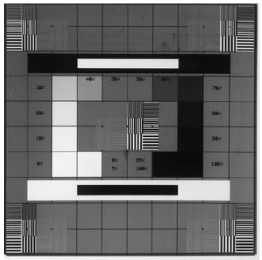

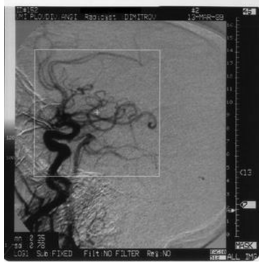

IMAGE QUALITY ASSESSMENT IN X-RAY FLUOROSCOPIC SYSTEMS - PRACTICAL QC

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OBJECTIVES

- Principles of Fluoroscopic Quality Control (QC)
- QC equipment and test objects
- AEC and patient dose assessment
- Scattered radiation assessment
- Assessment of contrast scale and image geometry
- Assessment of image noise and contrast resolution
- Spatial resolution
- Influence of window parameters
- Assessment of homogeneity
- Main problems in image quality

Main steps for a QC survey in Diagnostic Radiology

- General X-ray tube & generator assessment
- Image quality assessment
- Specific parameters assessment
- Quality Control protocols

Fluoroscopy delivers very high patient dose.
This can be illustrated with an example:

The electrical energy imparted to the anode during an exposure is

$$A = C_1 . U_a . I_a . T$$

The X-ray tube anode efficiency is

$$E = C_2 . Z. U_a$$

From the two equations follows that the energy produced in a single exposure will be

$$X = C . A . E = C . Z . (U_a)^2 . I_a . T = (C. Z) . kV^2 . mAs$$

Radiography of the lumbar spine (with parameters 80 kV, 30 mAs):

$$X = k. 80.80.30 = k. 192{,}000$$

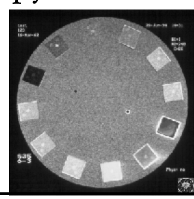
Fluoroscopy - 3 minutes Barium meal (with parameters 80 kV, 1mA)

$$X = k. 80.80.1.3.60 = k. 1{,}152{,}000$$

In this example fluoroscopy delivers approx. 6 times more X-ray energy (dose)

QC equipment for Fluoroscopy

- Dosimeter - dose rate - (flat ion. chamber)
- Image quality test objects (at least for contrast scale, limiting spatial resolution, II field size and contrast delectability)
- Attenuators (at least 1mm Cu)
- Special test objects for Digital Fluoroscopy
- (Oscilloscope)



Automatic Brightness Control (ABC/ABS)

- Check fluoroscopy timer-guard (2 min.)
- Measure the maximum dose delivered
- Measure Image Intens. entrance dose with standard beam attenuation (1mm Cu) for all II field sizes (inter-equip. comparison)

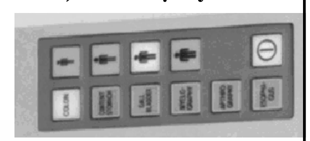
II field size cm	Read kV	Read mA	Dose rate (1mm Cu) (mR/min)	(mGy/s)
30	75	0.9	10.9	0.0016
23	75	2.4	24.8	0.0036
17	75	4.2	40.2	0.0058

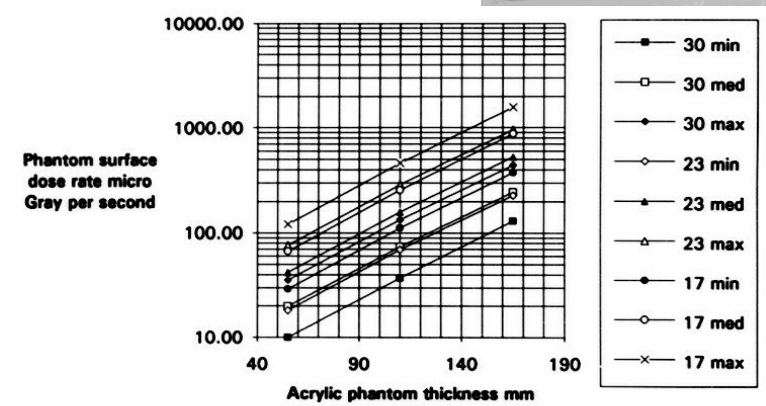
ABC - skin entrance dose

- Test all II field sizes (cm) and dose settings (patient thick.) with various attenuation (perspex ~ 50-200mm)
- Maximal patient skin entrance dose should not exceed 100 mGy/min
- II entrance dose measured together with the skin entrance dose (separately from 1mm Cu)

