SUBJECT : RECOMMENDED TRAINING OUTLINES FOR LEVEL 1 AND 2 NDT INDIVIDUALS

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LIST OF CHANGES	
REV	**CHANGES**
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1. REFERENCES:

EN 4179
PART 145.A.30(f)
ASNT SNT-TC-1A

2. APPLICABLE DOCUMENTS:

Employer's written practice.

3. SCOPE:

3.1. It is recognized that the effectiveness of non destructive testing (NDT) applications depends upon the capabilities of the personnel who are responsible for and perform NDT.

3.2. As stated in EN4179 the employer's shall develop a written practice for the common NDT methods listed in paragraph 6, the requirements for training are detailed in this standard.

3.3. This procedure provides guidelines for the establishment of a Non Destructive Testing trainings program.

3.4. These guidelines have been developed by the Netherlands Aerospace Non Destructive Testing Board to aid employers in recognizing the essential factors to be considered in training of personnel engaged in any of the in Para 6 listed NDT methods**.**

3.5. It is recognized that these guidelines may not be appropriate for certain employer's circumstances and/or applications, the employer should review the recommendations presented herein and modify them, as necessary, to meet particular needs.

3.6. In the event of a conflict between the text of this document and EN4179, the requirements of EN4179 shall take precedence.

4. PURPOSE:

The purpose of this procedure is to ensure uniform NDT training of personnel performing NDT in the aerospace industry.

5. DEFINITIONS:

Basic education	the minimum standard of education required for qualification
Documented	The condition of being in written or electronic form.
Employer	A government, prime contractor, sub-contractor, supplier, processor, or outside agency employing individuals performing NDT
Evaluation	A review, following interpretation of the indications noted during an NDT inspection, to determine whether they meet specified acceptance criteria or to determine its significance
Examiner	An individual approved to Level 3 in the method for which he/she is to conduct, supervise and grade examinations.
Experience	Actual performance or observation conducted in the work environment resulting in the acquisition of knowledge and skills, this does not include classroom or laboratory training but does include on the job training.
Instructor	An individual providing classroom or laboratory training for NDT personnel
Method	One of the disciplines of non destructive inspection or testing (e.g. ultrasonic) within which different techniques exist.
NANDTB	Netherlands Aerospace Non Destructive Testing Board An independent national aerospace organization representing a Nation’s aerospace industry that is chartered by the participating prime contractors and recognized by the nation’s regulatory agencies to provide or support NDT qualification and examination services in accordance with this standard, Such services may include participation in approval and certification.
On-the-job training	Training in the work environment, in learning instrument setup, equipment operation, recognition of indications, and interpretation under appropriate

	technical guidance.
Procedure	A general or detailed written instruction for conducting a given process.
Responsible Level 3	A Level 3 designated by the employer with the responsibility and authority to ensure that the requirements of this standard are met and to certify qualified individuals
Written	Retrievable electronic or hard copy.

6. APPLICATION:

This standard applies to all employers, or outside agency providing NDT training at all levels for the aerospace industry.

7. RESPONSIBILITIES:

7.1. It is the responsibility of the employer to use trainings material for training of his NDT personnel, in accordance with the requirements of EN4179 and the recommendations of the NANDTB.

7.2. It is the responsibility of the NANDTB to supply training outlines that are representative for NDT inspection in the aerospace industry.

7.3. It is the responsibility of the EN4179 approved level 3 by the NANDTB, to verify that the content of the training is in accordance with the outlines of EN4179 and the NANDTB.

8. NON DESTRUCTIVE TEST METHODS:

8.1. The following methods have outlines for NDT training by the NANDTB:

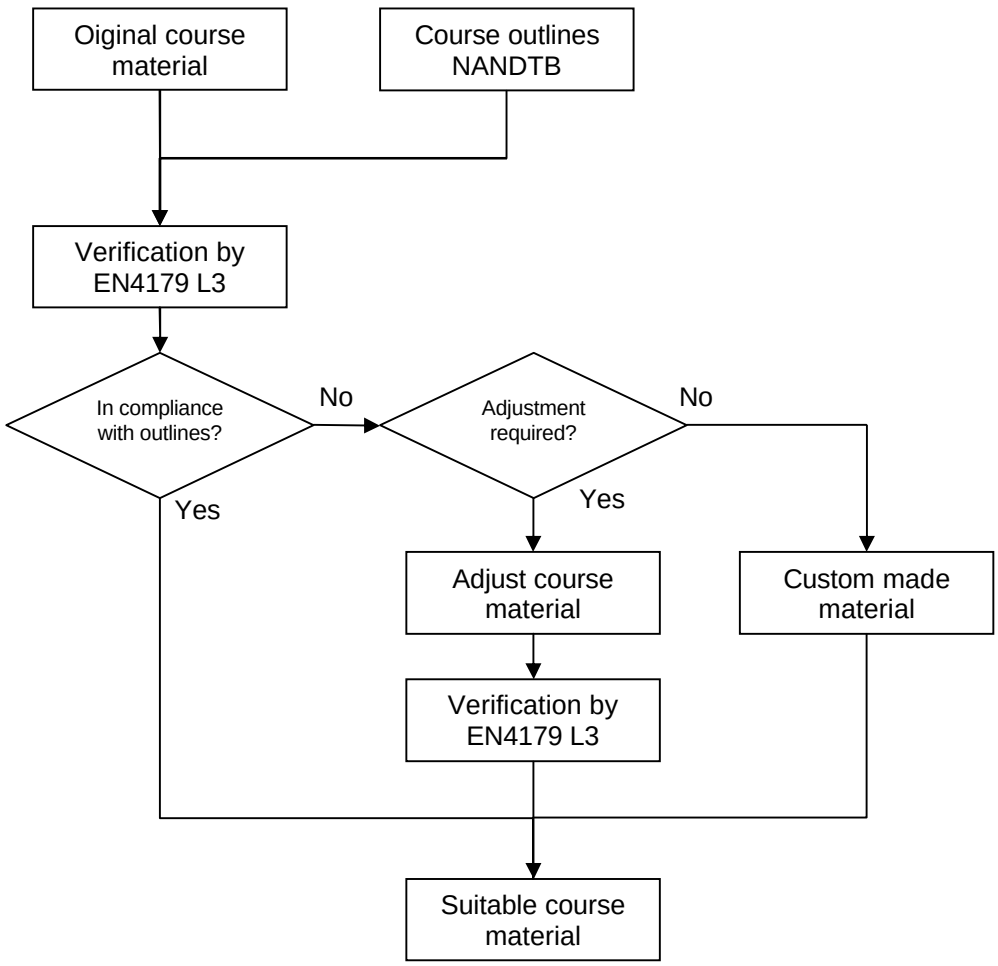
- § Eddy Current Testing (ET)
- § Liquid Penetrant Testing (PT)
- § Magnetic Particle Testing (MT)
- § Radiographic Testing (RT)
- § Ultrasonic Testing (UT)

