

Leeds Test Objects

Distributors' Meeting 2014



Leeds Test Objects
medical imaging phantoms



Welcome to York

- Thank you for taking the time to travel here to England to take part in this, Leeds Test Objects' third annual distributors' meeting.
- Following feedback from last year's meeting, we have made further improvements to the meeting. Most notably we have included more practical training sessions both today and tomorrow.
- Worldwide appeal – you have collectively travelled almost 2.6 times around the Earth to be here today!*

*distance travelled / circumference of Earth = number of times around Earth
 $65,654 / 24,901 = 2.6$

Aims

- Increase your awareness and understanding of LTO products
- Understand image quality parameters
- Practical demonstration of our phantoms
- Opportunity to discuss feedback from your market

Agenda

Monday 6th October

9:15 Meet at your hotel reception
9:30 Coffee & registration
10:00 Welcome
10:15 Paul Charnock: Why QA?
11:00 Image Quality Parameters
11:45 Tube, Radiography & Fluoroscopy

12:30 LUNCH

13:15 Mammography
13:45 Tube, Rad & Fluoro / Mammo DEMOS
14:30 Mammo / Tube, Rad & Fluoro DEMOS
15:15 MRI & Dental
15:45 OPG / MRI DEMOS
16:15 MRI / OPG DEMOS
16:45 FINISH

19:30 Meet at your hotel reception
20:00 Dinner @ Star Inn The City

Tuesday 7th October

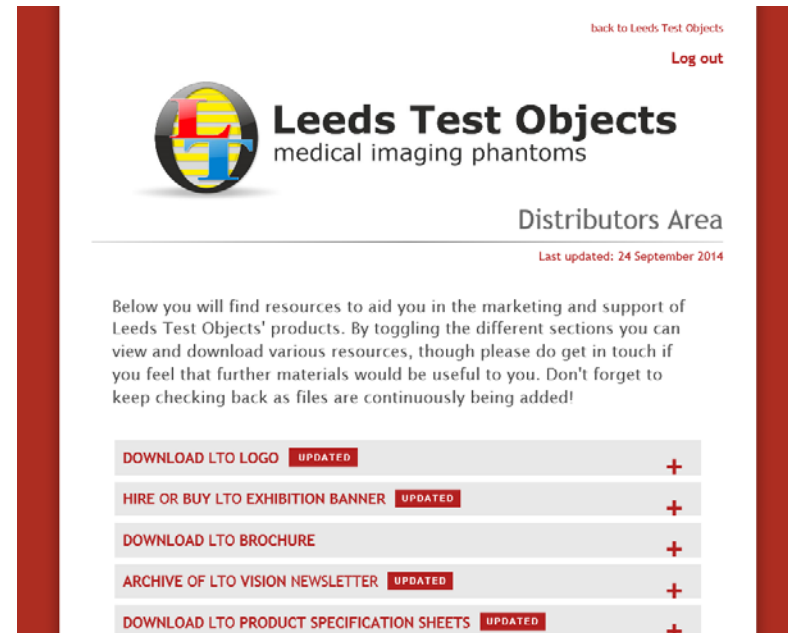
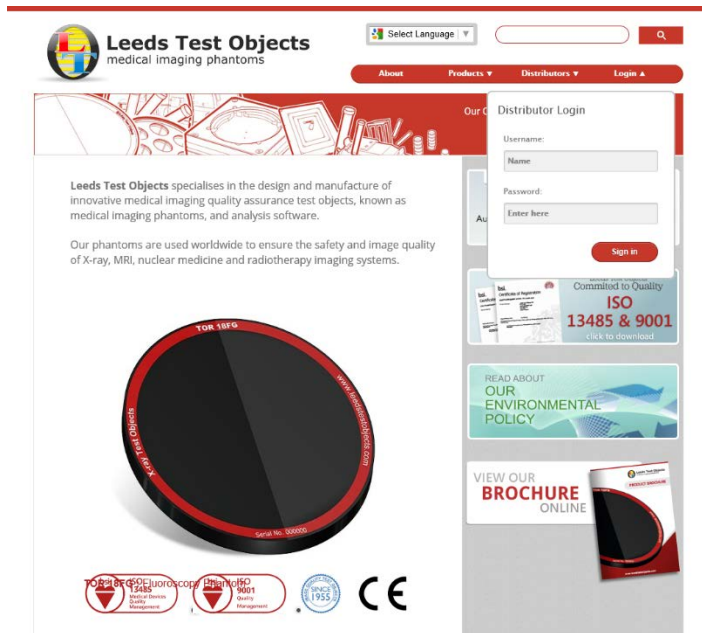
9:15 Meet at your hotel reception
9:30 Coffee & registration
10:00 Welcome – Day 2
10:05 CT
10:45 CT / Auto-Scoring Software DEMOS
11:30 Auto-Scoring Software / CT DEMOS
12:15 Nuclear Medicine

12:30 LUNCH

13:15 Radia Diagnostic
14:00 Coming Soon
14:10 Research & Development
14:20 Bespoke Phantoms
14:35 Marketing & Sales Materials
14:50 Q&A and CLOSING

Distributors' Area

All of today's presentations will be made available on the LTO distributors' area on the website
www.leadstestobjects.com



Quality Control – Why?

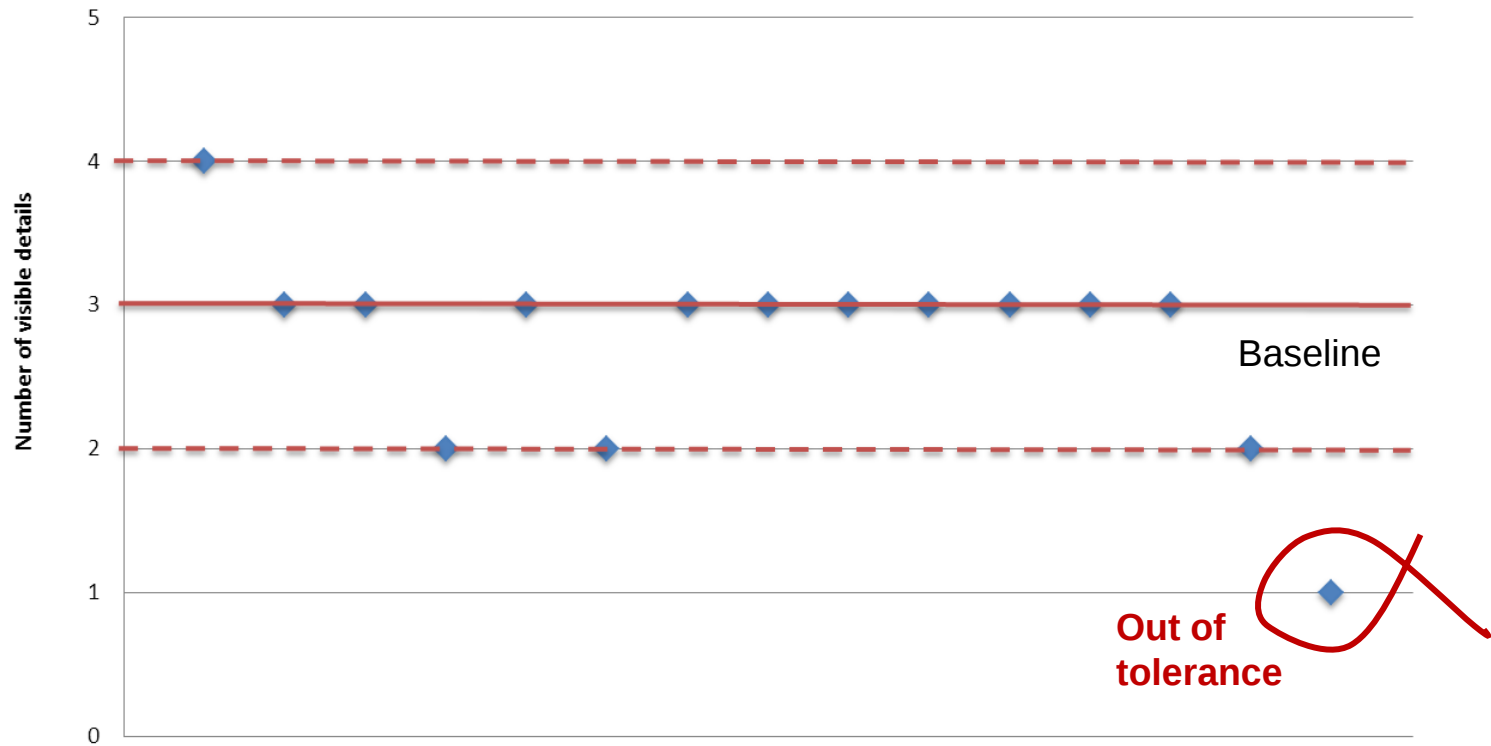
- Ionising radiation is necessary in radiology, but it is dangerous. It is essential that patient and professional doses are as low as reasonably achievable (ALARA), whilst still producing images of sufficient quality to permit accurate diagnosis.
- Measurement of image quality has an important role to play in controlling both image quality and radiation dose.

