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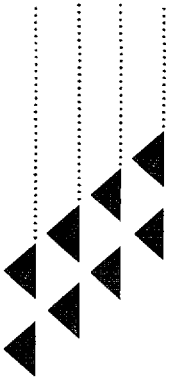
Diagnostic x-ray equipment compliance and facility survey



Canada

Diagnostic x-ray equipment compliance and facility survey

Recommended procedures for equipment and facility testing

Environmental Health Directorate
Health Protection Branch

Published by Authority of the Minister
of National Health and Welfare

Également disponible en français sous le titre
"Inspection des installations et de l'équipement de radiodiagnostic. Techniques recommandées pour la mise à l'essai de l'équipement et des installations"

94-EHD-184

Available in Canada through your local bookseller or by mail from:
Canada Communication Group — Publishing
Ottawa, Canada K1A 0S9
Cat. No. H46-2/94-184E
ISBN 0-660-15499-4

Canadian Cataloguing in Publication Data

Main entry under title:

Diagnostic X-Ray Equipment Compliance and Facility Survey — Recommended Procedures for Equipment and Facility Testing
Publ. aussi disponible en français sous le titre :
Inspection des installations et de l'équipement de radiodiagnostic
Cat. No. H46-2/94-184E
ISBN 0-660-15499-4

1. Radiography, Medical — Safety measures.
2. X-Rays — Equipment and Supplies — Safety measures.
I. Canada. Environmental Health Directorate.

RC78.5D52 1994 616.07'572 C94-980209-3

Explanatory notes

This document was prepared by the Radiation Protection Bureau. It sets out guidelines for the testing of diagnostic x-ray equipment and facilities[1]. This guide provides information for the X-ray inspector, test engineer, technologist, medical physicist and any other person responsible for verifying the regulatory compliance or safety of diagnostic x-ray equipment and facilities.

The radiation protection surveys detailed in this guide are primarily for the guidance of persons employed in the Federal Public Service Departments and Agencies including those persons under the jurisdiction of the Canada Labour Code. This guide also is intended to assist other users and manufacturers of x-ray equipment used for general patient diagnosis. However, it is important to recognize that facilities under provincial jurisdiction are subject to requirements specified under provincial statutes. Contact the appropriate authority listed in Appendix III for details of the regulatory requirements of individual provinces.

The words "must", "shall" and "should" in this guide have been chosen with purpose. The words "must" and "shall" indicate a requirement that is essential to meet the currently accepted standards of protection, while "should" indicates an advisory recommendation that is highly desirable and should be implemented where feasible.

In a field in which technology is advancing rapidly and where unexpected and unique problems continually occur the guide cannot cover all possible situations. Regulatory requirements may be modified and risks connected with x-radiation reassessed at any time. Blind adherence to rules cannot substitute for sound judgement. Therefore, recommendations may be modified in unusual circumstances, but only upon the advice of experts with recognized competence in radiation protection. This guide will be reviewed and revised periodically. Obtain interpretation or elaboration of any point by contacting the Bureau of Radiation Protection, Health Canada, 775 Brookfield Road Ottawa, Ontario K1A 1C1.

This guide reflects the results of the work of many individuals. It was prepared and compiled by Paul Chaloner, and reviewed by the professional and technical staff of the X-Ray Section, Radiation Protection Bureau, prior to publication.

Appreciation is expressed to all organizations, agencies and individuals whose comments and suggestions helped in the preparation of this guide.

[1] Originally referred to as Safety Code RPB-SC-20B (in Safety Code 20A - X-ray Equipment in Medical Diagnosis Part A, 1990).

Contents

1. Introduction

Diagnostic x-radiation is an essential part of present day medical practice. The largest contributor of irradiation to the general population comes from diagnostic x-radiation. Although individual irradiations are usually small, there is a concern of possible excess cancer risk when large populations are irradiated. Unnecessary irradiations to patients from radiological procedures can be significantly reduced with little or no decrease in the value of medical diagnostic information. This can be achieved by using well designed x-ray equipment which is installed, used and maintained by trained personnel, and by the adoption of standardized procedures. In general, when patient surface dose is reduced, there is a corresponding decrease in dose to x-ray equipment operators and other health care personnel.

The need for radiation protection exists because exposure to ionizing radiation can cause deleterious effects in both the exposed individual and in descendants. Such effects are called somatic and genetic effects, respectively. Somatic effects are characterized by adverse changes occurring in the body organs of the individual exposed. Genetic effects are attributed to chromosomal damage of the germ cells and may give rise to genetic defects that may show themselves in the progeny of exposed individuals.

While for radiation workers and the public permissible equivalent dose limits have been defined, only guidelines for the recommended upper limits on surface dose have been set for patients undergoing diagnostic x-ray procedures. For patients, the risk involved in the irradiation must always be weighed against the benefit of accurate medical diagnosis. However, consistent with quality images, there must always be a conscious effort to reduce irradiation to the lowest practical levels and eliminate unnecessary irradiation.

2. Principal aims and scope of the guide

This guide provides details on the testing of diagnostic x-ray equipment and survey procedures of the facility.

2.1 Principal aims

The principal aims of this guide are to outline survey procedures and list the measurements required for specific types of equipment and facilities.

2.2 Scope

To assist personnel in achieving these aims this guide:

1. details tests for diagnostic x-ray equipment;
2. identifies the relevant section of the regulations pertinent to the test being performed;
3. itemizes how to evaluate the results of the tests; and
4. specifies the acceptance criteria by which the equipment will be judged.

3. Responsibility and personnel

3.1 Responsibility

The owner is ultimately responsible for the radiation safety and operation of a diagnostic x-ray facility. The owner may delegate responsibility to staff. (For more information about the responsibilities of the Responsible user and the Radiation Protection (Safety) Officer see Safety Code 20A.)

The equipment manufacturer or importer is responsible for offering for sale only equipment that meets all applicable requirements under the Radiation Emitting Devices Act and Regulations. If equipment is modified by a person or persons who are at arm's length from the owner and the modification results in equipment which is non-compliant, then the person or persons paid for the work are considered manufacturers. That person or company has the same responsibility as if they supplied the original equipment in question. Similarly, the vendor of used equipment has to ensure that all regulatory requirements are met before the equipment can be used by the new owner.

Some tests may be detrimental to the x-ray equipment. Therefore it is the responsibility of those performing the tests to follow the manufacturer's specifications for equipment warm-up and operating conditions.

3.2 Personnel

Personnel performing equipment testing and evaluation of results should have adequate training and experience in radiation safety. A proven ability to perform the tests is necessary. A program for personnel of continuing education, refresher courses and attending scientific meetings is desirable. Personnel operating diagnostic x-ray equipment should be familiar with Safety Code 20A and its contents. Everybody testing equipment should have knowledge and understanding of the Radiation Emitting Devices Act and Radiation Emitting Devices Regulations, Part XII - Diagnostic X-ray Equipment.

4. Radiation protection surveys

4.1 General Information

The tests outlined later form part of the radiation survey and are intended to assess the compliance of the equipment based on measured data. The standard used is the Radiation Emitting Devices Act and Regulations and the wording used for the Acceptance Criteria are taken from those Regulations. For each test the specific part of the regulation is referenced and the Regulations must be referred to for the exact wording. Regulatory limits and requirements may change from time to time and new tests may be required to replace existing ones. The frequency of further testing should be determined by each individual facility.[2] Checking for labels and recording equipment information is excluded. However, it is standard practice to record pertinent information for each x-ray tube and generator. Reproducible operating procedures must be formulated and proper geometry used to ensure consistent results.

Measurements must be conducted using test equipment suitable to the type of x-ray equipment to be tested such as, the appropriate size of ionization chamber, uniform energy response etc. All test equipment should have a calibration traceable to a National Standard and the calibration should be rechecked according to the manufacturer's specifications. The exposure meters used by the Bureau of Radiation Protection, X-Ray Section are calibrated in units of roentgens, hence the values recorded are in these units. For ease of comparison with the regulations, the acceptance criteria for tests 4, 7A, 7B, 8, 9A, 9B, 16A and 16B are written using these units.

Most of the tests can be performed in the field. However, some of the tests require more intricate set-up and should be performed only in a laboratory. All the tests described are non-invasive. The manufacturer's instructions for warming up the diagnostic x-ray equipment should be followed before commencing the tests. All test equipment, such as the radiation detector, x-ray tube voltage measurement device and light meter, etc. should be allowed to stabilize for a suitable period before use.

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2 The National Council on Radiation Protection and Measurements, Publication Number 99, lists suggested frequencies in Appendix A.

The terminology used in this document is based on the International Electrotechnical Commission (IEC), Publication 788 titled: "Medical Radiology, Terminology" and published in 1984. The use of this terminology will allow a greater standardization between present and future Safety Codes, national and international publications, and the Radiation Emitting Devices Act and Regulations. However, some of the new terms may not be familiar to the reader and are introduced in APPENDIX VI

4.2 X-ray equipment compliance tests

1) Reproducibility of exposure

APPLICABILITY

This test applies to all radiographic x-ray equipment. The measurements are used to determine the coefficient of variation and the mean value of 10 consecutive irradiations.
[XII 19.(a)(i),(ii)]

ITEMS REQUIRED

a) An integrating exposure meter.

b) An attenuation block, if the equipment is operated under automatic exposure control.

PROCEDURE

1) Centre the x-ray tube over the sensitive volume of the exposure meter, and where applicable, the sensors for the automatic exposure control. Adjust the beam limiting device so that the visually defined field encompasses the sensitive volume and the sensors for the automatic exposure control.

2) On the control panel set typical loading factors used at the facility and record the set values. If automatic exposure control is selected, place an attenuation block between the sensitive volume and the table top. The block must ensure that the loading time is not less than 0.1 s.

3) Make ten consecutive irradiations within a period of one hour and record each exposure measurement. All exposure measurements must be at the same source-to-detector distance. Between irradiations set the loading factors (loading time, x-ray tube voltage and tube current) to alternate values and reset the original loading factors.

DATA COMPUTATION

1) Calculate the mean value of the ten measurements.

2) Calculate the per cent difference between the mean value and the maximum and minimum values of the ten measurements.

3) Calculate the coefficient of variation of the ten measurements using the formula:

$$C = \frac{S}{\bar{X}} = \frac{1}{\bar{X}} \left[\sum_{i=1}^{n} \frac{(X_i - \bar{X})^2}{n-1} \right]^{1/2}$$

where
- C = the coefficient of variation
- S = estimated standard deviation
- $\bar{X}$ = mean value of measurements
- X_i = i^{th} measurement
- n = number of measurements

ACCEPTANCE CRITERIA

1) The coefficient of variation, C, shall not exceed 0.05.

2) The maximum and minimum measurements shall be within 15 per cent of the mean value of the ten measurements.

2) Timing device accuracy

APPLICABILITY

This test applies to all radiographic timing devices. The measurements are used to compare the set loading times to the irradiation times and evaluate the timing device accuracy over the complete range of loading times which can be set on the unit.
[XII 19.(c)(ii)]

ITEM REQUIRED

a) An electronic irradiation time measuring device.

PROCEDURE

1) Centre the x-ray tube over the sensitive volume of the electronic irradiation time measuring device. Adjust the beam limiting device so that the visually defined field encompasses the sensitive volume.

2) Set a suitable tube current and x-ray tube voltage on the control panel and record the set values.

3) Set the radiographic timing device to the shortest possible loading time available on the unit.

4) Make an irradiation and record the set loading time and the irradiation time.

5) Make an irradiation for each loading time selection within the range of interest on the unit and record the set loading time and the irradiation time.

DATA COMPUTATION

1) For each set loading time shorter than 0.24* second calculate the difference between the set loading time and the irradiation time.

2) For each set loading time greater than 0.24* second calculate the per cent difference between the set loading time and the irradiation time.

ACCEPTANCE CRITERIA

1) For set loading times shorter than 0.24* second, the irradiation times must be accurate to l/60 second.

2) For set loading times greater than 0.24* second, the irradiation times must be accurate to 7% of the set time.

*Note: 0.24 second is the approximate time at which the crossover occurs between the 1/60 second and the 7% accuracy requirement

3A) Minimum loading time

APPLICABILITY

This test applies to all radiographic timing devices. The measurements are used to determine the minimum loading time available on the radiographic x-ray unit. [XII 19.(c)(i)]

ITEM REQUIRED

a) An electronic irradiation time measuring device.

PROCEDURE

1) Centre the x-ray tube over the sensitive volume of the irradiation time measuring device. Adjust the beam limiting device so that the visually defined light field encompasses the sensitive volume.

2) Set a suitable tube current and x-ray tube voltage on the control panel and record the set values.
3) Set the radiographic timing device to the shortest possible loading time.

4) Make an irradiation and record the loading time and the irradiation time.

DATA COMPUTATION

1) Calculate the product of the minimum loading time and the minimum tube current setting.

2) Compare the minimum irradiation time measurement to 1/60 second. Calculate the difference between them.

ACCEPTANCE CRITERIA

1) For selected tube currents of 300 milliamperes or less, the product of the minimum loading time setting and the minimum tube current must be less than or equal to 5 milliampere-seconds.

