Society of Automotive Engineers, Inc.
400 COMMONWEALTH DRIVE, WARRENDALE, PA. 15096

AEROSPACE MATERIAL SPECIFICATION

AMS 2633

Issued 7-15-77
Revised

ULTRASONIC INSPECTION
Centrifugally-Cast, Corrosion-Resistant Steel Tubular Cylinders

1. SCOPE:

1.1 Purpose: This procedure covers ultrasonic inspection of tubular, centrifugally-cast, corrosion-resistant steel cylinders.

1.2 Application: Primarily for locating defects such as cracks, voids, spongy areas, and other discontinuities. This procedure is not applicable to austenitic steels where grain boundaries mask results.

1.2.1 Immersion inspection is applicable to products whose wall thickness is 0.5 to 9.0 in. (13 to 229 mm). Contact inspection is applicable to product whose wall thickness in 3.0 to 9.0 in. (76 to 229 mm).

1.2.2 It is essential that thorough understanding be developed between purchaser and vendor regarding interpretation of the results of inspection and how they shall be recorded and reported. Ultrasonic testing is so comprehensive that it is necessary that all interested parties fully recognize that indications may appear which do not reflect conditions detrimental to use of the product.

2. APPLICABLE DOCUMENTS: The following publications form a part of this specification to the extent specified herein. The latest issue of Aerospace Material Specifications (AMS) shall apply. The applicable issue of other documents shall be as specified in AMS 2350.

2.1 SAE Publications: Available from Society of Automotive Engineers, Inc., 400 Commonwealth Drive, Warrendale, PA 15096.

2.1.1 Aerospace Material Specifications:

AMS 2350 - Standards and Test Methods

2.1.2 Standards and Recommended Practices:

SAE J300 - Crankcase Oil Viscosity Classification

2.2 ASTM Publications: Available from American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM E428 - Fabrication and Control of Steel Reference Blocks Used in Ultrasonic Inspection

2.3 ANSI Publications: Available from American National Standards Institute, Inc., 1430 Broadway, New York, NY 10018.

ANSI B46.1 - Surface Texture

2.4 ASNT Publications: Available from American Society for Nondestructive Testing, Inc., 3200 Riverside Drive, Columbus, OH 43221.

SNT-TC-1A - Training/Certification of NDT Personnel Supplement - Ultrasonic Testing Method

Printed in U.S.A.

3. TECHNICAL REQUIREMENTS:

3.1 Qualification:

3.1.1 Personnel: Personnel shall be certified to SNT-TC-1A. Personnel who read and interpret indications and evaluate them with reference to applicable codes and specifications shall be certified to SNT-TC-1A, level II or higher.

3.1.2 Facilities: Shall be subject to survey and approval by the purchaser.

3.2 Equipment:

3.2.1 Electronic Apparatus: The ultrasonic instrument shall be of the pulse-echo type capable of operating at 2.25 through 10 MHz. Gates, distance-amplitude correction systems, and other electronic aids to ultrasonic testing and interpretation shall be used as required. An alarm system and/or a recorder shall be used.

3.2.2 Transducers: The frequency used shall be the highest practical ultrasonic frequency which will provide the penetration and resolution required. The use of frequencies below 2.25 MHz or above 10 MHz is not permitted unless special permission is obtained from the purchaser. The pulser/receiver shall be operated at the same test frequency as the transducer element being used for inspection. Transducers shall be 0.5 to 1.0 in. (13 to 25 mm), incl, in diameter except that rectangular search units with a length-to-width ratio of 2:1 may be used provided the length does not exceed 1.5 in. (38 mm).

3.2.3 Other Equipment: Tanks, bridges, rotators, manipulators, and other equipment shall be adequate to perform the required tests.

3.2.3.1 Voltage Regulator: A voltage regulator shall be used on the power source when fluctuations in line voltage cause variations exceeding ± 5% in a signal with an amplitude equal to the upper linearity limit of the instrument.

3.2.4 Couplant:

3.2.4.1 Immersion Method: For inspection by the immersion method, clean tap water shall be used as the couplant material; rust inhibitors and/or wetting agents may be added. The water shall be free of air bubbles which could interfere with the ultrasonic test.

