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MFL

Magnetic Flux Leakage Testing Topical Outlines

Magnetic Flux Leakage Testing Level I Topical Outline

1.0 Magnetic Flux Leakage Testing
- 1.1 Brief history of testing
- 1.2 Basic principles of testing

2.0 Principles of Magnetic Fields
- 2.1 Magnetic fields characteristics
- 2.2 Flux line characteristics

3.0 Magnetism by Means of Electric Current
- 3.1 Field around a conductor
- 3.2 Right-hand rule
- 3.3 Field in ferromagnetic conductors

4.0 Indirect Magnetization
- 4.1 Circular fields
- 4.2 Longitudinal fields
- 4.3 Transverse fields

5.0 Magnetization Variables
- 5.1 Type of magnetizing current
- 5.2 Alloy magnetic properties
  - 5.2.1 Hysteresis curve
  - 5.2.2 Permeability
  - 5.2.3 Factors affecting permeability

6.0 Flux Leakage
- 6.1 Flux leakage theory
- 6.2 Normal component of flux leakage

7.0 Search Coils
- 7.1 Rate of change in the normal component of flux leakage
- 7.2 Faraday's law (rate of change versus induced voltage)
- 7.3 Factors that affect the voltage induced in a search coil

8.0 Hall Effect Search Units
- 8.1 Hall effect principles
- 8.2 Factors that affect the output voltage of Hall effect element

9.0 Signal Processing
- 9.1 Rectification
- 9.2 Filtering

10.0 Readout Mechanism
- 10.1 Displays
- 10.2 Strip-chart recorder
- 10.3 Computerized data acquisition

Magnetic Flux Leakage Testing Level II Topical Outline

Magnetic Flux Leakage Evaluation Course

1.0 Review of Magnetic Theory
- 1.1 Flux leakage theory
- 1.2 Types of flux leakage sensing probes

2.0 Factors that Affect Flux Leakage Fields
- 2.1 Degree of magnetization
- 2.2 Defect geometry
- 2.3 Defect location
- 2.4 Defect orientation
- 2.5 Distance between adjacent defects

3.0 Signal-to-Noise Ratio
- 3.1 Definition
- 3.2 Relationship to flux leakage testing
- 3.3 Methods of improving signal-to-noise ratio

4.0 Selection of Method of Magnetization for Flux Leakage Testing
- 4.1 Magnetization characteristics for various magnetic materials
- 4.2 Magnetization by means of electric fields
  - 4.2.1 Circular field
  - 4.2.2 Longitudinal field
  - 4.2.3 Value of flux density
- 4.3 Magnetization by means of permanent magnets
  - 4.3.1 Permanent magnet relationship and theory
  - 4.3.2 Permanent magnet materials
- 4.4 Selection of proper magnetization method

5.0 Coupling
- 5.1 "Lift-off" in flux leakage testing

6.0 Signal Processing Considerations
- 6.1 Amplification
- 6.2 Filtering

7.0 Applications
- 7.1 General
  - 7.1.1 Flaw detection
  - 7.1.2 Sorting for properties related to permeability
  - 7.1.3 Measurement of magnetic-characteristic values
- 7.2 Specific
  - 7.2.1 Tank floor and side inspection
  - 7.2.2 Wire rope inspection
  - 7.2.3 Tube inspection
  - 7.2.4 "Intelligent" pigs
  - 7.2.5 Bar inspection

8.0 User Standards and Operating Procedures
- 8.1 Explanation of standards and specifications used in magnetic flux leakage testing
- 8.2 Explanation of operating procedures used in magnetic flux leakage testing

Magnetic Flux Leakage Testing Level III Topical Outline

1.0 Principles/Theory
- 1.1 Flux leakage theory
- 1.2 Förster and other theories
- 1.3 Finite element methods
- 1.4 DC flux leakage/AC flux leakage

2.0 Equipment/Materials
- 2.1 Detectors
  - 2.1.1 Advantages/limitations
- 2.2 Coils
  - 2.2.1 Advantages/limitations
- 2.3 Factors affecting choice of sensing elements
  - 2.3.1 Type of part to be inspected
  - 2.3.2 Type of discontinuity to be detected
  - 2.3.3 Speed of testing required
  - 2.3.4 Amount of testing required
  - 2.3.5 Probable location of discontinuity
  - 2.3.6 Applications other than discontinuity detection
- 2.4 Read out selection
  - 2.4.1 Oscilloscope and other monitor displays
  - 2.4.2 Alarm, lights, etc.
  - 2.4.3 Marking system
  - 2.4.4 Sorting gates and tables
  - 2.4.5 Cutoff saw or shears
  - 2.4.6 Automation and feedback
  - 2.4.7 Strip-chart recorder
  - 2.4.8 Computerized data acquisition
- 2.5 Instrument design considerations
  - 2.5.1 Amplification
  - 2.5.2 Filtering
  - 2.5.3 Sensor configuration

