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# Procedure

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# Ultrasonic Thickness Testing Procedure

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# REVISION INDEX

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## 1.0 SCOPE

- 1.1 This procedure details the requirements for measuring the thickness of materials having an equivalent thickness in steel of 0.050 inch to 8.0 inches using the manual, straight beam, contact, pulse echo method.
- 1.2 This procedure is applicable to any material in which ultrasonic waves will propagate at a constant velocity throughout the part and from which back reflections can be obtained and resolved.
- 1.3 The primary application will be the measurement of steel plate, pipe and tubing, as required to determine remaining wall thickness.

## 2.0 REFERENCE DOCUMENTS

- 2.1 Industrial Performance Services Written Practice, IPS-WP-01, Procedure for Qualification and Certification of Personnel
- 2.2 ASME Section V, Article 5, Ultrasonic Examination Methods for Materials, 2025 Edition
- 2.3 ASTM E-797, Standard Practice for Measuring Thickness by Manual Ultrasonic Pulse-Echo Contact Method

## 3.0 PERSONNEL REQUIREMENTS

- 3.1 Personnel performing examinations to this procedure shall be certified as Level II Limited, Level I, Level II or Level III in accordance with Industrial Performance Services IPS-WP-01.
- 3.2 Personnel performing examinations in accordance with this procedure are responsible to ensure that all applicable requirements of this procedure are met.

## 4.0 EQUIPMENT AND MATERIALS

- 4.1 The following test equipment will be needed:
  - 4.1.1 UT Test Instrument
  - 4.1.2 UT Search Unit
  - 4.1.3 Search Unit Cables
  - 4.1.4 Wear Faces/Heat Shields as applicable
  - 4.1.5 Reference Blocks/Step Wedges
  - 4.1.6 Markers for Inspection Surface
  - 4.1.7 Reports
  - 4.1.8 Procedure
- 4.2 Test Instruments shall:
  - 4.2.1 Be able to operate off of battery power.
  - 4.2.2 Be a unit that is portable in size.
  - 4.2.3 Have a minimum thickness range of 0.050 inch to 10.00 inches.
  - 4.2.4 Be of the pulse-echo type, capable of producing frequencies over the range of at least 1MHz to 5MHz and have stepped gain control in increments of 2dB or less.

4.2.5 Have a resolution capability of at least 0.001 inch.

#### 4.3 Search Units

4.3.1 Transducers for thickness examination shall be broadband, highly damped and designed for good near surface resolution.

4.3.2 Based upon the application, single or dual crystal search units may be used.

4.3.3 The nominal frequency for search units utilized during examination(s) shall be between 1 MHz to 5MHz, unless variables such as production material grain structure require the use of other frequencies to assure adequate penetration or better resolution. A nominal frequency of 5 MHz is recommended.

4.3.4 Longitudinal wave search units range from 1/8 inch to 1 inch in diameter, with both smaller and larger units available for special applications.

4.3.5 Search unit selection shall be guided by thickness range, material characteristics, accessibility, temperature and compatibility with test instrument.

4.3.6 Stand-off wedges, delay lines, hi-temp shields and wear faces may be employed as needed to obtain readings under varying conditions.

4.3.7 The technician must maintain an awareness of the effect that wearing of delay lines, wear faces etc. may have on examination results. Frequently inspect faces and tips for wear or damage and replace as needed.

4.3.8 The technician must also be aware of the effect that temperature has on examination results, especially when using delay lines and dual element probes.

4.3.9 For high temperature applications, the probe should be rated for the temperature range to be examined. The recommended duty cycle for the transducer must be observed to prevent damage to the transducer.

4.3.10 Ensure there is adequate coupling at the wear face/ delay line, to transducer interface. High temperature couplant must be rated for the temperature of the examination surface.

4.3.11 When using a delay line, caution must be taken to not confuse the delay line multiple with a signal from the part under examination.

4.3.12 Search units should sit flat on the examination surface without rocking. For diameters of 4 inches and less, contoured (concave or convex) shoes or transducer faces may be used to eliminate insufficient contact between the search unit and the part, which could result in inaccurate data.