3.2.4.2 Contact Method: For inspection by the contact method, SAE 30 motor oil conforming to SAE J300 or penetrant emulsifier shall be used as the couplant. Cloroprene rubber sheet or other similar materials may be used between the transducer and the part under inspection to prevent transducer wear providing adequate compensation for its use is made.

3.2.5 Reference Standards: Shall be fabricated in accordance with ASTM E428 from centrifugally-cast, corrosion-resistant steel equivalent to the alloy to be tested; dimensions of reference standards (test blocks) shall conform to Table I.

TABLE I

METAL TRAVEL DISTANCES, LONGITUDINAL WAVE

Material Nominal Thickness (T) Inches	Near Depth Inches	Far Depth Inches	Between Near and Far Depths Inches
Up to 1, incl	*	T ± 1/16	T/2 ± 1/16
Over 1 to 3, incl	*	T ± 1/4	T/4 ± 1/8, T/2 ± 1/4
Over 3 to 6, incl	*	T ± 1/4	T/8 ± 1/8, T/4 ± 1/8, T/2 ± 1/4
Over 6	*	T ± 1/2	T/8 ± 1/8, T/4 ± 1/4, T/2 ± 1/2

*See Table II.

TABLE I (SI)

METAL TRAVEL DISTANCES, LONGITUDINAL WAVE

Material Nominal Thickness (T) Millimetres	Near Depth Millimetres	Far Depth Millimetres	Between Near and Far Depths Millimetres
Up to 25, incl	*	T ± 1.6	T/2 ± 1.6
Over 25 to 76, incl	*	T ± 6.4	T/4 ± 3.2, T/2 ± 6.4
Over 76 to 152, incl	*	T ± 6.4	T/8 ± 3.2, T/4 ± 3.2, T/2 ± 6
Over 152	*	T ± 12.7	

*See Table II.

3.2.5.1 The test block material shall have ultrasonic sound transmission characteristics equal to those of the material to be tested within ± 25%. If the sound transmission characteristics vary more than ± 25%, compensation correction techniques shall be approved by the purchaser.

3.2.5.2 For testing flat surfaces, flat test blocks shall be used. Except as permitted by 3.2.5.2.1, for testing curved surfaces, the reference standards shall have similar contour within ± 25% of the radius of curvature of the dimensions being tested. Surface finish of the calibration standard, if made from an actual part, shall be similar to that of the material being tested.

3.2.5.2.1 For testing curved surfaces having diameters greater than 20 in. (508 mm), flat test blocks may be used.

3.2.5.3 For longitudinal wave calibration, the calibration reflectors shall be flat-bottom holes 3/64, 5/64, and 8/64 in. (1.2, 2.0, and 3.2 mm) in diameter.

3.2.5.3.1 Near depth resolution is best obtained at higher frequencies as shown in Table II. Near depth resolution may be improved by using smaller diameter search units and short pulse length.

TABLE II

ENTRY SURFACE RESOLUTION

Ultrasonic Test Frequency (MHz)	2.25	5.0	10.0
Near Depth, Inches	0.70	0.50	0.30
Near Depth (Millimetres)	17.8	12.7	7.6

3.2.5.4 Axial shear wave inspection shall be performed in at least one direction. Calibration to circumferential ID and OD notches (Fig. 1) or side drilled holes (Fig. 2) shall be made. An elox notch (Notch A, Fig. 1) shall be used, unless otherwise specified. The notch shall be 1 in. (25 mm) long by T/10 or 0.1 in (3 mm) deep, whichever is less. This type of inspection will locate discontinuities oriented in a circumferential direction and classified as radial cracks.

3.2.5.5 Special test blocks to calibrate testing modes other than specified and any other blocks necessary to aid in testing or evaluation may be used as agreed upon by purchaser and vendor.

