for attachment to or use with X-ray equipment which when attached or used, affects the quantity, quality or direction of X-rays.

3.2 Aperture/beam port : It is an opening in the protective material of X-ray tube housing through which the primary beam emerges.

3.3 Competent Authority : Any officer or authority appointed by Central Government by notification under Radiation Protection Rules, 1971. The Chairman, Atomic Energy Regulatory Board (AERB) is the Competent Authority for radiation protection in India.

3.4 Control panel : A console containing means for activation and regulation of X-rays and for preselection and indication of various operating parameters.

3.5 Grade A test : Inspection and analysis of equipment design provided by the manufacturer as related to the specified radiation safety provisions.

3.6 Grade B test : Visual inspection or functional test or measurement of equipment parameters. The test procedures are specified by this standard. The test procedures are based on operating states (including fault states) achievable without interference with the circuitry of the equipment.

3.7 Grade C test : Functional test of equipment or measurement of the associated equipment parameters. The test procedures shall be specified by the manufacturer in the documents in accordance with this standard. The test procedures may involve operating states which require interference with the circuitry or construction of the equipment. In such cases of interference, the work should be performed by the manufacturer's personnel or under direct supervision or approval of manufacturer's personnel.

3.8 Fail-Safe design : It is a design in which any failure of indicators/safety components may cause the equipment to fail in a mode such that personnel/equipment are protected.

3.9 Primary/useful beam : That part of the X-radiation which passes through an aperture and is intended for use as the primary source of X-rays incident on a sample.

3.10 Radiation safety interlocks : Two or more components/pieces of equipment interconnected by electrical or mechanical means so that separation of these automatically prevents the escape of the primary beam.

3.11 Site test : A test of each individual component or equipment after installation to demonstrate compliance with certain criteria.

3.12 Stray radiation : Radiation other than the primary beam emitted from the X-ray tube assembly and its shielding. This includes scattered and leakage radiation.

3.13 Tube housing : The housing surrounding the X-ray tube and the parts of the equipment, that is constructed to provide adequate protection from primary radiation and incorporates apertures for the emergence of the primary beam in the desired direction.

3.14 Tube shutter : A movable cover for aperture designed to reduce, when closed, the intensity of the emerging primary beam to prevent inadvertent exposures of persons beyond the shutter.

3.15 Type test : A test by the manufacturer to demonstrate that the device or equipment complies with certain criteria.

3.16 X-ray installation : This consists of one or more X-ray equipments along with their enclosures and includes the room in which they are located.

3.17 X-ray analysis equipment : An assembly consisting of a high voltage generator, X-ray tube, tube assembly, control panel, accessory parts including attachments such as cameras, goniometer, radiation detectors but not including pulse analyser, scalers etc.

4. CLASSIFICATION OF X-RAY ANALYSIS EQUIPMENTS

The standard classifies X-ray analysis equipments into the following two classes :

1. Totally Enclosed Equipments
2. Semi Enclosed Equipments

5. DESIGN SAFETY REQUIREMENTS OF X-RAY ANALYSIS EQUIPMENTS

The design safety features to be incorporated in these equipments shall be consistent with following operational requirements :

i) frequency of change of attachments and configurations,
ii) need for making adjustments with the X-ray beam,
iii) motion of specimen and the detector.

5.1 GENERAL REQUIREMENTS :

5.1.1 X-ray tube housing : The tube housing for any X-ray analysis equipment shall satisfy the following requirements :

5.1.1.1 It shall be constructed of high density material of sufficient strength and thickness to ensure that it cannot be deformed or develop cracks by normal use accidental mishap or misuse.

5.1.1.2 The tube housing shall be supported by suitable mechanical means facilitating and maintaining its easy and convenient position for a particular work.

5.1.1.3 Each aperture in the tube housing shall be covered by shutter of appropriate material ; all accesses to which are interlocked so that opening of one immediately de-energizes the X-ray tube.

5.1.1.4 The X-ray accessory parts shall include a beam trap or other barrier with sufficient shielding so that dose rate due to transmitted primary beam shall not exceed 25 uGy in one hour under normal operation when tube is operated at any ratings specified by manufacturer.

5.1.2 Tube shutters : Each shutter shall meet the following requirements :

5.1.2.1 Each shutter shall be provided with a SHUTTER OPEN indication with fail-safe design. Shutter shall be connected to the X-ray tube housing in such a manner that it normally remains in fully closed position and a certain positive action has to be taken to open it.

5.1.2.2 It shall be so constructed that the dose due to stray radiation does not exceed 25 uGy in one hour at 5 cms from any accessible surface under the conditions specified by the manufacturer.

