Authorization and Inspection of Radiation Sources in Diagnostic Radiology
**Quality Management (Module 3.8)**

**Quality Assurance (QA):**

**Definition:**

A management tool which, through the development of policies and the establishment of review procedures, aims to ensure that every examination in a Diagnostic and Interventional Radiology Department is necessary and appropriate to the medical problem.



Authorization and Inspection of Radiation Sources in Diagnostic Radiology
**Quality Management (Module 3.8)**

To achieve an effective QA program in Diagnostic and Interventional Radiology, every examination should be performed :

- according to previously accepted clinical protocols
- by adequately trained personnel
- with properly selected and functioning equipment
- to the satisfaction of patients and referring physicians
- in safe conditions
- at minimum cost



Authorization and Inspection of Radiation Sources in Diagnostic Radiology
**Quality Management (Module 3.8)**

**Registrant and Licensee**

Responsibilities:

Shall establish a comprehensive Quality Assurance Program for radiation protection, safety and image quality to ensure that all necessary procedures are developed and implemented to comply with regulations for radiation protection within the terms and conditions of the authorization of the facility.



Authorization and Inspection of Radiation Sources in Diagnostic Radiology
**Quality Management (Module 3.8)**

**A Quality Assurance Program should include:**

- procedures to ensure that the medical exposures are in accordance with those prescribed by a medical practitioner.
- patient dose evaluation
- quality control of the x-ray system
- training and continuing education of staff
- clinical audit
- procedures for remedial actions, follow up and result evaluation



Authorization and Inspection of Radiation Sources in Diagnostic Radiology
**Quality Management (Module 3.8)**

The QC procedures manual should contain protocols for performing the different tests with indicating:

- the measuring instruments or tools to be used;
- the operational details;
- the level of qualification required to the staff performing the test;
- the recommended frequency; and
- the limiting values for and tolerances in the results



Authorization and Inspection of Radiation Sources in Diagnostic Radiology
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The following procedures shall be included :

- Acceptance tests
- Constancy tests
- Status tests (full testing at longer periods, e.g. annually)
- Calibration of quality control test equipment
- Follow up of any corrective actions required as a result of quality control tests.

**Quality Control (QC):**

- is part of the QA Program that deals with techniques used in the monitoring and maintenance of the technical elements of the systems that affect the quality of the image.

  Therefore, QC is part of the QA Program that deals with instrumentation and equipment





**Quality Control (QC):**

Goal:

The goal of a QC Program is to ensure the accuracy of the diagnosis or the intervention.

The minimum radiation dose should be used to achieve the objective of the diagnostic or interventional procedure.





**Acceptance Test:**

is performed on new equipment to demonstrate that it is performing within the manufactures specifications and criteria.

**Performance Test:**

is a specific test performed on the x-ray system in use after a certain amount of time has elapsed.





**Quality Control Instruments :**

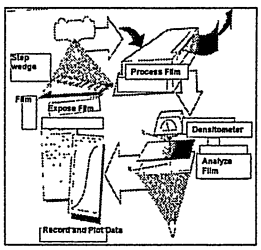
The instruments required are basically classified into four groups:

- Instruments to check the electromechanical performance of the x-ray system.
- Instruments to verify the accuracy of the radiation control settings. e.g. kVp meter
- Ionization chambers and electrometers to measure exposure and absorbed dose.
- Phantoms to measure image quality, e.g spatial resolution





**Quality Control Tests**




- Automatic Processor System
- Intensifying screens and film
- Radiography / Fluoroscopy Systems
- Mammography System
- Computed Tomography System

