

**RAFAEL Specification No. 5036****Revision 6****RAFAEL Additional Requirements  
to Specifications: AMS-STD-2154 and AMS 2631***Proprietary Notice*

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**Engineering Change Order:**

Revision	Change Description	ECO No.	Page/Paragraph Revised	Update Date	Approved By
6	Added/modified QA requirements		Par. 2.1	28/9/2022	
	Added requirements for personnel qualification		Par 2.2		
	Added/modified requirements for testing methods: <ul style="list-style-type: none"> <li>• Phased array</li> <li>• Change in technique/equipment</li> <li>• Procedure approval</li> </ul>		Par 3		
	Added requirements for performance of UT inspection: <ul style="list-style-type: none"> <li>• Reference parts materials</li> <li>• Calibration/reference parts geometry</li> <li>• Transducers size</li> </ul>		Par 4		
	Modified detectability requirements.		Figure 4a		
	Added requirements to report Recommended report form		Par 5 App. A		

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## 1. SCOPE

This Spec. Supplements the requirement of specifications: AMS-STD-2154 and AMS 2631, regarding the performance of ultrasonic inspection. It is mandatory for use, whenever specified by RAFAEL's purchase order, engineering drawing or contract.

## 2. QUALIFICATION

### 2.1 QA Requirement

External ultrasonic laboratories:

It is required that external ultrasonic Lab inspecting Rafael materials shall hold NADCAP and/or ISO 17025 certification. This requirement is valid for the cases when the manufacturer is using an outside Lab.

The outside ultrasonic laboratory shall be authorized by Rafael.

Manufacturer internal ultrasonic laboratories:

It is preferable when the Manufacture internal ultrasonic laboratory is holding NADCAP and/or ISO 17025 certifications. In any case, the manufacturer laboratory shall be authorized by Rafael.

Any non-conformances with AMS-STD-2154 and Annex 5036 should be reported during RFQ stage and prior actual testing.

### 2.2 Personnel Qualification

NDT personnel shall be qualified and certified in accordance with NAS 410 or EN 4179.

The results evaluation shall be performed by Level 2 and higher.

### 3. INSPECTION METHOD

#### 3.1 General:

If not otherwise specified in RAFAEL QA Requirement No. 5016, the ultrasonic inspection method covered by this Spec., is the automated immersion technique (Type I) by pulse-echo.

In very specific cases (i.e. extreme part sizes) semi-automated, manual or paintbrush (non-contact or contact) techniques should be discussed during RFQ stage and authorized by Rafael.

#### 3.2 Phased array technique:

- a. The Phased array technique is allowed to use for testing, if it stands AMS-STD-2154 par. 5.2.4.1 requirements.
- b. In the case the ultrasonic testing machine is separated from the production line, the machine should be capable to reach the area with flaw detection and perform the reevaluation of this specific region of interest.
- c. The period phased array system performance should be done based on machine manufacturer instructions. The lab may use the ASTM E 2491 for internal system performance testing, however it doesn't exchange the manufacturer requirements unless the manufacturer approves in written the ASTM E 2491 usage as a substitute for period system performance testing.
- d. The curved phased array probes should stand the requirements of AMS-STD-2154 par. 5.2.4.1, as a linear one.

#### 3.3 Change in testing method:

- a. Any change in calibration parts (i.e. exchange of curved reference part by planar one; non-conformance with calibration parts size requirements, etc.) requires Rafael's approval.
- b. Any essential change in testing method/machine that may influence on the detectability and/or evaluation process (i.e. phased array usage instead of conventional probes) requires Rafael's onsite re-audit and approval.

#### 3.4 Procedure approval by Rafael:

It is recommended to provide the specific procedure for first-time Rafael parts testing for inspection prior the test in order to reduce the chances for retesting if any parameters non-conformances will be detected in final report.

At call, the test supplier or/and manufacture will provide by email the testing procedure to Rafael or to its' representative, if the procedure related questions will be raised during testing report examination.

Presented specific procedures or any other related document should be written or/and translated to English.