Field size cm	Read kV	Read mA	Phantom thick' mm	I.I. entrance dose (mR/min)	(mGy/s)	Phantom surf' dose (mR/min)	(mGy/min)
30	75	0.3	55	29.9	0.004	264	2.27
	75	1.4	110	43.3	0.006	1010	8.69
	75	5.6	165	68.5	0.010	3880	33.37

Typical phantom surface (patient entrance) doses - **µGy/sec** during fluoroscopy with ABC





Scatter radiation in fluoroscopy

when the II is above the patient table the scatter radiation to staff is lower

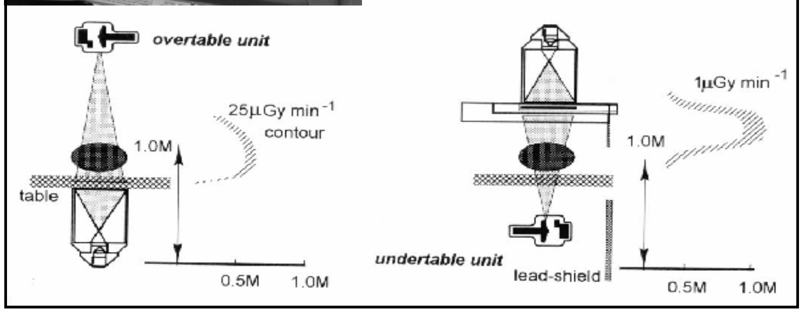
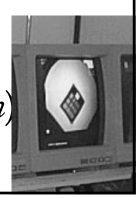


Image quality assessment

- Contrast scale
- Image uniformity and distortion
- Spatial (high contrast) resolution
- Noise (and Video signal)
- Contrast (low contrast) resolution
- Overall Image Quality (Contrast/Detail Diagr.)
- IQ dependence of "window" and matrix
- IQ dependence of reconstruction/frame rate
- IQ dependence of image processing (F,Sub)
- Artefacts

Fluoro analogue image quality assessment:

- Subjective assessment (eyes condition)
- Attenuate the X-ray output (1mm Cu)
- Check all II field sizes with all test objects
- Adjust TV monitor (contrast/brightness)
- II visible field size/distortions/homogeneity
- II noise, contrast resolution (contrast/detail)
- II lim.spatial resolution (*no attenuation*)
- (Video signal)



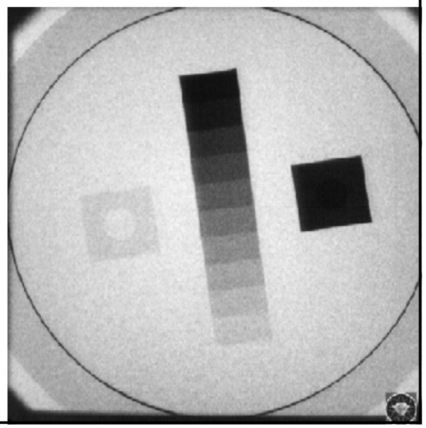
- Attenuating the X-ray tube output with 1mm Cu filter
- Selecting appropriate Test Objects (TO)
- Normally performed by two physicists

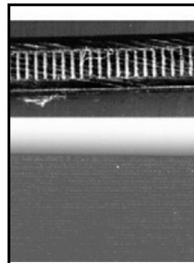


Assessment of Contrast Scale (TV monitor adjustment)

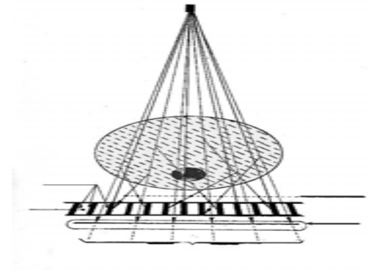
All test objects should be placed at the front of the II

(the presence/absence of the anti-scatter grid must be noted in the QC protocol)