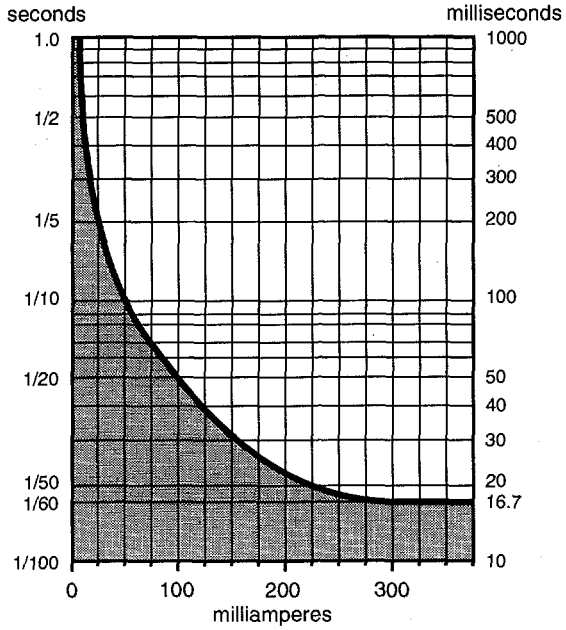
2) For selected tube currents of 300 milliamperes or more the minimum irradiation time must not exceed 1/60 second.

3) For mAs timing devices where the minimum nominal mAs is more than 5 mAs, the minimum irradiation time must not exceed 1/60 second.

4) Figure 1 shows the minimum irradiation time required for any given tube current setting. The allowed values are in the area below the curve.

NOTE: The minimum milliampere-seconds available is only an estimate because invasive methods of testing or clamp-on current measurement devices are required to verify the tube current.

Figure 1: Minimum Irradiation Time Requirements



3B) Minimum automatic exposure control time

APPLICABILITY

This test applies to all units with an automatic exposure control (AEC). The measurements are used to determine the minimum loading time or to estimate the minimum milliampere-seconds available in the AEC mode. [XII 19.(c)(i)]

ITEM REQUIRED

a) An electronic irradiation time measuring device.

PROCEDURE

1) Centre the x-ray tube over the irradiation sensing devices of the AEC. Place the sensitive volume of the electronic irradiation time measuring device adjacent to the irradiation sensing devices. The sensitive volume must not cover any of the irradiation sensing devices. Adjust the beam limiting device so that the visually defined field encompasses the sensitive volume and the sensing devices of the AEC.

2) Set the automatic exposure control mode of operation on the control panel, and where possible, record the selected loading factors.

3) Make an irradiation and record the irradiation time.

4) If the tube current can be selected before the initiation of the irradiation, check each tube current setting for the minimum loading time available.

DATA COMPUTATION

1) Calculate the product of the loading time and the tube current selected.

2) Compare the recorded irradiation time to 1/60 second. Calculate the difference between them.

ACCEPTANCE CRITERIA

1) For selected tube currents of 300 milliamperes or less the product of the minimum loading time setting and the minimum tube current must be less than or equal to 5 milliampere-seconds.

2) For selected tube currents of 300 milliamperes or more the minimum irradiation time must not exceed 1/60 second.

3) Figure 1 shows the minimum irradiation time required for any given tube current setting. The allowed values are in the area below the curve.

NOTE: The minimum milliampere-seconds available is only an estimate because invasive methods of testing or clamp-on current measurement devices are required to verify the tube current.

4) Average exposure ratios (linearity)

APPLICABILITY

This test applies only to radiographic x-ray units equipped with more than one tube current setting. It does not apply to those units where only the product of tube current and loading time (mAs) can be set. The measurements are used to determine whether or not any two consecutive tube current settings can produce average exposure ratios within the acceptable tolerance. [XII 19.(d)]

ITEM REQUIRED

a) An integrating exposure meter.

PROCEDURE

1) Centre the x-ray tube over the sensitive volume of the exposure meter. Adjust the beam limiting device so that the visually defined field encompasses the sensitive volume.

2) Set the lowest available tube current, a suitable loading time and x-ray tube voltage (usually within the range of 40 to 100 per cent of the maximum rated) on the control panel. Record the loading factors.

3) Make several irradiations and record each of the exposure measurements at the selected settings.

4) Change the tube current to the next higher setting and record the new tube current. The x-ray tube voltage and loading time must remain at the same values as those selected in step 2.

5) Make several irradiations and record each of the exposure measurements. Repeat steps 4 and 5 for all tube currents available.

DATA COMPUTATION

1) Calculate the average ratios of exposure (in milliroentgen) to the product of the tube current and loading time (in milliampere-seconds) obtained at any two consecutive tube current settings.

ACCEPTANCE CRITERION

1) The average milliroentgen (mR) per milliampere-second (mAs) values obtained at any two consecutive tube current settings shall not differ by more than 0.10 times their sum. That is to say,

$$|\overline{X}_1 - \overline{X}_2| \leq 0.10\,(\overline{X}_1 + \overline{X}_2)$$

where $\overline{X}_1$ and $\overline{X}_2$ are the average mR/mAs values obtained at two consecutive tube current settings.

5) X-ray tube voltage accuracy

APPLICABILITY

This test applies to all x-ray tubes. The measurements are used to compare the set and the measured x-ray tube voltage over the complete range of x-ray tube voltages and tube current settings. [XII 19.(b)(i),(ii)]

ITEM REQUIRED

a) An x-ray tube voltage measurement device.

PROCEDURE

1) Centre the x-ray tube over the sensitive volume of the measurement device. Adjust the beam limiting device so that the visually defined field encompasses the sensitive volume.

2) Set suitable loading factors on the control panel and record the set values.

3) Make an irradiation and record the x-ray tube voltage measurement.

4) Make irradiations at various x-ray tube voltages and tube current settings and record the set and measured values.

DATA COMPUTATION

1) Calculate the per cent difference between the recorded and the set x-ray tube voltage for each irradiation made.

ACCEPTANCE CRITERION

1) The actual x-ray tube voltage, for any selected setting, shall correspond to the selected value within plus or minus 5 per cent of the selected value.

6) Beam quality

APPLICABILITY

This test applies to all x-ray tubes. The measurements are used to estimate the half-value layer of the radiation beam.
[XII 5.(2)(f)(ii)]

ITEMS REQUIRED

a) An integrating exposure meter.

b) Several sheets of aluminum filters of various thicknesses, as shown in Table 1. The aluminum should be Aluminum Association type 1100 alloy.[3]

c) A means to support the aluminum filters between the x-ray tube and the sensitive volume of the exposure meter.

PROCEDURE

1) Centre the x-ray tube over the sensitive volume of the exposure meter. Adjust the beam limiting device so that the visually defined field encompasses the sensitive volume. The radiation beam must not extend beyond the aluminum filters when they are placed in the radiation beam.

2) Set loading factors on the control panel and record the set values. The loading factors and the target-to-sensitive volume distance must remain unchanged throughout the test. The selected x-ray tube voltage must be verified using Test 5: X-ray tube voltage accuracy. The measured value of x-ray tube voltage is used when determining whether the acceptance criterion has been met.

3) Make an irradiation and record the exposure measurement. For those units operating only with automatic exposure control the total thickness of aluminum attenuators must remain in the radiation beam at all times. That is, all of the aluminum must be between the sensitive volume and the sensing devices of the AEC. when the first irradiation is made. As steps 4, 5 and 6 are

[3] The nominal chemical composition of type 1100 aluminum alloy is 99.00 per cent minimum aluminum as given in "Aluminum Standards and Data", Table 6.2, (1979).

followed the appropriate aluminum attenuators are taken from the pile between the sensitive volume and the sensing devices of the AEC. and placed between the x-ray tube and the sensitive volume.

4) Place between the x-ray tube and the sensitive volume of the exposure meter the first aluminum filter shown in Table 1. The aluminum filters should be halfway between the focal spot of the x-ray tube and the sensitive volume of the exposure meter. Also, the filters must be perpendicular to the radiation beam axis. Make an irradiation and record the thickness of aluminum filter and the exposure measurement. Repeat the irradiations using increased filter thicknesses as shown in Table 1.

Table 1

HIGHEST DESIGN OPERATING RANGE	MILLIMETRES OF ALUMINUM FILTRATION TO BE ADDED BETWEEN THE X-RAY TUBE AND THE SENSITIVE VOLUME OF THE EXPOSURE METER			
BELOW 50 kVp	0.5	1.0	1.5	2.0
50-70 kVp	1.0	1.5	2.5	3.5
ABOVE 70 kVp	1.5	2.5	3.5	4.5

5) Continue the irradiations with increasing thicknesses of filter material between the x-ray tube and the sensitive volume until the exposure measurement is less than one-half of the exposure measurement obtained in step 3. The aluminum thicknesses listed in Table 1 may not be sufficient for all units, therefore more aluminum may be required.

6) Remove the aluminum filters from between the x-ray tube and the sensitive volume. Repeat step 3 to verify that the x-ray tube output remained stable during the test. If the measurement recorded in step 6 is not within 15 per cent of the measurement recorded in step 3 the x-ray unit should be checked by qualified service personnel and the beam quality test done again after the x-ray unit has been calibrated.

DATA COMPUTATION

1) Plot the recorded data on semi-log graph paper with the aluminum thicknesses on the linear scale and the exposure measurements on the logarithmic scale. The half-value layer is found as the aluminum thickness for which the exposure value is one half of the exposure value corresponding to zero aluminum thickness.

ACCEPTANCE CRITERION

1) The half-value layer of the radiation beam, for a measured x-ray tube voltage shall not be less than the values given in or obtained by linear interpolation or extrapolation of Table 2.

Table 2

DESIGN OPERATING RANGE (KILOVOLTS PEAK)	MEASURED X-RAY TUBE VOLTAGE (KILOVOLTS PEAK)	HALF-VALUE LAYER (MILLIMETRES OF ALUMINUM)
BELOW 50.....	30	0.3
	40	0.4
	49	0.5
50 to 70.....	50	1.2
	60	1.3
	70	1.5
ABOVE 70.....	71	2.1
	80	2.3
	90	2.5
	100	2.7
	110	3.0
	120	3.2
	130	3.5
	140	3.8
	150	4.1

7A) Leakage radiation from the x-ray tube housing (Field Testing)

APPLICABILITY

This test applies to all x-ray tubes. The measurements will be used to evaluate the leakage radiation at locations or in directions occupied by personnel during an irradiation. [XII 19.(g)]

ITEMS REQUIRED

a) An integrating exposure meter. The sensitive volume of the exposure meter shall have a detection area of 100 cm^2 and no linear dimension greater than 20 cm.

b) The tube rating chart for the x-ray tube being tested.

c) For the x-ray tube voltage used at least 10 half value layers of lead sheets to block the beam limiting device.

PROCEDURE

Where leakage limits are defined as a percentage of the exposure follow steps 1,2,3,4,5. Where leakage limits are defined as an exposure limit within a specified period follow steps 2,4,5.

1) Centre the x-ray tube over the sensitive volume of the exposure meter. Adjust the beam limiting device so that the visually defined field encompasses all of the sensitive volume.

2) Set suitable loading factors* on the control panel. The loading factors must remain the same throughout the test. Record the loading factors and the distance from the focal spot of the x-ray tube to the sensitive volume of the exposure meter.

* Use the maximum x-ray tube voltage at which the tube can be operated. Consult the tube rating chart and exercise caution to prevent damage to the x-ray tube. Make several irradiations, starting with a lower, commonly used x-ray tube voltage, and increasing the setting gradually until the maximum operating x-ray tube voltage is reached.

3) Make an irradiation and record the exposure measurement.

4) Adjust the beam limiting device to its minimum field size. Block the beam limiting device with at least ten half-value layers of lead for the operating x-ray tube voltage selected.

5) At various locations or directions around the x-ray tube housing place the sensitive volume of the exposure meter. Make an irradiation and record both the exposure measurements and the distance from the focal spot of the x-ray tube to the sensitive volume of the exposure meter.

DATA COMPUTATION

1) Using the inverse square law[4], normalize the exposure measurements from steps 3 and 5 of the procedure to 1 m from the focal spot of the x-ray tube.

2) Calculate the radiation leakage. Consult the x-ray tube rating chart and take into account the maximum loading time and tube current at which the x-ray tube can be operated when the x-ray tube voltage is also at maximum.

ACCEPTANCE CRITERIA

1) The leakage radiation at a distance of 1 m shall not exceed 0.1 per cent of the exposure rate at the same distance along the radiation beam axis.

2) The radiation leakage at a distance of 1 m shall not exceed 100 milliroentgen in one hour under any loading factor conditions within the rated limits of the x-ray tube[5].

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4 The inverse square law does not apply exactly; therefore the sensitive volume of the exposure meter should be placed as close as reasonable to 1 m from the focal spot to minimize error.

5 The X-ray Section of the Bureau of Radiation Protection will be following the ICRP Recommendations for leakage from an x-ray tube.

7B) Leakage radiation from the x-ray tube housing (Laboratory Testing)

APPLICABILITY

This test applies to all x-ray tubes which can be subjected to laboratory testing. The measurements will be used to evaluate leakage radiation in any direction from the focal spot of the x-ray tube. [XII 19.(g)]

ITEMS REQUIRED

a) An integrating exposure meter. The sensitive volume of the exposure meter shall have a detection area of 100 cm^2 and no linear dimension greater than 20 cm.

b) The tube rating chart for the x-ray tube being tested.

c) Image recording material in flexible holders.

d) Adhesive tape.

PROCEDURE

Where leakage limits are defined as a percentage of the exposure follow steps 1-9. Where leakage limits are defined as an exposure limit within a specified period follow steps 2,4-9.

1) Centre the x-ray tube over the sensitive volume of the exposure meter. Adjust the beam limiting device so that the visually defined field encompasses all of the sensitive volume.

2) Set suitable loading factors* on the control panel. The loading factors must remain the same throughout the test. Record the loading factors and the distance from the focal spot of the x-ray tube to the sensitive volume of the exposure meter.

