Radiation Safety Training Module: Diagnostic Radiology

Quality Assurance Criteria for Mammography X-ray Equipment

Radiological Safety Division
Atomic Energy Regulatory Board

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Expected questions to know after studying this lecture

- What do you mean by Quality Assurance in Mammography?
- Why the QA tests are required?
- Name of the QA tests for Mammography equipment ?
- How the leakage radiation of x-ray tube is measured?
- What do you mean of survey of Mammography x-ray installation and how will you ensure whether Mammography x-ray installation is safe from radiation safety view point?

Objective / Aim of Quality Assurance (QA)

- Optimum image quality with minimum possible dose to the patient

Why QA in Mammography?

- Frequent use and aging of the diagnostic X-ray equipment may cause change in its functional characteristics.

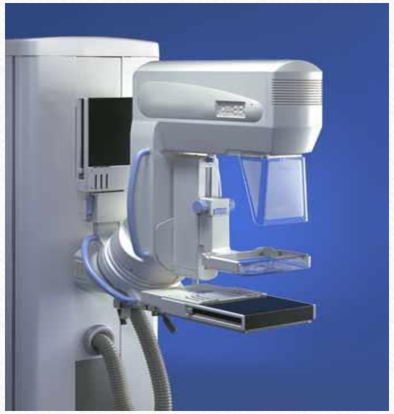
- To avoid retakes which reduces the radiation exposure to patient and radiological personnel and public.

Parameters Affecting Image Quality

- Operating Potential (kV)
- Operating Tube (mA)
- Exposure Time (msec)
- Effective Focal Spot Size
- Total Filtration
- Detector characteristics

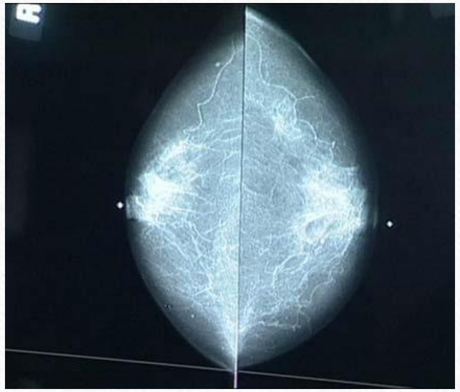
What is Mammography

Mammography is a specific type of imaging unit that uses a low-dose X-ray system to examine breasts.

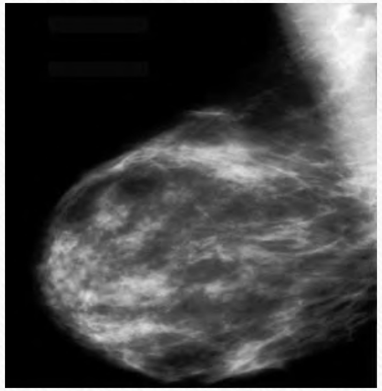


Mammography X-ray unit

A mammography exam, called a mammogram, is used to aid in the early detection and diagnosis of breast diseases in women.



Digital Mammogram



Normal Mammogram

Development of Mammography

- In 1913, radiographic appearance of breast cancers was first reported
- 1950's – Industrial grade X-ray film used
- 1960's – Xerography introduced – much lower dose
- 1975 – High speed/resolution film introduced
- 1992 – Mammography Quality Standard Test (MQSA) implemented

Risk Vs. Benefit

- Mortality risk from mammography induced radiation is 5 deaths/1 million patients using screen film mammography. (Pl. give reference)
- It is more risky to refuse mammography than to allow it.

