# Digital and Film Radiography Comparison and Contrast Reference Handout

A Special Seminar for the ASNT Fall 2015 Conference

# Terms and Definitions

- Direct Radiography (DR)* – Radiography that converts radiation directly to stored image data.

- Indirect Radiography – Radiography that uses an intermediate storage medium prior to storage of the image data.

- *Overloaded Acronyms and terms – Acronyms and terms are often used to mean different things, and we need to be careful to try to communicate clearly.  For example:

# Cameras

# Terms & Definitions

- Film Radiography (RT)

- A form of radiographic imaging, where photographic film is exposed to radiation transmitted through an item being inspected, and light or radioactive rays, an invisible image (called a latent image) and a latent image is formed in the emulsion layer of the film. Conversion of the latent image to a visible image is through chemical processing.   Traditional Film Radiography must use more radiation to produce an image of similar contrast to digital methods.

- The image is stored on a sheet of radiographic film which is viewed based on the transmission of light through the film.

# Terms and Definitions

Digital Radiography (DR)

- A form of radiographic imaging in which digital detectors are exposed to the radiation transmitted through an item being inspected, and convert the transmission data to a digital file to be stored and displayed on a computer.

- A form of radiographic imaging, where digital radiographic sensors are used instead of traditional radiographic film. Advantages include time efficiency through bypassing chemical processing and the ability to digitally transfer and enhance images. Also, in most cases, less radiation can be used to produce an image of similar contrast to film radiography.

- Instead of radiographic film, digital radiography uses a digital image capture device. This gives advantages of immediate image preview and availability; elimination of costly film processing steps; a wider dynamic range, which makes it more forgiving for over- and under-exposure; as well as the ability to apply special image processing techniques that enhance overall display of the image.

# Terms and Definitions

Computed Radiography (CR)

- Digital Radiography using storage phosphor plates as an intermediate storage media prior to scanning the plate to create a digital image.

- Implementation is similar to film radiography except that in place of a film to create the image, an imaging plate (IP) made of photostimulable phosphor is used.

- The imaging plate is housed in a cassette and placed under the body part or object to be examined and the radiographic exposure is made. Hence, instead of taking an exposed film into a darkroom for developing in chemical tanks or an automatic film processor, the imaging plate is run through a special laser scanner, or CR reader, that reads and digitizes the image.
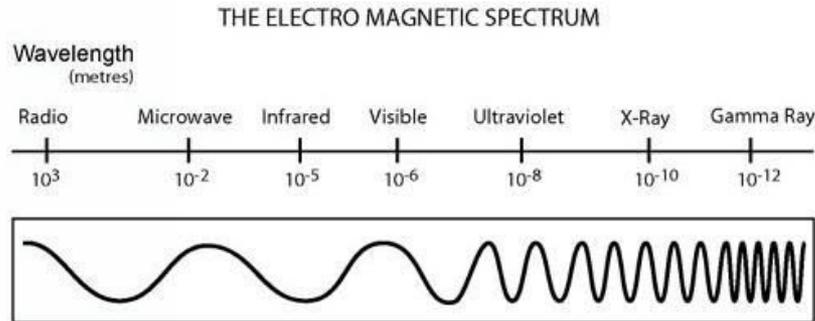
# Terms and Definitions

Computed Tomography (CT)

- Digital Radiography that allows data to be displayed in a non standard manner.

- Implementation requires additional image acquisition, additional handling hardware, and complex image processing algorithms

- Makes use of computer-processed combinations of many radiographic images taken from different angles to produce cross-sectional (tomographic) images (virtual 'slices') of specific areas of a scanned object, allowing the user to see inside the object without cutting.

- Image processing is used to generate a three-dimensional image of the inside of the object from a large series of two-dimensional radiographic images taken around a single axis of rotation.

# Film vs Digital Comparison

| Film | Digital |
|------|---------|
| Development time | Faster (immediate or near immediate results) |
| Technology and equipment well known and understood | Technology continuously developing and not as well understood |
| Requires HAZMAT chemical processing | No HAZMAT chemicals |
| Physical transfer of film | Electronic transfer of data |
| Simpler and better known process controls | More complex for setup and process controls |
| | Wider dynamic range |
| | Ability to process and manipulate data |
| | Requires less radiation and time for exposures |

# Radiation Spectrum

THE ELECTRO MAGNETIC SPECTRUM

Wavelength (metres)

| Radio | Microwave | Infrared | Visible | Ultraviolet | X-Ray | Gamma Ray |
|---|---|---|---|---|---|---|
| $10^3$ | $10^{-2}$ | $10^{-5}$ | $10^{-6}$ | $10^{-8}$ | $10^{-10}$ | $10^{-12}$ |

- Radiographic inspection utilizes energy levels exceeding ultraviolet light

- Develops penetrating, and ionizing capabilities

- Causes a reaction in the detector used to develop an observable image

- Areas of higher density will allow less radiation to pass through, while areas of lower density will allow more radiation to pass through. This creates an image of defects of higher or lower density than the material around it.