9. PROCEDURE:

9.1. The by the NANDTB, EN4179 approved level 3 shall verify, that the course material used, is in compliance with the outlines defined in the following appendices:

- § Appendix A for Eddy Current Testing (ET)
- § Appendix B for Liquid Penetrant Testing (PT)
- § Appendix C for Magnetic Particle Testing (MT)
- § Appendix D for Radiographic Testing (RT)
- § Appendix E for Ultrasonic Testing (UT)

9.2. Use the following flow chart for verification if the content of the material is suitable for usage.



9.2.1. The approved EN4179 level 3 shall verify if the existing course material is within the outlines given in the applicable appendix

9.2.2. If the course material is not in accordance with the applicable appendix the material shall be amended, and re-evaluated by the approved EN4179 level 3.

9.2.3. It is possible that these guidelines may not be appropriate for certain employer's circumstances and/or applications, the employer should review the recommendations presented herein and modify them, as necessary, to meet his particular needs. It is however the responsibility of the approved level 3 to verify the content of this course material.

9.3. EVALUATION

9.3.1. The NANDTB has the authority to evaluate the content of the used course material, if any doubt arises about the quality of the course material. If such a review will occur. The content of the material shall be handled as proprietary information and not be further distributed.

9.3.2. If the content of the material is not conform the outlines given in the applicable appendix, the material shall be amended and supplied to the NANDTB for review.

APPENDIX A:

EDDY CURRENT RECOMMENDED TRAINING FOR LEVEL 1

BASIC ELECTROMAGNETIC PHYSICS

1 Introduction to Electromagnetic Testing
- a. Brief History
- b. Basic principles of testing

2 Electromagnetic Theory
- a Eddy Current Theory
  - (1) Generation of eddy currents by means of an AC field
  - (2) Effect of fields created by eddy currents (impedance changes)
  - (3) Effect of change of impedance on instrumentation
  - (4) Properties of eddy currents
    - (a) Travel in circular direction
    - (b) Strongest on surface of test material
    - (c) Zero value at centre of solid conductor placed in an alternating magnetic field
    - (d) Strength, time relationship, and orientation as functions of test system parameters and test-part characteristics
    - (e) Have properties of compressible fluids
    - (f) Small magnitude of current flow
    - (g) Relationship of frequency and plane with current in coil
    - (h) Effective permeability variations when induced in magnetic materials
    - (i) Effect of discontinuity orientation
    - (j) Power losses
- b Flux leakage theory
  - (1) Terminology and units
  - (2) Principles of magnetization
    - (a) B-H curve
    - (b) Magnetic properties
    - (c) Magnetic field
    - (d) Hysteris loop
    - (e) Magnetic permeability
    - (f) Factors affecting permeability
  - (3) Magnetization - electromagnetism theory
    - (a) Oersted's law
    - (b) Faraday's law
    - (c) Electromagnetic
  - (4) Flux leakage theory and principle
    - (a) Residual
    - (b) Active
    - (c) Tangential leakage
    - (d) Normal leakage fields

ELECTROMAGNETIC TECHNIQUE

1 Read out Mechanism
- a. Calibrated or uncalibrated meter
- b. Null meter with dial indicator
- c. Oscilloscope and other monitor displays
- d. Alarm, lights, etc.
- e. Numerical counters
- f. Marking system
- g. Sorting gates and tables
- h. Cutoff saw or shears
- i. Automation and feedback
- j. Strip-chart recorder

2 Types of Eddy Current Sensing Elements
- a. Probes
  - (1) Types of arrangements
    - (a) Absolute
    - (b) Differential
  - (2) Lift-off
  - (3) Theory of operation
  - (4) Applications
  - (5) Advantages
  - (6) Limitations
- b. Through, encircling, or annular coils
  - (1) Types of arrangements
    - (a) Absolute
    - (b) Differential
  - (2) Fill factor
  - (3) Theory of operation
  - (4) Applications
  - (5) Advantages
  - (6) Limitations
- c. Factors affecting choice of sensing elements
  - (1) Type of part to be inspected
  - (2) Type of discontinuity to be detected
  - (3) Speed of testing required
  - (4) Amount of testing (percentage) required
  - (5) Probable location of discontinuity

