SAE Aerospace
An SAE International Group

AEROSPACE MATERIAL SPECIFICATION

SAE AMS 2628

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Reaffirmed FEB 2007

ULTRASONIC IMMERSION INSPECTION
Titanium and Titanium Alloy Billet
Premium Grade

RATIONALE

This document has been reaffirmed to comply with the SAE 5-year Review policy.

1. SCOPE:

1.1 Purpose:

This specification covers procedures for ultrasonic immersion inspection of premium grade wrought titanium and titanium alloy round billet 5.0 inches (127 mm) and over in nominal diameter.

1.2 Application:

This inspection procedure has been used typically for locating internal defects such as cracks, voids, inclusions, and other structural discontinuities which may or may not be exposed to the surface in billets, but usage is not limited to such applications. Testing normally will be by longitudinal procedure, but shear wave procedure may be added when agreed upon by purchaser and vendor. This specification includes zoned inspection and digital data acquisition.

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 317 Evaluating Performance Characteristics of Ultrasonic Pulse-Echo Testing Systems Without the Use of Electronic Measurement Instruments
ASTM E 1065 Evaluating Characteristics of Ultrasonic Search Units

TO PLACE A DOCUMENT ORDER: **Tel: 877-606-7323 (inside USA and Canada)**
Tel: 724-776-4970 (outside USA)
Fax: 724-776-0790
Email: CustomerService@sae.org
SAE WEB ADDRESS: **http://www.sae.org**

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

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

3. TECHNICAL REQUIREMENTS:

3.1 Qualification:

3.1.1 Personnel: Shall be certified to and shall function within the limits of their levels in accordance with MIL-STD-410 or other procedures acceptable to purchaser.

3.1.2 Facilities: Shall be subject to review and approval by purchaser. Reference specifications, procedures, and documentation necessary to verify the qualification of equipment and test personnel shall be available to purchaser upon request.

3.1.3 Written Procedure: Ultrasonic inspections performed in accordance with this specification shall be detailed in written procedures. Procedures shall be prepared by the vendor and approved by purchaser. Procedures shall include not less than the following information:

3.1.3.1 Billet diameter and alloy.

3.1.3.2 Equipment to be used, including software and software version numbers.

3.1.3.3 Inspection configuration including zones, if applicable.

3.1.3.4 Amplitudes for calibration, evaluation threshold, and reject limits.

3.1.3.5 Rotational speed and index.

3.1.3.6 Pulse repetition rate.

3.1.3.7 Calibration standard serial number, size, and correction factors.

3.1.3.8 Method used for distance amplitude corrections.

3.1.3.9 Method for attenuation correction.

3.1.3.10 Gate length and delay per zone, if applicable.

3.1.3.11 Methods for surface preparation and surface texture control.

3.1.3.12 Transducer manufacturer and model number.

3.1.4 Exceptions: No exception shall be taken to the written procedure or this specification unless approved by purchaser.

3.2 Equipment:

3.2.1 Ultrasonic Instrument: Shall be capable of producing, receiving, and displaying high frequency electrical pulses at the required frequencies and energy levels. Shall be capable of operating with the number of transducers required to test all zones including monitoring of the back surface echo. The instrument shall be able to operate in the pulse-echo mode at frequencies of 2.25 through 10 MHz. Gates, distance-amplitude correction system, and other electronic aids to ultrasonic testing and interpretation shall be used as required. An alarm system, auto-stop, recorder, or combination of these may be used.

3.2.1.1 Instrument Performance: The horizontal limit and linearity, the vertical limit and linearity, and the accuracy of calibrated gain controls shall be evaluated in accordance with ASTM E 317 with the following requirements and exceptions:

3.2.1.1.1 The horizontal limit and linearity shall be measured by plotting signal displacement against known thickness in the range of 1 to 8 inches (25 to 203 mm) in 1 inch (25 mm) increments; the allowable differences in thickness between that indicated by the signal displacement and actual measured thickness shall be within ±3% of the measured thickness of the respective block. Substitute performance checks are permissible when agreed upon by purchaser and vendor.

3.2.1.1.2 Vertical linearity shall be within ±2% of full scale over the range of 10 to 80% of full scale.

3.2.1.1.3 Accuracy of calibrated gain control shall be within ±2 dB over a range of 50 dB.

3.2.2 Ultrasonic Search Units: Search units shall be evaluated in accordance with ASTM E 1065 to determine frequency response, peak frequency, and band width. The peak frequency shall be not less than 4 MHz. Search units shall be tested to determine the beam width at -2 dB, -4 dB and -6 dB in the billet axial and circumferential directions. The beam width measurements should be performed using flat-bottom hole targets close to the focal plane of the transducer, in cylindrical test standards such as those shown in Annex C, Figures C1 through C9.

3.2.3 Voltage Regulator: The line voltage shall be regulated within ±10%.

3.2.4 Couplant: Clean water shall be used as the couplant material; rust inhibitors, wetting agents, or both, may be added. The water shall be free of visible air bubbles which may interfere with the ultrasonic test.

3.2.5 Data Acquisition System: If a digital data acquisition system is used to record the data, it shall meet the requirements listed in 3.2.5.1 to 3.2.5.6.

3.2.5.1 Components: The system shall consist of encoders for axial and circumferential position, an analog-to-digital (A/D) signal conversion device, a computer, graphic display monitor, graphic printer, an archival storage system, and appropriate software.

