SAE Aerospace
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AEROSPACE MATERIAL SPECIFICATION

SAE AMS2634 REV. B

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Superseding AMS2634A

Ultrasonic Inspection
Thin Wall Metal Tubing

RATIONALE

AMS2634B has been reaffirmed to comply with the SAE five-year review policy.

1. SCOPE:

1.1 Purpose:

This specification covers procedures for ultrasonic inspection of thin wall metal tubing of titanium, titanium alloy, and corrosion and heat resistant steels and alloys having nominal OD over 0.1875 inch (4.762 mm) with OD to wall thickness ratio of 8 or greater and wall thickness variation not exceeding ±10% of nominal.

1.2 Application:

This process has been used typically for locating internal defects, such as cracks, voids, seams, and other discontinuities, which may or may not be exposed to the surface, but usage is not limited to such applications.

2. APPLICABLE DOCUMENTS:

The following publications form a part of this specification to the extent specified herein. The applicable issue of referenced publications shall be the issue in effect on the date of the purchase order.

2.1 ASTM Publications:

Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM E 1065 Guide for Evaluating Characteristics of Ultrasonic Search Units

2.2 U.S. Government Publications:

Available from DODSSP, Subscription Services Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

MIL-STD-410 Nondestructive Testing Personnel, Qualification and Certification (Eddy Current, Liquid Penetrant, Magnetic Particle, Radiographic, and Ultrasonic)

2.3 ANSI Publications:

Available from American National Standards Institute, Inc., 11 West 42nd Street, New York, NY 10036-8002.

ANSI B46.1 Surface Texture

2.4 ASNT Publications:

Available from American Society for Nondestructive Testing, Inc., 4153 Arlingate Plaza, P.O. Box 28518, Columbus, OH 43228-0518.

SNT-TC-1A Recommended Practice, Personnel Qualification and Certification in Nondestructive Testing

2.5 ATA Publications:

Available from Air Transport Association, 1301 Pennsylvania Avenue, Suite 1100, Washington DC 20004-1707.

ATA-105 Guidelines for Training and Qualifying Personnel in Nondestructive Testing

3. TECHNICAL REQUIREMENTS:

3.1 Qualification/Certification:

3.1.1 Personnel: Shall be qualified and certified in accordance with MIL-STD-410. Alternate procedures (i.e. ASNT-TC-1A or ATA-105) may be used if specified by the drawing or purchase order. It is the supplier’s responsibility to ensure that personnel are certified and function within the limits of the applicable specification or procedure.

3.1.2 Facilities: Shall be subject to survey and approval by purchaser of the inspected product. Ultrasonic test facility equipment shall include, but not be limited to, the basic ultrasonic test instrument, search units (transducers), appropriate ultrasonic reference standards, fixtures, tube handling equipment, recorders, reference specifications, and documentation necessary to verify the qualification of equipment and test personnel.

3.2 Ultrasonic Test System:

3.2.1 Basic Ultrasonic Test Instrument: Shall be capable of producing, receiving, amplifying, and displaying on a cathode ray tube (CRT) high frequency signals at specific frequencies as required. The ultrasonic instrument shall be of a pulse-reflection (echo), pulse-transmission type capable of operation at frequencies of 2.0 MHz or higher. The instrument shall be capable of being adapted to electronic circuitry, such as flaw gates, distance amplitude corrections, and alarms, that can aid in testing and interpretation of flaw signals. The instrument shall have a minimum dynamic range of 30 decibels (dB) and shall have a transmit/receiver crosstalk separation of at least 40 decibels.

