

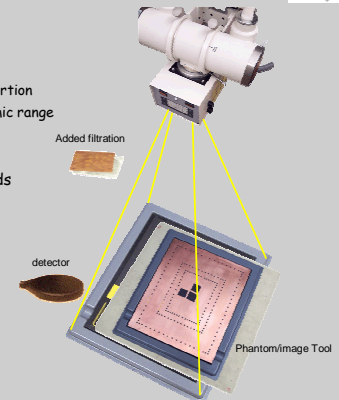


## Features and Weaknesses of Phantoms for CR/DR System Testing

Donald Peck, PhD  
Henry Ford Hospital

## Physics testing of image detectors

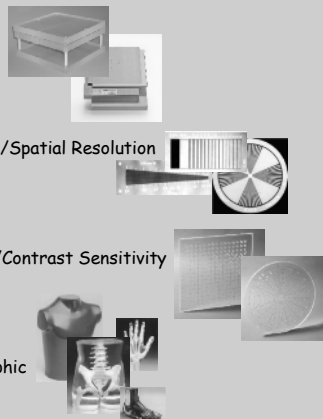
- Parameters to test
  - Spatial resolution
  - Contrast resolution
  - Uniformity/geometric distortion
  - Dose response/signal dynamic range
  - Noise
- Experiments/testing methods
  - Direct measurements
  - Phantoms/image tools
    - Qualitative
    - Quantitative



2

## Phantom Types

- Attenuation
- High Contrast/Spatial Resolution
- Low Contrast/Contrast Sensitivity
- Anthropomorphic



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## Attenuation test tools

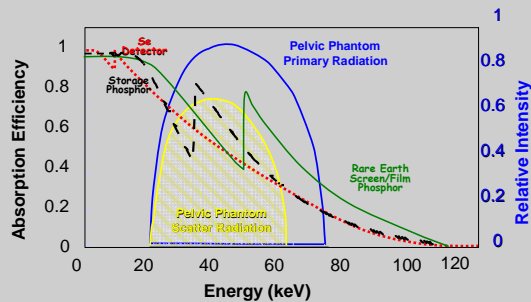
- Metals
  - Aluminum, Copper, etc.
- Plastics/Composite Materials
  - Lucite, Tissue Equivalent, etc.
- Water/Equivalent



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## Detectors - Energy Sensitivity

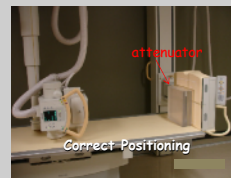
- Digital detectors can be significantly more sensitive to scatter radiation as compared to traditional phosphor screens
  - Scatter needs to be considered at setup when testing systems



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## Attenuator positioning

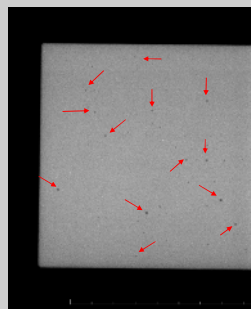
- Modifying beam quality
  - Position attenuators far from detector to minimize scatter contribution in measurement
- Simulating patient attenuation
  - Position close to detector in same location as patient



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## Attenuator Construction

- Attenuator "purity" may not be acceptable for the measurement
  - Measurement of mammography HVL requires attenuators that are at least 99.9% Aluminum
- Tissue equivalent materials may not be uniform



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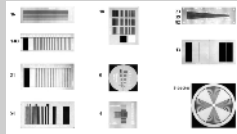
## Attenuation test tools

- Easy to use
- Placement of attenuator needs to be considered based on the test
- Purity or Uniformity of material may not be adequate for some tests

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## High Contrast/Spatial Resolution Test tools