Quality Control – How?

- **Commissioning or Annual or Baseline Testing**
 - Set the baseline for image quality at installation of the machine
 - Should meet regional standard (e.g. IPEM91)
- **Routine or Constancy Testing**
 - Repeat tests to check constancy of operation compared to the baseline
 - Set a tolerance or minimum required result for each image quality parameter (see regional standards/protocols)
- Know your regional protocols. In the UK they are often created at the IPEM. They should give details of test conditions, acceptance, tolerance and suspension levels (See copy of IPEM91).

Continued...

Contrast Resolution



Typical Image Quality Parameters

- Threshold Contrast Resolution
- Spatial Resolution
- Geometric Accuracy
- Dynamic Range
- Uniformity/Noise/Homogeneity
- Artefacts
- Patient Positioning
- Contrast to Noise Ratio
- Signal to Noise Ratio
- X-ray to Light Field Alignment
- Breast Compression
- Beam Centring
- Focal Spot Size
- HVL
- Slice thickness
- Ghosting

Image Quality Parameters



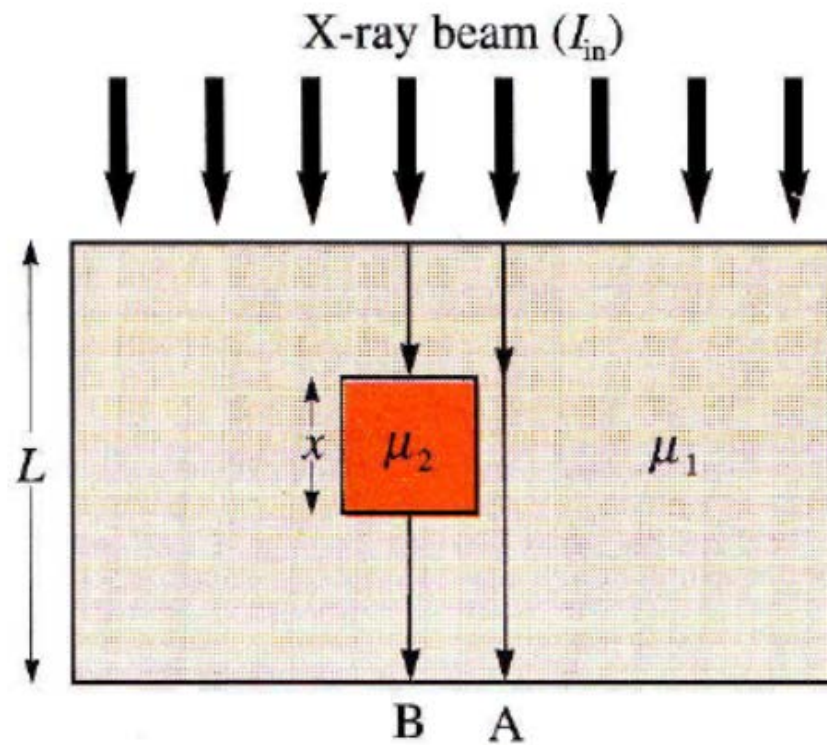
Leeds Test Objects
medical imaging phantoms



Contrast Resolution

- Contrast = $(\text{Intensity A} - \text{Intensity B}) / (\text{Intensity A} + \text{Intensity B})$
- Attenuation (μ) is due to the absorption and scatter of the x-ray beam by the material being imaged
- The attenuation coefficient of each subject material is proportional to its density and on the energy of the x-ray beam
- The attenuation of each subject material is proportional to its attenuation coefficient and the thickness (L, x) of material present
- When there is a different degree of total attenuation at points A and B, the signal received by the image receptor is proportionally different and hence there is contrast in the image (i.e. A and B are displayed at different grey levels)

