RT

RADIOGRAPHIC TESTING TOPICAL OUTLINES

Radiography Level I Topical Outline

Note: Independent of the training recommended for Level I and Level II certification, a trainee is required to receive radiation safety training as required by the regulatory jurisdiction. A Radiation Safety Topical Outline is available in Appendix A and can be used as guidance.

Basic Radiographic Testing Physics Course

1.0 Introduction
- 1.1 History and discovery of radioactive materials
- 1.2 Definition of industrial radiographic testing (RT)
- 1.3 Radiation protection – why?
- 1.4 Basic math review – exponents, square root, etc.

2.0 Fundamental Properties of Matter
- 2.1 Elements and atoms
- 2.2 Molecules and compounds
- 2.3 Atomic particles – properties of protons, electrons, and neutrons
- 2.4 Atomic structure
- 2.5 Atomic number and weight
- 2.6 Isotope versus radioisotope

3.0 Radioactive Materials
- 3.1 Production
  - 3.1.1 Neutron activation
  - 3.1.2 Nuclear fission
- 3.2 Stable versus unstable (radioactive) atoms
- 3.3 Becquerel – the unit of activity
- 3.4 Half-life of radioactive materials
- 3.5 Plotting of radioactive decay
- 3.6 Specific activity – becquerels/gram

4.0 Types of Radiation
- 4.1 Particulate radiation – properties: alpha, beta, neutron
- 4.2 Electromagnetic radiation – X-ray, gamma ray
- 4.3 X-ray production
- 4.4 Gamma ray production
- 4.5 Gamma ray energy
- 4.6 Energy characteristics of common radioisotope sources
- 4.7 Energy characteristics of X-ray machines

5.0 Interaction of Radiation with Matter
- 5.1 Ionization
- 5.2 Radiation interaction with matter
  - 5.2.1 Photoelectric effect
  - 5.2.2 Compton scattering
  - 5.2.3 Pair production
- 5.3 Unit of radiation exposure – coulomb per kilogram (C/kg)
- 5.4 Emissivity of commonly used radiographic sources
- 5.5 Emissivity of X-ray exposure devices
- 5.6 Attenuation of electromagnetic radiation – shielding
- 5.7 Half-value layers (HVL), tenth-value layers (TVL)
- 5.8 Inverse square law

6.0 Exposure Devices and Radiation Sources
- 6.1 Radioisotope sources
  - 6.1.1 Sealed-source design and fabrication
  - 6.1.2 Gamma ray sources
  - 6.1.3 Beta and bremsstrahlung sources
  - 6.1.4 Neutron sources
- 6.2 Radioisotope exposure device characteristics
- 6.3 Electronic radiation sources – 500 keV and less, low energy
  - 6.3.1 Generator – high-voltage rectifiers
  - 6.3.2 X-ray tube design and fabrication
  - 6.3.3 X-ray control circuits
  - 6.3.4 Accelerating potential
  - 6.3.5 Target material and configuration
  - 6.3.6 Heat dissipation
  - 6.3.7 Duty cycle
  - 6.3.8 Beam filtration
- 6.4* Electronic radiation sources – medium- and high-energy
  - 6.4.1* Resonance transformer
  - 6.4.2* Van de Graaff accelerator
  - 6.4.3* Linear accelerator
  - 6.4.4* Betatron
  - 6.4.5* Coulomb per kilogram (C/kg) output
  - 6.4.6* Equipment design and fabrication
  - 6.4.7* Beam filtration
- 6.5* Fluoroscopic radiation sources
  - 6.5.1* Fluoroscopic equipment design
  - 6.5.2* Direct-viewing screens
  - 6.5.3* Image amplification
  - 6.5.4* Special X-ray tube considerations and duty cycle
  - 6.5.5* Screen unsharpness
  - 6.5.6* Screen conversion efficiency

7.0 Radiographic Safety Principles Review
- 7.1 Controlling personnel exposure
- 7.2 Time, distance, shielding concepts
- 7.3 ALARA concept
- 7.4 Radiation detection equipment
- 7.5 Exposure device operating characteristics

* Topics may be deleted if the employer does not use these methods and techniques.

Radiography Technique Course

1.0 Introduction
- 1.1 Process of radiography
- 1.2 Types of electromagnetic radiation sources
- 1.3 Electromagnetic spectrum
- 1.4 Penetrating ability or "quality" of X-rays and gamma rays
- 1.5 Spectrum of X-ray tube source
- 1.6 Spectrum of gamma radioisotope source
- 1.7 X-ray tube – change of mA or kVp effect on "quality" and intensity

2.0 Basic Principles of Radiography
- 2.1 Geometric exposure principles
  - 2.1.1 "Shadow" formation and distortion
  - 2.1.2 Shadow enlargement calculation
  - 2.1.3 Shadow sharpness
  - 2.1.4 Geometric unsharpness
  - 2.1.5 Finding discontinuity depth
- 2.2 Radiography screens
  - 2.2.1 Lead intensifying screens
  - 2.2.2 Fluorescent intensifying screens
  - 2.2.3 Intensifying factors
  - 2.2.4 Importance of screen-to-film contact
  - 2.2.5 Importance of screen cleanliness and care
  - 2.2.6 Techniques for cleaning screens
- 2.3 Radiography cassettes
- 2.4 Composition of industrial radiography film
- 2.5 The "heel effect" with X-ray tubes

3.0 Radiographs
- 3.1 Formation of the latent image on film
- 3.2 Inherent unsharpness
- 3.3 Arithmetic of radiography exposure
  - 3.3.1 Milliamperage – distance-time relationship
  - 3.3.2 Reciprocity law
  - 3.3.3 Photographic density
  - 3.3.4 X-ray exposure charts – material thickness, kV, and exposure
  - 3.3.5 Gamma ray exposure chart
  - 3.3.6 Inverse square law considerations
  - 3.3.7 Calculation of exposure time for gamma and X-ray sources
- 3.4 Characteristic (Hurter and Driffield) curve
- 3.5 Film speed and class descriptions
- 3.6 Selection of film for particular purpose

4.0 Radiographic Image Quality
- 4.1 Radiographic sensitivity
- 4.2 Radiographic contrast
- 4.3 Film contrast
- 4.4 Subject contrast
- 4.5 Definition
- 4.6 Film graininess and screen mottle effects
- 4.7 Image quality indicators (IQIs)

5.0 Film Handling, Loading, and Processing
- 5.1 Safelight and darkroom practices
- 5.2 Loading bench and cleanliness
- 5.3 Opening of film boxes and packets
- 5.4 Loading of film and sealing cassettes
- 5.5 Handling techniques for "green film"
- 5.6 Elements of manual film processing

6.0 Exposure Techniques – Radiography
- 6.1 Single-wall radiography
- 6.2 Double-wall radiography
  - 6.2.1 Viewing two walls simultaneously
  - 6.2.2 Offset double-wall exposure single-wall viewing
  - 6.2.3 Elliptical techniques
- 6.3 Panoramic radiography
- 6.4 Use of multiple-film loading
- 6.5 Specimen configuration