3.2.5.2 A/D Conversion: For each pulse, the peak ultrasonic amplitude in the gated region of each inspection zone shall be digitized to a minimum resolution of 8 bits over the full range of amplitudes used for data acquisition. The A/D converter shall be calibrated and adjusted using procedures recommended by the manufacturer.

3.2.5.3 Recording System Linearity: Recording system shall be shown to reproduce recorded amplitude data to an accuracy of ±2% of full scale.

3.2.5.4 Digital Data Storage: Digital amplitudes and the corresponding encoder positions shall be stored. For each ultrasonic amplitude, the corresponding encoder positions shall be retrievable by the operator for relocation and evaluation of indications. Data storage system shall provide traceability of axial position of indications in the billet.

3.2.5.5 Digital Data Archiving: All inspection data files shall be archived and accessible on storage media acceptable to purchaser.

3.2.5.6 Analysis of Digital Data: Software to analyse the digital data shall perform not less than the following functions: display location and amplitude, select region of interest (ROI), calculate mean, minimum, maximum, and standard deviation of amplitude in ROI, and signal-to-noise ratio (See 4.1.1).

3.2.6 Reference Standards: Shall be fabricated from titanium alloy acoustically similar to the alloy to be tested (See 8.3).

3.2.6.1 Initial Selection of Material for Reference Standards: The reference standard material shall have ultrasonic attenuation similar to the material to be inspected. This shall be verified by comparison of the first back-surface reflection in the standard material, away from any edge in the test block, to the first back-surface reflection from similar regions, away from any edge, in a number of samples of typical production billet material. Back-surface echoes averaged over a region of 1 inch (25 mm) length by 360 degrees circumferential at three regions over the length of the billet shall be within ±6 dB. If the sound transmission characteristics vary more than 6 dB, a new standard more closely representative of the material being inspected shall be fabricated.

3.2.6.2 Reference standard diameter shall be within ±0.5 inch (±12.7 mm) of the nominal diameter of the material to be tested.

3.2.6.3 Calibration reflectors shall be flat-bottom holes of the diameter shown in Table 1. The standard shall contain a minimum of one hole at the shallow and deep depths of each inspection zone, and shall contain holes at a minimum of four depth locations, with the shallowest being at the depth shown in Table 1, and the deepest being 0.5 inch deeper than the center of the billet. Hole diameters shall be as shown in Table 1. Recommended configurations are shown in Annex C, Figures C1 through C9.

3.2.6.4 Reference standards shall include a full round section for attenuation compensation measurement. The full round section shall be of the same material, with the same attenuation properties as the rest of the reference standard, and shall be permanently attached or clearly identified as part of the reference standard (See 8.3).

3.2.6.5 Reference standards shall be subject to calibration, certification, and recall procedures required by purchaser.

3.2.7 System Operation (Dynamic Response): The total system shall have dynamic response adequate to provide correct amplitude data for all inspection scan and recording parameters.

3.3 Surface Preparation:

3.3.1 Surfaces to be inspected shall not produce ultrasonic reflections which interfere with the test. Surface texture shall be determined in accordance with ANSI B46.1. A surface roughness of 125 microinches (3.2 µm), or better, is normally sufficient to ensure inspectability.

3.3.2 Regions with surface discontinuities, such as local grindouts, are not considered inspectable and shall be cut out and removed from further processing. Such regions shall be reported on the inspection report. It is recommended that any required grind-out operations be performed after ultrasonic inspection.

3.4 Calibration of Apparatus:

Before inspecting the product, the equipment shall be adjusted, using appropriate reference blocks, to produce clearly defined echoes, of amplitude equal to or exceeding 80% of full scale, from all calibration targets in each zone.

3.4.1 Calibration amplitudes shall be achieved by use of electronic distance amplitude correction (DAC) or by direct comparison in a zoned inspection. In the case of zoned inspection, the zones shall be in accordance with Annex A, Tables A1 through A9, or equivalent, and approved by purchaser.

3.4.2 Instruments shall be warmed up for not less than 10 minutes before being used. Sufficient time shall also be allowed for temperature of water, reference blocks, transducers, and product to stabilize before calibration and testing, See Annex B, Tables B1 through B5.

3.4.3 Calibration Check: To ensure valid results, a calibration check shall be made prior to the test of each part configuration or start of each shift. Any change in equipment operation that results in a recalibration of the test system shall require retesting of all product or parts tested since the previous calibration. The interval between calibrations may be extended subject to purchaser agreement and documented history showing stability of equipment and consistency of calibration levels.

3.5 General Scanning Procedure:

3.5.1 Attenuation Compensation: Acoustic compatibility shall be applied by comparing the backwall echo (BE) or the reference standard material to the average BE over three regions (360 degrees circumferential by 1 inch (25 mm) length) of the material being tested at the center and each end of the billet. If the compatibility difference is within 4 dB, no gain compensation shall be required for inspection. If the compatibility of the BE of the material differs by 5 dB or more from the reference standard, the inspection gain shall be adjusted to compensate in accordance with the approved test procedure of 3.1.3.9.

3.5.2 Evaluation Threshold: An evaluation threshold shall be defined in the procedure such that any rejectable indication will be certain to exceed the evaluation threshold during scanning. Any signal exceeding the evaluation threshold during evaluation shall be relocated and further evaluated ultrasonically. Evaluation threshold will generally be 6 dB below the acceptance limit, but may be varied by indexing in accordance with 3.5.3.