Scattered radiation and anti-scatter grid

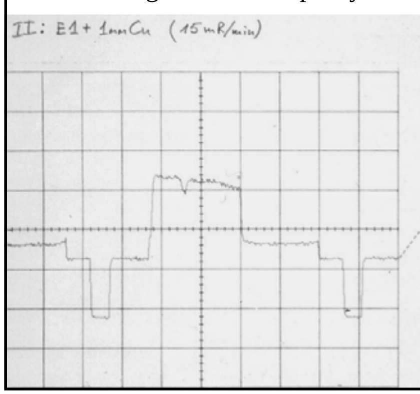


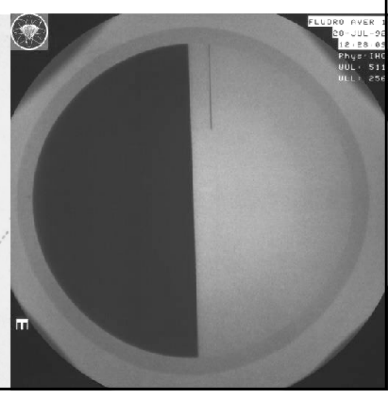
With anti-scatter grid

Without anti-scatter grid

Assessment of Sensitivity of the Imaging system (video signal assessment)

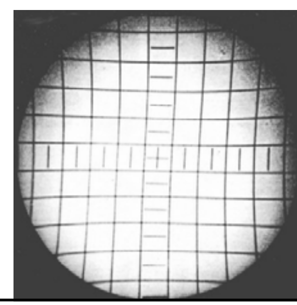
- use of a TV line selector is recommended
- do not measure the TV monitor input when assessing digital fluoroscopic systems

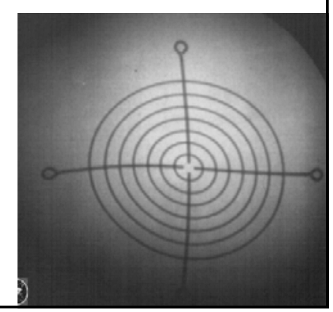




Assessment of Image Geometry and Sizing

- measuring of all II field sizes (horiz. and vert.)
- assessment of image distortion



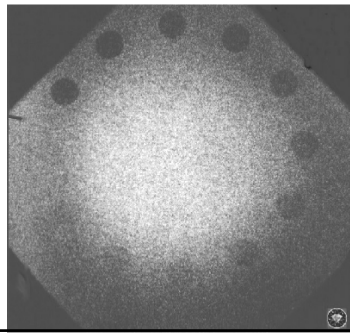


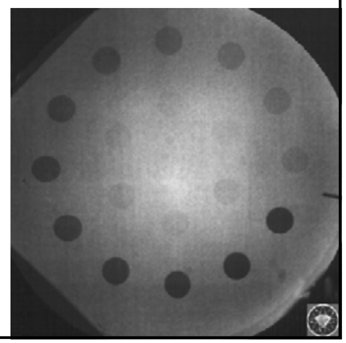
Assessment of Image Noise

- for all II field sizes

- proper adjustment of “Window” (and record of WW, WC !) is essential in digital fluoroscopy

- record the kV/mA displayed for all image quality tests!

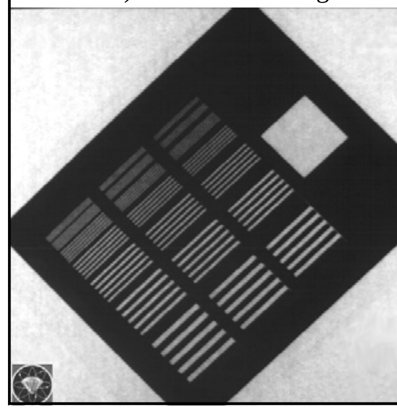




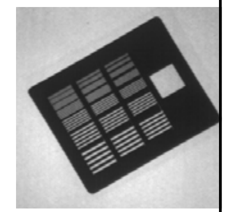
Assessment of Limiting Spatial Resolution (Unsharpness) !! REMOVE the 1mm Cu filter !!

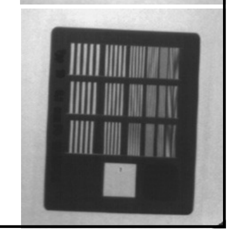
- for all II field sizes

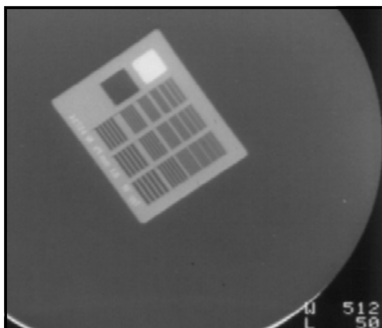
- proper adjustment of “Window” (and record of WW, WC !) is essential in digital fluoroscopy



Place the test object at 45^0 to TV raster!