7.0 Fluoroscopic Techniques
- 7.1 Dark adaptation and eye sensitivity
- 7.2 Special scattered radiation techniques
- 7.3 Personnel protection
- 7.4 Sensitivity
- 7.5 Limitations
- 7.6 Direct-screen viewing
- 7.7 Indirect- and remote-screen viewing

Radiography Level II Topical Outline

Film Quality and Manufacturing Processes Course

1.0 Review of Basic Radiographic Principles
- 1.1 Interaction of radiation with matter
- 1.2 Math review
- 1.3 Exposure calculations
- 1.4 Geometric exposure principles
- 1.5 Radiographic image quality parameters

2.0 Darkroom Facilities, Techniques, and Processing
- 2.1 Facilities and equipment
  - 2.1.1 Automatic film processor versus manual processing
  - 2.1.2 Safelights
  - 2.1.3 Viewer lights
  - 2.1.4 Loading bench
  - 2.1.5 Miscellaneous equipment

2.2 Film loading
   2.2.1 General rules for handling unprocessed film
   2.2.2 Types of film packaging
   2.2.3 Cassette loading techniques for sheet and roll
2.3 Protection of radiography film in storage
2.4 Processing of film – manual
   2.4.1 Developer and replenishment
   2.4.2 Stop bath
   2.4.3 Fixer and replenishment
   2.4.4 Washing
   2.4.5 Prevention of water spots
   2.4.6 Drying
2.5 Automatic film processing
2.6 Film filing and storage
   2.6.1 Retention-life measurements
   2.6.2 Long-term storage
   2.6.3 Filing and separation techniques
2.7 Unsatisfactory radiographs – causes and cures
   2.7.1 High film density
   2.7.2 Insufficient film density
   2.7.3 High contrast
   2.7.4 Low contrast
   2.7.5 Poor definition
   2.7.6 Fog
   2.7.7 Light leaks
   2.7.8 Artifacts
2.8 Film density
   2.8.1 Step-wedge comparison film
   2.8.2 Densitometers

3.0 Indications, Discontinuities, and Defects
3.1 Indications
3.2 Discontinuities
   3.2.1 Inherent
   3.2.2 Processing
   3.2.3 Service
3.3 Defects

4.0 Manufacturing Processes and Associated Discontinuities
4.1 Casting processes and associated discontinuities
   4.1.1 Ingots, blooms, and billets
   4.1.2 Sand casting
   4.1.3 Centrifugal casting
   4.1.4 Investment casting
4.2 Wrought processes and associated discontinuities
   4.2.1 Forgings
   4.2.2 Rolled products
   4.2.3 Extruded products
4.3 Welding processes and associated discontinuities
   4.3.1 Submerged arc welding (SAW)
   4.3.2 Shielded metal arc welding (SMAW)
   4.3.3 Gas metal arc welding (GMAW)
   4.3.4 Flux cored arc welding (FCAW)
   4.3.5 Gas tungsten arc welding (GTAW)
   4.3.6 Resistance welding
   4.3.7 Special welding processes – electron-beam, electroslag, electrogas, etc.

5.0 Radiographic Safety Principles Review
5.1 Controlling personnel exposure
5.2 Time, distance, shielding concepts
5.3 ALARA concept
5.4 Radiation detection equipment
5.5 Exposure device operating characteristics

Radiographic Interpretation and Evaluation Course

1.0 Radiograph Viewing
1.1 Film-illuminator requirements
1.2 Background lighting
1.3 Multiple-composite viewing
1.4 IQI placement
1.5 Personnel dark adaptation and visual acuity
1.6 Film identification
1.7 Location markers
1.8 Film density measurement
1.9 Film artifacts

2.0 Application Techniques
2.1 Multiple-film techniques
   2.1.1 Thickness variation parameters
   2.1.2 Film speed
   2.1.3 Film latitude
2.2 Enlargement and projection
2.3 Geometrical relationships
   2.3.1 Geometrical unsharpness
   2.3.2 IQI sensitivity
   2.3.3 Source-to-film distance
   2.3.4 Focal spot size
2.4 Triangulation methods for discontinuity location
2.5 Localized magnification
2.6 Film handling techniques

3.0 Evaluation of Castings
3.1 Casting method review
3.2 Casting discontinuities
3.3 Origin and typical orientation of discontinuities
3.4 Radiographic appearance
3.5 Casting codes/standards – applicable acceptance criteria
3.6 Reference radiographs

4.0 Evaluation of Weldments
4.1 Welding method review
4.2 Welding discontinuities
4.3 Origin and typical orientation of discontinuities
4.4 Radiographic appearance
4.5 Welding codes/standards – applicable acceptance criteria
4.6 Reference radiographs or pictograms

5.0 Standards, Codes, and Procedures for Radiography
5.1 ASTM standards
5.2 Acceptable radiography techniques and setups
5.3 Applicable employer procedures
5.4 Procedure for radiograph parameter verification
5.5 Radiography reports

Computed Radiography Level I Topical Outline

Note: Independent of the training recommended for Level I and Level II certification, a trainee is required to receive radiation safety training as required by the regulatory jurisdiction. A Radiation Safety Topical Outline is available in Appendix A and can be used as guidance.

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- 1.1 History and discovery of radioactive materials
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- 1.3 Radiation protection – why?
- 1.4 Basic math review – exponents, square root, etc.

2.0 Fundamental Properties of Matter
- 2.1 Elements and atoms
- 2.2 Molecules and compounds
- 2.3 Atomic particles – properties of protons, electrons, and neutrons
- 2.4 Atomic structure
- 2.5 Atomic number and weight
- 2.6 Isotope versus radioisotope

3.0 Radioactive Materials
- 3.1 Production
  - 3.1.1 Neutron activation
  - 3.1.2 Nuclear fission
- 3.2 Stable versus unstable (radioactive) atoms
- 3.3 Becquerel – the unit of activity
- 3.4 Half-life of radioactive materials
- 3.5 Plotting of radioactive decay
- 3.6 Specific activity – becquerels/gram

4.0 Types of Radiation
- 4.1 Particulate radiation – properties: alpha, beta, neutron
- 4.2 Electromagnetic radiation – X-ray, gamma ray
- 4.3 X-ray production
- 4.4 Gamma ray production
- 4.5 Gamma ray energy
- 4.6 Energy characteristics of common radioisotope sources
- 4.7 Energy characteristics of X-ray machines

5.0 Interaction of Radiation with Matter
- 5.1 Ionization
- 5.2 Radiation interaction with matter
  - 5.2.1 Photoelectric effect
  - 5.2.2 Compton scattering
  - 5.2.3 Pair production
- 5.3 Unit of radiation exposure – coulomb per kilogram (C/kg)
- 5.4 Emissivity of commonly used radiographic sources
- 5.5 Emissivity of X-ray exposure devices
- 5.6 Attenuation of electromagnetic radiation – shielding
- 5.7 HVL, TVL
- 5.8 Inverse square law

