XR 5-84 6470247 0005630 4
B-53-25

STANDARDS PUBLICATION/NO. XR 5-1984

nema

Measurement of Dimensions and Properties of Focal Spots of Diagnostic X-Ray Tubes

NEMA

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

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

© 1985 by the National Electrical Manufacturers Association

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

TABLE OF CONTENTS

		Page
	FOREWORD	i
	SCOPE	ii
Section 1	DEFINITIONS	1
Section 2	SLIT CAMERA METHOD OF MEASUREMENT	
	Basic Method	2
	Slit Camera	2
	Imaging Procedure	3
	Photographic Technique	3
	Electrical Conditions	5
	Measurement of X-Ray Image	5
	Determination of Modulation Transfer Function (MTF) of the Focal Spot	5
	Measurement	6
	Calculation of the MTF	7
Section 3	**RESOLUTION CAMERA (STAR PATTERN) METHOD OF EVALUATION**	
	Basic Method	8
	Star Pattern Camera	8
	Radiographic Film	8
	Photographic Technique	9
	Electrical Conditions	9
	Determination of Focal Spot Resolution (R)	9
Section 4	PINHOLE CAMERA METHOD OF EVALUATION	
	Introduction	11
	Basic Method	11
	Pinhole Camera	11
	Photographic Technique	11
	Electrical Conditions	12
	Method of Observation	12
Section 5	STATEMENT OF COMPLIANCE	12

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

List of Illustrations

Page

TABLES

2-1	Enlargement Factor (E) for Slit Camera	3
2-2	Technique Factors	5
2-3	Focal Spot Size Tolerance Limits (for slit camera method)	6
2-4	Standard Magnification for Modulation Transfer Functions	7
4-1	Pinhole Diaphragm Dimensions	11
4-2	Enlargement Factor (E) for Pinhole Camera	11

FIGURES

2-1	Slit Diaphragm	2
2-2	Reference Direction for Distorted Focal Spots	3
2-3	Imaging Geometry	4
2-4	Determination of Enlargement Factor (E)	4
2-5	Microdensitometer Scan	6
2-6	Limitation of Input Data	6
3-1	Essential Dimensions of the Test Pattern	8
3-2	Alignment of the Star Pattern Camera	8
3-3	Image of the Test Pattern	10
4-1	Cross-Section of Pinhole Diaphragm	12

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

Foreword

This publication describes three methods of assessing the properties of the focal spot for medical diagnostic x-ray tubes. User needs have been considered throughout the development of this standard. Test methods and performance values have been defined for correlation to end-use application.

Historically, the size designation was based on the approximate measured size when using exposure factors 75 kV and fluoroscopic level tube current. Then, as now, the tolerances were on the plus side, since a tube could not be safely loaded to its published rating with an undersized focal spot.

To provide the user with a better indication of the focal spot size under normal working conditions, more recent standards specified that the size was to be measured at 75 kV and half the rated load. These standards used the same nominal focal size designation as the earlier standards or measuring methods.

The actual focal spot of a diagnostic x-ray tube can be described in terms of its physical size and intensity distribution. For most x-ray tubes presently in use the focal spot is non-isotropic, usually having a twin-peaked intensity distribution. Its size and intensity distribution can further be affected by changes in voltage and current applied to the x-ray tube. The focal spot is often enlarged as current is increased and voltage is reduced. The blooming value is intended to inform the user of the change in focal spot size when the tube is operated at full load rating. The rated power loading is a function of the size and intensity distribution of the focal spot, as well as of other parameters.

The primary method for assessing focal spot characteristics shall be based on the use of the slit camera. Images obtained from this technique provide focal spot size measurements and blooming. The slit camera can be used to measure the full range of focal spot sizes. The modulation transfer function (MTF) can be developed from the slit image using a microdensitometer scan and computer.

The resolution camera (star pattern) method of measurement utilizes a lead star test pattern to provide the limit of resolving power of the focal spot. This resolution figure of merit can be compared to other components in the radiological system and be utilized in achieving optimum system performance. It is relatively simple to use in the field without having to remove the x-ray beam limiting device and covers the widest range of focal spots. The star method measures the limit of resolving power of the focal spot but does not provide information about the modulation of the low spatial frequencies. The star resolution method is not recommended for size determination.

The pinhole camera provides an image of the focal spot indicating the overall shape and intensity distribution which depicts the cross-section of the electron beam. The pinhole images are especially useful for determining power capabilities from the area measurements and the electron beam power density for different tube types. The resultant image can be used to ascertain the relative location of dual focal spots and principal orientation.

The virtue of these methods depends on the specific focal spot characteristics requiring analysis. The purpose of this publication is to provide a standard procedure for the use of the three methods.

METHODS FOR EVALUATING SPECIFIC ASPECTS CHARACTERIZING THE FOCAL SPOT

Parameter	Method of Measurement
Focal Spot Size	Slit Camera
MTF	Slit Camera
Blooming	Slit Camera
Orientation	Pinhole
Intensity Distribution	Pinhole
Limit of Resolution	Star Test

Proposed or recommended revisions should be submitted to:

Manager, Engineering Department
National Electrical Manufacturers Association
2101 L Street, N.W.
Washington, D.C. 20037

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

Scope

This document provides test methods for assessing the properties of focal spots for conventional medical diagnostic x-ray tubes and is not intended for use with x-ray tubes used in computed tomography (CT) scanners.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

MEASUREMENT OF DIMENSIONS AND PROPERTIES OF FOCAL SPOTS OF DIAGNOSTIC X-RAY TUBES

Section 1
DEFINITIONS

1.1 ACTUAL FOCAL SPOT

The section at which the anode of an x-ray tube intercepts the electron beam.

NEMA Standard 11-15-1984.

1.2 BLOOMING

The changed values (usually increased) in focal spot dimensions with focal spot measurements taken under the test conditions specified in 2.5.2 and 2.5.3.

NEMA Standard 11-15-1984.

1.3 CENTRAL RAY

A line perpendicular to the x-ray port plane and passing through the focal spot midpoint.

NEMA Standard 11-15-1984.