* Use the maximum x-ray tube voltage at which the tube can be operated. Consult the tube rating chart and exercise caution to prevent damage to the x-ray tube. Make several irradiations, starting with a lower, commonly used x-ray tube voltage, and increasing the setting gradually until the maximum operating x-ray tube voltage is reached.

3) Make an irradiation and record the exposure measurement.

4) Adjust the beam limiting device to its minimum field size. Block the beam limiting device with at least ten half-value layers of lead for the operating x-ray tube voltage selected.

5) Wrap the x-ray tube with the flexible holders containing the image recording material and secure with adhesive tape.

6) Make an irradiation.

7) Remove the flexible holders from the x-ray tube and process the image recording material according to the manufacturer's recommendations.

8) Review the image recording material and identify the highest levels of x-ray tube leakage.

9) At various locations or directions around the x-ray tube housing, identified as the highest levels of x-ray tube leakage, place the sensitive volume of the exposure meter. Make an irradiation and record both the exposure measurements and the distance from the focal spot of the x-ray tube to the sensitive volume.

DATA COMPUTATION

1) Using the inverse square law[6], normalize the exposure measurements from steps 3 and 9 of the procedure to 1 m from the focal spot of the x-ray tube.

2) Calculate the radiation leakage. Consult the x-ray tube rating chart and take into account the maximum loading time and x-ray tube current at which the x-ray tube can be operated when the x-ray tube voltage is also at maximum.

ACCEPTANCE CRITERIA

1) The leakage radiation at a distance of 1 m shall not exceed 0.1 per cent of the exposure rate at the same distance along the radiation beam axis.

2) The radiation leakage at a distance of 1 m shall not exceed 100 milliroentgen in one hour under any loading factor conditions within the rated limits of the x-ray tube[7].

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6 The inverse square law does not apply exactly; therefore the sensitive volume of the exposure meter should be placed as close as reasonable to 1 m from the focal spot to minimize error.

7 The X-ray Section of the Bureau of Radiation Protection will be following the ICRP Recommendations for leakage from an x-ray tube.

8) Radiation beam transmission through the mammographic image receptor support device

APPLICABILITY

This test applies to all mammographic units including those general purpose radiographic x-ray units which can be operated in a mammographic mode. The exposure measurements will show the transmission of the radiation beam through the image receptor support device. [XII 19.(e)]

ITEM REQUIRED

a) An integrating exposure meter suitable for measuring mammographic irradiations. The sensitive volume of the exposure meter shall have a detection area of 100 cm^2 and no linear dimension greater than 20 cm.

PROCEDURE

1) Adjust the x-ray tube to the minimum target-to-image receptor distance for which it is designed. Measure and record the distance from the focal spot to the image receptor support device.

2) Place the sensitive volume of the exposure meter behind the image receptor support device. Wherever practical, position the centre of the sensitive volume 5 cm from the support device. Care must be taken to minimize scattered radiation reaching the sensitive volume of the exposure meter. Measure and record the distance from the image receptor support device to the sensitive volume.

3) Ensure that the area of coverage by the radiation beam encompasses the sensitive volume of the exposure meter.

4) Record the maximum rated x-ray tube voltage and the maximum rated tube current-loading time product (mAs) for that x-ray tube voltage.

5) Set the maximum rated x-ray tube voltage on the control panel.

6) Set a suitable percentage of the maximum rated tube current-loading time product (i.e., less than 100%) for that x-ray tube voltage and record the loading factors.

7) Make several irradiations and record each of the exposure measurements.

DATA COMPUTATION

1) Calculate the average of the exposure measurements.

2) Normalize the average of the exposure measurements to the maximum rated tube current-loading time product for the x-ray tube voltage used.

3) Normalize the estimated maximum transmission exposure measurement to 5 cm beyond the image receptor support device.

ACCEPTANCE CRITERION

1) The radiation beam transmitted through the image receptor support device for the maximum rated x-ray tube voltage specified for mammography and maximum rated tube current-loading time product shall not exceed 0.1 milliroentgen for each activation of the x-ray tube.

9A) Standby radiation from capacitor energy storage equipment

APPLICABILITY

This test applies to x-ray tubes operated with capacitor discharge units. The exposure measurements will be used to determine whether or not an unacceptably high level of radiation is emitted by the x-ray tube when the capacitor is fully charged (standby) and when the irradiation switch or timing device are not activated.
[XII 19.(i)]

ITEM REQUIRED

a) An exposure rate meter. The sensitive volume of the exposure rate meter shall have a detection area of 100 cm^2 and no linear dimension greater than 20 cm.

PROCEDURE

1) Open the beam limiting device fully.

2) Place the sensitive volume of the exposure meter 5 cm in front of the face plate of the beam limiting device. If it is not practical to use 5 cm distance, use some other suitable distance, measure and record it.

3) Adjust the beam limiting device so that the visually defined field encompasses the sensitive volume.

4) Set the maximum x-ray tube voltage and the maximum tube current-loading time product on the control panel.

5) Charge the capacitor fully.

6) Without activating the irradiation switch or the timing device, measure the standby radiation emission and record the exposure rate. The period required for this measurement may require that the capacitors be recharged to full charge, when the x-ray tube voltage drops from its maximum level by more than 5 kilovolts.

DATA COMPUTATION

1) Normalize the exposure rate to 5 cm from the external surface of the x-ray tube housing by using the inverse square law.

ACCEPTANCE CRITERION

1) The exposure rate at 5 cm from any accessible external surface of the x-ray tube housing shall not exceed 2 milliroentgen per hour.

9B) Leakage radiation from capacitor energy storage equipment

APPLICABILITY

This test applies to all x-ray tubes operated with capacitor discharge units and is done in addition to standard tube leakage tests. The exposure measurements will be used to determine whether or not an unacceptably high level of radiation is emitted from the x-ray tube when the capacitor is discharged by means other than the irradiation switch or timing device. [XII 19.(i)]

ITEM REQUIRED

a) An integrating exposure meter. The sensitive volume of the meter shall have a detection area of 100 cm^2 and no linear dimension greater than 20 cm.

PROCEDURE

1) Centre the x-ray tube over the sensitive volume of the exposure meter. Adjust the beam limiting device so that the visually defined field encompasses the sensitive volume.

2) Set the maximum x-ray tube voltage and maximum tube current-loading time product on the control panel. Measure and record the distance from the focal spot of the x-ray tube to the sensitive volume of the meter.

3) Open the beam limiting device fully.

4) Charge the capacitor fully.

5) Discharge the capacitor by the means supplied by the manufacturer, other than the irradiation switch or the timing device. This may be a "CHARGE OFF" or "DISCHARGE" button or a release handle.

6) Record the exposure measurement.

7) Repeat steps 4,5 and 6 several times.

DATA COMPUTATION

1) Using the exposure measurements obtained in step 6 of the procedure calculate the mean of the exposure measurements recorded.

2) Using the inverse square law, normalize the estimated standby radiation emission to 1 m from the focal spot of the x-ray tube.

ACCEPTANCE CRITERION

1) The radiation leakage at a distance of 1 m from the focal spot of the x-ray tube shall not exceed 100 milliroentgen in one hour under any loading factor conditions.

10) Alignment and size comparison of the x-ray and light fields.

APPLICABILITY

This test applies to all mobile radiographic x-ray equipment. The results of the test will indicate if the visually defined field of the radiation beam and the minimum field size are within acceptable tolerances. [XII 9.(a), (c) (i)]

ITEMS REQUIRED

a) Image recording material.

b) 5 rectangular metal markers about 4 cm long with the middle of the long side marked, or 9 one cent pieces.

PROCEDURE

1) With the radiation beam axis perpendicular to the image recording material, centre the x-ray tube over the image recording material. Measure and record the distance from the focal spot of the x-ray tube to the image recording material.

2) Adjust the beam limiting device so that the visually defined field is within the borders of the image recording material.

3) Place one metal marker on each of the 4 sides. The long side of each marker should be half out of the light field. Alternatively, place 2 one cent pieces on each of the 4 sides. Position them so the edge of the light field is between them. Place the fifth marker or the ninth one cent piece in one of the quadrants to identify orientation. The set-up is shown in Figure 2.

4) Set suitable loading factors on the control panel and make an irradiation.

5) Adjust the beam limiting device to the minimum field size.

6) If the light field is not visible, indicating that the beam limiting device is fully closed, there is no need to make another irradiation.

7) Make another irradiation, if required.

8) Process the image recording material according to the manufacturer's recommendations.

DATA COMPUTATION

1) Measure and record the radiation field image size and the minimum radiation field image size (if an irradiation was made of the minimum setting).

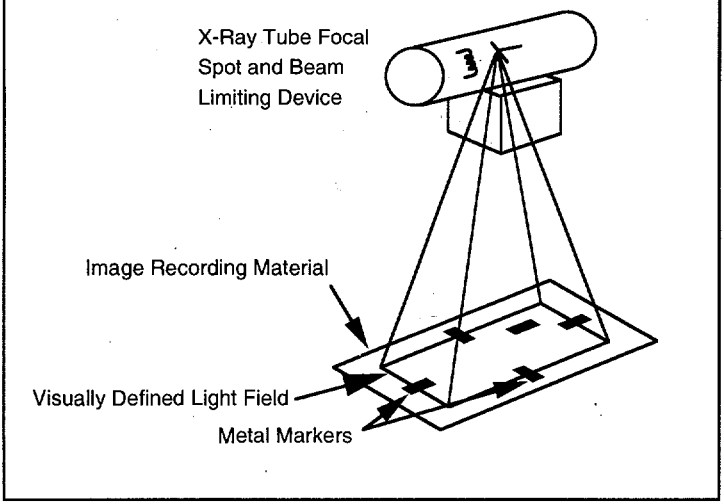
2) Reconstruct on the image recording material the size and shape of the light field by using the metal marker images as a guide.

3) Calculate and record 2 per cent of the target-to-image receptor distance.

4) Measure the distance on each of the 4 sides between the reconstructed light field and the x-ray field image.

5) Sum the distances found in step 4 for opposite sides of the x-ray field image and the light field. Compare the sum of the measured separations to 2 per cent of the target-to-image receptor distance.

Figure 2: Congruence of Light & Radiation Fields



6) Calculate the minimum field size image to the size at 100 cm target-to-image receptor distance, if an irradiation was made.

ACCEPTANCE CRITERIA

1) A beam limiting device on mobile radiographic x-ray equipment shall be in accordance with the following requirements:

   (i) a minimum field size that does not exceed 5 cm by 5 cm at a target-to-image receptor distance of 100 cm and

   (ii) the measured misalignment of the visually defined field and the x-ray field determined along the length or width of the x-ray field, shall not exceed 2 per cent of the target-to-image receptor distance.

11) Beam limiting device for general purpose x-ray equipment

APPLICABILITY

This test applies to all stationary general purpose radiographic x-ray equipment equipped with positive beam limitation (PBL). The results will be used to evaluate the light and radiation fields congruency, field size indicator accuracy, minimum radiation field size and radiation field size. [XII 8.(1)(a),(c)(i),(c)(ii),(e),(2)(a),(b)(i)(A)(B)(ii)]

ITEMS REQUIRED

a) Two sizes of image recording material, one substantially larger than the other.

b) Five metal markers about 4 cm long with the middle of the long side marked, or 9 one cent pieces.

c) Stopwatch.

PROCEDURE

1) Select positive beam limitation operation on the control panel.

2) Place the largest image recording material on the table top. The set-up is shown in Figure 3.

3) Place the other image recording material in the cassette tray underneath the image recording material on the table top. Record the time required for the automatic adjustment of the radiation field to the dimensions of the image receptor.

4) With the radiation beam axis perpendicular to the image recording materials centre the x-ray tube over the two image recording materials (on the table top and in the cassette tray).

5) Record the beam limiting device shutter settings and the target-to-image distances of the two image recording materials (on the table top and in the cassette tray).

6) On the table top image recording material place one metal marker on each of the four sides of the visually defined field. The long side of each metal marker should be half out of the light field. Alternatively place two one cent pieces on each of the 4 sides positioned so the edge of the light field is between them. Place the fifth marker or ninth one cent piece in one of the quadrants to identify orientation. The set-up is shown in Figure 2.

7) Set suitable loading factors on the control panel and make an irradiation.

8) Adjust the beam limiting device to the minimum field size.

9) If the visually defined field disappears, indicating that the beam limiting device is fully closed, there is no need to make another irradiation.

10) Make another irradiation, if required.

11) Process the two image recording materials according to the manufacturer's recommendations.

DATA COMPUTATION

1) Using the table top image recording material, measure and record the dimensions of the radiation field image. If a second irradiation was made, measure and record the minimum field size image.

2) Using the table top image recording material, reconstruct the size and shape of the visually defined field by using the metal marker images as a guide.

3) Calculate and record 2 per cent of the target-to-image receptor distance at the table top.

4) Measure on each of the four sides of the table top image recording material the distance between the reconstructed light field and the radiation field image.

5) Sum the distances found in step (4) for opposite sides of the fields and compare to 2 per cent of the target-to-image receptor distance at the table top.

6) Normalize the minimum radiation field size image to the size at 100 cm target-to-image receptor distance and record the result.

7) Using the size of the radiation field image at the table top and similar triangles calculate the size of the image at the cassette tray.

8) Calculate the difference between the calculated image size at the cassette tray and the beam limiting device shutter settings. Compare this difference to 2 per cent of the target-to-image distance at the cassette tray.

9) Calculate 3 and 4 per cent of the distance from the target to the image receptor in the cassette tray.

