



**Recommended  
Training Curriculum  
For  
Digital Radiography  
Personnel  
(Level II)**

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**Federal Working Group on Industrial Digital Radiography (FWGIDR)** - The FWGIDR is a self-chartered organization consisting of federal and government contract employees and endorsed by the Defense Working Group on Nondestructive Testing (DWGNDT). This working group provides a platform for identifying common concerns and critical issues facing the federal industrial radiographic community as it transitions from film to digital radiography (DR). The FWGIDR, utilizing expertise from within the community, organizes and coordinates technical committees that formulate positions, guidance, and/or solutions for the community's common concerns and issues.

**Background** – Recognizing significant difficulties in addressing technical advances in the digital radiographic field, several engineers from the Department of Energy (DOE) and Department of Defense (DoD) organized the FWGIDR in 2007 to address the problems and concerns faced by the industrial radiographic community in transitioning to DR. Digital X-ray systems are revolutionizing medical radiology, as digital cameras revolutionized the photographic community, and similarly have an ever-increasing role in radiographic nondestructive testing. Medical radiology backed by significant development and funding, and digital photography, with rapid public acceptance; have demonstrated the advantages that digital systems offer in image intensive applications. The FWGIDR is focused on a vision for the future radiographic inspection facility, and that vision is digital radiography.

The rapid growth in DR has created transitional issues difficult for the industrial community to assimilate while transitioning from film to digital techniques. These issues include personnel training; data formatting, storage and retrieval; technique development and qualification; equipment qualification and monitoring; process control; and development and acquisition of equipment suitable for industrial applications.

Participants in the FWGIDR are organizations that employ nondestructive testing in support of government contracts. DOE, DoD, prime government contractors, along with other government and contractor personnel are actively contributing to and supporting the efforts of this working group.

**Introduction** – This paper, “Recommended Training Curriculum for Digital Radiography Personnel (Level II)”, was developed by a task team established by the FWGIDR. It addresses a major concern of the federal industrial radiographic community regarding personnel training. Original equipment manufacturers (OEMs) commonly offer Digital Radiography (DR) equipment familiarization training but provides limited, if any, basic DR training. There has been a need to establish appropriate DR training curriculums for Level I, II and III personnel. In September of 2009, the FWGIDR released a white paper , Paper No. 001-009, which provided a recommended DR training curriculum for Level III personnel. This is a continuation of the FWGIDR efforts to improve DR training. This white paper provides a recommended training curriculum for Level II DR personnel that is specifically designed to ensure compliance with NAS 410 requirements.

**Purpose** – This paper is intended as a recommended reference/guide for DR training curriculums for Level II radiographic film personnel transitioning to Level II DR functions as well as those that are already employing DR systems and techniques.

**Scope** – This curriculum covers DR principles, equipment and implementation issues that should be understood by Level II DR personnel. This training curriculum is intended for personnel that will utilize computed radiography systems (CR) and/or digital detector array (DDA) based DR systems.

**Prerequisite** – This curriculum does not cover basic radiography inspection principles. It was designed for personnel who already have training equivalent to the 80 hours recommended by the ASNT’s recommended practice SNT-TC-1A, Aerospace Industries Association’s NAS 410, or equivalent knowledge.

This training curriculum is intended for certified Level II film radiographers who are transitioning to digital radiography. The recommended training hours for this curriculum is 40 hours. Suggested hours for each section are noted in parenthesis. *(If the candidate has completed formal training in Level I digital radiography, subject matter previously covered in the Level I training does not need to be repeated to the extent it was presented.)*

Note: Basic computer competency skills are necessary to transition from film radiography to non-film radiography.