9

# Nyquist-Shannon Sampling Theorem

- This theorem is typically utilized in digital radiography to answer the all important question:

**What resolution do I need to see the level of detail required for a given flaw size?**

# Nyquist-Shannon Sampling Theorem

Definition (abbreviated):

"In the field of digital signal processing, the **sampling theorem** is a fundamental bridge between continuous-time signals (often called "analog signals") and discrete-time signals (often called "digital signals"). It establishes a sufficient condition for a sample rate that permits a discrete sequence of *samples* to capture all the information from a continuous-time signal of finite bandwidth." [1]

"The sampling theorem introduces the concept of a sample rate that is sufficient for perfect fidelity for the class of functions that are bandlimited to a given bandwidth, such that no actual information is lost in the sampling process. It expresses the sufficient sample rate in terms of the bandwidth for the class of functions. The theorem also leads to a formula for perfectly reconstructing the original continuous-time function from the samples." [1]

[1] Excerpts from Wikipedia, the free encyclopedia.

# Nyquist-Shannon Sampling Theorem

- **Critical frequency** . [1]

To illustrate the necessity of $f_s > 2B$, consider the family of sinusoids (depicted in Fig. 8) generated by different values of θ in this formula:

$$x(t) = \frac{\cos(2\pi Bt + \theta)}{\cos(\theta)} = \cos(2\pi Bt) - \sin(2\pi Bt)\tan(\theta), \quad -\pi/2 < \theta < \pi/2.$$

With $f_s = 2B$ or equivalently $T = 1/(2B)$, the samples are given by:

$$x(nT) = \cos(\pi n) - \underbrace{\sin(\pi n)}_{0}\tan(\theta) = (-1)^n$$

# Nyquist-Shannon sampling theorem

Pixel pitch  = $\rho$

Nyquist frequency = $\frac{1}{2}\,\rho$  LP/mm

Examples

- 50 $\mu$m pixel pitch: NF = 10 LP/mm
- 100 $\mu$m pixel pitch: NF =  5 LP/mm
- 200 $\mu$m pixel pitch: NF =  2.5 LP/mm

# What is Noise?

- In Film Radiography noise is caused by scatter, is often referred to as graininess and can be corrected by using a finer film.

- In DR noise is caused by scatter, undesired radiation and other electronic effects that vary by the type of detector.

- In digital techniques, a number on a brightness scale is assigned to a particular value of radiation dose to create an image, when unwanted radiation is present, it takes up those values, reducing the range of values and sensitivity of the test.

# Viewing Noise on a Histogram

- A histogram is a representation of all values assigned to every level of dose received on the digital detector.

- If a particular system was capable of assigning 65,536 gray scale values, a test that assigned 45,000 of those values to radiation that passed through the part would be more sensitive then a test that had more scatter and only assigned 25,000 values to the radiation that passed through the part.