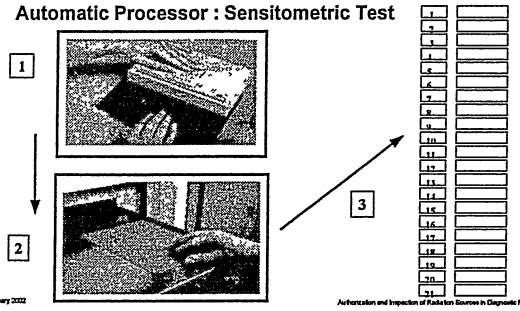




**Quality Control Tests**

**Automatic Processor Test**

**Automatic Processor : Sensitometric Test**





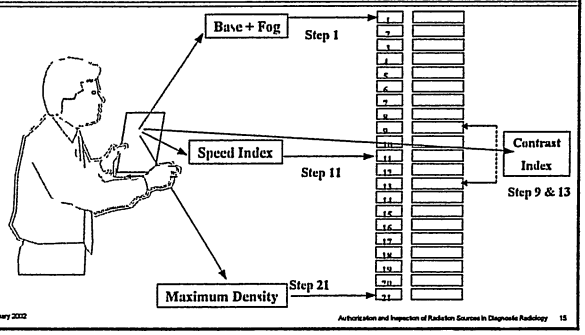



| Parameters | Definition |
|---|---|
| Base + Fog | Optical Density of step #1 (with no exposure). |
| Speed Index | Optical Density of step #11. |
| Contrast Index | Diference in Optical Density of step #13 and step #9. |
| Maximum Density | Maximum Optical Density of step #21. |

In practice, the steps used are dependent on sensitometer performance and film type and speed. However, the steps selected must be used consistently to assess variations in processor performance.









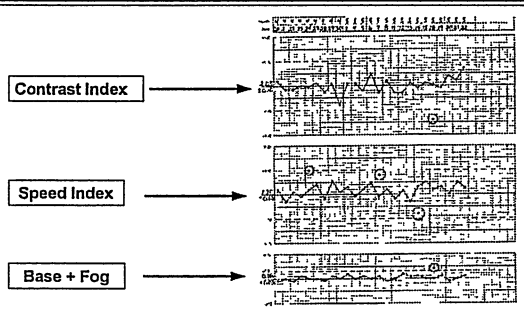



**Example #1:**

| | Sensitometric Step Number | | | | |
|---|---|---|---|---|---|
| | 1 | 11 | 13 | 9 | 21 |
| Time of test | Optical Density | | | | |
| 0700 | 0.16 | 1.05 | 2.20 | 0.49 | 3.12 |
| 0830 | 0.17 | 1.21 | 2.16 | 0.46 | 3.20 |
| 1000 | 0.17 | 1.12 | 2.21 | 0.48 | 3.30 |
| 1130 | 0.18 | 1.23 | 2.14 | 0.45 | 3.15 |
| 1300 | 0.17 | 1.21 | 2.10 | 0.43 | 3.10 |
| Total | 0.85 | 5.82 | 10.81 | 2.31 | 15.87 |
| Average | 0.17 | 1.16 | 2.16 | 0.46 | 3.17 |












**Quality Control Tests**

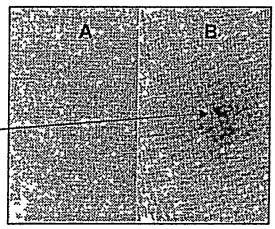
**Screen and Film**

### Screen- Film Contact test

Radiographs of wire mesh are used to check for screen–film contact.

Good contact is evident in **A**

Region of poor contact (blurring) is evident in **B**




**Recommended Tolerance:**
**No artefacts should be observed**

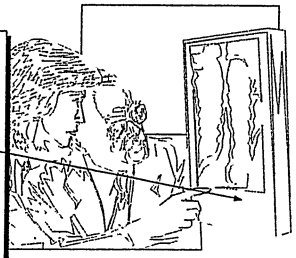




### Viewing Box Illuminators:

**Recommended Tolerance:**

- Conventional viewing box luminance should be at least 1500 cd/m², with 1700 cd/m² being standard.
- Illuminators for viewing mammograms should have a luminance of about 3500 cd/m².
- All viewing boxes should have uniform luminance and color