3.2.5.6 Special reference standards are required for circumferential shear wave inspection as illustrated in Fig. 3. Cylindrical standards shall have a thickness equal to ± 25% of the product thickness. The outer diameter shall be within ± 10% of the OD of the product or section being evaluated. Standards shall have flat-bottom holes of the size specified for the applicable grade, drilled not less than 1/4 in. (6.4 mm) on center line so that the maximum hole depth is exactly in the center of the tube wall. The flat bottom of the test hole shall be parallel to the tube radius as illustrated in Fig. 3.

3.3 Surface Preparation:

3.3.1 The OD and ID surfaces shall be uniformly machined prior to inspection.

3.3.2 Texture of surfaces shall be not rougher than 125 microin. (3.2 μm), determined in accordance with ANSI B46.1. Inspection surfaces not meeting the above requirements may be conditioned by machining, polishing, grinding, buffing, or other suitable method.

3.3.3 Surface discontinuities remaining after surface preparation shall not be removed before ultrasonic inspection as local grinding depressions can cause sonic wave attenuation, loss of back reflection, and inability to locally meet standards. Surfaces shall be free from loose scale, machining or grinding particles, oil, grease, cutting compounds, and other foreign materials.

3.4 Equipment Preparation: Instruments of the vacuum tube type shall be warmed up for not less than 15 min. before being used; instruments using solid state electronic components shall be warmed up for not less than 5 min. before being used. Sufficient time shall also be allowed for temperature of water, reference blocks, and material to stabilize before calibration and testing.

3.5 Calibration of Equipment: Before inspecting the product, the equipment shall be adjusted, using appropriate blocks, to produce clearly defined indications of sufficient height to ensure that the product under test can be inspected as required to locate any imperfections of detrimental size, nature, and location. The minimum pip height shall be not less than 1.0 in. (25 mm); the maximum pip height shall be not greater than 90% of the screen height.

3.6 Procedure: The product shall be inspected by the longitudinal wave method (Fig. 4). The sound beam entry angle for longitudinal wave (straight beam) testing shall be normalized by adjusting for maximum signal amplitude from the front (entry) surface. During testing, the angle established shall not vary more than ± 2 degrees. Axial and circumferential shear wave inspection shall also be performed as defined in Figs. 4 and 5. The product shall be inspected by immersion or contact methods, as applicable (See 1.2.1).

3.7 General:

3.7.1 Calibration for determination of loss in the back reflection pattern shall be performed on parallel surfaces of the product being tested. The back reflection pattern from the full material thickness section of the test block at the scanning sensitivity shall be recorded. If the back reflection pattern from the product being tested averages a variation of more than ± 50% from that recorded from the test block, no testing shall be performed until necessary corrective action is taken.

3.7.2 The permissible background noise shall not exceed 10% of saturation or 24% of the response height from the reference standard of the same alloy as the product being tested. If the background noise exceeds this level, the section involved shall be re-examined to ensure that the product meets the specified requirements.

3.7.3 The pulse rate shall be not lower than 600 per second.

3.7.4 Scanning Speed:

3.7.4.1 The scanning speed for calibration shall be not greater than that at which the calibration holes in the reference standards are resolved.

3.7.4.2 The scanning speed for testing the product shall be not greater than that established in 3.7.4.1.

3.7.4.3 The scanning speed shall not exceed the response time of the audible alarm or of the strip chart recorder.

3.7.4.4 If a C-scan recording system is used, the scanning speed shall be the same for the references and for the product.

3.7.4.5 For manual scanning without alarm systems, scanning speed shall not exceed 5.0 in. (127 mm) per second.

3.7.4.6 For manual or automatic scanning with alarm systems, scanning speed shall not exceed 20 in. (508 mm) per second.

3.7.5 When the alarm system is used during testing, it shall be set at "Hold" or "Manual Reset".

3.7.6 The instrument control settings and test parameters established during calibration shall not be changed during testing of the product.

3.7.7 Distance Amplitude Correction: Electronic distance amplitude correction is recommended; however, distance amplitude curves plotted on the screen face (cathode ray tube) using distance amplitude calibration blocks may be used if the minimum pip height complies with 3.5. Testing using the highest sensitivity from the distance amplitude calibration blocks and evaluating to the proper metal travels is also permitted provided noise levels do not obscure required information.