6.0 Exposure Devices and Radiation Sources
- 6.1 Radioisotope sources
  - 6.1.1 Sealed-source design and fabrication
  - 6.1.2 Gamma ray sources
  - 6.1.3 Beta and bremsstrahlung sources
  - 6.1.4 Neutron sources
- 6.2 Radioisotope exposure device characteristics
- 6.3 Electronic radiation sources – 500 keV and less; low energy
  - 6.3.1 Generator – high-voltage rectifiers
  - 6.3.2 X-ray tube design and fabrication
  - 6.3.3 X-ray control circuits
  - 6.3.4 Accelerating potential
  - 6.3.5 Target material and configuration
  - 6.3.6 Heat dissipation
  - 6.3.7 Duty cycle
  - 6.3.8 Beam filtration
- 6.4* Electronic radiation sources – medium- and high-energy
  - 6.4.1* Resonance transformer
  - 6.4.2* Van de Graaff accelerator
  - 6.4.3* Linear accelerator
  - 6.4.4* Betatron
  - 6.4.5* Coulomb per kilogram (C/kg) output
  - 6.4.6* Equipment design and fabrication
  - 6.4.7* Beam filtration

7.0 Radiographic Safety Principles Review
- 7.1 Controlling personnel exposure
- 7.2 Time, distance, shielding concepts
- 7.3 ALARA concept
- 7.4 Radiation detection equipment
- 7.5 Exposure device operating characteristics

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Computed Radiography Technique Course

1.0 Computed Radiography (CR) Overview
- 1.1 Photostimulable luminescence (PSL)
- 1.2 Comparison of radiography and CR
- 1.3 Digital images
  - 1.3.1 Bits
  - 1.3.2 Bytes
  - 1.3.3 Pixels/voxels
  - 1.3.4 Image file formats and compression
- 1.4 Advantages
- 1.5 Disadvantages
- 1.6 Examples

2.0 System Components
- 2.1 Imaging plates (IP)
- 2.2 IP readout devices
- 2.3 Monitors
- 2.4 Computers

3.0 Basic CR Techniques
- 3.1 Image acquisition
- 3.2 IQIs
- 3.3 Display of acquired images
- 3.4 Optimization of displayed image
- 3.5 Storage of acquired and optimized image

4.0 Digital Image Processing
- 4.1 Enhanced images
- 4.2 Signal-to-noise ratio (SNR)
- 4.3 Artifacts and anomalies

Computed Radiography Level II Topical Outline

Advanced Computed Radiography Course

1.0 CR Overview
- 1.1 Photostimulable luminescence (PSL)
- 1.2 Image acquisition
- 1.3 Image presentation
- 1.4 Artifacts

2.0 Image Display Characteristics
- 2.1 Image definition
- 2.2 Filtering techniques
- 2.3 SNR
- 2.4 Modulation transfer function (MTF)
- 2.5 Grayscale adjustments
- 2.6 IQIs

3.0 Image Viewing
- 3.1 Image monitor requirements
- 3.2 Background lighting
- 3.3 IQI placement
- 3.4 Personnel dark adaptation and visual acuity
- 3.5 Image identification
- 3.6 Location markers

4.0 Evaluation of CR Images
- 4.1 Pixel value
- 4.2 IQI
- 4.3 Artifact mitigation
- 4.4 System performance
- 4.5 Conformance to specifications
- 4.6 Image storage and transmission

5.0 Application Techniques
- 5.1 Multiple-view techniques
  - 5.1.1 Thickness variation parameters
- 5.2 Enlargement and projection
- 5.3 Geometric relationships
  - 5.3.1 Geometric unsharpness
  - 5.3.2 IQI sensitivity
  - 5.3.3 Source-to-image plate distance
  - 5.3.4 Focal spot size
- 5.4 Localized magnification
- 5.5 Plate handling techniques

6.0 Evaluation of Castings
- 6.1 Casting method review
- 6.2 Casting discontinuities
- 6.3 Origin and typical orientation of discontinuities
- 6.4 Radiographic appearance
- 6.5 Casting codes/standards – applicable acceptance criteria
- 6.6 Reference radiographs or images

7.0 Evaluation of Weldments
- 7.1 Welding method review
- 7.2 Welding discontinuities
- 7.3 Origin and typical orientation of discontinuities
- 7.5 Welding codes/standards – applicable acceptance criteria
- 7.6 Reference radiographs or images

8.0 Standards, Codes, and Procedures for Computed Radiography
- 8.1 ASTM/ASME standards
- 8.2 Acceptable computed radiography techniques and setups
- 8.3 Applicable employer procedures

9.0 Radiographic Safety Principles Review
- 9.1 Controlling personnel exposure
- 9.2 Time, distance, shielding concepts
- 9.3 ALARA concept
- 9.4 Radiation detection equipment
- 9.5 Exposure device operating characteristics

Computed Tomography Level I Topical Outline

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- 3.4 Half-life of radioactive materials
- 3.5 Plotting of radioactive decay
- 3.6 Specific activity – becquerels/gram

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- 4.1 Particulate radiation – properties: alpha, beta, neutron
- 4.2 Electromagnetic radiation – X-ray, gamma ray
- 4.3 X-ray production
- 4.4 Gamma ray production
- 4.5 Gamma ray energy
- 4.6 Energy characteristics of common radioisotope sources
- 4.7 Energy characteristics of X-ray machines

5.0 Interaction of Radiation with Matter
- 5.1 Ionization
- 5.2 Radiation interaction with matter
  - 5.2.1 Photoelectric effect
  - 5.2.2 Compton scattering
  - 5.2.3 Pair production
- 5.3 Unit of radiation exposure – coulomb per kilogram (C/kg)
- 5.4 Emissivity of commonly used radiographic sources
- 5.5 Emissivity of X-ray exposure devices
- 5.6 Attenuation of electromagnetic radiation – shielding
- 5.7 HVL, TVL
- 5.8 Inverse square law

6.0 Exposure Devices and Radiation Sources
- 6.1 Radioisotope sources
  - 6.1.1 Sealed-source design and fabrication
  - 6.1.2 Gamma ray sources
  - 6.1.3 Beta and bremsstrahlung sources
  - 6.1.4 Neutron sources
- 6.2 Radioisotope exposure device characteristics
- 6.3 Electronic radiation sources – 500 keV and less, low energy
  - 6.3.1 Generator – high-voltage rectifiers
  - 6.3.2 X-ray tube design and fabrication
  - 6.3.3 X-ray control circuits
  - 6.3.4 Accelerating potential
  - 6.3.5 Target material and configuration
  - 6.3.6 Heat dissipation
  - 6.3.7 Duty cycle
  - 6.3.8 Beam filtration
- 6.4 * Electronic radiation sources – medium- and high-energy
  - 6.4.1* Resonance transformer
  - 6.4.2* Van de Graaff accelerator
  - 6.4.3* Linear accelerator
  - 6.4.4* Betatron
  - 6.4.5* Coulomb per kilogram (C/kg) output
  - 6.4.6* Equipment design and fabrication
  - 6.4.7* Beam filtration

7.0 Radiographic Safety Principles Review
- 7.1 Controlling personnel exposure
- 7.2 Time, distance, shielding concepts
- 7.3 ALARA concept
- 7.4 Radiation detection equipment
- 7.5 Exposure device operating characteristics

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Basic Computed Tomography Technique Course

1.0 Computed Tomography (CT) Overview
- 1.1 Difference between CT and conventional radiography
- 1.2 Benefits and advantages
- 1.3 Limitations
- 1.4 Industrial imaging examples