# Viewing Noise on a Histogram

- This can be seen by looking at the histogram and viewing the assigned gray scale values.
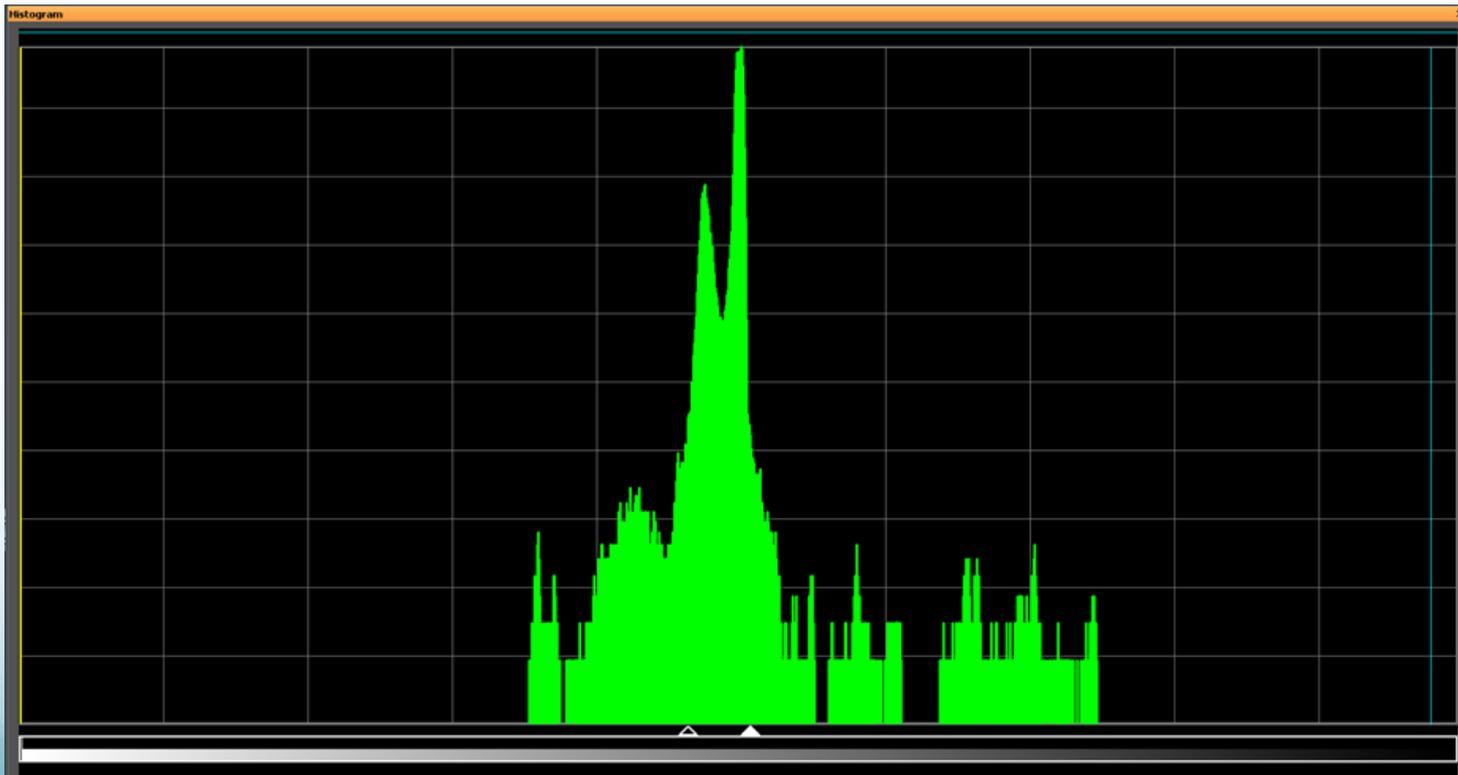
# Noise Comparison

| Film | DR |
|---|---|
| Less sensitive to scatter than DR | Far more sensitive to scatter than film |
| Controlled by scatter reduction | Most easily controlled by scatter reduction; Some detectors (DDA) offer frame averaging capability to increase the Signal to Noise Ratio without overexposing an image |
| Not easily quantified past IQI sensitivity | Easily and accurately quantifiable using SNR and CNR |
| | |
| | |
| | |

# Optimization

| Film | Digital |
|---|---|
| Use proper energy to avoid over/under exposure | Use proper energy and flux to avoid detector saturation (blooming effect) or damage |
| | Use of the "cleanest" source possible and shield detector system to reduce background and scatter problems |
| | Measurements at different energies can be used to increase/change contrast (ratio of radiographs at different energies for example) |
| | Depth-of-field can be adjusted with distance scintillator/converter-to-sensor |
| | |