3.7.8 Contact Method: Indexing increments used in scanning a product shall be not greater than 1/2 of the transducer diameter or 1/2 of the effective beam diameter, determined in accordance wtih 3.7.10.5. Transducer indexing shall be controlled by a mechanical system.

3.7.9 Immersion Method:

3.7.9.1 Water Path: The distance from search unit to product surface shall be such that the second front reflection from the test material does not appear between the first front and first back reflection or shall be not less than 3 in. (76 mm). Water path distance shall be equal within 1/4 in. (6.4 mm) for calibration, scanning, and evaluation.

3.7.10 Scanning Increment: The maximum scanning increment used shall be determined as follows and shall be documented:

3.7.10.1 Obtain maximum response from references set up for scanning.

3.7.10.2 Use linear instrument settings.

3.7.10.3 Use the same water path or coupling used for scanning.

3.7.10.4 Adjust sensitivity to obtain an 80% full scale response from the reference giving the least response.

3.7.10.5 At this setting, scan the references in the scan and index directions. In each case, obtain a maximum response from the reference and move the transducer until a maximum response of 40% full scale is obtained. Note position of transducer and move transducer in the opposite direction until signal peaks and returns to 40% of full scale. Note the distance the transducer was moved. This distance is effective beam width. The minimum effective beam width shall be established from the reference that produces the smallest effective beam width.

3.7.10.6 Scanning increments shall then meet one of the following:

3.7.10.7 Scanning increments shall be no greater than 1/32 in. (0.8 mm).

3.7.10.8 Scanning increments shall be no greater than 1/3 of the minimum effective beam width.

3.7.10.9 For fracture control parts, the maximum increment shall not exceed 10% of the effective beam width.

3.7.11 Zone testing may be used with separate calibrations for each zone.

4. QUALITY ASSURANCE PROVISIONS:

4.1 Acceptance Grades: Acceptance grades are defined in Table III for longitudinal wave inspection (L), Table IV for circumferential shear wave inspection (CS), and Table V for axial shear wave inspection (AS).

4.1.2 Acceptance standards for inspection by procedures other than specified and standards not covered in Tables III, IV, or V shall be as agreed upon by purchaser and vendor.

4.1.3 If the product is zoned for different grades of quality, the purchaser shall provide the vendor with a sketch showing the locations of the different zones.

4.2 Disposition:

4.2.1 Acceptable parts and/or inspection records shall be identified with an acceptance stamp which denotes that the product meets the applicable requirements.

4.2.2 Product exhibiting indications in excess of established standards but in a location which will be removed during manufacturing operations may be approved by authorized personnel for acceptance. Indications shall be reported to the purchaser on an appropriate form showing the size, location, and inspection grade and direction (L, CS, or AS) codes.

4.2.3 Product containing discontinuities in excess of established standards and not covered by 4.2.2 shall be rejected. The rejection report shall illustrate the size, location, and inspection grade and direction (L, CS, or AS) codes.

4.3 Records: The testing source shall prepare and maintain on file, for at least 5 years or other period agreed upon by purchaser and vendor, records of the requirements and techniques for each size and configuration of product. These records shall be made available for review by purchaser at any reasonable time.

5. PREPARATION FOR DELIVERY: Not applicable.

6. ACKNOWLEDGMENT: A vendor shall mention this specification number in all quotations and when acknowledging purchase orders.

7. REJECTIONS: Material not inspected in accordance with this specification or with authorized modifications will be subject to rejection.

8. NOTES:

8.1 Definitions:

8.1.1 A-Scan: A method of data presentation on a CRT (cathode ray tube) utilizing a horizontal base line that indicates distance or time, and a vertical deflection from the base line which indicates amplitude.

8.1.2 Amplitude: The vertical pulse height of a signal, usually base to peak, when indicated by a cathode ray tube A-scan presentation.

8.1.3 Attenuation: Loss of energy per unit distance.

8.1.4 Back Reflection: Indication of the echo from the far boundary of the product under test.

8.1.5 C-Scan: A means of data presentation which provides a plan view of the product and discontinuities therein.

8.1.6 DAC (Distance Amplitude Correction): Electronic change of amplification to provide equal amplitude from equal reflectors at different depths.