1.4 DIAGNOSTIC X-RAY TUBE

A high vacuum tube used for medical diagnostic purposes which produces x-rays by bombarding an anode with a beam of electrons accelerated by a potential difference.

NEMA Standard 11-15-1984.

1.5 EFFECTIVE FOCAL SPOT (F_{eff})

The size of the projected focal spot in a specified direction measured with the slit camera method.

NEMA Standard 11-15-1984.

1.6 ENLARGEMENT FACTOR (E)

The enlargement factor is the ratio of the pinhole-film distance to the focal spot-pinhole distance for the pinhole method of measurement. With the slit replacing the pinhole the definition applies to the slit camera.

NEMA Standard 11-15-1984.

1.7 FOCAL SPOT MTF

The absolute value of the Fourier transform of the one-dimensional focal spot intensity distribution or line spread function.

NEMA Standard 11-15-1984.

1.8 FOCAL SPOT RESOLUTION (R)

A figure of merit of the focal spot in terms of the limit of resolving power in line pairs per millimeter at a given magnification.

NEMA Standard 11-15-1984.

1.9 FOCAL SPOT RESOLUTION IMAGE

The image of the resolution star pattern obtained on an x-ray film under specified conditions.

NEMA Standard 11-15-1984.

1.10 MAGNIFICATION FACTOR (MF)

The magnification factor is the ratio of the focal spot-film (image) distance to the focal spot-test pattern (object) distance.

NEMA Standard 11-15-1984.

1.11 NOMINAL FOCAL SPOT DESIGNATION (F)

Dimensionless numerical value having a specific relation to the dimensions of the effective focal spot of an x-ray tube, measured under specific conditions.

NEMA Standard 11-15-1984.

1.12 PINHOLE CAMERA

The assembly of equipment, including a pinhole diaphragm, which is used to produce images of the projected focal spot. The pinhole image is a display of the two-dimensional intensity distribution of the projected focal spot.

NEMA Standard 11-15-1984.

1.13 PROJECTED FOCAL SPOT

The projection of the actual focal spot along the central ray, perpendicular to the x-ray port plane and passing through the center of the focal spot. (This publication sometimes refers to the projected focal spot by using the shorter term: "Focal Spot").

NEMA Standard 11-15-1984.

1.14 REFERENCE DIRECTION

For a radiation source, specified direction to which characteristics such as target angle, radiation field and

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

specifications with respect to the imaging quality of the radiation source are referenced.

NEMA Standard 11-15-1984

1.15 RESOLUTION CAMERA

The assembly of equipment, including a resolution star pattern which is used for measuring the resolution properties of focal spots.

NEMA Standard 11-15-1984.

1.16 SLIT CAMERA

Device to reproduce the intensity distribution in the projected focal spot on an x-ray film by means of a slit diaphragm in a direction perpendicular to the axis of the slit.

Section 2
SLIT CAMERA METHOD OF MEASUREMENT

2.1 BASIC METHOD

This section deals with the production of focal spot slit images to be used for the determination of focal spot dimensions, blooming and the determination of the modulation transfer function (MTF).

NEMA Standard 11-15-1984.

2.2 SLIT CAMERA

Focal spot imaging shall be taken with a slit camera containing a slit diaphragm as described in Figure 2-1.

NEMA Standard 11-15-1984.

The slit diaphragm shall be made from any of the materials listed below:

- tungsten,
- tantalum,
- alloy of 90% gold and 10% platinum, or
- alloy of platinum and 10% iridium

NEMA Standard 11-15-1984.

(DIMENSIONS IN MILLIMETERS)

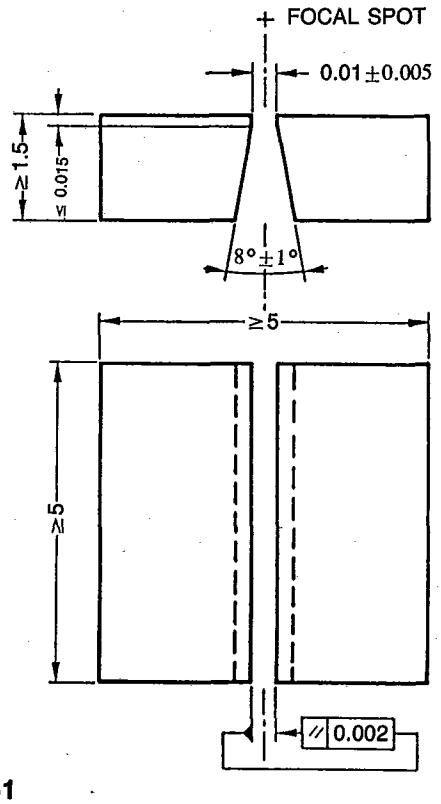


Figure 2-1
SLIT DIAPHRAGM

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

2.3 IMAGING PROCEDURE

2.3.1 Alignment of the Slit Camera

The slit camera shall be placed so that the center of symmetry of the slit diaphragm coincides with the reference direction of the x-ray tube assembly within ± 0.009 radian (± 0.5°). This tolerance is necessary for an accurate measurement of focal spot size using the slit camera. This precission will be closely approximated if the slit diaphragm is oriented to result in the minimum image dimension.

NEMA Standard 11-15-1984.

2.3.2 Orientation of the Slit Diaphragm

For the production of a pair of focal spot slit images, the slit diaphragm shall be oriented so that the length of the slit is normal within ± 0.009 radian (± 0.5°) to each of the two reference directions. This tolerance is necessary for an accurate measurement of focal spot size using the slit camera. This precission will be closely approximated if the slit diaphragm is oriented to result in the minimum image dimension.

NEMA Standard 11-15-1984.

For measurements over the length of the focal spot, the reference direction shall be parallel to the longitudinal axis of the x-ray tube assembly or as specified by the manufacturer.

NEMA Standard 11-15-1984.

For measurements over the width of the focal spot, the reference direction is in general normal to the reference direction according to the above paragraph.

Authorized Engineering Information 11-15-1984.