### Quality Control Tests

## Radiographic / Fluoroscopic Test



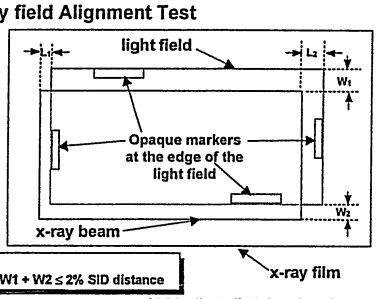


### Light field and X-ray field Alignment Test

**Example:-**
SID = 100 cm
L1 = 0.6 cm
L2 = 1.0 cm
W1 = 1.0 cm
W2 = 0.8 cm

$\frac{L_1 + L_2 \times 100}{SID} = 1.6\%$

$\frac{W_1 + W_2 \times 100}{SID} = 1.8\%$




**Recommended Tolerance**
**L1 + L2 ≤ 2% SID distance; W1 + W2 ≤ 2% SID distance**



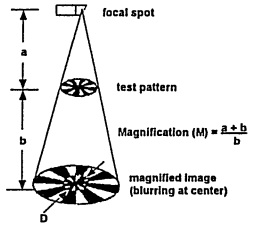


### Focal Spot Size - Example

Image Size I = 95 mm
Object Size O = 45 mm
Magnification M = I / O = 2.11
Separation blur distance (parallel$_{ca}$)
$D_1$ = 55 mm
Separation blur distance (perpendicular$_{ca}$)
$D_2$ = 67 mm

$F1 = \frac{1.5}{57.3} \cdot \frac{D_1}{M-1}$ = 1.29 mm

$F2 = \frac{1.5}{57.3} \cdot \frac{D_2}{M-1}$ = 1.58 mm




Recommended Tolerance: See next table





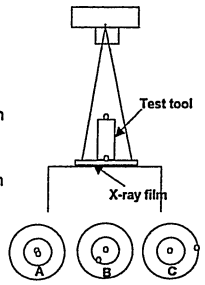
### Focal Spot Size - Recommended Tolerance

| Nominal Focal Spot Size (mm) | Effective Focal Spot Size (mm) | |
|---|---|---|
| | Parallel$_{ca}$ Axis | Perpendicular$_{ca}$ Axis |
| 0.10 | 0.15 | 0.15 |
| 0.15 | 0.23 | 0.23 |
| 0.20 | 0.30 | 0.30 |
| 0.30 | 0.65 | 0.45 |
| 0.40 | 0.85 | 0.60 |
| 0.60 | 1.30 | 0.90 |
| 1.00 | 2.00 | 1.40 |

## X-Ray beam Perpendicularity Test

1) If the images of the radio-opaque spheres are superimposed (A), the perpendicularity of the x-ray beam is within 0.5°
2) If the image of the sphere furthest from the film intercepts the first circle (B), the x-ray beam is approximately 1.5° out of perpendicular.
3) If the image of the sphere furthest from the film intercepts the second circle (C), the x-ray beam is approximately 3.0° out of perpendicular.

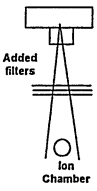
Note: Subject to the design of the test tool





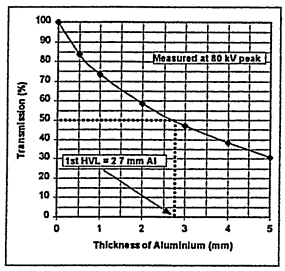



## Filtration Check (Half Value Layer - HVL) - Example




| mms Al | µGy | Transmission (%) |
|---|---|---|
| 0.0 | 3000 | 100.0 |
| 0.5 | 2520 | 84.0 |
| 1.0 | 2205 | 73.5 |
| 2.0 | 1755 | 58.5 |
| 3.0 | 1410 | 47.0 |
| 4.0 | 1155 | 38.5 |
| 5.0 | 930 | 31.0 |

Recommended Tolerance: See next Table








## Filtration Check (Half Value Layer - HVL) Recommended Minimum Values

| kV peak | mm Aluminium |
|---|---|
| 60 | 1.5 |
| 70 | 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 |