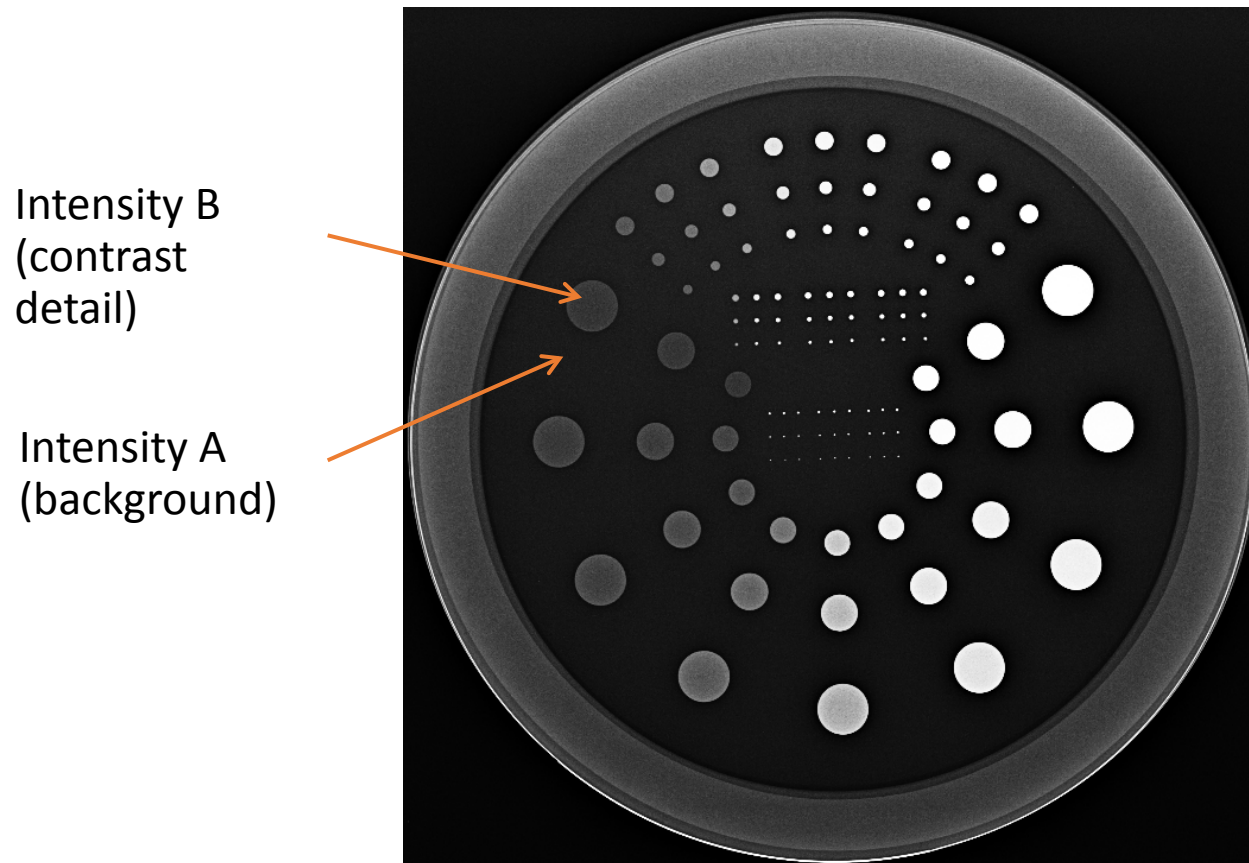
Contrast Resolution



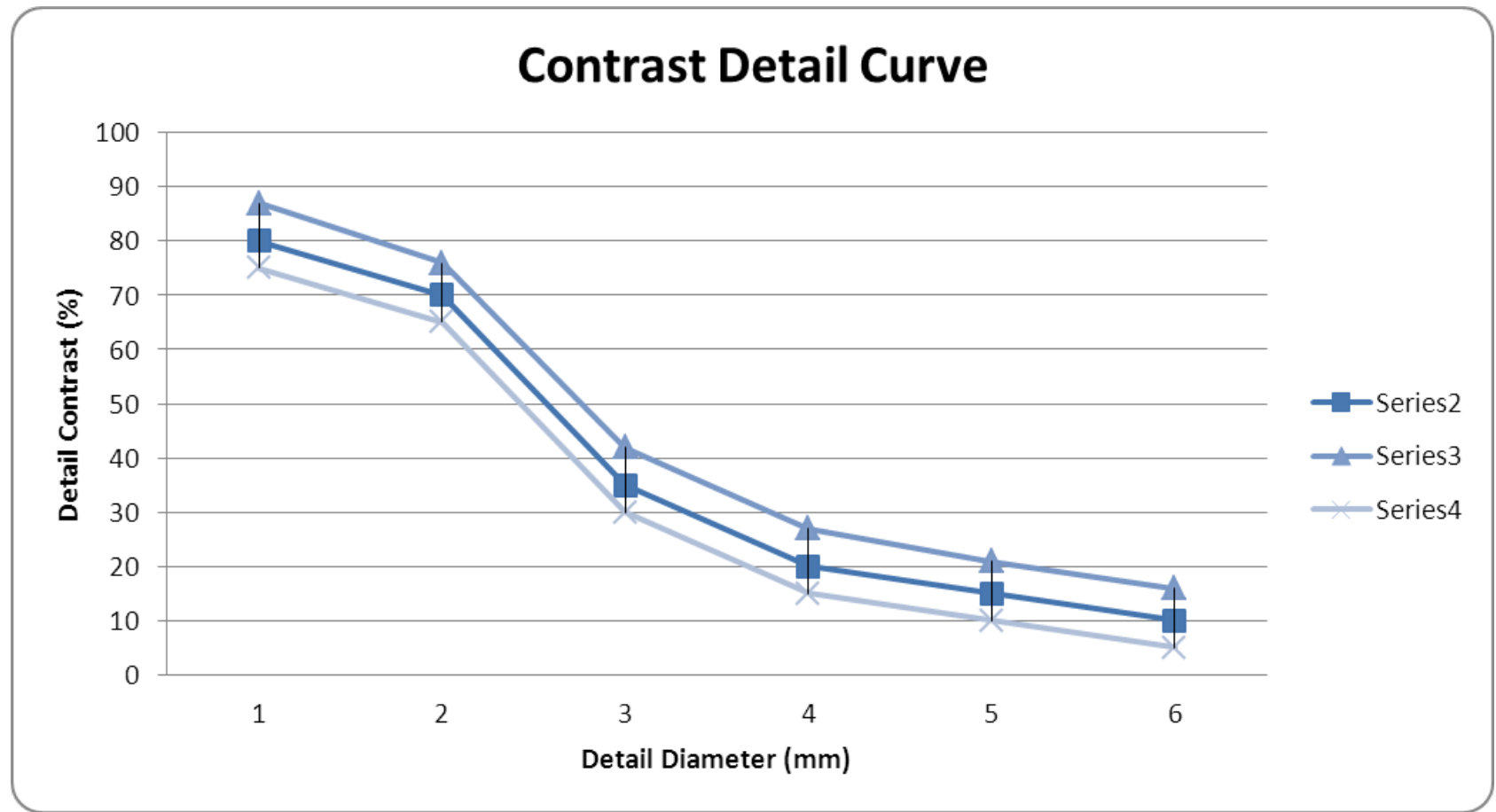
Contrast Resolution

- The more similar the amount of attenuation overlying point A and B, the more difficult it is to see/resolve the contrast. Where the signal at A and B is the same, there is zero contrast on the image
- A series of discs of different materials/thicknesses and diameter attenuate differently and thus provides a range of contrast values.
- The user counts the number of resolved (visible) discs (the contrast threshold) and sets this as the baseline. The more discs visible; the better the image quality.
- The results can be plotted on a contrast detail curve for comparison with other imaging systems, or the same system over time.

Contrast Resolution



Contrast Resolution



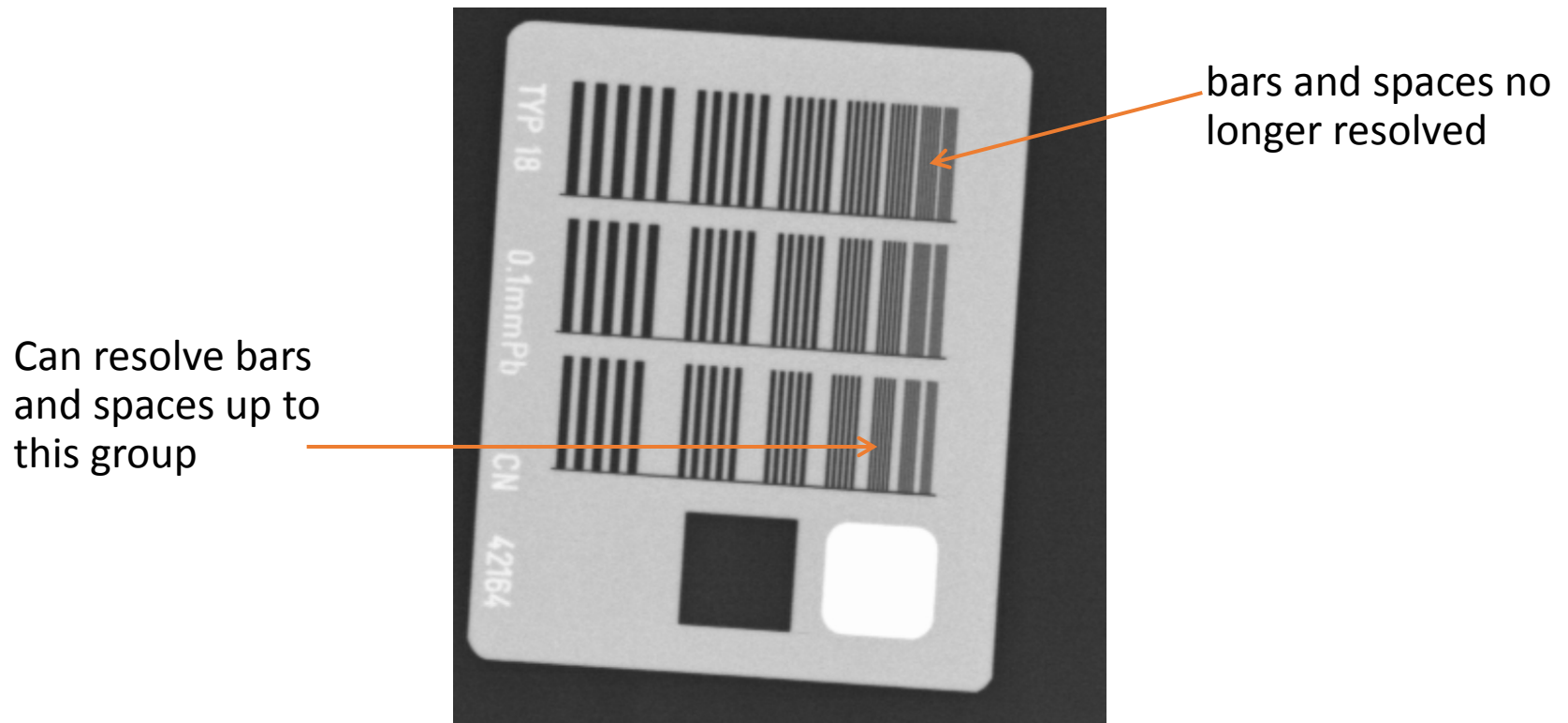
MTF / Spatial Resolution

- In the optimal case, the MTF value is 1 meaning that object and image contrast are identical. However, in reality the ability of the imaging system to accurately display fine details in close proximity is limited by the resolution of the detector elements (detector pitch), the display elements (pixel pitch), and noise from scatter.
- Can be measured using several types of test feature;
 - Line Pair Test Pattern (LP/mm)
 - Edge Spread Function (ESF)
 - Line Spread Function (LSF)
 - Point Spread Function (PSF)