2.0 Basic Hardware Configuration
- 2.1 Scan geometries – general configurations by generation
- 2.2 Radiation sources
- 2.3 Detection systems
- 2.4 Manipulation/mechanical system
- 2.5 Computer system
- 2.6 Image reconstruction
- 2.7 Image display
- 2.8 Data storage
- 2.9 Operator interface

3.0 Fundamental CT Performance Parameters
- 3.1 Fundamental scan plan parameters
- 3.2 Basic system tradeoffs for spatial resolution/noise/slice thickness

4.0 Basic Image Interpretation and Processing
- 4.1 Artifacts – definitions, detection, and basic causes
- 4.2 CT density measurements

Computed Tomography Level II Topical Outline

Computed Tomography Technique Course

1.0 General Principles of CT and Terminology
- 1.1 CT technical background
- 1.2 Physical basis – X-ray interactions with material properties
- 1.3 Mathematical basis – line integrals
- 1.4 Data sampling principles
- 1.5 Physical limitations of the sampling process
- 1.6 Reconstruction algorithms
  - 1.6.1 Convolution/backprojections
  - 1.6.2 Fourier reconstructions
  - 1.6.3 Fan/cone beam

2.0 CT System Performance – Characterizing System Performance
- 2.1 CT system performance parameters overview
- 2.2 Spatial resolution
- 2.3 Contrast sensitivity
- 2.4 Artifacts
  - 2.4.1 Beam hardening, streak, under-sampling, etc.
- 2.5 Noise
- 2.6 Effective X-ray energy
- 2.7 System performance measurement techniques
- 2.8 Spatial resolution
- 2.9 Contrast sensitivity
  - 2.9.1 Standardizing CT density
  - 2.9.2 Measuring CT density
  - 2.9.3 Performance measurement intervals

3.0 Image Interpretation and Processing
- 3.1 Use of phantoms to monitor CT system performance
- 3.2 Evaluation of CT system performance parameters
- 3.3 Determination of artifacts
- 3.4 Artifact mitigation techniques

4.0 Advanced Image-Processing Algorithms
- 4.1 Modulation transfer function calculation
- 4.2 Effective energy calculation
- 4.3 Application of image-processing algorithms
- 4.4 Artifact mitigation techniques application

5.0 Radiographic Safety Principles Review
- 5.1 Controlling personnel exposure
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| Radiographic Interpretation and Evaluation Course

1.0 Evaluation of Castings
- 1.1 Casting method review
- 1.2 Casting discontinuities
- 1.3 Origin and typical orientation of discontinuities
- 1.4 Radiographic appearance
- 1.5 Casting codes/standards – applicable acceptance criteria

2.0 Evaluation of Weldments
- 2.1 Welding method review
- 2.2 Welding discontinuities
- 2.3 Origin and typical orientation of discontinuities
- 2.4 Welding codes/standards – applicable acceptance criteria

3.0 Standards, Codes, and Procedures for Radiography
- 3.1 ASTM standards
- | 3.2 Acceptable computed tomography techniques and setups
- 3.3 Applicable employer procedures

Digital Radiography Level I Topical Outline

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  - 6.3.7 Duty cycle
  - 6.3.8 Beam filtration
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Basic Digital Radiography (DR) Technique Course

1.0 DR Overview
- 1.1 DR
- 1.2 Digital images
  - 1.2.1 Bits/bytes
  - 1.2.2 Pixels/voxels
- 1.3 Image file formats and compression
- 1.4 DR system overview
- 1.5 DR system capabilities
  - 1.5.1 DR versus film procedural steps
  - 1.5.2 Cost and environmental issues

2.0 DR System Components
- 2.1 Detector(s) used in the radiography shop
  - 2.1.1 Operating procedures to use the equipment

3.0 Image Fidelity Indicators (System Characterization)
- 3.1 IQIs: hole and wire types
- 3.2 Line pair gauges
- 3.3 Phantoms
- 3.4 Reference quality indicators (RQIs)
- 3.5 TV test patterns

4.0 Detector Issues
- 4.1 Scatter sensitivity
- 4.2 Radiation exposure tolerance
- 4.3 Portability
- 4.4 Detector handling

5.0 Technique Sheets

Digital Radiography Level II Topical Outline

Digital Radiography Technique Course

1.0 Basic DR versus Film Principles
- 1.1 Film versus DR images
  - 1.1.1 Linearity and latitude
  - 1.1.2 Contrast and resolution

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 Computer
  - 2.2.1 Operator interface
  - 2.2.2 System controller
  - 2.2.3 Image processor
- 2.3 Monitors
  - 2.3.1 CRT
  - 2.3.2 LCD
- 2.4 Data archive
  - 2.4.1 Removable media (CD, DVD, tape)
  - 2.4.2 Redundant array of inexpensive disks (RAID)
  - 2.4.3 Central archive

3.0 Image Fidelity
- 3.1 Measuring image fidelity
  - 3.1.1 Contrast and resolution
  - 3.1.2 SNR
- 3.2 Image fidelity indicators (system characterization)

4.0 Image Processing (Postprocessing)
- 4.1 Grayscale adjustments
  - 4.1.1 Windowing and leveling
  - 4.1.2 Lookup tables (LUTs)
  - 4.1.3 Thresholding
  - 4.1.4 Histogram equalization
  - 4.1.5 Pseudo color

- 4.2 Arithmetic
  - 4.2.1 Addition (integration)
  - 4.2.2 Subtraction
  - 4.2.3 Division
  - 4.2.4 Multiplication
  - 4.2.5 Averaging
- 4.3 Filtering (kernels)
  - 4.3.1 Convolution
  - 4.3.2 Low pass (smoothing)
  - 4.3.3 High pass (edge enhancement)
  - 4.3.4 Median
  - 4.3.5 Unsharp mask
- 4.4 Region of interest (ROI)

5.0 Detector Issues for the Detector(s) Used
- 5.1 Frame rate
- 5.2 Resolution (pixel pitch, pixel size, etc.)
- 5.3 Blooming, bleed over
- 5.4 Ghosting/latent image/lag
- 5.5 Scatter sensitivity
- 5.6 Bit depth
- 5.7 Dynamic range and SNR
- 5.8 Fabrication anomalies (bad pixels, chip grades, etc.)
- 5.9 Radiation exposure tolerance
- 5.10 Portability
- 5.11 Detector handling

6.0 Detector Calibrations for the Detector(s) Used
- 6.1 Gain and offset
- 6.2 Detector-specific calibration

7.0 Monitor and Viewing Environment
- 7.1 Limited bit-depth display
- 7.2 Monitor resolution
- 7.3 Monitor brightness and contrast
- 7.4 Monitor testing
  - 7.4.1 Test patterns
  - 7.4.2 Luminance – cd/m^2
  - 7.4.3 Contrast – min:max, digital driving level (DDL)
- 7.5 Monitor calibration
- 7.6 Viewing area

8.0 Technique Development Considerations
- 8.1 Image unsharpness and geometric magnification
  - 8.1.1 Determining required geometric magnification
  - 8.1.2 Geometry and geometric unsharpness
  - 8.1.3 Focal spot size measurement method
  - 8.1.4 Total image unsharpness
- 8.2 SNR compensation for spatial resolution
  - 8.2.1 Frame averaging
  - 8.2.2 Binning
  - 8.2.3 X-ray spectrum optimization
    - 8.2.3.1 Filtering
    - 8.2.3.2 Beam collimation
    - 8.2.3.3 Beam energy
- 8.3 Image processing
  - 8.3.1 Understanding of cost and benefits of common image-processing techniques – windowing, filtering, subtraction, etc.