3.5.3 Indexing: Index distance, pulse repetition rate, and rotational speed shall be controlled to provide adequate data sampling.

3.5.3.1 The maximum diagonal distance between sampled data points shall be calculated from the index distance, the pulse repetition rate, and the rotation speed. These parameters shall be controlled such that a rejectable indication will exceed the evaluation limit regardless of its location relative to the sampled points. For example, if the evaluation threshold is -6 dB from the reject level, then the -6 dB sound beam diameter from adjacent and diagonal pulses shall provide complete coverage as illustrated in Figure 1.

3.5.4 The instrument control settings and test parameters established during calibration shall not be changed during testing with the exception of changes in gate length which may be required to perform the dynamic calibration check.

3.6 Inspection:

3.6.1 Sound entry angle shall be perpendicular to the surface. Billet followers shall maintain perpendicularity within ±1.0 degree.

3.6.2 Water Travel: The water travel distance shall be within ±0.1 inch (2.5 mm) of that used for calibration.

3.6.3 Surface Area of Product to be Scanned: 100% of the circumference shall be scanned over the entire length of the billet.

3.6.4 Depth Range of Product to be Gated: The depth range from the near-surface hole shown in Table 1, to 0.5 inch (13 mm) past the center line, shall be gated as a minimum.

3.6.5 Use of DAC and/or zoning shall not be changed from calibration to inspection.

3.6.6 For premium grade materials, the entire heat shall be inspected to the same classification prior to shipment of any product from the heat.

4. QUALITY ASSURANCE PROVISIONS:

4.1 Acceptance Criteria:

Acceptance levels and classifications shall be as shown in Table 1. Additional high sensitivity sonic or other inspections will be specified as necessary to meet major rotor engine hardware operating requirements.

4.1.1 For purposes of determining signal acceptance based on its signal-to-noise ratio, signal-to-noise ratio is defined as:

(Signal - Mean) / (Peak - Mean)

Where signal is the highest amplitude obtained from the suspected indication, mean is the mean value of noise in a region surrounding or adjacent to the indication, and peak is the highest amplitude value of noise in the surrounding or adjacent region excluding electrical noise signals.

4.1.2 For Classification A, product must meet both amplitude and signal-to-noise acceptance requirements.

4.2 Disposition:

4.2.1 Product exhibiting ultrasonically evaluated indications not in excess of acceptance limits shown in Table 1 may be accepted without remedial operations.

4.2.2 All indications in excess of acceptance limits shown in Table 1 shall be removed and metallographically evaluated. Disposition of remaining product in a heat shall be in accordance with purchaser agreement.

4.3 Records:

The testing source shall prepare and maintain, for the time specified by purchaser, records of the requirements and techniques for each size and configuration of product, and all recorded data from billet inspection. These records shall be accessible for review by purchaser at any reasonable time.

4.4 Reporting:

The testing source shall provide a report with each shipment. This report shall contain not less than the following information:

Description of the product tested including alloy, heat number, billet identifications, and dimensions.
Report of all indications exceeding acceptance limits with disposition according to purchaser agreement.
Report of all indications over evaluation threshold as required by purchaser.
Billet map showing location of indication and any material removed due to indications or surface discontinuities.
Location of any regions not inspectable.
Noise level for each billet.

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:

Product not inspected in accordance with this specification, or with modifications authorized by purchaser, will be subject to rejection.

8. NOTES:

8.1 Test Conditions:

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. Agreement between purchaser and vendor should be established in advance on the following:

8.1.1 Local grinding depressions will cause sonic wave attenuation, loss of back reflection, and inability to meet standards locally.

8.2 Dimensions in inch/pound units are primary except for SI units used typically in inspection procedures; dimensions in SI units are shown as the approximate equivalents of the primary units and are presented only for information.

8.3 The following publications are listed for information only:

ASTM E 127 Fabricating and Checking Aluminum Alloy Ultrasonic Standard Reference Blocks

MIL-STD-2154 Ultrasonic Inspection, Wrought Metals

8.4 Inspection procedures meeting the requirements of this specification have been classified under Federal Standardization Area Symbol "NDTI".

PREPARED UNDER THE JURISDICTION OF AMS COMMITTEE"K"