# DR SYSTEM COMPONENTS



19
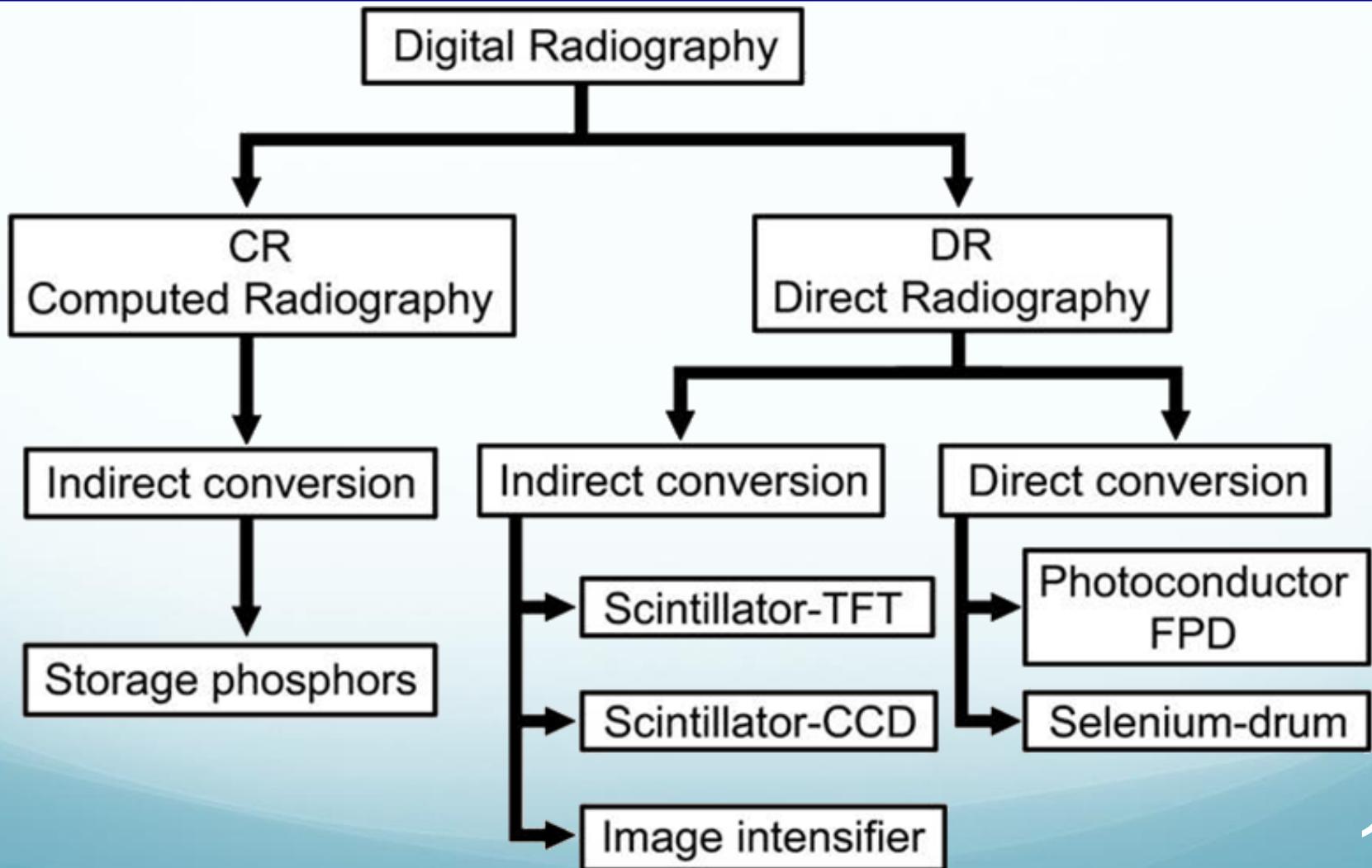
# Computed Radiography

## *How is CR Different Than Film*

- The CR Image Plate (IP) functions in a completely different fashion than film
- CR has substantially wider latitude than film
- The exposure process requires a different approach partly due to scatter
- The CR scanner functions in a completely different fashion than film processor
- The CR image is displayed on a computer monitor instead of a light box
- Software tools are used to adjust the image in ways film can't be changed
- Image quality measured by Signal to Noise Ratio (SNR) using software tools
- Additional operator training is required

THE ENTIRE PROCESS OF CREATING AN IMAGE
USING Computed Radiography
*IS DIFFERENT THAN FILM !*

# CCD

- CCD: Charge Coupled Device

- Advantages:
  - Large field of view (FOV)
  - High Quantum Efficiency (QE)
  - Different speed read-out (up to a few MHz)

- Disadvantages:
  - Relatively slow system (seconds acquisition time)
  - Lengthy transfer of the data causing dead time between acquisition of radiograph (seconds)
  - Dark current not negligible (reduced when CCD is cooled)

# Detector Comparison

| Film | Digital |
|------|---------|
| Film Speed | CR and DR generally faster requiring lower dose. |
| Limited Latitude.<br>Logarithmic film curves. | CR and DDA's have extremely high latitude (bit depth) and linear response.  12, 16, or 32-bit gray scale |
| Automatic or manual film processing | CR Scanning of IPs.<br>Direct link on DDA's<br>Computer Image Processing to produce images. |
| Reliance on Chemicals and | Clean processing |
| Manual Film Cassette Handling | Automation allows CT scans in seconds to minutes, Radiography in fractions of seconds<br>CR can be setup to handle same as film. |
| Storage of Film in large vaults with possible degradation of image. | Storage of data on file servers requires little space, and indefinite shelf life. |
| | Capability to perform lens-based magnification |
| | Lifetime is years (with appropriate shielding) |
| | Flexibility in field-of-view and spatial and/or time resolution |