If the projection of the effective focal spot in the reference direction is distorted, the reference direction over the width is normal to the pronounced orientation of the regions of highest radiation exposure, usually the direction over the focal spot showing the smallest width, see Figure 2-2. A pinhole image of the focal spot is required to describe the pronounced orientation; the pinhole method is discussed in Section 4.

Authorized Engineering Information 11-15-1984.

2.3.3 Imaging Geometry

The incident face of the slit diaphragm shall be placed normal to the reference direction at a distance from the focal spot such that the variation of the enlargement ratio over the extension of the focal spot does not exceed ±5% in the reference direction. In no case shall this distance be less than 100mm (see Figure 2-3 and 2-4).

NEMA Standard 11-15-1984.

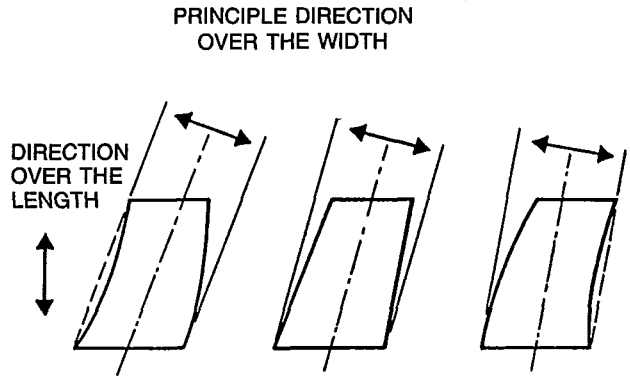


Figure 2-2
REFERENCE DIRECTION FOR DISTORTED FOCAL SPOTS

2.3.4 Enlargement Factor

The radiographic film shall be placed at a distance from the incident face of the slit diaphragm such that in each case, according to the nominal focal spot designation, the enlargement factor (E) is not smaller than the value given in Table 2-1.

NEMA Standard 11-15-1984.

Table 2-1
ENLARGEMENT FACTOR (E) FOR SLIT CAMERA

Nominal Focal Spot Designation (F)	Enlargement Factor (E)
$F < 0.4$	> 3
$0.4 \leq F \leq 1.0$	> 2
$1.0 < F$	> 1

2.4 PHOTOGRAPHIC TECHNIQUE

2.4.1 Type of Film

The film shall be any fine grain x-ray film designed for non-screen exposure.

NEMA Standard 11-15-1984.

2.4.2 Development of the Film

The film shall be exposed and developed to a density which is 0.8 to 1.2 above the density of the non-exposed

