

Protocol for the QA of Computed Radiography Systems

Commissioning and Annual QA Tests

This document describes a series of tests to assess CR plate and reader performance. The tests are intended to detect artefacts and monitor image quality and sensitivity. The tests are split into the following categories,

- commissioning tests
- annual QA tests.

All the tests described should be performed on all available reader systems.

1 Commissioning Tests

List of equipment

- Tape measure
- Adhesive tape
- 1.5 mm Copper filtration (>10 x 10 cm)
- TO20 threshold contrast test object
- Resolution test object (e.g. Huttner 18)
- M1 geometry test object or lead ruler
- Contact mesh
- Ionisation chamber
- Small lead or Copper block (~5 x 5 cm)
- Steel ruler

In all tests described the unique plate identification code should be recorded.

1.1 Monitor & laser printer set-up

Purpose: To test that devices used to view the image data are of sufficient quality to maximise the information available to the observer.

- a) View an image of the SMPTE test pattern on each of the monitors used for reporting clinical images or for the QA tests described here.
- b) Decide whether the 5% on 0% and 95% on 100% details are visible.
- c) Score the resolution bars at centre and corners of the image.

If images are viewed from hard copies then the laser printer should also be assessed.

Tolerances: The 5% on 0% and 95% on 100% details should be clearly visible. The horizontal and vertical resolutions should not differ by greater than 20%.

1.2 Dark Noise

Purpose: To assess the level of noise inherent in the system

- a) Erase an image plate and without making an exposure read it using the following parameters

Agfa: S=200,
examination type - 'System Diagnosis'
processing - 'Flat Field'

Fuji: Readout mode - 'Fixed'
S = 10000
L = 1

Kodak: Mode - 'pattern'

- b) Examine the images visually for uniformity and record the sensitivity index value (i.e. Agfa- Ig M, Fuji- Sensitivity S, Kodak – Exposure Index).
- c) Record a mean pixel value using region of interest analysis (for Fuji systems see appendix for details of how to measure a mean pixel value).
- d) If possible either archive or print the image for future reference.

For Agfa and Fuji systems a uniform artefact free image should be expected. Kodak systems add a collector profile to the image to compensate for non uniform collection efficiency across the plate. This results in series of bands appearing across the image.

1.3 Erasure cycle efficiency

Purpose: To test that minimal residual signal (ghosting) remains on a plate after readout and erasure.

- a) Position a plate on the table at ~1.5 m. Set a 10 cm x 10 cm field and position a piece of attenuating material (e.g. Copper or lead) at the centre of the CR plate. Expose at 80kVp, 25mAs with no filtration.
- b) Read the plate (the readout parameters are not important).
- c) Re-expose the plate with a 9 cm x 9 cm field centred on the same point on the plate with no attenuating material in place, using 80kVp, 0.5mAs and no filtration.
- d) Read the plate using the following parameters

Agfa: S=200,
examination type - 'System Diagnosis'
processing - 'Flat Field'

Kodak: Mode - 'Pattern'

Fuji: Readout mode - 'Semi Auto'
L = 1 or 2

- e) Visually inspect the resultant image for any remnant of the previous image, using region of interest analysis if available (i.e. Agfa or Kodak).

Tolerance: There should be <1% (remedial) difference between the pixel values in the ghosted region and the surrounding areas. A suspension level of <5% is set.

1.4 Sensitivity Index calibration

Purpose: To assess the accuracy of the plate exposure values calculated using exposure indicators.

- a) Position an ion chamber at ~1.2 m from the focus (see figure 1) and at least 30 cm above the table (record the actual distances). Collimate to the ion chamber.