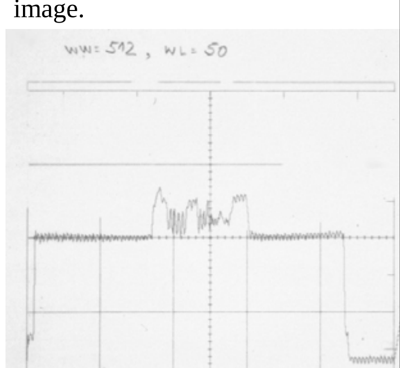


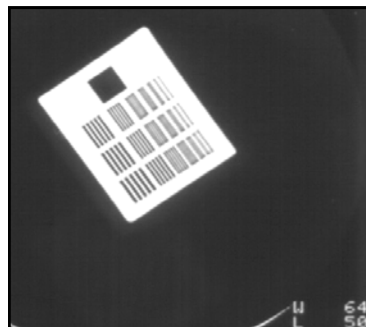


WINDOW PARAMETERS

IN DIGITAL FLUOROSCOPY

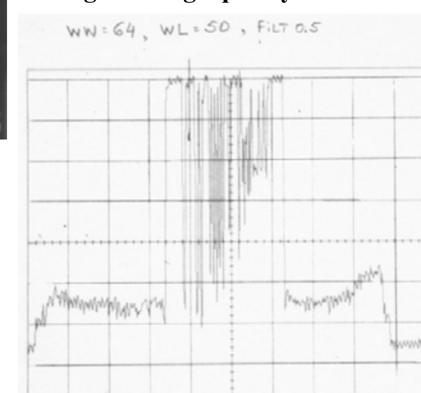
WW changes the image contrast - its amplitude is well seen from the video signal of the displayed image.





Small WW increases the contrast dynamic, what lead to visual increase of the spatial resolution.

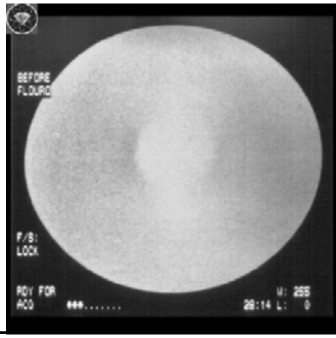
WW and WC change dramatically the digital image quality!

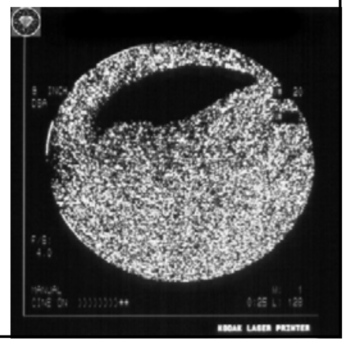


Example of II non-uniformity

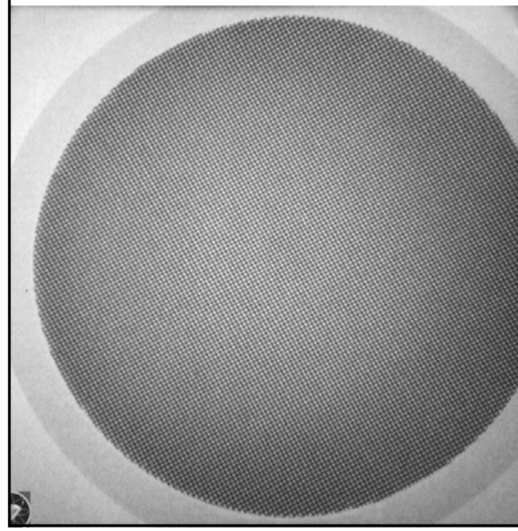
Note that using default WW and WC (on the left image) does not visualise the non-uniform region.

The substantial II defect is seen only with a narrow WW and precise WC (the right image).

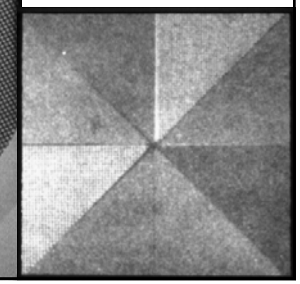




Assessment of II uniformity (non-uniformity)



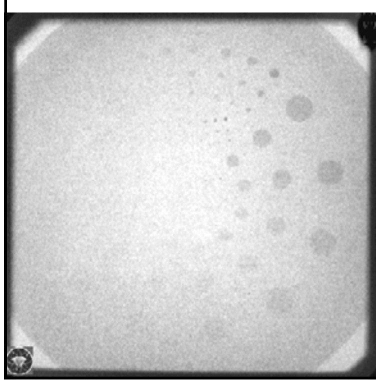
The Mesh “uniformity” test objects can also be used for assessment of spatial resolution.