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

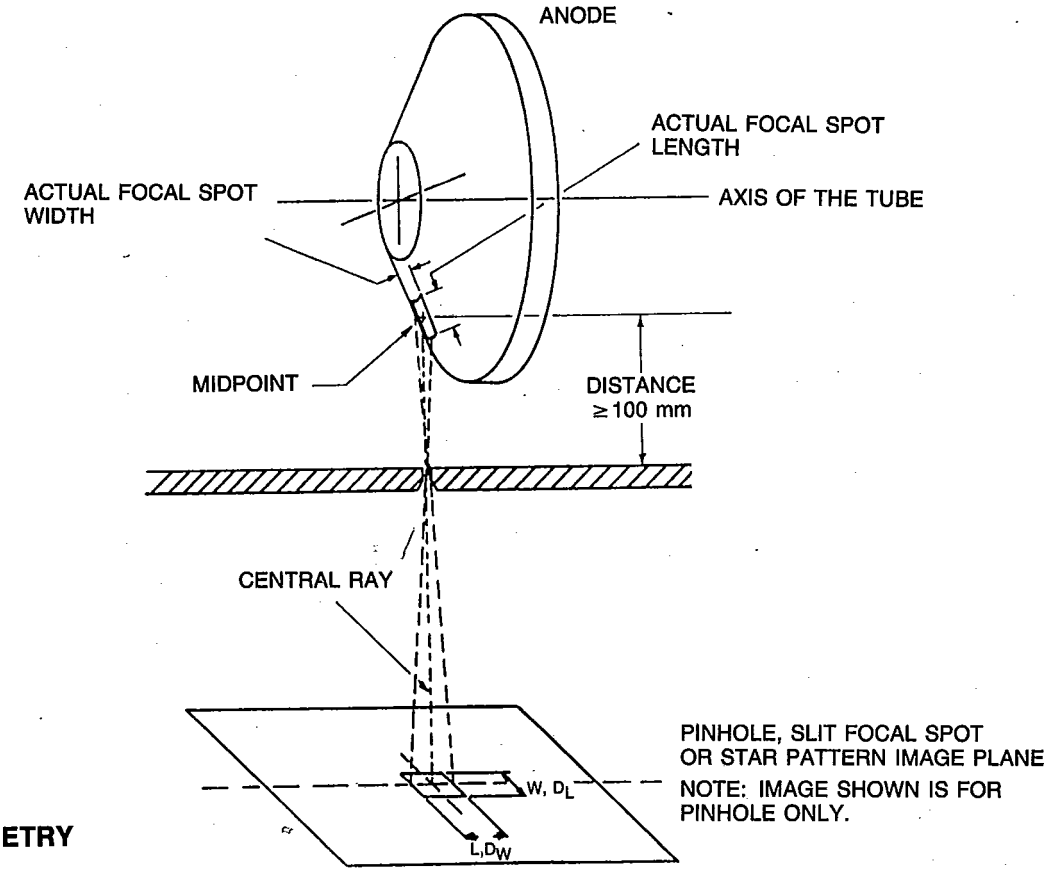


Figure 2-3
IMAGING GEOMETRY

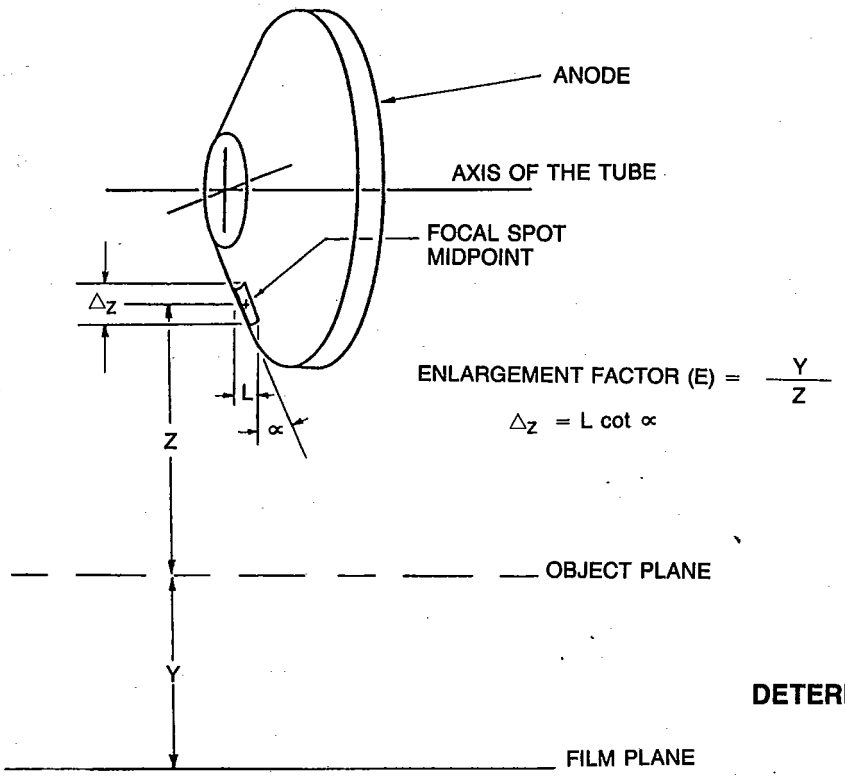


Figure 2-4
DETERMINATION OF ENLARGEMENT FACTOR (E)

NOTE: The upper and lower edges of the focal spot have different distances to the plane of the imaging camera as shown. The difference z can be calculated from the length "L" of the actual focal spot by $\triangle z = L \cot \propto$, where $\propto$ is the anode angle. The resulting relative change of the enlargement factor (E) amounts to $\triangle z/Z$, where Z is the distance between focal spot midpoint and imaging camera. For example, it gives rise ole camera image of a focal spot which in fact is ectangular.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

part of the film when measured in the most dense portion of the x-ray image. Fog density including the density of the base shall not exceed 0.2.

Density shall be controlled by means of the exposure time *only*.

NEMA Standard 11-15-1984.

2.5 ELECTRICAL CONDITIONS

2.5.1 Working Conditions

Prior to obtaining measurements, the x-ray tube shall be inserted in the shockproof tube shield or tank unit for which it is designed or shall be operated under otherwise equivalent mounting conditions.

For rotating anode tubes, the stator shall be excited as it would be for normal radiographic conditions.

NEMA Standard 11-15-1984.

2.5.2 Exposure Factors

Exposures shall be made using a three-phase full-wave rectified voltage waveform or a constant voltage. The focal spots shall be measured from a radiograph with exposure factors given in Table 2-2 (other waveforms will produce a size change when using the technique factors specified in Table 2-2). The time of exposure shall be chosen to give the film density specified in 2.4.2.

NEMA Standard 11-15-1984.

2.5.3 Exposure Factors (Blooming)

75 (kV) and rated maximum current at 75 kV voltage for 0.1 second exposure at the highest rotational speed for which the tube is rated shall be used to establish focal spot blooming.

Technique factors for x-ray tubes intended for special procedure or other dedicated applications varying significantly from the condition described shall be specified by the manufacturer.

NEMA Standard 11-15-1984.

2.6 MEASUREMENT OF X-RAY IMAGE

2.6.1 Lighting

The film shall be back lighted using a source having a luminance ranging between 1300 and 2600 candela/m^2.

NEMA Standard 11-15-1984.

2.6.2 Measurement Procedure

The size of the focal spot image shall be examined by eye through a magnifying glass having a built-in graticule of 0.1-millimeter divisions and 5X to 10X magnification. The dimensions of the focal spot shall be determined from a pair of slit images.

Dimension L: Focal Spot Length
Dimension W: Focal Spot Width

The extent of the discernible image shall be measured over each focal spot slit image normal to the length of the slit at half of its length. By eye, it is possible to perceive a contrast step of approximately 5 percent.

NEMA Standard 11-15-1984.

2.6.3 Dimensions of the Focal Spot (F_{eff})

The dimensions of the focal spot (F_{eff}) shall be obtained by dividing the dimensions of the focal spot image by the enlargement factor. The focal spot size tolerance limits are shown in Table 2-3.

NEMA Standard 11-15-1984.

2.7 DETERMINATION OF THE MODULATION TRANSFER FUNCTION (MTF) OF THE FOCAL SPOT

2.7.1 Basic Method

The one-dimensional focal spot intensity distribution or line spread function in a specified direction is the x-ray intensity distribution integrated over the total extension of the focal spot in a direction perpendicular to the specified direction. The one-dimensional intensity distribution as obtained from the slit exposures shall be used to develop the MTF Curves.

NEMA Standard 11-15-1984.

Table 2-2
TECHNIQUE FACTORS

Maximum Rated Voltage, U kV	Test Voltage	Test Current
$U \leq 75$	Maximum rated voltage	50 percent of maximum permissible current at the voltage for 0.1 second exposure at the highest rotation speed for which the tube is rated.
$75 < U \leq 150$	75 kV	
$U > 150$	50% of the maximum rated voltage	

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

Table 2-3
FOCAL SPOT SIZE TOLERANCE LIMITS
(FOR SLIT CAMERA METHOD)

Nominal Focal Spot Designation (F)	Maximum Focal Spot Dimensions in mm (F_{eff})	
	Width	Length
0.05	0.075	0.075
0.1	0.15	0.15
0.15	0.23	0.23
0.2	0.30	0.30
0.25	0.40	0.40
0.3	0.45	0.65
0.4	0.60	0.85
0.5	0.75	1.1
0.6	0.90	1.3
0.7	1.1	1.5
0.8	1.2	1.6
0.9	1.3	1.8
1.0	1.4	2.0
1.1	1.5	2.2
1.2	1.7	2.4
1.3	1.8	2.6
1.4	1.9	2.8
1.5	2.0	3.0
1.6	2.1	3.1
1.7	2.2	3.2
1.8	2.3	3.3
1.9	2.4	3.5
2.0	2.6	3.7

2.7.2 Measuring Arrangement

The focal spot slit images shall be scanned by means of a microdensitometer. The slit of the microdensitometer shall have a real width not exceeding the width of the slit diaphragm used for the production of the images.