Line Pairs (LP/mm)

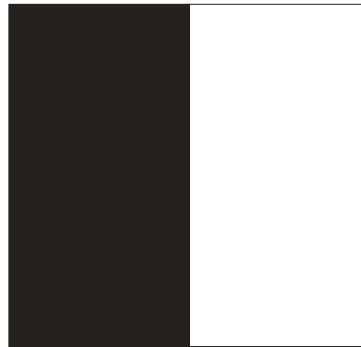
- Measured using a bar test pattern; high density material with groups of equally interspaced bars and spaces.
- The groups of bars and spaces have increasing spatial frequency. The spatial frequency is described in line pairs per millimetre (LP/mm) i.e. the number of pairs of 1 bar + 1 space that fit into one millimetre.
- The user counts the number of resolved groups (the limiting spatial resolution) and sets this as the baseline.

Line Pair Test Pattern

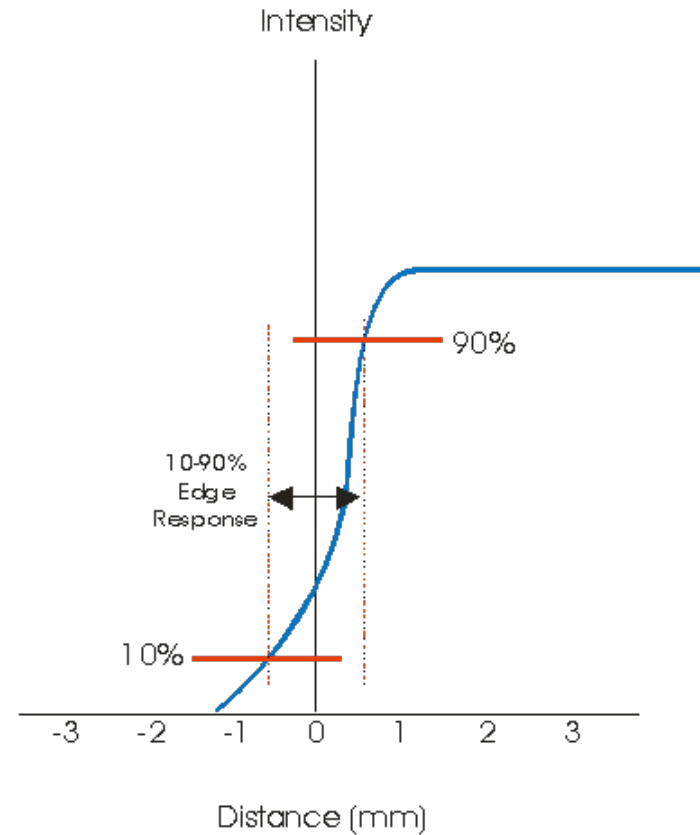


Edge Spread Function (ESF)

Ideal

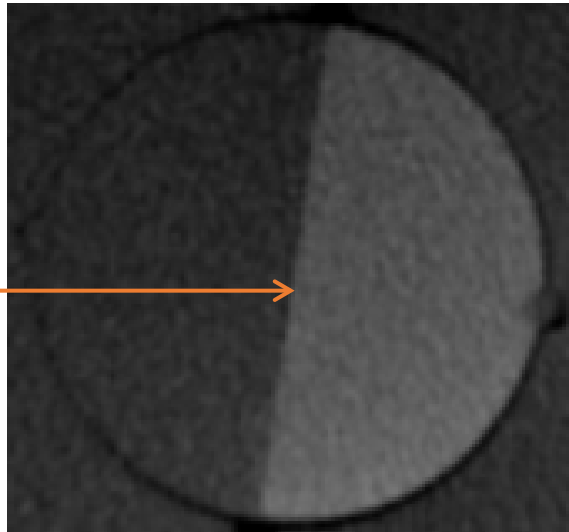


Actual



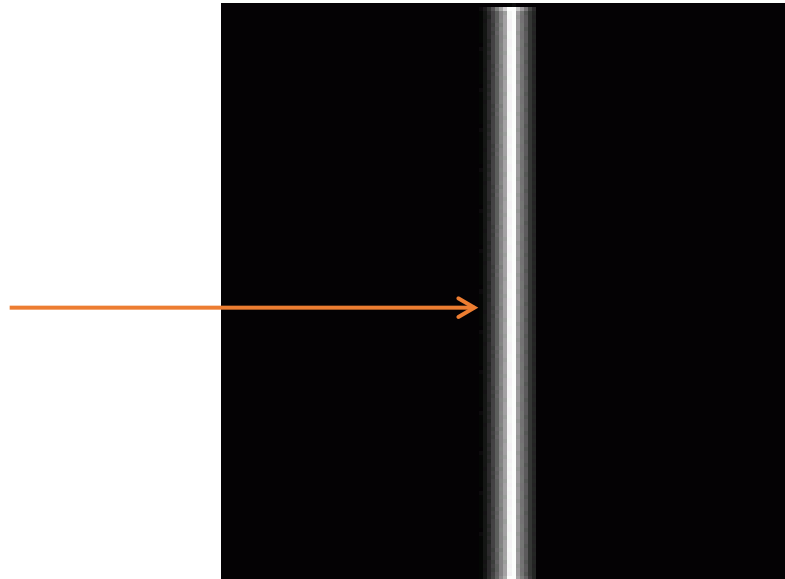
Edge Spread Function (ESF)

Measure the blur
(spread) of an ideal
edge at FWHM



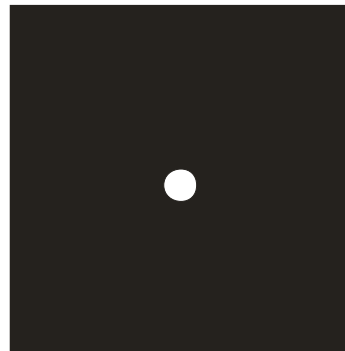
Line Spread Function (LSF)

Measure the blur
(spread) of an ideal
line at FWHM

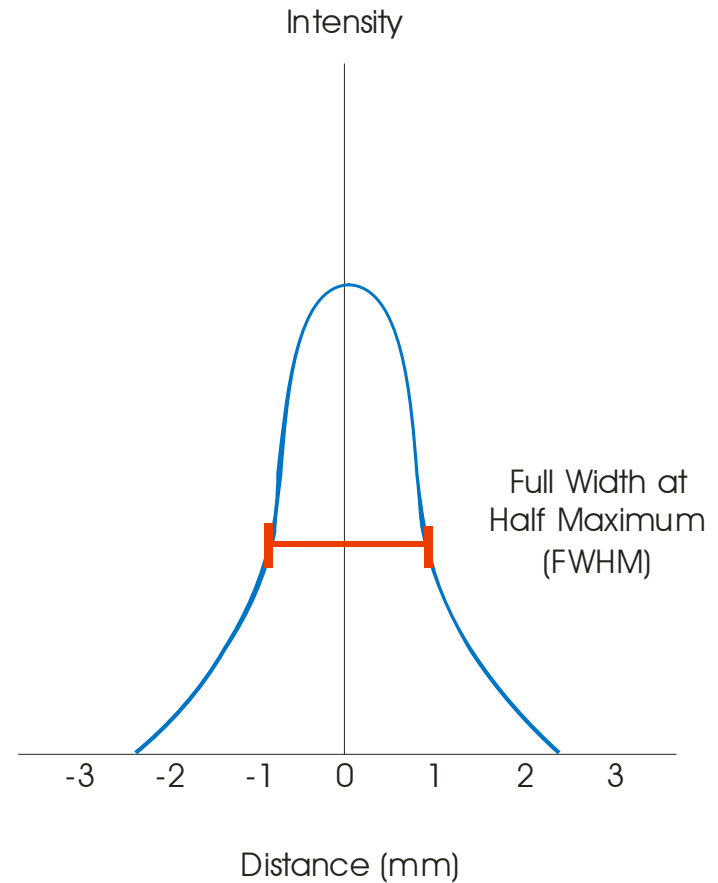
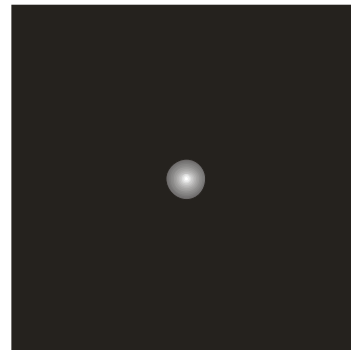