9.0 Detector Monitoring

10.0 Detector Maintenance

11.0 Use of Digital Reference Images
- 11.1 ASTM standards review
- 11.2 Use of reference images and contrast normalization

12.0 Radiographic Safety Principles Review
- 12.1 Controlling personnel exposure
- 12.2 Time, distance, shielding concepts
- 12.3 ALARA concept
- 12.4 Radiation detection equipment
- 12.5 Exposure device operating characteristics

Interpretation and Evaluation Course

1.0 Image Viewing
- 1.1 Image display requirements
- 1.2 Background lighting
- 1.3 Multiple-composite viewing
- 1.4 IQI placement
- 1.5 Personnel dark adaptation and visual acuity
- 1.6 Image identification
- 1.7 Location markers

2.0 Application Techniques
- 2.1 Multiple-view techniques
  - 2.1.1 Thickness variation parameters
- 2.2 Enlargement and projection
- 2.3 Geometric relationships
  - 2.3.1 Geometric unsharpness
  - 2.3.2 IQI sensitivity
  - 2.3.3 Source-to-detector distance
  - 2.3.4 Focal spot size
- 2.4 Triangulation methods for discontinuity location
- 2.5 Localized magnification

3.0 Evaluation of Castings
- 3.1 Casting method review
- 3.2 Casting discontinuities
- 3.3 Origin and typical orientation of discontinuities
- 3.4 Casting codes/standards – applicable acceptance criteria
- 3.5 Reference radiographs or images

4.0 Evaluation of Weldments
- 4.1 Welding method review
- 4.2 Welding discontinuities
- 4.3 Origin and typical orientation of discontinuities
- 4.4 Welding codes/standards – applicable acceptance criteria
- 4.5 Reference radiographs or images

5.0 Standards, Codes, and Procedures for Radiography
- 5.1 ASTM standards
- 5.2 Acceptable techniques and setups
- 5.3 Applicable employer procedures

Radiographic Testing Level III Topical Outline

Basic Radiographic Topics

1.0 Principles/Theory
- 1.1 Nature of penetrating radiation
- 1.2 Interaction between penetrating radiation and matter
- 1.3 Radiology overview
  - 1.3.1 Film radiography
  - 1.3.2 CR
  - 1.3.3 CT
  - 1.3.4 DR
    - 1.3.4.1 Radioscopy

2.0 Equipment/Materials
- 2.1 Electrically generated sources
  - 2.1.1 X-ray sources
    - 2.1.1.1 Generators and tubes as an integrated system
    - 2.1.1.2 Sources of electrons
    - 2.1.1.3 Electron accelerating methods
    - 2.1.1.4 Target materials and characteristics
    - 2.1.1.5 Equipment design considerations
    - 2.1.1.6 Microfocus sources
- 2.2 Isotope sources
  - 2.2.1 Exposure devices
  - 2.2.2 Source changers
  - 2.2.3 Remote handling equipment
  - 2.2.4 Collimators
  - 2.2.5 Specific characteristics
    - 2.2.5.1 Half-lives
    - 2.2.5.2 Energy levels
    - 2.2.5.3 HVL
    - 2.2.5.4 TVL
- 2.3 Radiation detection overview
  - 2.3.1 Direct imaging
    - 2.3.1.1 Film overview
    - 2.3.1.2 Radioscopy overview
    - 2.3.1.3 X-ray image intensifier system
  - 2.3.2 Digital data acquisition/detectors
    - 2.3.2.1 Film digitizers
    - 2.3.2.2 CR
    - 2.3.2.3 CT
    - 2.3.2.4 DR
- 2.4 Manipulators
  - 2.4.1 Manual versus automated
  - 2.4.2 Multiple axis
  - 2.4.3 Weight capacity
  - 2.4.4 Precision
- 2.5 Visual perception
  - 2.5.1 Spatial frequency
  - 2.5.2 Contrast
  - 2.5.3 Displayed brightness
  - 2.5.4 SNR
  - 2.5.5 Probability of detection (single versus multiple locations, scanning)
  - 2.5.6 Receiver operator characteristic curves

3.0 Safety and Health
- 3.1 Exposure hazards
  - 3.1.1 Occupational dose limits
- 3.2 Methods of controlling radiation exposure
  - 3.2.1 Time
  - 3.2.2 Distance
    - 3.2.2.1 Inverse square law
  - 3.2.3 Shielding
    - 3.2.3.1 HVL
    - 3.2.3.2 TVL
- 3.3 Operational and emergency procedures
- 3.4 Dosimetry and film badges
- 3.5 Gamma leak testing
- 3.6 Transportation regulations

Radiographic Testing

1.0 Techniques/Standardization
- 1.1 Imaging considerations
  - 1.1.1 Sensitivity
  - 1.1.2 Contrast and definition
  - 1.1.3 Geometric factors
  - 1.1.4 Intensifying screens
  - 1.1.5 Scattered radiation
  - 1.1.6 Source factors
  - 1.1.7 Detection media
  - 1.1.8 Exposure curves
- 1.2 Film processing
  - 1.2.1 Darkroom procedures
  - 1.2.2 Darkroom equipment and chemicals
  - 1.2.3 Film processing
- 1.3 Viewing of radiographs
  - 1.3.1 Illuminator requirements
  - 1.3.2 Background lighting
  - 1.3.3 Optical aids
- 1.4 Judging radiographic quality
  - 1.4.1 Density
  - 1.4.2 Contrast
  - 1.4.3 Definition
  - 1.4.4 Artifacts
  - 1.4.5 IQIs
  - 1.4.6 Causes and correction of unsatisfactory radiographs
- 1.5 Exposure calculations
- 1.6 Radiographic techniques
  - 1.6.1 Blocking and filtering
  - 1.6.2 Multifilm techniques
  - 1.6.3 Enlargement and projection
  - 1.6.4 Stereoradiography
  - 1.6.5 Triangulation methods
  - 1.6.6 Autoradiography
  - 1.6.7 Flash radiography
  - 1.6.8 In-motion radiography
  - 1.6.9 Control of diffraction effects

- 1.6.10 Pipe welding exposures
  - 1.6.10.1 Contact
  - 1.6.10.2 Elliptical
  - 1.6.10.3 Panoramic
- 1.6.11 Gauging
- 1.6.12 Real-time imaging
- 1.6.13 Image analysis techniques
- 1.6.14 Image-object relationship

2.0 Interpretation/Evaluation

- 2.1 Material considerations
  - 2.1.1 Materials processing as it affects use of item and test results
  - 2.1.2 Discontinuities, their causes and effects
  - 2.1.3 Radiographic appearance of discontinuities
  - 2.1.4 Nonrelevent indications
  - 2.1.5 Film artifacts
  - 2.1.6 Code considerations