1. Introduction (1.0 Hours)
  - 1.1. Definition of Digital Radiography (DR)
  - 1.2. Overview of DR Systems
    - 1.2.1. Basic System Components
      - 1.2.1.1. Computed Radiography (CR) systems
      - 1.2.1.2. Digital Detector Array (DDA) based systems
      - 1.2.1.3. Image Intensifier (II) based systems
    - 1.2.2. DR System Capabilities
    - 1.2.3. Advantages and Disadvantages of DR
    - 1.2.4. Application Examples
  - 1.3. Digital Image Terminology
    - 1.3.1. Bits
    - 1.3.2. Bytes
    - 1.3.3. Pixels
    - 1.3.4. Bit Depth
  - 1.4. Cost and Environmental Impact Comparisons (Film vs. DR)
2. DR vs. Film Images (1.0 Hours)
  - 2.1. Image Quality Parameters
    - 2.1.1. Linearity
    - 2.1.2. Latitude
    - 2.1.3. Pixel Value (Grey Value)
    - 2.1.4. Signal to Noise Ratio (SNR)
    - 2.1.5. Contrast Sensitivity (CS)
    - 2.1.6. Contrast to Noise Ratio (CNR)
    - 2.1.7. Spatial Resolution (SR)
  - 2.2. Image File Formats
    - 2.2.1. Compression
    - 2.2.2. Lossy and Lossless (jpg, tiff, etc.)
    - 2.2.3. DICOM

- 3. DR System Components (Detailed) (6.0 Hours)
  - 3.1. Sources (X-Ray and Gamma Ray)
    - 3.1.1. Energy, Current, Power
    - 3.1.2. Curies
    - 3.1.3. Focal Spot / Source Size
    - 3.1.4. X-Ray Tubes
      - 3.1.4.1. Open Tubes vs. Closed Tubes
      - 3.1.4.2. Directional vs. Transmission Tubes
    - 3.1.5. Gamma Sources
      - 3.1.5.1. Iridium-192, Cobalt-60, Selenium-75, Ytterbium-169
  - 3.2. Scatter Control Devices
    - 3.2.1. Filters (Pre and Post Specimen)
    - 3.2.2. Collimators and Diaphragms
    - 3.2.3. Masks
    - 3.2.4. Shielding
  - 3.3. Hardware Manipulators
    - 3.3.1. Multiple Axis
    - 3.3.2. Precision and Repeatability
    - 3.3.3. Weight Capacity
    - 3.3.4. Motion Control
      - 3.3.4.1. Manual and Automated
      - 3.3.4.2. Crash Protection (Limits)
  - 3.4. Detector Types
    - 3.4.1. Digital Detector Arrays (DDA)
      - 3.4.1.1. Flat Panel Detectors
        - 3.4.1.1.1. Amorphous Silicon
        - 3.4.1.1.2. Amorphous Selenium
        - 3.4.1.1.3. CMOS
      - 3.4.1.2. Cameras
        - 3.4.1.2.1. CCD
        - 3.4.1.2.2. CMOS
      - 3.4.1.3. Linear Diode Arrays (LDA)
        - 3.4.1.3.1. CMOS
        - 3.4.1.3.2. Photodiode
      - 3.4.1.4. Scintillators
    - 3.4.2. Computed Radiography System
      - 3.4.2.1. Photostimulable Luminescence (PSL)
      - 3.4.2.2. Imaging Plates (IPs) and Cassettes
      - 3.4.2.3. CR Scanner and Settings
        - 3.4.2.3.1. Laser
        - 3.4.2.3.2. Photomultiplier Tube

