

Practical Medical Physics

*Adapting Traditional Clinical Medical Physics
to Digital Radiography*

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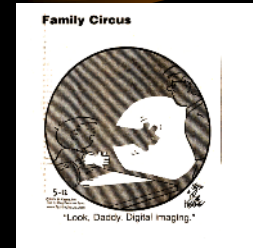
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Learning Objectives:

- Understand how some conventional tests should be modified for a digital radiographic system that is integrated into an electronic image management system.
- Identify key references and standards that can be useful in testing of DR.
- Appreciate opportunities for improvement of testing of DR systems.



Workshop Overview

- Inspection of a radiographic unit using CR or DR - *C. Willis*
- AEC setup for CR or DR exams - *K. Jones*
- Exposure indicator verification for CR and DR - *M. Flynn*
- Phantoms for CR/DR - *D. Peck*

"What's my motivation?"
(unknown screen actor)

- Regulatory Compliance
 - Title 12, Code of Federal Regulations (CFR) Part 20, Standards for Protection against Radiation
 - State regulations <http://www.tdh.state.tx.us/radiation/>
- Standards of Care
 - ACR Standard for Diagnostic Medical Physics Performance Monitoring of Radiographic and Fluoroscopic Equipment
 - ACR Radiography and Fluoroscopy Accreditation Program
 - NCRP Report No. 99 "Quality Assurance for Diagnostic Imaging"
 - Nationwide Evaluation of X-ray Exposure Trends (NEXT)
 - Reference Values
- Providing the highest quality medical care
- MANAGING RADIATION DOSE!!! (and image quality)

Many factors affect image quality and patient dose

Wolbarst. Physics of Radiology (1993) Table 19-1

Factor	Contrast	Resolution	Noise	Patient Dose
Focal spot size		X		
Off-focus radiation	x	(x)		x
Beam filtration	x			X
Voltage waveform	(x)	x		x
kVp	X		(x)	X
mA		(x)		
S		X		
mAs	(x)		X	X
SID		X		X
Field size	X			X
Scatter rejection	X			X

Components of a digital radiographic system

- System
- X-ray generator
- Collimator and assembly
- Patient support
- Grid
- AEC ← *K. Jones*
- Image receptor
- Image processing } *AAPM Report 93 (for CR)*
- Connectivity
- Display ← *AAPM TG 18*

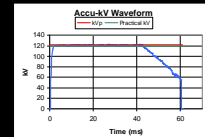
Evaluations of the system

- Visual inspection and general requirements - CFR
- Measurement of ESE
 - *State limits*
 - *Reference levels*

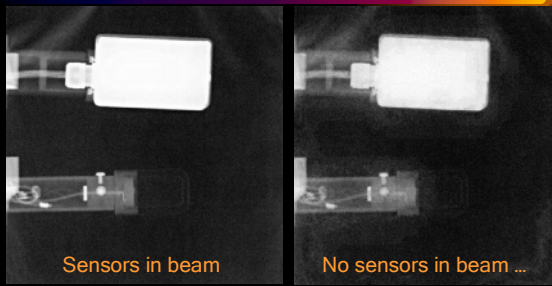
Gray JE, Archer BR, Butler PF, Hobbs BB, Mettler FA, Pizzutiello RJ, Jr., Schueler BA, Strauss KJ, Suleiman OH, and Yaffe MJ.(2005) "Reference Values for Diagnostic Radiology: Application and Impact". American Association of Physicists in Medicine Task Group on Reference Values for Diagnostic X-Ray Examinations. Radiology; 235:354-358.

Evaluations of the x-ray generator

- HVL minimum requirement /total filtration
- Exposure timer accuracy
- Exposure reproducibility
- Exposure rates/Output
- mA/mAs linearity
- kVp linearity
- kVp accuracy
- kVp waveform
- Focal spot size
- SID indication accuracy
- Alignment of central axis
- Reproducibility



Non-invasive kVp measurement of a DR system



Lesson #1: Tests that involve production of large amounts of radiation require protection of the image receptor.

Methods to protect the image receptor

- Point the tube away from the detector
- Cover the detector with a lead apron or beam block of $\geq 1/8$ " Pb
- Remove receptor from direct x-ray beam and scatter (cassette-based receptor)

Goldman LW (2004) "Inspecting Radiographic and Fluoroscopic Equipment: Providing Value" AAPM Monograph No. 30: Specifications, Performance Evaluations and Quality Assurance of Radiographic and Fluoroscopic Systems in the Digital Era. Goldman and Yester eds. Medical Physics Publishing: Madison p 304

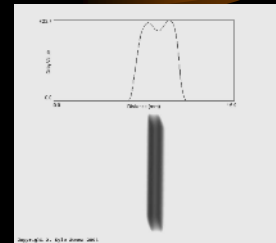
Evaluation of focal spot size may differ ("measure me first!")