3.2.1.1 Instrument Sensitivity: Instrument sensitivity or gain controls shall function so that a given amount or degree of sensitivity can be repeated, or returned to, with a pip height accuracy of ±10%. If signal attenuators are used, they shall be accurate over the attenuation range and test frequency used so that attenuation measurement will represent an amplitude ratio within ±10% of the correct value. The dB attenuation value may be converted to an amplitude ratio by use of tables with dB versus voltage ratios. Alternatively, it may be calculated from the relationship shown in Equation 1.

$$\text{Amplitude Ratio} = \log_{10}^{-1} \frac{dB}{20} \qquad \text{(Eq.1)}$$

3.2.1.2 Pulse Repetition Rate: The repetition rate of the pulser/receiver shall be calibrated at least semi-annually to an accuracy of ±10% or better. If the pulse repetition rate is variable, the adjustment pot shall have its movement calibrated for direct readout. When there are other adjustments which can affect the pulse repetition rate, these should be noted and positions fixed if the measured pulse repetition rate is used in the equation in 3.5.1.3. Otherwise, the lowest value that can be obtained with any adjustment shall be used for determining pulse repetition rate.

3.2.1.3 Voltage Regulation: If fluctuations in line voltage cause variations in the displayed signal amplitude or sweep length of ±2.5% or greater of full screen height in a signal with an amplitude equal to one-half of the vertical limit of the instrument, a power source voltage regulator shall be used. If fluctuations persist, proper adjustments to instrument or power source shall be made so that the system will operate within the ±2.5% limits. Battery powered systems are exempt from this requirement, but such systems shall not be operated when the power source is below the level to achieve full vertical and horizontal display as viewed on the CRT graticule.

3.2.1.4 Automatic Monitoring System: The test system shall be monitored automatically by using a recorder, by automatic marking of the tubes, by line shut down, or by an automatic tube sorting system such that an operator’s continuous attention is not required during operation.

3.2.1.4.1 Recorders: Recordings shall be produced by a strip chart recorder with a drive speed ratio and tolerance such that the actual linear location of a tube defect may be determined from the chart with an accuracy of ±0.5 inch (±13 mm). The recorder shall be interpreted as an event marker to indicate that one or more ultrasonic pulse returns have exceeded the

3.2.1.4.1 (Continued)

rejection alarm level at a known (±0.5 inch (±13 mm)) linear location on the tube. The recorder shall have a response equivalent to, or faster than, the pulse repetition rate of the pulser/receiver of the ultrasonic system or the automatic gating system shall be equipped with a pulse stretcher, a one shot multi-vibrator capable of being turned off and on, a pulse counter and a recorder combination, or other means which will make it impossible for more than one pulse to remain unrecorded; alternatively, the throughput may be adjusted to be compatible with the frequency response of the recorder, in which case the frequency response of the recorder shall be used in determining the maximum RPM as required by 3.5.1.3. The pulses may be recorded as one response or as individual pulses. The system shall be checked at least semi-annually.

3.2.1.4.2 Electronic Gating: The gating system of the ultrasonic response shall trigger on the initial pulse of the pulser/receiver.

3.2.2 Ultrasonic Search Units: Unless use of other types of transducers is approved by purchaser of the product to be inspected, all search units shall be serialized and tested in accordance with ASTM E 1065 before being placed in service. All performance parameters listed below shall be measured and recorded. In addition, where specific values are delineated, they shall be met or the search unit shall not be used for inspection to this specification.

3.2.2.1 The center frequency shall be not less than 5 MHz for search units used for titanium tubing and not less than 2 MHz for corrosion-resistant steel tubing and shall be within ±10% of the specified frequency.

3.2.2.2 The band width shall be not greater than ±20% of the specified frequency.

3.2.2.3 The damping factor shall be 4 to 8 half-cycles.

3.2.2.4 The focal distance and the focal zone shall be determined using the appropriate ball reflector. The distance from the reflector to the transducer at the peak reflected amplitude shall be the focal distance. The focal zone shall be determined as the range of distances from the reflector to the transducer within which the reflected amplitude does not drop below 50% of the peak amplitude (at the focal distance) (See Figure 1).