3.0 Techniques/Standardization
- 3.1 Consideration affecting choice of test
  - 3.1.1 Signal-to-noise ratio
  - 3.1.2 Response speed
  - 3.1.3 Skin effect
- 3.2 Coupling
  - 3.2.1 Fill factor
  - 3.2.2 Lift-off
- 3.3 Field strength
  - 3.3.1 Permeability changes
  - 3.3.2 Saturation
- 3.4 Comparison of techniques
- 3.5 Standardization
  - 3.5.1 Techniques
  - 3.5.2 Reference standards
- 3.6 Techniques – general
  - 3.6.1 Surface or subsurface flaw detection
  - 3.6.2 Noise suppression

4.0 Interpretation/Evaluation
- 4.1 Flaw detection
- 4.2 Process control
- 4.3 General interpretations
- 4.4 Defect characterization

5.0 Standards
- 5.1 ASME Section V Article 16 Magnetic Flux Leakage
- 5.2 API 653 Appendix G

6.0 Procedures

Magnetic Flux Leakage Testing Method, Level I, II, and III Training References

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MW

Microwave Testing Topical Outlines

Microwave Technology Level I Topical Outline

Theory Course

1.0 Introduction to Microwave Theory
- 1.1 Microwave scanning
- 1.2 Reflection interference pattern
- 1.3 Differential amplitude measurement
- 1.4 Basic math review

2.0 Basic Electromagnetic Theory
- 2.1 Nature of EM waves
- 2.2 Wave generation
- 2.3 Propagation and modes

3.0 Material Properties
- 3.1 Conductors and dielectrics

4.0 Scanning Microwave Basics
- 4.1 Scanning microwave interference pattern image
  - 4.1.1 Interference pattern
  - 4.1.2 Compare amplitude of reflected signal with standing wave
  - 4.1.3 Emitter and receiver in probe fixed physical relationship
  - 4.1.4 Fixed phase relationship
- 4.2 Probe design
  - 4.2.1 Phase relation
  - 4.2.2 2 channel receiver
  - 4.2.3 Stand off
- 4.3 Antenna and sensor pattern
  - 4.3.1 Reflected signal pattern
- 4.4 Image creation
  - 4.4.1 Signal voltage – position
  - 4.4.2 Interference map – phase relationship
  - 4.4.3 Channel relationship
- 4.5 Signal differential and phase relationship
- 4.6 Interference pattern image
  - 4.6.1 Line and circle patterns
  - 4.6.2 Nodes and depth
- 4.7 Measurement
  - 4.7.1 Interference patterns
  - 4.7.2 Wavelength in material

Technique Course

1.0 Basic Scanning Microwave Instrument
- 1.1 System hardware

2.0 Instrument Electronics
- 2.1 Transmitter
- 2.2 Receiver
- 2.3 Antennas
- 2.4 Probe
- 2.5 Position interface
- 2.6 Sampling
- 2.7 Data format

3.0 Position Control
- 3.1 Positioning interface
- 3.2 Position feedback

4.0 Antenna Design
- 4.1 Phase relation
- 4.2 2 channel receiver
- 4.3 Stand off

5.0 Display System
- 5.1 Hardware
- 5.2 Display software

6.0 Control Functions
- 6.1 Power
- 6.2 Signal penetration
- 6.3 Response amplification

7.0 Data Collection and Formatting

Microwave Technology Level II Topical Outline

Theory Course

1.0 Measure Electromagnetic Wave Interaction with Part
- 1.1 Attenuation
- 1.2 Reflection

2.0 Maxwell's Equations

3.0 Microwave Propagation
- 3.1 Wave propagation
- 3.2 Wave interaction with matter

4.0 Microwave Energy and Excitation Energies

5.0 Microwave Energy Field – Charge Interaction
- 5.1 Dipole moment
- 5.2 Polarity
- 5.3 Interference
- 5.4 Anisotropic material properties