- Focal spot size/resolution
 - pinhole camera
 - slit camera
 - star pattern
 - line pair tool (implied)
- National Electrical Manufacturers Association (NEMA)
"Standards Publication No. XR 5: Measurement of dimensions and properties of focal spots of diagnostic x-ray tubes" NEMA Washington DC (1992)
- Rong XJ, Krugh KT, Shepard SJ and Geiser WR (2003)
Measurement of focal spot size with slit camera using computed radiography and flat-panel based digital detectors. *Med Phys* 30 1768-1775.

Lesson #2: Tests that rely on the receptor to assess generator performance must be modified.

Complications with focal spot measurement

- Receptor characteristic function
- Objective localization of $1/2$ maximum (pinhole or slit camera) or blur (star pattern)



Lesson #3: Tests that rely on evaluation of digital images may require specialized software and/or export of digital images.

Evaluations of collimator and assembly

- Beam limitation to receptor edges/congruence
- Convergence of light and x-ray field
- Positive Beam Limitation (if equipped) - CFR
- Light field illumination - CFR
- Leakage radiation

Evaluation of "congruence" and positive beam limitation may differ

- RediPak
- GAFChromic Film
- Digital x-ray field indicators
- CR cassette
- Adjust light field to receptor boundary; decrease SID



Evaluation of patient support

- Uniformity
- Transmittance



Evaluation of grid

- Scatter removal
- Grid alignment
- Focus
- Uniformity
- * • Bucky factor
- Bucky motion (if applicable)



SU-FF-1-161 Non-destructive grid ratio measurement (Pasciak and Jones)

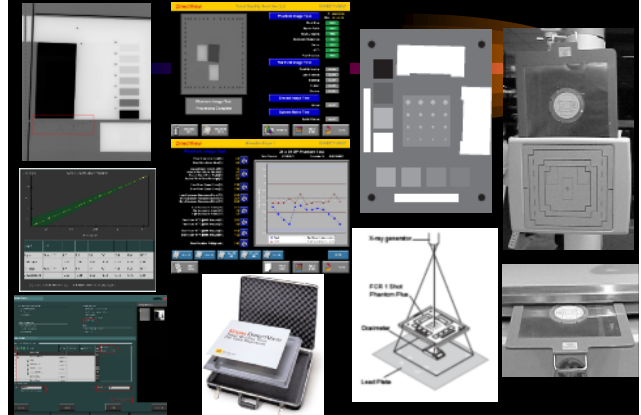
Caveats:
May involve pixel values and ROIs
* May involve removal of fixed grid

M. B. Williams, E. A. Krupinski, K. J. Strauss, W. K. Breeden III, M. S. Rzeszutowski, K. Applegate, M. Wyatt, S. Bjork, and J. A. Seibert, "Digital radiography image quality: Acquisition," J. Am. Coll. Radiol. 4, 371-388 2007.

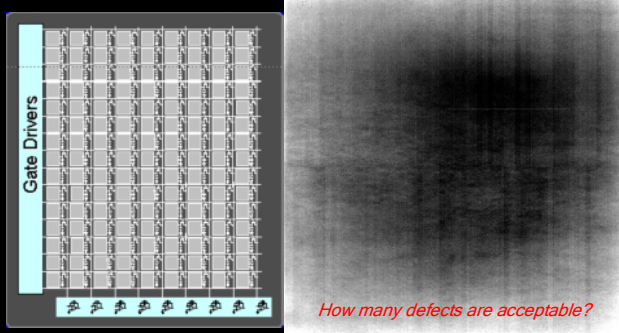
Evaluation of image receptor

- Sharpness
- Uniformity (gain and offset correction)
- Artifacts
- Noise
- Speed
- Characteristic function/contrast
- Lag, ghosting, erasure
- Dark noise = lag?
- DQE?