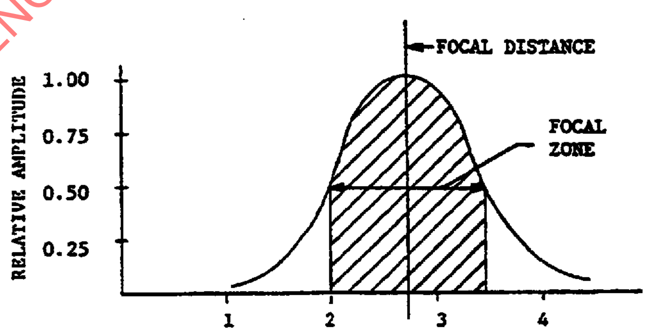

FIGURE 1 - Focal Zone Description

3.2.2.5 The sound beam shall be profiled at the focal distance in two perpendicular directions. For line focused search units the directions shall be parallel to the axis of the cylindrical lens (longitudinal profile) and perpendicular to the axis of the cylindrical lens (transverse profile). The effective beam diameter and/or width and length shall be measured at the focal distance as follows:

3.2.2.5.1 Using the proper ASTM E 1065 target reflector balls, the transducer profile shall be displayed on the CRT such that the peak amplitude within the profile is displayed at 88% of full scale screen amplitude. The extremities of the effective beam diameter and/or width and length shall be the points where the amplitude falls below 72% of full screen amplitude. The mean amplitude shall be 80% of the full screen amplitude and the reflected amplitude shall not deviate more than ±10% of the mean amplitude over the effective beam diameter and/or width and length. The effective beam diameter or width of an acceptable transducer shall be 0.050 inch (1.27 mm) or less.

3.2.2.6 The search units shall be reprofiled semi-annually to ensure that the sound beam symmetry and the effective beam diameter and/or width and length meet the requirements of 3.2.2.5. The profiling shall be performed in accordance with ASTM E 1065 and this specification, using the proper target reflector balls. The reprofiling may be performed on site.

3.2.2.7 The use of lithium sulfate (nondominant) transducers is not recommended in conjunction with broad-banded ultrasonic receivers. Quartz or ceramic (dominant) transducers cut accurately to meet the frequency requirement of 3.2.2.1 are recommended for use with broad-banded receivers. Either dominant or nondominant transducers cut to the specified frequency may be used with narrow-banded receivers.

3.2.2.8 Serialized records for each search unit used in inspections shall be retained as required by 3.4.2.

3.2.3 Tube Handling System: The test system shall utilize the immersion or the bubbler (squirter) method. The system shall be capable of fully automatic, as well as manual, operation and shall include a powered feed system capable of maintaining a tube helix pitch and rotational speed within a tolerance of ±10% of the rate established during calibration. The mechanical tube rotating and traversing system shall be checked initially and after any adjustment in the drive mechanism to ensure that the limiting off-axis excursion of the tube is less than 0.005 inch (0.13 mm) in any direction at a sound entrance/exit point, measured at normal inspection speed. The system shall employ a tachometer or revolution counter for measuring the rotational speed (RPM) of the tube but this device shall not be in direct contact with the tube.

3.2.3.1 A suitable water filtering and/or deaerating system may be used on-line to reduce the amount of entrained air and debris which would degrade the ultrasonic response. The water may be heated and the water temperature controlled to reduce the amount of entrained air.

3.2.4 Ultrasonic References (Standards): Ultrasonic references are required for all inspections to establish the performance of the inspection system and to interrelate the test results with reference reflectors.

3.2.4.1 Material: The alloy and heat treat condition shall be nominally the same as the tube to be inspected. Also, the nominal OD, wall thickness, ovality, straightness, and dimensional tolerances of the reference standard shall be within the requirements for the tube being tested.

3.2.4.2 Surface Condition: The surface texture shall be not rougher than 63 microinches (16 µm) on interior surfaces and 32 microinches (8 µm) on exterior surfaces, defined in accordance with ANSI B46.1. The surface shall be free of surface defects such as creases, laps, etc, which would produce an unusually high front-surface response. When production tubes are etched prior to ultrasonic inspection, reference standards shall also be etched by the same procedure.