3.0 Procedures

Common Digital System Elements and Digital Image Properties

1.0 Digital Image Properties

- 1.1 Bits/bytes
- 1.2 Pixels/voxels
- 1.3 Image file formats and compression (JPEG, TIFF, DICONDE)
  - 1.3.1 Advantages/disadvantages
  - 1.3.2 Lossy versus lossless
- 1.4 Sampling theory (digitizing)
  - 1.4.1 Pixel size (aperture)
  - 1.4.2 Pixel pitch
  - 1.4.3 Bit depth
  - 1.4.4 Nyquist theory

2.0 Digital System Specific: Components

- 2.1 Computer
  - 2.1.1 Operator interface
  - 2.1.2 System controller
  - 2.1.3 Image processor
- 2.2 Monitor and viewing environment
  - 2.2.1 Type of monitors/displays
  - 2.2.2 Limited bit-depth display
  - 2.2.3 Monitor resolution
  - 2.2.4 Monitor brightness and contrast
  - 2.2.5 Monitor testing
  - 2.2.6 Monitor calibration
  - 2.2.7 Viewing area and ergonomics
- 2.3 Data archive
  - 2.3.1 Removable media – single media (CD, DVD, tape)
  - 2.3.2 Redundant array of inexpensive disks (RAID)
  - 2.3.3 Central archive
  - 2.3.4 Image retrieval

3.0 Digital System Specific: Image Processing Topics

- 3.1 ROI and measurements
  - 3.1.1 Line profiles
  - 3.1.2 Histograms (mean/standard deviations)
  - 3.1.3 Discontinuity sizing
    - 3.1.3.1 Length
    - 3.1.3.2 Area
    - 3.1.3.3 Wall thickness
    - 3.1.3.4 Blob/cluster analysis
- 3.2 Grayscale display adjustments
  - 3.2.1 Window width and level
  - 3.2.2 LUTs
  - 3.2.3 Thresholding
  - 3.2.4 Histogram equalization
  - 3.2.5 Pseudo color
- 3.3 Filtering (kernels)
  - 3.3.1 Convolution
  - 3.3.2 Low pass
  - 3.3.3 High pass
  - 3.3.4 Median
  - 3.3.5 Unsharp mask

4.0 Acquisition System Considerations

- 4.1 Portability
- 4.2 Access requirements for detectors
- 4.3 High-energy applications

Computed Radiography (CR)

1.0 CR System Capabilities

- 1.1 CR system overview
- 1.2 CR versus film procedural steps
- 1.3 Cost and environmental issues
- 1.4 Film versus CR images
- 1.5 Linearity and latitude
- 1.6 Contrast and resolution

2.0 Measuring Image Fidelity

- 2.1 Contrast and resolution
- 2.2 MTF
- 2.3 SNR

3.0 Image Fidelity Indicators (System Characterization)

- 3.1 IQIs: hole and wire types
- 3.2 Line pair gauges
- 3.3 Phantoms
- 3.4 RQIs
- 3.5 TV test patterns

4.0 CR Technical Requirements

- 4.1 Qualification of CR systems
- 4.2 Classification of CR systems
- 4.3 Maintenance of CR systems
- 4.4 Technical requirements for inspection

5.0 CR Technical Development
- 5.1 Hardware development
  - 5.1.1 Hard/soft cassette usage
  - 5.1.2 Image plate wear and damage
  - 5.1.3 Image plate artifacts
- 5.2 Software development
- 5.3 CR image optimization
  - 5.3.1 Laser spot size optimization
  - 5.3.2 Use of lead screens

6.0 Use of Digital Reference Images
- 6.1 ASTM standards review
- 6.2 Digital reference images installation
  - 6.2.1 Include reference image resolutions/pixel size
- 6.3 Use of reference images and contrast normalization

7.0 Review of DR Industry Standards (e.g., ASTM)

Computed Tomography (CT)

1.0 Practice of CT
- 1.1 Capabilities of CT
- 1.2 Cost-effective application areas
- 1.3 Digital laminographic and fan beam CT methods

2.0 Principals of CT
- 2.1 Historical background
- 2.2 Principals of CT operation
- 2.3 Tomographic reconstruction/filtered backprojection
- 2.3 Hounsfield number
- 2.4 Resolution and contrast in CT

3.0 CT Systems
- 3.1 CT system configurations
  - 3.1.1 First generation
  - 3.1.2 Second generation
  - 3.1.3 Third generation
  - 3.1.4 Fourth generation
  - 3.1.5 Cone beam CT
- 3.2 CT system elements
- 3.3 CT system attributes and ramifications

4.0 Image Quality Measurement and System Characterization
- 4.1 Resolution and MTF
  - 4.1.1 Line pair gauges
- 4.2 Contrast sensitivity and contrast discrimination curves
- 4.3 Material density phantoms
- 4.4 Geometrical evaluation phantoms
- 4.5 Artifacts

5.0 CT Visualization, Advanced CT Analysis and Tools
- 5.1 Single slice rendering
- 5.2 3D/volume rendering
- 5.3 Rolled view
- 5.4 Porosity inclusion analysis
- 5.5 Coordinate measurement
- 5.6 Nominal actual comparison
- 5.7 Fiber composite material analysis
- 5.8 Foam analysis

6.0 Qualification of CT Procedures
- 6.1 Qualification plan
- 6.2 System performance characterization
  - 6.2.1 Process controls
- 6.3 Technique documentation
- 6.4 Technique validation

Digital Radiography (DR)

1.0 DR System Capabilities
- 1.1 DR system overview
- 1.2 DR versus film procedural steps
- 1.3 Cost and environmental issues
- 1.4 Film versus DR images
- 1.5 Linearity and latitude
- 1.6 Contrast and resolution

2.0 Measuring Image Fidelity
- 2.1 Contrast and resolution
- 2.2 MTF
- 2.3 SNR

3.0 Image Fidelity Indicators (System Characterization)
- 3.1 IQIs: hole and wire types
- 3.2 Line pair gauges
- 3.3 Phantoms
- 3.4 RQIs
- 3.5 TV test patterns

4.0 Detector Selection
- 4.1 ASTM E 2597 data interpretation
  - 4.1.1 Frame rate, resolution, ghosting/lag, bit depth
  - 4.1.2 Basic spatial resolution
  - 4.1.3 Bad pixel characterization
  - 4.1.4 Contrast sensitivity
  - 4.1.5 Efficiency
  - 4.1.6 Specific material thickness
  - 4.1.7 MTF
  - 4.1.8 SNR
- 4.2 Additional detector selection criteria/parameters
  - 4.2.1 Frame rate
  - 4.2.2 Blooming
  - 4.2.3 Ghosting/latent image/lag
  - 4.2.4 Scatter sensitivity
  - 4.2.5 Bit depth
  - 4.2.6 Fabrication anomalies (e.g., bad pixels, chip grades, etc.)
  - 4.2.7 Radiation exposure tolerance

5.0 DR Image Quality Topics

5.1 Standardization optimization
5.2 Setting bad pixel limits versus application
5.3 Image unsharpness and geometric magnification
 5.3.1 Determining required geometric magnification
 5.3.2 Geometry and geometric unsharpness
 5.3.3 Focal spot size measurement method
 5.3.4 Total image unsharpness
5.4 SNR compensation for spatial resolution
 5.4.1 Frame averaging
 5.4.2 Binning
 5.4.3 X-ray spectrum optimization
  5.4.3.1 Filtering
  5.4.3.2 Beam collimation
  5.4.3.3 Beam energy
5.5 Radiation damage management

6.0 Qualification of DR Procedures

6.1 Qualification plan
6.2 System performance characterization
 6.2.1 Process controls
6.3 Technique documentation
6.4 Technique validation

7.0 Use of Digital Reference Images

7.1 ASTM standards review
7.2 Digital reference images installation
 7.2.1 Include reference image resolutions/pixel size
7.3 Use of reference images and contrast normalization

Limited Certification for Radiographic Testing Interpretation Topical Outlines

Note: Independent of the training recommended for Level I and Level II certification, a trainee is required to receive radiation safety training as required by the regulatory jurisdiction. A Radiation Safety Topical Outline is available in Appendix A and can be used as guidance.