3.4.2.3.3. Analog to Digital Converter

3.5. Computer

3.5.1. Operator Interface

3.5.2. System Controller

3.5.3. Image Processor

3.6. Image Displays

3.6.1. Display Card

3.6.2. Image Display Monitors

3.6.2.1. CRT, LCD, LED, Plasma, etc.

3.7. Image Archive and Transmission Media

3.7.1. Removable Media (CD/DVD/Blue Ray/Tape, Portable Hard Drive, etc.)

3.7.2. Redundant Array of Inexpensive Disks (RAID)

3.7.3. Central Server

4. Image Fidelity Attributes (1.0 Hours)

4.1. Signal

4.2. Noise

4.3. Contrast

4.4. Spatial Resolution

4.5. Software Tools to Measure Image Attributes

4.5.1. Histogram

4.5.2. Line Profile

4.5.3. Mean and Standard Deviation

5. Image Processing (4.0 Hours)

5.1. Intensity Transforms

5.1.1. Windowing (Width and Level)

5.1.2. Gray Scale Mapping (Look Up Tables)

5.1.3. Thresholding

5.1.4. Pseudo Color

5.2. Image Math

5.2.1. Addition (Integration)

5.2.2. Subtraction

5.2.3. Division

5.2.4. Multiplication

5.2.5. Averaging

5.3. Filtering

5.3.1. Convolution (Spatial)

5.3.1.1. Smoothing (Low Pass)

5.3.1.2. Sharpening (High Pass)

5.3.1.3. Median

5.3.1.4. Unsharp Mask

- 5.4. Advantages and Disadvantages of Image Processing
  
- 6. Detector Attributes (4.0 Hours)
  - 6.1. DDA - Pixel Pitch and Fill Factor
  - 6.2. CR – Pixel Size vs. Laser Size, Laser Intensity, IP Grain Size and Thickness
  - 6.3. Sampling Frequency
  - 6.4. Frame Rates
  - 6.5. Triggers
  - 6.6. Bit Depth
  - 6.7. Linear vs. Log
  - 6.8. Dynamic Range
  - 6.9. Low Energy X-Ray Sensitivity (Scatter)
  - 6.10. Signal To Noise Ratio
  - 6.11. Fabrication Anomalies (Bad Pixels, Artifacts, panel grading, etc.)
  - 6.12. Handling and Portability
  - 6.13. Preset and Manual Settings
  - 6.14. Radiation Tolerance
  
- 7. Image Display Monitor Characteristics (0.5 Hours)
  - 7.1. Resolution and Pixel Size
  - 7.2. Bit Depth
  - 7.3. Brightness
  - 7.4. Contrast
  - 7.5. Dynamic Range
  
- 8. Viewing Environment (0.5 Hours)
  - 8.1. Ambient Lighting
  - 8.2. Humidity and Temperature
  - 8.3. Glare, Reflections, Fingerprints, etc.
  - 8.4. Eye Adaptation
  - 8.5. Ergonomics
  
- 9. DR Techniques (Part Specific) (4.0 Hours)
  - 9.1. Basic Parameters and Settings
    - 9.1.1. Radiation Energy (kV) / Gamma Source
    - 9.1.2. X-Ray Tube Current (mA) / Gamma Source Strength
    - 9.1.3. Exposure Time (Frame Rate or Integration Time for DDAs)
    - 9.1.4. Filtering (pre or post)
    - 9.1.5. Masking
    - 9.1.6. IQI Selection and Placement
      - 9.1.6.1. IQI pixel value vs. Area of Interest (plus/minus 15%)
  - 9.2. DR Distinctive Parameters and Settings
    - 9.2.1. Signal To Noise Ratio (SNR)

- 9.2.2. Contrast to Noise Ratio (CNR)
- 9.2.3. Basic Spatial Resolution ( $SR_b$ )
- 9.2.4. Geometric Magnification (FDD, FOD, Optimizing for focal spot and  $SR_b$ )
- 9.2.5. Normalized Image Unsharpness ( $U_{im}$ )
- 9.2.6. Field of View
- 9.2.7. Pixel Dimension (Apparent pixel size at field of view based on known dimension )
- 9.2.8. DDA Specific
  - 9.2.8.1. Gain and Offset Corrections (Detector Calibration)
  - 9.2.8.2. Frame Rate
  - 9.2.8.3. Frame Integration
  - 9.2.8.4. Frame Averaging
  - 9.2.8.5. Binning
  - 9.2.8.6. Triggering (Internal and External)
- 9.2.9. CR Specific
  - 9.2.9.1. IP Selection
  - 9.2.9.2. IP Erasure
  - 9.2.9.3. Scanner Settings
- 9.2.10. Image Processing
  - 9.2.10.1. Window Width and Level
  - 9.2.10.2. Intensity Transforms Parameters
  - 9.2.10.3. Filtering Parameters
  - 9.2.10.4. Processing Algorithms and Parameters
- 9.3. Technique Documentation
  - 9.3.1. Exposure Parameters
    - 9.3.1.1. Radiation Source Parameters
      - 9.3.1.1.1. kV, current, Focal Spot, Beam Filters, etc.
    - 9.3.1.2. DDA Settings
      - 9.3.1.2.1. Frame Rate
      - 9.3.1.2.2. Frame Averaging
      - 9.3.1.2.3. Binning
      - 9.3.1.2.4. Gain/Offset
      - 9.3.1.2.5. Post Filters
    - 9.3.1.3. CR Scanner Settings and IPs
      - 9.3.1.3.1. IP Type, Cassette Type, Cassette Screens/Filters
      - 9.3.1.3.2. Laser Spot Size
      - 9.3.1.3.3. Scanner Presets
      - 9.3.1.3.4. Sampling Rate
      - 9.3.1.3.5. Gain Settings (Photomultiplier Tube)
  - 9.3.2. Set-up Geometry
    - 9.3.2.1. Focal Spot to Detector Distance (FDD)
    - 9.3.2.2. Focal Spot to Object Distance (FOD)