3 Types of Flux Leakage Sensing Elements
- a. Principles of magnetic-measurement techniques
- b. Inductive-coil sensors
  - (1) Theory of electromotive force (emf) induced in coil
  - (2) Various constructions and designs of coils
  - (3) Coil parameters affecting the flux leakage response
  - (4) Sensing-coil systems and connections (single- and multielement probes)
- c. Semiconductor sensing elements
  - (1) Hall-effect probes
  - (2) Magneto resistors
  - (3) Magneto diodes
  - (4) Magneto transistors
  - (5) Magnetic and electric characteristics of semiconductor sensing elements
- d. Other methods of magnetic leakage field detection
  - (1) Magnetic-tape system
  - (2) Magnetic powder
  - (3) Magnetic-resonance sensor

EDDY CURRENT RECOMMENDED TRAINING FOR LEVEL 2

ELECTROMAGNETIC EVALUATION

1 Review of Electromagnetic Theory
- a. Eddy current theory
- b. Flux leakage theory
- c. Types of eddy current sensing probes
- d. Types of flux leakage sensing probes

2 Factors That affect Coil Impedance
- a Test part
  - (1) Conductivity
  - (2) Permeability
  - (3) Mass
  - (4) Homogeneity
- b Test system
  - (1) Frequency
  - (2) Coupling
  - (3) Field strength
  - (4) Test coil and shape

3 Factors That Affect Flux Leakage Fields
- a. Degree of magnetization
- b. Defect geometry
- c. Defect location
- d. Defect orientation
- e. Velocity factor
- f. Distance between adjacent defects

4. Signal-to-Noise Ratio
- a. Definition
- b. Relationship to eddy current testing
- c. Relationship to flux leakage testing
- d. Methods of improving signal-to-noise ratio

5. Selection of Test Frequency
- a. Relationship of frequency to type of test
- b. Considerations affecting choice of test
  - (1) Signal-to-noise ratio
  - (2) Phase discrimination
  - (3) Response speed
  - (4) Skin effect

6. Selection of Method of Magnetization for Flux Leakage Testing
- a. Magnetization characteristics for various magnetic materials
- b. Magnetization by means of electric fields
  - (1) Circular field
  - (2) Longitudinal field
  - (3) Value of flux density
- c. Magnetization by means of permanent Magnets
  - (1) Permanent magnet relationship and theory
  - (2) Permanent magnet materials
- d. Selection of proper magnetization method

7. Coupling
- a. “Fill factor” in through-coil inspection
- b. “Lift-off” and compensation in probe coil inspection
- c. . Flux leakage “fill factor” in flux leakage testing
- d. “Lift-off” in flux leakage testing

8. Field Strength and Its Selection
- a. Permeability changes
- b. Saturation
- c. Effect of AC field strength on eddy current testing
- d. Effect of field strength in flux leakage testing

9. Field Orientation for Flux Leakage Testing
- a. Circular field
- b. Longitudinal field

10. Instrument Design and Control
- a. Amplification
- b. Phase detection
- c. Differentiation of filtering

11. Applications
- a. Flaw detection
  - (1) Eddy current methods
  - (2) Flux leakage methods
- b. Sorting for properties related to conductivity eddy current
- c. Sorting for properties related to permeability
  - (1) Eddy current methods
  - (2) Flux leakage methods
- d. Thickness evaluation - eddy current
- e. measurement of magnetic-characteristic values
  - (1) Eddy current methods
  - (2) Flux leakage methods

12. User Standards and Operating Procedures
- a. Explanation of standards and specifications used in electromagnetic testing
- b. Explanation of operating procedures used in electromagnetic testing

APPENDIX B:

MAGNETIC PARTICLE RECOMMENDED TRAINING FOR LEVEL 1

1 Principles of Magnets and Magnetic Fields
- a. Theory of magnetic fields
  - (1) Earth's magnetic field
  - (2) Magnetic fields around magnetized materials
- b. Theory of Magnetism
  - (1) Magnetic poles
  - (2) Law of magnetism
  - (3) Materials influenced by magnetic fields
    - (a) Ferromagnetic
    - (b) Paramagnetic
  - (4) Magnetic characteristics of nonferrous
- c. Terminology associated with magnetic particle testing materials

2 Characteristics of Magnetic Fields
- a Bar magnet
- b Ring magnet

3. Effect of Discontinuities of Materials
- a Surface cracks
- b Scratches
- c Subsurface defects

4. Magnetization by Means of Electric Current
- a Circular field
  - (1) Field around a straight conductor
  - (2) Right-hand rule
  - (3) Field in parts through which current flows
    - (a) Long, solid, cylindrical, regular parts
    - (b) Irregularly-shaped parts
    - (c) Tubular parts
    - (d) Parts containing machined holes, slots, etc.
  - (4) Methods of inducing current flow in parts
    - (a) Contact plates
    - (b) Prods
  - (5) Discontinuities commonly discovered by circular fields
- b Longitudinal field
  - (1) Field produced by current flow in a coil
  - (2) Field direction in a current-carrying coil
  - (3) Field strength in a current-carrying coil
  - (4) Discontinuities commonly discovered by longitudinal fields
  - (5) Advantages of longitudinal magnetization
  - (6) Disadvantages of longitudinal magnetization