- Line pair patterns



- Mesh patterns

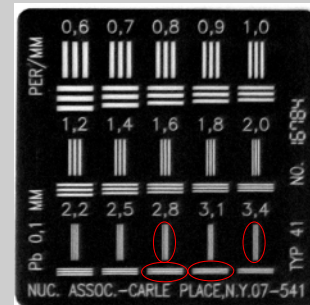


- Edge phantoms



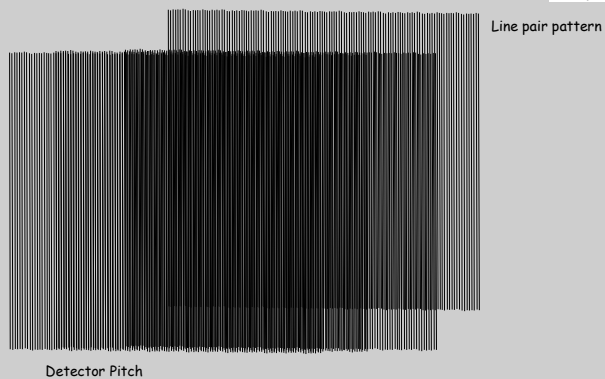
9

## Line pair patterns



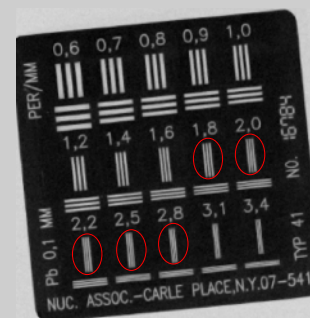
10

## Aliasing and Moiré Effect



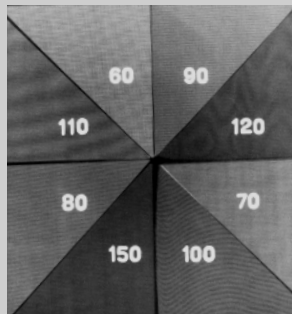
11

## Line pair patterns



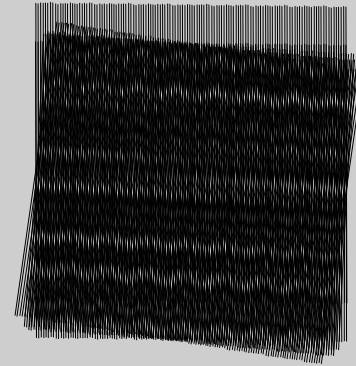
12

## Mesh Patterns



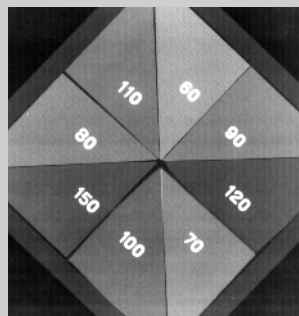
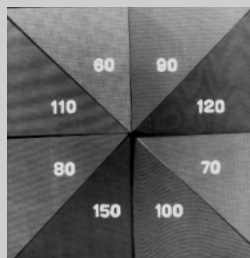
13

## Moiré Effect



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## Mesh Patterns

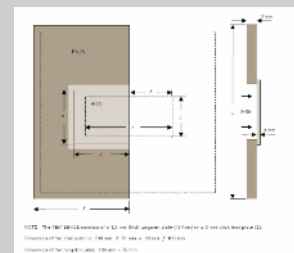


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## MTF/DQE Measurement



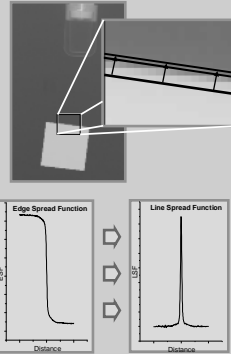
- IEC 62220-01 (2003)
  - Method for determining Detective Quantum Efficiency (DQE) of digital imaging systems
  - Defines specifications for a test device required to make these measurements



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## MTF/DQE Measurement Issues

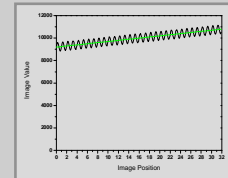
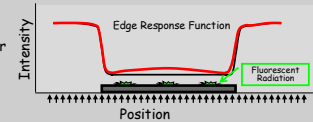
- Requires Pre-processed image values that are "linear" with exposure
- Determination of edge response
  - Need to bin pixel data along edge
  - Phantom positioning critical for consistent results
- Smoothing/fitting of edge response curves to allow utilization of Fourier Analysis
  - Variations in method used may produce different results
  - Important to standardize if comparing to other MTF/DQE measurements



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## MTF/DQE Measurement Issues

