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Test Standard for the Measurement of the Image Signal Uniformity of an X-Ray Image Intensifier System

NEMA

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION ■ 2101 L STREET, N.W., WASHINGTON, D.C. 20037

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TEST STANDARD FOR THE MEASUREMENT OF THE IMAGE SIGNAL UNIFORMITY OF AN X-RAY IMAGE INTENSIFIER SYSTEM

Published by

National Electrical Manufacturers Association
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FOREWORD

This NEMA Standards Publication is one of a series of test standards developed by the X-Ray Imaging Products Section and the medical diagnostic imaging industry for the measurement of performance characteristics governing the image quality of X-Ray image intensifier (XRII) systems. These test standards are intended for the use of equipment manufacturers, prospective purchasers, and users alike. Manufacturers may find these standards useful in establishing standard test conditions for the determination of system performance specifications. Prospective equipment purchasers may benefit from these standards as the employment of standard test conditions and methods enables meaningful comparisons to be made of NEMA-referenced, competitive, equipment performance specifications. Users may also benefit from these standards through a better appreciation of the performance of XRII systems.

Characterizing the parameters that govern image quality is a non-trivial task. The assessment of image quality lies in the eye of the beholder and so is a somewhat subjective measure influenced by the spatial, temporal, contrast, and noise characteristics of the image. Historically, many techniques have been developed employing varying degrees of sophistication to establish subjective and objective measures of these parameters, and the following non-exhaustive list of parameters can be considered as relevant to image quality.

a. Contrast Ratio
b. Detective Quantum Efficiency (DQE)
c. Fixed Pattern Noise
d. Gain
e. Image Signal Uniformity
f. Lag
g. Limiting Spatial Resolution
h. Modulation Transfer Function (MTF)
i. Noise Power Spectrum
j. Radial Image Distortion
k. Signal to Noise Ratio
l. Visible Entrance Field Size

These parameters are not all independent and some of them may partially overlap in assessing the image quality. Moreover, it must be recognized that not all of these parameters lend themselves to measurement at the installation site. Some parameters require instrumentation better suited to factory measurements while others require the facilities of an instrumentation laboratory to assure the stable test conditions necessary for reliable measurements. The NEMA X-Ray Image Intensifier Systems Subcommittee intends to make a selection from the above-mentioned list of parameters where practical and mechanically feasible measurements can be made at the system level and to prepare a set of NEMA standards.

This publication has been prepared by the X-Ray Imaging Products Section of NEMA which periodically reviews it for revisions necessary to keep it up to date with advancing technology.

Comments or proposed revisions are welcomed and should be submitted to:

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INTRODUCTION

This document defines the NEMA test method for measuring the image signal uniformity of an X-Ray image intensifier (XRII) system. The test method described in this Standard Publication includes system test conditions, measurement procedures, determination of results, indication and Statement of Compliance.

SCOPE

The procedures in this standard define the method of measuring the image signal uniformity produced by a XRII system under a given set of test conditions. Imaging systems considered in the Standard include video, photofluorographic, and cine systems. The XRII system shall be assembled and adjusted according to the instructions of the manufacturer.

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Section 1
REFERENCED STANDARDS AND DEFINITIONS

1.1 REFERENCED STANDARDS

American National Standards Institute
11 West 42nd Street, 11th Floor
New York, NY 10036

PH2.48-1981 — *Method for the Sensitometry of Medical and Dental X-Ray Film Used with Fluorescent Screens*

National Electrical Manufacturers Association
2101 L Street, NW
Washington, DC 20037

XR 10-1992 — *Measurement of the Maximum Symmetrical Radiation Field from a Rotating Anode X-Ray Tube Used for Medical Diagnosis*

1.2 DEFINITIONS

1.2.1 Actual Focal Spot

Area on the surface of the X-ray tube target that intercepts the beam of electrons.

1.2.2 Aluminum Equivalent

The thickness of 99.8 percent pure aluminum affording the same attenuation, under specific conditions, as the material in question.

1.2.3 Center of the Image

That point in the entrance plane of the XRII system which corresponds to the center of the smallest circle circumscribing the image.

1.2.4 Central Axis of the X-Ray Field

The line perpendicular to the entrance plane of the XRII system passing through the center of the actual focal spot.