3.2.4.3 Length: The length of the reference standard shall be sufficient to provide stability for setting up equipment and to allow the equipment to achieve stabilization at normal scanning speed and rotation.

3.2.4.4 Notch Configuration: Transverse and longitudinal reference notches shall be produced by electrical discharge machining in the inner and outer surfaces of the standards. The end of the electrode used to generate transverse notches shall be curved to match the curvature of the standard being machined. The size of the notches is related to the acceptance class and shall be in accordance with 4.1. Figure 2 illustrates the accepted notch configuration and the dimensions referenced in 4.1. Figure 2 shows square corners but radii as great as 0.005 inch (0.13 mm) are acceptable at the bottom corners as illustrated. Separation of the notches from each other, from an end of the standard, or from identification marks in or on the reference standard shall be sufficient to avoid interference or interpretation difficulties. The ID and OD notches, both longitudinal and transverse, shall be straight within 4% of the notch length and shall lie within ±5.0 degrees of the longitudinal or transverse tube axis, as applicable. All upset metal, burrs, etc adjacent to the notches shall be removed.

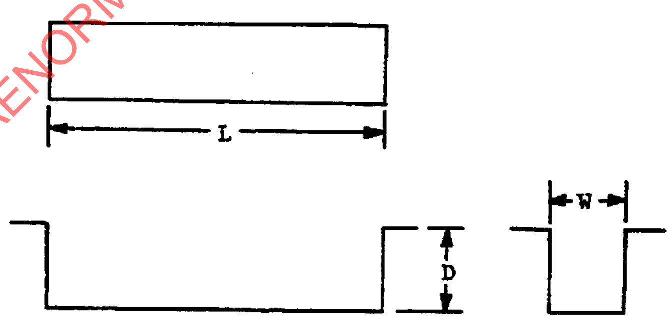

FIGURE 2 - Notch Configuration

3.2.4.4.1 The notch depth shall be measured from the circular surface to the deepest penetration of the notch. Measurements may be made by replication or by destructive means on a duplicate notch which has identical ultrasonic response (amplitude within 90 to 110% of the reference notch amplitude).

3.2.4.5 (R) Identification: The serial number of the reference standard shall be permanently marked on the standard and the following information shall either be marked on the standard or maintained in a log book:

Alloy
Heat treat condition
Diameter
Wall thickness
Size and location of reference notches

3.3 Surface Preparation:

Visual examination shall be performed on each tube to ensure that surfaces are free from loose scale, oxides, oil, grease, machining or grinding particles, excessive machining or grinding marks, and other surface conditions that could interfere with the sound beam and affect the test.

3.4 Testing Procedure:

3.4.1 Written Procedure: Ultrasonic inspections shall be detailed in a written procedure. Unless otherwise specified, procedures shall be prepared by the vendor and approved by purchaser. Procedures shall identify the type of ultrasonic equipment, method(s) of test, ultrasonic test reference, search unit type, style, and frequency, search unit qualification, fixturing, method of reporting indications, and all other instructions that pertain to the actual test. Procedures shall be detailed sufficiently that another qualified investigator could duplicate the test and obtain equivalent information.

3.4.2 Documentation: Shall provide for the complete inspection procedure for each size of each alloy to be inspected. Documentation format is flexible, but sketches, photographs, and graphics are recommended wherever practical. As a minimum, the procedure shall specify:

3.4.2.1 Specific product, stage of fabrication, surface condition, and configuration of the tubing to be tested.

3.4.2.2 Manufacturer and model numbers of instrumentation modules, recording equipment if used, fixturing, tanks, tube handling equipment, and coupling means used in the test.

3.4.2.3 Types and sizes of search units, including frequency, transducer element material, incident angle, and approximate effective beam length and width determined as in 3.2.2.5.

3.4.2.4 The type of ultrasonic references pused to calibrate equipment and the calibration procedure.

3.4.2.5 Testing plan, including the recording procedure, scanning plan including rotational speed and helical pitch, sensitivity, method of interpreting results, and relationship to ultrasonic references.

