Federal Working Group on Industrial Digital Radiography

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Recommended Training Curriculum For Digital Radiography Personnel (Level III)

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Federal Working Group on Industrial Digital Radiography (FWG-IDR) - The FWG-IDR is a self chartered organization consisting of federal employees and government contract employees and is endorsed by the Defense Working Group on Nondestructive Testing (DWG-NDT). 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 FWG-IDR, utilizing expertise from within the community, organizes and coordinates technical committees that formulate postions, guideance, and/or solutions for the community's common concerns and issues.

Background - With tremendous advances being made in digital radiography (DR), fueled largely by significant research investments by the medical community, and the acceptance by the general public of digital photography, it became apparent that digital radiography will have an ever increasing role in industrial radiography. Recognizing the value of DR, a good number of Federal Radiographic Facilities embraced the new technology in its earliest developmental stages and implemented DR technology. Spurred by this expanding use of DR and the recognition that a number of technological and process shortcomings existed, several meetings, attended by Department of Energy (DOE), Department of Defense (DOD), and other government and contractor NDT employees, were held to discuss the future vision for industrial digital radiography in the Federal community. Those meetings became the foundation for the Federal Working Group on Industrial Digital Radiography.

The attendees emerged from those first meetings with a consensus that, indeed, DR would be the future of industrial radiography and there were many areas of common concern. They further recognized that a concerted and organized effort needed to be mounted to ensure that all issues concerning transitioning from old to new technology be addressed. An extensive list of issues were discussed among these nondestruction evaluation (NDE) professionals and several topics were determined to be common amongst the attendees. These common issues were prioritized and task teams established to develop recommendations and guidance for the industrial radiographic community.

Introduction – This paper, "Recommended Training Curriculum for Digital Radiography Personnel (Level III)", was developed by a task team established by the FWG-IDR. It addresses a major concern of the federal industrial radiographic community, personnel training. Organizations providing training for industrial DR are very limited at the present time. They are primarily original equipment manufacturers (OEMs) that offer limited general DR training in conjuction with training on the operation of their specific DR systems. The American Society for Nondestructive Testing (ASNT), a professional nondestructive testing society that traditionally establishes personnel training and certification guidelines and requirements, has published a training curriculum for technician level personnel. Completion of this training along with limited work experience (175 hours) can qualify a technician for <u>Limited</u> Level II certification. The most critical training need identified for successful transition of the industry was appropriate education of the technical leads at industrial radiography activities. These technical leads at radiographic activities are commonly referred to as Level IIIs and customarily hold Level III certifications issued by their employers or by appropriate professional societies (i.e. ASNT). DR training for Level IIIs was expressed as a common concern with high priority having significant impact on the industry's transition from film to DR. This paper was written as a significant step towards meeting the industry's training needs. It provides a documented DR personnel training curriculum targeting lead radiographers.

Purpose - This paper is intended as a recommended reference/guide for DR training curriculums for lead radiographers transitioning from film to digital radiography, as well as, those already employing DR systems and techniques.

Scope – This curriculum covers DR principles, equipment and implementation issues that should be understood by lead radiographers. DR, as expressed by the FWG-IDR, encompasses any radiographic method that results in a digital radiographic image. This includes computed radiography (CR), camera, 2-D panel, and linear array detector based DR systems, computed tomography (CT) systems, radioscopy systems that result in digital images, and film digitizers. It should be noted that the CT training covered by this curriculum is introductory and is not considered sufficient training for lead radiographers employing CT 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 number SNT-TC-1A or equivalent knowledge.