4.3.13 For very small diameter piping, it is possible to obtain accurate readings using a small, flat, dual element transducer with the crosstalk barrier-oriented perpendicular to the axis of the pipe. However, care must be taken to ensure calibration is performed with the transducer oriented the same as during examination.

#### 4.4 Couplants

4.4.1 Couplant must not be detrimental to the product being tested.

4.4.1.1 Petroleum based couplant shall not be used unless specifically approved by the client.

- 4.4.1.2 Petroleum (hydrocarbon) based couplant is not to be used in applications where contact with chemicals in the area (e.g. Chlorine) could result in combustion or other undesirable reactions.
- 4.4.1.3 Silicone based hi-temp grease (e.g. DOW Corning Molykote 3451) is recommended for these applications.
- 4.4.1.4 The same couplant used for scanning must be used for calibration.
- 4.4.1.5 Couplant may be made up of water, oil, or glycerin.
- 4.4.1.6 When approved by the client, a high temperature couplant may be lithium or other high temperature grease for designated temperatures or a couplant designed for the purpose.
  - 4.4.1.7 It is recommended, when used for inspection of austenitic stainless steels or titanium alloys that couplants not contain more than 250ppm of halides (chlorides + fluorides) and for nickel base alloys it's recommended to contain no more than 250 ppm of sulfur.

#### 4.5 Reference Standards

- 4.5.1 Reference standards shall be used to ensure proper set-up and calibration prior to all thickness examinations. These standards may be in the form of step wedges, blocks or plates.
- 4.5.2 Standards may be purchased commercially or manufactured from sound material to meet specific requirements. (See E-797)
- 4.5.3 Standards may be contoured or machined from tubular products to match the curvature (concave or convex) of the item to be examined.
- 4.5.4 Standards shall be of ultrasonically similar material to the item being examined.
- 4.5.5 Artificial reflectors, i.e. flat-bottomed holes (FBH), side-drilled holes (SDH) or notches may be used as required to provide consistent reference standards for sensitivity when needed.
- 4.5.6 The surface finish of the reference standard and the item to be examined should be similar. If not, gain correction should be employed to ensure accuracy of the readings.
- 4.5.7 Prior to examination, the following shall be considered when selecting the reference standard(s) to be used:
  - 4.5.7.1 Nominal thickness of the material
  - 4.5.7.2 Thickness range to be examined
  - 4.5.7.3 Type, grade of material
  - 4.5.7.4 Temperature of material
  - 4.5.7.5 Material condition (casting, forging, etc.)
  - 4.5.7.6 Surface condition (painted, corroded, polished, etc.)
  - 4.5.7.7 Criteria or client specification
- 4.5.8 Step wedges/blocks for thickness measurement calibration shall have at least 3 steps as indicated below:
  - 4.5.8.1 The thinnest step on the wedge shall have a thickness less than or equal to 50% of the minimum thickness measured.
  - 4.5.8.2 The center step(s) should be within +/- 25% of the actual material thickness.
  - 4.5.8.3 The thickest step shall be greater than or equal to 125% of the

thickness to be measured.

4.5.8.4 When performing thickness calibration, standard manufactured round number step wedges are approved as long as the thickness of the material to be measured is within the range described in this procedure. See Table 1 for a reference of allowable ranges.

## 5.0 PROCEDURE

5.1 The ultrasonic instrument measures the transit time of the ultrasonic pulse through the part.

5.2 Thickness (T) when measured by the pulse-echo method is a product of the velocity of sound in the material and one-half the transit time (round trip) through the material.

$T = Vt / 2$  Where: T = Thickness V = Velocity t = transit time

5.3 Items to be addressed with the client:

5.3.1 Any site-specific safety issues or requirements.

5.3.2 Coating and/or lining type and method of accounting for coating or lining thickness.

5.3.3 Surface preparation requirements and methods allowed.

5.3.4 Method of gaining access to examination surface on insulated components.

5.3.5 Follow the procedural or client-specific instructions for the specific type of inspection being performed, e.g. boiler, piping, tank, or pressure vessel.

5.3.6 Code and/or client minimum and maximum thickness requirements.

5.3.7 Client and/or code report requirements.

5.3.8 The acceptance criteria shall be set by the client or the client's representative and should include direction on whether the thickness readings are to be performed for information only or if there is a minimum thickness value criteria. Any thickness value recorded that is below the minimum thickness value criteria shall be verified and reported to the project supervisor, client or client representative.