1.2.5 Center of the Entrance Field

That point in the entrance plane which is imaged at the center of the output of the XRII system.

1.2.6 Entrance Plane of the XRII System

The plane perpendicular to the axis of the XRII and grazing that part of the XRII, including its housing, which protrudes most in the direction of the radiation source. The following components shall not be considered elements of the XRII housing.

a. Antiscatter grid
b. Collision sensors
c. Ionization chambers
d. Protective cover
e. Removable magnetic shields and coils
f. Spot film device

1.2.7 Half-Value Layer

The thickness of a specified material required to decrease the exposure rate of a beam of X-rays to one-half its initial value. For the purpose of this definition, the solid angle of the radiation beam shall be as small as possible so that the quantity of scattered radiation included in the beam is minimized.

1.2.8 Image Signal

The relative luminance measured over a specified area of the video display monitor for video systems, the relative exposure at the film plane for photofluorographic camera and cine camera systems.

1.2.9 Output Image of the XRII System

The image produced by the XRII SYSTEM that is visually perceivable by a human observer. Output image channels of the system include:

a. Processed photofluorographic film
b. Processed cine film
c. Television monitor display screen

1.2.10 Source-to-Entrance Plane Distance (SED)

The distance from the actual focal spot to the entrance plane of the XRII system measured along the central axis of the X-ray field.

1.2.11 Uniformity of Image Signal

The uniformity of image signal is the minimum signal divided by the maximum signal. The maximum and minimum are determined within a specified area.

$$\% \text{ Uniformity} = (\text{Min. Signal}/\text{Max. Signal}) \times 100$$

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1.2.12 Visible Entrance Field Size

The dimensions in the entrance plane of the XRII system of the field that is used for transmission of the X-ray pattern measured along two specified axes.

1.2.13 X-Ray Tube Voltage

Potential difference applied to an X-ray tube between anode and the cathode. Usually, X-ray tube voltage is expressed by its peak value in kilovolts (kV).

1.2.14 X-Ray Image Intensifier (XRII) Systems

That portion of an X-ray imaging system consisting of the XRII with its housing and the subsequent components of the imaging chain responsible for transmitting and displaying the detected X-ray patterns. The following components shall not be considered elements of the XRII system.

a. Antiscatter grid
b. Spotfilm device
c. Collision sensors
d. Removable magnetic shields
e. Coils

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Section 2
TEST EQUIPMENT

2.1 IMAGE CALIBRATION TEMPLATE

An image position calibration template is used to locate the center of the image. A suggested template is shown in Figure 2-1 consisting of a thin X-ray transparent panel with X-ray absorbing demarcations along which distance measurements are made. The overall size of the template shall be larger than the visible entrance field size to be measured.

2.2 PHOTOMETER

An instrument capable of measuring the luminance of a source of light over a well-defined and specified area.

2.3 DENSITOMETER

An instrument capable of measuring the optical density of a film over a well-defined and specified area.

2.4 SENSITOMETER

An instrument capable of giving a calibrated and graded exposure to film. This sensitometer shall be appropriately filtered to simulate the light spectrum and exposure conditions typically of the XRII system under test.