Digital Radiography (DR) Training Curriculum

Basic DR Training

1.0 Introduction
- 1.1 Digital Radiography (DR)
  - 1.1.1 Definition
- 1.2 Digital Image
  - 1.2.1 Bits
  - 1.2.2 Bytes
  - 1.2.3 Pixels/Voxels
  - 1.2.4 Image file formats and compression (lossy vs. lossless) (include JPEG, TIFF, DICONDE)
- 1.3 DR System Overview
  - 1.3.1 Basic components and functions
- 1.4 DR System Capabilities
  - 1.4.1 DR vs. film procedural steps
  - 1.4.2 Cost and environmental issues

2.0 DR System Components
- 2.1 X-Ray and Gamma Ray Sources
  - 2.1.1 Energy, mA, Focal Spot
  - 2.1.2 Stability
  - 2.1.3 Open and Closed X-Ray Tubes
  - 2.1.4 Filtration
- 2.2 Manipulators
  - 2.2.1 Manual vs. automated, multiple axis, weight capacity, precision
- 2.3 Detectors (Digital data acquisition)
  - 2.3.1 Scanner Based
    - 2.3.1.1 Film Digitizers
      - 2.3.1.1.1 Film
      - 2.3.1.1.2 Scanner/digitizer
    - 2.3.1.2 Computed Radiography (CR)
      - 2.3.1.2.1 Imaging plate
      - 2.3.1.2.2 Scanner/digitizer
  - 2.3.2 Digital Detector Arrays
    - 2.3.2.1 Scintillators
      - 2.3.2.1.1 Cesium Iodide (CsI)
      - 2.3.2.1.2 Gadolinium Oxysulfide (GOS)
      - 2.3.2.1.3 Glass Plates
      - 2.3.2.1.4 Fiber-Optic

- 2.3.2.2 Flat Panels
  - 2.3.2.2.1 Amorphous Silicon (am-Si)
  - 2.3.2.2.2 Amorphous Selenium (am-Se)
  - 2.3.2.2.3 Complementary metal-oxide-semiconductor (CMOS)
- 2.3.2.3 Cameras (2-D)
  - 2.3.2.3.1 Charged-coupled Devise (CCD) (interlace, progressive, frame transfer, back thinned)
  - 2.3.2.3.2 CMOS
  - 2.3.2.3.3 CID
  - 2.3.2.3.4 Lenses and Fiber Optic Coupling
- 2.3.2.4 Linear Arrays (1-D)
  - 2.3.2.4.1 Linear Diode Array (LDA)
  - 2.3.2.4.2 CMOS Linear Array
  - 2.3.2.4.3 CCD Line Scan
  - 2.3.2.4.4 CCD TDI (Time Delayed Integration)
- 2.3.2.5 X-Ray Image Intensifier
  - 2.3.2.5.1 Image Intensifier
  - 2.3.2.5.2 Video camera (include Automatic Gain Control, AGC)

- 2.4 Computer
  - 2.4.1 Operator Interface
  - 2.4.2 System Controller
  - 2.4.3 Image Processor
- 2.5 Monitors (display)
  - 2.5.1 CRT
  - 2.5.2 Flat panel (LCD)
- 2.6 Data Archive
  - 2.6.1 Removable Media - Single media (CD, DVD, tape)
  - 2.6.2 Redundant Array of Inexpensive Disks (RAID)
  - 2.6.3 Central archive

3.0 Sampling Theory (Digitizing)

- 3.1 Discrete Elements
- 3.2 Pixel size (Aperture)
- 3.3 Pixel pitch
- 3.4 Bit depth
- 3.5 Nyquist Theory

4.0 Image Fidelity

- 4.1 Measuring Image Fidelity
  - 4.1.1 Contrast
  - 4.1.2 Resolution

- 4.1.3 Modulation Transfer Function (MTF)
- 4.1.4 Signal-to-Noise Ratio (SNR)

4.2 Image Fidelity Indicators (System characterization)

- 4.2.1 Line pair gauges
- 4.2.2 Phantoms
- 4.2.3 TV test patterns

4.3 DR Sensitivity Indicators (Technique verification)

- 4.3.1 Image Quality Indicators (IQI)
  - 4.3.1.1 Plaques (Hole type)
  - 4.3.1.2 Wires
  - 4.3.1.3 Line pair gauges
  - 4.3.1.4 Reference Quality Indicators (RQI)