The length of the slit of the microdensitometer shall be limited so that it can be aligned to the direction of the diaphragm slit projected on the image in order that the effective width of the microdensitometer slit normal to the direction of the projected diaphragm slit will be smaller than twice the real width of the microdensitometer slit as shown in Figure 2-5.

The scanning direction shall be aligned normal to the direction of the diaphragm slit to within ± 1 degree.

NEMA Standard 11-15-1984.

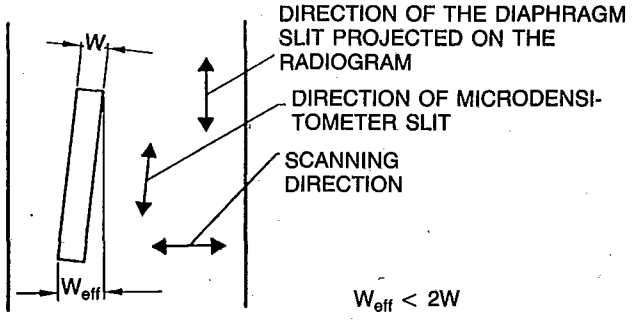


Figure 2-5
MICRODENSITOMETER SCAN

2.8 MEASUREMENT

2.8.1 Measurement of the Density Distribution

The density over each focal spot slit image shall be scanned continuously normal to its longitudinal direction at half of its length.

The results of this measurement shall be presented as a curve showing density over the width of the image.

NEMA Standard 11-15-1984.

2.8.2 Corrections to be Applied

The values of density shall be corrected with respect to the base of the film.

The values of density with respect to base plus fog shall be converted to radiation exposure by means of a characteristic curve of the film materials used and processed under the same conditions.

NEMA Standard 11-15-1984.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

2.9 CALCULATION OF THE MODULATION TRANSFER FUNCTION

2.9.1 Basic Calculation

The one-dimensional modulation transfer function of the geometry of a focal spot shall be calculated by means of the Fourier transform.

The input values for carrying out the Fourier transform shall be the values of the linear distribution of radiation exposure over the focal spot slit radiograph, the abscissae in Figure 2-6, divided by the magnification used for the production of the focal spot slit radiograph and the corresponding values of radiation exposure, the ordinates in Figure 2-6.

The mesh of ordinates along the axis of abscissae shall be chosen so fine that the extent and the structures of the linear distribution of radiation exposure over the focal spot will be taken into account and a further refinement of the mesh would not result in a significant change of the calculated modulation transfer function.

NEMA Standard 11-15-1984.

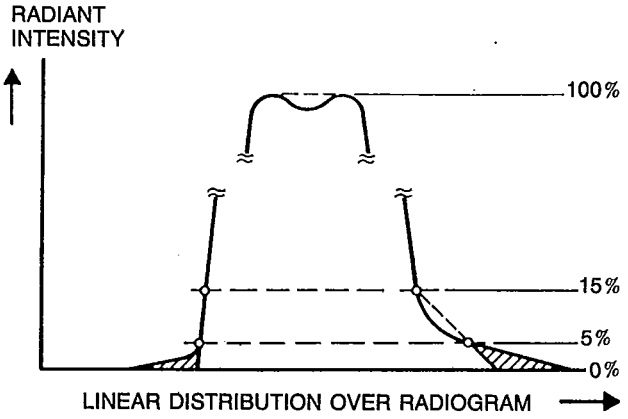


Figure 2-6
LIMITATION OF INPUT DATA

2.9.2 Calculation for the Standard Magnification

The values of spatial frequency obtained according to 2.9.1 shall be transformed according to the formula:

$$f_s = f_i \frac{M_s}{M_s - 1}$$

where:

f_s is the spatial frequency for the standard magnification given in Table 2-4.

f_i the spatial frequency obtained according to 2.9.1.

M_s the standard magnification.

NEMA Standard 11-15-1984.

Table 2-4
STANDARD MAGNIFICATION FOR MODULATION TRANSFER FUNCTIONS

Nominal Focal Spot Value f	Standard Magnification M_s
$f < 0.6$	2
$0.6 \leq f$	1.3

2.9.3 Calculation for Finite Magnification

For the application of the modulation transfer function under practical radiological conditions, the values obtained or those given according to 2.9.4 are transformed according to the formula:

$$f_p = f_s \quad \frac{M_s - 1}{M_s} \quad \frac{M_p}{M_p - 1}$$

where:

f_p is the spatial frequency for the desired magnification.

f_s the spatial frequency for the standard magnification.

M_s the standard magnification.

M_p the desired magnification.

2.9.4 Presentation of the Modulation Transfer Function

The modulation transfer function shall be given as a curve showing the magnitude of the Fourier transform for the standard magnification given in Table 2-4 as a function of spatial frequency in cycles per millimeter (1p/mm) in a linear scale for both axes of co-ordinates so that for the spatial frequency zero the magnitude of the Fourier transform is 100%.

The modulation transform shall extend at least to the spatial frequency at which the magnitude of Fourier transform falls to 10% but beyond this not further than to the spatial frequency at which it reaches a first minimum or reaches the spatial frequency axis.

NEMA Standard 11-15-1984.

The pair of one-dimensional modulation transfer functions of the geometry of the width and the length of one focal spot shall be presented in one diagram, together with the nominal focal spot value and the standard magnification according to Table 2-4.