6.0 Material Properties
- 6.1 Conductors and dielectrics
- 6.2 Excitation energies

7.0 Wave Propagation
- 7.1 Attenuation and impedance
- 7.2 Reflection
- 7.3 Refraction
- 7.4 Beam spread

8.0 Microwave Antennas
- 8.1 Antenna pattern polarization
  - 8.1.1 Energy profile

9.0 Phase Relationship

Technique Course

1.0 Data Format and Collection
- 1.1 Meta data (heading and reference data)
- 1.2 Scan pattern
- 1.3 Sample density
- 1.4 File management
- 1.5 Transportability

2.0 Instrument Characteristics
- 2.1 Scanning microwave interference pattern image
  - 2.1.1 Interference pattern
  - 2.1.2 Compare amplitude of reflected signal with standing wave
  - 2.1.3 Emitter and receiver in probe fixed physical relationship
  - 2.1.4 Fixed phase relationship
- 2.2 Probe design
  - 2.2.1 Phase relation
  - 2.2.2 Multi-channel receiver
  - 2.2.3 Stand off
- 2.3 Antenna pattern
  - 2.3.1 Optimizing beam geometry
- 2.4 Image creation
  - 2.4.1 Multiple channels
  - 2.4.2 Variable frequency
- 2.5 Signal differential and phase relationship
  - 2.5.1 Phase vector
  - 2.5.2 Unit circle
  - 2.5.3 Analysis

3.0 Calibration
- 3.1 Frequency selection
- 3.2 Standoff
- 3.3 Power
- 3.4 Gain
- 3.5 Sample rate
- 3.6 Scan separation

4.0 Calibration Blocks
- 4.1 Nominal specimen
- 4.2 Fault examples
- 4.3 Measurement
  - 4.3.1 Dielectric constant
  - 4.3.2 Wave length in material
  - 4.3.3 Loss tangent

5.0 Imaging Surfaces at a Distance

6.0 Thickness Measurement

7.0 Density Measurement

8.0 Evaluation
- 8.1 Codes and standards
- 8.2 Determination of relative condition
  - 8.2.1 Comparison of tested part to prototype
  - 8.2.2 Comparison to nominal
- 8.3 Evaluation of artifacts
- 8.4 Validation of results

Microwave Technology Level III Topical Outline

Theory Course

1.0 Microwave Signal Phase Relationship

2.0 Wave Behavior in Complex Structures

3.0 Lenses and Horns

4.0 Microwave Interaction with Matter

Technique Course

5.0 Basic Materials, Fabrication, and Product Technology
- 5.1 Fundamentals of material technology
  - 5.1.1 Properties of materials
    - 5.1.1.1 Strength and elastic properties
    - 5.1.1.2 Physical properties
    - 5.1.1.3 Material properties testing
  - 5.1.2 Origin of discontinuities and failure modes
    - 5.1.2.1 Inherent discontinuities
    - 5.1.2.2 Process-induced discontinuities
    - 5.1.2.3 Service-induced discontinuities
  - 5.1.3 Statistical nature of detecting and characterizing discontinuities

- 5.2 Dielectric materials susceptible to microwave examination
  - 5.2.1 Plastics
  - 5.2.2 Rubber
  - 5.2.3 Resins
  - 5.2.4 Fiberglass reinforced plastic
  - 5.2.5 Ceramics
  - 5.2.6 Composites
  - 5.2.7 Advanced materials
  - 5.2.8 Glass
  - 5.2.9 Coatings
- 5.3 In-process materials
- 5.4 Structures of interest

6.0 Origin of Discontinuities and Failure Modes

- 6.1 Process-induced discontinuities
  - 6.1.1 Placement geometry
  - 6.1.2 Contaminants
  - 6.1.3 Bonds between layers
  - 6.1.4 Voids
  - 6.1.5 Porosity
  - 6.1.6 Incorrect chemistry
  - 6.1.7 Incorrect material phase/crystallization
- 6.2 Service-induced discontinuities
  - 6.2.1 Inherent discontinuities
  - 6.2.2 Mechanical disruption
  - 6.2.3 Thermal damage
    - 6.2.3.1 Material phase differences
    - 6.2.3.2 Crystal structure changes

7.0 Properties of Materials

- 7.1 Strength and elastic properties
- 7.2 Physical properties
- 7.3 Material properties testing