Film Interpretation Technique Course

1.0 Introduction

1.1 Process of radiography
1.2 Types of electromagnetic radiation sources
1.3 Electromagnetic spectrum
1.4 Penetrating ability or "quality" of X-rays and gamma rays
1.5 X-ray tube – change of mA or kVp effect on "quality" and intensity

2.0 Basic Principles of Radiography

2.1 Geometric exposure principles
 2.1.1 "Shadow" formation and distortion
 2.1.2 Shadow enlargement calculation
 2.1.3 Shadow sharpness
 2.1.4 Geometric unsharpness
 2.1.5 Finding discontinuity depth
2.2 Radiography screens
 2.2.1 Lead intensifying screens
 2.2.2 Fluorescent intensifying screens
 2.2.3 Intensifying factors
 2.2.4 Importance of screen-to-film contact
 2.2.5 Importance of screen cleanliness and care
2.3 Radiography cassettes
2.4 Composition of industrial radiography film

3.0 Radiographs

3.1 Formation of the latent image on film
3.2 Inherent unsharpness
3.3 Arithmetic of radiography exposure
 3.3.1 Milliamperage – distance-time relationship
 3.3.2 Reciprocity law
 3.3.3 Photographic density
 3.3.4 Inverse square law considerations
3.4 Characteristic (Hurter and Driffield) curve
3.5 Film speed and class descriptions
3.6 Selection of film for particular purpose

4.0 Radiographic Image Quality

4.1 Radiographic sensitivity
4.2 Radiographic contrast
4.3 Film contrast
4.4 Subject contrast
4.5 Definition
4.6 Film graininess and screen mottle effects
4.7 IQIs

5.0 Exposure Techniques – Radiography

5.1 Single-wall radiography
5.2 Double-wall radiography
 5.2.1 Viewing two walls simultaneously
 5.2.2 Offset double-wall exposure single-wall viewing
 5.2.3 Elliptical techniques
5.3 Panoramic radiography
5.4 Use of multiple-film loading
5.5 Specimen configuration

Film Quality and Manufacturing Processes Course

1.0 Darkroom Facilities, Techniques, and Processing

1.1 Facilities and equipment
 1.1.1 Automatic film processor versus manual processing
1.2 Protection of radiography film in storage
1.3 Processing of film – manual
 1.3.1 Developer and replenishment
 1.3.2 Stop bath
 1.3.3 Fixer and replenishment
 1.3.4 Washing
 1.3.5 Prevention of water spots
 1.3.6 Drying

- 1.4 Automatic film processing
- 1.5 Film filing and storage
  - 1.5.1 Retention-life measurements
  - 1.5.2 Long-term storage
  - 1.5.3 Filing and separation techniques
- 1.6 Unsatisfactory radiographs – causes and cures
  - 1.6.1 High film density
  - 1.6.2 Insufficient film density
  - 1.6.3 High contrast
  - 1.6.4 Low contrast
  - 1.6.5 Poor definition
  - 1.6.6 Fog
  - 1.6.7 Light leaks
  - 1.6.8 Artifacts
- 1.7 Film density
  - 1.7.1 Step-wedge comparison film
  - 1.7.2 Densitometers

2.0 Indications, Discontinuities, and Defects

- 2.1 Indications
- 2.2 Discontinuities
  - 2.2.1 Inherent
  - 2.2.2 Processing
  - 2.2.3 Service
- 2.3 Defects

3.0 Manufacturing Processes and Associated Discontinuities

- 3.1 Casting processes and associated discontinuities
  - 3.1.1 Ingots, blooms, and billets
  - 3.1.2 Sand casting
  - 3.1.3 Centrifugal casting
  - 3.1.4 Investment casing
- 3.2 Wrought processes and associated discontinuities
  - 3.2.1 Forgings
  - 3.2.2 Rolled products
  - 3.2.3 Extruded products
- 3.3 Welding processes and associated discontinuities
  - 3.3.1 Submerged arc welding (SAW)
  - 3.3.2 Shielded metal arc welding (SMAW)
  - 3.3.3 Gas metal arc welding (GMAW)
  - 3.3.4 Flux cored arc welding (FCAW)
  - 3.3.5 Gas tungsten arc welding (GTAW)

Radiography Interpretation and Evaluation Course

1.0 Radiograph Viewing

- 1.1 Film-illuminator requirements
- 1.2 Background lighting
- 1.3 Multiple-composite viewing
- 1.4 IQI placement
- 1.5 Personnel dark adaptation and visual acuity
- 1.6 Film identification
- 1.7 Location markers
- 1.8 Film density measurement
- 1.9 Film artifacts

2.0 Application Techniques

- 2.1 Multiple-film techniques
  - 2.1.1 Thickness variation parameters
  - 2.1.2 Film speed
  - 2.1.3 Film latitude
- 2.2 Enlargement and projection
- 2.3 Geometric relationships
  - 2.3.1 Geometric unsharpness
  - 2.3.2 IQI sensitivity
  - 2.3.3 Source-to-film distance
  - 2.3.4 Focal spot size
- 2.4 Triangulation methods for discontinuity location
- 2.5 Localized magnification
- 2.6 Film handling techniques

3.0 Evaluation of Castings

- 3.1 Casting method review
- 3.2 Casting discontinuities
- 3.3 Origin and typical orientation of discontinuities
- 3.4 Radiographic appearance
- 3.5 Casting codes/standards – applicable acceptance criteria
- 3.6 Reference radiographs

4.0 Evaluation of Weldments

- 4.1 Welding method review
- 4.2 Welding discontinuities
- 4.3 Origin and typical orientation of discontinuities
- 4.4 Radiographic appearance
- 4.5 Welding codes/standards – applicable acceptance criteria
- 4.6 Reference radiographs or pictograms

5.0 Standards, Codes, and Procedures for Radiography

- 5.1 Acceptable radiography techniques and setups
- 5.2 Applicable employer procedures
- 5.3 Procedure for radiograph parameter verification
- 5.4 Radiography reports

Limited Certification for Digital Radiography and Computed Radiography Interpretation