3.4.3 Testing System:

3.4.3.1 The immersion (or bubbler/squirter) pulse-echo angle-beam method shall be used. When notches with depths under 0.010 inch (0.25 mm) are used, the ID shall be clean and dry because water droplets may be mistaken for true indications. The pulse-echo procedures shall involve multiple search units as required for the evaluation.

3.4.3.2 All equipment used for the tests, such as ultrasonic test instruments, ultrasonic search units, ultrasonic references, recording system, and electronic gates shall be assembled in one location and evaluated as a complete system. Once assembled, they shall remain together as part of the test equipment until the tests are completed. Any substitution of electronic gates, displays, search units, tube handling equipment, etc, for any reason, shall require recalibration of the complete system.

3.5 Calibration of Test System:

3.5.1 Scanning Adjustment: The scanning adjustment for inspection of titanium tubing shall include all of the following; for inspection of other tubing, 3.5.1.1, 3.5.1.2, and 3.5.1.3 are not required:

3.5.1.1 Helical Scan Pitch: The maximum helical scan pitch (distance in the axial direction per revolution) shall not exceed the following:

Circumferential scan	P_c = 0.33d or 0.33L, whichever is greater
Axial scan	P_a = 0.33f or 0.33L, whichever is greater
Combined circumferential and axial scan	P = P_c or P_a, whichever is less

where:

P = Helical scan pitch
d = Effective beam length for circumferential scan (See 3.2.2.5 and Figure 3)
f = Effective beam length for axial scan (See 3.2.2.5 and Figure 3)
L = Length of reference notch

3.5.1.2 (R) Helix Angle: The maximum helix angle to be used for scanning during calibration and inspection shall be determined by Equation 2.

$$\theta = \mathrm{Tan}^{-1}\left(\frac{P}{\pi D}\right) \qquad \text{(Eq.2)}$$

3.5.1.2 (Continued):

where:

6 = Helix angle
P = Helix scan pitch (See 3.5.1.1)
x = 3.14
D = Nominal OD of finished tube

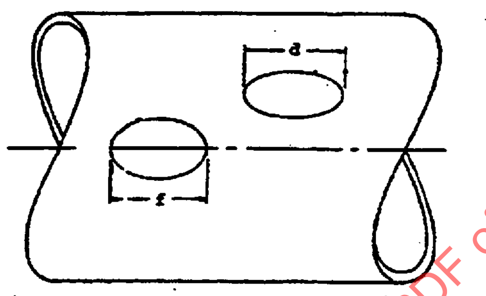

FIGURE 3 - Effective Beam Dimensions

3.5.1.3 (R) Rotational Speed: The maximum rotational speed of the tubing during calibration and inspection shall not exceed the value R, determined by Equation 3,

$$R = \frac{14.3\ Kw}{D} \qquad \text{(Eq.3)}$$

where:

R = Rotational speed in revolutions per minute
w = Effective beam width (See 3.2.2.5)
K = Repetition rate of the pulser/receiver unit in pulses per second
D = Nominal OD of finished tube

3.5.1.4 Scanning Speed Tolerance: The speed of rotation and translation used for calibration and inspection shall be maintained constant within ±10%.

3.5.1.5 Waterpath: The waterpath shall be adjusted so that the focal spot of the sound beam lies at the middle of the wall thickness of the tubing during calibration and inspection.

3.5.2 Response Optimization: Each search unit shall be adjusted to produce the optimum balance between the responses from the ID and OD notches at a refracted angle of approximately 45 degrees with the search unit focused at the sound entry surface of the tube. The response chosen for gating shall demonstrate a multiple-skip type of response as the notch is rotated toward or away from the sound entry point. If a pulse stretcher is to be used for inspection of tubes, it shall be turned on during all calibrations, during inspection, and during evaluation of discontinuities.