- 9.3.2.3. Geometric Magnification
  - 9.3.2.4. Geometric Unsharpness ( $U_g$ )
  - 9.3.2.5. Normalized Image Unsharpness ( $U_{im}$ )
  - 9.3.3. Image Review Requirements
    - 9.3.3.1. Window Width and Level
    - 9.3.3.2. Digital Zoom
  - 9.3.4. Image Processing Requirements
  - 9.3.5. Measurement Calibration Requirements
  - 9.3.6. Digital Reference Images
10. Image Interpretation (3.0 Hours)
- 10.1. Image Qualification
    - 10.1.1. Area of Interest (AOI) vs. Region of Interest (ROI)
    - 10.1.2. IQI and/or RQI Feature Verification (type, material, size, position, visibility, etc.)
    - 10.1.3. Measure SNR
    - 10.1.4. Measure CNR
    - 10.1.5. Pixel Value Range
    - 10.1.6. Image Identification, Traceability
    - 10.1.7. Part Coverage
  - 10.2. Image Evaluation
    - 10.2.1. Identify Artifacts (acceptable or re-image required)
    - 10.2.2. Relevant vs. Non-Relevant Indications
    - 10.2.3. Measurement Calibration and Accuracy
    - 10.2.4. Accept/Reject Criteria
      - 10.2.4.1. Discrete vs. Digital Reference Images
  - 10.3. Examination Reports and Records
11. Process Controls (System Baseline and Degradation Monitoring) (6.0 Hours)
- 11.1. CR System Performance Tests (System Characterization – E2445)
    - 11.1.1. Normalized SNR ( $SNR_N$ )
    - 11.1.2. Geometric Distortion
    - 11.1.3. Laser Beam Function
    - 11.1.4. Blooming/Flare
    - 11.1.5. Jitter
    - 11.1.6. Scanner Slippage
    - 11.1.7. Shading
    - 11.1.8. IP Erasure
    - 11.1.9. IP Artifacts
    - 11.1.10. Characterization Tools and Use
      - 11.1.10.1. CR Phantoms
        - 11.1.10.1.1. ASTM E2445 Phantom
        - 11.1.10.1.2. USAF CR Process Control Standard (AFRL-RX-WP-TR-2009-4069)

- 11.1.10.2. Gages and Use
  - 11.1.10.2.1. E2002 Duplex Wire Gage
  - 11.1.10.2.2. Converging and Parallel Line Pair Gages
  - 11.1.10.2.3. EPS Gages (E746 and E1735)
- 11.2. DDA System Performance Tests (System Characterization – E2737)
  - 11.2.1. Basic Spatial Resolution (SRb)
  - 11.2.2. Contrast Sensitivity
  - 11.2.3. Material Thickness Range
  - 11.2.4. SNR
  - 11.2.5. Signal Level
  - 11.2.6. Image Lag
  - 11.2.7. Burn-In
  - 11.2.8. Offset Level
  - 11.2.9. Bad Pixel Distribution
  - 11.2.10. DDA Phantoms
    - 11.2.10.1. Duplex Plate
      - 11.2.10.1.1. E2002 Duplex Wire Gage
      - 11.2.10.1.2. IQIs (E1025 or E1742)
    - 11.2.10.2. Five Groove Wedge
- 11.3. Image Display Monitor Performance Tests
  - 11.3.1. SEMPTE - RP 133 Test Pattern
  - 11.3.2. Minimum Brightness
  - 11.3.3. Minimum Contrast Ratio
  - 11.3.4. Aliasing
  - 11.3.5. Resolution
  - 11.3.6. Screen Flicker
  - 11.3.7. Distortion
  - 11.3.8. 5% DDL Blocks
  - 11.3.9. Background Ambient Light
  - 11.3.10. Performance check periodicity
- 12. Equipment Maintenance (1.0 Hours)
  - 12.1. Open X-Ray Tubes
    - 12.1.1. Focal Spot Degradation
  - 12.2. CR Scanners
  - 12.3. IP Cleaning and Artifact Management
  - 12.4. Manipulators
  - 12.5. Image Display Monitor Cleaning
- 13. Specific Equipment Training (8.0 Hours)
  - 13.1. Software
  - 13.2. Hardware

### 13.3. Total System

Note: The listed 8 hours may be conducted separately from a classroom environment, and shall be conducted on specific equipment and procedures used by the employer.