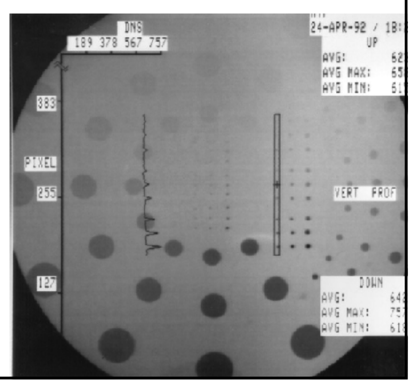


Overall Image Quality Assessment (Contrast Resolution) !! WITH 1mm Cu filter !!

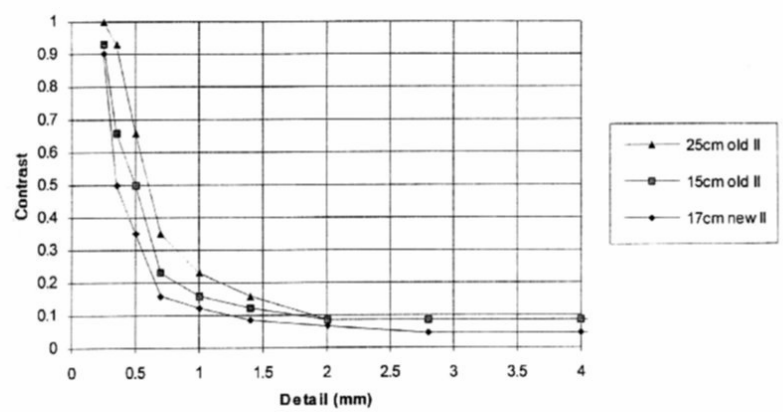
- for all II field sizes

- proper adjustment of “Window” (and record of WW, WC !) is essential in digital fluoroscopy





Typical Contrast/Detail diagram for the *Leeds TO 10* phantom for various II filed sizes (old and new II)



Fluoro digital image quality assessment

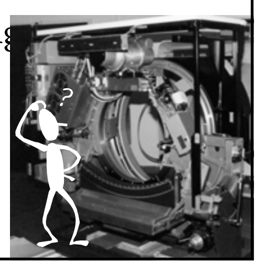
- Objective/subjective assessment
- Perform set-up/calibration of imaging chain
- Record the Window parameters for each measurement (width/centre ; contr/bright)
- Record image processing parameters used (filters, matrix, masks, subtract., frame rate)
- Use the built-in measuring functions and densoprofile
- Special (quantitative) functions
- Other specific parameters (Grey level/Dose, etc)

Non-uniform image and loss of contrast most often due to:

- Non-uniform cassette/film contact
- Poor film developing
- TV contrast/brightness misadjustment
- Non-uniform dose distribution
- Exhausted Image Int.,TV camera, monitor
- Incorrect Window parameters
- Frame speed problem, incorrect filtering

Blurred image & loss of spatial resolution most often due to:

- Exhausted X-ray tube (Broad focus)
- Incorrect bucky/grid centring
- Poor film developing
- Defocused II/TV camera
- Small matrix, incorrect filtering
- Incorrect Window parameters
- Noisy imaging chain



Effectiveness of Quality Control in Fluoroscopy

S Tabakov, A Cvetkov

Effectiveness of Quality Control in Fluoroscopy

QC statistics made on the basis of :

60 X-ray non-digital fluoroscopic units (surveyed over 3 consecutive years) – in the period 1992-1999 (no QC made to these equipment for some 2 years before 1992)

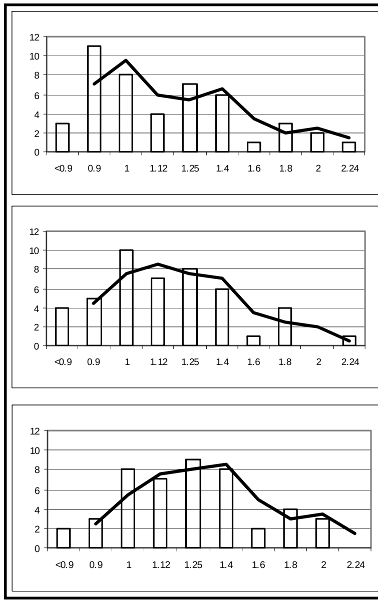
- The equipment has been tested using normal protocols (Emerald and IPEM recommendations) and Leeds Test Objects