# Computed Tomography

- Radiographs are limited to the collapsing of a 3D object on a 2D image

- Computed/Computerized Tomography (CT) allows reconstruction of the information inside an object

- Reconstruction of a 3D object from 2D radiographs/projections at different angles around the object:
  - Usually stepping angle is fixed
  - Reconstruction provides cross-sections of the object showing density/linear attenuation coefficient mapping

- Some reading material:  G. T. Herman, "Fundamentals of Computerized Tomography", Springer, ISBN: 978-1-85233-617-2

# Reconstruction

- Several algorithms can be used to reconstruct an object in 3D:
  - Filtered-back projection:
    - Works in Fourier Space
    - Fast but requires data acquisition of projections at a defined stepping angle
    - Little to no missing projection
    - Object with good contrast/attenuation

  - Iterative reconstruction
    - Works in Real Space
    - Computer-intensive
    - Is able to reconstruct an object even with missing projections
    - Can reconstruct objects with very low contrast/attenuation

# Reconstruction

- Algebraic – Algorithm that iteratively solves a system of linear equations

- Bayesian – Algorithm that works based calculating a result using probabilistic mathematics

- Compressive Sampling – Reconstruction based on minimizing the sparseness of data

# Filtered Back Projection

- Projection is smeared back across the reconstructed image

- Based on Radon Transform
  - Filtering performed before normalization
  - Similar to Fourier Transform: line integrals through f(x,y)
  - Data is moved to reciprocal space (1/real space)



http://homepages.inf.ed.ac.uk/rbf/CVonline/LOCAL_COPIES /AV0405/HAYDEN/Slice_Reconstruction.html

- Data is filtered before reconstruction
  - Sharp filter improves achievable spatial resolution

26
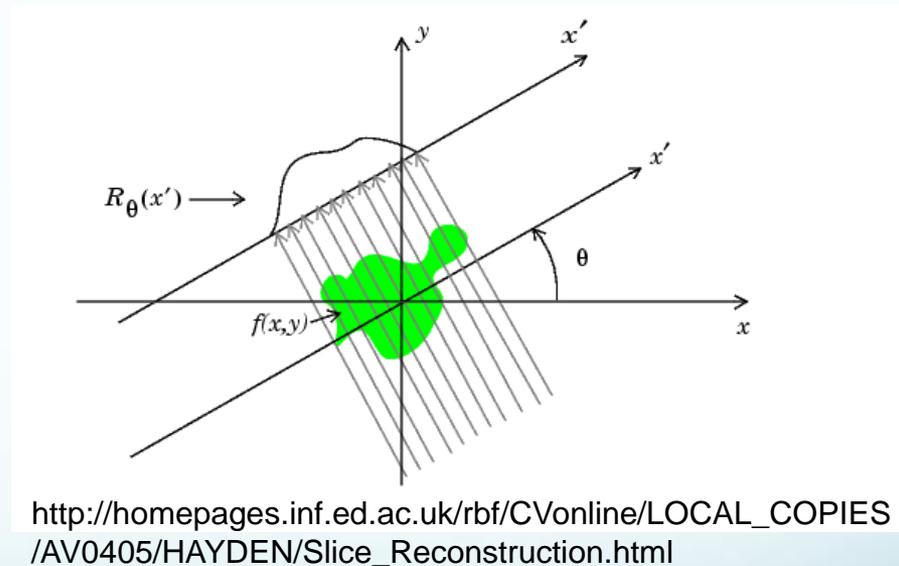
# DDA vs. CR vs. Film

| Process/criteria | DDA  Radiography | Computed Radiography | Film |
|---|---|---|---|
| Procedure: | Direct Image | IP Scanner | Film Development |
| Resolution: | $\geq$ High Quality Film | Equivalent to MX125 | **Universal Image Std.** |
| Image Format: | Digital – Discrete Pixels | Digital – Sampled Pixels | Analog |
| Time to image: | Seconds or Less | Up to 90 sec | 10-30 min |
| Environmental: | None | None | Chemical Disposal |
| Image Enhancement: | Software Adjust | Software Adjust | Cannot Adjust |
| Equipment Cost: | $160K | $100K | $80K |
| Consumable Cost: | Occasional Detector | Small – Replace IP | Relatively Larger |
| Cassette: | N/A | Flex or rigid | Flex or rigid |
| Image Storage: | Electronic | Electronic | Physical |
| Equipment Space: | Computer and Monitor | Computer & Monitor | Dark Room |
| Portability: | Semi portable | Yes | Yes |