10) Calculate, for the length and width, the difference between the size of the image receptor in the cassette tray and the calculated size of the image at the cassette tray. Compare these differences to 3 per cent of the distance from the target to the image receptor in the cassette tray.

11) Compare the sum of the differences of the length and width to 4 per cent of the distance from the target to the image receptor in the cassette tray.

12) Draw diagonals across the image recording material from the cassette tray to determine the centre of the image recording material.

13) Using the image recording material from the cassette tray draw diagonals across the radiation field image to determine the centre of the radiation field. (If the radiation field image is not contained within the image recording material, the centre of the radiation field image is calculated from the radiation beam size as determined in step 7.)

14) Measure and record the distance between the centre of the image recording material and the centre of the radiation field image. Compare this distance to 2 per cent of the target-to-image receptor distance in the cassette tray.

ACCEPTANCE CRITERIA

1) The measured misalignment of the visually defined field and the radiation field, along the length or width of the radiation field, shall not exceed 2 per cent of the target-to-image receptor distance.

2) The indicated field size dimensions shall be accurate to within 2 per cent of the target-to-image receptor distance.

3) The alignment of the centres of the radiation field and the image recording material shall be within 2 per cent of the target-to-image receptor distance.

4) The minimum field size shall not exceed 5 cm by 5 cm at a target-to-image receptor distance of 100 cm.

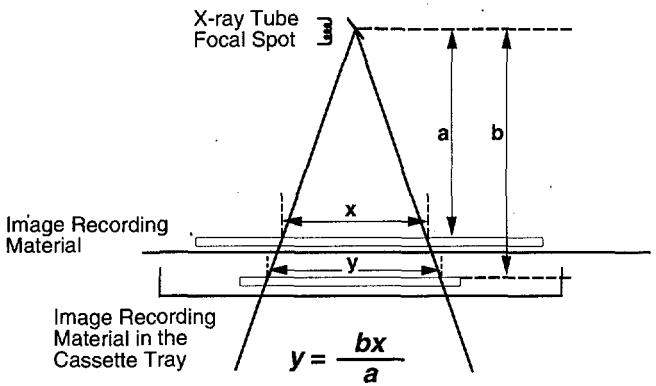
5) The radiation field size shall not exceed, in width or length, the image receptor by more than 3 per cent of the target-to-image receptor distance. Also, the sum of the width and length of the radiation field shall not exceed the sum of the length and width of the image receptor by more than 4 per cent.

6) The beam limiting device shall either:

   (i) provide, within 5 seconds of insertion of the image receptor, automatic adjustment of the radiation field to
   (A) the dimensions of the image receptor, or
   (B) the dimension of a preselected portion of the image receptor, or

   (ii) prevent irradiation production until the beam limiting device is manually adjusted so the size of the radiation beam is no greater than the image receptor size.

Figure 3: Determination of the Radiation Field Size at the Image Receptor



12) Light localizer illumination

APPLICABILITY

This test applies to all beam limiting devices equipped with a light localizer. The average illumination from the light localizer is checked. [XII 8.(1)(b) 9.(b)]

ITEM REQUIRED

a) A light meter.

PROCEDURE

1) Place the sensitive area of the light meter on the table top. Where practical, the ambient room lighting should be adjusted to a low level. Adjust the x-ray tube to a distance of 100 cm or the maximum target-to-image receptor distance, whichever is the lesser, from the sensitive volume.

2) Centre the x-ray tube over the sensitive volume and measure and record the ambient illumination with the light localizer switched off.

3) Adjust the beam limiting device so that the visually defined field will encompass the sensitive volume in each of the four quadrants displayed.

4) Switch on the light localizer and sample the illumination in each of the four quadrants and record the level of illumination.

DATA COMPUTATION

1) Calculate the average illumination of the four quadrants.

2) Calculate the difference between the average illumination and the ambient illumination to obtain the net average illumination.

3) Compare the net average illumination to 100 lux.

ACCEPTANCE CRITERION

1) The light localizer which visually defines the outline of the radiation field shall give a net average illumination of not less than 100 lux at 100 cm distance or at the maximum target-to-image receptor distance, whichever is less.

13A) Target-to-table top distance for under-table x-ray tubes

APPLICABILITY

This test applies to all x-ray tubes located beneath the table. The measurements will be used to determine the distance from the table top to the x-ray tube focal spot. [XII 15.(h)(i),(ii),(iii)]

ITEMS REQUIRED

a) Image recording material.

b) Two radiopaque markers of known separation distance such as 5 cm.

c) Lead sheets of sufficient thickness to block the whole of the image intensifier input area. The minimum lead thickness should be 3.2 mm.

d) A means to support the image recording material and the lead above the table top.

PROCEDURE

1) Place the radiopaque markers of known separation distance on the table top. The set-up is shown in Figure 4.

2) Using fluoroscopy centre the x-ray tube under the radiopaque markers. Adjust the beam limiting device so that the radiation field encompasses the radiopaque markers.

3) Place the image recording material above the radiopaque markers. The distance from the image recording material to the table top should be 20-30 cm. The markers and the image recording material must lie in a plane perpendicular to the radiation beam axis.

4) Protect the image intensifier by placing sufficient sheets of lead on the support between the image recording material and the image intensifier.

5) Measure and record the distance from the table top to the image recording material.

6) Set suitable loading factors on the control panel and using fluoroscopy make an irradiation. Where more than one size of focal spot is available, the smallest should be used.

7) Process the image recording material according to the manufacturer's recommendations.

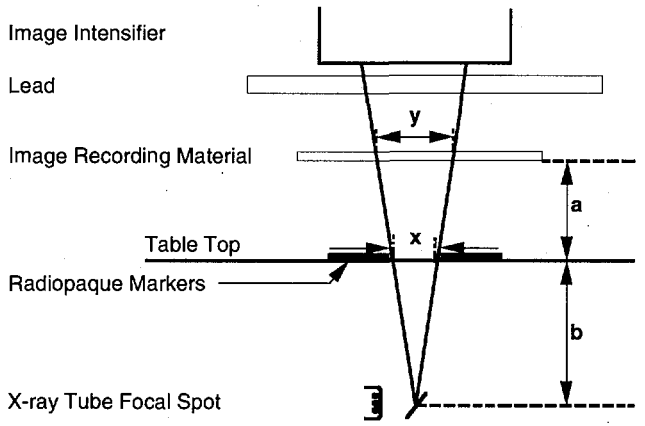
DATA COMPUTATION

1) Measure the distance between the image of the radiopaque markers on the image recording material.
2) Using similar triangles, that is the formula shown below, calculate the distance from the focal spot to the table top.

ACCEPTANCE CRITERIA

1) The target-to-skin distance (table top) must not be less than 30 cm for mobile equipment.
2) The target-to-skin distance (table top) must not be less than 38 cm for stationary equipment.
3) The target-to-skin distance (table top) must not be less than 20 cm for an image intensified equipment designed for special applications.
4) The focal spot shall be indicated to within ± 4 mm on the external surface of the tube housing.

Figure 4: Target-to-Table Top Distance



13B) Target-to-image receptor distance for over-table x-ray tubes.

APPLICABILITY

This test applies to all x-ray tubes located above the table. The measurements will be used to determine the location of the x-ray tube focal spot, check the accuracy of the source-to-image receptor distance indicator and check the alignment of the centre of the x-ray field with respect to the centre of the image receptor.
[XII 4.(c),(i)(A),(B)8.(1),(e)]

ITEMS REQUIRED

a) Image recording material.

b) Two radiopaque markers of known separation distance such as 5 cm.

c) A radiolucent means to support the radiopaque markers above the image recording material.

d) A small radiopaque marker such as a ball bearing.

PROCEDURE

1) Place the two radiopaque markers of known separation distance on the radiolucent stand.

2) Using fluoroscopy centre the x-ray tube over the radiopaque markers. Adjust the beam limiting device so that the visually defined field encompasses the radiopaque markers.

3) Tape the ball bearing to the centre of the image recording material holder and place the image recording material in the cassette tray. Centre the image recording material to the visually defined light field.

4) Measure and record the two distances from the indicated focal spot:
   a) to the radiopaque markers; and
   b) to the image recording material in the cassette tray.
   The markers and the image recording material must lie in a plane perpendicular to the radiation beam axis.

5) Set suitable loading factors on the control panel and make an irradiation. Where more than one size of focal spot is available, the smallest should be used.

6) Process the image recording material according to the manufacturer's recommendations.

DATA COMPUTATION

1) Measure the distance between the image of the radiopaque markers on the image recording material.
2) Using similar triangles calculate the distance from the focal spot to the image recording material.
3) Compare the calculated distance from the focal spot to the image recording material, to the measured and indicated distance from the focal spot to the image recording material.
4) Mark two points on each of the four sides of the image. Through the two points on each side draw a straight line. These four lines when extended will intersect forming a rectangle which is an approximation of the actual radiation field.
5) Draw the diagonals across the rectangle. The point at which the diagonals cross is assumed to be the centre of the radiation field.
6) Measure the distance between the assumed centre of the radiation field and the image of the ball bearing. Compare this distance to 2 per cent of the target-to-image receptor distance.

ACCEPTANCE CRITERIA

1) The focal spot shall be indicated to within ±4 mm on the external surface of the tube housing.
2) The target-to-image distance indicator shall be accurate to within 2 per cent of the target-to-image receptor distance.
3) The alignment of the centres of the radiation field and the image receptor shall be within 2 per cent of the target-to-image receptor distance.

In the case of x-ray tubes capable of fluoroscopy the following criteria also apply:

1) The target-to-skin distance must not be less than 30 cm for mobile equipment.
2) The target-to-skin distance must not be less than 38 cm for stationary equipment.
3) The target-to-skin distance must not be less than 20 cm for an image intensified equipment designed for special applications.

14) Beam limiting device for mammographic equipment

APPLICABILITY

This test is applicable to all x-ray equipment designed specifically for mammography and general purpose radiographic x-ray equipment equipped with special attachments for mammography. The test results will be used to evaluate the beam limiting device. [XII 11.(1)(a)(i)(ii), 12.]

ITEMS REQUIRED

a) Image recording material larger than the maximum image recording material used.

b) A radiopaque marker.

PROCEDURE

1) Adjust the distance between the image receptor tray or breast support and the x-ray tube to the maximum distance.

2) Measure and record the focal spot-to-image receptor distance.

3) Measure and record the distance from the breast support to the image receptor tray where applicable.

4) Place the image recording material on the breast support.

5) Place the radiopaque marker so that it will indicate the chest wall side.

6) Set suitable loading factors on the control panel and make an irradiation.

7) Process the image recording material according to the manufacturer's recommendations.

DATA COMPUTATION

1) Measure and record the radiation field size image.

2) Using similar triangles calculate the size of the radiation field at the image receptor tray, where applicable.

3) Calculate 2 per cent of the distance from the target to the image receptor tray.

4) Compare the calculated size of the radiation field at the image receptor tray to the maximum size of image recording material used.

5) Calculate the difference between the calculated size of the radiation field and the maximum size of image recording material used along the axis parallel and adjacent to the chest. Compare the difference to 2 per cent of the target-to-image receptor distance.

ACCEPTANCE CRITERION

1) The radiation field shall not exceed the edge of the image receptor next to the chest wall by more than 2 per cent of the target-to-image receptor distance and shall not extend beyond any other edge of the image receptor.

15) Beam limiting device for use with only one size of image receptor and a fixed target-to-image receptor distance

APPLICABILITY

This test applies to all radiographic x-ray equipment using only one size of image receptor and a fixed target-to-image receptor distance. The test results will be used to evaluate both the beam limiting device coverage and the alignment of the centre of the radiation field with the image receptor.[XII 10.(a),(b)]

ITEM REQUIRED

a) Image recording material normally used.

PROCEDURE

1) Place the normally used image recording material in the image receptor support device (cassette tray).

2) Align the x-ray tube with the image receptor.

3) Measure and record the target-to-image receptor distance.

4) Set suitable loading factors on the control panel and make an irradiation.

5) Process the image recording material according to the manufacturer's recommendations.

DATA COMPUTATION

1) Using the image recording material from the cassette tray draw in the diagonals of the image recording material to determine the centre of the image receptor.

2) Using the image recording material from the cassette tray draw in the diagonals of the recorded image to determine the centre of the radiation field.

3) Calculate 2 per cent of the target-to-image receptor distance.

4) Measure the distance between the centre of the image recording material and the centre of the recorded image. Compare the measured distance to 2 per cent of the target-to-image receptor distance.

ACCEPTANCE CRITERIA

1) The centre of the radiation field must be aligned with the centre of the image receptor to within 2 per cent of the target-to-image receptor distance.

2) The radiation field in the plane of the image receptor must not extend beyond any edge of the image receptor.

Note: If the radiation field extends beyond the edge of the image receptor the full size of the coverage should be determined. With this information the surveyor can detect whether the tube and cassette are misaligned and determine the degree of hazard involved.

16A) Maximum fluoroscopic exposure rate at the table top for under-table x-ray tubes

APPLICABILITY

This test applies to all under-table x-ray tubes operating in fluoroscopic mode and the results will be used to determine the exposure rate at the table top. [XII 19.(f)(i)(A),(B)(ii)(A),(B)]

ITEMS REQUIRED

a) An exposure rate meter.

b) Lead sheets of sufficient thickness to block the whole of the image intensifier input area. The minimum lead thickness should be 3.2 mm.

c) A means to support the lead above the sensitive volume of the exposure rate meter.

PROCEDURE

1) Place the sensitive volume of the exposure rate meter on the table top.

2) Measure and record the distance from the sensitive volume to the table top.