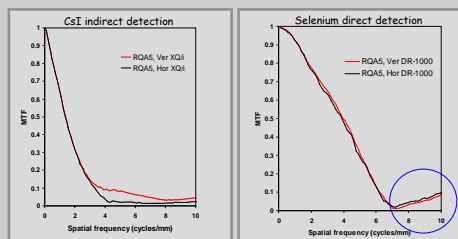
- Fluorescent radiation
  - Only issue at high kVp
  - Important if comparing to other MTF/DQE measurements
- Noise Power Spectrum (NPS) determination
  - Need to remove effects of trends associate with heel effect, etc.
  - Variations in method used may produce different results
  - Important to standardize if comparing to other MTF/DQE measurements



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## MTF Measurements

- Quantitative results
- Good indication of changes
- Subtleties in the measurement and analysis of data can make comparisons between measurements by different tests inaccurate
- Need to understand artifacts in results due to aliasing, etc.



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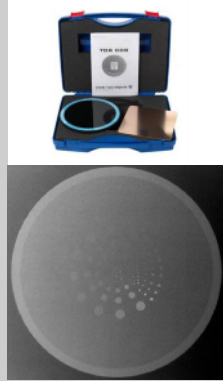
## High Contrast/Spatial Resolution Test tools

- Line pair patterns
  - Subjective
  - Need to consider detector pitch in relation to resolution pattern
- Edge Phantoms
  - Objective
    - MTF Determination
  - Valid for determining if changes have occurred over time if performed "consistently"
    - Requires standardization of methods used if comparison between systems or results from different physicists is desired
    - Would benefit from development of "standardized" software package to do the calculations
      - Task Group No. 162 "Research Software for 2D Image"

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## Low Contrast/Contrast Sensitivity test tools

- Contains objects of varying size and attenuation
- Requires observers to determine which objects are visible
  - Subjective



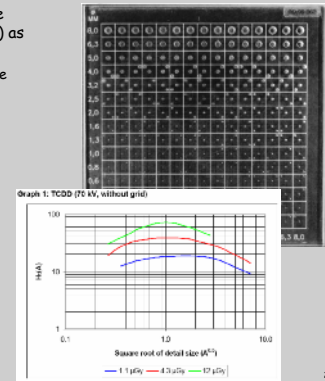
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## Threshold Contrast Detail Detection index (TCDD)

- TCDD gives an indication of the lowest contrast detectable ( $C_T$ ) as a function of the detail size
- given in terms of square root of the object area ( $A^{1/2}$ )
- Can be quoted in terms of the threshold detection index ( $H_T$ )

$$H_T(A) = 1/[C_T * A^{1/2}]$$

- High value for  $H_T(A)$  indicates good visibility



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## Institute of Physics and Engineering in Medicine (IPeM)

- Goals:
  - Improving standards in clinical practice
  - Providing advice on scientific and engineering issues in healthcare to other healthcare professionals, *government* and the public.
- Develops Reports and other publications to achieve these goals
  - Owns several journals:
    - Physics in Medicine and Biology
    - Physiological Measurement
    - Medical Engineering and Physics
  - Report 91 Recommended Standards for the Routine Performance Testing of Diagnostic X-Ray Imaging Systems
    - Specifies the use of phantoms throughout the testing procedures