8.0 Statistical Nature of Detecting and Characterizing Discontinuities

9.0 Thickness Measurements

- 9.1 Coatings
- 9.2 Parts

10.0 Fundamentals of Fabrication and Product Technology

- 10.1 Raw materials processing
  - 10.1.1 Castings
  - 10.1.2 Extrusions
  - 10.1.3 Layered composites
  - 10.1.4 Resin-coated fabrics
  - 10.1.5 Ceramics
    - 10.1.5.1 Sintered materials
    - 10.1.5.2 Ceramic composites
    - 10.1.5.3 Monolithic ceramics
  - 10.1.6 Organic composites
    - 10.1.6.1Reinforcement
  - 10.1.7 Plastics
  - 10.1.8 Elastomers
    - 10.1.8.1 Reinforcement
- 10.2 Joining
  - 10.2.1 Adhesives
  - 10.2.2 Thermally welded joints
  - 10.2.3 Resin joining
  - 10.2.4 Mechanical coupling
- 10.3 Coatings
  - 10.3.1 Coating inspection
  - 10.3.2 Inspection under coatings

11.0 Evaluation

- 11.1 Codes and standards
- 11.2 Design and construction specifications
- 11.3 Development of reference standards
- 11.4 Determination of relative condition
  - 11.4.1 Comparison of tested part to prototype
  - 11.4.2 Comparison to nominal
- 11.5 Evaluation of artifacts
- 11.6 Validation

12.0 Responsibilities of Levels of Certification

- 12.1 Level III
- 12.2 Level II
- 12.3 Level I trainee

Microwave Technology Level I, II, and III Training References

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NR

Neutron Radiographic Testing Topical Outlines

Neutron Radiographic Testing 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 Neutron Radiographic Physics Course

1.0 Introduction
- 1.1 History of industrial neutron radiography
- 1.2 General principles of examination of materials by penetrating radiation
- 1.3 Relationship of penetrating neutron radiation, radiography and radiometry
- 1.4 Comparison with other NDT methods, particularly with X-rays and gamma rays
- 1.5 General areas of application
  - 1.5.1 Imaging
  - 1.5.2 Metrology
  - 1.5.3 Product

2.0 Physical Principles
- 2.1 Sources for neutron radiography (general description)
  - 2.1.1 Isotopes
  - 2.1.2 Nuclear reactors
  - 2.1.3 Accelerators
- 2.2 Interaction between neutrons and matter
  - 2.2.1 Absorption
    - 2.2.1.1 Thermal neutrons
    - 2.2.1.2 Resonance neutrons
    - 2.2.1.3 Fast neutrons
  - 2.2.2 Scatter
    - 2.2.2.1 Elastic
    - 2.2.2.2 Inelastic
- 2.3 Neutron radiography techniques
  - 2.3.1 Film imaging techniques
  - 2.3.2 Non-film imaging techniques
- 2.4 Glossary of terms and units of measure

3.0 Radiation Sources for Neutrons (Specific Description)
- 3.1 Reactors
  - 3.1.1 Principle of fission chain reactions
  - 3.1.2 Neutron thermalization (slowing down)
  - 3.1.3 Thermal neutron flux
- 3.2 Accelerators
  - 3.2.1 Types of accelerators
  - 3.2.2 Neutron-producing reactions
- 3.3 Isotopic sources
  - 3.3.1 Radioisotope + Be
    - 3.3.1.1 α – Be
    - 3.3.1.2 γ – Be
  - 3.3.2 Radioisotope + D
    - 3.3.2.1 γ – D
  - 3.3.3 Spontaneous fission
    - 3.3.3.1 ^{252}Cf

4.0 Personnel Safety Radiation Protection Review
- 4.1 Hazards of excessive exposure
  - 4.1.1 General – beta-, gamma-radiation
  - 4.1.2 Specific neutron hazards
    - 4.1.2.1 Relative biological effectiveness
    - 4.1.2.2 Neutron activation
- 4.2 Methods of controlling radiation dose
  - 4.2.1 Time
  - 4.2.2 Distance
  - 4.2.3 Shielding
- 4.3 Specific equipment requirements
  - 4.3.1 Neutron monitoring dosimeters
  - 4.3.2 Gamma-ray monitoring dosimeters
  - 4.3.3 Radiation survey equipment
    - 4.3.3.1 Beta/gamma
    - 4.3.3.2 Neutron
  - 4.3.4 Recording/record keeping
- 4.4 Radiation work procedures
- 4.5 Federal, state, and local regulations