3) Set suitable loading factors on the control panel.

4) Using fluoroscopy, centre the image intensifier over the sensitive volume of the exposure rate meter. Adjust the beam limiting device so that the sensitive volume is encompassed within the radiation beam. The radiation field must not extend beyond the sheets of lead when they are placed in the radiation beam. Lock the image intensifier in place.

   For manually set loading factors follow steps 5,6,7 and 10. For automatic exposure control follow steps 8,9 and 10.

5) Protect the image intensifier by placing sufficient sheets of lead on the support between the sensitive volume and the image intensifier.

6) Using manual loading factors, where provided, set the maximum tube current and x-ray tube voltage.

7) Using fluoroscopy make an irradiation and record the exposure rate.

8) To protect the image intensifier and obtain the highest exposure rate when using automatic exposure control loading factors, where provided, place sufficient lead sheets between the sensitive volume and the image intensifier.

9) Using fluoroscopy make an irradiation using automatic exposure control loading factors and record the maximum exposure rate.

10) When a means is provided to optimize the image by increasing the exposure rate, measure the exposure rate at the table top using the high level control and the magnified mode.

DATA COMPUTATION

1) Using the target-to-table top distance calculated in test 13A and the inverse square law, calculate the exposure rate at the table top for the measurements taken.

ACCEPTANCE CRITERIA

1) At the shortest target-to-skin distance specified for the equipment, no combination of x-ray tube voltage and current shall result in an exposure rate of:

   i) for manual systems,
      (A) 5 roentgen per minute except during the recording of fluoroscopic images, or
      (B) where an optional high level control is provided, 10 roentgen per minute with the high level control activated,

   ii) for automatic exposure rate control,
      (A) 10 roentgen per minute except during the recording of fluoroscopic images, or
      (B) where an optional high level control is provided, 5 roentgen per minute unless the high level is activated.

16B) Maximum fluoroscopic exposure rate at 30 cm above the table top for over-table x-ray tubes

APPLICABILITY

This test applies to all over-table x-ray tubes operating in fluoroscopic mode. The results will be used to determine the exposure rate at 30 cm above the table top. The regulation stipulates that the limits shall not be exceeded at the point where the radiation beam axis enters the patient. Therefore, 30 cm was selected to represent a large patient. [XII 19.(f)(i)(A),(B)(ii)(A),(B)]

ITEMS REQUIRED

a) An exposure rate meter.

b) Lead sheets of sufficient thickness to block the whole of the image intensifier input area. The minimum lead thickness should be 3.2 mm.

c) A means to support the sensitive volume of the exposure rate meter 30 cm above the table.

PROCEDURE

1) Place the sensitive volume of the exposure rate meter 30 cm above the table top using the support.

2) Set suitable loading factors on the control panel.

3) Adjust the x-ray tube to the minimum height above the table at which fluoroscopy can be performed.

4) Using fluoroscopy, centre the image intensifier under the sensitive volume of the exposure rate meter. Adjust the beam limiting device so that the sensitive volume is encompassed within the radiation beam and lock the image intensifier in place.

   For manually set loading factors follow steps 5,6,7 and 10. For automatic exposure control follow steps 8,9 and 10.

5) Protect the image intensifier by placing sufficient sheets of lead on the table top between the sensitive volume and the image intensifier.

6) Using manual loading factors, where provided, set the maximum tube current and x-ray tube voltage.

7) Using fluoroscopy make an irradiation and record the exposure rate.

8) To protect the image intensifier and obtain the highest exposure rate when using automatic exposure control loading factors, where provided, place sufficient lead between the sensitive volume and the image intensifier.

9) Using fluoroscopy make an irradiation and record the maximum exposure rate.

10) When a means is provided to optimize the image by increasing the exposure rate, measure the exposure rate at 30 cm above the table using the high level control and magnified mode.

DATA COMPUTATION

1) Where it was not possible to measure the exposure rate at the correct distance above the table top use the inverse square law to calculate the exposure rate at 30 cm above the table top for the measurements taken.

ACCEPTANCE CRITERIA

1) At the shortest target-to-skin distance specified for the equipment, no combination of x-ray tube voltage and current shall result in an exposure rate of:

   i) for manual systems,
      (A) 5 roentgen per minute except during the recording of fluoroscopic images, or
      (B) where an optional high level control is provided, 10 roentgen per minute with the high level control activated,

   ii) for automatic exposure rate control,
      (A) 10 roentgen per minute except during the recording of fluoroscopic images, or
      (B) where an optional high level control is provided, 5 roentgen per minute unless the high level is activated.

17A) Spot film device for under-table x-ray tubes

APPLICABILITY

This test applies to all units which have spot film devices. The automatic collimation of the radiation beam, size and misalignment of the field are checked.[XII 13.(a)(c)]

ITEM REQUIRED

a) Two image recording materials.

PROCEDURE

1) Lock the image intensifier tower in place.

2) Place one of the image recording materials in the spot film device.

3) Using fluoroscopy adjust the beam limiting device to a suitable size so that the radiation field is greater than the portion of the image receptor selected on the spot film selector.

4) Place the other image recording material on the table top. The set-up is shown in Figure 5.

5) Measure and record the distance from the table top to the image recording material in the spot film device.

6) Set loading factors on the control panel.

7) On the spot film selector choose four views on one image receptor. (There must not be any diaphragms, cones or beam limiting devices between the image recording material in the spot film device and the image recording material on the table top.)

8) Make an irradiation.

9) Advance the spot film selector to the quadrant of the image receptor diametrically opposite the first irradiation.

10) Make another irradiation.

11) Process the two image recording materials according to the manufacturer's recommendations.

DATA COMPUTATION

1) Measure and record the size of the image which was on the table top.

2) Using similar triangles, that is, the formula shown below, calculate the size of the radiation field at the spot film device. (Calculate the distance from the table top to the x-ray tube using test 13A.)

3) Compare the calculated size of the radiation field to the size of that portion of the image receptor selected on the spot film device. Calculate the difference between the calculated size of the radiation field and the size of that portion of the image receptor on the spot film device.

4) Calculate 3 and 4 per cent of the target-to-image receptor distance at the spot film device.

5) Compare the difference between the length or width of the calculated size of the radiation field and the length or width of that portion of the image receptor selected on the spot film device to 3 per cent of the target-to-image receptor distance at the spot film device.

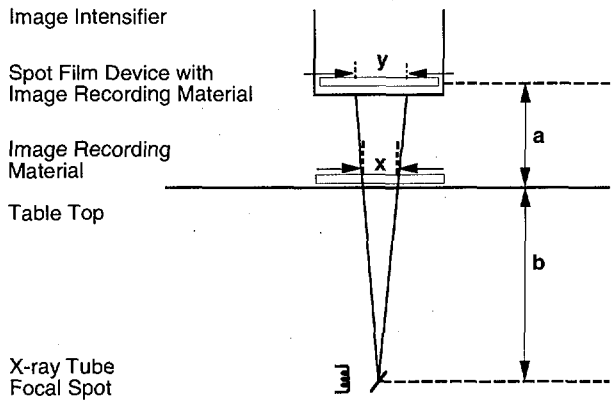
6) Compare the difference between the sum of the length and width of the calculated size of the radiation field and the sum of the length and width of that portion of the image receptor selected on the spot film device selector to 4 per cent of the target-to-image receptor distance at the spot film device.

ACCEPTANCE CRITERIA

1) The size of the radiation field, in the plane of the image receptor, must automatically adjust to the size of that portion of the image receptor selected on the spot film device selector, except where that field is smaller than that of the selected portion of image receptor.

2) Misalignment of the edges of the radiation field with that portion of the image receptor selected, along the length or width, must not exceed 3 per cent of the target-to-image receptor distance. The misalignment along any two orthogonal dimensions shall not exceed 4 per cent of the target-to-image receptor distance.

Figure 5: Determination of Field Size at the Spot Film Device



$$y = \frac{x(a + b)}{b}$$

17B) Spot film device for over-table x-ray tubes

APPLICABILITY

This test applies to all units which have spot film devices. The automatic collimation of the radiation beam, the size and misalignment of the radiation field are checked. [XII 13.(a)(c)]

ITEMS REQUIRED

a) Two image recording materials.

b) A means to support one of the image recording materials above the table.

PROCEDURE

1) Lock the x-ray tube in place.

2) Place one of the image recording materials in the spot film device.

3) Using fluoroscopy adjust the beam limiting device to a suitable size so that the radiation field is greater than the portion of the image receptor selected on the spot film device selector.

4) Support the other image recording material above the table top.

5) Measure and record the distance from the focal spot of the x-ray tube to the image recording material in the spot film device. Also, measure the distance from the focal spot of the x-ray tube to the image recording material supported above the table top.

6) Set suitable loading factors on the control panel.

7) On the spot film device selector choose four views on one image receptor. (There must not be any diaphragms, cones or beam limiting devices between the image recording material in the spot film device and the image recording material supported above the table top.)

8) Make an irradiation.

9) Advance the spot film device selector to the quadrant of the image receptor diametrically opposite the first irradiation.

10) Make another irradiation.

11) Process the two image recording materials according to the manufacturer's recommendations.

DATA COMPUTATION

1) Measure and record the size of the image on the image recording material supported above the table top.

2) Using similar triangles calculate the size of the radiation field at the spot film device. (Calculate the distance from the x-ray tube to the spot film device using test 13B.)

3) Compare the calculated size of the radiation field to the size of that portion of the image receptor selected on the spot film device. Calculate the difference between the calculated size of the radiation field and the size of that portion of the image receptor selected on the spot film device.

4) Calculate 3 and 4 per cent of the target-to-image receptor distance.

5) Compare the difference between the length or width of both the calculated size of the radiation field and that portion of the image receptor selected on the spot film device to 3 per cent of the target-to-image receptor distance.

6) Compare the difference between the sum of the length and width of both the calculated size of the radiation field and that portion of the image receptor selected on the spot film device selector to 4 per cent of the target-to-image receptor distance.

ACCEPTANCE CRITERIA

1) The size of the radiation field in the plane of the image receptor must be automatically adjusted to the size of that portion of the image receptor selected on the spot film device selector, except where that field is smaller than that of the selected portion of the image receptor.

2) Misalignment of the edges of the radiation field with that portion of the image receptor selected, along the length or width, must not exceed 3 per cent of the target-to-image receptor distance. Also, the misalignment along any two orthogonal dimensions shall not exceed 4 per cent of the target-to-image receptor distance.

18A) Beam limiting device for under-table fluoroscopic x-ray tubes.

APPLICABILITY

This test applies to all units which have fluoroscopic capability. The test results will allow the length and width of the radiation field at the input phosphor of the image intensifier to be calculated. [XII 15.(f)]

ITEMS REQUIRED

a) Image recording material.

b) Lead sheets of sufficient thickness to block the whole of the image intensifier input area. The minimum lead thickness should be 3.2 mm.

c) A means to support the lead above the image recording material.

PROCEDURE

1) From the manufacturer's information, find and record the size of the image intensifier input phosphor.

2) Lower the image intensifier tower to the lowest level and adjust the beam limiting device to its maximum aperture.

3) Measure and record the distance from the table top to the image intensifier input phosphor. The set-up is shown in Figure 6.

4) Protect the image intensifier by placing sufficient sheets of lead on the support between the table top and the image intensifier.

5) Place the image recording material on the table top.

6) Set suitable loading factors on the control panel. Using fluoroscopy make an irradiation.

7) Repeat the test at different heights of the image intensifier tower above the table top with a separate image recording material for each height above the table top.

8) Process the image recording materials according to the manufacturer's recommendation.

DATA COMPUTATION

1) Measure and record the size of each image.

2) For each of the distances checked calculate and record 3 and 4 per cent of the target-to-input phosphor distance.

3) Using similar triangles, that is, the formula shown below, calculate and record the length and width of the radiation field at the input phosphor of the image intensifier. Compare the calculated field size to the length and width of the recorded size of the image intensifier input phosphor. (Calculate the distance from the table top to the x-ray tube using test 13A.)

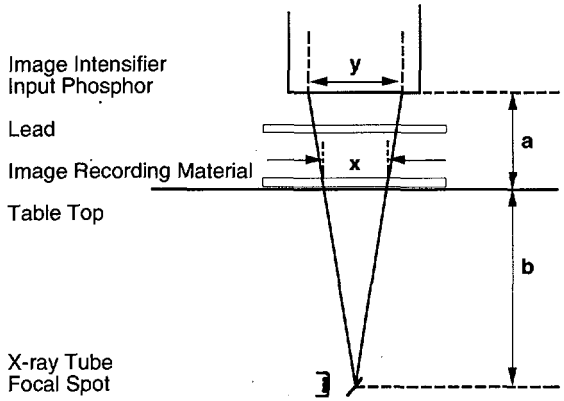
4) Compare the difference between the length and width of both the calculated size of the radiation field and the input phosphor to 3 per cent of the target-to-input phosphor distance.

5) Compare the difference between the sum of the length and width of both the calculated radiation field and the input phosphor to 4 per cent of the target-to-input phosphor distance.

ACCEPTANCE CRITERION

1) All fluoroscopic equipment shall have positive field limitation. The misalignment of the edges of the radiation field shall not exceed 3 per cent of the target-to-input phosphor distance. Also, the sum of the excess length and width shall not exceed 4 per cent of the target-to-image receptor distance.