3.5.2.1 (R) Circumferential Scan: The average of ID and OD reflection angles shall be adjusted to approximately 45 degrees, accomplished by adjusting the location of the search unit(s) along a line perpendicular to the axis of the search unit and the axis of the tube to produce a maximum response from the tube (See Figure 4). The search unit(s) is translated a distance(s) normal to the plane defined by the tube axis and the search unit(s) axis. If two search units are to be used simultaneously for circumferential inspection, they shall be translated in opposite directions. The distance (S) shall be determined as in Equation 4.

$$S = \frac{OD}{2\sqrt{1 + \left[\frac{OD}{ID}\right]^2}} \times \left[\frac{Vw}{Vt}\right] \quad \text{(Eq.4)}$$

where:

S = Offset distance
ID = Nominal ID of tubing
OD = Nominal OD of tubing
vw = Longitudinal sound velocity in water
vt = Transverse (shear) sound velocity in the tubing

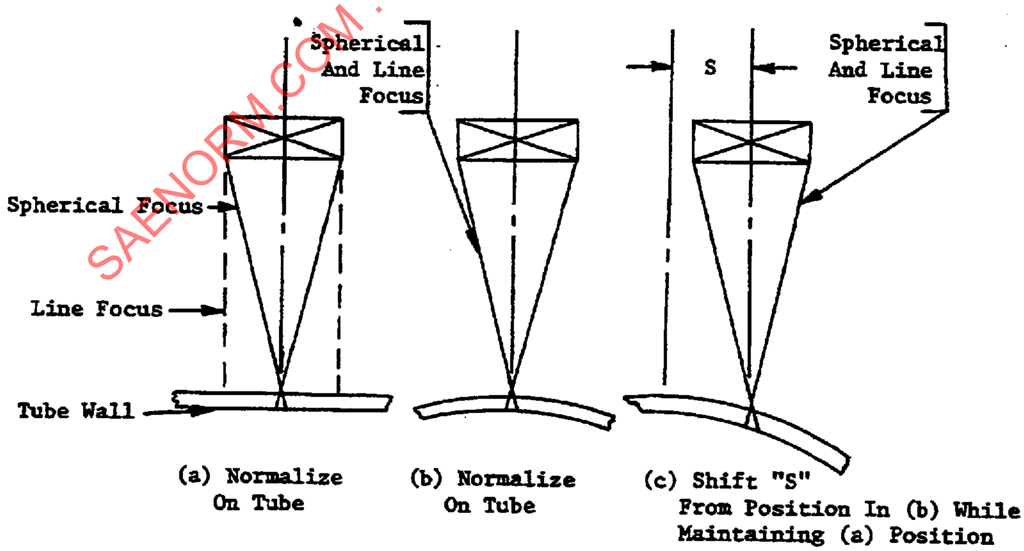

FIGURE 4 - Circumferential Angulation

3.5.2.2 Axial Scan: The axial scans shall be accomplished by positioning the search unit(s) to direct sound along the tube in a plane parallel to its axis and with the refracted sound beam in the tube wall at an approximate angle of 45 degrees, accomplished by adjusting the position of the search unit(s) so that a maximum reflection is obtained from the tube OD (See Figure 5A) and adjusting the search unit in the plane defined by its axis and the tubing (See Figure 5B) to establish the incident angle defined in Equation 5.

$$\theta_i = \mathrm{Sin}^{-1}\left(0.707\ \frac{Vw}{Vt}\right) \qquad \text{(Eq.5)}$$

where:

6 = Incident angle
Vw = Longitudinal velocity of sound in water
Vt = Transverse (shear) sound velocity in the tubing