5.1.2.3 There shall be provision for locking the shutters when not in use to prevent causal opening.

5.1.2.4 It shall be impossible to remove either the shutter or any of its mechanism without the use of special tools. The shutter shall effectively cover the entire aperture and shall be located as close to it as possible.

5.1.3 Beam traps/stops : Only a fraction of the primary beam is utilised by the specimen in the process of diffraction, absorption or both. Rest of the

primary beam which passes the specimen has to effectively absorbed to prevent inadvertent exposures to persons in the vicinity. This shall be achieved by using a beam trap.

5.1.3.1 The beam trap shall be made of high density material such as Pb, Cu or steel with such thickness so that the dose rate due primary beam beyond this shall not exceed 25 uGy in one hour at 5 cms.

5.1.3.2 The diameter of beam trap shall be such that it effectively covers entire cross section of primary beam. This shall form a fixed part of the equipment removable by means of special tools.

5.1.4 Control panel : All the operations related to the ON/OFF mechanism of the X-ray tube and preselection of operating parameters shall be done from a control panel which also has various indicators in form of lights. All these controls and indicators shall be of fail safe nature.

The control panel shall have the following controls and indications :

5.1.4.1 Line Power ON/OFF control with a permanent label " POWER ON" and the corresponding light indication.

5.1.4.2 A X-ray ON/OFF control with a permanent " X-rays ON " label and the corresponding light indication.

5.1.4.3 High voltage and tube current indication (either a calibrated meter or a digital display) to indicate the kV and the mA selected. The selection of high voltage and tube current shall be done by using a continuously varying or a step potentiometer.

5.1.4.4 In case of equipments having more than one X-ray beam operating simultaneously, or having more than one beam port, an indicator should display clearly the selected beam port. If an alphanumeric code is used as an indicator, a reference table explaining the code shall be permanently affixed on the control panel.

5.1.4.5 Shutter status indicators consisting of two light indicators of contrasting colours shall be used to indicate whether shutters are opened or closed. The indicator shall also display which shutter is open.

5.1.4.6 A timer for controlling duration of the exposure for each beam shall be provided on the panel. Production of X-rays should stop as soon as timer

returns to its " zero " position. Any subsequent exposure shall not be possible unless the timer is reset for the required duration followed by switching " ON " the X-ray ON/OFF control.

5.1.5 Safety interlocks : The interlocks used shall be of " fail safe " design. Interlock on one beam port shall not prevent access to the other beam ports . Interlocks shall be provided for each of the following so that removal or mishandling of these shall automatically shield primary beam or de-energise X-ray tube :

1) tube housing/tube shield
2) every beam port shutter
3) timer unit
4) beam trap
5) all openings of enclosures and shielding apertures.

Apart from all the above interlocks, guards or barriers shall be provided to prevent any part of the human body intercepting the path of primary beam.

5.1.6 Key lock switch : To prevent unauthorised use of the equipment, there shall be provision of a key-lock switch on control panel. The removal of the key from the lock shall automatically terminate the production of X-rays.

5.2 SPECIFIC REQUIREMENTS :

5.2.1 Totally enclosed equipments : These equipments are enclosed in a cabinet wherein all beam paths are shielded by interlocked barriers and/or shields so that there is no possibility of exposures of persons to primary beam during use. In addition to requirements in 5.1, these equipments shall meet the following :-

5.2.1.1 The specimens, samples, analysing crystal (if used) and detector shall be enclosed in a cabinet that cannot be entered by any part of the body during the normal operations.

5.2.1.2 Such equipments shall be so constructed that unless all operations and adjustments are completed and all enclosures are closed and properly interlocked, the X-ray beam cannot be energised.

5.2.1.3 Removal of any part of the enclosure or opening of enclosure shall automatically de-energise the beam or close the shutter.

5.2.1.4 All shutters and enclosures shall have fail-safe interlocks with X-ray tube ON/OFF mechanism to prevent any inadvertent exposures.

5.2.1.5 The inherent shielding of the cabinet walls shall be sufficient to limit the dose rate in all regions 5cms from its outer surface to 25 uGy in one hour during normal operations.

5.2.2 Semi enclosed equipments : In this type of equipment the X-ray beam paths are partially enclosed by interlocked fixed barriers and/or shields which need special tools for their removal. In addition to requirements in 5.1, these equipments shall also meet the following :

5.2.2.1 The enclosures shall have adequate thickness of shielding so that radiation dose at any accessible point 5 cms from surface of each partial enclosure shall not exceed 25 uGy in one hour.

5.2.2.2 The equipment shall be so sited that if for any reason a shutter is opened while an entrance to an enclosure is uncovered or barriers are incomplete , resultant primary beam is directed away from areas that maybe occupied. Adequate beam stops/traps shall also be provided for protection against primary beam.