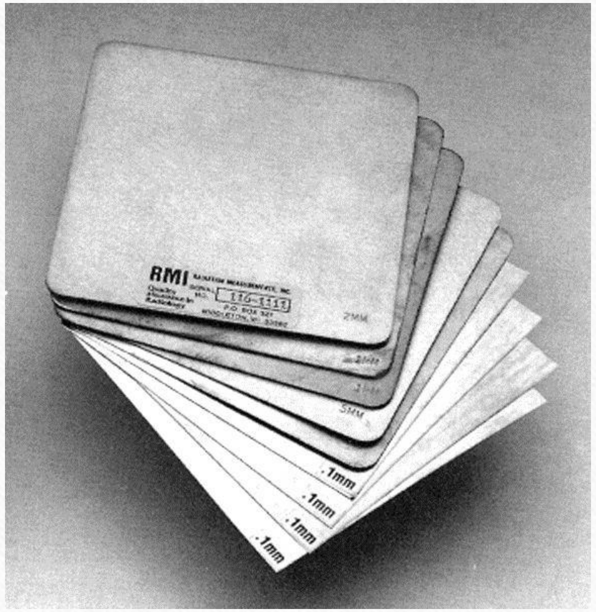
Breast Cancer Screening

- American Cancer Society and American College of Radiology suggest that all women over 50 years should undergo mammography examinations annually.

- Women between 40 and 49 should have one mammography every or every other year.

- A baseline mammogram should be done at the onset of menopause.

Multi -parameter measuring Instrument



Al filter

Mammography X-ray unit

Survey meter

Tissue Equivalent Phantom for Mammography

Parameters Tested are:

- Correspondence between X-ray Field and Image Reception Area
- Effective Focal Spot Size Measurement
- Accelerating Potential (kVp)
- Accuracy of Exposure Time
- Linearity of mA Loading Stations
- Linearity of Timer Loading Stations
- Radiation Out put consistency
- Total Filtration x-ray Tube

Cont…

- Calibration of Compression Device
- Imaging Performance Evaluation
- Constancy of the Automatic Exposure Control (AEC) on Film Screen Receptors
- Radiation Leakage through Tube Housing and Collimator

1. CORRESPONDENCE BETWEEN X-RAY FIELD AND IMAGE RECEPTION AREA

- X-ray field to be positioned to cover the region of interest and the sensitive volumes of the Automatic Exposure Control

- X-ray field is adjusted in normal use for full coverage of the image reception area

- **Result** : within ______ mm

CORRESPONDENCE BETWEEN X-RAY FIELD AND IMAGE RECEPTION AREA (Contd..)

Tolerance: The X-ray field

- shall extend to the edge of the patient support that is designed to be adjacent to the chest wall of the patient and shall not extend beyond this edge by more than 5 mm.

- shall not extend by more than 2% of the direct focal distance beyond all edges of the image receptor area.

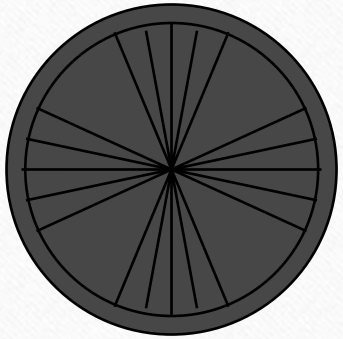
(IS13450(Part 2/Sec 45) :2007 Clause 29.203.4, page 22)

2. EFFECTIVE FOCAL SPOT SIZE MEASUREMENT

The ability for resolving the smallest size of the image (i.e detail) in a radiograph depends on the focal spot size.

Techniques for the measurement of focal spot

- Pin hole
- Slit
- Star pattern or resolution pattern



- Minimum focal spot to skin distance is 20 cm

  in mammography with geometric magnification

Tolerance:

Nominal Focal Spot Value	Focal Spot Dimension (mm)	
f	Width	Length
0.1	0.1-0.15	0.1-0.15
0.15	0.15-0.23	0.15-0.23
0.2	0.2-0.3	0.2-0.3
0.25	0.25-0.38	0.25-0.38
0.3	0.3-0.45	0.3-0.45
0.4	0.4-0.46	0.4-0.46
Ref: Table 5 IEC 336 :1993 Section 5, page 43		

Accelerating Potential (kVp)

- The peak potential of the x-ray generator affects quality of the x-ray beam and exposure to the patient.

- Presently solid – state detectors, which employ non-invasive method for peak tube potential measurement, are quite handy for this test.

Accelerating Potential (kVp)

Tolerance : ± 1 kV

Accuracy of Exposure Time

- If the exposure time of the x-ray unit is not in order, the radiograph can be under exposed or overexposed.