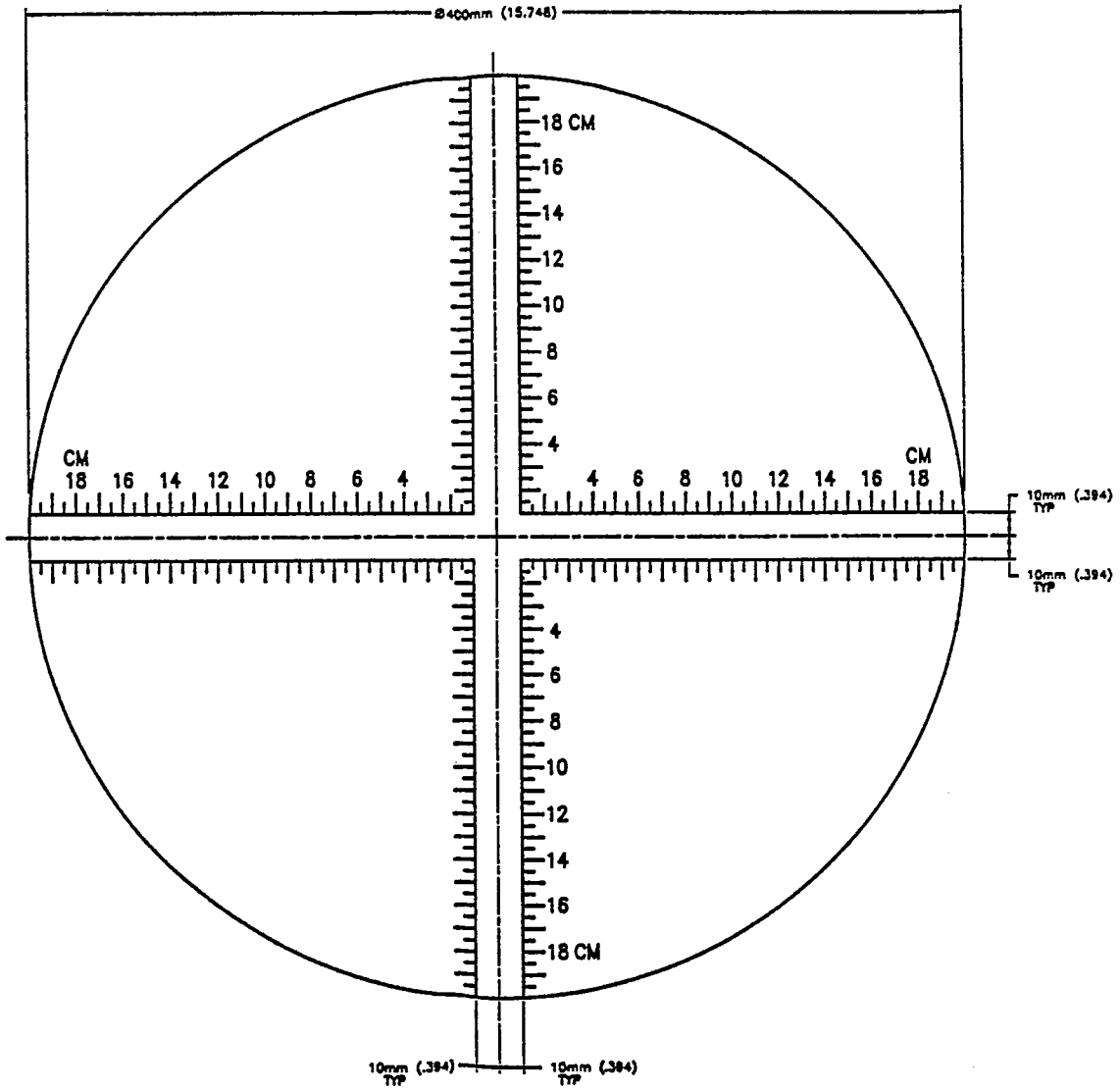

Figure 2-1
IMAGE POSITION CALIBRATION TEMPLATE

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Section 3
STANDARD TEST CONDITIONS

3.1 GENERAL REQUIREMENTS

The system shall be set up according to the specifications of the manufacturer, except as noted in paragraphs below. During the test, except where explicitly permitted, no change shall be made to the system setup. This includes, but is not limited to, adjustment of the X-ray image intensifier and video camera, as well as the focus of the XRII and any lenses and video cameras.

It is recognized that under some conditions it will be necessary to remove a grid or disassemble a window covering to satisfy the test condition. Deviations from the standard test conditions are permitted only where it is impractical to meet those conditions. Such deviations must be explicitly stated in the Presentation of Results.

3.2 SOURCE TO ENTRANCE PLANE DISTANCE (SED)

The standard SED shall be 100 cm ±1 cm. Equipment of fixed SED or whose adjustment range does not span the standard SED shall be tested at the spacing recommended by the manufacturer and such spacing shall be reported in the Presentation of Results.

3.3 RADIATION REQUIREMENTS

3.3.1 Exposure Rate

The exposure rate shall be the normal level as prescribed by the manufacturer for the application for which the image signal uniformity is specified.