Section	IPeM Page 111	IPeM Page 111	IPeM Page 111
1.1.1.1.1.1	1.1	1.1.1.1.1.1	1.1.1.1.1.1
1.1.1.1.1.2	1.2	1.1.1.1.1.2	1.1.1.1.1.2
1.1.1.1.1.3	1.3	1.1.1.1.1.3	1.1.1.1.1.3
1.1.1.1.1.4	1.4	1.1.1.1.1.4	1.1.1.1.1.4
1.1.1.1.1.5	1.5	1.1.1.1.1.5	1.1.1.1.1.5
1.1.1.1.1.6	1.6	1.1.1.1.1.6	1.1.1.1.1.6
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1.1.1.1.1.49	1.49	1.1.1.1.1.49	1.1.1.1.1.49
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1.1.1.1.1.51	1.51	1.1.1.1.1.51	1.1.1.1.1.51
1.1.1.1.1.52	1.52	1.1.1.1.1.52	1.1.1.1.1.52
1.1.1.1.1.53	1.53	1.1.1.1.1.53	1.1.1.1.1.53
1.1.1.1.1.54	1.54	1.1.1.1.1.54	1.1.1.1.1.54
1.1.1.1.1.55	1.55	1.1.1.1.1.55	1.1.1.1.1.55
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1.1.1.1.1.68	1.68	1.1.1.1.1.68	1.1.1.1.1.68
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1.1.1.1.1.75	1.75	1.1.1.1.1.75	1.1.1.1.1.75
1.1.1.1.1.76	1.76	1.1.1.1.1.76	1.1.1.1.1.76
1.1.1.1.1.77	1.77	1.1.1.1.1.77	1.1.1.1.1.77
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1.1.1.1.1.79	1.79	1.1.1.1.1.79	1.1.1.1.1.79
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1.1.1.1.1.81	1.81	1.1.1.1.1.81	1.1.1.1.1.81
1.1.1.1.1.82	1.82	1.1.1.1.1.82	1.1.1.1.1.82
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1.1.1.1.1.84	1.84	1.1.1.1.1.84	1.1.1.1.1.84
1.1.1.1.1.85	1.85	1.1.1.1.1.85	1.1.1.1.1.85
1.1.1.1.1.86	1.86	1.1.1.1.1.86	1.1.1.1.1.86
1.1.1.1.1.87	1.87	1.1.1.1.1.87	1.1.1.1.1.87
1.1.1.1.1.88	1.88	1.1.1.1.1.88	1.1.1.1.1.88
1.1.1.1.1.89	1.89	1.1.1.1.1.89	1.1.1.1.1.89
1.1.1.1.1.90	1.90	1.1.1.1.1.90	1.1.1.1.1.90
1.1.1.1.1.91	1.91	1.1.1.1.1.91	1.1.1.1.1.91
1.1.1.1.1.92	1.92	1.1.1.1.1.92	1.1.1.1.1.92
1.1.1.1.1.93	1.93	1.1.1.1.1.93	1.1.1.1.1.93
1.1.1.1.1.94	1.94	1.1.1.1.1.94	1.1.1.1.1.94
1.1.1.1.1.95	1.95	1.1.1.1.1.95	1.1.1.1.1.95
1.1.1.1.1.96	1.96	1.1.1.1.1.96	1.1.1.1.1.96
1.1.1.1.1.97	1.97	1.1.1.1.1.97	1.1.1.1.1.97
1.1.1.1.1.98	1.98	1.1.1.1.1.98	1.1.1.1.1.98
1.1.1.1.1.99	1.99	1.1.1.1.1.99	1.1.1.1.1.99
1.1.1.1.1.100	2.00	1.1.1.1.1.100	1.1.1.1.1.100

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## IPeM Criteria (example)

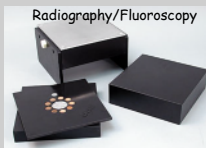
- Most results are subjective !

Parameter	Physical parameter	Level of acceptance	Frequency	Priority	Threshold level	Suspension level
DEME01	Detector dose rate uniformity	A	1-3 monthly	1	Baseline ±20% <sup>(1)</sup>	Baseline ±50% (a)
DEME02	Detector dose rate uniformity	A	1-3 monthly	1	Baseline ±20% <sup>(1)</sup>	Baseline ±50% (a)
DEME03	Detector dose rate uniformity	A	4-6 monthly	2	Baseline ±20% <sup>(1)</sup>	Baseline ±50% (a)
DEME04	Detector dose rate uniformity	A	4-6 monthly	2	Baseline ±20% <sup>(1)</sup>	Baseline ±50% (a)
DEME05	Detector dose rate uniformity	B	12 monthly	1	Baseline ±20% <sup>(1)</sup>	Baseline ±50% (a)
DEME06	Detector dose rate uniformity	B	12 monthly	1	Baseline ±20% <sup>(1)</sup>	Baseline ±50% (a)
DEME07	Detector dose rate uniformity	B	12 monthly	1	Baseline ±20% <sup>(1)</sup>	Baseline ±50% (a)
DEME08	Detector dose rate uniformity	B	12 monthly	1	Baseline ±20% <sup>(1)</sup>	Baseline ±50% (a)
DEME09	Detector dose rate uniformity	B	12 monthly	2	Baseline ±20% <sup>(1)</sup>	Baseline ±50% (a)
DEME10	Detector dose rate uniformity	B	12 monthly	2	Baseline ±20% <sup>(1)</sup>	Baseline ±50% (a)
DEME11	Detector dose rate uniformity	B	12 monthly	2	Baseline ±20% <sup>(1)</sup>	Baseline ±50% (a)
DEME12	Detector dose rate uniformity	B	12 monthly	2	Baseline ±20% <sup>(1)</sup>	Baseline ±50% (a)
DEME13	Detector dose rate uniformity	B	12 monthly	2	Baseline ±20% <sup>(1)</sup>	Baseline ±50% (a)

<sup>(1)</sup> These threshold and suspension levels are based on delivery, where the DQE is not linear with exposure.