NEMA Standard 11-15-1984.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA,
No reproduction or networking permitted without license from IHS
Not for Resale

Section 3
RESOLUTION CAMERA (STAR PATTERN) METHOD OF EVALUATION

3.1 BASIC METHOD

An image of a test pattern shall be produced on a fine grain x-ray film. The equivalent focal spot resolution shall be determined from the measurements of the test pattern image at a stated magnification factor (M).

NEMA Standard 11-15-1984.

3.2 STAR PATTERN CAMERA

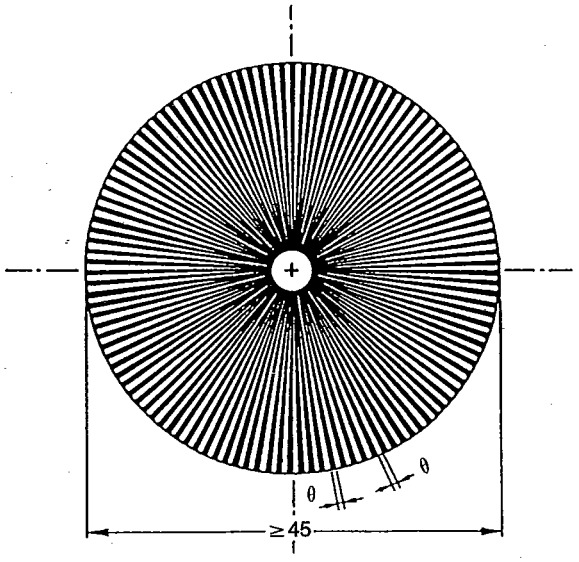
Focal spot star radiographs shall be obtained by means of a star pattern camera containing a test pattern, which consists of an array of alternating highly absorbing and low absorbing wedges. The highly absorbing wedges shall be made of lead or an equivalent material and shall have a thickness of 0.03 to 0.05 mm.

All wedges shall have a vertex angle θ equal to or less than 0.035 radian (approximately 2°).

The active area of the test pattern shall cover 2π radians and shall have a diameter of at least 45 mm.

The essential dimensions of the test pattern and its basic structure shall be as shown in Figure 3-1.

NEMA Standard 11-15-1984.



DIMENSIONS IN MILLIMETERS

Figure 3-1
ESSENTIAL DIMENSIONS OF THE TEST PATTERN

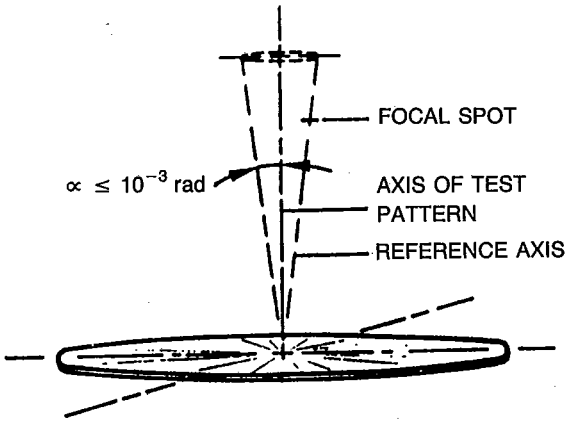


Figure 3-2
ALIGNMENT OF THE STAR PATTERN CAMERA

3.3 RADIOGRAPHIC FILM

Focal spot star radiographs shall be made on any fine grain radiographic film designed for non-screen use.

NEMA Standard 11-15-1984.

3.3.1 Alignment of the Star Pattern Camera

The reference axis shall form an angle with the axis of the test pattern smaller than or equal to 0.009 radian (0.5°) (see Figure 3-2).

NEMA Standard 11-15-1984.

3.3.2 Position of the Star Pattern Camera

The incident face of the test pattern shall be placed normal to the reference direction at a distance from the focal spot allowing a magnification M of a value such that the dimensions D_W and D_L, will be more than or, where this is not practicable, as near as possible to one-third of the diameter of the image of the test pattern but not less than 25 mm.

The test magnification shall be selected so that the first disappearing frequency shall fall within the image of the test pattern.

NEMA Standard 11-15-1984.

3.3.3 Position of the Radiographic Film

The radiographic film shall be placed normal to the reference direction at a distance from the incident face of the test pattern, which results in a magnification M as determined from the expected star pattern resolution limit R according to the formula:

$$M = R Z \theta$$

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS

Not for Resale

where:

M is the magnification to be used.

R the expected star pattern resolution limit in line pairs per millimeter.

Z the dimension on the radiograph of the appropriate outmost distorted zone in millimeters.

θ the vertex angle of the absorbing wedges in radians.

NEMA Standard 11-15-1984.

3.4 PHOTOGRAPHIC TECHNIQUE

3.4.1 Type of Film

The film specified in 2.4.1 shall be used.

NEMA Standard 11-15-1984.

3.4.2 Development of Film

The procedure specified in 2.4.2 shall be followed.

NEMA Standard 11-15-1984.

3.4.3 Lighting

The film shall be back lighted using a source having a luminance ranging between 1300 and 2600 candela/m^2.

3.5 ELECTRICAL CONDITIONS

3.5.1 Working Conditions

The working conditions specified in 2.5.1 shall be used.

NEMA Standard 11-15-1984.

3.5.2 Exposure Factors

The exposure factors specified in 2.5.2 and 2.5.3 shall be used.

NEMA Standard 11-15-1984.

3.6 DETERMINATION OF FOCAL SPOT RESOLUTION (R)

The resolution (R) is a function of the mean dimensions, D_W and D_L, the magnification factor (M) and the vertex angle, θ (in radians) of the star pattern and shall be calculated as follows:

$$R_{(W,\,L)}\ \text{(in cycles/millimeter (1p/mm)} = \frac{M}{D_{(W,\,L)}\,\theta}$$

M (magnification factor) is also the ratio of the distance between reference points on the film to the distance between reference points on the test pattern.

$D_{(W,L)}$ shall be measured in millimeters.

D_W is the diameter where the repetitive pattern can no longer be differentiated from the diffused background (diameter where the repetitive pattern disappears or reverses) and shall be measured in the direction shown in Figure 3-3.