Digital Radiography and Computed Radiography Technique Course

1.0 Introduction

- 1.1 Process of radiography testing
- 1.2 Types of electromagnetic radiation sources
- 1.3 Electromagnetic spectrum
- 1.4 Penetrating ability or "quality" of X-rays and gamma rays
- 1.5 X-ray tube – change of mA or kVp effect on "quality" and intensity

2.0 Basic Principles of Digital Radiography (DR)
- 2.1 Geometric exposure principles
  - 2.1.1 "Shadow" formation and distortion
  - 2.1.2 Shadow enlargement calculation
  - 2.1.3 Shadow sharpness
  - 2.1.4 Geometric unsharpness
  - 2.1.5 Finding discontinuity depth
- 2.2 Digital detector array types and operating principles
- 2.3 Computed radiography (CR) systems and image plate types

3.0 Digital Radiographs
- 3.1 Inherent unsharpness
- 3.2 Arithmetic of radiography exposure
  - 3.2.1 Milliamperage – distance-time relationship
  - 3.2.2 Reciprocity law
  - 3.2.3 Detector gray value
  - 3.2.4 Inverse square law considerations

4.0 Digital Radiography Image Quality and Indicators
- 4.1 Contrast and resolution
- 4.2 MTF
- 4.3 SNR
- 4.4 IQIs – hole and wire types
- 4.5 Line pair gauges
- 4.6 Phantoms
- 4.7 RQIs
- 4.8 Monitor test patterns

5.0 Exposure Techniques – Digital Radiography
- 5.1 Single-wall technique
- 5.2 Double-wall technique
  - 5.2.1 Viewing two walls simultaneously
  - 5.2.2 Offset double-wall exposure single-wall viewing
  - 5.2.3 Elliptical techniques
- 5.3 Panoramic technique
- 5.4 Specimen configuration

Digital Radiography and Computed Radiography Interpretation and Evaluation Course

1.0 Use of Digital Reference Images
- 1.1 ASTM standards review
- 1.2 Digital reference images installation
  - 1.2.1 Include reference image resolutions/pixel size
- 1.3 Use of reference images and contrast normalization
- 1.4 Background lighting
- 1.5 IQI placement
- 1.6 Personnel dark adaptation and visual acuity
- 1.7 Image identification
- 1.8 Location markers

2.0 Application Techniques
- 2.1 Enlargement and projection
- 2.2 Geometric relationships
  - 2.2.1 Geometric unsharpness
  - 2.2.2 IQI sensitivity
  - 2.2.3 Source-to-detector/image plate distance
  - 2.2.4 Focal spot size
- 2.3 Triangulation methods for discontinuity location
- 2.4 Localized magnification
- 2.5 Detector and image plate handling techniques

3.0 Evaluation of Castings
- 3.1 Casting method review
- 3.2 Casting discontinuities
- 3.3 Origin and typical orientation of discontinuities
- 3.4 DR appearance
- 3.5 Casting codes/standards – applicable acceptance criteria
- 3.6 Digital reference radiographs

4.0 Evaluation of Weldments
- 4.1 Welding method review
- 4.2 Welding discontinuities
- 4.3 Origin and typical orientation of discontinuities
- 4.4 DR appearance
- 4.5 Welding codes/standards – applicable acceptance criteria
- 4.6 Digital reference radiographs or pictograms

5.0 Standards, Codes, and Procedures for Radiography
- 5.1 Acceptable DR techniques and setups
- 5.2 Applicable employer procedures
- 5.3 Procedure for radiograph parameter verification
- 5.4 DR reports

Limited Certification for Computed Tomography Interpretation

Computed Tomography Technique Course

1.0 Introduction
- 1.1 Types of electromagnetic radiation sources
- 1.3 Electromagnetic spectrum
- 1.4 Penetrating ability or "quality" of X-rays and gamma rays
- 1.5 X-ray tube – change of mA or kVp effect on "quality" and intensity

2.0 Basic Principles of Computed Tomography
- 2.1 Principals of computed tomography (CT) operation
- 2.2 Tomographic reconstruction/filtered backprojection
- 2.3 Hounsfield number
- 2.4 Resolution and contrast in CT

3.0 CT Systems
- 3.1 CT system configurations
  - 3.1.1 Cone beam CT
- 3.2 CT system elements
- 3.3 CT system attributes and ramifications

4.0 Image Quality Measurement and System Characterization
- 4.1 Resolution and MTF
  - 4.1.1 Line pair gauges
- 4.2 Contrast sensitivity and contrast discrimination curves
- 4.3 Material density phantoms
- 4.4 Geometrical evaluation phantoms
- 4.5 Artifacts

Computed Tomography Interpretation and Evaluation Course

1.0 Image Interpretation and Processing
- 1.1 Use of phantoms to monitor CT system performance
- 1.2 Evaluation of CT system performance parameters
- 1.3 Determination of artifacts
- 1.4 Artifact mitigation techniques

2.0 CT Visualization, Advanced CT Analysis and Tools
- 2.1 Single slice (2D) rendering
- 2.2 3D/volume rendering
- 2.3 Rolled view
- 2.4 Porosity inclusion analysis
- 2.5 Coordinate measurement
- 2.6 Nominal actual comparison
- 2.7 Fiber composite material analysis

3.0 Evaluation of Castings
- 3.1 Casting method review
- 3.2 Casting discontinuities
- 3.3 Origin and typical orientation of discontinuities
- 3.4 CT image appearance and artifacts
- 3.5 Casting codes/standards – applicable acceptance criteria

4.0 Evaluation of Weldments
- 4.1 Welding method review
- 4.2 Welding discontinuities
- 4.3 Origin and typical orientation of discontinuities
- 4.4 CT image appearance and artifacts
- 4.5 Welding codes/standards – applicable acceptance criteria
- 4.6 Digital reference radiographs or pictograms

RADIOGRAPHIC TESTING LEVEL I, II, AND III TRAINING REFERENCES

ASM. 1989. *Nondestructive Evaluation and Quality Control*. vol. 17. *ASM Handbook*. Metals Park, OH: ASM International.

ASNT, latest edition, *ASNT Level II Study Guide: Radiographic Testing*, Columbus, OH: American Society for Nondestructive Testing Inc.*

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ASTM, latest edition, *Annual Book of ASTM Standards*, Vol. 03.03: *Nondestructive Testing*, ASTM International, Philadelphia, PA.

AWS, latest edition, *Welding Inspection Handbook*, American Welding Society, Miami, FL.

Eastman Kodak, 1980, *Radiography in Modern Industry*, www.pqt.net/Radiography-in-Modern-Industry-4th-Edition.pdf, Carestream, Rochester, NY.

McGuire, S., and C. Peabody, latest edition, *Working Safely in Radiography*, Columbus, OH: American Society for Nondestructive Testing Inc.*

Mix, P. 2005. *Introduction to Nondestructive Testing: A Training Guide*. 2nd ed. New York: John Wiley & Sons.

Schneeman, J., 1985, *Industrial X-ray Interpretation*, Columbus, OH: American Society for Nondestructive Testing Inc.*

Note: Technical papers on much of the subject material can be found in the journal of ASNT, *Materials Evaluation*. For specific topics, search the archive of *Materials Evaluation*, on the ASNT website (source.asnt.org).

* Available from The American Society for Nondestructive Testing Inc., Columbus, OH.