3.3.2 Filtration of Radiation

The total filtration of the X-ray beam at the point in the entrance plane corresponding to the center of the image shall be 22.5 ±0.5 mm of aluminum equivalent, of which 20 mm shall be of 99.8 percent pure aluminum. The distance from the source to the filter shall not exceed 50 cm.

3.3.3 Limitation of the X-Ray Beam

The beam of radiation shall be collimated in accordance with the imaged field size. The collimator shall be positioned between the X-ray source and the added filtration described in Section 3.3.2. Collimators shall be adjusted so that the collimator blades are tangent to the area imaged.

3.3.4 Radiation Quality

The incident beam of radiation shall be adjusted to have an aluminum half-value layer 7.0 mm ±0.2 mm at the point in the entrance plane corresponding to the center of the image. This radiation quality shall be obtained by using the filtration described in Section 3.3.2 and adjusting the X-ray tube voltage to approximately 75 kV.

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Section 4
DETERMINATION

4.1 MEASUREMENT PROCEDURES

4.1.1 Location of the Image Position Calibration Template

The Image Position Calibration Template shall be positioned in the entrance plane of the XRII system and centered in the respective output image of the XRII system using demarcations along the axes of the template. For video systems one of the orthogonals of the template shall be oriented parallel to the scan lines. For photofluorographic systems, one of these axes shall be oriented across the diagonal of the film image.

4.2 MEASUREMENT OF THE IMAGE SIGNAL DISTRIBUTION

4.2.1 Size of the Measuring Field

The effective sampled areas at each measured location shall not exceed 0.25% of the image area or an area, in the entrance plan, with a diameter of 4% of entrance field diameter, whichever is larger.

4.2.2 Measurement

The image signal distribution may be measured either with a continuous scan across the image, or at discrete points. In either case, the measurement shall sample along two orthogonal directions up to 90% of the largest diameter. For measurements at discrete points, this requires that the distance between sample points shall be less than the width of the effective sample area.

For photofluoroscopic film and cine film systems, the film density shall be determined in the image and these density measurements converted to Image Signal values by use of the characteristic curve of the film. The characteristic curve of the film shall be determined by the intensity scale sensitometry using a light spectrum and exposure times resembling the XRII system measurement parameters. Refer to ANSI PH2.48-1981 for general sensitometry principles.

For video systems, the display monitor shall be adjusted to display the maximum number of gray levels. Using the SMPTE test pattern or equivalent for video displays and hard copy cameras (Ref.1), the brightest step shall be set to give a reading of 15 ft-L, while the blackest step will be simultaneously 0.5 ft-L above the cathode ray tube cutoff. Note that care must be taken to avoid any effects of ambient light when establishing monitor settings.

The values obtained for image signal uniformity shall be corrected for non-uniformity of the radiation beam as specified in Section 4.3.7.

4.2.3 Accuracy of the Image Signal Measurement

A relative deviation of ±2% in signal level shall be detectable. No particular specifications are required with respect to absolute accuracy of the image signal measurements.

4.3 CORRECTION FOR NON-UNIFORMITY OF THE BEAM OF RADIATION

4.3.1 General

The image signal uniformity of an XRII system is defined for a uniform beam of radiation. Therefore, measurements of the relative intensity of the radiation beam shall be made at the entrance plane of the XRII system, and the measurements of image signal shall be corrected according to the distribution of the radiation beam.

4.3.2 X-Ray Exposure or Exposure Rate

The X-ray exposure or exposure rate used to define the non-uniformity of the incident X-ray beam shall be the same kV and half-value layer as the image signal distribution measurement. The time of exposure or exposure rate may vary between the two beams.

4.3.3 Recommended Measurement Method

An analysis of the density distribution of a radiograph on non-screen film is recommended for measuring the non-uniformity of the image system entrance X-ray beam. See NEMA Standard Publication XR 10. Other methods of comparable sensitivity and precision are acceptable.

4.3.4 Measurement Sampling Area

The effective sampled area at each measured location shall not exceed the sampled area used in Section 4.2.1.

4.3.5 Arrangement

Measurements of the uniformity of the beam of radiation shall be made with the effective area of the measuring device (i.e. film) in the entrance plane and parallel to it. The XRII system should be moved away for this measurement, but the Image Position Calibration Template must remain in place according to Section 4.1. Care should be taken that the Image Position Calibration Template not disturb the uniformity measurement.

4.3.6 Sensitivity of the Measurement

A relative deviation of ±2% shall be detectable.

4.3.7 Method for Correction of Non-Uniformity

The image signal values shall be corrected using measurements of the relative intensity of the radiation beam. The Image Position Calibration Template shall be used

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to relate points on the entrance plane to corresponding points on the output image. When correcting for the non-uniformity of the radiation beam, the distance from any point of a image signal measurement and the corresponding non-uniformity shall be less than 1% of the visible entrance field size.

4.4 DETERMINATION OF UNIFORMITY

The values of the image signal measurements in the various image system configurations (i.e. photospot, cine, and video) shall be individually corrected in accordance with the non-uniformity of the incident X-ray beam. All measurements are referenced to the entrance plane, with the Image Position Calibration Template serving as the distance gauge and position reference.

4.5 INDICATION

The percentage uniformity is the minimum corrected signal level divided by the maximum corrected signal level multiplied by 100.

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Section 5
STATEMENT OF COMPLIANCE

If a manufacturer states that a product is in compliance with this NEMA standard, the presentation of the results of the determination shall be according to Section 4.5. Any deviations from the standard test conditions shall be stated.

Compliance with this Standard shall be stated as "image signal uniformity per NEMA Standard XR 17-1993."

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APPENDIX A

Further information on this subject can be found by consulting the following.

1. Gray et al. "Test Pattern for Video Displays and Hard-Copy Cameras." Radiology, 1985; 154: pp. 519-527.

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NEMA STANDARDIZIATION BACKGROUND

The purpose of NEMA standards, their classification, and status are set forth in certain clauses of the NEMA *Standardization Policies and Procedures* manual and are referenced below:

Purpose of Standards

National Electrical Manufacturers Association Standards are adopted in the public interest and are designed to eliminate misunderstandings between the manufacturer and the purchaser and to assist the purchaser in selecting and obtaining the proper product for their particular needs. Existence of a National Electrical Manufacturers Association Standard does not in any respect preclude any member or nonmember from manufacturing or selling products not conforming to the standard.

Definition of a Standard

A standard of the National Electrical Manufacturers Association defines a product, process, or procedure with reference to one or more of the following: nomenclature, composition, dimensions, tolerances, safety, operating characteristics, performance, rating, testing, and the service for which they are designed.

(Standardization Policies and Procedures, p. 1)

Dimensions

Where dimensions are given for interchangeability purposes, alternate dimensions satisfying the other provisions of the Standards Publication may be capable of otherwise equivalent performance.

(Standardization Policies and Procedures, p. 6)

Categories of Standards

National Electrical Manufacturers Association Standards are of three classes, which have received the affirmative vote of at least two-thirds of the Subdivision votes cast in the affirmative or negative:

1. NEMA Standard, which relates to a product, process, or procedure commercially standardized and subject to repetitive manufacture.
2. Suggested Standard for Future Design, which may not have been regularly applied to a commercial product, but which suggests a sound engineering approach to future development.
3. Adoptive Standard, which is adopted in whole or in part from the standards of another organization, either domestic, regional, or international.

(Standardization Policies and Procedures, pp. 5)

Authorized Engineering Information

Authorized Engineering Information consists of explanatory data and other engineering information of an informative character not falling within the classification of NEMA Standard or Suggested Standard for Future Design, which standard has received the affirmative vote of at least two-thirds of the Subdivision votes cast in the affirmative or negative.

(Standardization Policies and Procedures, pp. 5)

Identification of Status

Standards in NEMA Standards Publications are identified as "NEMA Standard," "Suggested Standard for Future Design," or "Adoptive Standard." These indicate the status of the standard. A statement incorporating the auxiliary verb "shall" indicates that compliance with a requirement is mandatory for compliance with the standard. These classes of standards are identified in the foreword or throughout the text.

The material identified as "Authorized Engineering Information" is designated similarly. Statements incorporating other auxiliary verbs such as "should," "may," etc. refer to the authorized engineering information and not to procedures required for compliance with the standard.

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