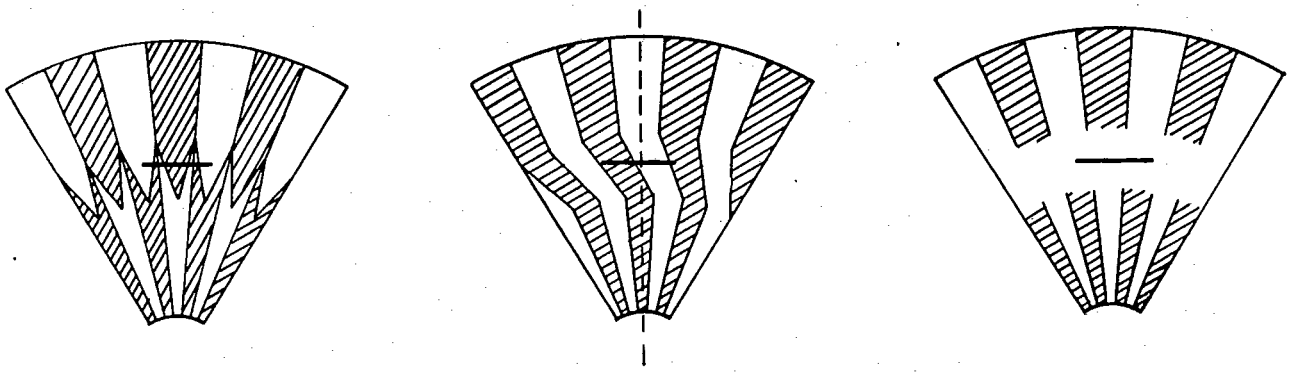
D_L shall be measured similarly.

θ = The vertex angle of the absorbing wedges in radians.

View the image of the star pattern with the unaided eye or at low magnification, observing each quadrant (sets of radial lines) individually. In each quadrant, determine the outermost "disappearance frequency" (area of non-resolution). These zones of blurred resolution may take several forms of appearance as described in the sketches in Figure 3-3.

In each quadrant, mark the approximate *midpoint* of the zone blurred resolution, using a fine felt-tipped pen. Use an eye loupe magnifier where necessary. The mark shall be placed along the most central radial bars in each quadrant. There are some density distributions such as Gaussian which will not show a disappearance frequency on a star pattern camera image.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale



ZONES OF BLURRED RESOLUTION

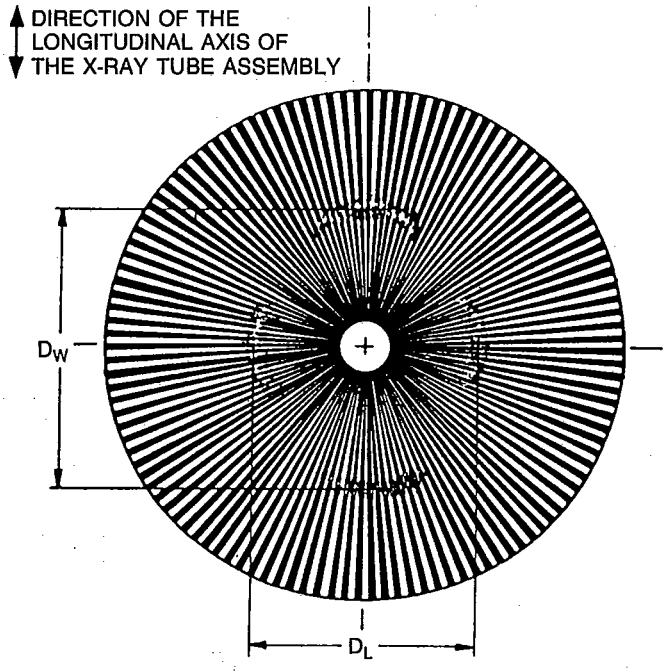


Figure 3-3
IMAGE OF THE TEST PATTERN

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

Section 4
PINHOLE CAMERA METHOD OF EVALUATION

4.1 INTRODUCTION

The assembly of equipment, including a pinhole diaphragm is used for determining the overall shape, orientation, intensity distribution and relative location of dual focal spots. The image can be used to align the slit camera.

Authorized Engineering Information 11-15-1984.

4.2 BASIC METHOD

An x-ray image of the focal spot shall be produced by means of a pinhole camera. The pinhole diaphragm and film shall be placed on the central perpendicular line of the x-ray port (central ray) used in normal operation (or in a specified direction for which other focal spot projections will be obtained).

NEMA Standard 11-15-1984.

4.3 PINHOLE CAMERA

4.3.1 Pinhole Diaphragm Construction

The pinhole diaphragm shall be made from one of the following:

1. An alloy of 90 percent gold and 10 percent platinum; or
2. Tungsten; or
3. Tungsten-carbide; or
4. Tungsten alloy; or
5. 90 percent platinum and 10 percent iridium alloy; or
6. Tantalum.

The dimensions of the pinhole diaphragm shall be in accordance with Table 4-1 and Figure 4-1.

NEMA Standard 11-15-1984.

Table 4-1
PINHOLE DIAPHRAGM DIMENSIONS

Nominal Designation of Focal Spot, (F)	Diameter D mm	L mm
$0.3 < F \leq 1.2$	0.030 ± 0.005	0.075 ± 0.010
$1.2 < F \leq 2.5$	0.075 ± 0.005	0.350 ± 0.010
$2.5 < F$	0.100 ± 0.005	0.500 ± 0.010

4.3.2 Distance and Alignment of Focal Spot and Pinhole Diaphragm (See Figure 2-3)

The focal spot midpoint, pinhole and film shall be on the axis of the cone of radiation used in normal operation (central ray) within ± ½ degree and spaced to obtain the nominal enlargement stated in Table 4-2.

NEMA Standard 11-15-1984.