Point Spread Function (PSF)

Ideal

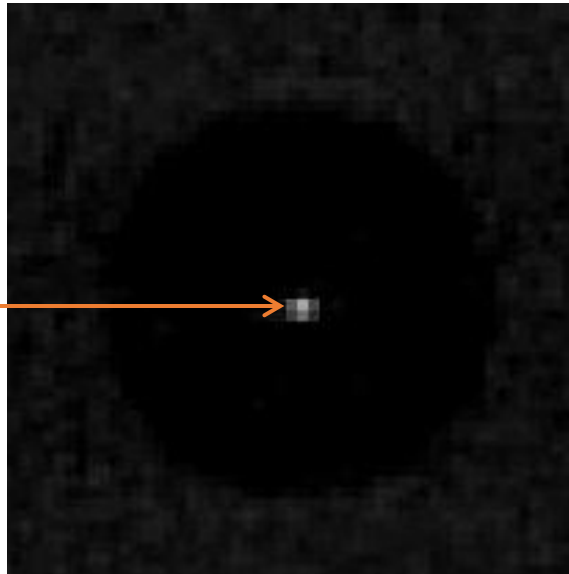


Actual



Point Spread Function (PSF)

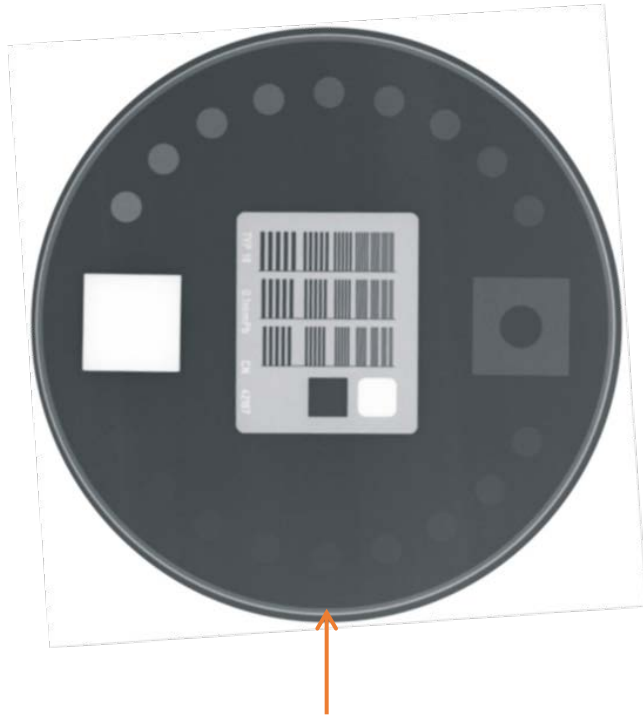
Measure the blur
(spread) of an ideal
point at FWHM



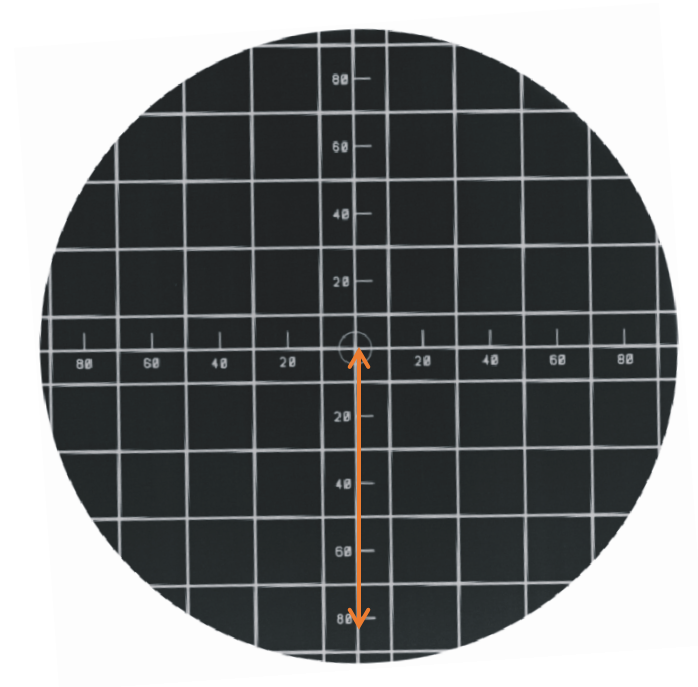
Geometric Accuracy

- The accuracy with which the geometry of the image is captured and displayed.
- Distortion is measured by the user either;
 - **subjectively** (does the circle appear circular? Is the grid skewed?)
or
 - **objectively** (measure the distance between two points of known distance e.g. an x-ray ruler).

Geometric Accuracy



High contrast circle
appears circular to
the eye

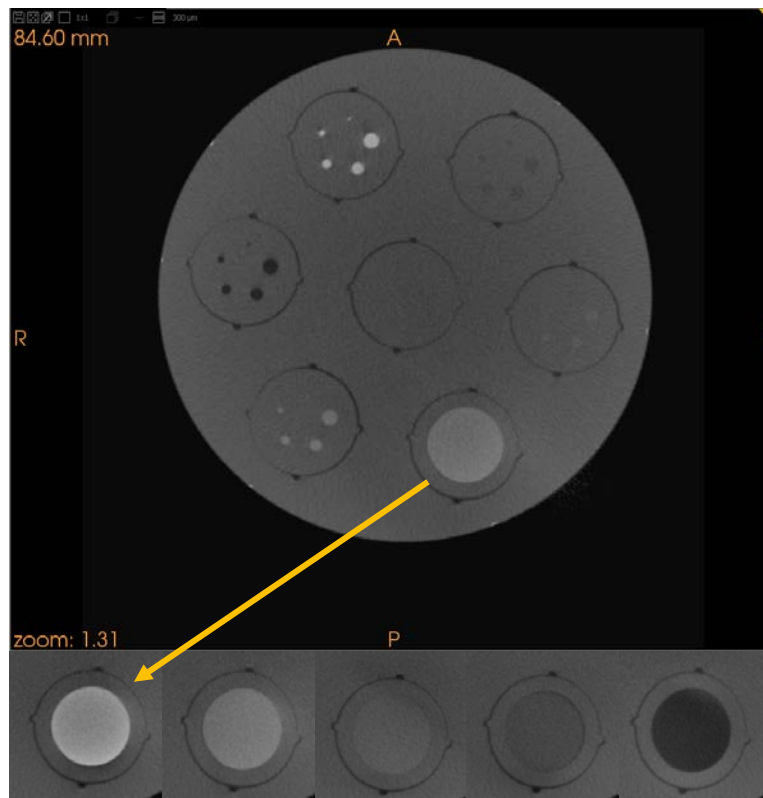


Measure image
and compare to
actual distance on
object

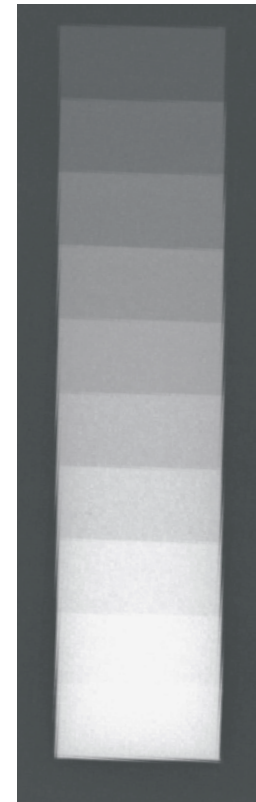
Dynamic Range

- The range of incident beam intensities over which contrast (and therefore an image) is formed. The full range of contrast is displayed on the image i.e. there is no over or under-exposure.
- Determined using a step wedge.
- The user ensures that each step of the step wedge can be resolved from its neighbouring steps.
- For CT phantoms, a range of different density materials is supplied to ensure that the CT number or Hounsfield Units (HU) measures as expected i.e. does a water-like material give the same HU as water (0 HU), does a bone-like material give the same HU as bone (+1000)?