-All equipment had been in use for less than 10 years

- Image Intensifiers are grouped in 2 FoV groups: “normal” (18-23 cm) and “magnified” (12-17 cm)

- All QC data had been presented to the X-ray service engineers

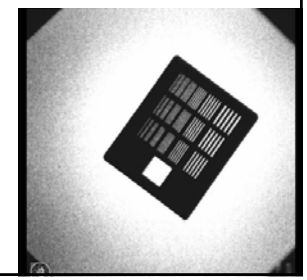
- The analysed parameters (statistics with SPSS package) are presented on the slides to follow



Spatial Resolution of “normal” II (45 equip.) - TREND

(lp/mm measured with Huttner Test Object)

Slow improvement (increased sp. res.)



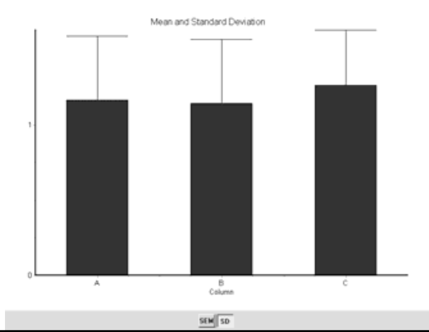
Spatial Resolution of “normal” II (45 equip.)

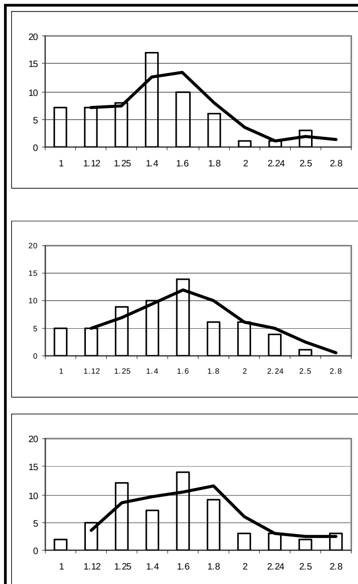
(lp/mm measured with Huttner TO)

Years 1 >2>3 : P<0.01 (very significant)

Spatial resolution shows slow increase with time.

Friedman Test (Nonparametric Repeated Measures ANOVA)

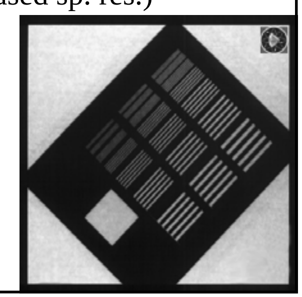




Spatial Resolution of “magnified” II (59 equip.) - TREND

(lp/mm measured with Huttner Test Object)

Slow improvement (increased sp. res.)



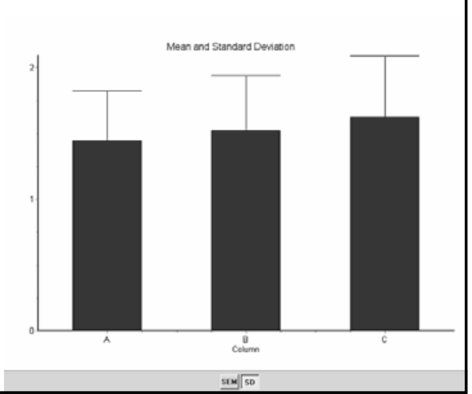
Spatial Resolution of “magnified” II (59 equip.)

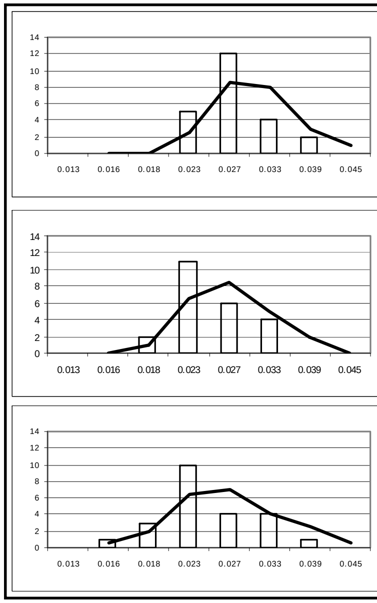
(lp/mm measured with Huttner TO)

Years 1 >2>3 : P<0.01 (very significant)

Spatial resolution shows more noticeable increase with time.