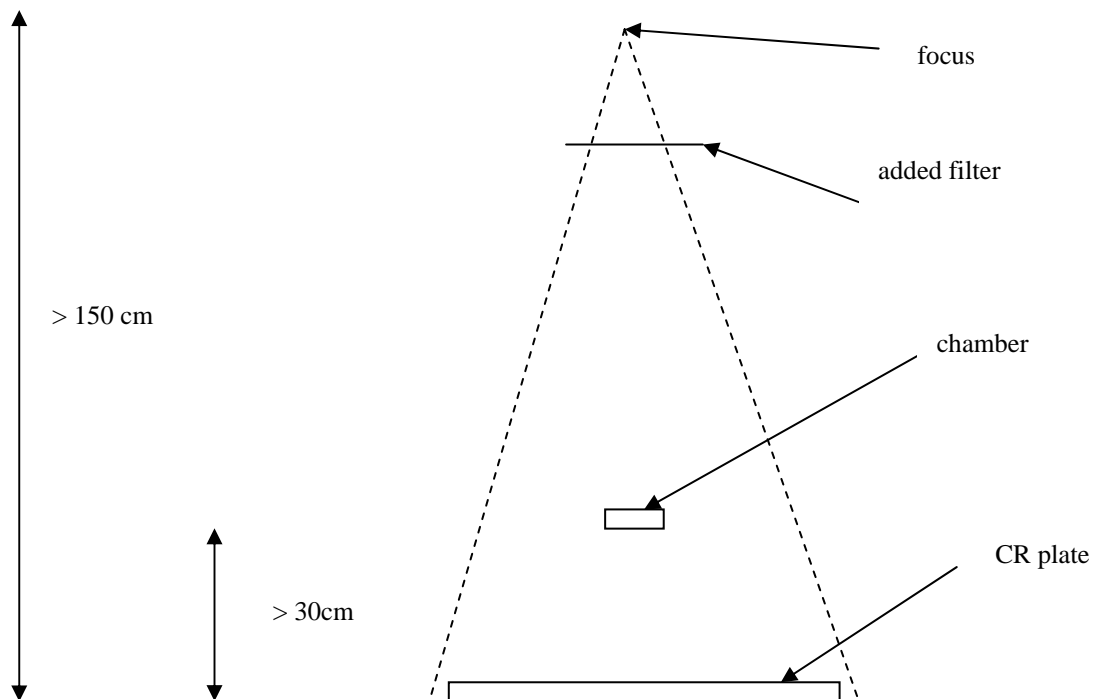


Figure 1: Set-up for exposure index calibration

- b) Expose the chamber such that the inverse square law corrected dose to the table level is approximately $10\mu\text{Gy}$, using the following beam qualities

CR system	Filtration	Tube Voltage (kVp)
Agfa	1.5mm Cu	75
Kodak	0.5mm Cu +1mm Al	80
Fuji	none	80

- c) Record the measured dose and repeat twice.
- d) Remove the chamber and place a 24 x 30 cm cassette on the table. Set the field to just cover the cassette. Mark the corners of the cassette on the table with transpore, so that the cassette can be easily repositioned.

N.B. An alternative dosimetry set up can be used: Position the chamber on a 20cm foam pad to determine the mAs required to deliver the required plate dose. Then position the plate on the foam pad. This negates the need for an inverse square law correction.

- e) Expose the plate to a known dose of $\sim 10\mu\text{Gy}$ as above.
- f) Read the plate out as described below

Agfa: no delay between exposure and readout, $S=200$, system diagnosis/flat field processing and linear sensitometry.

Kodak: A 15 minute delay between exposure and readout, readout on Pattern mode body part.

Fuji: A 10 minute delay between exposure and readout, readout using semi-auto. $L=1$ or 2

- g) Record the sensitivity index, and calculate the indicated exposure using the following equations.
- h) Repeat twice and take a mean value of the indicated exposures.

For Agfa systems the indicated exposure, E_{Agfa} , in μGy , for a 200 speed readout is given by

$$E_{Agfa} = 99.3 (10^{(\lg M - 3.2768)}) \quad (1)$$

For Kodak systems the indicated exposure, E_{Kodak} , in μGy , is given by

$$E_{kodak} = 8.7 \times 10^n, \text{ where } n = \left(\frac{EI - 2000}{1000} \right) \quad (2)$$

For Fuji systems the indicated exposure, E_{fuji} , in μGy , is given by

$$E_{fuji} = \frac{1740}{S} \quad (3)$$

Tolerance: The indicated exposure should agree with the measured exposure within 20%.