Table 4-2
ENLARGEMENT FACTOR (E)
FOR PINHOLE CAMERA

Nominal Focal Spot Focal Spot, (F)	Enlargement Factor (E)
$0.3 < F < 1.2$	2
$1.2 < F < 2.5$	2
$2.5 < F$	1

4.4 PHOTOGRAPHIC TECHNIQUE

4.4.1 Type of Film

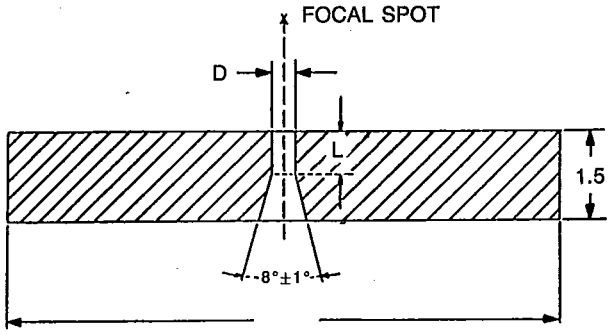
The film specified in 2.4.1 shall be used.

NEMA Standard 11-15-1984.

4.4.2 Development of the Film

The procedure specified in 2.4.2 shall be followed.

NEMA Standard 11-15-1984.



DIMENSIONS IN MILLIMETERS

Figure 4-1
CROSS-SECTION OF PINHOLE DIAPHRAGM

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

4.5 ELECTRICAL CONDITIONS

4.5.1 Working Conditions

The working conditions specified in 2.5.1 shall be used.

NEMA Standard 11-15-1984.

4.5.2 Exposure Factors

The exposure factors specified in 2.5.2 shall be used.

NEMA Standard 11-15-1984.

4.6 METHOD OF OBSERVATION

4.6.1 Lighting

The film shall be back lighted using a source having a luminance ranging between 1300 and 2600 candela/m^2.

NEMA Standard 11-15-1984.

Section 5
STATEMENT OF COMPLIANCE

Should a manufacturer desire to state his product is in compliance with this NEMA standard it shall be so indicated on the tube nameplate as shown in Figure 5-1. Any typical focal spot data provided to the user shall have been measured in accordance with this standard.

Nominal focal spot designation (F) or other manufacturer designation	Complies with NEMA XR 5-1984

Figure 5-1
TUBE NAMEPLATE

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

NEMA STANDARDIZATION

The purpose of NEMA Standards, their classification and status are set forth in certain clauses of the NEMA Bylaws, which are quoted 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 its particular need. 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.

(Bylaw—Art. V, Sec. 1)

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, construction, dimensions, tolerances, safety, operating characteristics, performance, rating, testing, and the service for which they are designed.

(Bylaw—Art. V, Sec. 2, Subsection A)

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.

(NEMA Policy Memorandum 84-2, dated June 7, 1984)

Classes of Standards

National Electrical Manufacturers Association Standards are of two classes:

1. NEMA Standard, which relates to a product commercially standardized and subject to repetitive manufacture, which standard has been approved by at least 90 percent of the members of the Subdivision eligible to vote thereon;
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, which standard has been approved by at least two-thirds of the members of the Subdivision eligible to vote thereon.

(Bylaw—Art. V, Sec. 2, Subsection B)

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.

(Bylaw—Art. V, Sec. 6, 1st Sentence)

Official Standards Proposal

An Official Standards Proposal is an official draft of a proposed standard which is formally recommended to an outside organization(s) for consideration, comment and/or approval.

(Bylaw—Art. V, Sec. 4, Subsection A)

Identification of Status

Standards in NEMA Standards Publications are identified in the foreword or following each standard as "NEMA Standard" or "Suggested Standard for Future Design." These indicate the status of the standard. These words are followed by a date which indicates when the standard was adopted in its present form by the Association.

The material identified as "Authorized Engineering Information" and "Official Standards Proposal" is designated similarly.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

X-RAY IMAGING PRODUCTS SECTION
OF THE
NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION

MEMBER COMPANIES

ADAC Laboratories
San Jose, CA 95138

Advanced Instrument Development, Inc.
Melrose Park, IL 60160

Belmont Equipment Corporation
Somerset, NJ 08873

Bennett X-Ray Corporation
Copiague, NY 11726

Continental X-Ray Corporation
Chicago, Il 60606

Dent-X Corporation
Stamford, CT 06902

Eastman Kodak Company
Rochester, NY 14650

EIMAC—Division of Varian
Salt Lake City, UT 84104

Elema-Schonander, Inc.
Schaumberg, IL 60195

Elscint, Inc.
Itasca, IL 60143

Eureka X-Ray Tube Company
Chicago, IL 60641

Fischer Imaging Corporation
Denver, CO 80241

Gammex, Inc.
Milwaukee, WI 53226

General Electric Company
Medical Systems Group
Milwaukee, WI 53201

Hewlett-Packard Company
Medical Products Group
McMinnville, OR 97128

Liebel-Flarsheim Division of
Sybron Corporation
Cincinnati, OH 45215

Lixi, Inc.
Downers Grove, IL 60515

Machlett Laboratories
Stamford, CT 06907

Medical Data Systems Division of
Medtronic, Inc.
Ann Arbor, MI 48105

Medicor USA Ltd
Columbus, OH 43212

J. Morita Dental Corp. of America
Culver City, CA 90230

Nuclear Associates Division of
Victoreen, Inc.
Carle Place, NY 11514

Oldelft Corporation of America
Fairfax, VA 22030

Philips Medical Systems, Inc.
Shelton, CT 06484

Picker International, Inc.
Highland Heights, OH 44143

Ritter-Midwest Division of
Sybron Corporation
Des Plaines, IL 60018

Siemens Medical Systems, Inc.
Iselin, NJ 08830

Technicare Corporation
Cleveland, OH 44101

Thomson-CGR Medical Corporation
Columbia, MD 21046

Thomson-CSF Electron Tubes
Rutherford, NJ 07070

3M, Imaging Systems Division
St. Paul, MN 55144

Transworld X-Ray Corporation
Charlotte, NC 28210

Universal X-Ray, Inc.
Bensenville, IL 60106

Varian Image Tube Division
Palo Alto, CA 94304

The S. S. White Company
Holmdel, NJ 07733

Xerox Medical Systems
Pasadena, CA 91107

XRE Corporation
Littleton, MA 01460

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale