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NEMA STANDARDS PUBLICATION

NEMA XR 18

TEST STANDARD FOR THE DETERMINATION OF THE RADIAL IMAGE DISTORTION OF AN X-RAY IMAGE INTENSIFIER SYSTEM

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TEST STANDARD FOR THE DETERMINATION OF THE RADIAL IMAGE DISTORTION OF AN X-RAY IMAGE INTENSIFIER SYSTEM

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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 technically 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

Many X-ray imaging systems produce images which are spatially distorted. The image intensifier (II) and video imaging chain normally generates images which exhibit pincushion distortion; i.e., the magr ification is not constant over the image field but increases from the center towards the periphery. This distortion is caused by:

a. The curving of the dish-shaped input screen of the image intensifier away from the X-ray focal spot

b. Trade-offs in the design of the electron-optics

Other components of the imaging chain, namely the lenses, the television pick-up tube, the video electronics, and the video display monitor, can contribute to the distortion.

If the components of the imaging chain are well shielded from magnetic fields, this type of distortion is very nearly symmetrical about the center of the image. Disturbances due to magnetic fields, originating from magnetized components and/or from the earth, depend on orientation and position and are, in most circumstances, asymmetrical. Since stating compliance with this standard at a variety of image intensifier orientations is impractical, selecting the direction which minimizes the asymmetrical component of the distortion is recommended for the measurement described in this Standard.

Unequal horizontal and vertical magnification on the TV monitor will also produce image distortion. This type of distortion, which has no circular symmetry, can be minimized by appropriate setting of the aspect ratio and is not addressed in this Standard.

Only methods for measuring the circularly symmetrical distortion are treated by this Standard. The differential radial image distortion describes how the magnification scale in the radial direction changes with distance from the center of the image. The integral image distortion yields directly the gross magnification (hence the size of the image) of an object placed symmetrically about the center of the image. For reasons of central symmetry, integral radial, integral tangential, and differential tangential image distortion are equal in the absence of S-shaped distortion. Hence integral image distortion is sufficient to cover all of the distortions which conserve the angle in a polar coordinate system.

A centrally symmetric, S-shaped distortion (of a straight line) may persist after the image intensifier has been moved to the direction of minimum asymmetric distortion. The S-shaped distortion has negligible influence on the measurement of local radial magnification, which is required for the determination of the differential radial image distortion, and no influence (for reasons of central symmetry) on the measurement of integral magnification, which is required for integral image distortion.

The distortion in the TV camera and/or monitor, due to incorrect setting of the aspect ratio, has no influence on the integral image distortion and differential radial image distortion as defined in this standard.

Radial image distortion is not independent of other measures of system image quality. In particular, the distortion of the output image of the XRII system affects the image signal uniformity.

Since the radial image distortion is a measurable feature of X-ray imaging system performance and it has found general acceptance as a measure of image quality, the measurement of radial image distortion is deemed worthy of coverage in a NEMA Standards Publication.

SCOPE

This document defines the NEMA standard method for determining radial image distortion of XRII systems under a given set of test conditions. This standard includes the video chain, photofluorographic cameras, and cine cameras assembled and adjusted into a complete imaging system according to the instructions of the manufacturer.

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Section 1
REFERENCED STANDARDS AND DEFINITIONS

1.1 REFERENCED STANDARDS

No standards are referenced herein.

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 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.

1.2.3 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.

1.2.4 Central Magnification (A_c)

With a small test object of known length placed symmetrically about the center of the image, the ratio of the test object length in the image to the test object length itself.

1.2.5 Differential Radial Image Distortion (V_d)

Variation of the local radial magnification (A_d) as a function of the distance from the center of the image.

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 chamber
d. Protective cover
e. Removable magnetic shields and coils
f. Spot film device

1.2.7 Integral Magnification (A_i)

Given a circular test object placed symmetrically about the center of the image, the ratio of the test object diameter in the image to the test object diameter itself.

Integral magnification is expressed as a function of test object radius.

1.2.8 Integral Image Distortion (V_i)

Variation of the integral magnification (A_i) as a function of test object radius.