1.5 Sensitivity Index consistency

Purpose: To assess the variation of sensitivity between plates, and set a baseline for monitoring system sensitivity for future QA testing

- a) Place a 24 x 30 cm CR cassette on the couch and set up as described for test 1.4 (see figure 1).
- b) Expose the plate using the beam qualities described in test 1.4, to a known dose of $\sim 10 \mu\text{Gy}$. The dose to the plate calculated from inverse square law corrected ion chamber measurements should be recorded.
- c) Read the plate as described for test 1.4, but with minimal delay (or short fixed-e.g.5 mins.) between exposure and readout for any system.
- d) Record the sensitivity index, and calculate the indicated exposure using equations 1-3. Repeat three times for the same plate.

- e) Repeat this test for all plates if time allows (making only one exposure to each plate).

Tolerance: The variation in the calculated indicated exposures should not differ by greater than 20% between plates. The measurements repeated on the same plate should be used to lay down a baseline for future QA tests.

1.6 Uniformity

Purpose: To assess the uniformity of the recorded signal from a uniformly exposed plate. A non-uniform response could affect clinical image quality.

- a) Expose a plate as described for test 1.5 but with half the mAs.
- b) Rotate the plate through 180° about the vertical axis and re-expose using the same parameters (this should largely cancel out the non uniformities due to the anode heel affect).
- c) Read the plate as described for test 1.5 with no delay between exposure and read out.
- d) Visually inspect all images obtained in test 1.5 for uniformity and artefacts. Likely artefacts include dust on the plate or readout optics, and scratches on plates.
- e) The uniformity of the image obtained in 1.6b should be assessed using region of interest analysis if available, to measure the mean pixel values in positions a-e, as indicated in figure 2 below. For Fuji systems where ROI analysis is not available, read uniformly exposed plates using the FIX mode with S-200 and L=2. Print the images onto laser films and measure the optical densities in the positions indicated in figure 2.

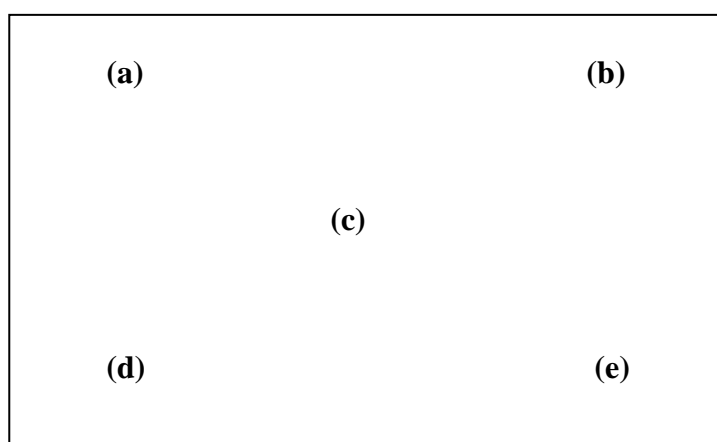


Fig 2: Positions of the ROI's for uniformity tests

Tolerance: The images should not have obvious artefacts. If measuring uniformity from film the maximum variation in optical densities should be less than 10%. Using region of interest analysis, values should be within a range of 10% of each other.

1.7 Scaling errors

Purpose: To assess the accuracy of software distance indicators and check for distortion.

- a) Position the M1 test object directly on the centre of a CR cassette at > 150 FDD.
- b) Expose at 50-60 kVp with no filtration and 10mAs.

N.B. A lead ruler could be used in place of the M1 test object. If so 2 exposures should be made with the ruler placed in first the scan direction then the subscan direction.

- c) Read out plate using processing as for test 1.4 but without delays between exposure and readout.
- d) If digital callipers are available in the software, check that the pixel size is correctly calibrated for the particular image receptor size.
- e) Using the distance measuring software tools measure the dimensions (x and y) of five central squares in both fast and slow scan directions. Calculate the aspect ratio x/y.
- f) Reposition the test object over the edge of the plate as indicated in figure 3 and repeat steps b to d.