Automated evaluations of the image receptor



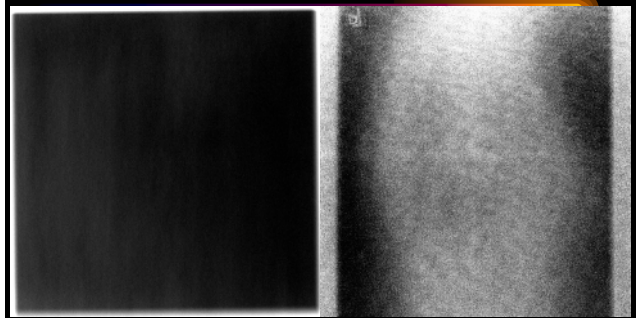
Uncorrected DR image is inherently non-uniform



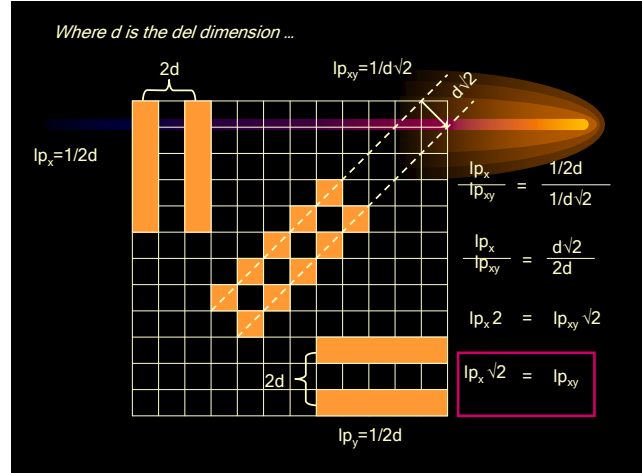
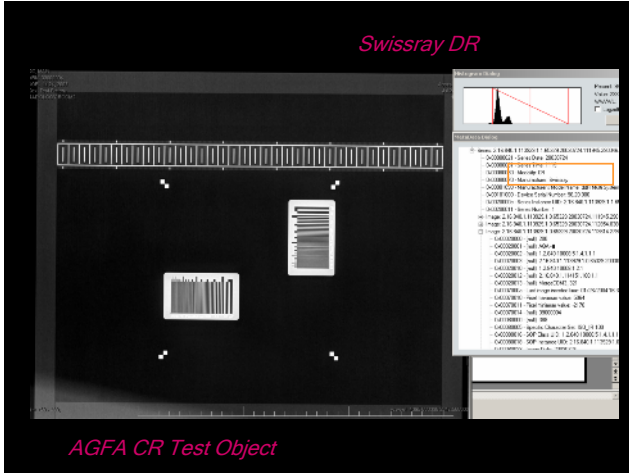
How many defects are acceptable?

Assessing the receptor may require access to uncorrected image.

Non-uniformities are corrected by "flat-fielding"

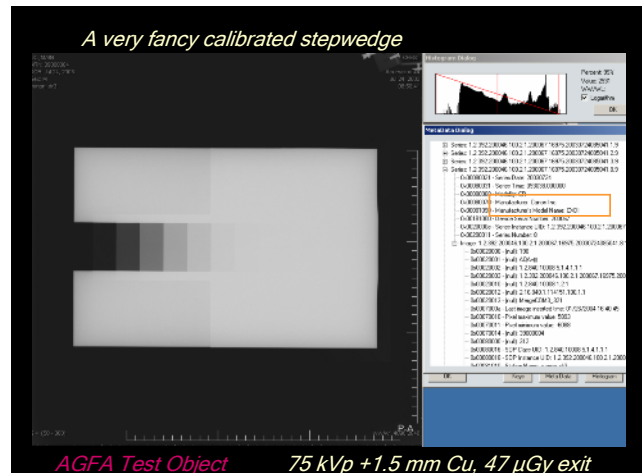


Seibert JA, Boone JM, Lindfors KK. Flat-field correction technique for digital detectors. Proc. SPIE 1998; 3336: 348-354.



Evaluation of image processing

- Autoscaling
- Gradation mapping
- Edge restoration



Where can we find instructions for how to perform QC tests?

- AAPM Report 74: Quality Control in Diagnostic Radiology (2002)
- AAPM Monograph 20: Specification, Acceptance Testing and Quality Control of Diagnostic X-ray Imaging Equipment (1991)
- AAPM Monograph No. 30: Specifications, Performance Evaluations and Quality Assurance of Radiographic and Fluoroscopic Systems in the Digital Era (2004)
- AAPM Report 93: CR Acceptance Testing and QC (2007)
- IPEM Report 91: Recommended Standards for the Routine Performance Testing of Diagnostic X-Ray Imaging Systems (2005)
- AAPM TG-150 (*eventually, if not sooner!*)

Pass/fail criteria: How do you know?

- Government regulations
- Specifications and service manuals
- Scientific literature
 - *Medical Physics, SPIE Proceedings, Journal of Digital Imaging*
 - *Samei E, Seibert JA, Willis CE, Flynn MJ, Mah E, and Junck KL. Performance evaluation of computed radiography systems. Medical Physics 28(3):361-371, 2001.*
- Comparison with other devices or customer experience