# Techniques

- Film – Film Speed, Processor Type, Source to Film Distance, Energy Level, exposure time

- DR – Detector Type, Image Processing, Energy Level, Source to Object Distance, Source to Detector Distance, CNR/SNR Usage, Monitor (selection, verification), automation, measurement tool calibration

- CR Plates – sampling rate, pixel resolution of scanner, exposure time

- DDA – pixel resolution of detector, exposure time, frame averaging, detector calibrations

- CCD Camera – pixel resolution, exposure time, image averaging, detector calibrations, detector cooling, florescent screen properties (thickness, brightness, decay, grain size), lens properties (focal spot, F-Stop)

# ASTM Standards

| General Radiography | Neutron Radiography |
|---|---|
| 94 – Radiographic Examination | STP-624 Neutron Radiography |
| 747- Wire IQIs | E-803-91 Determination of L/D ratio |
| 801 – RT of Electronic Devices | E-748 Thermal Neutron Radiography |
| 1025 – Hole Type IQIs | E-748-2 Thermal Neutron Radiography |
| 1030 – RT of Metal Castings | E-2023-11 Fabrication of Neutron Radiographic Sensitivity Indicators |
| 1032 – RT of Welds | E-2003-10 NRT Beam Purity Indicators |
| 1165 - Focal Spots for X-ray tubes | E-2861-11 Measurements of Beam Divergence and Alignment in Neutron Radiographic Beams |
| 1411 – Qualification of RT Systems | E-721-11 Neutron Energy Spectra from Neutron Sensors for Radiation-Hardness Testing for Electronics |
| 1647 – Contrast Sensitivity | |
| 1817 – Use of Radiographic Quality Indicators | |

# ASTM Standards

| Film | Digital |
|------|---------|
| 999 - Film Processing | 1255 – Radioscopy |
| 1079 - Densitometer Calibration | 1416 – Radioscopy of Welds |
| 1254 – Storage of Radiographs and Film | 1441 – Guide for CT Imaging |
| 1390 – Illuminators for RT | 1475 – Computer Fields for Transferring Digital Data |
| 1815 – Classification of Film Systems | 1570 – Standard Practice for CT |
| | 1695 – Test Method for CT System Performance |
| | 2002 – Image Unsharpness |
| | 2007– Standard Guide for CR |
| | |

# ASTM Standards

| Film (continued) | DR (continued) |
|---|---|
| | 2033 – Standard Practice for CR |
| | 2339 - DICONDE |
| | 2445 – Long Term Stability for CR |
| | 2446 – Classification of CR Systems |
| | 2597 – Characterization DDAs |
| | 2698 – Standard Practice for Using DDA |
| | 2736 – Guide for DDA |

Standards with reference images were ignored for purposes of this comparison

# ASTM Standards

| Film (continued) | DR (continued) |
|---|---|
|  | 2737 – Long Term Stability DDA |
|  | RP 133 – SMPTE Monitor Test Pattern |
|  |  |
|  |  |
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|  |  |
|  |  |

Standards with reference images were ignored for purposes of this comparison

# ASTM Standards

There are specific standards applicable to each of the radiographic modalities, covering:

- General Radiography – 10 standards

- Neutron Radiography – 8 standards

- Film Radiography – 5 standards

- Digital Radiography – 17 standards

| | Source | Detector | Image Review | Process controls for image quality |
|---|---|---|---|---|
| **Neutron Radiography** | Isotope<br>Electrical (accelerator)<br>Nuclear Reactor | Film | Reader must understand neutron attenuation; Film viewer with optical magnification (loupe, magnifying glass, etc.) | Film density, different IQI based on difference in radiation attenuation |
| **Film radiography** | Isotope<br>Electrical (tube or accelerator) | Film | Film viewer with optical magnification (loupe, magnifying glass, etc) | Film density |
| **Digital Radiography (DR)** | Isotope<br>Electrical (tube or accelerator) | Linear Array<br>CMOS<br>DR Panel<br>Cameras | Computer Review with image manipulation and analysis tools | Monitor checks, CNR, SNR, image processing filters, detector calibrations |
| **Digital Radiography (CR)** | Isotope<br>Electrical (tube or accelerator) | Phosphor Imaging Plates | Computer Review with image manipulation and analysis tools | Monitor checks, CNR, SNR, image processing filters |
| **Computed Tomography (CT)** | Isotope<br>Electrical (tube or accelerator) | Linear Array<br>CMOS<br>DR Panel<br>Cameras | Computer Review with image manipulation and analysis tools | Monitor checks, CNR, SNR, image processing filters, detector calibrations |