8.1.7 Indication: That which marks or denotes the presence of a reflector.

8.1.8 Longitudinal Wave: Those waves in which the particle motion within the product is essentially in the same direction as the wave propagation.

8.1.9 Noise: Any undesired signal that tends to interfere with the normal reception of the desired signal. Origin may be electrical or from small reflectors such as grain boundaries.

8.1.10 Pip Height: See amplitude.

8.1.11 Reference Block: A block machined from material similar to the product to be inspected used to produce a reflection of known characteristics.

8.1.12 Saturation: Maximum amplitude response of reflected signal.

8.1.13 Shear Wave: Wave motion in which the particle motion is perpendicular to the direction of propagation.

8.1.14 Transducer: An electro-acoustical device for converting electrical energy into acoustical energy and vice versa.

TABLE III

ACCEPTANCE CRITERIA, LONGITUDINAL WAVE INSPECTION (L) (4)

Grade	Single Discontinuity Indications Max Size Equivalent Ref. Std.	Multiple Discontinuity Indications Max Size Equivalent Ref. Std.	Multiple Discontinuity Indications Min Spacing (2)	Linear Discontinuity Indications Max Size Equivalent Ref. Std.	Linear Discontinuity Indications Max Length (3)	Attenuation Max (1) % Normal Back Reflection
A Standard	#5	#3	1 in. (25 mm)	#3	1 in. (25 mm)	50
B	#8	#5	1 in. (25 mm)	#5	1 in. (25 mm)	50

NOTES: (1) A loss of back reflection greater than 50% when compared to normal sound material in a similar location in the same or similar product, is not acceptable when associated with a twofold increase in ultrasonic noise within the product.

(2) Center-to-center distance.

(3) End points are defined as those points where the signal amplitude drops to 50% of that amplitude obtained over the center of the linear discontinuity.

(4) Any discontinuity with an indication greater than the response from the reference flat-bottom hole at the estimated discontinuity depth is not acceptable.

TABLE IV

ACCEPTANCE CRITERIA, CIRCUMFERENTIAL SHEAR WAVE INSPECTION (CS)

Grade	Single Discontinuity Indications Max Size Equivalent Ref. Std.	Multiple Discontinuity Indications Max Size Equivalent Ref. Std.	Multiple Discontinuity Indications Min Spacing (1)	Linear Discontinuity Indications Max Size Equivalent Ref. Std.	Linear Discontinuity Indications Max Length
A Standard	#5	#3	1 in. (25 mm)	#3	1 in. (25 mm)
B	#8	#5	1 in. (25 (mm)	#5	1 in. (25 mm)

NOTE: (1) Center-to-center distance.