## 14. Reference Documents

### Government Documents:

#### United States Air Force Research Lab

AFRL-RX-WP-TR-2009-4069, Development of USAF Computed Radiography (CR) Process Control

### Industry Documents:

#### Aerospace Industries Association of America (AIA/NAS)

NAS 410        NAS Certification and Qualification of Nondestructive Test Personnel

#### ASME Boiler and Pressure Vessel Code (BPVC)

Section V – Nondestructive Examination, Article 2 – Radiographic Examination

Section V – Nondestructive Examination, Article 2, Appendix VIII & IX

#### America Society for Nondestructive Testing (ASNT)

SNT-TC-1A       Personnel Qualification and Certification in Nondestructive Testing

#### ASTM International

E746    Standard Practice for Determining Relative Image Quality Response Industrial Radiographic Imaging Systems

E747    Standard Practice for Design, Manufacture and Material Grouping Classification of Wire Image Quality Indicators (IQI) Used for Radiology

E1000   Standard Guide for Radioscopy

E1025   Standard Practice for Design, Manufacture and Material Grouping Classification of Hole-Type Image Quality Indicators (IQI) Used for Radiology

E1161   Standard Practice for Radiologic Examination of Semiconductors and Electronic Components

E1165   Standard Test Method for Measurement of Focal Spots of Industrial X-Ray Tubes by Pinhole Imaging

E1255   Standard Practice for Radioscopy

E1316   Standard Terminology for Nondestructive Examinations

E1411   Standard Practice for Qualification of Radioscopic Systems

E1416   Radiologic Examination of Semiconductors and Electronic Components

E1647   Standard Practice for Determining Contrast Sensitivity in Radiology

E1734   Standard Practice for Radioscopic Examination of Castings

E1742   Standard Practice for Radiographic Examination

E1817   Standard Practice for Controlling Quality of Radiological Examinations by using Representative Quality Indicators (RQIs)

- E1936 Standard Reference Radiograph for Evaluating the Performance of Radiographic Digitization Systems
- E2002 Standard Practice for Determining Total Image Unsharpness in Radiology
- E2007 Standard Guide for Computed Radiology (Photostimulable Luminescence Method)
- E2033 Standard Practice for Computed Radiology (Photostimulable Luminescence Method)
- E2104 Standard Practice for Radiological Examination of Advanced Aero and Turbine Materials and Components
- E2339 Standard Practice for Digital Imaging and Communication in Nondestructive Evaluation (DICONDE)
- E2422 Standard Digital Reference Images for Inspection of Aluminum Castings
- E2445 Standard Practice for Qualification and Long Term Stability of Computed Radiology Systems
- E2446 Standard Practice for Classification of Computed Radiology Systems
- E2597 Standard Practice for Manufacturing Characterization of Digital Detector Arrays
- E2660 Standard Digital Reference Images for Investment Steel Castings for Aerospace Applications
- E2662 Standard Practice for Radiological Examination of Flat Panel Composites and Sandwich Core Materials Used in Aerospace Applications
- E2669 Standard Digital Reference Images for Titanium Castings
- E2698 Standard Practice for Radiological Examination Using Digital Detector Arrays
- E2699 Standard Practice for Digital Imaging and Communication in Nondestructive Evaluation (DICONDE) for Digital Radiographic (DR) Test Methods
- E2736 Standard Guide for Digital Detector Array Radiology
- E2738 Standard Practice for Digital Imaging and Communication in Nondestructive Evaluation (DICONDE) for Computed Radiology (CR) Test Methods
- E2737 Standard Practice for Digital Detector Array Performance Evaluation and Long Term Stability

#### European Standards

- EN12534-5 Characteristics of Focal Spots in Industrial X-Ray Systems for Use in Non-Destructive Testing, Part 5: Measurement of the Effective Focal Spot Size of Mini and Micro Focus X-Ray Tubes

#### Society of Motion Picture and Television Engineers (SMPTE)

- SMPTE RP 133 Specification for Medical Diagnostic Imaging Test Pattern for Television Monitors and Hard Copy Recording Cameras