Dynamic Range



SedentexCT IQ – PIV insert



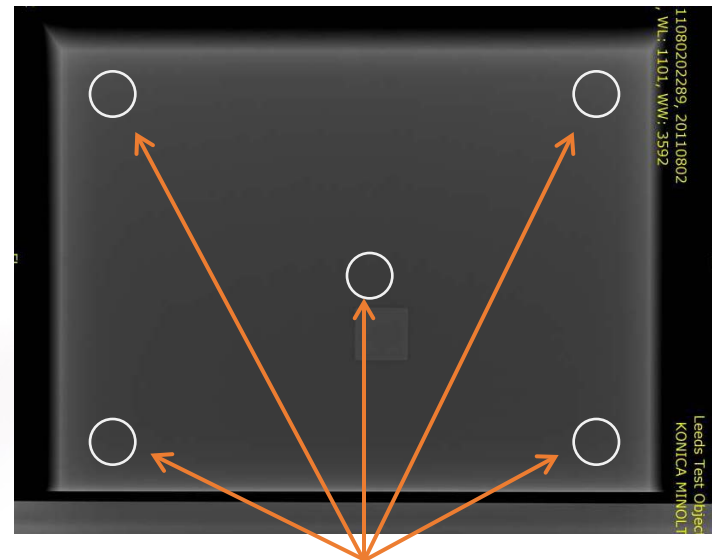
Uniformity/Noise/Homogeneity

- The ability of the image receptor to display material of identical attenuation and thickness (and scatter) in the same way across the field of view.
- Measured using a homogeneous material (usually PMMA).
- The PMMA is exposed and the resultant image is analysed to ensure that the percentage difference in mean pixel value at a region of interest (ROI) in the centre of the image and at the corners of the image is with the specified tolerance (e.g. $\pm 10\%$).
- The user captures the required data using the ROI function on a DICOM viewer, then calculates the % difference = $(\text{ROI centre} - \text{ROI corner}) / \text{ROI centre}$

Uniformity/Noise/Homogeneity



PIXMAM

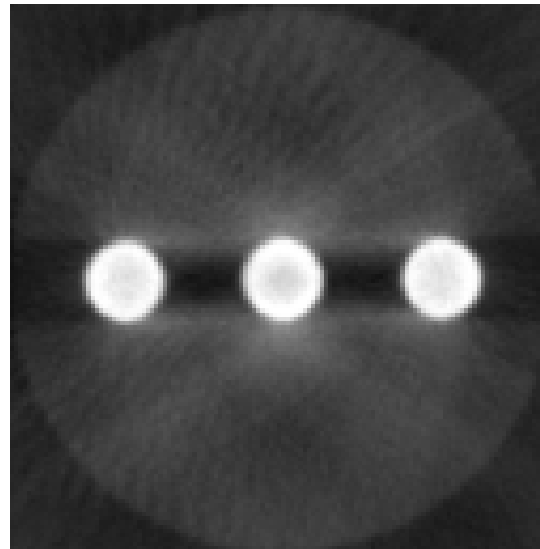


ROIs

Artefacts

- Erroneous features (lines, spots, blurring etc.) showing things that "are not really there" which appear on the image, obscuring the real object and altering the interpretation of the image (either for diagnostic or QC purposes)
- Many causes including;
 - Pieces of debris (hair, dirt, contrast agent etc.) found on the phantom, the imaging platform or the cassette
 - Flawed reconstruction of the image (digital imaging) such as stitching artefacts
 - Streaking from high density features (CT imaging)

Artefacts



Streaking Artefact (CT)

Patient Positioning Accuracy

- The ability of the patient positioning aids on the imaging system to accurately demark the correct patient position.
- In some modalities incorrect patient positioning can affect image quality. Especially critical for OPG (panoramic dental x-ray) systems.

Patient Positioning Accuracy

- OPG (panoramic dental x-ray) systems require accurate positioning of the patient in order to maximise image quality. This is because the movement of the source/detector array is based on the focal trough of an average (Caucasian) human jaw.
- OPG systems include patient positioning systems (laser alignment, chin rests, bite blocks) to aid accurate patient positioning. The accuracy of these systems should be checked.
- On an OPG image, items appearing in the focal trough will be geometrically correct. Items outside of the focal trough will be distorted.
- A series of spherical objects within and at offsets from the focal trough can be used to determine the accuracy of patient positioning.

Patient Positioning Accuracy

In the image below, the centre row of features is within the focal trough (as determined by the patient positioning system), above and below are rows of features which are offset from the focal trough by -10, -5, +5, +10 mm.

In which row are the test features geometrically accurate (i.e. spherical)?

In which rows are the test features geometrically skewed (i.e. rugby balls)?



Patient Positioning



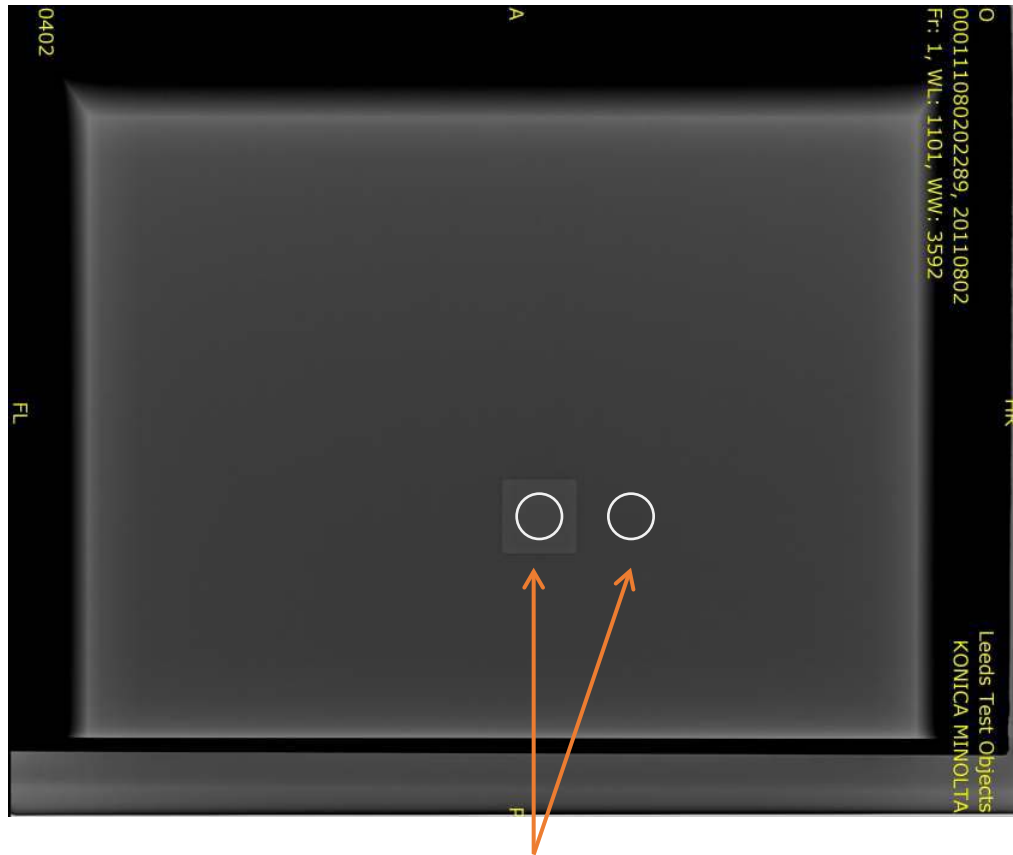
Correct
patient
position

Contrast to Noise Ratio (CNR)

- The ratio between the signal of two tissues in an image, divided by the noise in the image.
- Measure the average pixel value (m) and standard deviation (σ) in ROI 1 on the pre-processed image and in the area of the aluminium square in ROI 2.

$$CNR = \frac{|m_1 - m_2|}{\sqrt{\frac{\sigma_1^2 + \sigma_2^2}{2}}}$$

Contrast to Noise Ratio (CNR)



ROIs in PIXMAM

X-ray to Light Field Alignment

- Collimation restricts the X-ray beam to expose the desired field of view
- For convenience and to minimise patient exposure, a light and mirror system inside the collimator safely indicates the X-ray field of view
- If the mirror is out of adjustment, the light field will not match the X-ray field, causing a mis-exposure of the patient. Calibration ensures that the two fields match

X-ray to Light Field Alignment

- Using a radiopaque (visible on an x-ray) grid, it is possible to measure the alignment of the x-ray and light fields.
- Align light field to radiopaque markers, then take an exposure. Using the grid and Cross scales, determine the amount of offset.