For Mammography:-

Without the compression device

$$HVL \geq \frac{kV\ peak}{100}$$

With the compression device

$$HVL \geq \frac{kV\ peak}{100} + 0.03$$





## Reproducibility of Air Kerma, Exposure Time and KV peak - Example

| Exposure No. | µGy | Time (sec) | kV peak |
|---|---|---|---|
| 1 | 1244 | 0.0531 | 80.5 |
| 2 | 1251 | 0.0531 | 80.5 |
| 3 | 1225 | 0.0530 | 80.7 |
| 4 | 1247 | 0.0530 | 80.5 |
| 5 | 1246 | 0.0530 | 80.8 |
| 6 | 1248 | 0.0530 | 80.4 |
| CV | 0.007 | 0.001 | 0.002 |

Recommended Tolerance: CV ≤ 0.05

Coefficient of Variation (CV)

$$= \frac{1}{\bar{X}} \sqrt{\frac{\sum_{i=1}^{n} (X_i - \bar{X})^2}{n-1}}$$





## Accuracy of kV peak and Exposure Time - Example

| kV peak Indicated | kV peak Measured | Error (%) | Exposure time (s) indicated | Exposure time (s) measured | Error (%) |
|---|---|---|---|---|---|
| 50 | 51.5 | 3.0 | 1.00 | 0.99 | 1.0 |
| 60 | 61.5 | 2.5 | 0.78 | 0.79 | 1.3 |
| 70 | 70.4 | 0.6 | 0.62 | 0.62 | 0 |
| 80 | 80.3 | 0.4 | 0.31 | 0.32 | 3.2 |
| 90 | 89.8 | 0.2 | 0.22 | 0.24 | 9.1 |
| 100 | 100.8 | 0.8 | 0.12 | 0.12 | 0 |
| 110 | 112.3 | 2.1 | 0.06 | 0.06 | 0 |
| 120 | 123.6 | 3.0 | 0.03 | 0.03 | 0 |

Recommended Tolerances:
kV peak error ≤ 5%; Timer error ± 10% + 0.001 s





## Linearity Test - Example (at a nominal kV peak)

| mAs | Air kerma (mGy) | Air kerma rate (mGy/mAs) | Linearity (adjoining mAs values) |
|---|---|---|---|
| 20 | 2.52 | 0.126 | |
| 40 | 5.01 | 0.125 | 0.004 |
| 50 | 10.61 | 0.212 | 0.26 |
| 150 | 18.71 | 0.124 | 0.26 |
| 250 | 31.06 | 0.124 | 0 |
| 400 | 50.37 | 0.126 | 0.008 |

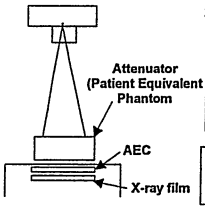
Linearity = $\frac{|X_1 - X_2|}{|X_1 + X_2|}$

Recommended Tolerance: ≤ 0.1

Note: In this example linearity has been calculated between the adjacent mAs values. Ideally the linearity of any two settings should be in compliance. However, the IEC stipulates testing at settings that do not differ by more than a factor of 2.

## Automatic Exposure Control (AEC)
## Assessing performance for variable patient thickness.

In this example, data is quoted for a mammography x-ray machine




| Thickness (cm) | Optical Density |
|---|---|
| 3.0 | 1.12 |
| 4.5 | 1.27 |
| 6.0 | 1.05 |
| Mean | 1.15 |

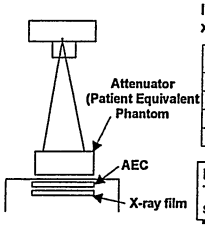
**Recommended Tolerance:**
The optical density at each thickness assessed should not differ by more than ± 0.2 of the mean





## Automatic Exposure Control (AEC)
## Assessing performance for variation in kV peak

In this example, data is quoted for a mammography x-ray machine




| kV peak | Optical Density |
|---|---|
| 25 | 1.18 |
| 26 | 1.09 |
| 27 | 1.05 |
| Mean | 1.11 |

**Recommended Tolerance:**
The optical density at each thickness assessed should not differ by more than ± 0.2 of the mean



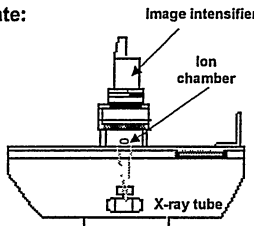


## Maximum Fluoroscopic Dose Rate:

**Recommended Tolerance:**

The intensity of the fluoroscopic x-ray beam at the table top should not exceed **50 milliGray per minute.**

A limit of **100 milliGray per minute** may be applied to equipment fitted with automatic brightness (doserate) control, subject to appropriate warnings to the fluoroscopist.