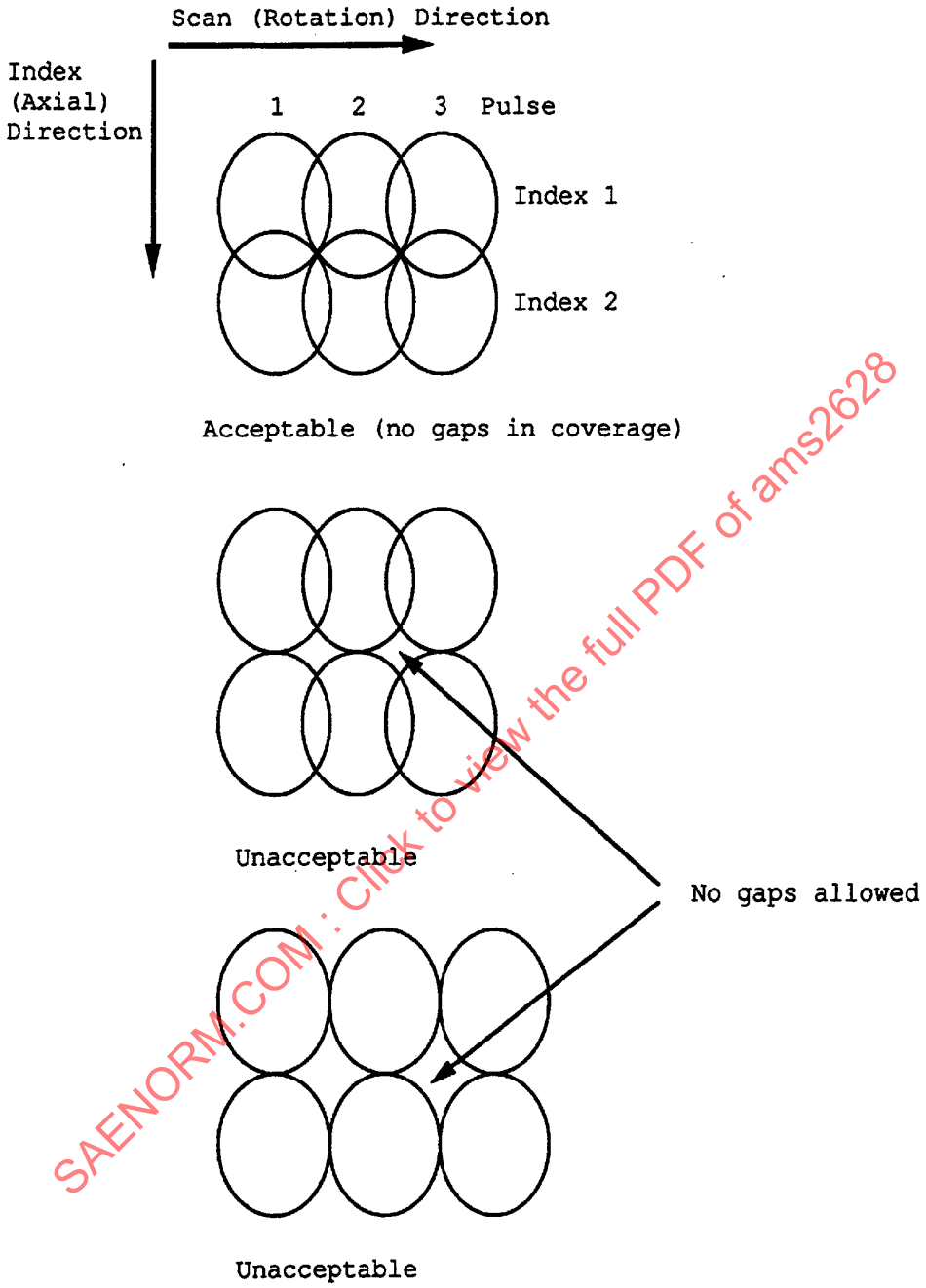

FIGURE 1 - Acceptable beam overlap conditions in accordance with 3.5.3.1

TABLE 1 A - Acceptance Levels and Classification (See 3.2.6.3)

Ultrasonic Classification	Near-Surface Hole Depth Inch	Billet Diameter Inches	Calibration fbh Diameter Inch	Calibration Amplitude	Max Acceptable Amplitude	Max Acceptable Signal-to-Noise Ratio	Data Recording
A	0.20	≤10	2/64	80%	70%	2.5	Digital
		>10	3/64	80%	40%(1)	2.5	
					60%(2)	2.5	
B	0.375	≤10	2/64	80%	80%	N/A	Strip Chart or Digital
		>10	3/64	80%	80%	N/A	Strip Chart or Digital
C	0.375	> 5	3/64	80%	80%	N/A	Optional

Note 1: Depth less than 4 inches.
Note 2: Depth 4 inches and over.

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TABLE 1 B - Acceptance Levels and Classification

Ultrasonic Classification	Near-Surface Hole Depth Millimeters	Billet Diameter Millimeters	Calibration fbh Diameter Millimeters	Calibration Amplitude	Max Acceptable Amplitude	Max Acceptable Signal-to-Noise Ratio	Data Recording
A	5.1	≤254	0.8	80%	70%	2.5	Digital
		>254	1.2	80%	40%(1)	2.5	Digital
					60%(2)	2.5	Digital
B	9.52	≤254	0.8	80%	80%	N/A	Strip Chart or Digital
		>254	1.2	80%	80%	N/A	Strip Chart or Digital
C	9.52	> 127	1.2	80%	80%	N/A	Optional

Note 1: Depth less than 102 mm.
Note 2: Depth 102 mm and over.

ANNEX A

A.1 RECOMMENDED INSPECTION ZONES:

A.1.1 Billet Diameter 5 Inches (127 mm).

Use transducers for 5 to 6 inches (127 to 152 mm) diameter with 3.5 inches (89 mm) waterpath.

TABLE A1

Zone	Zone Start Inches	Zone Start mm	Zone End Inches	Zone End mm	Gate Start Inches	Gate Start mm	Gate End Inches	Gate End mm	Pulses per Rev.
1	0.2	5	0.75	19.0	0.2	5	1.15	29.2	1024
2	0.75	19.0	1.5	38	0.35	8.9	1.9	48	512
3	1.5	38	2.25	57.2	1.1	28	2.65	67.3	512
4	2.25	57.2	3.0	76	1.85	47.0	3.4	86	256

A.1.2 Billet Diameter 6 Inches (152 mm):

Use transducers for 5 to 6 inches (127 to 152 mm) diameter with 3.0 inches (76 mm) waterpath.