# Summary

- Overview of Digital and Film Radiography was presented:
  - Further in-depth understanding is critical for digital radiography as the field is broad and is constantly evolving
  - Method selection depends on the source and the application (for example, fast kinetics with ms time resolution may be best suited with digital imaging, whereas hard-to-reach field applications may be better suited with film)

# Summary

- Digital capabilities are versatile and flexible, provide the capability to collect data with higher dynamic range, and require image processing and analysis expertise, along with equipment set-up knowledge and fast computers/servers for data storage, processing and analysis.

# ASTM Standards

E 94    Standard Guide for Radiographic Examination
E192    Reference Radiographs of Investment Steel Castings for Aerospace Applications
E 543    Standard Specifications for Agencies Performing Nondestructive Testing
E 592    Standard Guide to Obtainable ASTM Equivalent Penetrameter Sensitivity for Radiography of Steel
          Plates 1/4 to 2 in. (6 to 51 mm) Thick with X-Rays and 1 to 6 in. (25 to 152 mm) Thick with Cobalt-60
E 746    Standard Practice for Determining Relative Image Quality Response of Industrial Radiographic
          Imaging Systems
E 747    Standard Practice for Design, Manufacture, and Material Grouping Classification of Wire Image Quality
          Indicators (IQI) Used for Radiology
E 748    Standard Practices for Thermal Neutron Radiography of Materials
E 801    Standard Practice for Controlling Quality of Radiological Examination of Electronic Devices
E 999    Guide for Controlling the Quality of Industrial Radiographic Film Processing
E 1000   Standard Guide for Radioscopy
E 1025   Practice for Design, Manufacture, and Material Grouping Classification of Hole-Type Image Quality
          Indicators (IQI) Used for Radiology
E 1030   Standard Test Method for Radiographic Examination of Metallic Castings
E 1032   Standard Test Method for Radiographic Examination of Weldments
E 1079   Practice for Calibration of Transmission Densitometers
E 1165   Standard Test Method for Measurement of Focal Spots of Industrial X-Ray Tubes by Pinhole Imaging
E 1254   Standard Guide for Storage of Radiographs and Unexposed Industrial Radiographic Films
E 1255   Standard Practice for Radioscopy
E 1316   Standard Terminology for Nondestructive Examinations
E 1390   Standard Specification for Illuminators Used for Viewing Industrial Radiographs
E 1411   Standard Practice for Qualification of Radioscopic Systems
E 1441   Standard Guide for Computed Tomography (CT) Imaging
E 1453   Standard Guide for Storage of Media that Contains Analog or Digital Radioscopic Data
E 1475   Standard Guide for Data Fields for Computerized Transfer of Digital Radiological Examination Data
E 1570   Standard Practice for Computed Tomographic (CT) Examination
E 1647   Standard Practice for Determining Contrast Sensitivity in Radiology
E 1672   Standard Guide for Computed Tomography (CT) System Selection
E 1695   Standard Test Method for Measurement of Computed Tomography (CT) System Performance
E 1735   Standard Test Method for Determining Relative Image Quality of Industrial Radiographic Film Exposed
          to X-Radiation from 4 to 25 MeV
E 1742   Standard Practice for Radiography Examination
E 1815   Standard Test Method for Classification of Film Systems for Industrial Radiography
E 1817   Standard Practice for Controlling Quality of Radiological Examination by Using Representative Quality
          Indicators (RQIs)
E 2002   Standard Practice for Determining Total Image Unsharpness in Radiology
E 2003   Standard Practice for Fabrication of the Neutron Radiographic Beam Purity Indicators
E 2007   Standard Guide for Computed Radiology (Photostimulable Luminescence (PSL) Method)
E 2033   Practice for Computed Radiology (PSL Method)
E 2339   Standard Practice for Digital Imaging and Communication in Nondestructive Evaluation (DICONDE)
E 2422   Standard Digital Reference Images for Inspection of Aluminum Castings
E 2445   Standard Practice for Qualification and Long-Term Stability of Computed Radiology Systems
E 2446   Standard Practice for Classification of Computed Radiology Systems
E 2597   Standard Practice for Manufacturing Characterization of Digital Detector Arrays
E 2660   Standard Digital Reference Images for Investment Steel Castings for Aerospace Applications
E 2663   Digital Imaging and Communication in Nondestructive Evaluation (DICONDE) for Ultrasonic Test
          Methods
E 2669   Standard Digital Reference Images for Titanium Castings
E 2698   Standard Practice for Radiological Examination Using Digital Detector Arrays
E 2699   Standard Practice for Digital Imaging and Communication in Nondestructive Evaluation (DICONDE) for
          Digital Radiographic (DR) Test Methods