X-ray to Light Field Alignment

Measure the displacements ('a' + 'c') and ('b' + 'd') and compare with a tolerance level;

$$a + c \leq 2\% \times \text{FFD}$$

$$b + d \leq 2\% \times \text{FFD}$$



Figure 5a: Illustration of the effective radiation field and light fields aligned correctly.

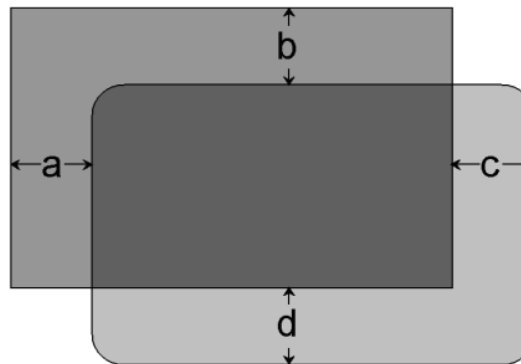


Figure 5b: Illustration of the fields not aligned correctly: misalignments shown by labelled arrows

KEY:

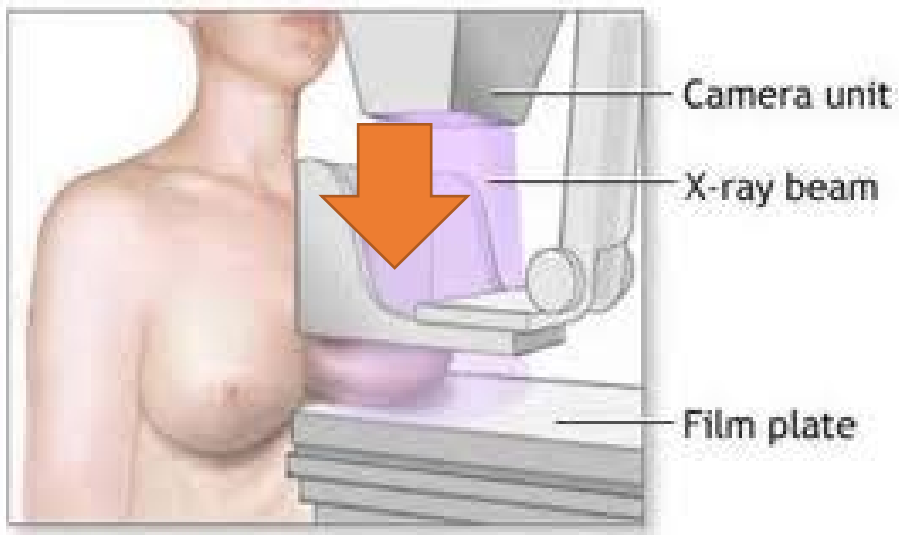
- Light grey area represents light field
- Mid-grey area represents effective radiation field
- Dark grey area represents field overlap

Breast Compression

- pressure applied to the breast during X-ray exposure in order to optimize image quality. More specifically the compression results in:
 - reduced scatter
 - reduced object to receptor distance improving resolution
 - separation of breast structures reducing overprojection
 - immobilization of the breast which reduces motion unsharpness
- Accuracy better than $\pm 2\text{N}$ (=10% of max. breast compression deviation 20N)
- Max. measurement 300N (or 30kg)
- IPEM Report 89 – p.53
- EUREF 2a.2.1.4 – p.76

Breast Compression

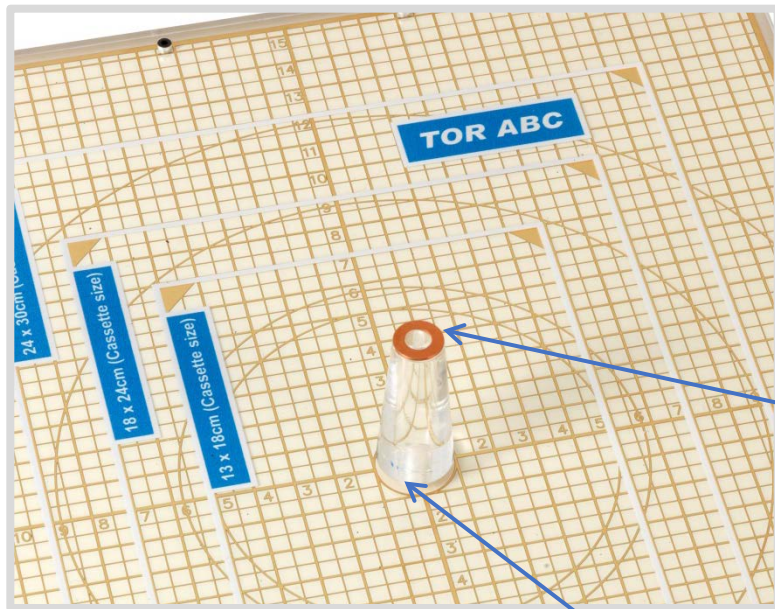
- Can be measured using a force gauge such as LTO's Coarto



Beam Centring and Angulation

- For normal radiographic procedures the x-ray beam should be centred on the required field of view, and the centre of the beam should be perpendicular to the plane of the image receptor.
- Failure to ensure this will result in errors in geometry, magnification and shadowing from overlying material.

Beam Centring



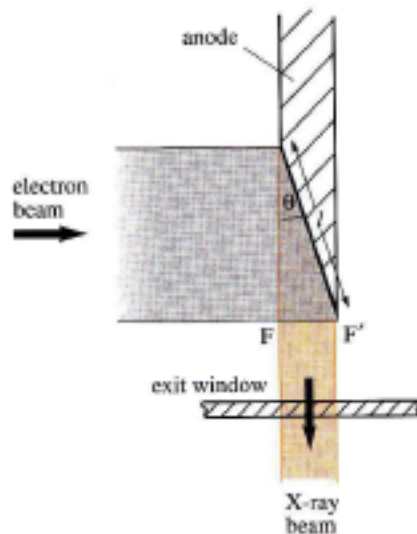
Ring (at top of tower)

Disc (at bottom of tower)



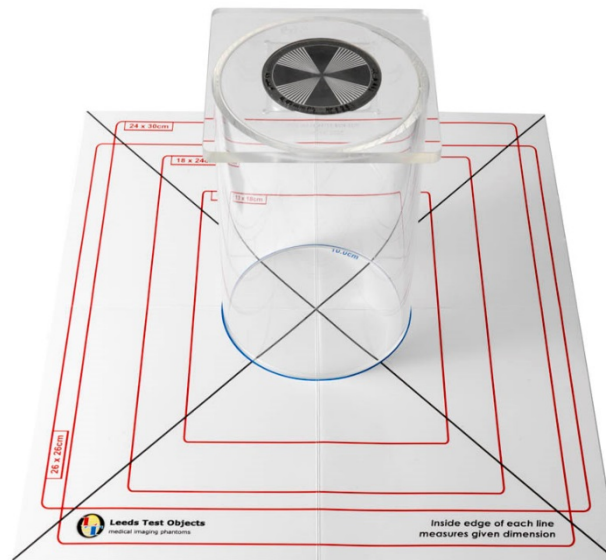
Focal Spot Size

- A small apparent source size (focal spot size) ensures minimal unsharpness and hence produces a better image quality.
- Measurement of the focal spot size is necessary to ensure constancy of operation of the imaging system. The anode can be pitted by the heat of the bombarding electrons



Focal Spot Size

- The focal spot size can be measured using a star pattern and focal spot jig (TO.FSJ).