1.2.9 Local Radial Magnification (A_d)

With a small test object placed symmetrically about a given point in the entrance plane of the XRII system and oriented radially to the center of the image, the ratio of the test object length in the image to the test object length itself.

Local radial magnification is expressed as a function of the distance from the center of the image.

1.2.10 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 cine film
b. Processed photofluorographic film
c. Television monitor display screen
d. Direct viewing system

1.2.11 Radial Image Distortion

The radially dependent variation of the XRII system magnification. Radial image distortion is expressed, with respect to a reference magnification (central magnification), as a function of either test object position (differential radial image distortion) or test object diameter (integral image distortion).

1.2.12 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.

1.2.13 Useful Entrance Field Diameter

For an electro-optical XRII system, the diameter of the field in the entrance plane of the (electro-optical) XRII system that can be used for transmission of the X-ray pattern when the SED equals one meter. Limitations of this diameter other than by the XRII itself shall not be considered.

For an XRII with more than one magnification mode, the useful entrance field diameter for each of the magnification modes shall correspond to the same diameter of the XRII output image occurring with the largest useful entrance field diameter.

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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 TEST OBJECT

The test object shall consist of a thin X-ray transparent panel with X-ray absorbing markings along which distance measurements can be made. Horizontal and vertical, equidistant hashmarks shall be used for the measurement of the central and local radial magnification.

Circular markings shall be used for the measurement of integral magnification. This avoids measurement difficulties arising from severe S-shaped distortion (see introduction).

The precision of the markings shall be checked by measuring their spacing on a contact radiograph made of the template.

The distance between the hashmarks shall not be greater than 10 mm or 10 percent of the useful entrance field diameter, whichever is smaller.

A suggested template is shown in Figure 2-1.

2.2 LENGTH MEASUREMENT EQUIPMENT

In the case of photofluorographic film and cine film, the measurements are made on the film itself. In the case of the television monitor image, the monitor shall be photographed with a large format camera (100 mm by 100 mm if possible), and the measurements shall be made on the resulting film.

The lens system of the large format camera and its alignment to the monitor shall not distort the photographic image such that the permissible magnification measurement error of two percent is exceeded. If the lens system does distort the photographic image, a correction for the distortion due to the camera lens alone shall be applied.

In order to achieve the required accuracy, the large format camera shall be mounted on a stable mechanical support which insures precise and reproducible alignment between the camera and the monitor.

In all cases the measurements on the film can be made with the aid of a low-power microscope for viewing the markings and micrometric gauges for determining lengths.

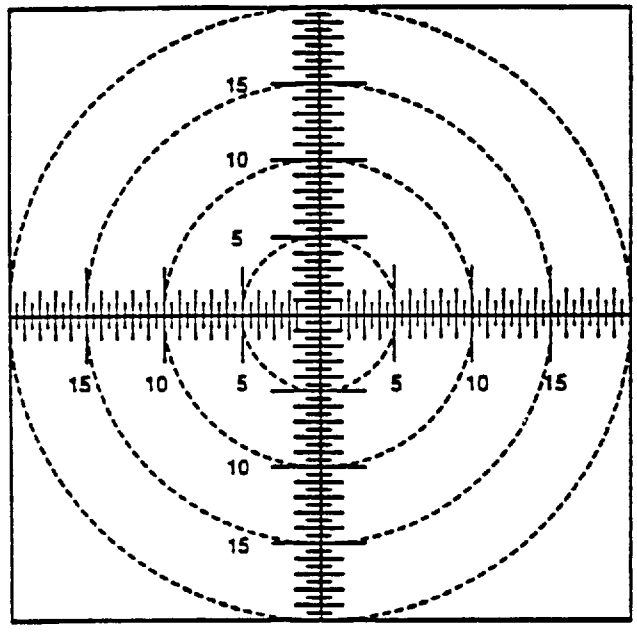

Figure 2-1
SUGGESTED ENTRANCE PLANE TEMPLATE

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Section 3
STANDARD SYSTEM 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, the 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 conditions. 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.

(Determination of the radial image distortion for any useful entrance field diameter shall be made with a single system configuration.)

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 do not span the standard SED, shall be tested with the smallest of the SED's recommended by the manufacturer.