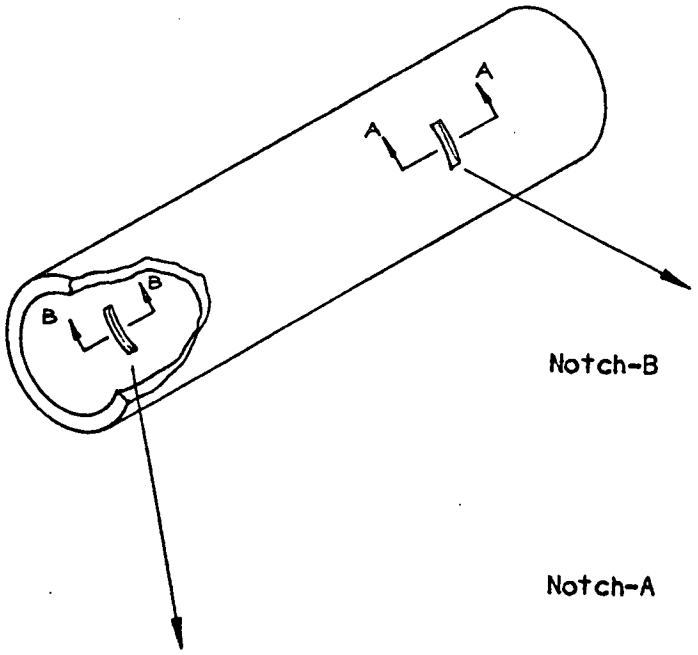
TABLE V

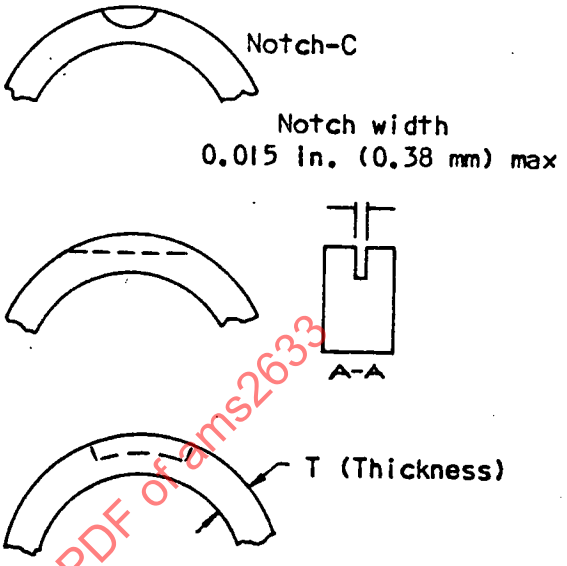
ACCEPTANCE CRITERIA, AXIAL SHEAR WAVE INSPECTION (AS)

Grade	Single Discontinuity Indications	Multiple Discontinuity Indications		Linear Discontinuity Indications	
	Max Size Equivalent Ref. Std.	Max Size Equivalent Ref. Std.	Min Spacing (1)	Max Size Equivalent Ref. Std.	Max Length (2) (Circumferential)
A Standard	Signal Amplitude Equal to or Greater than Ref. Notch	Signal Amplitude Less Than 50% of Ref. Notch	2 In. (51 mm)	Signal Amplitude Less Than 50% of Ref. Notch	2 In. (51 mm)

NOTE: (1) Center-to-center distance (axial or circumferential).

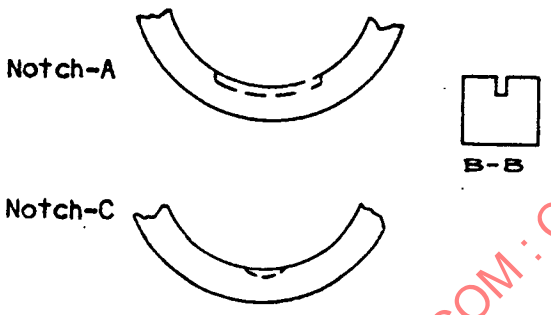
(2) End points are defined as those points where the signal amplitude drops to 50% of that amplitude obtained over the center of the linear discontinuity.

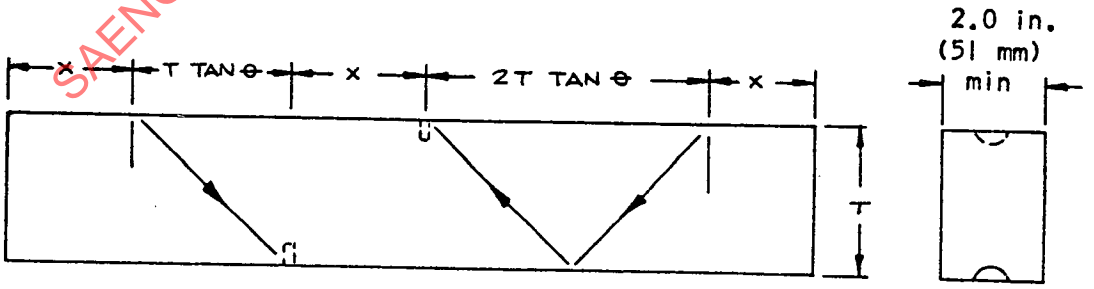




NOTES:

(1) Notch depth - specify percent of T.
(2) Notch type
    (a) Elox - specify length
    (b) Jewelers saw - length based on T and OD
    (c) 1-in. (25-mm) dia. radial saw - length based on depth.