TABLE A2

Zone	Zone Start Inches	Zone Start mm	Zone End Inches	Zone End mm	Gate Start Inches	Gate Start mm	Gate End Inches	Gate End mm	Pulses per Rev.
1	0.2	5	0.8	20	0.2	5	1.25	31.8	1024
2	0.8	20	1.7	43	0.4	10	2.15	54.6	1024
3	1.7	43	2.6	66	1.25	31.8	3.05	77.5	512
4	2.6	66	3.5	89	2.15	54.6	3.95	100.3	512

A. 1.3 Billet Diameter 7 Inches (178 mm):

Use transducers for 7 to 8 inches (178 to 203 mm) diameter with 3.5 inches (89 mm) waterpath.

TABLE A3

Zone	Zone Start Inches	Zone Start mm	Zone End Inches	Zone End mm	Gate Start Inches	Gate Start mm	Gate End Inches	Gate End mm	Pulses per Rev.
1	0.2	5	0.8	20	0.2	5	1.2	30	1024
2	0.8	20	1.6	41	0.4	10	2.0	51	1024
3	1.6	41	2.4	61	1.2	30	2.8	71	512
4	2.4	61	3.2	81	2.0	51	3.6	91	512
5	3.2	81	4.0	102	2.8	71	4.4	112	256

A. 1.4 Billet Diameter 8 Inches (203 mm):

Use transducers for 7 to 8 inches (178 to 203 mm) diameter with 3.0 inches (76 mm) waterpath.

TABLE A4

Zone	Zone Start Inches	Zone Start mm	Zone End Inches	Zone End mm	Gate Start Inches	Gate Start mm	Gate End Inches	Gate End mm	Pulses per Rev.
1	0.2	5	0.9	23	0.2	5	1.35	34.3	1024
2	0.9	23	1.8	46	0.45	11.4	2.25	57.2	1024
3	1.8	46	2.7	69	1.35	34.3	3.15	80.0	512
4	2.7	69	3.6	91	2.25	57.2	4.05	102.9	512
5	3.6	91	4.5	114	3.15	80.0	4.95	125.7	256

A.1.5 Billet Diameter 9 Inches (229 mm):

Use transducers for 9 to 10 inches (229 to 254 mm) diameter with 3.5 inches (89 mm) waterpath.

TABLE A5

Zone	Zone Start Inches	Zone Start mm	Zone End Inches	Zone End mm	Gate Start Inches	Gate Start mm	Gate End Inches	Gate End mm	Pulses per Rev.
1	0.2	5	0.8	20	0.2	5	1.2	30	1024
2	0.8	20	1.6	41	0.4	10	2.0	51	1024
3	1.6	41	2.4	61	1.2	30	2.8	71	1024
4	2.4	61	3.2	81	2.0	51	3.6	94	512
5	3.2	81	4.1	104	2.8	71	4.5	114	512
6	4.1	104	5.0	127	3.7	94	5.4	137	256

A.1.6 Billet Diameter 10 Inches (254 mm):

Use transducers for 9 to 10 inches (229 to 254 mm) diameter with 3 inches (76 mm) waterpath.

TABLE A6

Zone	Zone Start Inches	Zone Start mm	Zone End Inches	Zone End Mm	Gate Start Inches	Gate Start mm	Gate End Inches	Gate End mm	Pulses per Rev.
1	0.2	5	0.9	23	0.2	5	1.35	34.3	1024
2	0.9	23	1.8	46	0.45	11.4	2.25	57.2	1024
3	1.8	46	2.7	69	1.35	34.3	3.15	80.0	1024
4	2.7	69	3.6	91	2.25	57.2	4.05	102.9	512
5	3.6	91	4.5	114	3.15	80.0	4.95	125.7	512
6	4.5	114	5.5	140	4.05	102.9	5.95	151.1	256

A.1.7 Billet Diameter 12 Inches (305 mm):

Use transducers for 12 to 13 inches (305 to 330 mm) diameter with 4 inches (102 mm) waterpath.

TABLE A7

Zone	Zone Start Inches	Zone Start mm	Zone End Inches	Zone End mm	Gate Start Inches	Gate Start mm	Gate End Inches	Gate End mm	Pulses per Rev.
1	0.2	5	0.9	23	0.2	5	1.35	34.3	1024
2	0.9	23	1.8	46	0.45	11.4	2.25	57.2	1024
3	1.8	46	2.7	69	1.35	34.3	3.15	80.0	1024
4	2.7	69	3.6	91	2.25	57.2	4.05	102.9	1024
5	3.6	91	4.5	114	3.15	80.0	4.95	125.7	512
6	4.5	114	5.5	140	4.05	102.9	5.95	151.1	512
7	5.5	140	6.5	165	5.05	128.3	6.95	176.5	256

A.1.8 Billet Diameter 13 Inches (330 mm):

Use transducers for 12 to 13 inches (305 to 330 mm) diameter with 3.5 inches (89 mm) waterpath.

TABLE A8

Zone	Zone Start Inches	Zone Start mm	Zone End Inches	Zone End mm	Gate Start Inches	Gate Start mm	Gate End Inches	Gate End mm	Pulses per Rev.
1	0.2	5	1.0	25	0.2	5	1.5	38	1024
2	1.0	25	2.0	51	0.5	13	2.5	64	1024
3	2.0	51	3.0	76	1.5	38	3.5	89	1024
4	3.0	76	4.0	102	2.5	64	4.5	114	1024
5	4.0	102	5.0	127	3.5	89	5.5	140	512
6	5.0	127	6.0	152	4.5	114	6.5	165	512
7	6.0	152	7.0	178	5.5	140	7.5	190	256

A.1.9 Billet Diameter 14 Inches (356 mm):

Use transducers for 14 inches (356 mm) diameter with 4.0 inch (102 mm) waterpath.