For overtable x-ray tubes and mobile fluoroscopic equipment, the doserate should be measured 30 cm from the input of the image intensifier.





## Fluoroscopic Image Quality:

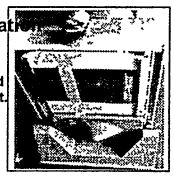
| Parameter | Recommended Limit |
|---|---|
| Image Distortion | Any distortion should be reported for correction |
| Low contrast threshold / sensitivity | Not greater than 5 % for 10 mm diameter detail |
| Low contrast detail detectability | Not greater than 1 mm diameter detail at 10 % contrast |
| High contrast / limiting resolution | Not less than 1.2 lp.mm$^{-1}$ (for 25/23 cm field sizes) and 1.6 lp.mm$^{-1}$ (for 15/13 cm field sizes) |

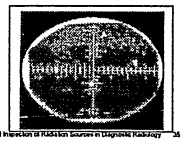




## Fluoroscopic Image Size and Beam Limitat

**The objective of the test is to ensure that the fluoroscopic imaging system displays only the area for which it was designed. i.e. that the patient is not unnecessarily exposed by irradiating an area larger than the image intensifier input.**





**Recommended Tolerance:**

- **The fluoroscopic x-ray beam should be restricted by a collimator to a circle or rectangle so that only the selected image intensifier input area is exposed. eg 23 cm diameter beam for a 23 cm II field; 15 cm for a 15 cm field.**
- **The maximum alignment error between the II input and the x-ray beam should not be greater than 3% of the SID. For rectangular beams, the sum of the errors on axes at 90°**



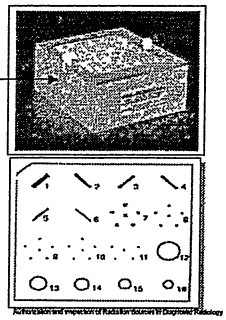


## Quality Control

## Mammography Test

## Image Quality

**Accreditation Phantom** equivalent to a breast of nominal thickness and density - typically 4.5 cm and 50/50 adipose / fat.



**Recommended Tolerance:**
**Fibers > 4**
**Specks groups > 3**
**Masses >> 3**

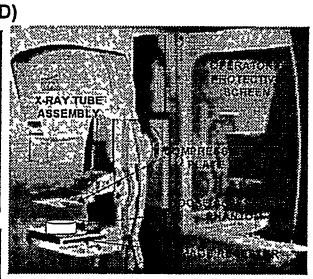




## Mean Glandular Dose (MGD)

**Recommended Tolerances**

- **The maximum MGD should not exceed 3 mGy for a 50% adipose and 50% glandular tissue breast, uniformly compressed to 5 cm and with an anti-scatter grid. Without a grid, the MGD should not exceed 1 mGy.**
- **The mean background optical density for clinical diagnosis should be 1.6 ± 0.2.**




**Most facilities should be able to comply with a 3 mGy limit for a 5 cm breast even at the lowest tube voltage clinically used.**





## Quality Control

## Computed Tomography Test

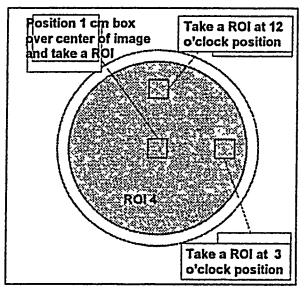




## Uniformity of CT Number

Using an appropriate water phantom, the mean CT number of water in the central ROI should not deviate from zero by more than ± 4 CT numbers. The ROIs should be circles of 20 mm diameter.