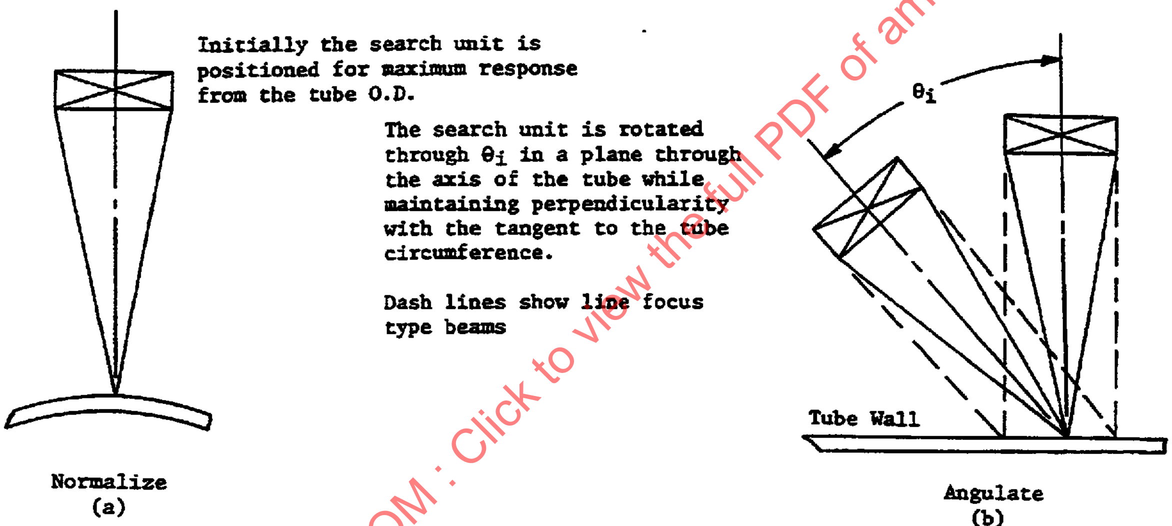

FIGURE 5 - Axial Angulation

3.5.2.3 The response from the inner and outer notches of the reference shall be adjusted to obtain a range of 50 to 90% of full screen height for each search unit. When recorders are used, the responses from the inner and outer notches shall produce a recorded response of 50 to 90% of full response on the particular recording trace. The gate shall be set to trigger on the initial pulse of the pulser/receiver. First echo synchronization shall not be used to trigger the gate for flaw detection. Normally, the gate start position and length adjustments should not be used to maximize the response from any one notch in order to achieve the 50 to 90% requirement. The gate should be set to trigger on the first or second half-skip immediately after the front surface response. Gate lengths may be varied in order to catch more than the first one or two half-skips.

3.5.2.4 All search units shall be locked in the positions and angles determined above. No changes shall be allowed without a complete recalibration.

3.5.2.5 The reference standard shall be dynamically inspected to ensure that each reference notch will trigger the alarm reliably and repeatably. Not less than three such calibration runs shall be made and each reference notch shall be detected above the alarm level at least twice on each run. When recordings are made, each notch shall be recorded at least twice with each search unit on each run. The lowest amplitude notch response for each search unit over the three calibration runs shall be the rejection level.

3.5.3 Calibration Record: When permanent records are established as part of the test plan, calibration of the test system shall include a record of the appropriate ultrasonic reference reflector.

3.6 Inspection:

3.6.1 Inspection Coverage: All tubing requiring inspection shall be inspected with 100% coverage with the exception of the ultrasonic envelope required at the tube ends for axial shear scans defined as 2t x tangent of the shear angle. Corrosion and heat resistant steel and alloy tubing shall be inspected with ultrasound transmitted in two 180-degree opposed circumferential scans, and titanium and titanium alloy tubing shall be additionally inspected with two 180-degree opposed axial scans. Inspection shall be under identical conditions to those used for equipment calibration.

3.6.2 Inspection Sequence: Tubing shall be ultrasonically inspected after all straightening and metal removal operations.

3.6.3 Tube Connections: Tubes following in succession shall be attached internally only or each tube shall be plugged. No tape on the outside surface of the tube is permitted.

3.6.4 Adjustments:

3.6.4.1 No equipment adjustments shall be made other than at the time of calibration. The chart speed of the recorder may be altered after calibration but shall be returned to the original speed used during calibration when evaluating an indication.