Figure 6: Determination of Fluoroscopic Field Size at the Image Intensifier



$$y = \frac{x(a+b)}{b}$$

18B) Beam limiting device for over-table fluoroscopic x-ray tubes

APPLICABILITY

This test applies to all units which have fluoroscopic capability. The test results will allow the length and width of the radiation field at the input phosphor to be calculated. [XII 15.(f)]

ITEMS REQUIRED

a) Image recording material.

b) Lead sheets of sufficient thickness to block the whole of the image intensifier input area. The minimum lead thickness should be 3.2 mm.

PROCEDURE

1) From the manufacturer's information find and record the size of the image intensifier input phosphor.

2) Lower the x-ray tube to the lowest level and adjust the beam limiting device to its maximum aperture.

3) Measure and record the distance from the x-ray tube focal spot to the image intensifier input phosphor.

4) Protect the image intensifier by placing sufficient sheets of lead on the table top.

5) Place the image recording material on the sheets of lead on the table top.

6) Measure and record the distance from the x-ray tube focal spot to the image recording material.

7) Set suitable loading factors on the control panel. Using fluoroscopy make an irradiation.

8) Repeat the test at different heights of the x-ray tube above the table top with a separate image recording material for each height used.

9) Process the image recording materials according to the manufacturer's recommendation.

DATA COMPUTATION

1) Measure and record the size of each image.

2) For each of the distances checked calculate and record 3 and 4 per cent of the target-to-input phosphor distance.

3) Using similar triangles, calculate and record the size of the length and width of the radiation field at the input phosphor of the image intensifier. Compare the calculated size of the length and width to the recorded size of the image intensifier input phosphor.

4) Compare the difference between the length and width of both the calculated size of the radiation field size and the input phosphor to 3 per cent of the target-to-input phosphor distance.

5) Compare the difference between the sum of the length and width of both the radiation field size and the input phosphor to 4 per cent of the target-to-input phosphor distance.

ACCEPTANCE CRITERION

1) All fluoroscopic x-ray equipment shall have positive field limitation. The misalignment of the edges of the radiation field shall not exceed 3 per cent of the target-to-input phosphor distance. Also, the sum of the excess length and width shall not exceed 4 per cent of the target-to-input phosphor distance.

19) Image intensifier and shielding interlocks for fluoroscopic under-table x-ray tubes

APPLICABILITY

This test applies to all fluoroscopic x-ray equipment with under-table tubes. The measurements recorded will be used to ascertain whether or not the radiation beam protective shielding interlock will prevent an irradiation. [15.(a)(i)(c)]

ITEMS REQUIRED

a) An exposure rate meter.

b) Lead sheets of sufficient thickness to block the whole of the image intensifier input area. The minimum lead thickness should be 3.2 mm.

c) A means to support the lead above the sensitive volume of the exposure rate meter.

PROCEDURE

1) Place the sensitive volume of the exposure rate meter on the table top.

2) Set suitable loading factors on the control panel.

3) Using fluoroscopy, position the fluoroscopic tower at the farthest transverse position from the front of the table. Place the sensitive volume of the exposure rate meter in the radiation beam. Adjust the beam limiting device so that the sensitive volume is encompassed within the radiation beam. Lock the image intensifier in place.

4) Protect the image intensifier by placing sufficient sheets of lead on the support between the sensitive volume and the image intensifier.

5) Using fluoroscopy make an irradiation and ensure there is a reading on the exposure rate meter. The actual reading is not important.

6) Where possible, remove the image intensifier from the fluoroscopic tower.

7) Before making the next irradiation place the irradiation switch as far away from the table as possible. Momentarily activate the irradiation switch, check and record whether or not there is any reading on the exposure rate meter.

8) Where necessary place the image intensifier on the fluoroscopic tower and move the fluoroscopic tower from over the table without changing the relative positions of the x-ray tube and the sensitive volume of the exposure rate meter.

9) Momentarily activate the irradiation switch, check and record whether or not there is any reading on the exposure rate meter.

ACCEPTANCE CRITERION

1) All fluoroscopic x-ray equipment shall be designed and constructed to include an image intensification system that includes a shielded protective barrier and shielding. The x-ray tube used for fluoroscopy shall not produce x-radiation unless the shielding is in place to intercept the radiation beam. The exposure rate meter should indicate that the tube has not been activated in either step 7 or 9.

4.3 Facility testing

Facility testing is intended to determine whether the operator is providing the optimum service possible at that facility and if not, to make appropriate recommendations. It involves reviewing patient positioning, collimation, film processing, and availability of protective devices at the facility. A questionnaire is shown below and the analysis of the answers to the questions will allow the surveyor to draw conclusions and make recommendations as necessary. Every effort must be made to ensure that the operator uses the optimum loading factors to produce a diagnostic radiogram of high quality for interpretation by the physician. In most cases, the use of the optimum loading factors means the lowest surface dose to the patient. This inevitably results in the lowest surface dose to both the operator and other health care personnel.

Image recording and processing

Film

Which film brand is used?_____
How are the films stored?_____
What is the expiry date of the films?_____
Other film used?_____

Cassettes and screens

Name and model of cassette_____
Name and model of intensifying screen_____
What is the system speed?_____
What is the date of the screens installation?_____
Are the cassettes in good condition?_____
Are the intensifying screens in good condition?_____
Are the film and intensifying screens compatible?_____
Are screen contact tests done?_____

Processing

Type of processing: Manual or automatic?_____
If automatic: name of manufacturer_____
name of model_____
Is the processor in good condition?_____
Is the processor cleaned on a regular basis?_____
Are the processor rollers in good condition?_____
Are the tanks clean?_____
Is there a maintenance program for the processor?_____

Is there a timer?_____
Is there a thermometer?_____
Is the manufacturer's time/temperature chart followed?_____
Is there a quality control program for the film processor?_____
If yes, identify the tests done _____
_____
_____
_____

Is there a silver recovery unit?_____
Solutions used _____
Do the solutions appear fresh and clear?_____
Developer brand _____
Fixer brand _____
How often is the chemistry changed?_____
What is the developer temperature?_____
How many seconds/minutes is the film in the developer?_____
How long is the automatic film processing cycle?_____
What are the replenishment rates? Developer _____
Fixer _____

Darkroom

Is the dark room light tight?_____
Is the film processing area clean?_____

Safelighting

Is the safelight on the ____wall ____bench ____ceiling ?
Filter model _____
Is the safelight bulb of the correct wattage?____ watts
Is the safelight compatible with the film in use?_____
Is the safelight in good condition?_____

X-ray room

Is the x-ray room well maintained?_____
Do the walls and doors appear to provide sufficient shielding?_____

Loading factors and control

Are suitable loading factor charts used?_____
Is there a procedure manual of views to be taken?_____
Is the base fog acceptable? Heat _____ Age _____
Chemical _____ Light _____

Operator protection

Is the B.R.P. or other dosimetry service used? _____

Are the dosimetry records available? _____

Are there any unusual readings? _____

Is there protective equipment available? _____

Protective barrier _____ 3m distance from the source _____

Lead screen _____ Lead aprons _____ Lead gloves _____

Is the protective equipment adequate? _____

Protection of other personnel

Are the x-ray room doors closed during operation? _____

Are only authorized personnel allowed in the x-ray room? _____

Patient protection

Is patient protective equipment available? _____

Lead apron _____ Lead strip _____ Thyroid shield _____

Is the protective equipment adequate? _____

Is the protective equipment checked for defects? _____

Are positioning and restraining devices available? _____

Is the pregnancy status of the patient questioned? _____

Quality control

Is there an equipment preventive maintenance program? _____

By whom? _____

Tests done? _____

How often? _____

Does the facility have a quality control program for the x-ray equipment? _____

If yes, identify the tests conducted. _____

_____

_____

_____

4.4 Verification of the adequacy of the shielding

When x-ray equipment is first installed, a radiation survey of all areas (the operator's controlled area, the control panel area and various areas outside the x-ray room) must be conducted. This will determine whether or not the operator and other persons are likely to receive more than the permissible equivalent dose limits as specified in APPENDIX II of this guide. Section 5 of Safety Code 20A[8] should be reviewed and the recommendations implemented.

ITEMS REQUIRED

a) An integrating exposure meter with a sensitive volume suitable for detecting x-radiation transmission through primary and secondary protective barriers.

b) A phantom of suitable density, such as 30 cm of water or tissue equivalent material, which when irradiated will produce an adequate amount of scattered radiation to simulate actual and worst case conditions in the x-ray room.

PROCEDURE

1) Centre the x-ray tube over the tissue equivalent material and adjust the beam limiting device (where applicable) to its maximum aperture.

2) Select suitable loading factors on the control panel and record the settings. This should include the maximum x-ray tube voltage used by the operator.

3) Place the sensitive volume of the exposure meter behind appropriate protective barriers such as :
   in the control booth,
   at the operator's normal position for making an irradiation, and,
   at various locations outside of the x-ray room, for example in adjacent rooms, halls, washrooms and any other areas which may be occupied by personnel or members of the public from time to time.

[8] Safety Code 20A, X-ray Equipment in Medical Diagnosis, Part A: Recommended safety procedures for installation and use.

4) At each of the locations selected make several irradiations and record the exposure measurements.

5) Point the x-ray tube at selected protective barriers for areas such as those listed in step 3 and adjust the beam limiting device to the largest field size.

6) Position the sensitive volume of the exposure meter in the radiation beam with the protective barrier to be assessed between the x-ray tube and the sensitive volume. Measure the distance from the focal spot of the x-ray tube to the sensitive volume.

7) Make several irradiations and record the exposure measurements.

8) Without a protective barrier to attenuate the radiation beam, position the sensitive volume of the exposure meter in the radiation beam and adjust the beam limiting device to larger than the sensitive volume.

9) Measure and record the distance from the focal spot of the x-ray tube to the sensitive volume.

10) Make several irradiations using the same loading factors as step 7 and record the exposure measurements.

11) Obtain the weekly workload data from the operator.

DATA COMPUTATION

1) Calculate the weekly workload.

2) Using the inverse square law, calculate the exposure corrected to the same distance from the focal spot as the radiation beam attenuated by the protective barrier.

3) Calculate the ratio of the attenuated radiation beam to the radiation beam to determine the transmission factor of the protective barrier for each of the locations checked.

4) Using the weekly workload, the loading factors used to determine the measurements and the measured exposures calculate the weekly exposure for scattered and leakage radiation for all the locations checked.

5) Using the transmission factor of the radiation beam through the protective barrier, the weekly workload and the loading factors used to determine the measurements calculate the exposure behind each of the barriers checked.

ACCEPTANCE CRITERIA

1) For occupational workers the dose equivalent must not exceed 0.4 millisievert per week or 20 millisievert per year.

2) For non-occupational workers the dose equivalent must not exceed 0.02 millisievert per week or 1 millisievert per year.

APPENDIX I

Survey Equipment

This appendix provides a list of the survey equipment currently used by the X-ray Section of the Bureau of Radiation Protection*.

1) The Center for Devices and Radiological Health test stand with aluminum filters (1100 Alloy), metal markers, lead diaphragm, focal spot test tool and image recording material holder.

2) Radcal MDH 1015 with 6 cm^3 chamber and 180 cm^3 chamber.

3) R.M.I. Model 230 kilovoltage meter calibrated to an x-ray tube voltage measurement device.

4) Optikon Model ANA-999 lux meter.

5) Cardboard cassette.

6) Kodak Linagraph paper, direct print, type 1895.

7) Victoreen digital thermometer Model 07-402.

8) Tape measure.

**Disclaimer*

Any mention of commercial products or their use in this document is not intended to be construed as either an actual or implied endorsement of such products by the Bureau of Radiation Protection.

APPENDIX II

Recommended Dose Limits of X-Radiation to Operators and Other Occupationally Exposed Personnel

For the purpose of radiation protection, individuals may be classified in one of two categories: those exposed to radiation from man-made sources during the course of their work (radiation workers), and others. Maximum permissible levels are given for both categories in the following table. These equivalent dose limits are based on the latest recommendations of the International Commission on Radiological Protection (ICRP) as specified in ICRP Publication 60.

It *must* be noted that the permissible equivalent dose limits for radiation workers apply only to irradiation resulting directly from their occupation and do not include irradiation from other sources, such as medical diagnosis and background radiation.

Applicable Body Organ or Tissue	Annual Recommended Dose Limits	
	Radiation Workers	Other workers and members of the public
Whole body	20 mSv	1 mSv
Lens of the eye	150 mSv	15 mSv
Skin	500 mSv	50 mSv
Hands	500 mSv	50 mSv

Notes:

1. It is emphasized that any irradiation may involve some degree of risk and although the levels recommended in this Appendix are maximum permitted values, all doses *should* be kept as low as reasonably achievable and any unnecessary irradiations *must* be avoided.

2. ICRP does not recommend discrimination in the dose limits between men and women of reproductive capacity, if the dose is received at an approximately regular rate.

3. For occupationally exposed women, once pregnancy has been declared, the conceptus *should* be protected from external irradiation by setting an equivalent dose limit of 2 mSv to the surface of the abdomen for the remainder of the pregnancy.

4. For operators-in-training and students, equivalent dose limits for members of the general public *should* apply.

5. ICRP does not recommend different limits for individual organs. For occupationally exposed workers, ICRP believes that deterministic effects will be prevented by applying an equivalent dose limit of 500 mSv in a year to all tissues except the lens of the eye, for which it recommends a limit of 150 mSv in a year.

6. For the skin, the equivalent dose is averaged over its whole area. In situations where deterministic effects are possible, the recommended equivalent dose limit for the skin is 500 mSv and is averaged over areas of no more than 1 cm^2. This limit applies to the skin of the face and the hands.