5.0 Visual Perception

- 5.1 Spatial frequency
- 5.2 Contrast
- 5.3 Displayed Brightness
- 5.4 Signal-to-Noise Ratio (SNR)
- 5.5 Probability of Detection (POD) (single vs. multiple locations, scanning)
- 5.6 Receiver Operator Characteristic (ROC) curves

6.0 Image Processing (Post Processing)

- 6.1 Gray scale adjustments
  - 6.1.1 Windowing
  - 6.1.2 Look-Up-Tables (LUT)
  - 6.1.3 Thresholding
  - 6.1.4 Histogram equalization
  - 6.1.5 Pseudo color
- 6.2 Arithmetic
  - 6.2.1 Addition (integration)
  - 6.2.2 Subtraction
  - 6.2.3 Division
  - 6.2.4 Multiplication
  - 6.2.5 Averaging
- 6.3 Filtering (kernels)
  - 6.3.1 Convolution
  - 6.3.2 Low pass (smoothing)
  - 6.3.3 High pass (edge enhancement)
  - 6.3.4 Median
  - 6.3.5 Unsharp mask
- 6.4 Morphological Transforms
  - 6.4.1 Erosion

        6.4.2 Dilation
    6.5 Region of Interest (ROI)

Application

7.0 Film vs. DR Images
- 7.1 Linearity
- 7.2 Latitude
- 7.3 Contrast
- 7.4 Resolution

8.0 Detector Comparisons & Selection Issues
- 8.1 Frame Rate
- 8.2 Resolution (pixel pitch, pixel size, etc.)
- 8.3 Blooming, Bleed Over
- 8.4 Burning
- 8.5 Ghosting/Latent Image/Lag
- 8.6 Scatter Sensitivity
- 8.7 Bit Depth
- 8.8 Dynamic Range and Signal to Noise Ratio
- 8.9 Fabrication anomalies (i.e. bad pixels, chip grades, etc.)
- 8.10 Radiation Exposure Tolerance

9.0 Detector Calibrations
- 9.1 CR Imaging Plate (IP) and Scanner
- 9.2 Flat Panel (include interpolation for bad pixels)
- 9.3 Cameras (CCD, etc.)
- 9.4 Linear Diode Arrays

10.0 Monitor and Viewing Environment
- 10.1 Limited bit depth display
- 10.2 Monitor resolution
- 10.3 Monitor Brightness and Contrast
- 10.4 Monitor testing
    - 10.4.1 Test Patterns
    - 10.4.2 Luminance – cd/m^2
    - 10.4.3 Contrast – min:max, Digital Driving Level (DDL)
- 10.4 Monitor calibration
- 10.5 Viewing Area and Ergonomics

11.0 Technique Development Considerations
- 11.1 Signal-to-Noise
  - 11.1.1 Tube Diaphragm
  - 11.1.2 Masking
  - 11.1.3 Lower Energy
  - 11.1.4 Filtering
  - 11.1.5 Object-to-Detector Distance
  - 11.1.6 Averaging/Integration
  - 11.1.7 Binning
- 11.2 Image Unsharpness & Sampling
  - 11.2.1 Geometry (FDD and ODD)
  - 11.2.2 Focal Spot
  - 11.2.3 Field of View
- 11.3 Image Processing
  - 11.3.1 With care (Pluses and minuses of common image processing techniques – windowing, filtering, subtraction, etc.)

12.0 Image Acquisition (Scanner Based and DDA DR)
- 12.1 Portability
- 12.2 Access Requirements for Detectors
- 12.3 Image Retrieval

13.0 Qualification of DR Procedures
- 13.1 Qualification plan
- 13.2 System Characterization
- 13.3 Process Controls
- 13.4 Technique Documentation
- 13.5 Technique Validation

14.0 Review DR Industry Standards (i.e. ASTM)

15.0 Introduction to Computed Tomography (CT)
- 15.1 Data Collection (parallel, fan, and cone beam)
- 15.2 Reconstruction (Filtered Back Projection, FFT, Feldkamp)