Friedman Test (Nonparametric Repeated Measures ANOVA)

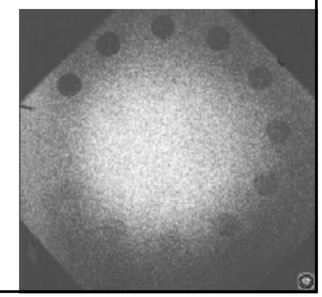




Noise of “normal” II (22 equip.) - TREND

(% contrast measured with N3 Leeds Test Object)

Slow improvement (decreased noise)



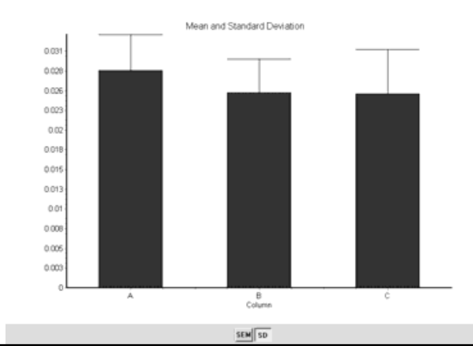
Noise of “normal” II (22 equip.)

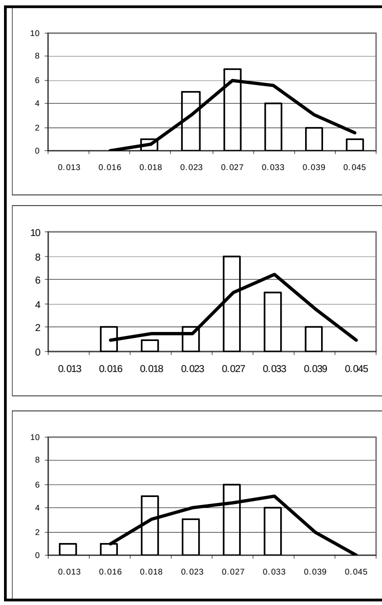
(% contrast measured with N3 Leeds TO)

Years 1 >2>3 : P<0.05 (significant)

Noise level shows decrease with time.

Friedman Test (Nonparametric Repeated Measures ANOVA)

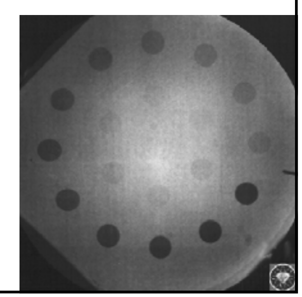




Noise of “magnified” II (20 equip.) - TREND

(% contrast measured with N3 Leeds Test Object)

Slow improvement (decreased noise)



Noise of "magnified" II (20 equip.)

(% contrast measured with N3 Leeds TO)

Years 1 >2>3 : P<0.01 (very significant)

Noise level shows decrease with time.

Friedman Test (Nonparametric Repeated Measures ANOVA)

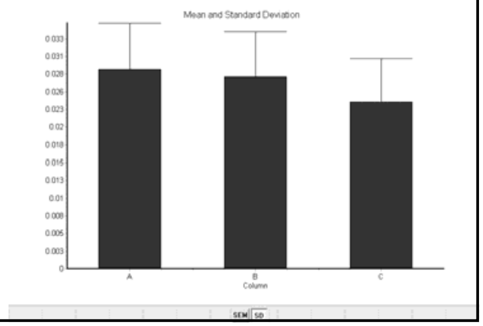


Image Intensifier entrance dose for "normal" and "magnified" II

(mR/min measured with 1mm Cu)

3 Years ("normal", 27 equip) : P~0.05 (not very significant)

3 Years ("magnified", 30 equip) : P>0.05 (not significant)

In most 3 years periods measurements of II entrance doses have been made at different distances from Image Intensifier and re-calculation of the results is not possible.

Due to this reason pairs of two consecutive years (measurements) have been used.

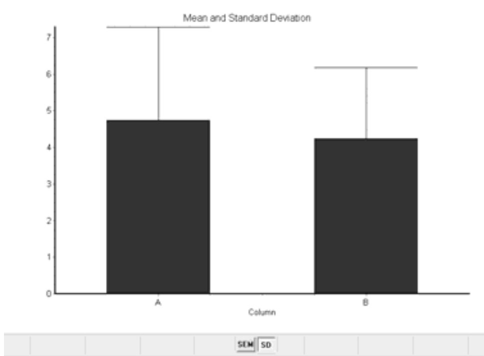
II entrance dose "normal" II (34 equip.)

(mR/min measured with 1mm Cu)

2 Years : P~0.05 (not very significant)

II entrance dose slowly decreases.