6. MARKING AND LABELLING

6.1 Every equipment shall be marked and labelled in a conspicuous manner on control panel and X-ray tube housing to indicate whether it is an enclosed or semi enclosed equipment. The following inscription shall be marked clearly on the label :-

'CAUTION' -- THIS EQUIPMENT PRODUCES X-RAYS WHEN ENERGISED. TO BE OPERATED BY AUTHORISED PERSONNEL ONLY.

This equipment confirms to AERB SS-5(1992)
Type Approval Number AERB/

6.2 The control panel as well as the housing or equipment shall have a conspicuous sign which is illuminated when the X-rays are ON to aware the user of the status of X-ray beam.

7. TEST REQUIREMENTS

Following tests shall be carried out by the manufacturer to ensure correct functioning of the built-in safety features.

7.1 TIMER :

Type Test : Grade A

Design analysis to ensure that running up of TIMER and irradiation terminating capabilities are tested between irradiation.

Site Test : Grade B

Verify that the TIMER

(i) counts up with radiation

(ii) switches ON and OFF with radiation

(iii) retains its reading after irradiation is interrupted

(iv) requires resetting to zero before subsequent irradiation can be initiated

(v) terminates irradiation when preset time has elasped.

7.2 RADIATION SAFETY INTERLOCKS :

Type Test : Grade A

Design analysis of each interlock circuit to ensure that the required terminating capability is verified between irradiation.

Site Test : Grade C

Verification of correct functioning of radiation terminating capability of the interlocks by simulation of failure of each element.

7.3 LIGHT INDICATORS :

Site Test : Grade B

Verify correct functioning of all the indicators for their specific selection/indication operations.

8. ACCOMPANYING DOCUMENTS

8.1 The manufacturer shall supply the user with manuals regarding installation, assembly, interconnections and adjustment for each X-ray equipment.

8.2 The manufacturer shall supply operating, servicing and maintenance manuals along with the equipment.

8.3 The manufacturer shall submit to the Competent Authority the reports on the above mentioned tests. These reports shall specify test conditions, procedures, test devices and results of all tests along with type specification of the equipment i.e. either a totally enclosed or semi enclosed equipment.

9. QUALITY ASSURANCE PROGRAM

In order to maintain adequate radiation protection, quality assurance programs shall be carried out by the manufacturer of the equipments. These programs shall include main equipment, accessories and recording system. Quality assurance programs include acceptance tests of new equipments to ensure that they meet applicable performance specifications as have been determined in this standard. The manufacturer shall establish adequate QA programs covering the design, construction and test requirements adopted for the equipments.

10. TYPE APPROVAL

10.1 Every X-ray analysis equipment shall not be marketed unless it is type approved by the Competent Authority.

10.2 Type approval is subject to an adequate demonstration of compliance with requirements specified under sections 5,6 and 7 of this standard.

10.3 Built-in safety of such equipments is an important criteria for approval and should be demonstrated for both normal and accidental conditions.

The manufacturer shall make an application to the Competent Authority as per application form given in Appendix-1. The manufacturer shall submit with the application, the accompanying documents, test procedure specification of the manufacturer for Grade C tests, and documentation of the manufacturer demonstrating compliance with tests specified in this standard. The test documentation shall specify test conditions, test devices and results of all tests.

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APPENDIX I

Government of India
Atomic Energy Regulatory Board

Vikram Sarabhai Bhavan,
4th Floor, North Wing,
Anushaktinagar,
Bombay 400 094.

Ref: AERB/RSD/TA/ Date :

APPLICATION FOR THE TYPE APPROVAL OF

X-RAY ANALYSIS EQUIPMENTS

A] DETAILS OF MANUFACTURER :-

1. Name and address of the applicant :

2. Name and address of the manufacturer :

3. Persons to be contacted regarding this application :

B] SPECIFICATIONS OF THE EQUIPMENT :-

1. Name of the equipment :

2. Model/Category classification :

3. Anticipated life of the equipment :

4. Number of beam ports :

5. Beam energy at each port :

   i)
   ii)
   iii)
   iv)

6. Built-in safety features/radiation safety interlocks provided :

7. Standard to which equipment complies :

C] DOCUMENTS SUBMITTED ALONG WITH THE APPLICATION :-
(Tick the appropriate)

a) Details of design and construction of the equipment particularly as related to the shielding and radiation safety interlocks.

b) Drawings along with functional description of all the control and safety systems.

c) Instructions for the installation, use and maintenance of the equipment.

d) Performance test reports demonstrating the compliance with the National Standard.

e) Performance report of any equipment of the same type used in India during the past five years.

D] Any other information you may like to furnish :

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

Place :

Date :

Signature .....

Name .....

Designation .....

.....

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