Basic Neutron Radiographic Technique Course

1.0 Radiation-Detection Imaging
- 1.1 Converter screens
  - 1.1.1 Principles of operation
  - 1.1.2 Direct-imaging screens
  - 1.1.3 Transfer-imaging screens
- 1.2 Film – principles, properties, and uses with neutron converter screens
  - 1.2.1 Radiation response
  - 1.2.2 Vacuum/contact considerations
  - 1.2.3 Radiographic speed
  - 1.2.4 Radiographic contrast

- 1.3 Track-etch
  - 1.3.1 Radiation response
  - 1.3.2 Vacuum/contact considerations
  - 1.3.3 Radiographic speed
  - 1.3.4 Radiographic contrast

2.0 Neutron Radiographic Process: Basic Imaging Considerations

- 2.1 Definition of sensitivity (including image quality indicators)
- 2.2 Contrast and definition
  - 2.2.1 Neutron energy and neutron screen relationship
  - 2.2.2 Effect of scattering in object
- 2.3 Geometric principles
- 2.4 Generation and control of scatter
- 2.5 Choice of neutron source
- 2.6 Choice of film
- 2.7 Use of exposure curves
- 2.8 Cause of correction of unsatisfactory radiographs
  - 2.8.1 High film density
  - 2.8.2 Low film density
  - 2.8.3 High contrast
  - 2.8.4 Low contrast
  - 2.8.5 Poor definition
  - 2.8.6 Excessive film fog
  - 2.8.7 Light leaks
  - 2.8.8 Artifacts
- 2.9 Arithmetic of exposure

3.0 Test Result Interpretation

- 3.1 Relationship between X-ray and n-ray
- 3.2 Effects on measurement and interpretation of test
- 3.3 Administrative control of test quality by interpreter
- 3.4 Familiarization with image

Neutron Radiographic Testing Level II Topical Outline

Neutron Radiographic Physics Course

1.0 Introduction

- 1.1 General principles of examination of materials by penetrating radiation
- 1.2 Relationship of penetrating neutron radiation, radiography, and radiometry
- 1.3 Comparison with other methods, particularly with X-rays and gamma rays
- 1.4 Specific areas of application in industry

2.0 Review of Physical Principles

- 2.1 Nature of penetrating radiation (all types)
  - 2.1.1 Particles
  - 2.1.2 Wave properties
  - 2.1.3 Electromagnetic waves
  - 2.1.4 Fundamentals of radiation physics
  - 2.1.5 Sources of radiation
    - 2.1.5.1 Electronic sources
    - 2.1.5.2 Isotopic sources
    - 2.1.5.3 Nuclear reactors
    - 2.1.5.4 Accelerators
- 2.2 Interaction between penetrating radiation and matter (neutron and gamma ray)
  - 2.2.1 Absorption
  - 2.2.2 Scatter
  - 2.2.3 Other interactions
- 2.3 Glossary of terms and units of measure

3.0 Radiation Sources for Neutrons

- 3.1 Neutron sources – general
  - 3.1.1 Reactors
    - 3.1.1.1 Principle of fission chain reactions
    - 3.1.1.2 Fast-neutron flux – energy and spatial distribution
    - 3.1.1.3 Neutron thermalization
    - 3.1.1.4 Thermal-neutron flux – energy and spatial distribution
  - 3.1.2 Accelerators
    - 3.1.2.1 Types of accelerators
    - 3.1.2.2 Neutron-producing reactions
    - 3.1.2.3 Available yields and energy spectra
  - 3.1.3 Isotopic sources
    - 3.1.3.1 Radioisotope + Be
    - 3.1.3.2 Radioisotope + D
    - 3.1.3.3 Spontaneous fission ^{252}Cf
  - 3.1.4 Beam design
    - 3.1.4.1 Source placement
    - 3.1.4.2 Collimation
    - 3.1.4.3 Filtering
    - 3.1.4.4 Shielding

4.0 Radiation Detection

- 4.1 Imaging
  - 4.1.1 Converter screens
    - 4.1.1.1 Principles of operations
    - 4.1.1.2 Types of screens
      - 4.1.1.2.1 Direct exposure
      - 4.1.1.2.2 Transfer exposure
      - 4.1.1.2.3 Track-etch process
      - 4.1.1.2.4 Spectral sensitivity (each process)
  - 4.1.2 Film – principles, properties, use with neutron converter screens
    - 4.1.2.1 Material examination
    - 4.1.2.2 Monitoring
  - 4.1.3 Fluoroscopy
    - 4.1.3.1 Fluorescent screen
    - 4.1.3.2 Image amplification
    - 4.1.3.3 Cine techniques
  - 4.1.4 Direct TV viewing
  - 4.1.5 Special instrumentation associated with above techniques