TABLE A9

Zone	Zone Start Inches	Zone Start mm	Zone End Inches	Zone End mm	Gate Start Inches	Gate Start mm	Gate End Inches	Gate End mm	Pulses per Rev.
1	0.2	5	1.0	25	0.2	5	1.5	38	1024
2	1.0	25	2.0	51	0.5	13	2.55	64.8	1024
3	2.0	51	3.1	79	1.5	38	3.65	92.7	1024
4	3.1	79	4.2	107	2.55	64.8	4.75	120.6	1024
5	4.2	107	5.3	135	3.65	92.7	5.85	148.6	512
6	5.3	135	6.4	163	4.75	120.6	6.95	76.5	512
7	6.4	163	7.5	190	5.85	148.6	8.05	204.5	256

ANNEX B

B.1 RECOMMENDED TRANSDUCERS FOR ZONED INSPECTION:

B.1.1 Recommended Transducers for 5 to 6 Inches (127 to 152 mm) Diameter.

TABLE B1

Zone	Diameter Inches	Diameter mm	Focal Length Axial Inches	Focal Length Axial mm	Focal Length Circum. Inches	Focal Length Circum. mm	Focal Depth Inches	Focal Depth Mm
1	0.75	19.0	4.5	114	4.5	114	0.4	10
2	1.0	25	8.0	203	5.2	132	1.2	30
3	1.375	34.92	11.8	300	5.7	145	2.1	53
4	1.75	44.4	15.5	394	6.0	152	3.0	76

B.2.2 Recommended Transducers for 7 to 8 Inches (178 to 203 mm) Diameter.

TABLE B2

Zone	Diameter Inches	Diameter mm	Focal Length Axial Inches	Focal Length Axial mm	Focal Length Circum. Inches	Focal Length Circum. mm	Focal Depth Inches	Focal Depth mm
1	0.75	19.0	4.5	114	4.5	114	0.4	10
2	1.0	25	8.4	213	5.7	145	1.3	33
3	1.375	34.92	12.2	310	6.3	160	2.2	56
4	1.75	44.4	15.9	404	6.7	170	3.1	79
5	2.35	59.7	19.7	500	7.0	178	4.0	102

B.1.3 Recommended Transducers for 9 to 10 Inches (229 to 254 mm) Diameter.

TABLE B3

Zone	Diameter Inches	Diameter mm	Focal Length Axial Inches	Focal Length Axial mm	Focal Length Circum. Inches	Focal Length Circum. mm	Focal Depth Inches	Focal Depth Mm
1	0.75	19.0	4.5	114	4.5	114	0.4	10
2	1.25	31.8	8.6	218	6.0	152	1.3	33
3	1.5	38	12.3	312	6.9	175	2.2	56
4	1.75	44.4	16.1	409	7.4	188	3.1	79
5	2.0	51	19.8	503	7.7	196	4.0	102
6	2.35	59.7	23.5	597	8.0	203	5.0	127

B.1.4 Recommended Transducers for 12 to 13 Inches (305 to 330 mm) Diameter.

TABLE B4

Zone	Diameter Inches	Diameter mm	Focal Length Axial Inches	Focal Length Axial mm	Focal Length Circum. Inches	Focal Length Circum. mm	Focal Depth Inches	Focal Depth Mm
1	0.75	19.0	5.4	137	5.4	137	0.4	10
2	1.0	25	9.8	249	7.0	178	1.5	38
3	1.375	34.92	13.9	353	8.1	206	2.5	64
4	1.75	44.4	18.1	460	8.9	226	3.5	89
5	2.35	59.7	22.3	566	9.3	236	4.5	114
6	2.35	59.7	26.4	671	9.7	246	5.5	140
7	2.35	59.7	30.6	777	10.0	254	6.5	165

B.1.5 Recommended Transducers for 14 Inches (356 mm) Diameter.

TABLE B5

Zone	Diameter Inches	Diameter mm	Focal Length Axial Inches	Focal Length Axial mm	Focal Length Circum. Inches	Focal Length Circum. mm	Focal Depth Inches	Focal Depth Mm
1	0.75	19.0	6.0	152	6.0	152	0.5	13
2	1.0	25	10.3	262	7.6	193	1.5	38
3	1.375	34.92	14.4	366	8.7	221	2.5	64
4	1.75	44.4	19.0	483	9.5	241	3.6	91
5	2.35	59.7	23.6	599	10.0	254	4.7	119
6	2.35	59.7	28.2	716	10.3	262	5.8	147
7	2.35	59.7	32.8	833	10.6	269	6.9	175