If the SED used is not 100 cm, the value of the SED used shall be reported in the presentation of results.

3.3 ALIGNMENT OF THE X-RAY TUBE

The X-ray tube and the X-ray image intensifier shall be positioned relative to each other so that the center of the image lies on the central axis of the X-ray field to within 5 mm or within 3 percent of the useful entrance field diameter, whichever is greater.

3.4 RADIATION COLLIMATION

The X-ray beam collimators shall be adjusted so that the collimator blades are just visible in the image.

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Section 4
DETERMINATION

4.1 MEASUREMENT PROCEDURES

4.1.1 Measurement of Magnification

For X-ray image intensifiers with more than one magnification mode, the measurements shall be made for each mode.

4.1.2 Positioning of the Test Object

The test object shall be placed in a plane as close as possible to and parallel to the entrance plane of the XRII system. This may require the removal of system components between the X-ray source and the entrance plane of the XRII system such as grid holders, cones, and compression devices. If placing the test object at the entrance plane of the XRII system is impossible, the distance from the test object to the entrance plane of the XRII system shall be stated in the presentation of results.

For determination of the local radial magnification, the line of hashmarks on the test object shall pass through the center of the image.

For the determination of central magnification, the test object shall be placed symmetrically to the center of the image. The departure from symmetry with respect to the center of the image shall not exceed 2 percent of the useful entrance field diameter.

4.1.3 Photofluorographic and Cine Cameras

The overall uncertainty of the determination of all values of the magnification shall be less than 1 percent in the case of photofluorographic film and less than 2 percent in the case of cine film. This shall be achieved by adjusting the kVp, mAs, and film processing in order to yield a sharp, high-contrast image of the markings and by using the length-measuring equipment specified in Section 2.2.

4.1.4 Television Monitor

The overall uncertainty of the determination of all values of magnification shall be less than 2 percent. This shall be achieved by adjusting the X-ray tube voltage and current, monitor controls, and film processing in order to yield a sharp, high-contrast image of the markings and by using the length-measuring equipment specified in Section 2.2.

4.1.5 Determination of the Image Distortion

4.1.5.1 DIFFERENTIAL RADIAL IMAGE DISTORTION

The differential radial image distortion, $V_d(r)$, as a function of the radius r shall be determined from:

$$V_2(r) = \frac{A_d(r)}{A_c} - 1$$

Where $A_d(r)$ is the average of the Local Radial Magnification at two opposite points on the same diameter at the distance r from the center of the x-ray field.

NOTE: With this sign convention, V_d assumes positive values for pincushion distortion, negative values for barrel distortion.

4.1.5.2 INTEGRAL IMAGE DISTORTION

The integral image distortion $V_i(r)$ as a function of the radius r shall be determined from:

$$V_i(r) = \frac{A_i(r)}{A_c} - 1$$

Where A_i (r) is the integral magnification measured with a circular test object of radius r and A_c is the central magnification.

NOTE: As in 4.1.5.1, V_i assumes positive values for pincushion distortion, negative values for barrel distortion.

4.2 PRESENTATION OF RESULTS

The presentation of results shall include the XRII system type identification, e.g., model name or number, and the output image type and magnification mode, and the accuracy of the results.

Differential radial image distortion shall be presented as a curve or a table of numerical values. These data shall correspond to magnification measurements made along the line in the entrance plane of the XRII system defined by the center of the image and the point of maximum differential radial image distortion. The data shall be expressed as a function of the distance (in centimeters) from the center of the image and shall cover a range of at least 90 percent of the useful entrance field diameter.

If, in addition, integral image distortion is presented, it shall be presented as a curve or a table of numerical values along the same diagonal used. These data shall correspond to magnification measurements made along the line in the entrance plane of the XRII system defined by the center of the image and the point of maximum differential radial image distortion. The data shall be expressed as a function of test object radius (in centimeters) and shall cover a range of at least 90 percent of the useful entrance field diameter.

Deviations from the standard test conditions shall be listed.

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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 determination shall be according to paragraph 4.2. Any deviations from the standard test conditions shall be listed.

Compliance with this standard shall be stated as "radial image distortion per NEMA Standard XR 18-1993."

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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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