- 4.2 Non-imaging devices
  - 4.2.1 Solid-state
    - 4.2.1.1 Scintillometer
    - 4.2.1.2 Photo-resistive devices
    - 4.2.1.3 Other
  - 4.2.2 Gaseous
    - 4.2.2.1 Proportional counters
    - 4.2.2.2 Geiger counters
    - 4.2.2.3 Ionization chambers
    - 4.2.2.4 Other
  - 4.2.3 Neutron detectors
    - 4.2.3.1 Boron-based gas counters
    - 4.2.3.2 Fission counters
    - 4.2.3.3 Helium-3 detectors
    - 4.2.3.4 Lithium-based scintillator
    - 4.2.3.5 Instrumentation
      - 4.2.3.5.1 Rate meters
      - 4.2.3.5.2 Counters
      - 4.2.3.5.3 Amplifiers and preamplifiers
      - 4.2.3.5.4 Recording readouts
      - 4.2.3.5.5 Other

5.0 Radiological Safety Principles Review

- 5.1 Controlling personnel exposure
- 5.2 Time, distance, shielding concepts
- 5.3 As low as reasonably achievable (ALARA) concept
- 5.4 Radiation-detection equipment
- 5.5 Exposure-device operating characteristics

Neutron Radiographic Technique Course

1.0 Neutron Radiographic Process

- 1.1 Basic neutron-imaging considerations
  - 1.1.1 Definition of sensitivity (including image quality indicators)
  - 1.1.2 Contrast and definition
    - 1.1.2.1 Neutron energy and neutron screen relationship
    - 1.1.2.2 Effect of scattering in object
    - 1.1.2.3 Exposure versus foil thickness
  - 1.1.3 Geometric principles
  - 1.1.4 Intensifying screens
    - 1.1.4.1 Fluorescent (neutron-sensitive)
    - 1.1.4.2 Metallic (neutron-sensitive)
  - 1.1.5 Generation and control of scatter
  - 1.1.6 Choice of source
  - 1.1.7 Choice of film/detector
  - 1.1.8 Use of exposure curves and process by which they are generated
  - 1.1.9 Fluoroscopic inspection
    - 1.1.9.1 Theory of operation
    - 1.1.9.2 Applications
    - 1.1.9.3 Limitations
  - 1.1.10 Film processing
    - 1.1.10.1 Darkroom procedures
    - 1.1.10.2 Darkroom equipment and chemicals
    - 1.1.10.3 Film processing do's and don'ts
  - 1.1.11 Viewing of radiographs
    - 1.1.11.1 Illuminator requirements (intensity)
    - 1.1.11.2 Background lighting
    - 1.1.11.3 Judging quality of neutron radiographs
  - 1.1.12 Causes and correction of unsatisfactory radiographs
    - 1.1.12.1 High film density
    - 1.1.12.2 Insufficient film density
    - 1.1.12.3 High contrast
    - 1.1.12.4 Low contrast
    - 1.1.12.5 Poor definition
    - 1.1.12.6 Excessive neutron scatter
    - 1.1.12.7 Fog
    - 1.1.12.8 Light leaks
    - 1.1.12.9 Artifacts
  - 1.1.13 Arithmetic of exposure and of other factors affecting neutron radiographs
- 1.2 Miscellaneous applications
  - 1.2.1 Blocking and filtering
  - 1.2.2 Multi-film techniques
  - 1.2.3 Enlargement and projection
  - 1.2.4 Stereoradiography
  - 1.2.5 Triangulation methods
  - 1.2.6 Autoradiography
  - 1.2.7 Flash neutron radiography
  - 1.2.8 "In-motion" radiography and fluoroscopy
  - 1.2.9 Backscatter neutron radiography
  - 1.2.10 Neutron tomography
  - 1.2.11 Micro-neutron radiography
  - 1.2.12 Causes of "diffraction" effects and minimization of interference with test
  - 1.2.13 Determination of focal-spot size
  - 1.2.14 Panoramic techniques
  - 1.2.15 Altering film contrast and density
  - 1.2.16 Gaging and control processes