5. Selecting the Proper Method of Magnetization
- a Alloy, shape, and condition of part
- b Type of magnetizing current
- c Direction of magnetic field
- d Sequence of operations
- e Value of flux density

6. Inspection Materials
- a Wet particles
- b Dry particles

7. Principles of Demagnetization
- a Residual magnetism
- b Reasons for requiring demagnetization
- c Longitudinal and circular residual fields
- d Basic principles of demagnetization
- e Retentivity and coercive force
- f Methods of demagnetization

8. Magnetic Testing equipment
- a Equipment-selection considerations
  - (1) Type of magnetizing current
  - (2) Location and nature of test
  - (3) Test materials used
  - (4) Purpose of test
  - (5) Area inspected
- b Manual inspection equipment
- c Medium- and heavy-duty equipment
- d Stationary equipment
- e Mechanized inspection equipment
  - (1) Semiautomatic inspection equipment
  - (2) Single-purpose semiautomatic equipment
  - (3) Multipurpose semiautomatic equipment
  - (4) Fully automatic equipment

9. Types of Discontinuities Detected by Magnetic Particle Testing
- a Inclusions
- b Blowholes
- c Porosity
- d Flakes
- e Cracks
- f Pipes
- g Laminations
- h Laps
- i Forging bursts
- j Voids

10. Magnetic Particle Test Indications and Interpretations
- a Indications of nonmetallic inclusions
- b Indications of surface seams
- c Indications of cracks
- d Indications of laminations
- e Indications of laps
- f Indications of bursts and flakes
- g Indications of porosity
- h Non relevant indications

MAGNETIC PARTICLE RECOMMENDED TRAINING FOR LEVEL 2

1 Principles
- a. Theory
  - (1) Flux patterns
  - (2) Frequency and voltage factors
  - (3) Current calculations
  - (4) Surface flux strength
  - (5) Subsurface effects
- b. magnets and magnetism
  - (1) Distance factors vs. strength of flux
  - (2) Internal and external flux patterns
  - (3) Phenomenon action at the discontinuity
  - (4) Heat effects on magnetism
  - (5) Material hardness vs. magnetic retention

2 Flux Fields
- a. Direct current
  - (1) Depth of penetration factors
  - (2) Source of current
- b. Direct pulsating current
  - (1) Similarity to direct current
  - (2) Advantages
  - (3) Typical fields
- c. Alternating current
  - (1) Cyclic effects
  - (2) Surface strength characteristics
  - (3) Safety precautions
  - (4) Voltage and current factors
  - (5) Source of current

3 Effects of Discontinuities
- a. Design factors
  - (1) Mechanical properties
  - (2) Part use
- b. Relationship to load-carrying ability

4 Magnetization by Means of electric Current
- a. Circular techniques
  - (1) Current calculations
  - (2) Depth-factor considerations
  - (3) Precautions - safety and overheating
  - (4) Contact prods and yokes
    - (a) Requirements for prods and yokes
    - (b) Current-carrying capabilities
  - (5) Discontinuities commonly detected
- b. Longitudinal technique
  - (1) Principles of induced flux fields
  - (2) Geometry of part to be inspected
  - (3) Shapes and sizes of coils
  - (4) Use of coils and cables
    - (a) Strength of field
    - (b) Current directional flow vs. flux field
    - (c) Shapes, sizes, and current capacities
  - (5) Current calculations
    - (a) Formulas
    - (b) Types of current required
    - (c) Current demand
  - (6) Discontinuities commonly detected

5 Selecting the Proper Method of Magnetization

a. Alloy, shape, and condition of part
b. Type of magnetizing current
c. Direction of magnetic field
d. Sequence of operations
e. Value of flux density

6 Demagnetization Procedures
a. Need for demagnetization of parts
b. Current, frequency, and field orientation
c. Heat factors and precautions
d. Need for collapsing flux fields

7 Equipment
a. Portable type
   (1) Reason for portable equipment
   (2) Capabilities of portable equipment
   (3) Similarity to stationary equipment
b. Stationary type
   (1) Capability of handling large and heavy parts
   (2) Flexibility in use
   (3) Need for stationary equipment
   (4) Use of accessories and attachments
c. Automatic type
   (1) Requirements for automation
   (2) Sequential operations
   (3) Control and operation factors
   (4) Alarm and rejection mechanisms
d. Liquids and powders
   (1) Liquid requirements as a particle
   (2) Safety precautions
   (3) Temperature needs
   (4) Powder and paste contents
   (5) Mixing procedures
   (6) Need for accurate proportions
e. Black-light type
   (1) Black light and fluorescence
   (2) Visible- and black-light comparisons
   (3) Requirements in the testing cycle
   (4) Techniques in use
f. Light-sensitive instruments
   (1) Need for instrumentation
   (2) Light characteristics

8 Types of Discontinuities
a. In castings
b. In ingots
c. In wrought sections and parts
d. In welds

APPENDIX C:

LIQUID PENETRANT RECOMMENDED TRAINING FOR LEVEL 1

1 Introduction
- a. Brief history of nondestructive testing and liquid penetrant testing
- b. Purpose of liquid penetrant testing
- c. Basic principles of liquid penetrant testing
- d. Types of liquid penetrants commercially available
- e. Method of personnel qualification

2 Liquid Penetrant processing
- a Preparation of parts
- b Adequate lighting
- c. Application of penetrant to parts
- d. Removal of surface penetrant
- e. Developer application and drying
- f. Inspection and evaluation
- g. Post cleaning

3. Effect of Discontinuities of Materials
- a Current standards
- b Characteristics of each method
- c General applications of each method

4. Magnetization by Means of Electric Current
- a Liquid Penetrant testing units
- b Lighting equipment and light meters
- c. Materials for liquid penetrant testing
- d. Precautions in liquid penetrant inspection

LIQUID PENETRANT RECOMMENDED TRAINING FOR LEVEL 2

1 Review
- a. Basic principles
- b. Process of various methods
- c. Equipment

2 Selection of the Appropriate Penetrant Testing method
- a. Advantages of various methods
- b. Disadvantages of various methods

3 Inspection and Evaluation of Indications
- a. General
  - (1) Discontinuities inherent in various
  - (2) Reason for indications
  - (3) Appearance of indications
  - (4) Time for indications to appear
  - (5) Effects of temperature and lighting (white to UV)
  - (6) Effects of metal smearing operations (shotpeening, machining, etc.)
  - (7) Preferred sequence for penetrant inspection
  - (8) Part preparation (pre cleaning materials stripping, etc.)
- b. Factors affecting indications
  - (1) Penetrant used
  - (2) Prior processing
  - (3) Technique used
- c. Indications from cracks
  - (1) Cracks occurring during solidification
  - (2) Cracks occurring during processing
  - (3) Cracks occurring during service
- d. Indications from porosity
- e. Indications from specific material forms
  - (1) Forgings
  - (2) Castings
  - (3) Plate
  - (4) Welds
  - (5) Extrusions
- f. Evaluation of indications
  - (1) True indications
  - (2) False indications
  - (3) Relevant indications
  - (4) Non relevant indications
  - (5) Process Control
    - (a) Controlling process variables
    - (b) Testing and maintenance materials

4 Selecting the Proper Method of Magnetization
- a. Inspection procedures (minimum requirements)
- b. Standards/codes
  - (1) Applicable methods/processes
  - (2) Acceptance criteria

5 Demagnetization Procedures

APPENDIX D:

RADIOGRAPHIC TESTING RECOMMENDED TRAINING FOR LEVEL 1

RADIOGRAPHIC EQUIPMENT OPERATING AND EMERGENCY INSTRUCTION COURSE

Note: It is recommended that the trainee receive instruction in the items below prior to performing work in radiography.

Note: * Topics may be deleted if the radiography is limited

1 Personnel Monitoring
- a. Wearing of monitoring badges
- b. Reading of pocket dosimeters
- c. Recording of daily dosimeter readings
- d. "Off-scale" dosimeter-action required
- e. Permissible exposure limits

2 Survey Instruments
- a Types of radiation instruments
- b Reading and interpreting meter indications
- c. Calibration frequency
- d. Calibration expiration-action
- e. Battery check-importance

3. Leak Testing of Sealed Radioactive Sources
- a Requirements for leak testing
- b Purpose of leak testing
- c Performance of leak testing

4. Radiation Survey Report
- a Requirements for completion
- b Description of report format

5 Radiographic Work Practices
- a Establishment of restricted areas
- b Posting and surveillance of restricted areas
- c. Use of time, distance, and shielding to reduce personnel radiation exposure
- d. Applicable regulatory requirements for surveys, posting, and control of radiation and high-radiation areas

6 Exposure Devices
- a Daily inspection and maintenance
- b Radiation exposure limits for gamma-ray
- c. Labeling
- d. Use
- e. Use of collimators to reduce personnel exposure
- f. * Use of "source changers" for gamma-ray sources

7 Emergency Procedures
- a * Vehicle accidents with radioactive sealed
- b * Fire involving sealed sources
- c. * "Source out" - failure to return to safe shielded conditions
- d. * Emergency call list sources

8 Storage and Shipment of Exposure Devices and Sources
- a * Vehicle storage
- b * Storage vault - permanent
- c. * Shipping instructions - sources
- d. * Receiving instructions - radioactive material

9 Radiographic Work Practices

a Nuclear regulatory authority
b License reciprocity
c. * Radioactive materials license requirements for industrial radiography
d. Qualification requirements for radiography personnel
e. Regulations for the control of radiation
f. Transportation regulations for radiographic-source shipment
g. Regulatory requirements for X-ray machines

BASIC RADIOGRAPHIC PHYSICS COURSE

1 Introduction

a. History and discovery of radioactive materials
b. Definition of industrial radiography
c. Radiation protection - why?
d. Basic math review: exponents, square root etc

2 Fundamental Properties of Matter

a. Elements and atoms
b. Molecules and compounds
c. Atomic particles - properties of protons, electrons, and neutrons
d. Atomic structure
e. Atomic number and weight
f. Isotope vs. radioisotope

3 Radioactive Materials

a. Production
   (1) Neutron activation
   (2) Nuclear fissio
b. Stable vs. unstable (radioactive) atoms
c. Curie - the unit of activity
d. Half-life of radioactive materials
e. Plotting of radioactive decay
f. Specific activity - curies/gram

4 Types of Radiation

a. Particulate radiation - properties: alpha, beta, neutron
b. Electromagnetic radiation - X-ray, gamma-ray
c. X-ray production
d. Gamma-ray production
e. Gamma-ray energy
f. Energy characteristics of common radioisotope sources
g Energy characteristics of X-ray machines

5 Interaction of Radiation with Matter

a Ionization
b Radiation interaction with matter
   (1) Photoelectric effect
   (2) Compton scattering
   (3) Pair production
      (a) Unit of radiation exposure – the roentgen
      (b) Emissivity of commonly used radiographic sources
      (c) Emissivity of X-ray exposure devices
      (d) Attenuation of electromagnetic radiation - shielding
      (e Half-value layers; tenth-value layers
      (f) Inverse-square law

6 Biological Effect of Radiation

a. "Natural" background radiation

b. Unit of radiation dose – rem
c. Difference between radiation and contamination
d. Allowable personnel-exposure limits and the banking concept
e. Theory of allowable dose
f. Radiation damage - repair concept
g Symptoms of radiation injury
h Acute radiation exposure and somatic injury
i Personnel monitoring for tracking exposure
j Organ radio sensitivity

7 Radiation Detection

a. Pocket dosimeter
b. Difference between dose and dose rate
c. Survey instruments
   (1) Geiger-Muller tube
   (2) Ionization chambers
   (3) Scintillation chambers, counters
d. Film badge - radiation detector
e. TLDs (thermo luminescent dosimeters)
f. Calibration

8 Exposure Devices and Radiation Sources

a. Radioisotope sources
   (1) Sealed-source design and fabrication
   (2) Gamma-ray sources
   (3) Beta and bremsstrahlung sources
   (4) Neutron sources
b. Radioisotope exposure device characteristics
c. Electronic radiation sources - 500 keV and less, low-energy
   (1) Generator - high-voltage rectifiers
   (2) X-ray tube design and fabrication
   (3) X-ray control circuits
   (4) Accelerating potential
   (5) Target material and configuration
   (6) Heat dissipation
   (7) Duty cycle
   (8) Beam filtration
d. * Electronic radiation sources - medium- and high-energy
   (1) * Resonance transformer
   (2) * Van de Graaff accelerator
   (3) * Linac
   (4) * Betatron
   (5) * Roentgen output
   (6) * Equipment design and fabrication
   (7) * Beam filtration
e. * Fluoroscopic radiation sources
   (1) * Fluoroscopic equipment design
   (2) * Direct-viewing screens
   (3) * Image amplification
   (4) * Special X-ray tube considerations and duty cycle
   (5) * Screen unsharpness
   (6) * Screen conversion efficiency

9 Special Radiographic Sources and Techniques
- a. * Flash radiography
- b. * Stereo radiography
- c. * In-motion radiography
- d. * Autoradiography

RADIOGRAPHIC TECHNIQUE COURSE

1 Introduction
- a. Process of radiography
- b. Types of electromagnetic radiation sources
- c. Electromagnetic spectrum
- d. Penetrating ability or “quality” of X-rays and gamma rays
- e. Spectrum of X-ray tube source
- f. Spectrum of gamma-radioisotope source
- g. X-ray tube - change of mA or kVp effect on “quality” and intensity

2 Basic Principles of Radiography
- a. Geometric exposure principles
  - (1) “Shadow” formation and distortion
  - (2) Shadow enlargement calculation
  - (3) Shadow sharpness
  - (4) Geometric unsharpness
  - (5) Finding discontinuity depth
- b. Radiographic screens
  - (1) Lead intensifying screens
  - (2) Fluorescent intensifying screens
  - (3) Intensifying factors
  - (4) Importance of screen-to-film contact
  - (5) Importance of screen cleanliness and care
  - (6) Techniques for cleaning screens
- c. Radiographic cassettes
- d. Composition of industrial radiographic film
- e. The “heel effect” with X-ray tubes

3 Radiographs
- a. Formation of the latent image on film
- b. Inherent unsharpness
- c. Arithmetic of radiographic exposure
  - (1) Mill amperage - distance-time relationship
  - (2) Reciprocity law
  - (3) Photographic density
  - (4) X-ray exposure charts – material thickness, kV, and exposure
  - (5) Gamma-ray exposure chart
  - (6) Inverse-square-law considerations
  - (7) Calculation of exposure time for gamma and X-ray sources
- d. Characteristic Hurter and Driffield (H&D) curve
- e. Film speed and class descriptions
- f. Selection of film for particular purpose

4 Radiographic Image Quality
- a. Radiographic sensitivity
- b. Radiographic contrast
- c. Film contrast
- d. Subject contrast
- e. Definition
- f. Film graininess and screen mottle effects
- g Penetrameters or image-quality indicators

5 Film Handling, Loading, and Processing
- a. Safe light and darkroom practices
- b. Loading bench and cleanliness
- c. Opening of film boxes and packets
- d. Loading of film and sealing cassettes
- e. Handling techniques for “green film”
- f. Elements of manual film processing

6 Exposure Techniques - Radiography
- a Single-wall radiography
- b Double-wall radiography
  - (1) Viewing two walls simultaneously
  - (2) Offset double-wall exposure single-wall
  - (3) Elliptical techniques
- c. Panoramic radiography
- d. Use of multiple-film loading
- e. Specimen configuration viewing

7 Fluoroscopic Techniques
- a. Dark adaptation and eye sensitivity
- b. Special scattered radiation techniques
- c. Personnel protection
- d. Sensitivity
- e. Limitations
- f. Direct screen viewing
- g Indirect and remote screen viewing

RADIOGRAPHIC TESTING RECOMMENDED TRAINING FOR LEVEL 2

FILM QUALITY AND MANUFACTURING PROCESSES

1 Review of Basic Radiographic Principles
- a. Interaction of radiation with matter
- b. Math review
- c. Exposure calculations
- d. Geometric exposure principles
- e. Radiographic-image quality parameters

2 Darkroom Facilities, Techniques, and Processing
- a. Facilities and equipment
  - (1) Automatic film processor vs. manual processing
  - (2) Safe lights
  - (3) Viewer lights
  - (4) Loading bench
  - (5) Miscellaneous equipment
- b. Film loading
  - (1) General rules for handling unprocessed film
  - (2) Types of film packaging
  - (3) Cassette-loading techniques for sheet and roll
- c. Protection of radiographic film in storage
- d. Processing of film - manual
  - (1) Developer and replenishment
  - (2) Stop bath
  - (3) Fixer and replenishment
  - (4) Washing
  - (5) Prevention of water spots
  - (6) Drying
- e. Automatic film processing
- f. Film filing and storage
  - (1) Retention-life measurements
  - (2) Long-term storage
  - (3) Filing and separation techniques
- g. Unsatisfactory radiographs - causes and cures
  - (1) High film density
  - (2) Insufficient film density
  - (3) High contrast
  - (4) Low contrast
  - (5) Poor definition
  - (6) Fog
  - (7) Light leaks
  - (8) Artefacts
- h. Film density
  - (1) Step-wedge comparison film
  - (2) Densitometers

3 Inspection and Evaluation of Indications
- a. Indications
- b. Discontinuities
  - (1) Inherent
  - (2) Processing
  - (3) Service
- c. Defects

4 Manufacturing Processes and Associated Discontinuities
- a. Casting processes and associated discontinuities
  - (1) Ingots, blooms, and billets
  - (2) Sand casting
  - (3) Centrifugal casting
  - (4) Investment casting
- b. Wrought processes and associated discontinuities
  - (1) Forgings
  - (2) Rolled products
  - (3) Extruded products
- c. Welding processes and associated discontinuities
  - (1) Submerged arc welding (SAW)
  - (2) Shielded metal arc welding (SMAW)
  - (3) Gas metal arc welding (GMAW)
  - (4) Flux corded arc welding (FCAW)
  - (5) Gas tungsten arc welding (GTAW)
  - (6) Resistance welding
  - (7) Special welding processes – electron beam, electro slag, electro gas, etc.

5 Radiological Safety Principles Review
- a. Controlling personnel exposure
- b. Time, distance, shielding concepts
- c. ALARA (as low as reasonably achievable) concept
- d. Radiation-detection equipment
- e. Exposure-device operating characteristics

RADIOGRAPHIC EVALUATION AND INTERPRETATION

1 Radiographic Viewing
- a. Film-illuminator requirements
- b. Background lighting
- c. Multiple-composite viewing
- d. Penetrameter placement
- e. Personnel dark adaptation and visual acuity
- f. Film identification
- g. Location markers
- h. Film-density measurement
- i. Film artefacts

2 Application Techniques
- a. Multiple-film techniques
  - (1) Thickness-variation parameters
  - (2) Film speed
  - (3) Film latitude
- b. Enlargement and projection
- c. Geometrical relationships
  - (1) Geometrical unsharpness
  - (2) Penetrameter sensitivity
  - (3) Source-to-film distance
  - (4) Focal-spot size
- d. Triangulation methods for discontinuity location
- e. Localized magnification
- f. Film-handling techniques

3 Evaluation of Castings
- a. Casting-method review
- b. Casting discontinuities
- c. Origin and typical orientation of discontinuities
- d. Radiographic appearance
- e. Casting codes/standards – applicable acceptance criteria
- f. Reference radiographs

4 Evaluation of Weldments
- a. Welding-method review
- b. Welding discontinuities
- c. Origin and typical orientation of discontinuities
- d. Radiographic appearance
- e. Welding codes/standards - applicable acceptance criteria
- f. Reference radiographs or pictograms

5 Standard, Codes, and Procedures for Radiography
- a. ASTM E94/E142
- b. Acceptable radiographic techniques and setups
- c. Applicable employer procedures
- d. Procedure for radiograph parameter verification
- e. Radiographic reports

APPENDIX E:

ULTRASONIC TESTING RECOMMENDED TRAINING FOR LEVEL 1

BASIC ULTRASONIC

1 Introduction
- a. Definition of ultrasonics
- b. History of ultrasonic testing
- c. Applications of ultrasonic energy
- d. Basic math review
- e. Responsibilities of levels of certification

2 Basic Principles of Acoustics
- a. Nature of sound waves
- b. Modes of sound-wave generation
- c. Velocity, frequency, and wavelength of sound waves
- d. Attenuation of sound waves
- e. Acoustic impedance
- f. Reflection
- g. Refraction and mode-conversion
- h. Snell's law and critical angles
- i. Fresnel and Fraunhofer effects

3. Equipment
- a Basic pulse-echo instrumentation (A-, B-, C-scan and computerized systems)
  - (1) Electronics - time base, pulser, receiver and various monitor displays
  - (2) Control functions
  - (3) Calibration
    - (a) Basic instrument calibration
    - (b) Calibration blocks (types and use)
- b Digital thickness instrumentation
- c Transducer operation and theory
  - (1) Piezoelectric effect
  - (2) Types of crystals
  - (3) Frequency (crystal-thickness relationships)
  - (4) Near field and far field
  - (5) Beam spread
  - (6) Construction, materials, and shapes
  - (7) Types (straight, angle, dual, etc.)
  - (8) Beam-intensity characteristics
  - (9) Sensitivity, resolution, and damping
  - (10) Mechanical vibration into part
- d Couplants
  - (1) Purpose and principles
  - (2) Materials and their efficiency

4. Basic Testing Methods
- a Contact
- b Immersion

ULTRASONIC TECHNIQUE

1 Testing Methods
- a. Contact
  - (1) Straight-beam
  - (2) Angle-beam
  - (3) Surface-wave
  - (4) Pulse-echo transmission
  - (5) Multiple transducer
  - (6) Curved surfaces
- b. Immersion
  - (1) Transducer in water
  - (2) Water column, wheels, etc
  - (3) Submerged test part
  - (4) Sound-beam path - transducer to part
  - (5) Focused transducers
  - (6) Curved surfaces
- c. Comparison of contact and immersion methods

2 Calibration (Electronic and Functional)
- a. Equipment
  - (1) Monitor displays (amplitude, sweep, etc.)
  - (2) Recorders
  - (3) Alarms
  - (4) Automatic and semiautomatic systems
  - (5) Electronic distance/amplitude correction
  - (6) Transducers
- b. Calibration of equipment electronics
  - (1) Variable effects
  - (2) Transmission accuracy
  - (3) Calibration requirements
  - (4) Calibration reflectors
- c. Inspection calibration
  - (1) Comparison with reference blocks
  - (2) Pulse-echo variables
  - (3) Reference for planned tests (straight beam, angle-beam, etc.)
  - (4) Transmission factors
  - (5) Transducer
  - (6) Couplants
  - (7) Materials

3. Straight-Beam Examination to Specific Procedures
- a Selection of parameters
- b Test standards
- c Evaluation of results
- d Test reports

4. Angle-Beam Examination to Specific Procedures
- a Selection of parameters
- b Test standards
- c Evaluation of results
- d Test reports

ULTRASONIC TESTING RECOMMENDED TRAINING FOR LEVEL 2

ULTRASONIC EVALUATION

1 Review of Ultrasonic Technique
- a. Principles of ultrasonics
- b. Equipment
  - (1) A-Scan
  - (2) B-Scan
  - (3) C-scan
  - (4) Computerized systems
- c. Testing techniques
- d. Calibration
  - (1) Straight-beam
  - (2) Angle-beam
  - (3) Resonance
  - (4) Special applications

2 Evaluation of Base-Material Product Forms
- a. Ingots
  - (1) Process review
  - (2) Types, origin, and typical orientation of discontinuities
  - (3) Response of discontinuities to ultrasound
  - (4) Applicable codes/standards
- b. Plate and sheet
  - (1) Rolling process
  - (2) Types, origin, and typical orientation of discontinuities
  - (3) Response of discontinuities to ultrasound
  - (4) Applicable codes/standards
- c. Bar and rod
  - (1) Forming process
  - (2) Types, origin, and typical orientation of discontinuities
  - (3) Response of discontinuities to ultrasound
  - (4) Applicable codes/standards
- d. Pipe and tubular products
  - (1) Manufacturing process
  - (2) Types, origin, and typical orientation of discontinuities
  - (3) Response of discontinuities to ultrasound
  - (4) Applicable codes/standards
- e. Forgings
  - (1) Process review
  - (2) Types, origin, and typical orientation of discontinuities
  - (3) Response of discontinuities to ultrasound
  - (4) Applicable codes/standards
- f. Castings
  - (1) Process review
  - (2) Types, origin, and typical orientation of discontinuities
  - (3) Response of discontinuities to ultrasound
  - (4) Applicable codes/standards
- g. Composite structures
  - (1) Process review
  - (2) Types, origin, and typical orientation of discontinuities
  - (3) Response of ultrasound to discontinuities
  - (4) Applicable codes/standards
- h. Other product forms as applicable - rubber, glass, etc.

3 Evaluation of Weldments
- a. Welding processes
- b. Weld geometries
- c. Welding discontinuities
- d. Origin and typical orientation of discontinuities
- e. Response of discontinuities to ultrasound
- f. Applicable codes/standards

4 Evaluation of Bonded Structures
- a. Manufacturing processes
- b. Types of discontinuities
- c. Origin and typical orientation of discontinuities
- d. Response of discontinuities to ultrasound
- e. Applicable codes/standards

5 Discontinuity Detection
- a. Sensitivity to reflections
  - (1) Size, type, and location of discontinuities
  - (2) Techniques used in detection
  - (3) Wave characteristics
  - (4) Material and velocity
  - (5) Discontinuity
- b. Resolution
  - (1) Standard reference comparisons
  - (2) History of part
  - (3) Probability of type of discontinuity
  - (4) Degrees of operator discrimination
  - (5) Effects of ultrasonic frequency
  - (6) Damping effects
- c. Determination of discontinuity size
  - (1) Various monitor displays and meter indications
  - (2) Transducer movement vs. display
  - (3) Two-dimensional testing techniques
  - (4) Signal patterns
- d. Location of discontinuity
  - (1) Various monitor displays
  - (2) Amplitude and linear time
  - (3) Search technique

6 Evaluation
- a. Comparison procedures
  - (1) Standards and references
  - (2) Amplitude, area, and distance relationship
  - (3) Application of results of other NDT methods
- b. Object appraisal
  - (1) History of part
  - (2) Intended use of part
  - (3) Existing and applicable code interpretation
  - (4) Type of discontinuity and location