Paired t test



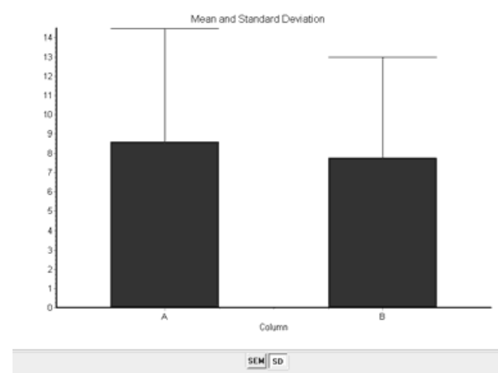
II entrance dose "magnified" II (39 equip.)

(mR/min measured with 1mm Cu)

2 Years : P<0.05 (significant)

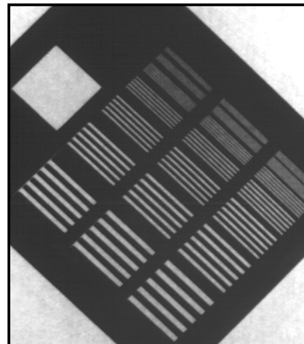
II entrance dose slowly decreases.

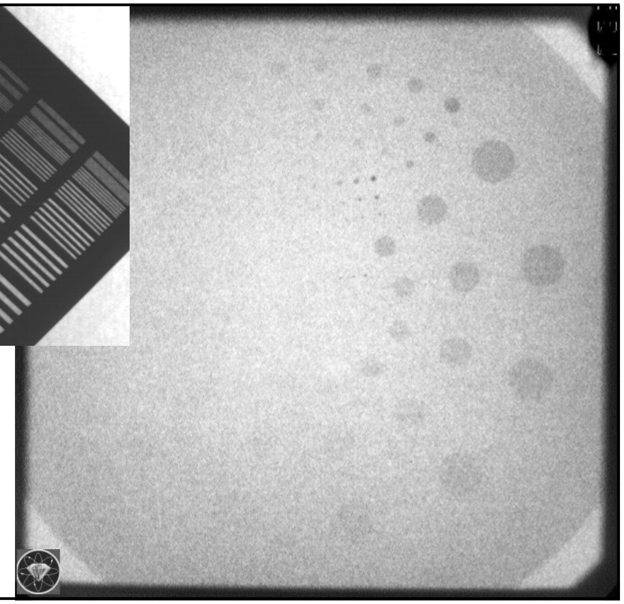
Paired t test



Conclusions

- The pre-1991 data (without regular QC) shows significant inconsistency and inaccuracy of the performance of the X-ray systems PLUS deteriorated image quality - lower resolution and higher noise and Image Intens. entrance dose
- Regular QC tests help to maintains the consistency of X-ray systems parameters and image quality within specification
- The improvement is small (perhaps just keeping a stable acceptable level) as it relates to equipment specifications.
- Close collaboration with the service engineers is essential.
- QC statistics is difficult as often colleagues do not follow strictly the protocols
- Statistical analysis of the equipment “thumb curve” would be useful for predicting the life of the device, but would be much more difficult to make …..



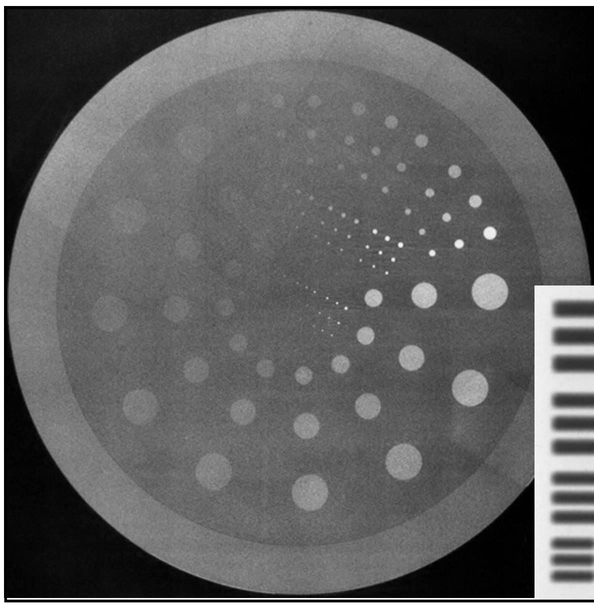


TASK:

*Draw C/D curves for both images (using TO tables);

**Assess sp.res.

***Discuss image quality of both systems



TASK 2:

Where is the limiting sp.res. On the image below