ANNEX C

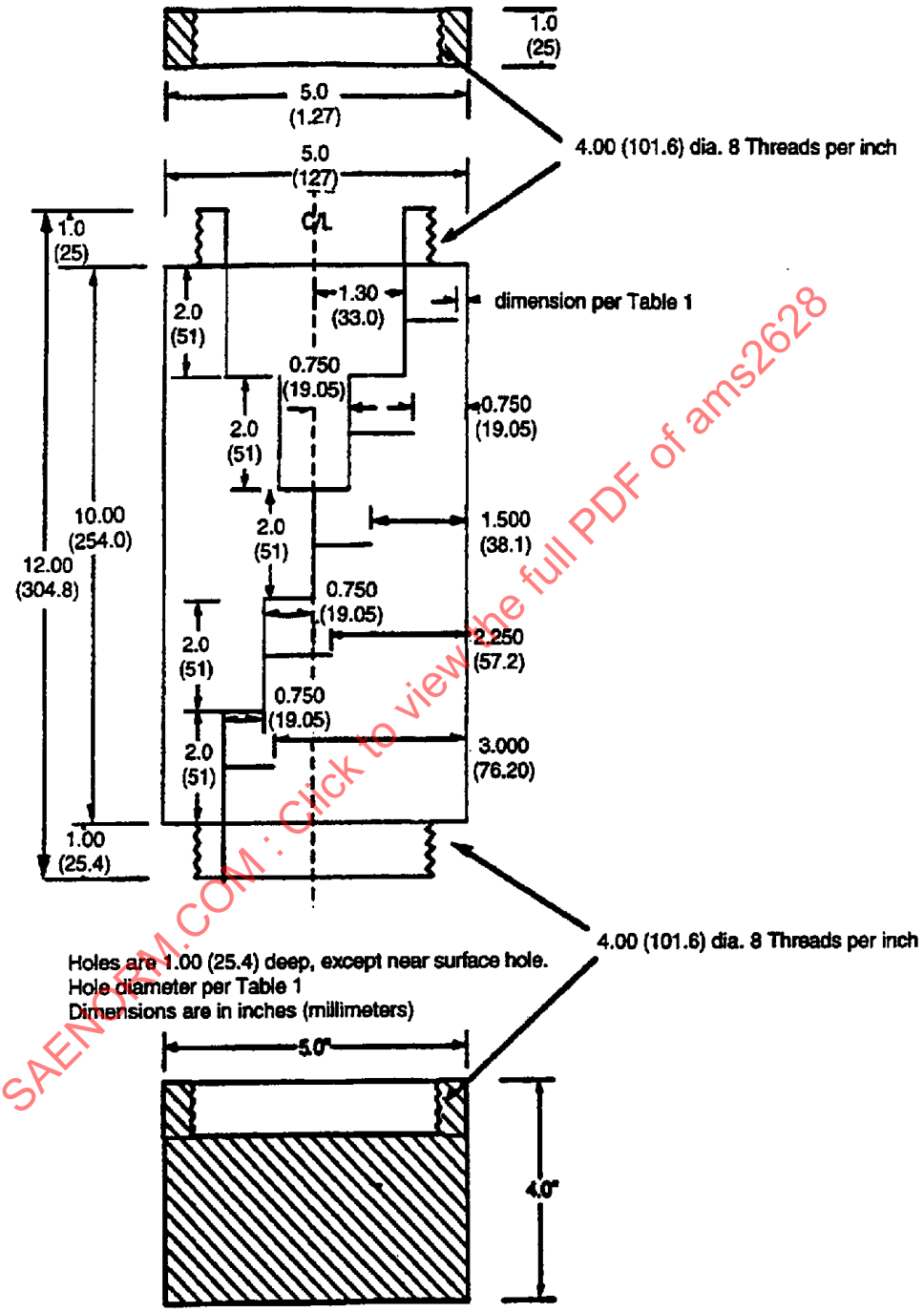

FIGURE C1 - Titanium Calibration Standard, 5.0 Inches (127 mm) Diameter

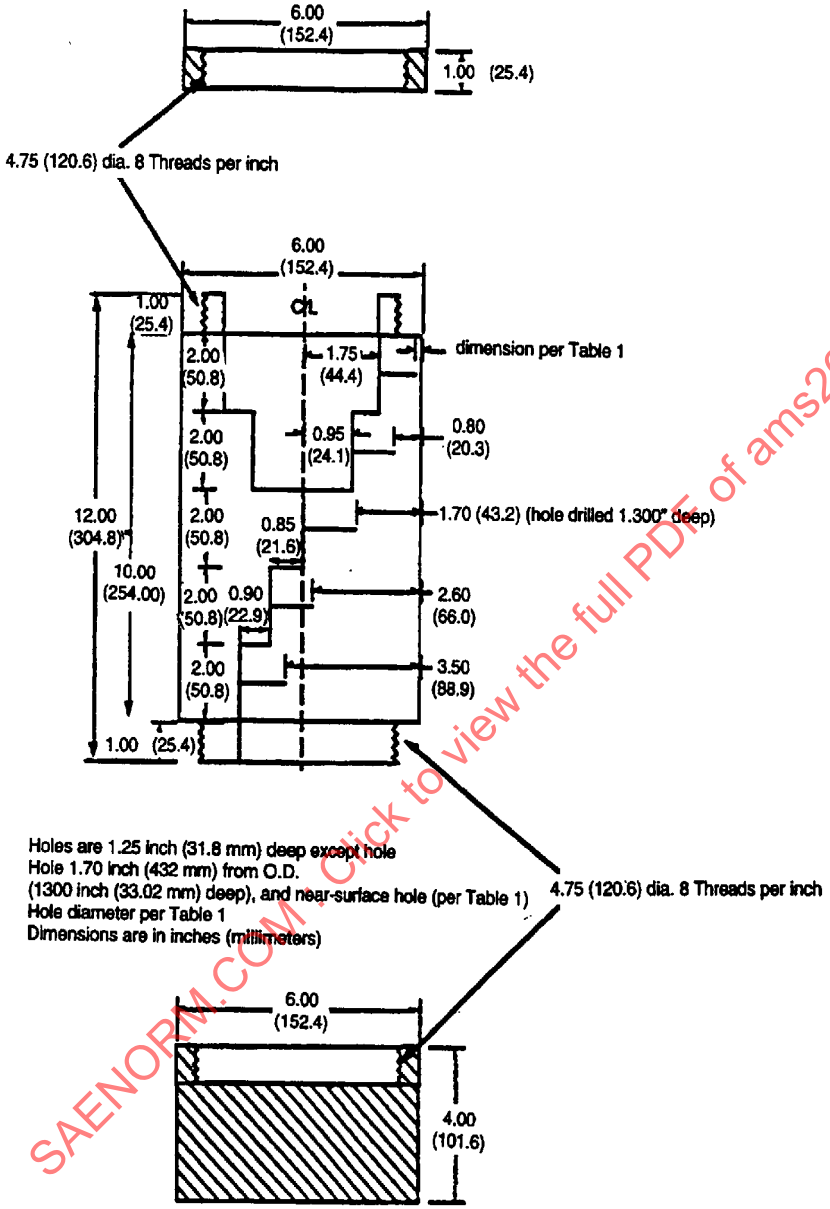