- For this absolute timer method is adopted by measuring set and measured time with digital timers.

Accuracy of exposure timer ± 10 %

Linearity of mA loading stations

- The tube current (mA) is equal to the number of electrons flowing from the cathode to the anode per unit time.
- The exposure of the beam for a given kVp and filtration is proportional to the tube current.
- **This test is carried out to check the linearity of radiation output with respect to change in tube current (mA) stations by keeping timer station constant at a particular kV station.**

Linearity of mA loading stations (contd..)

- Keeping exposure time and kVp constant, radiation output is measured at different mA stations.
- Measurement for mA loading station is to be repeated for a number of times each to eliminate statistical errors.
- Each mA loading station readings are averaged and the coefficient of linearity (CoL) is evaluated from average (mR/mAs) or (mGy/mAs) as follows:

Dose measuring instrument

Coefficient of linearity =

$$(X_{max} - X_{min}) \div (X_{max} + X_{min})$$

Tolerance: Coefficient of Linearity < 0.1

Linearity of timer loading stations

- The exposure time is the duration of X-ray production.
- Keeping the kVp and mA constant, radiation output is measured at different timer stations and Coefficient of Linearity is evaluated.
- **This test is carried out to check the linearity of radiation output with respect to change in timer stations by keeping mA station constant at a particular kV station.**

Tolerance: Coefficient of timer linearity < 0.1

RADIATION OUTPUT CONSISTENCY

- To check the constancy of radiation output.
- Arrange the X-ray source assembly, the diaphragm and the radiation detector for measurement under narrow beam condition without the compression plate.
- Ensure that the radiation quality of the X-ray beam emerging from the X-ray source assembly complies with applicable specified conditions for normal use.

- If no such conditions are specified, ensure that the total filtration in the X-ray source assembly is such as to comply with the general standard as applicable

IS13450(Part 2/Sec 45) :2007 Clause 29.1.105, page 21

Out put Consistency

- Keeping fixed mA and time, radiation output is measured at various available kVp stations. average(X) of mR/mAs (mGy/mAs) is calculated.

- Consistency at each kVp station is checked by Evaluating the coefficient of variation.

- **Coefficient of variation =** $\frac{1}{\overline{X}}\sqrt{\frac{\sum\left(\mathrm{Xi}-\overline{\mathrm{X}}\right)^2}{n-1}}$

Tolerance : The coefficient of variation of measured values of air kerma shall not be greater than 0.05 for any combination of loading factors