2.0 Test Result Interpretation

- 2.1 Basic factors
  - 2.1.1 General aspects (relationship between X-ray and neutron radiographs)
  - 2.1.2 Effects on measurement and interpretation of test
  - 2.1.3 Administrative control of test quality by interpreter
  - 2.1.4 Familiarization with image
- 2.2 Material considerations
  - 2.2.1 Metallurgy or other material consideration as it affects use of item and test results
  - 2.2.2 Materials-processing effects on use of item and test results
  - 2.2.3 Discontinuities – their causes and effects
  - 2.2.4 Radiographic appearance of discontinuities
- 2.3 Codes, standards, specifications, and procedures
  - 2.3.1 Thermal neutron radiography
  - 2.3.2 Resonance neutron radiography
  - 2.3.3 Other applicable codes, etc.

Neutron Radiographic Testing Level III Topical Outline

1.0 Principles/Theory
- 1.1 Nature of penetrating radiation
- 1.2 Interaction between penetrating radiation and matter
- 1.3 Neutron radiography
  - 1.3.1 Imaging by film
  - 1.3.2 Imaging by fluorescent materials
  - 1.3.3 Imaging by electronic devices
- 1.4 Radiometry

2.0 Equipment/Materials
- 2.1 Sources of neutrons
  - 2.1.1 Reactors
  - 2.1.2 Accelerators
  - 2.1.3 Isotopic sources
  - 2.1.4 Beam control factors
- 2.2 Radiation detectors
  - 2.2.1 Imaging
    - 2.2.1.1 Converter screens
    - 2.2.1.2 Film principles, properties, use with neutron converter screens
    - 2.2.1.3 Fluoroscopy
    - 2.2.1.4 TV and optical systems
- 2.3 Non-imaging devices
  - 2.3.1 Solid-state detectors
  - 2.3.2 Gaseous ionization detectors
  - 2.3.3 Neutron detectors
  - 2.3.4 Instrumentation
  - 2.3.5 Gaging and control processes

3.0 Techniques/Calibrations
- 3.1 Blocking and filtering
- 3.2 Multi-film technique
- 3.3 Enlargement and projection
- 3.4 Stereoradiography
- 3.5 Triangulation methods
- 3.6 Autoradiography
- 3.7 Flash radiography
- 3.8 In-motion radiography
- 3.9 Fluoroscopy
- 3.10 Electron emission radiography
- 3.11 Micro-radiography
- 3.12 Laminography (tomography)
- 3.13 Control of diffraction effects
- 3.14 Panoramic exposures
- 3.15 Gaging
- 3.16 Real time imaging
- 3.17 Image analysis techniques

4.0 Interpretation/Evaluation
- 4.1 Radiographic interpretation
  - 4.1.1 Image-object relationships
  - 4.1.2 Material considerations
    - 4.1.2.1 Material processing as it affects use of item and test results
    - 4.1.2.2 Discontinuities, their cause and effects
    - 4.1.2.3 Radiographic appearance of discontinuities
  - 4.1.3 Codes, standards, and specifications

5.0 Procedures
- 5.1 The radiographic process
  - 5.1.1 Imaging considerations
    - 5.1.1.1 Sensitivity
    - 5.1.1.2 Contrast and definition
    - 5.1.1.3 Geometric factors
    - 5.1.1.4 Intensifying screens
    - 5.1.1.5 Scattered radiation
    - 5.1.1.6 Source factors
    - 5.1.1.7 Detection media
    - 5.1.1.8 Exposure curves
- 5.2 Film processing
  - 5.2.1 Darkroom procedures
  - 5.2.2 Darkroom equipment and chemicals
  - 5.2.3 Film processing
- 5.3 Viewing of radiographs
  - 5.3.1 Illuminator requirements
  - 5.3.2 Background lighting
  - 5.3.3 Optical aids
- 5.4 Judging radiographic quality
  - 5.4.1 Density
  - 5.4.2 Contrast
  - 5.4.3 Definition
  - 5.4.4 Artifacts
  - 5.4.5 Image quality indicators (IQIs)
  - 5.4.6 Causes and corrections of unsatisfactory radiographs

6.0 Safety and Health
- 6.1 Personnel safety and radiation hazards
  - 6.1.1 Exposure hazards
    - 6.1.1.1 General – beta, gamma
    - 6.1.1.2 Specific neutron hazards
  - 6.1.2 Methods of controlling radiation exposure
  - 6.1.3 Operation and emergency procedures