7. ICRP limits allow, in special circumstances, a higher value of effective dose than is allowed in a one year period, as long as the average dose over a five year period is not greater than the annual limit. This higher value is 50 mSv for occupationally exposed personnel.

APPENDIX III

Agencies Responsible for Radiation Safety of X-Ray Facilities

ALBERTA

Radiation Health Services
Occupational Health & Safety
Division of Policy and Professional Services
4th Floor, Donsdale Place
10709 Jasper Avenue
Edmonton, Alberta
T5J 3N3

Tel: (403) 427-2691
FAX: (403) 427-3410

BRITISH COLUMBIA

Radiation Protection Service
Ministry of Health
Government of British Colombia
Suite 210
4940 Canada Way
Vancouver, British Columbia
V5G 4K6

Tel: (604) 660-6630
FAX: (604) 660-6663

MANITOBA

Radiation Protection Section
Manitoba Cancer Foundation
100 Olivia Street
Winnipeg, Manitoba
R3E 0V9

Tel: (204) 787-2211
FAX: (204) 783-1875

NEW BRUNSWICK

Radiation Protection Services
Department of Health and
Community Services
2nd Floor, Carleton Place
King Street
P.O. Box 5100
Fredericton, New Brunswick
E3B 5G8

Tel: (506) 453-2360
FAX: (506) 453-2626

NEWFOUNDLAND

Medical and Hygiene Services
Employment and Labour Relations
Fall River Plaza
270 Torbay Road
P.O. Box 8700
St. John's, Newfoundland
A1B 4J6

Tel: (709) 729-2644
FAX: (709) 729-2142

NORTH WEST TERRITORIES

Occupational Health and Safety Division
Safety and Public Services
Government of the Northwest Territories
Box 1320,
Yellowknife, N.W.T.
X1A 2L9

Tel: (403) 873-7468
FAX: (403) 873-0117

NOVA SCOTIA

Department of Health and Fitness
7th Floor, Joseph Howe Building
P.O. Box 488
Halifax, Nova Scotia
B3J 2R8

Tel: (902) 424-4077
FAX: (902) 424-0558

ONTARIO

X-Ray Inspection Service
Ontario Ministry of Health
7 Overlea Boulevard, 6th Floor
Toronto, Ontario
M4H 1A8

Tel: (416) 963-1035
FAX: (416) 963-2688

Radiation Protection Service
Ontario Ministry of Labour
81 Resources Road
Weston, Ontario
M9P 3T1

Tel: (416) 235-5922
FAX: (416) 235-5926

PRINCE EDWARD ISLAND

Environmental Health Division
Department of Health and Social Services
P.O. Box 2000
Charlottetown, Prince Edward Island
C1A 7N8

Tel: (902) 368-4970
FAX: (902) 368-5544

QUEBEC

Contrôle de la qualité
Ministère de la Santé et des
Services sociaux
1075, chemin Ste-Foy, 10e étage
Québec, (Québec)
G1S 2M1

Tel: (418) 643-7061
FAX:(418) 643-9024

Service de Radioprotection
Ministère de l'Environnement
Gouvernement du Québec
Suite 3860
5199 est, rue Sherbrooke
Montréal, Québec
H1T 3X9

Tel: (514) 873-1978
FAX: (514) 873-5662

SASKATCHEWAN

Radiation Safety Unit
Department of Human Resources,
Labour and Employment
Saskatchewan Place
1870 Albert Street
Regina, Saskatchewan
S4P 3V7

Tel: (306) 787-4486
FAX: (306) 787-2208

YUKON

Occupational Health and Safety
Government of the Yukon Territory
P.O. Box 2703
Whitehorse, Yukon
Y1A 2C6

Tel: (403) 667-3424
FAX: (403) 667-3609

CANADA

Health Canada
Bureau of Radiation Protection
X-ray section
775 Brookfield Road
Ottawa, Ontario
K1A 1C1

Tel: (613) 954-0320
FAX: (613) 941-1734

APPENDIX IV

Survey forms used by the X-ray Section of the Bureau of Radiation Protection.

GENERAL REQUIREMENT STANDARDS
DIAGNOSTIC MEDICAL X-RAY EQUIPMENT

Facility :_____ **Inspector :**_____ **Date :** __/__/__

INSTRUMENTS USED:

X-ray monitor: MDH 1015 S/N: _____ Pressure setting: _____
Chambers: 10x5-6 _____
10x5-180 _____
Others: RMI 230 _____ S/N: _____
Optikon ANA 999 _____

Type of unit: ☐ Radiographic ☐ Stationary
☐ Fluoroscopic ☐ Mobile

1. IDENTIFICATION:

a. Is control panel correctly labelled? ☐ Y ☐ N
(1) Manufacturer: _____
(2) Model : _____
(3) Serial No: _____
(4) Country of Manufacture: _____
(5) Date (Y/M/D): _____

2. STANDARDS OF DESIGN & CONSTRUCTION:

a. Are required manuals available ☐ Y ☐ N

b. Does x-radiation warning symbol meet standards? ☐ Y ☐ N

c. Does warning sign on panel meet standards? ☐ Y ☐ N

CAUTION X-RAYS
WARNING
X-rays are emitted when this control panel is energized and the exposure switch is activated. Unauthorized use is prohibited.

ATTENTION RAYONS X
MISE EN GARDE
Cet appareil produit des rayons x lorsque le tableau de commande est allumé et que l'interrupteur d'exposition est activé. L'utilisation sans autorisation est interdite.

d. Do controls, meters, lights, etc. meet standards? ☐ Y ☐ N
___ In clear view of operator.
___ Readily discernible.
___ Clearly labelled as to function.

e. Does multiple-tube unit meet standards? ☐ Y ☐ N
___ Only one tube operated at a time.
___ Tube selection indicated on main control panel and "READY" clearly visible on or near the tube housing.

f. Does main control panel meet standards? ☐ Y ☐ N
___ Distinct "READY" light.
___ Distinct irradiation "ON" light.
___ Radiographic loading factors indicated before irradiation.
kVp range: _____
mA(s) range: _____, time range: _____
___ Non-auto fluoro loading factors indicated before irradiation.
kVp range: _____, mA range:
___ Battery status indicator (battery powered generators only)

g. Do hand operated irradiation switches meet standards? ☐ Y ☐ N
___ Require continuous pressure.
___ Can only be operated in protected area. (Stationary only).
___ Irradiation switch cable is at least 3 metres long. (Mobile only).

h. Do foot operated irradiation switches meet standards? ☐ Y ☐ N

___ Require continuous pressure.

___ Cannot cause unintentional irradiations.

REMARKS (list by item):

Item: _____

RADIOGRAPHIC MODE OPERATED UNIT
DIAGNOSTIC MEDICAL X-RAY EQUIPMENT

Facility :_____ **Inspector :**_____ **Date :** __/__/__

1. IDENTIFICATION:

a. X-ray source assembly no:_____ ; (one survey form per tube)

b. Is x-ray tube housing correctly labelled? ☐Y ☐N

	Housing	Insert
(1) Manufacturer:		
(2) Model :		
(3) Serial No:		
(4) Country of Manufacture:		
(5) Date (Y/M/D):		

2. STANDARDS OF DESIGN AND CONSTRUCTION:

a. Can x-ray focal spot(s) be located? ☐Y ☐N

b. Can x-ray tube polarity be determined? ☐Y ☐N

c. Does tube housing assembly permanent beam filtration labelling meet standards? ☐Y ☐N
Record exactly as shown if not correct: _____

d. Does stability of x-ray tube support system meet standards? ☐Y ☐N
(1) Type:_____
(2) Identify if not compliant:_____

3. STANDARDS OF FUNCTIONING:

a. Timing device (manually set):
(1) Does exposure reproducibility meet standards? ☐Y ☐N

	kVp	1	2	3	4	5	6	7	8	9	10	m.d.	CofV
Exp													
Time													
Exp													
Time													

(2) Does timing device meet accuracy standards? ☐Y ☐N

kVp	mA	Sel. time	Meas. time	Exposure	% Error

(3) Does timing device performance meet standards? ☐Y ☐N

___ Automatically terminates irradiation.

___ Automatically resets to original loading time when irradiation is terminated by the timing device or operator and irradiation switch release required to repeat an irradiation.

___ Meets minimum loading time requirements (___).

___ Irradiation blocked if timing device can be switched OFF.

___ All loading time positions are identified (marked).

___ Loading factor charts provided for unit with arbitrary (anatomical) settings.

___ Subsequent irradiation times unaffected when previous irradiation terminated by timing device, operator or power interruption.

b. Automatic Exposure Control (AEC):

(1) Does AEC timing device meet reproducibility standards? ☐Y ☐N

___ Chest stand

___ Table

	kVp	1	2	3	4	5	6	7	8	9	10	m.d.	CofV
Exp													
Time													
Exp													
Time													

(2) Does AEC timing device performance meet standards? ☐Y ☐N

___ Automatically terminates irradiation.

___ Irradiation terminated when irradiation switch released.

___ No irradiation when there is a "0", "OFF", "BLANK" position.

___ Indication of selection on main control panel.

___ Meets minimum irradiation time requirements (___).

(3) Does AEC have a BACK-UP timing device which meets standards? ☐Y ☐N

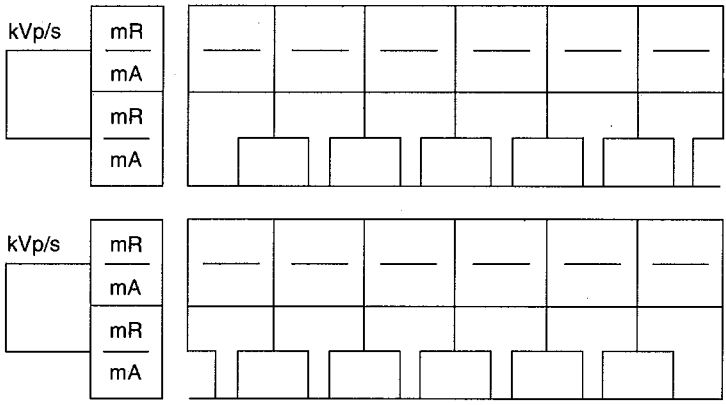
___ Requires manual reset.

___ Light on main control panel indicates activation.

___ Irradiation interrupted: 600mAs or 60,000 HU (kVp x mA x s)

c. Does exposure/milliamperage linearity meet standards? ☐Y ☐N

Note: Omit if reproducibility deviates by more than 15%.



d. Does x-ray tube voltage (kVp) meet standards? ☐Y ☐N

mA												
kVp	RMI	corr	%err	RMI	corr	%err	RMI	corr	%err	RMI	corr	%err
60												
80												
100												
120												

4. RADIATION BEAM FILTRATION:

a. *Does radiation beam filtration meet standards?* ☐Y ☐N

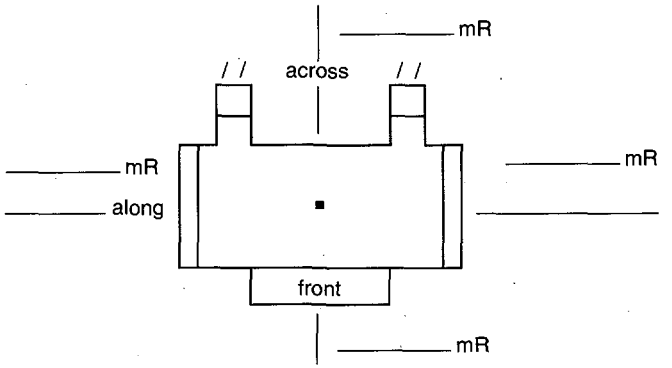
b. Do parasitic attenuators meet standards? ☐Y ☐N
(Test at 100 kVp)

Aluminum (mm)	0.0	0.5	1.5	2.5	3.5	4.5	0.0	HVL	att.
set kVp meas									

Identify attenuators: _____

5. LEAKAGE MEASUREMENTS:

a. Can x-ray tube voltage exceed 50 kVp? if YES; ☐Y ☐N
(1) factors: ___kVp(max.) at ___mAs = ___ mR at 1.0 m
(2) indicate levels:



(3) Is location and extent verified? ☐Y ☐N

b. Is unit specifically designed for mammography? ☐Y ☐N
If YES;
(1) Does it meet standards? ☐Y ☐N
(2) Tube leakage:
___mR/hr at 5cm(___kVp, ___mAs)
max
(3) Beam transmission:
___mR/exp. at ___kVp(max),
___mAs at ___cm(min).

c. Is unit capacitor discharge? If YES: ☐Y ☐N
(1) Does it meet standards?
(2) Charging time: ___, discharging time: ___
(3) Capacitor leakage (standby radiation):
___mR/hr at 5 cm(_____ kVp, _____mAs)
max max
(4) Discharge, charge off (leakage radiation):
___mR/hr at 100 cm (____ kVp, ____ mAs)
max max

REMARKS (list by item):

Item: _____

BEAM LIMITING DEVICE
DIAGNOSTIC MEDICAL X-RAY EQUIPMENT

Facility :_____ **Inspector :**_____ **Date :** __/__/__

Type of unit: ☐ Stationary ☐ Mobile

1. GENERAL INFORMATION:

a. X-ray tube assembly no: _____; (one survey form per tube)

b. Manufacturer: _____ Date: _____
Model:_____ S/N: _____

c. Type of PBL: ☐ automatically adjusted; t less than 5 sec. ☐ Y ☐ N
☐ Manually adjusted. ☐ Y ☐ N

2. MANDATORY FEATURES:

a. Does radiation beam filtration labelling meet standards? ☐ Y ☐ N
Record exactly as shown on the label if not correct:_____
_____

b. Radiation field size indicated at selected distances? ☐ Y ☐ N
(1) Sizes & SIDs: _____
(2) Type of SID indicator used: _____

c. Means to indicate radiation field perpendicular to receptor? ☐ Y ☐ N

d. Means to centre radiation field to image receptor? ☐ Y ☐ N

e. Does light field illumination meet standards? ☐ Y ☐ N
___ lux at ___cm. distance.
Note: If light field indicator is not functioning, omit all remaining checks, except 4 (without the metal strips).

f. Is stepless adjustment of radiation (light) field available? ☐ Y ☐ N

g. Does radiation (light) field reduction mode meet standards? ☐ Y ☐ N
___ Proper PBL operation when SID is changed.
___ Proper PBL operation when image receptor is changed.