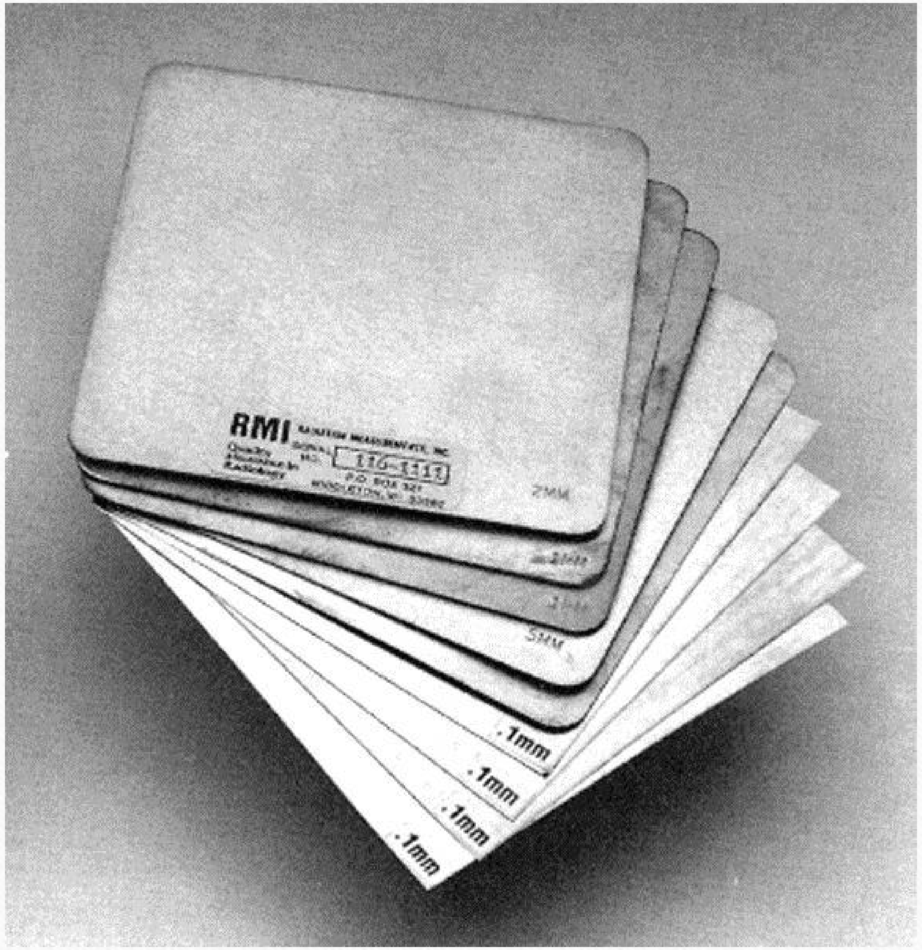
Total Filtration of X-ray tube

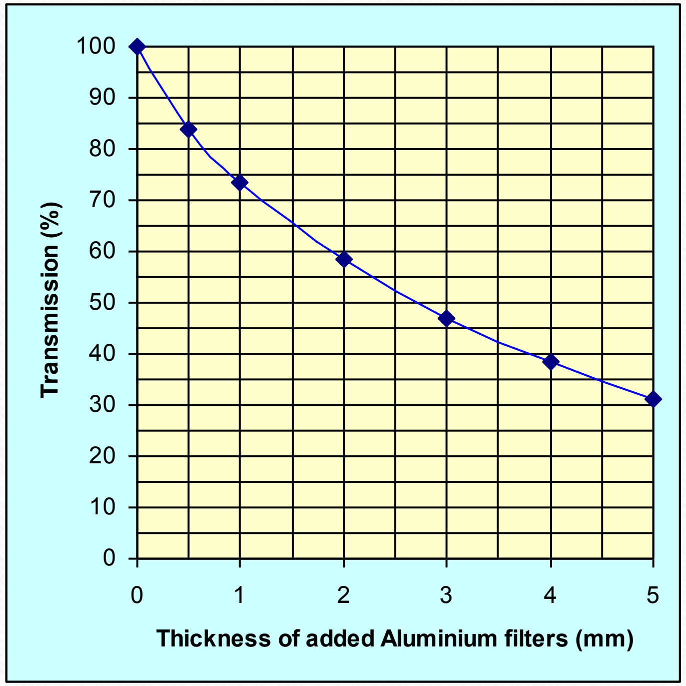
- **To cutoff low energy components from X-ray beam, which do not contribute to diagnostic image formation but result in unnecessary patient exposure.**

- If the filtration is too high, image contrast will be poor and unit will be overloaded. Therefore it is necessary that the total filtration (inherent + added) provided for the X-ray tube be as per the recommended value.

- The determination of half value thickness (HVT) of the X-ray beam is the method of evaluation of total aluminum equivalent filtration of the X-ray tube.

Evaluation of HVL and Total Filtration





- Total aluminum equivalent filtration of the x-ray tube is evaluated by determining the half value thickness of the beam.
- Transmission curve of the x-ray beam can be prepared by plotting a graph between the absorber thickness and corresponding percentage transmission.
- **The absorber thickness for 50 % transmission will be the half value thickness of the x-ray beam.**
- Total aluminum filtration could be determined from HVT using calibration tables.
- **Presently, new solid state detectors directly gives the values of HVT and total filtration used in diagnostic X-ray equipment.**

Operating Potential	mAs	Added filter (mm Al)						Compression Device	HVT mm Al
30kVp		0.0	0.1	0.2	0.3	0.4	0.5		
40kVp									

FIGURE 13.12 Compression device.