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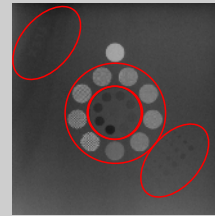
### ACR Accreditation Phantoms



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### ACR Radiography/Fluoroscopy

- Modules included
  - Chest
  - General
  - Fluoroscopy
- Phantom image
  - Radiography Chest/Abdomen
- ACR Discontinued Radiography/Fluoroscopy Accreditation Program in 2005



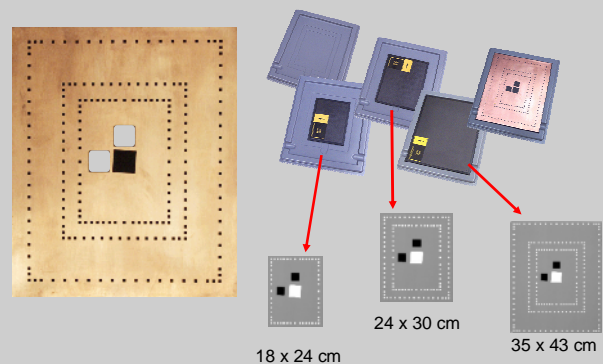
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### Original Equipment Manufacturer (OEM) Products

- Automated Image Quality Control Tool
  - Reproducible quantitative results
  - May detect sub-visible changes in image quality performance to initiate timely preventive maintenance
  - Highly automated procedure
  - Most provide data reporting in spreadsheet format



### Test Phantom for Kodak (i.e. CareStream) DIRECTVIEW Total Quality Tool

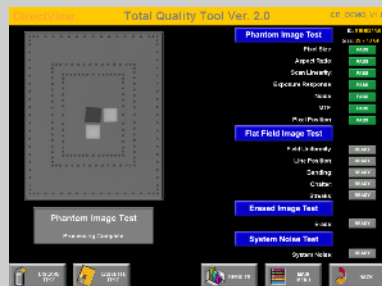


\*Images provided by Eastman Kodak Company



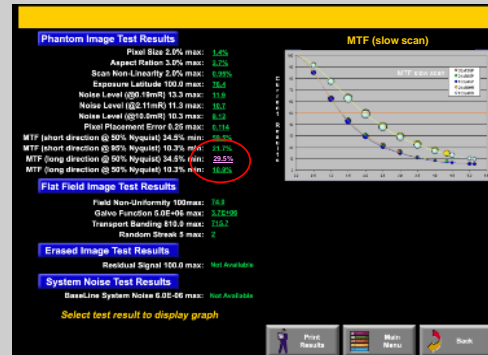
## KODAK User Interface

- Uniformity
- Noise
- Spatial frequency response (MTF)
- Exposure linearity
- Pixel size accuracy and aspect ratio
- Phantom image artifacts
- Laser Beam Function
- Residual signal erase



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## Kodak Test Result Details



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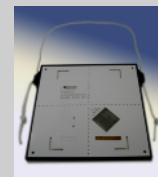
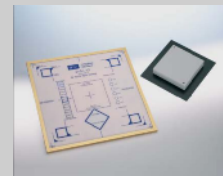
## Test Limits

- Pre-set by OEM
- Basis for limit may not be justified in OEM literature
- If system fails a test, Service Engineer may not be educated how to correct problem
- AAPM Report 93: Acceptance Testing and Quality Control of Photostimulable Storage Phosphor Imaging Systems Recommends using vendor/manufacturer supplied phantom for Quality Control testing
  - Since each vendor/manufacturer system would be different, the Report could not specify exactly what to do or look for in the results

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## DIN 6868-58 (2001) and 6868-13 (2002)

- Acceptance testing and constancy checks of projection radiography systems with digital image receptors
  - German standard for testing of Storage Phosphor systems using a specially designed phantom to measure image quality parameters
  - Can purchase a phantom that will meet the requirements of this standard from several vendors