E 2736 Standard Guide for Digital Detector Array Radiology
E 2737 Standard Practice for Digital Detector Array Performance Evaluation and Long-Term Stability
E 2738 Digital Imaging and Communication Nondestructive Evaluation (DICONDE) for Computed Radiography (CR) Test Methods
E 2767 Digital Imaging and Communication in Nondestructive Evaluation (DICONDE) for X-ray Computed Tomography (CT) Test Methods
E 2903 Standard Test Method for Measurement of the Effective Focal Spot Size of Mini and Micro Focus X-ray Tubes
E 2934 Standard Practice for Digital Imaging and Communication in Nondestructive Evaluation (DICONDE) for Eddy Current (EC) Test Methods

# ASTM E2699

ASTM **E2699** - 11 Standard Practice for Digital Imaging and Communication in Nondestructive Evaluation (DICONDE) for Digital Radiographic (DR) Test Methods

**Significance and Use**

Personnel that are responsible for the creation, transfer, and storage of digital X-ray test results will use this standard. This practice defines a set of information modules that along with Practice E2339 and the DICOM standard provide a standard means to organize digital X-ray test parameters and results. The digital X-ray test results may be displayed and analyzed on any device that conforms to this standard. Personnel wishing to view any digital X-ray inspection data stored according to Practice E2339 may use this document to help them decode and display the data contained in the DICONDE-compliant inspection record.

**1. Scope**

1.1 This practice facilitates the interoperability of digital X-ray imaging equipment by specifying image data transfer and archival methods in commonly accepted terms. This document is intended to be used in conjunction with Practice E2339 on Digital Imaging and Communication in Nondestructive Evaluation (DICONDE). Practice E2339 defines an industrial adaptation of the NEMA Standards Publication titled Digital Imaging and Communications in Medicine (DICOM, see http://medical.nema.org), an international standard for image data acquisition, review, storage and archival storage. The goal of Practice E2339, commonly referred to as DICONDE, is to provide a standard that facilitates the display and analysis of NDE results on any system conforming to the DICONDE standard. Toward that end, Practice E2339 provides a data dictionary and a set of information modules that are applicable to all NDE modalities. This practice supplements Practice E2339 by providing information object definitions, information modules and a data dictionary that are specific to digital X-ray test methods.

1.2 This practice has been developed to overcome the issues that arise when analyzing or archiving data from digital X-ray test equipment using proprietary data transfer and storage methods. As digital technologies evolve, data must remain decipherable through the use of open, industry-wide methods

for data transfer and archival storage. This practice defines a method where all the digital X-ray technique parameters and test results are communicated and stored in a standard manner regardless of changes in digital technology.

1.3 This practice does not specify:

1.3.1 A testing or validation procedure to assess an implementation's conformance to the standard.

1.3.2 The implementation details of any features of the standard on a device claiming conformance.

1.3.3 The overall set of features and functions to be expected from a system implemented by integrating a group of devices each claiming DICONDE conformance.

1.4 Although this practice contains no values that require units, it does describe methods to store and communicate data that do require units to be properly interpreted. The SI units required by this practice are to be regarded as standard. No other units of measurement are included in this standard.

1.5 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

## 2. Referenced Documents *(purchase separately)* ⓘ The documents listed below are referenced within the subject standard but are not provided as part of the standard.

### ASTM Standards

E1316 Terminology for Nondestructive Examinations
E1475 Guide for Data Fields for Computerized Transfer of Digital Radiological Examination Data
E2339 Practice for Digital Imaging and Communication in Nondestructive Evaluation (DICONDE)
E2597 Practice for Manufacturing Characterization of Digital Detector Arrays

### Other Standard

DICOM National Electrical Manufacturers Association Standard for Digital Imaging and Communications in Medicine (DICOM), 2008

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