IEC 601-1-3:1994 section 29.201.3, page 33age 29

TOTAL FILTRATION AND ALUMINIUM EQUIVALENCE OF THE COMPRESSION DEVICE

Tolerance:

Total filtration in mammography equipment with Mo-Mo target filter combination shall not be less than 0.03 mm of Mo. For any other combination the above values of first HVL will apply.

The minimum total filtration equivalent to first HVL shall be provided as

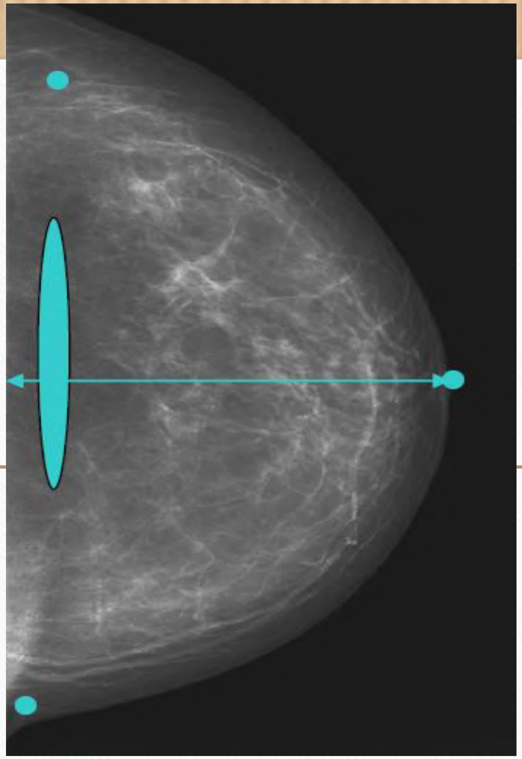
First HVL at 30 kVp $\geq$ 0.3 mm Al
First HVL at 40 kVp $\geq$ 0.4 mm Al
First HVL at 50 kVp $\geq$ 0.5 mm Al

CALIBRATION OF COMPRESSION DEVICE

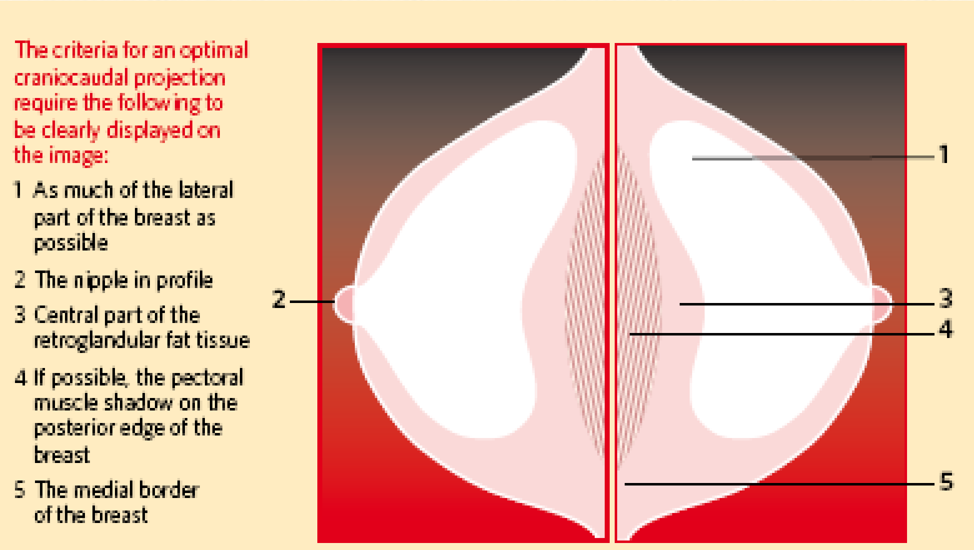
- **Test Equipment**
- A soft rubber block, 20 mm to 50 mm thick and 100 mm to 120 mm long wide
- **Test Procedure:**
- Position the X-ray tube-image receptor assembly to acquire a cranio-caudal projection of the breast.
- Place the force balance on the patient support and place the soft rubber block on the sensitive area of the force balance.
- Operate the compression device, clamping the soft rubber block and record the reading.
- Measure the highest achievable forces for all compression modes.
- Repeat the procedure for at least three other orientations.