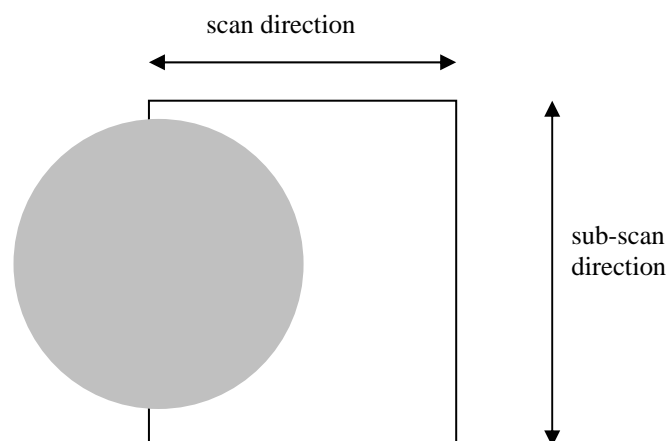


Figure 3

- g) Along the edge of the plate measure the horizontal (x_1) and vertical (y_1) sizes of two squares as indicated in figure 4. Calculate the aspect ratio x_1/y_1 .

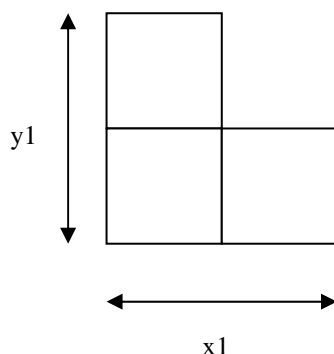


Figure 4

Tolerance: The measured distances x and y should agree within 3% of the actual distances. All calculated aspect ratios should be within 1.00 ± 0.03

1.8 Blurring

Purpose: To test for any localised distortion or blurring of the image.

- With the contact mesh in place expose and read a plate as described for test 1.7.
- Visually inspect the image for distortions. If distortion occurs clean the plate and repeat.
- Repeat for at least two other plates.
- Repeat with a fine mesh if available.

Tolerance: No blurring should be present. If blurring is present on all plates this suggests the reader is at fault, whilst imperfections in individual plates may also lead to blurring. If blurring remains on a region of a plate after cleaning it should not be used clinically.

1.9 Limiting Spatial Resolution

Purpose: To test the high contrast limit of the systems ability to resolve details.

- Place a general purpose cassette on the couch with the Huttner test object positioned at its centre aligned at 45° to its edges.
- Set 50 kVp expose the cassette to ~ 10 mAs.
- Readout the plate using the following parameters

Agfa: S=200,
examination type - 'System Diagnosis'
processing - 'Flat Field'

Fuji: Readout mode - 'fix' with L=2 and S=200

Kodak: Mode - 'Pattern' with raw data and no edge enhancement

- d) Adjust the window level and magnification to optimise the resolution. Score the number of resolvable groups of lines from the screen. Look up the corresponding resolution.
- e) Repeat the measurement twice with the resolution test object placed at a slight angle to the first the lateral or then the longitudinal axis.
- f) Repeat this process for all available image plate resolutions.
- g) If possible either archive or print the image for future reference.

Tolerance: For the 45° angled test object the resolved line pairs per mm should be $>1.2/2p$ where p is the pixel dimension in mm. In the scan and subscan directions the limiting resolution should be $>0.85/2p$. These measurements should be used to set a baseline for future QA tests.

N.B. A Huttner test object with line spacings up to 8 lp.mm^{-1} may be required.

1.10 Threshold Contrast Detail Detectability

Purpose: To monitor image quality by assessing the visibility of low contrast details.

- a) With the tube, plate, and copper in the same positions as for the sensitivity tests, place the TO20 (or equivalent) test object on the plate. Collimate down to the size of the test object.
- b) Set 75 kVp and an mAs to deliver $\sim 4 \mu\text{Gy}$. Read the plate using the following parameters.

Agfa: S=200,
examination type - 'System Diagnosis'
processing - 'Flat Field'

Fuji: Readout mode - 'semi-auto' with test/sensitivity GA=1

Kodak: Mode - 'Pattern' with raw data and no edge enhancement

- c) Ascertain whether clinical images are most commonly viewed soft or hard copy. If they view hardcopy, adjust the window to optimise the visibility of the details, ensuring that background noise is perceptible, and print the image out on the largest film size. View the image on a masked light box, and score each detail size using fixed distance viewing (<1m). If images are viewed softcopy, score them on a reporting workstation optimising window and level settings for each detail size.
- d) Calculate an image quality factor, IQF,

$$IQF = \frac{1}{n} \sum_{i=1}^n \frac{H_T(A_i)}{H_T^{ref}(A_i)} \left[\frac{D_{ref}}{D} \right]^{0.5} \quad (4)$$

where

$H_T(A)$ = threshold contrast detail index values calculated from the image,
 $H_T^{ref}(A)$ = threshold contrast detail index values calculated from a reference image of a system known to be in good adjustment
 D = the dose to the image plate
 D_{ref} = the dose to the image plate for the reference image
 n = the number of details in the test object.