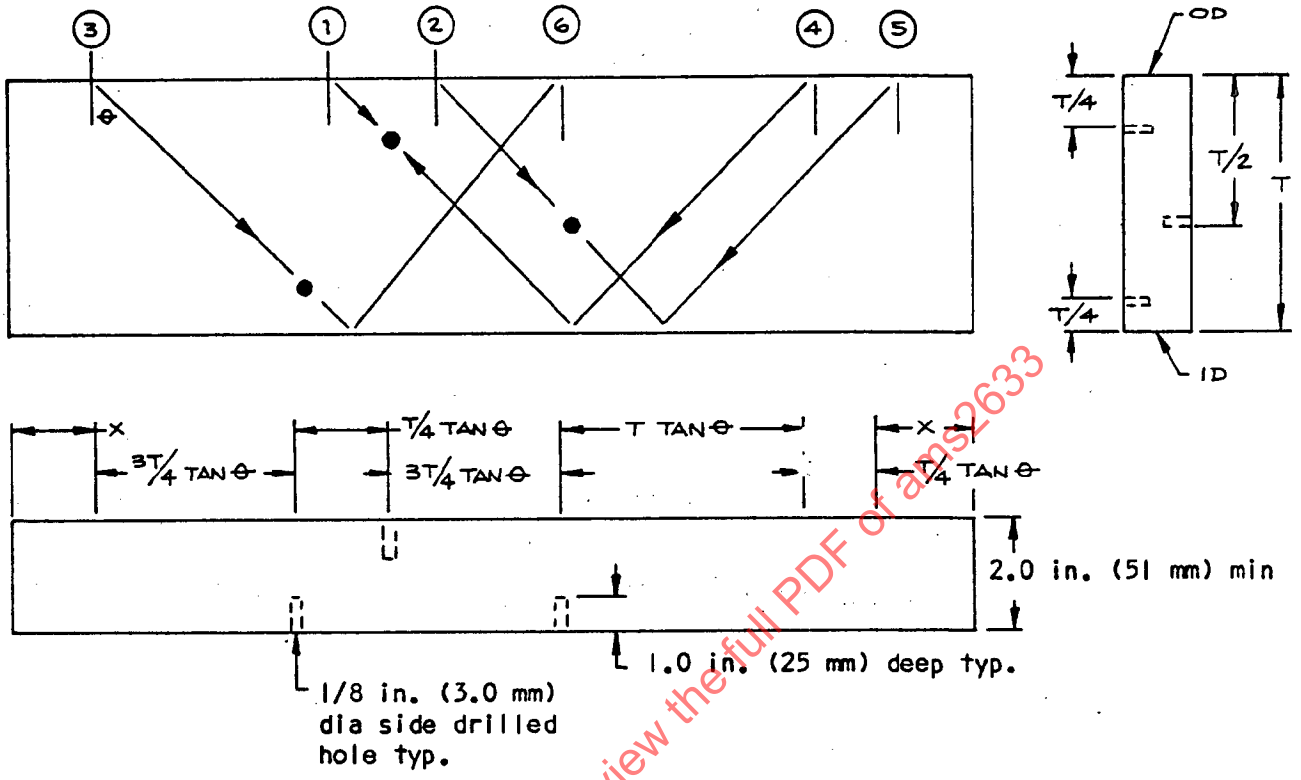




NOTES:

(1) X = T or 2 in. (51 mm), whichever is less
(2) θ = 60° for T = 0.5 to 3.0 in. (13 to 76 mm)
(3) θ = 45° for T over 3.0 in. (76 mm)

FIGURE 1
NOTCH REFERENCE STANDARD FOR AXIAL SHEAR-WAVE INSPECTION OF CYLINDERS



NOTES:

(1) X = T or 2 in. (51 mm), whichever is less

(2) OD and ID surface may have radii equal to product or may be flat

(3) θ = 60° for T = 0.5 to 3.0 in. (13 to 76 mm)
θ = 45° for T over 3.0 in. (76 mm)

(4) Make from section of production product

FIGURE 2
DRILL-HOLE REFERENCE STANDARD FOR
AXIAL SHEAR-WAVE INSPECTION OF CYLINDERS