IS13450(Part 2/Sec 45) :2007 Clause 22.102.5, page 16

Cranio-caudal (CC) Projection



- The CC view is particularly valuable in detecting small valuable cancer



IS13450(Part 2/Sec 45) :2007 Clause 22.102.5, page 16

CALIBRATION OF COMPRESSION DEVICE (Contd..)

Tolerance :

- No compression device shall be able to apply a force exceeding 300 N.
- For power-driven compression, the compression device shall be able to apply a force of at least 150 N and it shall be unable to apply a force exceeding 200 N.
- For power-driven compression, the available operating force shall be adjustable down to 70 N or less.
- If the value of applied force is displayed, the indication shall be accurate to ±20 N.

IS13450(Part 2/Sec 45) :2007 Clause 22.102.5, page 16

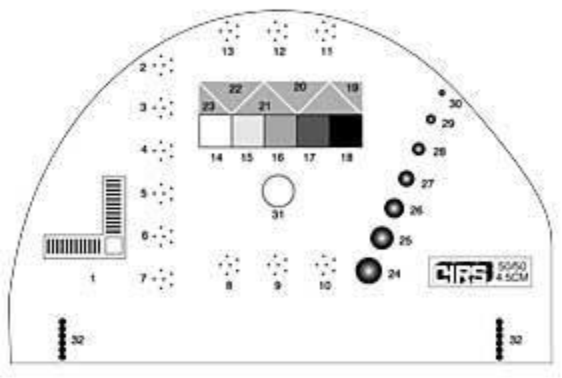
IMAGING PERFORMANCE EVALUATION

Tolerance:

To pass the mammography image quality standards at least

- four fibers,
- three calcification group and
- three masses

must be clearly visible (With no oblivious artifacts) at an average glandular dose of less than 3 mGy



CONSTANCY OF THE AUTOMATIC EXPOSURE CONTROL (AEC) ON FILM SCREEN RECEPTORS

- **TEST METHOD**

➢ Measure the transmitted doses through the phantoms made of breast tissue equivalent material, water or polymethyl methacrylate (PMMA), produced with AEC in operation.

- Tolerance: AEC shall be designed such that the transmitted dose shall not vary by more than 20% for all phantom thicknesses.

PMMA Breast Phantom

Breast imaging phantom

Radiation Leakage Levels through Housing and Collimator

Radiation Leakage through Tube Housing

- The radiation leakage measurement is carried with an ionization radiation survey meter. For checking the leakage radiation, the collimator of the tube housing is fully closed and the tube is energized at maximum rated tube potential and current at that kVp.

- The exposure rate at one meter from the target is measured at different locations (anode side, cathode side, front back and top) from the tube housing and collimator.

- From the maximum leakage rate (mR/h) from both tube housing and collimator, **leakage radiation in one hour** is computed on the basis of the workload of the unit.

- Workload used for medical X-ray unit :

  40 mA-min in 1 hour

- Max leakage from tube housing

$$= \frac{\text{40 mAmin X ----Max. leakage mR/hr}}{\text{60 min X ----- mA used for measurement}}$$

Codal Requirements:

The leakage radiation averaged over an area of 10 cm^2, with no linear dimension greater than 20 cm and located at 5 cm from any point on the external surface of X-ray tube housing does not exceed 0.02 mGy in one hour.

Survey of the X-Ray Installation

- **Estimation of Dose Levels from measured dose rate values:**
- If x (mR/hr) is the exposure level measured at a point with I (mA) current and W (mA-min / wk) is the work load of the unit, then the weekly exposure level at that point can be calculated as follows:
- Exposure level at the point = x mR / hr with I mA

$$= \frac{x}{I} = \frac{mR}{mA-hr} = \frac{x}{I*60} = \frac{mR}{mA-\min} = y$$

- Weekly exposure = Y * W mR
- Weekly exposures due to all the three beam directions are added to get the total weekly exposure at any location
- Permissible limit:
- For location of Radiation Worker:
- 20 mSv in a year (40 mR/week)
- For Location of Member of Public: 1 mSv in a year (2mR/week)

CONCLUSION:

- With all this discussion we can conclude that QA is
- very important in diagnostic radiology facilities to confirm the real diagnostic information with minimum dose to patient.