FIGURE C2 - Titanium Calibration Standard, 6.0 Inches (152 mm) Diameter

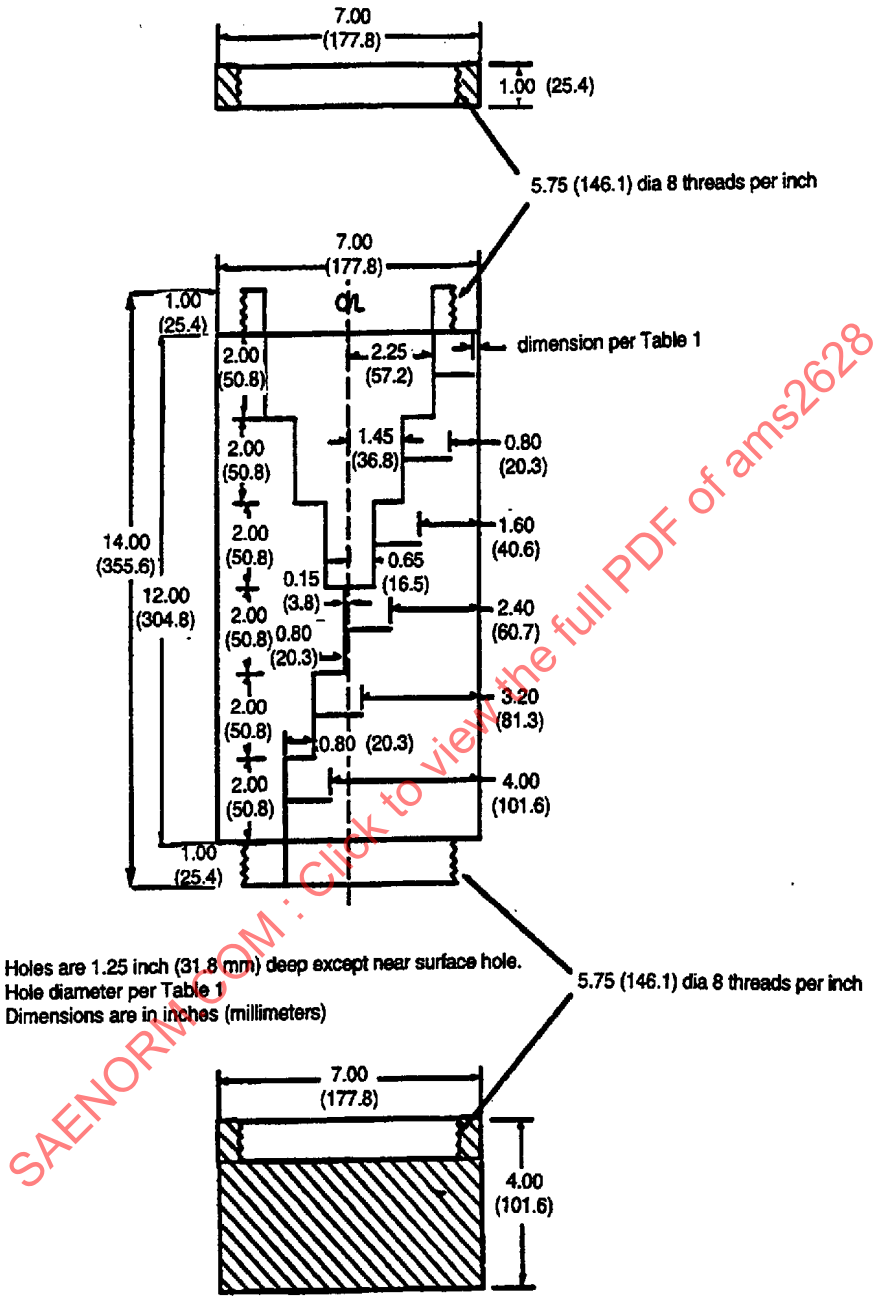

FIGURE C3 - Titanium Calibration Standard, 7.0 Inches (178 mm) Diameter