Focal Spot Size

- The radiograph of the star pattern exhibits blurring at the limits of the focal spot. Therefore the size of the focal spot can be measured.

$$F = \frac{N}{57.3} \times \frac{D}{(M - 1)}$$

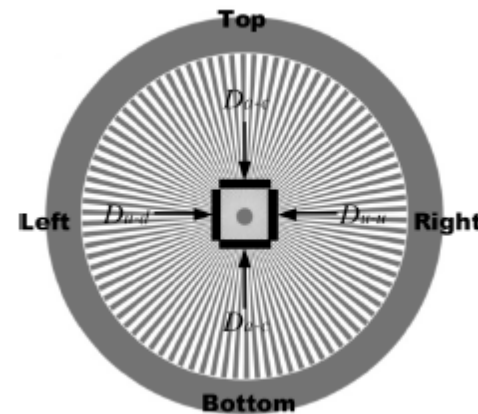
Where:

F is the focal spot size in mm

N is the angle of the star pattern line (which is marked on the test plates, 0,5°; 1,0°; 1,5° or 2,0°)

D is the diameter of the zero contrast region in mm (either D1 or D2)

M is the magnification



Half Value Layer (HVL)

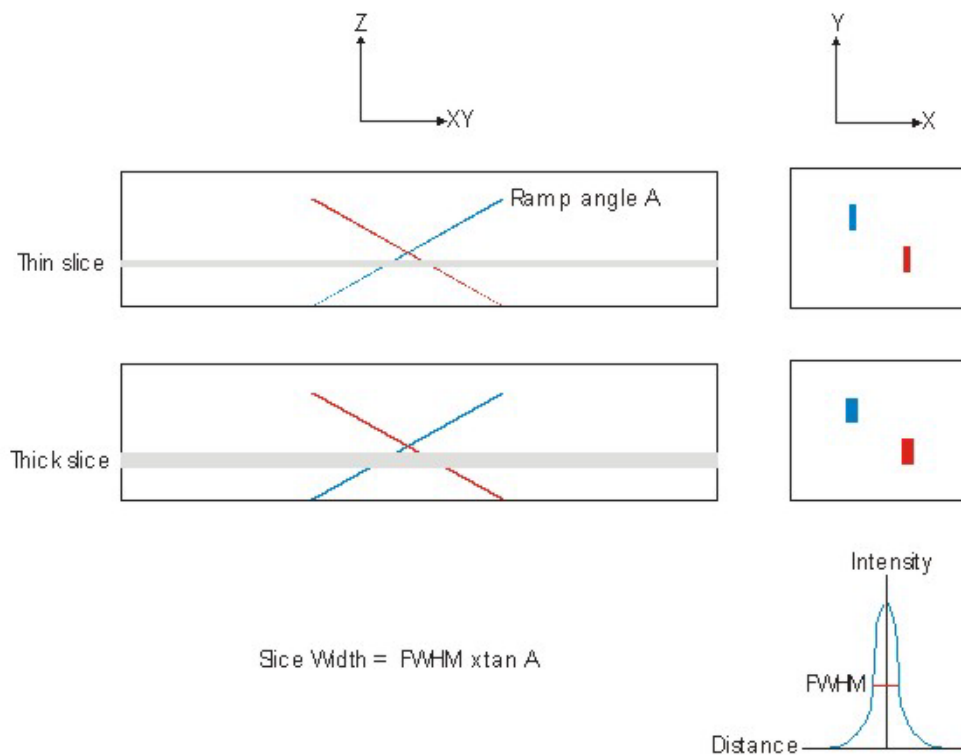
- A measure of the actual penetrating power of the x-ray beam. Required because attenuation coefficients are correct only for a single energy beam. In reality most beams are a spectrum of energies.
- HVL is the amount of material that is required to reduce the intensity of a (narrow) x-ray beam by half.
- Normally expressed in aluminium thickness.
- The mean energy of the x-ray beam is increased following the 1st HVL, so the 2nd HVL will be higher as the higher energy beam is more penetrating.

Half Value Layer (HVL)

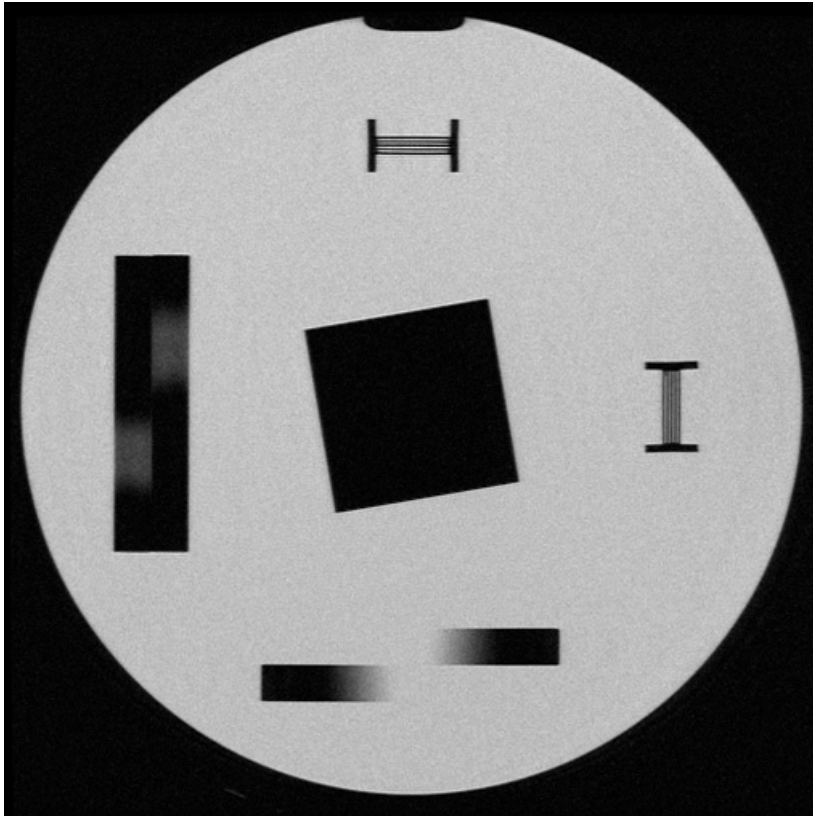
- Measured using a set of high purity Aluminium filters in conjunction with a stand to hold the filter at the correct FFD and to house a dosimeter.
- Many dosimeters can measure HVL without the need for a set of filters.

Slice Thickness (CT, MRI)

- Calculated using a pair of ramps of thickness less than the nominal slice width



Slice Thickness (CT, MRI)



Automatic Exposure Control (AEC)

Automatic Exposure Control (AEC) is an exposure termination device. The intention of the AEC termination device is to provide consistent x-ray image appearance regardless of the patient size and shape.

An AEC system uses a radiation ionisation detector "AEC chamber" positioned between the patient being x-rayed and the x-ray detector. X-rays passing through the patient also pass through the AEC chamber before they strike the x-ray detector.

The total dose of radiation received by the AEC chamber rises throughout the exposure until it matches a pre-set threshold. At this point the x-ray exposure is terminated.

The Leeds Product Family



Leeds Test Objects
medical imaging phantoms



Our Products

- Our range of products includes phantoms for the following modalities:
 - Fluoroscopy
 - Radiography
 - Mammography
 - Dental Radiography
 - CT
 - MRI
 - Nuclear Medicine

In 2015

- Radiotherapy and Planning
- Ultrasound

Brochures

- Our handy pocket sized brochure and our on-line brochure and product specifications (see website) give you more detail of our range of products.



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