Summary

Parameters affecting image quality

- Operating Potential
- Current/Time (mAs)
- Focal Spot Size
- Filtration
- Detector characteristics

Additional Information

Ready values to remember

Sr No	Name of QA test	Tolerance
1	kVp	**± 1 kV**
2	Accuracy of time	**± 10%**
3	mA /mAs / Timer linearity (coeff. of linearity)	0.1
4	Output consistency (Coeff. of variation)	0.05
5	Image Quality	➢ four fibers, ➢ three calcification group and ➢ three masses
6	Tolerance for filtration	Total filtration for Mo-Mo filter 0.03 mm of Mo First HVL at 30 kVp $\geq$ 0.3 mm Al First HVL at 40 kVp $\geq$ 0.4 mm Al First HVL at 50 kVp $\geq$ 0.5 mm Al
7	Leakage from X-ray tube	0.02 mGy in 1 hour

Questions and Answers (Min 10)

- Q- What are the x-ray unit operating parameter on which output of x-ray unit depends?

  Ans- kVp, mA and time

- Q -What is the tolerance of kV

  A - ± 1 kV

- Q- What is the tolerance for leakage radiation

  A – 0.02 mGy in one hour

- Q- What is the unit of work-load

  A – mA-min per week

Questions and Answers

- Q- What is the role of filtration in x-ray unit?

A - To cutoff low energy components from X-ray beam, which do not contribute to diagnostic image formation but result in unnecessary patient exposure.

- Q- What is the role of focal spot in image quality?

A- The ability for resolving the smallest size of the image (i.e detail) in a radiograph depends on the focal spot size. The effective focal spot size is the length and width of the focal spot as projected down the central ray in the X-ray field.

- Q. What is the criteria for passing image Quality standard

A. To pass the mammography image quality standards at least four fibers, three calcification group and three masses must be clearly visible (With no oblivious artifacts) at an average glandular dose of less than 3 mGy.

- Q.Tolerance for total HVL in mammography x-ray tube?

A.- Total filtration in mammography equipment with Mo-Mo target filter combination shall not be less than 0.03 mm of Mo. For any other combination the above values of first HVL will apply. The minimum total filtration equivalent to first HVL shall be provided as

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First HVL at 50 kVp $\geq$ 0.5 mm Al

References and sources for additional information:

- IS 13450 (Part 2/Sec 45) : 2007 / IEC 60601-2-45: 2001 'Medical electrical equipment Part 2/45: Particular requirements for the safety of mammographic X-ray equipment and mammographic stereotactic devices'
- IEC 60601-2-28 : 1993 Medical electrical equipment - Part 2-28: Particular requirements for the safety of X-ray source assemblies and X-ray tube assemblies for medical diagnosis
- IEC 61223-3-2: 1996 Evaluation and routine testing in medical imaging departments - Part 3-2: Acceptance tests - Imaging performance of mammographic X-ray equipment
- IEC 60601-1-3 (1994) General requirements for the safety; Section 3 Collateral Standard: General requirements for radiation protection in diagnostic X-ray equipment
- IEC 60788:1984, Medical radiology - Terminology
- AERB Safety Code for Medical Diagnostic X-ray Equipment and Installations, AERB/SC/MED-2 (Rev.1)
- For additional information please refer to AERB website: www.aerb.gov.in
- http://www.aerb.gov.in/AERBPortal/pages/English/t/XRay/forms/QAMammography.doc

List of presentations in the training Module

Basics of Diagnostic X-ray Equipment
Biological effects of Radiations
Medical X-ray imaging techniques
Planning of Diagnostic X-ray facilities
Quality Assurance of X-ray equipment
Quality Assurance of Computed Tomography equipment
Radiation Protection in Diagnostic Radiology Practice
Causes, prevention and investigation of excessive exposures in diagnostic radiology
Regulatory Requirements for Diagnostic Radiology Practice

THANK YOU