UT

ULTRASONIC TESTING TOPICAL OUTLINES

Ultrasonic Testing Level I Topical Outline

Basic Ultrasonic Testing Course

Note: It is recommended that the trainee receive instruction in this course prior to performing work in ultrasonic testing (UT).

1.0 Introduction
- 1.1 Definition of ultrasonics
- 1.2 History of UT
- 1.3 Applications of ultrasonic energy
- 1.4 Basic math review
- 1.5 Responsibilities of levels of certification

2.0 Basic Principles of Acoustics
- 2.1 Nature of sound waves
- 2.2 Modes of sound-wave generation
- 2.3 Velocity, frequency, and wavelength of sound waves
- 2.4 Attenuation of sound waves
- 2.5 Acoustic impedance
- 2.6 Reflection
- 2.7 Refraction and mode conversion
- 2.8 Snell's law and critical angles
- 2.9 Fresnel and Fraunhofer effects

3.0 Equipment
- 3.1 Basic pulse-echo instrumentation (A-scan, B-scan, C-scan, and computerized systems)
  - 3.1.1 Electronics – time-base, pulser, receiver, and various monitor displays
  - 3.1.2 Control functions
  - 3.1.3 Standardization
    - 3.1.3.1 Basic instrument standardization
    - 3.1.3.2 Reference blocks (types and use)
- 3.2 Digital thickness instrumentation
- 3.3 Transducer operation and theory
  - 3.3.1 Piezoelectric effect
  - 3.3.2 Types of transducer elements
  - 3.3.3 Frequency (transducer elements – thickness relationships)
  - 3.3.4 Near field and far field
  - 3.3.5 Beam spread
  - 3.3.6 Construction, materials, and shapes
  - 3.3.7 Types (straight, angle, dual, etc.)
  - 3.3.8 Beam intensity characteristics
  - 3.3.9 Sensitivity, resolution, and damping
  - 3.3.10 Mechanical vibration into part
  - 3.3.11 Other type of transducers (laser UT, EMAT, etc.)
- 3.4 Couplants
  - 3.4.1 Purpose and principles
  - 3.4.2 Materials and their efficiency

4.0 Basic Testing Methods
- 4.1 Contact
- 4.2 Immersion
- 4.3 Air coupling

Ultrasonic Testing Technique Course

1.0 Testing Methods
- 1.1 Contact
  - 1.1.1 Straight beam
  - 1.1.2 Angle-beam
  - 1.1.3 Surface-wave and plate waves
  - 1.1.4 Pulse-echo transmission
  - 1.1.5 Multiple transducer
  - 1.1.6 Curved surfaces
    - 1.1.6.1 Flat entry surfaces
    - 1.1.6.2 Cylindrical and tubular shapes
- 1.2 Immersion
  - 1.2.1 Transducer in water
  - 1.2.2 Water column, wheels, etc.
  - 1.2.3 Submerged test part
  - 1.2.4 Sound beam path – transducer to part
  - 1.2.5 Focused transducers
  - 1.2.6 Curved surfaces
  - 1.2.7 Plate waves
  - 1.2.8 Pulse-echo and through-transmission
- 1.3 Comparison of contact and immersion methods

2.0 Calibration (Electronic and Functional)
- 2.1 Equipment
  - 2.1.1 Monitor displays (amplitude, sweep, etc.)
  - 2.1.2 Recorders
  - 2.1.3 Alarms
  - 2.1.4 Automatic and semiautomatic systems
  - 2.1.5 Electronic distance/amplitude correction
  - 2.1.6 Transducers

- 2.2 Standardization of equipment electronics
  - 2.2.1 Variable effects
  - 2.2.2 Transmission accuracy
  - 2.2.3 Standardization requirements
  - 2.2.4 Standardization reflectors
- 2.3 Inspection standardization
  - 2.3.1 Comparison with reference blocks
  - 2.3.2 Pulse-echo variables
  - 2.3.3 Reference for planned tests (straight beam, angle-beam, etc.)
  - 2.3.4 Transmission factors
  - 2.3.5 Transducer
  - 2.3.6 Couplants
  - 2.3.7 Materials

3.0 Straight-Beam Examination to Specific Procedures
- 3.1 Selection of parameters
- 3.2 Test standards
- 3.3 Evaluation of results
- 3.4 Test reports

4.0 Angle-Beam Examination to Specific Procedures
- 4.1 Selection of parameters
- 4.2 Test standards
- 4.3 Evaluation of results
- 4.4 Test reports

Ultrasonic Testing Level II Topical Outline

Ultrasonic Testing Evaluation Course

1.0 Review of UT Technique Course
- 1.1 Principles of ultrasonics
- 1.2 Equipment
  - 1.2.1 A-scan
  - 1.2.2 B-scan
  - 1.2.3 C-scan
  - 1.2.4 Computerized systems
- 1.3 Testing techniques
- 1.4 Standardization
  - 1.4.1 Straight beam
  - 1.4.2 Angle-beam
  - 1.4.3 Resonance
  - 1.4.4 Special applications