The uniformity of the image should be such that the mean CT number of the central ROI is within ± 2 CT numbers of the mean CT number of each outer ROI.





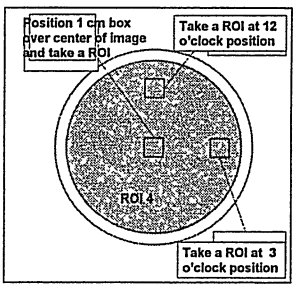



## Noise

***Sample Measurements***

| ROI | SD |
|---|---|
| *1* | *2.7* |
| *2* | *2.2* |
| *3* | *2.2* |

**Recommended Tolerance:**
SD ≤ 4 (in every ROI).

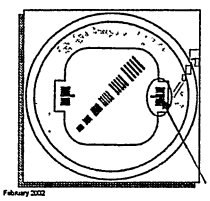







## Slice Thickness

The purpose of the test is to ensure that the actual slice width is the same as that selected. The nominal slice width is compared to the full width half maximum (FWHM) value of the slice sensitivity profile



**Sample measurements for a nominal slice thickness of 10 mm.**

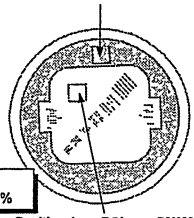
| | | *Lines* |
|---|---|---|
| **Left side** | = | **10 mm** |
| **Right side** | = | **10 mm** |

***Recommended Tolerance:***
**± 1 mm of the nominal slice thickness**

**Each blank line represents one millimetre of slice thickness. Gray lines represent fractions of a millimetre**

## Contrast Scale

Position 1 cm ROI over water



Sample measurements based on the phantom shown

CT number in PMMA = 123.4

CT number in water = -1

CT number in PMMA - CT number in water = 124.4

Recommended Tolerance:
CT number in PMMA - CT number in water = 118 ± 10%

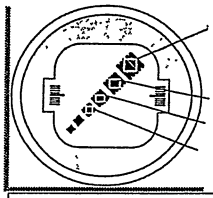
Position 1 cm ROI over PMMA





## High Contrast Spatial Resolution

**Measurement (based on phantom shown): Standard deviation in 1.6 mm bar pattern = 32 HU**



Position box cursor over largest bar pattern, and size it until fits over the 1.6mm pattern

Optional: Repeat for 1.3 pattern

Optional: Repeat for 1.0 pattern

Optional: Repeat for 0.8 pattern

Recommended Tolerance:
Standard Deviation for an ROI in the 1.6 mm bar pattern should be = 36 HU ± 20%.

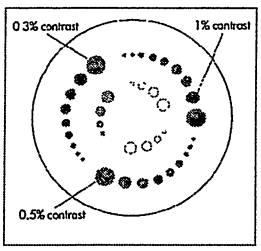




## Low Contrast Detectability

Recommended Tolerance:

The CT scanner should be capable of displaying 3 mm objects with density differences 0.5 % or less





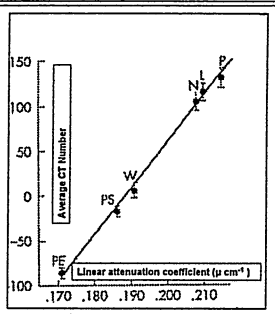



## Linearity

Recommended Tolerance:

The plotted values should demonstrate a straight line between the average CT numbers and the Linear Attenuation.

Any deviation from the straight line could indicate that inaccurate CT numbers are being generated or that the scanner is malfunctioning.

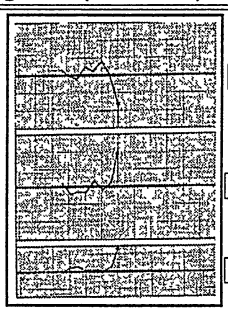







## Exercise

Evaluate the adjacent graphs and determine the cause of the problem and the possible corrective action.



Speed Index

Contrast Index

Base + Fog

Return