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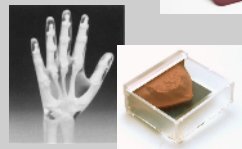


## Anthropomorphic phantoms

- Shape "mimicking"

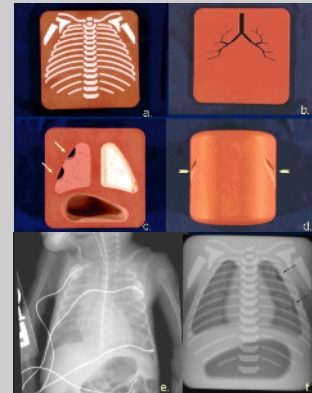


- Anatomically Accurate



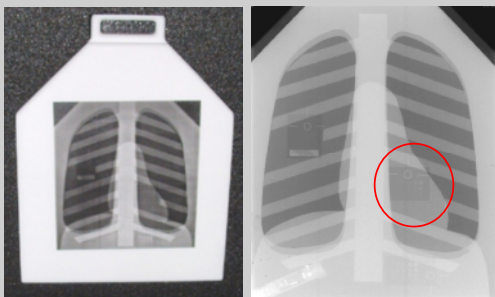
33

## Shape "mimicking"



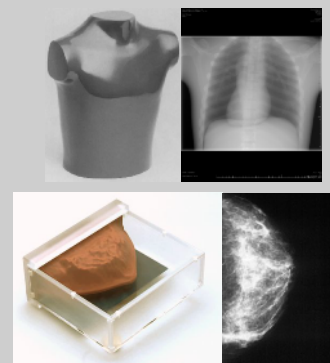
34

## Shape "mimicking"



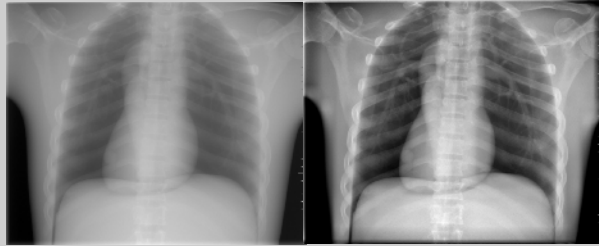
35

## Anatomically Accurate



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## Image Processing



Un-Processed

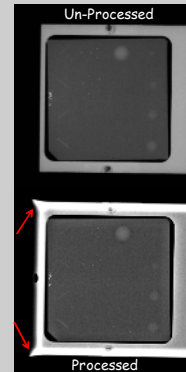
Processed

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## European Protocol for QC of ... mammography Addendum on Digital Mammography

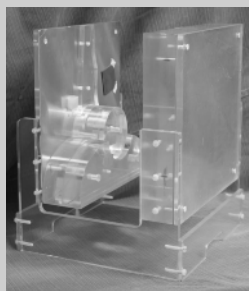
- It is acknowledged that at present it is not possible to get unprocessed images from some systems
- The image processing may introduce artifacts on phantom images and may be different from image processing for mammograms due to histogram or local texture based processing techniques
- Therefore care needs to be taken in interpretation of these processed images



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## Image Processing

- To optimize image processing parameters the phantom would need to accurately mimic "true" anatomy
- At least one reference of a study attempting to accomplish this with a phantom for a specific vendor processing method\*
- Impractical to do this for all Body Parts/Views and all vendor's image processing systems



\*Moore CS, et al. "A method to optimize the processing algorithm of a computed radiography system for chest radiography". British Journal of Radiology, 80 (2007), 724-730

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## Phantom vs. Real Life



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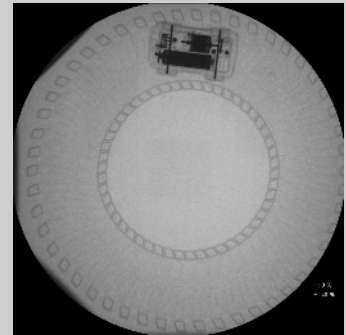
AAPM Report 93: Acceptance Testing and Quality Control of  
Photostimulable Storage Phosphor Imaging Systems



- Lists anthropomorphic phantoms in the recommended equipment list
- Doesn't specify how to use the anthropomorphic phantoms in the Report

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Government Phantom



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