2.0 Evaluation of Base-Material Product Forms
- 2.1 Ingots
  - 2.1.1 Process review
  - 2.1.2 Types, origin, and typical orientation of discontinuities
  - 2.1.3 Response of discontinuities to ultrasound
  - 2.1.4 Applicable codes/standards
- 2.2 Plate and sheet
  - 2.2.1 Rolling process
  - 2.2.2 Types, origin, and typical orientation of discontinuities
  - 2.2.3 Response of discontinuities to ultrasound
  - 2.2.4 Applicable codes/standards
- 2.3 Bar and rod
  - 2.3.1 Forming process
  - 2.3.2 Types, origin, and typical orientation of discontinuities
  - 2.3.3 Response of discontinuities to ultrasound
  - 2.3.4 Applicable codes/standards
- 2.4 Pipe and tubular products
  - 2.4.1 Manufacturing process
  - 2.4.2 Types, origin, and typical orientation of discontinuities
  - 2.4.3 Response of discontinuities to ultrasound
  - 2.4.4 Applicable codes/standards
- 2.5 Forgings
  - 2.5.1 Process review
  - 2.5.2 Types, origin, and typical orientation of discontinuities
  - 2.5.3 Response of discontinuities to ultrasound
  - 2.5.4 Applicable codes/standards
- 2.6 Castings
  - 2.6.1 Process review
  - 2.6.2 Types, origin, and typical orientation of discontinuities
  - 2.6.3 Response of ultrasound to discontinuities
  - 2.6.4 Applicable codes/standards
- 2.7 Composite structures
  - 2.7.1 Process review
  - 2.7.2 Types, origin, and typical orientation of discontinuities
  - 2.7.3 Response of ultrasound to discontinuities
  - 2.7.4 Applicable codes/standards
- 2.8 Other product forms as applicable – rubber, glass, etc.

3.0 Evaluation of Weldments
- 3.1 Welding processes
- 3.2 Weld geometries
- 3.3 Welding discontinuities
- 3.4 Origin and typical orientation of discontinuities
- 3.5 Response of discontinuities to ultrasound
- 3.6 Applicable codes/standards

4.0 Evaluation of Bonded Structures
- 4.1 Manufacturing processes
- 4.2 Types of discontinuities
- 4.3 Origin and typical orientation of discontinuities
- 4.4 Response of discontinuities to ultrasound
- 4.5 Applicable codes/standards

5.0 Discontinuity Detection
- 5.1 Sensitivity to reflections
  - 5.1.1 Size, type, and location of discontinuities
  - 5.1.2 Techniques used in detection
  - 5.1.3 Wave characteristics
  - 5.1.4 Material and velocity

- 5.2 Resolution
  - 5.2.1 Standard reference comparisons
  - 5.2.2 History of part
  - 5.2.3 Probability of type of discontinuity
  - 5.2.4 Degrees of operator discrimination
  - 5.2.5 Effects of ultrasonic frequency
  - 5.2.6 Damping effects
- 5.3 Determination of discontinuity size
  - 5.3.1 Various monitor displays and meter indications
  - 5.3.2 Transducer movement versus display
  - 5.3.3 Two-dimensional testing techniques
  - 5.3.4 Signal patterns
- 5.4 Location of discontinuity
  - 5.4.1 Various monitor displays
  - 5.4.2 Amplitude and linear time
  - 5.4.3 Search technique

6.0 Evaluation
- 6.1 Comparison procedures
  - 6.1.1 Standards and references
  - 6.1.2 Amplitude, area, and distance relationship
  - 6.1.3 Application of results of other NDT methods
- 6.2 Object appraisal
  - 6.2.1 History of part
  - 6.2.2 Intended use of part
  - 6.2.3 Existing and applicable code interpretation
  - 6.2.4 Type of discontinuity and location

Full Matrix Capture Ultrasonic Testing Level II Topical Outline

Note: It is recommended that this course have as a minimum prerequisite an Ultrasonic Testing Level II unrestricted certification. The intent of this document is to provide "basic" knowledge on full matrix capture (FMC) ultrasonic testing consistent with other methods and to acknowledge FMC as unique enough to warrant an additional body of knowledge and qualification requirements.

1.0 Overview
- 1.1 Introduction
- 1.2 FMC terminology
- 1.3 History
- 1.4 Ultrasonic theory
  - 1.4.1 Beam divergence
  - 1.4.2 Wavelength
- 1.5 Overview of phased array ultrasonic testing (PAUT)

2.0 Basics of FMC Data Collection

3.0 Equipment
- 3.1 Computer-based system
- 3.2 Processors and throughput
- 3.3 Block diagram showing basic internal components
- 3.4 Portable versus full computer-based systems

4.0 Probe
- 4.1 Review of arrays
  - 4.1.1 Types and configurations
  - 4.1.2 Effects of pitch and element size relevant to sound transmission
  - 4.1.3 Aperture size and effects
- 4.2 Probe selection
- 4.3 Dead-element check

5.0 Essential Variables

6.0 Scan Plan
- 6.1 Major components of a scan plan
- 6.2 Paths

7.0 Standardization
- 7.1 Single probe
- 7.2 Tandem probe
- 7.3 Reflectors versus paths
- 7.4 Delay and velocity
- 7.5 TCG

8.0 FMC Characteristics
- 8.1 Signal characteristics
- 8.2 Scale factor for FMC
- 8.3 FMC data size
- 8.4 Different FMC techniques
- 8.5 FMC versus other data collection
- 8.6 How to use FMC data
- 8.7 Typical FMC data explained

9.0 Total Focusing Method (TFM) Characteristics
- 9.1 Signal characteristics
- 9.2 TFM frame parameters and FMC
- 9.3 TFM and delay laws
- 9.4 Focusing capability
- 9.5 Coverage capability
- 9.6 Impact of frame parameters on amplitude
- 9.7 Adaptive algorithms

10.0 Examination
- 10.1 Types of equipment
  - 10.1.1 Fully automated
  - 10.1.2 Semiautomated
  - 10.1.3 Manual
  - 10.1.4 Advantages and disadvantages

11.0 Evaluation
- 11.1 Display and display settings
  - 11.1.1 Imaging
  - 11.1.2 3D
- 11.2 Flaw characterization
- 11.3 Flaw dimensioning
- 11.4 Software tools
- 11.5 Image artifacts and saturation

12.0 Documentation
- 12.1 Images
- 12.2 Equipment settings
- 12.3 Plotting
- 12.4 Onboard reporting, requirements

13.0 Amplitude
- 13.1 Amplitude fidelity
- 13.2 Amplitude subject to resolution
- 13.3 Amplitude and interface/dead zones

14.0 Use Cases
- 14.1 Weld examinations
  - 14.1.1 Examination volume
  - 14.1.2 Impact of geometry
  - 14.1.3 Material type
  - 14.1.4 Material thickness
  - 14.1.5 Probe considerations
  - 14.1.6 Review typical welding defects and responses
- 14.2 Corrosion examinations
  - 14.2.1 Advantages, disadvantages
  - 14.2.2 Probe considerations
- 14.3 Other examples
  - 14.3.1 Aluminum
  - 14.3.2 Composites
  - 14.3.3 Effects of probe frequency and wavelength
  - 14.3.4 Manufacturing processes and defects
  - 14.3.5 Types of welding processes
  - 14.3.6 Historical processes and defects

15.0 Procedures and Requirements
- 15.1 Codes and standards specific
- 15.2 Customized specific applications

Phased Array Ultrasonic Testing Level II Topical Outline

Note: It is recommended that this course have as a minimum prerequisite of an Ultrasonic Testing Level II unrestricted certification. The intent of this document is to provide "basic" knowledge on phased array ultrasonic testing (PAUT) consistent with other methods and to acknowledge PAUT as unique enough to warrant an additional body of knowledge and qualification requirements.

Phased Array Ultrasonic Testing Evaluation Course

1.0 Introduction
- 1.1 Terminology of PAUT
- 1.2 History of PAUT – medical ultrasound, etc.
- 1.3 Responsibilities of levels of certification

2.0 Basic Principles of PAUT
- 2.1 Review of ultrasonic wave theory – longitudinal and shear wave
- 2.2 Introduction to PAUT concepts and theory

3.0 Equipment
- 3.1 Computer-based systems
  - 3.1.1 Processors
  - 3.1.2 Control panel including input and output sockets
  - 3.1.3 Block diagram showing basic internal circuit modules
  - 3.1.4 Multielement/multichannel configurations
  - 3.1.5 Portable battery-operated versus full computer-based systems
- 3.2 Focal law generation
  - 3.2.1 Onboard focal law generator
  - 3.2.2 External focal law generator
- 3.3 Probes
  - 3.3.1 Composite materials
  - 3.3.2 Pitch, gap, and size
  - 3.3.3 Passive planes
  - 3.3.4 Active planes
  - 3.3.5 Arrays – 1D, 2D, polar, annular, special shape, etc.
  - 3.3.6 Beam and wave forming
  - 3.3.7 Grating lobes
- 3.4 Wedges
  - 3.4.1 Types of wedge designs
- 3.5 Scanners
  - 3.5.1 Mechanized
  - 3.5.2 Manual

4.0 Testing Techniques
- 4.1 Linear scans
- 4.2 Sectorial scans
- 4.3 Electronic scans

5.0 Standardization
- 5.1 Active element and probe checks
- 5.2 Wedge delay
- 5.3 Velocity
- 5.4 Exit point verifications
- 5.5 Refraction angle verifications
- 5.6 Sensitivity
- 5.7 DAC, TCG, time varied gain (TVG), and angle corrected gain (ACG) variables and parameters
- 5.8 Effects of curvature
- 5.9 Focusing effects
- 5.10 Beam steering
- 5.11 Acquisition gates

6.0 Data Collection
- 6.1 Single probes
- 6.2 Multiple probes
- 6.3 Multiple groups or multiplexing single/multiple probes
- 6.4 Nonencoded scans
  - 6.4.1 Time-based data storage
- 6.5 Encoded scans
  - 6.5.1 Line scans
  - 6.5.2 Raster scans

6.6 Zone discrimination
6.7 Scan plans and exam coverages
 6.7.1 Sectorial
 6.7.2 Linear
 6.7.3 Electronic raster scans
6.8 Probe offsets and indexing

7.0 Procedures
7.1 Specific applications
 7.1.1 Material evaluations
  7.1.1.1 Composites
  7.1.1.2 Nonmetallic materials
  7.1.1.3 Metallic materials
  7.1.1.4 Base-material scan
  7.1.1.5 Bar, rod, and rail
  7.1.1.6 Forgings
  7.1.1.7 Castings
 7.1.2 Component evaluations
  7.1.2.1 Ease with complex geometries
   7.1.2.1.1 Turbines (blades, dovetails, rotors)
   7.1.2.1.2 Shafts, keyways, etc.
   7.1.2.1.3 Nozzles
   7.1.2.1.4 Flanges
  7.1.2.2 Geometric limitations
 7.1.3 Weld inspections
  7.1.3.1 Fabrication/in-service
  7.1.3.2 Differences in material – carbon steel, stainless steel, high-temperature nickel-chromium alloy, etc.
  7.1.3.3 Review of welding discontinuities
  7.1.3.4 Responses from various discontinuities
7.2 Data presentations
 7.2.1 Standard (A-scan, B-scan, and C-scan)
 7.2.2 Other (D-scan, S-scan, etc.)
7.3 Data evaluation
 7.3.1 Codes/standards/specifications
 7.3.2 Flaw characterization
 7.3.3 Flaw dimensioning
 7.3.4 Geometry
 7.3.5 Software tools
 7.3.6 Evaluation gates
7.4 Reporting
 7.4.1 Imaging outputs
 7.4.2 Onboard reporting tools
 7.4.3 Plotting, ACAD, etc.

Time of Flight Diffraction Level II Topical Outline

Note: It is recommended that this course have as a minimum prerequisite an Ultrasonic Testing Level II unrestricted certification. The intent of this document is to provide "basic" knowledge on time of flight diffraction (TOFD) ultrasonic testing consistent with other methods and to acknowledge TOFD as unique enough to warrant an additional body of knowledge and qualification requirements.

Time of Flight Diffraction Evaluation Course

1.0 Introduction
1.1 Terminology of TOFD
1.2 History of TOFD (e.g., M.G. Silk)
1.3 Responsibilities of levels of certification

2.0 Basic Principles of TOFD
2.1 Review of ultrasonic wave theory, refracted longitudinal waves
2.2 Introduction to TOFD concepts and theory
2.3 Technique limitations

3.0 Equipment
3.1 Computer-based systems
 3.1.1 Processors
 3.1.2 Control panel including input and output sockets
 3.1.3 Block diagram showing basic internal circuit modules
 3.1.4 Portable battery-operated versus full computer-based systems
3.2 Beam profile tools
 3.2.1 Probe center separation (PCS) calculators for "flat" material/components
 3.2.2 PCS calculators for "curved" surfaces
 3.2.3 Beam-spread effects and control
 3.2.4 Multiple-zone coverage and limitations
3.3 Probes
 3.3.1 Composite materials
 3.3.2 Damping characteristics
 3.3.3 Selection of frequency and diameter
3.4 Wedges
 3.4.1 Incident- and refracted-angle selections
 3.4.2 High-temperature applications
3.5 Scanners
 3.5.1 Mechanized
 3.5.2 Manual

4.0 Testing Techniques
4.1 Line scans (single tandem-probe setups)
4.2 Line scans (multiple-probe setups)
4.3 Raster scans

5.0 Standardization
- 5.1 Material velocity calculations
- 5.2 Combined probe delay(s) calculation(s)
- 5.3 Digitization rates and sampling
- 5.4 Signal averaging
- 5.5 Pulse width control
- 5.6 PCS and angle selection
- 5.7 Sensitivity
- 5.8 Preamplifiers
- 5.9 Effects of curvature

6.0 Data Collection
- 6.1 Single probe setups
- 6.2 Multiple probe setups
- 6.3 Nonencoded scans
  - 6.3.1 Time-based data storage
- 6.4 Encoded scans
  - 6.4.1 Line scans
  - 6.4.2 Raster scans
- 6.5 Probe offsets and indexing

7.0 Procedures
- 7.1 Specific applications
  - 7.1.1 Material evaluations
    - 7.1.1.1 Base-material scans
  - 7.1.2 Weld inspections
    - 7.1.2.1 Detection and evaluation of fabrication welding flaws
    - 7.1.2.2 Detection and evaluation of in-service cracking
    - 7.1.2.3 Detection of volumetric loss such as weld root erosion and partial penetration weld dimensional verifications
    - 7.1.2.4 Geometric limitations
    - 7.1.2.5 Cladding thickness and integrity evaluations
  - 7.1.3 Complex geometries
    - 7.1.3.1 Transitions, nozzles, branch connections, tees, saddles, etc.
- 7.2 Data presentations
  - 7.2.1 Standard (A-scan, D-scan)
  - 7.2.2 Other (B-scan, C-scan)
- 7.3 Data evaluation
  - 7.3.1 Codes/standards/specifications
  - 7.3.2 Flaw characterization
  - 7.3.3 Flaw dimensioning
  - 7.3.4 Geometry
  - 7.3.5 Software tools
    - 7.3.5.1 Linearization
    - 7.3.5.2 Lateral/backwall straightening and removal
    - 7.3.5.3 Synthetic aperture focusing technique (SAFT)
    - 7.3.5.4 Spectrum processing
    - 7.3.5.5 Curved surface compensation
  - 7.3.6 Parabolic cursor(s)
- 7.4 Reporting
  - 7.4.1 Imaging outputs
  - 7.4.2 Onboard reporting tools
  - 7.4.3 Plotting, ACAD, etc.

Ultrasonic Testing Level III Topical Outline

1.0 Principles/Theory
- 1.1 General
- 1.2 Principles of acoustics
  - 1.2.1 Nature of sound waves
  - 1.2.2 Modes of sound-wave generation
  - 1.2.3 Velocity, frequency, and wavelength of sound waves
  - 1.2.4 Attenuation of sound waves
  - 1.2.5 Acoustic impedance
  - 1.2.6 Reflection
  - 1.2.7 Refraction and mode conversion
  - 1.2.8 Snell's law and critical angles
  - 1.2.9 Fresnel and Fraunhofer effects

2.0 Equipment/Materials
- 2.1 Equipment
  - 2.1.1 Pulse-echo instrumentation
    - 2.1.1.1 Controls and circuits
    - 2.1.1.2 Pulse generation (spike, square wave, and toneburst pulsers)
    - 2.1.1.3 Signal detection
    - 2.1.1.4 Display and recording methods, A-scan, B-scan, and C-scan and digital
    - 2.1.1.5 Sensitivity and resolution
    - 2.1.1.6 Gates, alarms, and attenuators
      - 2.1.1.6.1 Basic instrument standardization and calibration
      - 2.1.1.6.2 Reference blocks
  - 2.1.2 Digital thickness instrumentation
  - 2.1.3 Transducer operation and theory
    - 2.1.3.1 Piezoelectric effect
    - 2.1.3.2 Types of transducer elements
    - 2.1.3.3 Frequency (transducer elements – thickness relationships)
    - 2.1.3.4 Near field and far field
    - 2.1.3.5 Beam spread
    - 2.1.3.6 Construction, materials, and shapes
    - 2.1.3.7 Types (straight, angle, dual, etc.)
    - 2.1.3.8 Beam-intensity characteristics
    - 2.1.3.9 Sensitivity, resolution, and damping
    - 2.1.3.10 Mechanical vibration into parts
    - 2.1.3.11 Other types of transducers (laser UT, EMAT, etc.)
  - 2.1.4 Transducer operation/manipulations
    - 2.1.4.1 Tanks, bridges, manipulators, and squirters
    - 2.1.4.2 Wheels and special hand devices
    - 2.1.4.3 Transfer devices for materials
    - 2.1.4.4 Manual manipulation

2.1.5 Resonance testing equipment
  2.1.5.1 Bond testing
  2.1.5.2 Thickness testing

2.2 Materials
  2.2.1 Couplants
    2.2.1.1 Contact
      2.2.1.1.1 Purpose and principles
      2.2.1.1.2 Materials and their efficiency
    2.2.1.2 Immersion
      2.2.1.2.1 Purpose and principles
      2.2.1.2.2 Materials and their efficiency
    2.2.1.3 Air coupling
  2.2.2 Reference blocks
  2.2.3 Cables/connectors
  2.2.4 Test specimen
  2.2.5 Miscellaneous materials

3.0 Techniques/Standardization

3.1 Contact
  3.1.1 Straight beam
  3.1.2 Angle-beam
  3.1.3 Surface-wave and plate waves
  3.1.4 Pulse-echo transmission
  3.1.5 Multiple transducer
  3.1.6 Curved surfaces

3.2 Immersion
  3.2.1 Transducer in water
  3.2.2 Water column, wheels, etc.
  3.2.3 Submerged test part
  3.2.4 Sound beam path – transducer to part
  3.2.5 Focused transducers
  3.2.6 Curved surfaces
  3.2.7 Plate waves
  3.2.8 Pulse-echo and through-transmission

3.3 Comparison of contact and immersion methods

3.4 Remote monitoring

3.5 Standardization (electronic and functional)
  3.5.1 General
  3.5.2 Reference reflectors for standardization
    3.5.2.1 Balls and flat-bottom holes
    3.5.2.2 Area-amplitude blocks
    3.5.2.3 Distance-amplitude blocks
    3.5.2.4 Notches
    3.5.2.5 Side-drilled holes
    3.5.2.6 Special blocks – IIW and others
  3.5.3 Equipment
    3.5.3.1 Various monitor displays (amplitude, sweep, etc.)
    3.5.3.2 Recorders
    3.5.3.3 Alarms
    3.5.3.4 Automatic and semiautomatic systems
    3.5.3.5 Electronic distance amplitude correction
    3.5.3.6 Transducers
  3.5.4 Standardization of equipment electronics
    3.5.4.1 Variable effects
    3.5.4.2 Transmission accuracy
    3.5.4.3 Standardization and calibration requirements
    3.5.4.4 Standardization reflectors
  3.5.5 Inspection standardization
    3.5.5.1 Comparison with reference blocks
    3.5.5.2 Pulse-echo variables
    3.5.5.3 Reference for planned tests (straight-beam, angle-beam, etc.)
    3.5.5.4 Transmission factors
    3.5.5.5 Transducers
    3.5.5.6 Couplants
    3.5.5.7 Materials

4.0 Interpretations/Evaluations

4.1 Evaluation of base material product forms
  4.1.1 Ingots
    4.1.1.1 Process review
    4.1.1.2 Types, origin, and typical orientation of discontinuities
    4.1.1.3 Response of discontinuities to ultrasound
    4.1.1.4 Applicable codes, standards, specifications
  4.1.2 Plate and sheet
    4.1.2.1 Process review
    4.1.2.2 Types, origin, and typical orientation of discontinuities
    4.1.2.3 Response of discontinuities to ultrasound
    4.1.2.4 Applicable codes, standards, specifications
  4.1.3 Bar and rod
    4.1.3.1 Process review
    4.1.3.2 Types, origin, and typical orientation of discontinuities
    4.1.3.3 Response of discontinuities to ultrasound
    4.1.3.4 Applicable codes, standards, specifications
  4.1.4 Pipe and tubular products
    4.1.4.1 Process review
    4.1.4.2 Types, origin, and typical orientation of discontinuities
    4.1.4.3 Response of discontinuities to ultrasound
    4.1.4.4 Applicable codes, standards, specifications
  4.1.5 Forgings
    4.1.5.1 Process review
    4.1.5.2 Types, origin, and typical orientation of discontinuities
    4.1.5.3 Response of discontinuities to ultrasound
    4.1.5.4 Applicable codes, standards, specifications

- 4.1.6 Castings
  - 4.1.6.1 Process review
  - 4.1.6.2 Types, origin, and typical orientation of discontinuities
  - 4.1.6.3 Response of discontinuities to ultrasound
  - 4.1.6.4 Applicable codes, standards, specifications
- 4.1.7 Composite structures
  - 4.1.7.1 Process review
  - 4.1.7.2 Types, origin, and typical orientation of discontinuities
  - 4.1.7.3 Response of discontinuities to ultrasound
  - 4.1.7.4 Applicable codes, standards, specifications
- 4.1.8 Miscellaneous product forms as applicable (rubber, glass, etc.)
  - 4.1.8.1 Process review
  - 4.1.8.2 Types, origin, and typical orientation of discontinuities
  - 4.1.8.3 Response of discontinuities to ultrasound
  - 4.1.8.4 Applicable codes, standards, specifications

4.2 Evaluation of weldments
- 4.2.1 Process review
- 4.2.2 Weld geometries
- 4.2.3 Types, origin, and typical orientation of discontinuities
- 4.2.4 Response of discontinuities to ultrasound
- 4.2.5 Applicable codes, standards, specifications

4.3 Evaluation of bonded structures
- 4.3.1 Manufacturing process
- 4.3.2 Types, origin, and typical orientation of discontinuities
- 4.3.3 Response of discontinuities to ultrasound
- 4.3.4 Applicable codes, standards, specifications

4.4 Variables affecting test results
- 4.4.1 Instrument performance variations
- 4.4.2 Transducer performance variations
- 4.4.3 Test specimen variations
  - 4.4.3.1 Surface condition
  - 4.4.3.2 Part geometry
  - 4.4.3.3 Material structure
- 4.4.4 Discontinuity variations
  - 4.4.4.1 Size and geometry
  - 4.4.4.2 Relation to entry surface
  - 4.4.4.3 Type of discontinuity
- 4.4.5 Procedure variations
  - 4.4.5.1 Recording criteria
  - 4.4.5.2 Acceptance criteria
- 4.4.6 Personnel variations
  - 4.4.6.1 Skill level in interpretation of results
  - 4.4.6.2 Knowledge level in interpretation of results

4.5 Evaluation (general)
- 4.5.1 Comparison procedures
  - 4.5.1.1 Standards and references
  - 4.5.1.2 Amplitude, area, distance relationship
  - 4.5.1.3 Application of results of other NDT methods
- 4.5.2 Object appraisal
  - 4.5.2.1 History of part
  - 4.5.2.2 Intended use of part
  - 4.5.2.3 Existing and applicable code interpretation
  - 4.5.2.4 Type of discontinuity and location

5.0 Procedures

5.1 Specific applications
- 5.1.1 General
- 5.1.2 Flaw detection
- 5.1.3 Thickness measurement
- 5.1.4 Bond evaluation
- 5.1.5 Fluid flow measurement
- 5.1.6 Material properties measurements
- 5.1.7 Computer control and defect analysis
- 5.1.8 Liquid level sensing
- 5.1.9 Process control
- 5.1.10 Field inspection

5.2 Codes, standards, specifications

Phased Array Ultrasonic Testing

1.0 Introduction

- 1.1 Terminology of PAUT
- 1.2 History of PAUT – medical ultrasound, etc.
- 1.3 Responsibilities of levels of certification

2.0 Basic Principles of PAUT

- 2.1 Review of ultrasonic wave theory: longitudinal and shear wave
- 2.2 Introduction to PAUT concepts and theory
  - 2.2.1 Phasing
  - 2.2.2 Beam scanning patterns
  - 2.2.3 Delay laws or focal laws
  - 2.2.4 Imaging
  - 2.2.5 Dynamic depth focusing

3.0 Equipment

3.1 Computer-based systems
- 3.1.1 Processors
- 3.1.2 Control panel including input and output sockets
- 3.1.3 Block diagram showing basic internal circuit modules
- 3.1.4 Multielement/multichannel configurations
- 3.1.5 Portable battery-operated versus full computer-based systems

3.2 Focal law generation
- 3.2.1 Onboard focal law generator
- 3.2.2 External focal law generator

- 3.3 Probes
  - 3.3.1 Composite materials
  - 3.3.2 Passive planes
  - 3.3.3 Active planes
  - 3.3.4 Arrays – 1D, 2D, polar, annular, special shape, etc.
    - 3.3.4.1 Linear arrays
      - 3.3.4.1.1 Aperture (active, effective, minimum, passive)
      - 3.3.4.1.2 Element pitch, gap, width, and size
  - 3.3.5 Beam and wave forming
    - 3.3.5.1 Sweep range
    - 3.3.5.2 Steering focus power
    - 3.3.5.3 Compensation gain
    - 3.3.5.4 Beam (length and width)
    - 3.3.5.5 Focal depth, depth of field, and focal range
    - 3.3.5.6 Resolution
      - 3.3.5.6.1 Near-surface resolution
      - 3.3.5.6.2 Far-surface resolution
      - 3.3.5.6.3 Lateral and axial resolution
      - 3.3.5.6.4 Angular-surface resolution
  - 3.3.6 Lobes
    - 3.3.6.1 Main lobes
    - 3.3.6.2 Side lobes
    - 3.3.6.3 Grating lobes
    - 3.3.6.4 Grating lobe amplitude
  - 3.3.7 Beam apodization
- 3.4 Wedges
  - 3.4.1 Types of wedge designs
- 3.5 Scanners
  - 3.5.1 Mechanized
  - 3.5.2 Manual

4.0 Testing Techniques

- 4.1 Linear scans
- 4.2 Sectorial scans
- 4.3 Electronic scans

5.0 Standardization

- 5.1 Active element and probe checks
- 5.2 Wedge delay
- 5.3 Velocity
- 5.4 Exit point verifications
- 5.5 Refraction angle verifications
- 5.6 Sensitivity
- 5.7 DAC, TCG, TVG, and ACG variables and parameters
- 5.8 Effects of curvature
- 5.9 Focusing effects
- 5.10 Beam steering
- 5.11 Acquisition gates

6.0 Data Collection

- 6.1 Single probes
- 6.2 Multiple probes
- 6.3 Multiple groups or multiplexing single/multiple probes
- 6.4 Nonencoded scans
  - 6.4.1 Time-based data storage
- 6.5 Encoded scans
  - 6.5.1 Line scans
  - 6.5.2 Raster scans
- 6.6 Zone discrimination
- 6.7 Scan plans and exam coverages
  - 6.7.1 Sectorial
  - 6.7.2 Linear
  - 6.7.3 Electronic raster scans
- 6.8 Probe offsets and indexing

7.0 Procedures

- 7.1 Specific applications
  - 7.1.1 Material evaluations
    - 7.1.1.1 Composites
    - 7.1.1.2 Nonmetallic materials
    - 7.1.1.3 Metallic materials
    - 7.1.1.4 Base-material scan
    - 7.1.1.5 Bar, rod, and rail
    - 7.1.1.6 Forgings
    - 7.1.1.7 Castings
  - 7.1.2 Component evaluations
    - 7.1.2.1 Ease with complex geometries
      - 7.1.2.1.1 Turbines (blades, dovetails, rotors)
      - 7.1.2.1.2 Shafts, keyways, etc.
      - 7.1.2.1.3 Nozzles
      - 7.1.2.1.4 Flanges
    - 7.1.2.2 Geometric limitations
  - 7.1.3 Weld inspections
    - 7.1.3.1 Fabrication/in-service
    - 7.1.3.2 Differences in material – carbon steel, stainless steel, high-temperature nickel-chromium alloy, etc.
    - 7.1.3.3 Review of welding discontinuities
    - 7.1.3.4 Responses from various discontinuities
- 7.2 Data presentations
  - 7.2.1 Standard (A-scan, B-scan, and C-scan)
  - 7.2.2 Other (D-scan, S-scan, etc.)
- 7.3 Data evaluation
  - 7.3.1 Codes, standards, specifications
  - 7.3.2 Flaw characterization
  - 7.3.3 Flaw dimensioning
  - 7.3.4 Geometry
  - 7.3.5 Software tools
  - 7.3.6 Evaluation gates
- 7.4 Reporting
  - 7.4.1 Imaging outputs
  - 7.4.2 Onboard reporting tools
  - 7.4.3 Plotting, ACAD, etc.

Time of Flight Diffraction (TOFD)

1.0 Introduction
- 1.1 Terminology of TOFD
- 1.2 History of TOFD (e.g., M.G. Silk)
- 1.3 Responsibilities of levels of certification

2.0 Basic Principles of TOFD
- 2.1 Review of ultrasonic wave theory, refracted longitudinal waves
- 2.2 Introduction to TOFD concepts and theory
- 2.3 Technique limitations

3.0 Equipment
- 3.1 Computer-based systems
  - 3.1.1 Processors
  - 3.1.2 Control panel including input and output sockets
  - 3.1.3 Block diagram showing basic internal circuit modules
  - 3.1.4 Portable battery-operated versus full computer-based systems
- 3.2 Beam profile tools
  - 3.2.1 PCS calculators for "flat" material/components
  - 3.2.2 PCS calculators for "curved" surfaces
  - 3.2.3 Beam-spread effects and control
  - 3.2.4 Multiple-zone coverage and limitations
- 3.3 Probes
  - 3.3.1 Composite materials
  - 3.3.2 Damping characteristics
  - 3.3.3 Selection of frequency and diameter
- 3.4 Wedges
  - 3.4.1 Incident and refracted-angle selections
  - 3.4.2 High-temperature applications
- 3.5 Scanners
  - 3.5.1 Mechanized
  - 3.5.2 Manual

4.0 Testing Techniques
- 4.1 Line scans (single tandem probe setups)
- 4.2 Line scans (multiple-probe setups)
- 4.3 Raster scans

5.0 Standardization
- 5.1 Material velocity calculations
- 5.2 Combined probe delay(s) calculation(s)
- 5.3 Digitization rates and sampling
- 5.4 Signal averaging
- 5.5 Pulse width control
- 5.6 PCS and angle selection
- 5.7 Sensitivity
- 5.8 Preamplifiers
- 5.9 Effects of curvature

6.0 Data Collection
- 6.1 Single-probe setups
- 6.2 Multiple-probe setups
- 6.3 Nonencoded scans
  - 6.3.1 Time-based data storage
- 6.4 Encoded scans
  - 6.4.1 Line scans
  - 6.4.2 Raster scans
- 6.5 Probe offsets and indexing

7.0 Procedures
- 7.1 Specific applications
  - 7.1.1 Material evaluations
    - 7.1.1.1 Base-material scans
  - 7.1.2 Weld inspections
    - 7.1.2.1 Detection and evaluation of fabrication welding flaws
    - 7.1.2.2 Detection and evaluation of in-service cracking
    - 7.1.2.3 Detection of volumetric loss such as weld root erosion and partial penetration weld dimensional verifications
    - 7.1.2.4 Geometric limitations
    - 7.1.2.5 Cladding thickness and integrity evaluations
  - 7.1.3 Complex geometries
    - 7.1.3.1 Transitions, nozzles, branch connections, tees, saddles, etc.
- 7.2 Data presentations
  - 7.2.1 Standard (A-scan, D-scan)
  - 7.2.2 Other (B-scan, C-scan)
- 7.3 Data evaluation
  - 7.3.1 Codes/standards/specifications
  - 7.3.2 Flaw characterization
  - 7.3.3 Flaw dimensioning
  - 7.3.4 Geometry
  - 7.3.5 Software tools
    - 7.3.5.1 Linearization
    - 7.3.5.2 Lateral/backwall straightening and removal
    - 7.3.5.3 Synthetic aperture focusing technique (SAFT)
    - 7.3.5.4 Spectrum processing
    - 7.3.5.5 Curved surface compensation
  - 7.3.6 Parabolic cursor(s)
- 7.4 Reporting
  - 7.4.1 Imaging outputs
  - 7.4.2 Onboard reporting tools
  - 7.4.3 Plotting, ACAD, etc.

ULTRASONIC TESTING LEVEL I, II, AND III TRAINING REFERENCES

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Limited Certification for Ultrasonic Digital Thickness Measurement Topical Outline

1.0 Principles/Theory
- 1.1 General
- 1.2 Principles of acoustics
  - 1.2.1 Nature of sound waves
  - 1.2.2 Modes of sound-wave generation
  - 1.2.3 Velocity, frequency, and wavelength of sound waves
  - 1.2.4 Attenuation/scattering of sound waves

2.0 Equipment/Materials
- 2.1 Equipment
  - 2.1.1 Pulse-echo instrumentation
    - 2.1.1.1 Pulse generation
    - 2.1.1.2 Signal detection
    - 2.1.1.3 Display and recording methods, A-scan, B-scan, C-scan, and digital
    - 2.1.1.4 Sensitivity and resolution
  - 2.1.2 Digital thickness instrumentation
  - 2.1.3 Transducer operation and theory
    - 2.1.3.1 Piezoelectric effect
    - 2.1.3.2 Frequency (crystal-thickness relationships)
    - 2.1.3.3 Types (straight, angle, single, dual, etc.)
- 2.2 Materials
  - 2.2.1 Couplants
    - 2.2.1.1 Purpose and principles
    - 2.2.1.2 Material and their efficiency
  - 2.2.2 Reference blocks
  - 2.2.3 Cables/connectors
  - 2.2.4 Test specimen

3.0 Techniques/Standardization – Contact Straight Beam

4.0 Variables Affecting Test Results
- 4.1 Instrument performance variations
- 4.2 Transducer performance variations
- 4.3 Test specimen variations
  - 4.3.1 Surface condition
  - 4.3.2 Part geometry
  - 4.3.3 Material structure

5.0 Procedure/Specification Applications/Thickness Measurement

Limited Certification for Ultrasonic A-scan Thickness Measurement Topical Outline

1.0 Principles/Theory
- 1.1 General
- 1.2 Principles of acoustics
  - 1.2.1 Nature of sound waves
  - 1.2.2 Modes of sound-wave generation
  - 1.2.3 Velocity, frequency, and wavelength of sound waves
  - 1.2.4 Attenuation of sound waves
  - 1.2.5 Acoustic impedance
  - 1.2.6 Reflection

2.0 Equipment/Materials
- 2.1 Equipment
  - 2.1.1 Pulse-echo instrumentation
    - 2.1.1.1 Controls and circuits
    - 2.1.1.2 Pulse generation
    - 2.1.1.3 Signal detection
    - 2.1.1.4 Display and recording methods – A-scan, B-scan, C-scan, and digital
    - 2.1.1.5 Sensitivity and resolution
    - 2.1.1.6 Gates, alarms, and attenuators
    - 2.1.1.7 Basic instrument standardization
    - 2.1.1.8 Reference blocks
  - 2.1.2 Digital thickness instrumentation
  - 2.1.3 Transducer operation and theory
    - 2.1.3.1 Piezoelectric effect
    - 2.1.3.2 Types of crystals
    - 2.1.3.3 Frequency (crystal-thickness relationships)
    - 2.1.3.4 Types (straight, angle, single, dual, etc.)
  - 2.1.4 Resonance testing equipment
    - 2.1.4.1 Thickness testing

- 2.2 Materials
  - 2.2.1 Couplants
    - 2.2.1.1 Purpose and principles
    - 2.2.1.2 Material and their efficiency
  - 2.2.2 Reference blocks
  - 2.2.3 Cables/connectors
  - 2.2.4 Test specimen
  - 2.2.5 Miscellaneous materials

3.0 Techniques/Standardization – Contact Straight Beam

- 3.1 Contact
  - 3.1.1 Straight beam
  - 3.1.2 Pulse-echo transmission

4.0 Variables Affecting Test Results

- 4.1 Instrument performance variations
- 4.2 Transducer performance variations
- 4.3 Test specimen variations
  - 4.3.1 Surface condition
  - 4.3.2 Part geometry
  - 4.3.3 Material structure
- 4.4 Personnel variations
  - 4.4.1 Skill level in interpretation of results
  - 4.4.2 Knowledge level in interpretation of results

5.0 Procedures

- 5.1 Thickness measurement