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U.S. DEPARTMENT OF COMMERCE / National Bureau of Standards

American National Standard N537: Radiological Safety Standard for the Design of Radiographic and Fluoroscopic Industrial X-Ray Equipment

AMERICAN NATIONAL STANDARD N 537-1977

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American National Standard N537; Radiological Safety Standard for the Design of Radiographic and Fluoroscopic Industrial X-Ray Equipment

American National Standards Institute
Subcommittee N43-7

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American National Standard

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Preface

(This Preface is not a part of American National Standard N537, Radiological Safety Standard for the Design of Radiographic and Fluoroscopic Industrial X-Ray Equipment.)

The industrial use of x rays for the inspection, testing, and evaluation of a wide variety of objects and materials is employed extensively today. The objective of this standard is to minimize the exposure of persons to x-radiation from industrial radiographic and fluoroscopic equipment. This objective will be achieved in part by the design of industrial x-ray equipment and appropriate controls, warning displays, adequate interlocks, shielding (where necessary), and operating instructions.

It is the responsibility of the user to install and operate the equipment in accordance with the instructions provided by the manufacturer and in accordance with existing national and State health and safety codes. Safe operation and installation procedures are covered in detail in other documents.

American National Standards Committee N43 (Equipment for Nonmedical Radiation Applications), realizing the need to establish radiological safety standards in the design of radiographic and fluoroscopic industrial x-ray equipment, approved the development of such a standard in March, 1971. The responsibility to develop this standard was assigned to Subcommittee N43-7.

Beginning in June, 1971, Subcommittee meetings were held wherein this standard was developed, reviewed, and edited by organizations and people knowledgeable in this field. It was then submitted to American National Standards Committee N43 for approval, and it was subsequently submitted to the Board of Standards Review where final approval was received on December 7, 1976.

Suggestions for improvement of this standard will be welcome. They should be sent to the American National Standards Institute, 1430 Broadway, New York, New York 10018.

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American National Standard

Radiological Safety Standard for the Design of Radiographic and Fluoroscopic Industrial X-Ray Equipment

This standard provides guidelines specific to the radiation safety aspects of the design of industrial x-ray equipment operating at energies below 1 MeV for radiographic and fluoroscopic applications, wherein the x rays are generated by electronic means. The objective is to achieve safe design of industrial x-ray equipment by establishing requirements for some of the components which are critical for radiation safety. These include controls, panel displays, warning indicators, tube assembly, and shielding. Other considerations which are generally the responsibility of the manufacturer are also included, such as instructions, provision of means for connecting interlocks, and labelling. This standard does not include safety considerations outside the realm of radiation safety, nor does it apply to safe operation of such equipment.

Key words: Design standard; fluoroscopy; national standard; radiation safety; radiography; x-ray equipment; x-ray safety; x-ray tube.

1. Scope

This standard provides guidelines specific to the radiation safety aspects of the design of industrial x-ray equipment operating at energies below 1 MeV for radiographic and fluoroscopic applications, wherein the x rays are generated by electronic means. It does not include safety guidelines or other safety considerations outside the realm of radiation safety.

2. Definitions

The definitions and terms contained in this standard, or in other American National Standards referred to in this document, are not intended to embrace all legitimate meanings of the terms. They are applicable only to the subject treated in this standard.

accessory—an optional component part intended for attachment to or use with x-ray equipment which, when attached or used, affects quantity, quality, or direction of x rays.
control panel—a device containing means for regulation and activation of x-ray equipment, or for the preselection and indication of operating factors.
deadman switch—a device so designed that a closed circuit can be maintained only by continuous operator pressure.
ground fault—an accidental electrical grounding of an electrical conductor.
key switch—a device which requires a key for making and breaking electrical connections.
leakage radiation—radiation other than the useful beam emitted from the x-ray tube assembly.
line power switch—a device for making and breaking the connections to the electrical supply.
manufacturer—any person engaged in the business of manufacturing, assembling, or importing x-ray equipment.
nonshielded x-ray tube assembly—an x-ray tube assembly which does not meet the requirements of paragraph 8.1.1 of this standard.
radiation safety interlock—a device for precluding access to an area of radiation hazard by automatically removing the hazard.
shall—where "shall" is used for a provision specified herein, that provision is intended to be a requirement.
shielded x-ray tube assembly—an x-ray tube assembly designed to meet the requirements of paragraph 8.1.1 of this standard.
should—"should" is used to indicate provisions which are not required but which are here recommended as good practice.
shutter—a movable device used to block the useful beam emitted from an x-ray tube assembly.
supplier—the person or organization from which the user buys or takes delivery of a product.
timer—a time-measuring device designed to automatically make or break electrical connections at the end of a preset time interval.
user—that person or organization which will have administrative control over the equipment.
useful beam—all radiation from an x-ray tube assembly which emerges through the port, diaphragm, or cone.
x-ray tube assembly—a tube housing with the tube installed. It may include high voltage and filament transformers and other appropriate elements when they are contained within the tube housing.