5.4 Surface Conditions and Preparation

5.4.1 The surface shall be sufficiently clean and smooth to allow adequate coupling.

5.4.2 The surface shall be free of weld spatter, loose scale, loose coatings, rust or other materials that would affect the outcome of the examination.

5.4.3 Localized surface preparation such as wire brushing, light grinding or sanding, may be required to provide a surface suitable for examination. Take caution when removing base metal, so that only the minimal amount is removed and always verify with the client before doing so.

5.4.4 Tightly adhering coating need not be removed unless so directed by the client. However, if base metal only readings are to be obtained through the coating, a suitable method must be employed to ensure accuracy of the data, e.g. echo to echo, etc.

5.4.5 Removal of coating and/or lining is prohibited unless approval from client has been acquired.

- 5.4.6 For insulated surfaces, use only those methods approved by the client to gain access. Do not cut access holes or remove insulation without prior approval from the client.
- 5.4.7 Temperature of the surface shall be measured when extremely low or high temperatures (less than 40°F or greater than 200°F) are suspected to ensure proper couplant and transducer selection.

## 5.5 Calibration

- 5.5.1 Prior to calibration, ensure the temperature of the specimen falls within the acceptable range of this procedure and that the temperature of the calibration standard is within 25° F of the item to be examined. This may require placing the step wedge on the part to be examined or placing the unit and wedge in the ambient temperature until temperatures are normalized.
- 5.5.2 Using the reference standards that bracket the thickness range to be measured, calibrate the unit per the manufacturer's instructions for the type of unit and transducer used.
- 5.5.3 Calibrate the unit using the couplant to be used during examination.
- 5.5.4 Ensure the digital readout is within 0.001 inch of the actual value at the high, target and low ends of the standard.
- 5.5.5 Adjust the amplitude to be between 80% and 90% (full screen height) FSH at the target thickness. If the surface roughness is such that the back reflection is significantly less than 80% FSH, increase the gain setting to provide back wall reflection amplitude between 80 and 90% FSH on the test object. However, you must recalibrate on the calibration standard at this gain setting. If required, the additional dB entered can be recorded as the gain correction.
- 5.5.6 Verify calibration frequently, (not to exceed 30 minutes or every 100 readings, whichever comes first) during examination and when readings near either end of the range are detected, after change in battery, operator or transducer. Finally, verify calibration is still within parameters upon completion of the examination.
- 5.5.7 Due to the non-linearity of dual element transducers and the potential for "doubling" of readings, care must be taken when gauging thicknesses below 0 .100 inch. Proper transducer selection and calibration is paramount.
- 5.5.8 On curved surfaces , the orientation of the "cross-talk" barrier in dual element transducers must be the same when applied to the object being tested as that used when calibrating.

## 5.6 Measurement

- 5.6.1 Thickness readings shall be taken at designated points sometimes referred to as "Thickness Measurement Locations" (TMLs), "Condition Monitoring Locations" (CMLs) or test bands in accordance with client specifications or item specific instructions.
- 5.6.2 On tanks or vessels, the best results are usually obtained by interrogating a specified area, (e.g. 2 in. x 2 in.) instead of a single point.