- e) Repeat this test for two other imaging plates and also for a single plate at exposures of $\sim 1\mu\text{Gy}$ and $\sim 12\mu\text{Gy}$.
- f) If possible either archive or print the images for future reference.

Tolerance: The results of this test are used to set a baseline for future QA tests. Results could be compared to those from other similar systems if available.

1.11 Laser beam function

Purpose: To assess laser beam scanline integrity and jitter

- a) Place a steel ruler slightly angled to the subscan direction on a large cassette.
- b) Expose at ~ 80 kVp, 150cm FSD and an mAs to deliver an incident exposure of $\sim 50\mu\text{Gy}$.
- c) Using the software magnify the image x10. Select a narrow window width such that the image appears largely polarised to black or white. This should allow the edge to be easily differentiated from the background. Laser beam jitter can be evaluated by examining the edge of the ruler on the image.

Tolerance: The edge should be continuous across the full length of the image. Stair step characteristics should be uniform across the length of the image. Regions of over or undershoot of the scan lines indicate a timer or laser beam modulation problem.

1.12 Moiré Patterns

Purpose: To test for the presence of Moiré pattern artefacts caused by grids.

- a) Place a CR cassette in the bucky such that the scan lines are vertical to the gridlines. The cassette should be 1.5m from the focus, and the collimation should cover the whole plate.
- b) Expose at 70 kVp using the AEC with 1.5 mm of copper in the beam, and the grid in place.
- c) Read the plate as described for test 1.4 but with minimal delay, with the highest possible sampling rate.
- d) Visually inspect the image for Moiré line pattern artefacts.
- e) Repeat with the CR cassette positioned in the bucky such that the scan lines are horizontal to the gridlines.
- f) Repeat for all buckies and grids that may be used with the CR system, including any grids used in mobile radiography.

Tolerance: No Moiré patterns should be visible. If Moiré patterns are visible with a particular grid, it should not be used with the CR plates. The cause of Moire patterns may be the failure of the motion of moving grids or insufficient grid density.

2 Annual QA tests

The following routine QA tests should be performed approximately annually

- 1.1 Monitor set-up/laser film set-up
- 1.3 Erasure cycle efficiency
- 1.5 Sensitivity index consistency/sensitivity (for 1 plate of each size)
- 1.6 Uniformity
- 1.7 Scaling errors
- 1.8 Blurring
- 1.9 Limiting resolution (45° only)
- 1.10 TCDD (only 4 μ Gy).

The tests should be performed as described in the previous section. Table 1 below summarises the relevant remedial levels where these are different to those described for commissioning.

Test	Remedial Level
sensitivity index consistency (sensitivity)	baseline \pm 20% exposure equivalent
limiting resolution	baseline \pm 20%
TCDD (Quality Index)	baseline \pm 30%

It should be noted that TCDD and limiting resolution are subjective measures. Some effort should therefore be made to train scorers to score to similar thresholds.

Appendix A – Measuring a mean pixel value using a Fuji CR system

Reduce the window width to 1, so that the image has only pixels appear as either one of just two levels, black or white. Adjust the level until approximately half the pixels are black and half are white. This level value is the mean pixel value of the image.

References

[1] Draft Report of Task Group #10, American Association of Physicists in Medicine, Acceptance Testing and Quality Control of Photostimulable Storage Phosphor Imaging Systems, August 1998

[2] British Institute of Radiology, 'Assurance of the quality in the diagnostic imaging department', 2001, ISBN 0-905749-48-0

[3] IPEM draft CR QC protocol

[4] Samei E, Seibert JA, Willis CE, Flynn MJ, Mah E, Junck KL, 'Performance evaluation of computed radiography systems', 2001, Med.Phys. Vol28 (3) p361-371.