3. OPERATIONAL FEATURES:

a. PBL BYPASS or OVERRIDE feature provided? If YES is:

___ (1) Key lock switch needed to operate?

___ (2) Key removal reactivates PBL operation?

___ (3) Is return to PBL operation automatic each time image receptor changed?

___ (4) Is there a warning light when PBL BYPASS or OVERRIDE in effect?

b. Which operation parameters are bypassed?

___ Radiation beam angulation from perpendicular,

___ Collimation,

___ Bucky tray not used,

___ X-ray tube centering,

___ X-ray tube movement and tracking of collimation.

4. ACCURACY CHECK:

a. Parameters used:

Location	**TEST #1** Table	**TEST #2** Chest Stand
Indicated SID:	____	
Measured SID:	____ ____%	____ ____%
Tests film dist.:	____ ____CF	____ ____ CF
Dial settings:	____ by ____	____ by ____

b. Accuracy:

	TEST #1 Table	**TEST #2** Chest Stand
(1) Does radiation field/light field congruency meet standards? ☐Y ☐N		
Across:	____ mm (____%)	____ mm (____%)
Along:	____ mm (____%)	____ mm (____%)
(2) Is radiation field/indicated size within limits? ☐Y ☐N		
Across:	____ mm (____%)	____ mm (____%)
Along:	____ mm (____%)	____ mm (____%)
(3) Is radiation field/image receptor size within limits? ☐Y ☐N		
Across:	____ mm (____%)	____ mm (____%)
Along:	____ mm (____%)	____ mm (____%)
	Total (____%)	**Total (____%)**

(4) Are radiation and light field centres aligned within limits? ☐ Y ☐ N

____ mm (____%) ____ mm (____%)

(5) Does minimum radiation field size meet standards? ☐ Y ☐ N

____ by ____ cm at 100 cm SID.

REMARKS (list by item):

Item: _____

FLUOROSCOPIC MODE OPERATED UNIT
DIAGNOSTIC MEDICAL X-RAY EQUIPMENT

Facility :_____ **Inspector :**_____ **Date :** __/__/__

1. IDENTIFICATION:

a. X-ray source assembly no:_____ ; (one survey form per tube)

b. Is x-ray tube housing correctly labelled? ☐Y ☐N

	Housing	Insert
(1) Manufacturer:		
(2) Model :		
(3) Serial No:		
(4) Country of Manufacture:		
(5) Date (Y/M/D):		

2. STANDARDS OF DESIGN AND CONSTRUCTION:

a. Can x-ray focal spot(s) be located? ☐Y ☐N

b. Can x-ray tube polarity be determined? ☐Y ☐N

c. Does x-ray tube housing assembly permanent radiation beam filtration labelling meet standards? _____ ☐Y ☐N
Record exactly as shown if not correct: _____
_____

d. Are loading factors shown on control panel during operation? ☐Y ☐N

e. Does stability of x-ray tube support system meet standards? ☐Y ☐N
(1) Type: _____
(2) Identify if not compliant: _____
_____

f. Is radiation beam always shielded (interlocks, etc.)? ☐Y ☐N

g. Does image intensifier housing meet shielding standards? ☐Y ☐N
if NO; Exposure rate: ____kVp:____mA:_____
Location:_____
_____

h. Does minimum SSD meet standards for type of unit? ☐Y ☐N
___cm

i. Is radiation field/receptor edge alignment within limits? ☐Y ☐N

- Full-field (___cm) ___% + ___% = ___% at ___cm
  dia. width length total SID
- First-mag. (___cm) ___% + ___% = ___% at ___cm
  dia.
- Sec. mag. (___cm) ___% + ___% = ___% at ___cm
  dia.

j. Does "FLUORO-ON" timing device meet standards? ☐Y ☐N
___ Means that permit operator to set loading time.
___ Continuous steady or pulse audible signal when reset required.
___ Maximum loading time without reset of 5 minutes.

3. STANDARDS OF FUNCTIONING:

a. Does x-ray tube voltage (kVp) meet standards? ☐Y ☐N

	Fluoro kVp			Spot film kVp								
mA												
kVp	RMI	corr	%err	RMI	corr	%err	RMI	corr	%err	RMI	corr	%err
60												
80												
100												
120												

b. Fluoroscopic Brightness control.
(1) Does fluoro manual brightness control meet standards? ☐Y ☐N
___ Normal control system (___,___ R/min.)
___ High level control feature (___,___ R/min.)
___ Continuous audible signal while activated.
___ Special activation device that requires continuous pressure.

(2) Does automatic or semi-auto ABC system meet standards? ☐Y ☐N

___ Normal control system (___,___ R/min.)
___ High level control feature (___,___ R/min.)
___ Continuous audible signal while activated.
___ Special activation device that requires continuous pressure.

c. Does x-ray tube assembly leakage meet standards? ☐Y ☐N

4. RADIATION BEAM FILTRATION:

a. Does radiation beam filtration meet standards? ☐Y ☐N

Aluminum (mm)	0.0	0.5	1.5	2.5	3.5	4.5	0.0
set kVp meas							

HVL

5. RADIOGRAPHIC SPOTFILM FEATURE:

a. Is AEC on radiographic spotfilm device used? ☐Y ☐N

(1) Does spotfilm AEC reproducibility meet standards? ☐Y ☐N

	kVp	1	2	3	4	5	6	7	8	9	10	m.d.	CofV
Exp													
Time													
Exp													
Time													

(2) Does spotfilm AEC meet the following standards? ☐Y ☐N

___ Automatically terminates irradiation.
___ Irradiation terminated when irradiation switch released.
___ No irradiation when there is a "0", "OFF", "BLANK" position.
___ Selection indicated on main control panel.
___ Meets minimum irradiation time requirements (___).

(3) Does it have a BACK-UP timing device that meets standards? ☐Y ☐N

___ Requires manual reset.
___ Light on main control panel indicates activation.
___ Irradiation interrupted: 600mAs or 60,000 HU (kVp x mA x s).

b. Does PBL for spotfilm device meet standards? ☐ Y ☐ N

___ Automatically adjusts to selected radiation field size.

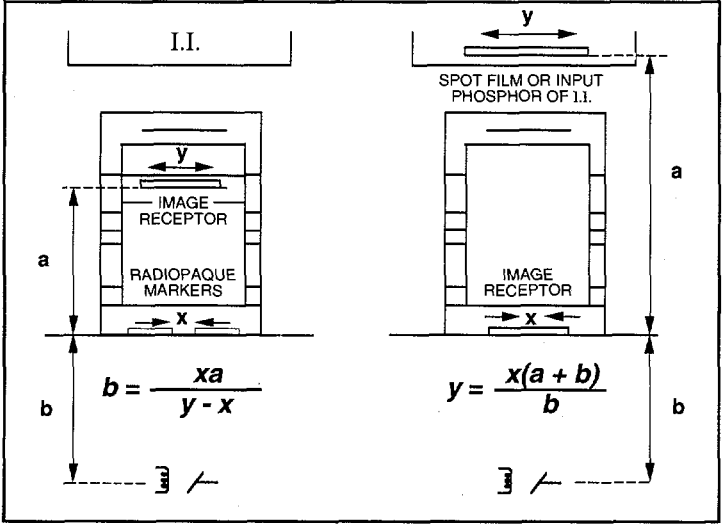
___ Manual adjustment of radiation field required if less than selection.

___ Edge alignment within standards.

REMARKS (list by item):

Item: _____

FLUOROSCOPIC MODE OPERATED UNIT



Fluoroscopy: (collimation only)

	Error (width)	Error (length)
1.	Full-field mode: SID= ___cm.	
	W1=___mm (___%) total	L1=___mm (___%) total
	W2=___mm (___%) ___%	L2=___mm (___%) ___%
2.	First magnification mode: SID= ___cm.	
	W1=___mm (___%) total	L1=___mm (___%) total
	W2=___mm (___%) ___%	L2=___mm (___%) ___%

Radiographic Spotfilmer: SID=__cm.

1.	Spotfilm format: ___, size of spot: ___ by ___cm.	
	W1=___mm (___%) total	L1=___mm (___%) total
	W2=___mm (___%) ___%	L2=___mm (___%) ___%

APPENDIX V

Sample calculations for tests.

Test 1. Reproducibility of exposure.

$$C = \frac{S}{\overline{X}} = \frac{1}{\overline{X}} \left[\sum_{i=1}^{n} \frac{(X_i - \overline{X})^2}{n-1} \right]^{1/2}$$

where C = the coefficient of variation
S = estimated standard deviation
$\overline{X}$ = mean value of measurements
X_i = i^{th} measurement
n = number of measurements

Irradiation 1 = 102 mR
Irradiation 2 = 92 mR
Irradiation 3 = 90 mR
Irradiation 4 = 101 mR
Irradiation 5 = 98 mR
Irradiation 6 = 95 mR
Irradiation 7 = 103 mR
Irradiation 8 = 103 mR
Irradiation 9 = 97 mR
Irradiation 10 = 103 mR

Enter the data into the statistical function of a scientific calculator. Calculate the standard deviation of population data (S = 4.565) and divide it by the mean value of the measurements (X = 98.4).

$$C = \frac{S}{\overline{X}}$$

$$C = \frac{4.565}{98.4}$$

$$C = 0.0456$$

Mean Value of Measurements = 98.4

Maximum Value = 103

Minimum Value = 92

Enter the data into the calculator and find the result

$$\frac{|\text{Mean Value} - \text{Maximum Value}|}{\text{Mean Value}} \times 100 \leq 15\%$$

$$\frac{|98.4 - 103|}{98.4} \times 100 \leq 15\%$$

$$4.67 \leq 15\%$$

Test 4. Average Exposure Ratios (linearity).

80 Kvp 0.2 seconds	Milliamperes	
	100	200
Exposures	Average: 53 mR	Average: 92 mR

$$\frac{53 \text{ mR}}{0.2 \text{ seconds x } 100 \text{ mA}} = 2.65 \text{ mR/mAs}$$

$$\frac{92 \text{ mR}}{0.2 \text{ seconds x } 200 \text{ mA}} = 2.3 \text{ mR/mAs}$$

$$\left| (\bar{X}_1 - \bar{X}_2) \right| \leq 0.10 \ (\bar{X}_1 + \bar{X}_2)$$

$$\frac{\left| (\bar{X}_1 - \bar{X}_2) \right|}{(\bar{X}_1 + \bar{X}_2)} \leq 0.10$$

$$\frac{|2.65 - 2.3|}{2.65 + 2.3} \leq 0.10$$

$$\frac{0.35}{4.95} \leq 0.10$$

$$0.07 \leq 0.10$$

Test 11. Positive Beam Limitation Figure 3.

a = 100 cm

b = 106 cm

x = 28.3 cm

y = Size of the Recording Material at Cassette Tray

$$y = \frac{bx}{a}$$

$$y = \frac{106 \text{ x } 28.3}{100} \text{ cm}$$

y = 30 cm

Test 13A. Target-to-Table Top Distance for Under-table Tubes. Figure 4

a = 30 cm

x = 5 cm

y = 8.3 cm

b = Target-to-Table Top Distance

$$b = \frac{5 \times 30}{8.3 - 5} \text{ cm}$$

$$b = \frac{150}{3.3} \text{ cm}$$

b = 45.46 cm

Test 17A. Spot Film Device Field Limitation. Figure 5
Test 18A. Positive Field Limitation for Under-table Fluoroscopic X-ray Tubes. Figure 6

a = 42 cm

b = 45 cm

x = 12 cm

y = Spot Film Device Field Size, or

y = Field Size for Fluoroscopic Under-table Tube

$$y = \frac{x\,(a+b)}{b} \text{ cm}$$

$$y = \frac{12\,(42+45)}{45} \text{ cm}$$

$$y = \frac{1044}{45} \text{ cm}$$

$$\% \text{ Error} = \frac{\text{Calculated Field Size} - \text{Image Intensifier Field Size}}{\text{Distance from Source to Image Receptor}} \times 100$$

$$\% \text{ Error} = \frac{23.2 \text{ cm} - 23 \text{ cm}}{87 \text{ cm}} \times 100$$

% Error = 0.22

APPENDIX VI

Glossary of Terminology

Terms in this guide	Commonly used terms
Beam limiting device	Collimator
Irradiation switch	Exposure switch
Irradiation time	Exposure time (to radiation)
Irradiation	Exposure (of an object)
Loading time	Exposure time (to electric supply)
Loading factors	Technique factors
Loading	Exposure (of an x-ray tube)
Radiation beam	X-ray beam
Radiation field	X-ray field
Radiation beam axis	Central ray
Radiogram	Radiograph
Scattered radiation	Scatter
Timing device	Timer
X-radiation	X-ray

The term "exposure" is reserved for the physical quantity describing the amount of ionization produced by interaction of x-radiation with air and measured by instrumentation.