- 5.6.3 When “scanning” is specified, e.g. boiler tubes or piping quadrants, CRT display flaw detectors work best. However, accurate data can be obtained with the A-scan/data logger by careful observation of the signal and actually linking together a series of spot readings to obtain full coverage.
  - 5.6.4 When scanning with a flaw detector, the scan rate shall not exceed 6 inches per second. When scanning with a thickness gauge, scanning rates shall not exceed 2 inches per second.
  - 5.6.5 Perform thickness examinations with a back reflection between 80 and 95% FSH. Do not perform thickness examinations with a back reflection greater than 100% unless specifically instructed by the referencing code or specification. Excessive gain can result in inaccurate thickness readings and exaggerated perception of inclusions or voids.
  - 5.6.6 Gates/alarms may be used to assist in detecting flag values
  - 5.6.7 When measuring thickness on high temperature applications, be sure not to exceed the temperature duty cycle of the transducer. Refer to the manufacturer’s data sheet or contact the Level III when the duty cycle of a transducer is unknown.
  - 5.6.8 Every effort must be made to be consistent in returning the transducer to ambient temperature between readings. A transducer that isn’t cooled between readings may increase in temperature indicating increasing thickness values as the delay lines expand.
  - 5.6.9 When readings outside of the calibration bracket range are found, recalibrate to bracket the thickness range of the readings to ensure accuracy of the data.
  - 5.6.10 When measuring through coatings, it is not acceptable to simply subtract the measured or estimated coating thickness from the thickness reading. It is necessary to employ the echo-to-echo function when coatings cannot be removed.
- 5.7 Evaluation
- 5.7.1 It is imperative to monitor the A-scan presentation during examination and especially when anomalies are being evaluated.
  - 5.7.2 General thinning
    - 5.7.2.1 When an item in good condition is scanned, a consistent A-scan presentation should be evident. Movement across the test surface should cause only very slight lateral movement of the signal, if any, and no appreciable loss in amplitude should be noted if surface conditions are consistent.
    - 5.7.2.2 In comparison, if the signal moves from right to left without noticeable loss in amplitude when scanning across an area, this is indicative of general thinning. The greater the movement relative to percent screen width, the greater the loss. e.g. Grooving in a pipe will be much more abrupt than a wear spot on a tube face.
  - 5.7.3 Laminar Indications
    - 5.7.3.1 If a signal appears ahead of the backwall that increases in amplitude as you move on to it, accompanied by a relative decrease in back wall amplitude, with no lateral movement of the

back wall, ending with a total loss of back wall, this is indicative of a lamination that is larger than the sound beam at that depth. The boundaries of the lamination can be determined using the 6 dB drop method.

5.7.3.2 If a signal appears ahead of the backwall that increases in amplitude as you move on to it, accompanied by a relative decrease in back wall amplitude, with no lateral movement of the back wall, ending with a reduction back wall, this is indicative of a lamination smaller than the beam width at that depth.

#### 5.7.4 Pitting

5.7.4.1 Pitting can present itself in many different ways depending upon the dimensions and topography of the pits. There is usually partial loss of signal when moving onto the pit, due to sloping sides, and the pit often appears to “walk” in from the right accompanied by a total loss of back wall reflection or a diminished presentation depending on the beam diameter to pit diameter ratio.

5.7.4.2 If this condition is suspected, UT angle beam may be utilized to determine if the discontinuity is ID connected, or radiography may be used if geometry and access permits to identify pitting.

#### 5.7.5 Other

5.7.5.1 Other conditions such as surface pitting can cause false readings if careful attention is not paid. Glycerin’s velocity is similar to that of water which is 1/4 that of steel. As a result, a glycerin filled pit, 0.100-inch-deep, could appear as 0.400 inch of steel.

5.7.5.2 Surface pitting can also cause “grass” on the screen and a widening of the initial pulse or dead zone. This effect is greatly reduced when using dual element transducers due to the focusing effect of the roof angle.

## 6.0 REPORTING

6.1 Thickness examination results are usually presented as digital thickness values in actual numerical format or sometimes as symbols representing a thickness value.

6.2 The symbols may be colorized to represent thickness ranges, in order to present an overall wear pattern or thickness profile for the item being examined.

6.3 Additional options that may be provided include B-scan or C-scan images that present a side view or plan view of the object being tested as an additional means of item evaluation.

6.4 Unless otherwise directed by the client, relevant information shall be reported. In any case, the examination report shall provide the following information relating to the examination:

6.4.1 Client name

6.4.2 Location

6.4.3 Item(s) being examined, material and nominal thickness

6.4.4 Identifier for the item being examined as applicable

6.4.5 Technician/name(s) and certification level

6.4.6 Date(s) of test

- 6.4.7 Surface condition/preparation method(s) if applicable
- 6.4.8 Instrument make, model and serial number
- 6.4.9 Transducer type, size and frequency
- 6.4.10 Reference standard type, material type, dimensions and serial number
- 6.4.11 Couplant type
- 6.4.12 Surface temperature
- 6.4.13 Sketch or drawing showing location of data points (if applicable)
- 6.4.14 Data sheets or other presentation of thickness data