3. Instructions

3.1 Written instructions for the installation, assembly, interconnection, adjustment, and test of each x-ray unit or accessory shall be supplied by the manufacturer or supplier of such equipment at the time of sale or transfer to the first user.

3.1.1 Installation instructions shall describe radiation safety considerations pertaining to positioning and fastening each unit or accessory in place.

3.1.2 Assembly instructions shall include instructions for assembly operations not performed by the manufacturer.

3.1.3 Interconnection instructions shall include, but not be limited to, descriptions of cable and wire connections not performed by the manufacturer, including interconnection of radiation safety interlock systems, warning light systems, and audible alarm systems not supplied by the manufacturer.

3.1.4 Test instructions shall include a description of the steps necessary for the user to determine that the unit and accessory components are operating properly. Such instructions shall be written in a step-by-step manner.

3.1.5 Instructions shall state that, when any component affecting the radiation safety of the x-ray system is serviced or replaced, then the installation shall again be suitably surveyed to assure continuity of adequate personnel safety.

3.1.6 Instructions shall include a warning of hazards caused by the improper installation of the x-ray equipment. The warning shall include the classification of the x-ray tube assembly.

3.1.7 Instructions shall state the classification of the x-ray tube assembly. (See 8.1.)

3.1.8 Written instructions shall state that the final acceptance should be acknowledged by both the supplier and the user.

3.1.9 The person who installs the x-ray equipment should acknowledge to the supplier/manufacturer that the installation has been performed according to the manufacturer's instructions.

3.1.10 The user should acknowledge to the supplier/manufacturer that the interlock system, warning lights, and other radiation safety devices were all operating properly after installation.

3.2 Written instructions for the operation of each x-ray unit or accessory equipment shall be supplied by the manufacturer or supplier of the equipment at the time of sale or transfer to the first user. Such instructions shall:

3.2.1 Direct the user to consult governmental regulations and industry standards governing the operation of x-ray equipment.

3.2.2 Inform the user of the need for proper training and supervision in the use of x-ray equipment.

3.2.3 Describe personnel dosimetry and survey devices suitable for measurements associated with the use of the equipment and accessories. Such instructions shall include the characteristics of the radiation to be measured and may include reference to specific commercially available instruments.

3.2.4 Include a warning of hazards caused by the improper use of x-ray equipment. The warning shall include the classification of the x-ray tube assembly.

3.2.5 Include concise descriptions of shutdown procedures to be followed by the operator in case of emergency.

3.2.6 Include periodic equipment safety check and maintenance procedures, with the suggested time intervals in which such procedures shall be performed.

3.3 An instruction manual should be obtainable from the manufacturer for a period of at least 7 years from the date of initial purchase of the equipment. The cost of the instruction manual should not exceed the cost of printing and distribution.

4. Controls

4.1 Line Power Control

4.1.1 The control panel shall be equipped with a device which shall disconnect the line power from all components involved in the production of x rays. This function can be accomplished by a device such as, but not limited to, a "power switch" or a "circuit breaker." However, it is not necessary to be able to disconnect components independent from the production of x rays such as, but not limited to, cooling pumps.

4.1.2 The function and the "on-off" positions of the component disconnecting the line power shall be clearly marked.

4.1.3 When toggle or lever type switches are used, the "on" position shall be uppermost or most forward or most right.

4.1.4 When rotary type switches are used, the "on" position shall be clockwise.

4.2 Key Switch

4.2.1 The control panel will be equipped with a key switch which shall prevent the production of x rays when placed in the "off" position.

4.2.2 The key shall be removable only when the switch is in the "off" position.

4.2.3 The function and the "on" and "off" position of the key switch shall be clearly marked.

4.2.4 When toggle or lever type key switches are used, the "on" position shall be the uppermost, or the most forward, or the most right.

4.2.5 When rotary type key switches are used, the "on" position shall be clockwise.

4.3 "X-Ray On" Control

4.3.1 The production of x rays shall be initiated only by actuating a device provided solely for this purpose.

4.3.2 The function of a push button or the function and position of other types of devices shall be clearly labeled.

4.3.3 The "x-ray on" control shall not be of red color. (See paragraph 5.1.1.)

4.4 "X-Ray Off" Control

4.4.1 A device which can instantaneously terminate the production of x rays when actuated shall be located near each "x-ray on" control. The control line power switch or safety interlock system shall not be used for this function.

4.4.2 When the object to be inspected (radiographed or fluoroscoped) automatically initiates the exposure or causes x rays to irradiate the object, an "x-ray off" control shall be located on the main control panel.

4.4.3 The function of a push button or the function and position of other types of devices shall be clearly labeled.

4.4.4 The "x-ray off" control shall be permanently of red color.

4.5 X-Ray Production Limiting Device

4.5.1 A device shall be provided which shall terminate the production of x rays after a preset time interval not to exceed 2 hours. As an alternate, a "deadman" switch may be used.

4.5.2 The requirement of 4.5.1 may be waived in systems requiring undetermined length of radiation production provided that radiation emission is confined to a protective installation as defined in ANSI N543-1974. (It should be noted that cabinet x-ray systems must comply with the performance standard established under the Radiation Control for Health and Safety Act, 21 CFR 1020.40).

5. Control Panel Display

5.1 Panel Lights

5.1.1 Devices used to control x-ray emission shall have status indicator lamps adjacent to or part of the control device. Indicator lamps shall be placed in a clear unambiguous arrangement on the control panel. They shall be clearly labeled, marked, or easily identified as to their function. Control devices required to activate indicator lamps are:

5.1.1.1 "X-Ray On" control device as described in Section 4.3.1. This lamp shall be red.

5.1.1.2 Shutter control device. If emission of useful beam is controlled by shutters, the shutter control device at the operator's station shall activate two indicator lamps of contrasting colors, one of which shall be activated when the shutters are fully closed and the other when the shutters are not fully closed.

5.2 Line Power Indicator

5.2.1 The line power on/off control shall have a lamp or other visual indicator to show the control status. It shall be clearly labeled, marked, or easily identified as to its function.

5.3 High Voltage Indicator

5.3.1 The control panel shall be equipped with a device for indicating value of the high voltage selected. This may consist of a calibrated meter, calibrated scale (or equivalent) or indicator lamps for fixed multiple high voltage values, or a statement on the control panel for equipment that operates at a single fixed high voltage value. The function of the indicating device shall be identified.

5.4 Selection Indicator(s) for X-Ray Tube Assembly(s) and Focal Spot

5.4.1 If more than one x-ray tube assembly(s) or focal spot can be operated sequentially or simultaneously from a control panel, lamps or other visual indicators located on the control panel shall indicate which tube assembly(s) or focal spot has been selected. The selectors shall be identified as to their function. If a letter or number reference code is used on the control, a reference card or table explaining the code shall be affixed to the control panel.

5.5 "X-Ray On" Indicators

5.5.1 At least two indicators shall be provided on the control panel to indicate x-ray production when, and only when, x rays are produced. Failure of a single component shall not cause failure of both indicators.

5.5.2 One, but not both, of the indicators may be a suitable meter labeled to indicate tube current.

6. Radiation Warning Indicators

6.1 Warning Displays on Equipment

6.1.1 The control panel shall be clearly labeled:

"CAUTION"
"THIS EQUIPMENT PRODUCES X RAYS WHEN ENERGIZED. TO BE OPERATED BY QUALIFIED PERSONNEL ONLY."

6.1.2 The x-ray tube assembly shall be labeled with the words:

"CAUTION"
"THIS EQUIPMENT PRODUCES X RAYS WHEN ENERGIZED. TO BE OPERATED BY QUALIFIED PERSONNEL ONLY."

This statement should be legible at a distance of at least 2 meters.

6.1.3 The x-ray tube assembly shall also be labeled as specified in Section 8.4.

6.2 Warning Devices for the X-Ray Tube Assembly

6.2.1 A red warning lamp or audible device, or both, shall be provided on or at any x-ray tube assembly which is used in a non-permanent installation (open installation as described in ANSI N543-1974). These devices shall be activated only when x rays are produced and—

6.2.1.1 If a single device is provided and is inoperative, no x rays can be produced, or

6.2.1.2 Multiple warning devices, wired in parallel, shall be provided.

6.3 External Warning System

6.3.1 Provisions shall be made to enable activation of an external warning system simultaneous with or prior to x-ray production.

6.4 Shutters Status Indicators

6.4.1 If emission of useful beam is controlled by shutters, the shutter device shall have on it two visible signals of contrasting colors to indicate the shutter status. One signal shall show when the shutters are fully closed, and the other when the shutters are not fully closed. These signals may be electrical or mechanical.

7. Safety Interlocks

7.1 The production of x rays shall not be initiated by the action of safety interlocks.

7.2 The equipment shall be provided with receptacles or terminals for connection to the radiation safety interlocks.

8. X-Ray Tube Assembly

8.1 Classification. An x-ray tube assembly shall be classified as either shielded or nonshielded. The requirements for these classifications are as follows:

8.1.1 Shielded—The leakage radiation from a shielded x-ray tube assembly, at 1 meter from the target, shall not exceed 1 roentgen in 1 hour when the tube is operated at any of its specified ratings.

8.1.2 Nonshielded—If the leakage radiation at 1 meter from the target exceeds 1 roentgen in 1 hour when the tube is operated at any of its specified ratings, the tube assembly shall be classified as nonshielded.

8.2 Any item incorporated into an x-ray tube assembly which affects the leakage radiation characteristics shall be securely affixed and shall not be subject to shifting during normal handling procedures.

8.3 Measurement of X-Ray Tube Assembly Leakage Radiation

8.3.1 The leakage radiation measurements shall be averaged over an area of 100 square centimeters with no linear dimension greater than 20 centimeters. Leakage radiation shall be measured at 1 meter distance from the x-ray tube target.

8.3.2 Measurements shall be in the absence of any scatter radiation due to the useful beam.

8.3.3 The x-ray tube shall be operated, within specified ratings, so as to produce maximum leakage radiation.

8.3.4 When a shutter is used, the shutter position shall be that which produces maximum leakage radiation.

8.4 X-Ray Tube Assembly Classification Label

8.4.1 An X-ray tube assembly shall be conspicuously labeled indicating the classification specified in paragraph 8.1.

8.4.2 The classification label should state whether the design leakage is less than/greater

than 1 R (roentgen) in an hour at 1 meter from the x-ray tube target.

8.4.3 The label may be engraved directly on the tube housing or may be embossed or engraved on a metallic or polymer label which is securely affixed.

8.5 The manufacturer shall provide a description of the leakage radiation characteristics including the design or expected maximum value of the leakage radiation and its direction. Such information may be provided on a model rather than item basis.

9. Beam Limitation

When a collimator, cone, diaphragm, or shutter is used to limit the beam for the purpose of radiation protection, the total leakage radiation from the x-ray tube assembly and the beam-limiting device shall not exceed that permitted from the x-ray tube assembly alone.

10. Fluoroscopic Shielding

10.1 General

10.1.1 Fluoroscopic installations shall be designed to conform to the requirements of either a Protective Installation, or Enclosed Installation, or an Open Installation as specified in ANSI N543-1974.

10.1.2 The design of the shielding shall be based on the maximum radiation output available from the x-ray source when operated at any of its specified ratings.

10.2 Design Considerations for Viewing

10.2.1 If the fluoroscopic installation does not conform to the requirements for a Protective Installation as specified in ANSI N543-1974, the equipment shall be so constructed that the radiation level at the operator's station shall not exceed 0.5 mR in any 1 hour at any accessible region 5 cm from the outside surface of the shielding barrier.

10.2.2 Removal of the shielding barrier shall terminate x-ray production unless such removal can be accomplished only with the use of tools.

11. Other Considerations

11.1 Ground Fault

11.1.1 A ground fault shall not result in x-ray production.

11.2 Automatically Discharging Capacitors

11.2.1 X-ray generating equipment containing high voltage type capacitors in the high voltage transformer shall be equipped with a grounding device which automatically discharges the capacitors within two seconds of when the equipment is turned off.

12. Revision of American National Standards Referred to in this Document

When the following American National Standard referred to in this document is superseded by a revision approved by the American National Standards Institute, Inc., the revisions shall apply:

N543-1974, General Safety Standard for Installations Using non-Medical X-Ray and Sealed Gamma-Ray Sources, Energies Up to 10 MeV.

Appendix. Radiation Measurements

(This appendix is not part of American National Standard N537, Radiological Safety Standard for the Design of Radiographic and Fluoroscopic Industrial X-Ray Equipment.)

A1 This appendix provides guidelines for making measurements required to ensure compliance with this standard. The basic principles of radiation measurement and instrumentation are covered in other publications.

A2 Instrumentation

A2.1 A wide range of instruments is used for the above purpose. The sensitivities of these instruments vary by a factor of several millions, and they also differ in other respects depending on their specific application.

A2.2 Scanning Devices. The detection of pinhole and other minute voids in shielding requires instruments with high sensitivity as only a small fraction of the sensitive volume of the detector may be exposed to radiation. GM or scintillation counter survey instruments are particularly useful for this purpose. However, most of these instruments are highly energy dependent and are, therefore, less suitable for quantitative measurements. Photographic films and the fluoroscopic screens serve to determine the configuration of the void and its exact location.

A2.3 Exposure and Dose Meters. Most quantitative measurements are made with

ionization chamber instruments. The chamber may be either permanently attached to the measuring system, as in the case of the survey instrument, or be detachable, as with the condenser R-meter. The survey instrument measures exposure rate and is usually calibrated in mR/hour. The condenser R-meter is used to measure exposure in Roentgens and with appropriate filters can be used to measure quality (absorption curve or half-value-layer) of the useful x-ray beam.

A2.4 Thermoluminescent Detectors. Various systems have been developed for the use of phosphor materials, such as LiF, in dosimeters. Their application in the field of personnel monitoring is particularly useful due to their wide linear range and relatively low energy dependence.

A3 Special Instrument Requirements

A3.1 Energy Dependence. The detecting device should have a minimum energy dependence in the radiation quality region of interest. For low energy radiation, such as unfiltered x rays produced at 50 kV or less, the wall of the ionization chamber should be sufficiently thin not to cause significant attenuation of the rays. For high energy radiation, the chamber wall should be sufficiently thick to ensure electronic equilibrium.

A3.2 Saturation Voltage. Special precautions are required when measuring pulsed x-ray beams of high instantaneous exposure rates. The ionization chamber must have saturation voltage, that is, sufficient potential to collect all the ions before they recombine. Tests for saturation may be made by taking readings using different voltages across the chamber. There is no significant recombination if the indicated R/min is the same for the lower as for the higher chamber voltage.

A3.3 Time Response. The time response of the measuring instrument is of particular importance where the exposure time has to be kept short in order not to overload the x-ray tube at high mA techniques.

A3.4 Uniform Radiation Field. The correct reading of a radiation instrument requires that its entire sensitive volume is in a uniform radiation field. If this is not the case, correction must be made (e.g., a 5 cm^2 beam entering the face of a 100 cm^2 ion chamber may indicate only 1/20 of the true exposure rate). In the testing of tube housing leakage radiation, the exposure rate may be averaged over an area of 100 cm^2.

A3.5 Shielding Against HF (High Frequency) Fields. When x-ray measurements are made in the presence of HF fields, as in the case of microwave equipment, the radiation instrument must be electrically shielded. The effectiveness of the shielding may be checked by using a radioisotope as a known additional source of radiation.

A3.6 Instrument Calibration. Radiation instruments for quantitative measurements should have a complete calibration using radiations with energies similar to those expected in the field. The calibration should be traceable to instruments calibrated at the National Bureau of Standards. The calibration report should indicate when correction factors should be applied for the different qualities of radiation within the useful energy range of the instrument. The instrument calibration should be checked periodically. A radioactive source of low activity may be used for this purpose.

A4 Measurement of the Useful Beam

A4.1 It is sometimes necessary to determine the output of the x-ray tube and the quality of the beam in order to ensure that the x-ray tube is operating at its maximum rated potential (kV) and current (mA) during the protection measurements. The output is expressed by its exposure rate in R/min at 1 meter distance (Rmm) and the quality by the absorption curve, or half-value-layer (HVL) in aluminum, copper, or lead.

A4.2 The absorption curve completely identifies the quality of the x-ray beam. However, for most practical purposes, the measurement of the HVL is sufficient. The HVL can be used in estimating the x-ray tube potential, provided the total filtration (inherent plus added) is known. Table A1 can be used for this purpose; it gives expected HVL's for representative conditions.

TABLE A1 *Approximate half-value layers*

Potential	Total Filtration[a]		HVL	
kV	Al mm	Pb mm	Al mm	Pb mm
50	1.0	.	1.0	.
100	3.0	.	3.1	.
150	.	2.0	.	0.30
200	.	3.0	.	0.45
250	.	6.0	.	0.90
300	.	10.0	.	1.6
400	.	16.0	.	2.4
500	.	24.0	.	3.3

[a] Including Al or Pb equivalent of x-ray tube window.

A5 Radiation Protection Surveys

A5.1 Survey of New Facilities. Before a new x-ray facility is placed in routine operation, a radiation protection survey should be made by a qualified expert. (See ANSI N543-1974.)

A5.2 Changes in Existing X-Ray Facilities. A radiation protection resurvey or reevaluation by a qualified expert should be made when changes have been made in shielding, operation, equipment, or occupancy of adjacent areas, and these changes may have adversely affected radiation protection. A qualified expert should be consulted in case of doubt.

A5.3 Report of Radiation Protection Survey. No existing facility should be assumed to conform with the provisions of this standard unless a radiation protection survey has been made by a qualified expert and a report of the survey has been placed on file at the installation.

A5.4 Elimination of Hazards. Any radiation hazard found in the course of a survey should be eliminated before the installation is used routinely. A record should be kept of the action taken.

A5.5 Radiation Measurements. The radiation levels in mR/hour should be measured in all adjacent areas that can be occupied. The measurements should be made under practical conditions of operation that would result in the greatest exposure rates at the points of interest. X-ray apparatus should be operated at the maximum kilovoltage and at its maximum milliamperage for continuous operation at that voltage.

A5.6 Common Causes of Inadequate Structural Shielding.

A5.6.1 Type or use of equipment different from that originally specified.

A5.6.2 Defective workmanship causing leakage at joints, doors, and lead glass windows.

A5.6.3 Concrete density less than that specified.

A5.6.4 Recessed ducts, switch boxes, etc., not lead shielded to compensate for reduced concrete thickness.

A5.6.5 Inadequate shielding against multiple scattered radiation such as "skyshine."

A5.7 Contents of Radiation Protection Survey Report. The report of a radiation protection survey should include:

A5.7.1 Identity of persons conducting the survey and date.

A5.7.2 Identification of the radiation facility by suitable means, e.g., serial number, room number, and building number or name.

A5.7.3 Identification of measuring instruments used.

A5.7.4 Potential and current at which the x-ray tube was operated during the test.

A5.7.5 The location of the x-ray tube target and the orientation of the useful beam with relation to each exposure measurement.

A5.7.6 Exposure rates in all nearby areas which can be occupied. The locations of the measurements should be suitably identified, if necessary, by appropriate drawings.

A5.7.7 A description of the existing mechanical and electrical limiting devices that restrict the orientation of the useful beam and the position of the source.

A5.7.8 A statement indicating the appropriate classification of the installation, as specified in ANSI N543-1974.

References:

[A1] ICRU Report #20, Radiation Protection Instrumentation and Its Application, October 1, 1971, International Commission on Radiation Units and Measurements.

[A2] NCRP Report #10, Radiological Monitoring Methods and Instruments, April 7, 1952, National Council on Radiation Protection and Measurements.

[A3] Los Alamos Handbook of Radiation Monitoring, 1970, LA4400 Superintendent of Documents, Washington, D.C. 20402.

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16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

This standard provides guidelines specific to the radiation safety aspects of the design of industrial x-ray equipment operating at energies below 1 MeV for radiographic and fluoroscopic applications, wherein the x rays are generated by electronic means. The objective is to achieve safe design of industrial x-ray equipment by establishing requirements for some of the components which are critical for radiation safety. These include controls, panel displays, warning indicators, tube assembly, and shielding. Other considerations which are generally the responsibility of the manufacturer are also included, such as instructions, provision of means for connecting interlocks, and labelling. This standard does not include safety considerations outside the realm of radiation safety, nor does it apply to safe operation of such equipment.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

Design standard; fluoroscopy; national standard; radiation safety; radiography; x-ray equipment; x-ray safety; x-ray tube.

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