#### 4. PERFORMANCE OF ULTRASONIC INSPECTION

- 4.1 If not otherwise specified, the ultrasonic inspection shall be 100% of all the items in a lot. The ultrasonic inspection must cover the whole cross-section of the inspected item, without any loss due to dead zones or inaccurate gate positioning.
- 4.2 Until otherwise specified, each item shall be inspected at least in two directions, as shown in Figure 1 for wrought metals, not included forgings.  
*Note:* Aluminum plates may be inspected from one side only, as shown in Figure 1.
- 4.3 Ultrasonic inspection directions for forgings shall be performed according to the forging drawing requirements attached to the purchase order. If for some reason, the UT directions are not included in the forging drawing, it is the manufacturer responsibility to achieve it before starting to perform the ultrasonic inspections.  
*Note:* Ultrasonic inspection directions for forged tubes, rings and discs are shown in Figure 2. Ultrasonic inspection directions for forged blocks are shown in Figure 3.
- 4.4 Transfer technique (AMS-STD-2154 Para 5.4.15): The determination and using of the Transfer value is very important, especially for forgings inspection.
- 4.5 In general, the reference part material should be chosen from the same material as the tested one. However, if the reference material is not the same as a tested (forging excluded - see 4.6):
  - 4.5.1 If reference material is from the same material family as tested (i.e. stainless steel), but not from the same alloy, it is allowed to use it for the calibration, as long as the transfer value is in range  $\pm 4\text{dB}$ . Please see next table with approved reference materials for common alloys:

Test part material	Recommended reference standard materials
Aluminum Alloys	2024 (rolled or extruded bar) 7075 (rolled or extruded bar) 7075 (rolled plate)
Titanium Alloys	Ti-6Al-4V annealed
Alloy Steels: 4130, 4330, 4340  Low alloy high strength steels such as NAX, T-1  Straight carbon steels  H-11 tool steels  Maraging 250	4340 annealed or 4130 annealed
Stainless Steels and Heat Resisting Alloys	301 or 302 or 321/347 (annealed)
Participation hardening stainless steels	PH15-5, Custom 455, A286, 4340*
Magnesium	AZ804 or ZX60A in the F temper
Nickel based alloys, Cobalt alloys, Refractory metals	Inconel X750

\* If other stainless steels are not available.

4.5.2 If laboratory suggested reference material is not in table and not from the same family as the tested one, then the laboratory has to perform attenuation comparison test as it is explained in ASTM E 428 (steels) and in ASTM E 127 (aluminum). The attenuation of the reference material compared to tested should be in range  $\pm 10\%$  (for same probe frequency). If attenuation factor is not in range, the chosen calibration material is not permitted. The request for approval a non-mentioned reference material should be send to Rafael during RFQ and prior the parts testing, including the attenuation comparison data.

- 4.6 It is required that the Reference Standards for forgings inspections will be manufactured from the same material and with the same manufacture process as the part forging.
- 4.7 Hollow cylindrical and round bar standards:  
The outer diameter of the curved surface reference standard for straight beam calibration and for angle beam calibration shall be similar and within  $\pm 10\%$  of the outer diameter of the product being inspected. Hollow cylindrical standards shall have a thickness equal to  $\pm 25\%$  of the part thickness.

- 4.8 Curved surface reference standards for angle beam inspection can be either with FBH(s) or surface notches as illustrated in Figure 4a and 4b of this Spec. The refracted shear waves inside the material inspected shall be with an angle of 45° only for solid round bars

For hollow cylindrical parts the refracted shear waves can be with different angle, but above the first critical angle, in order to cover full material's cross section. If the part size doesn't allow to cover the cross section with one shear wave scan, then the lab should perform several scans in order to cover the full cross section. The calibration part should have all required artificial flaws in order to perform full cross section evaluation of the tested part. AMS-STD-2154 Figure 10 demonstrates the angle of refraction and beam off-set for cylindrical standards.

*Note:* It is required to use several FBH(s) with different Metal Travel Distances to cover the full distance of the waves inside the material.

- 4.9 For parts with curvature diameter higher than 8" it is permitted to use planar calibration part with SDH based on figure 3 in AMS-STD-2154. In this case the laboratory should perform DAC/TCG curve correction based on the FBH reflection at truncated side of the block. FBH should represent customer detectability requirements. The slope of the truncated side should have the same value as desired refracted angle in tested material.
- 4.10 It is allowed to use the transducer with active diameter differ from 3/8" – 1" but in this case, it should comply the requirements of table 2 of AMS-STD-2154. Complying evidences should be submitted to Rafael prior parts testing. The Rafael approval should be submitted as a part of the report.
- 4.11 For materials with cross diameter equal or lower than 0.75", the test should be in longitudinal waves only. For any diameter larger than 0.75" the test should include longitudinal and shear waves.

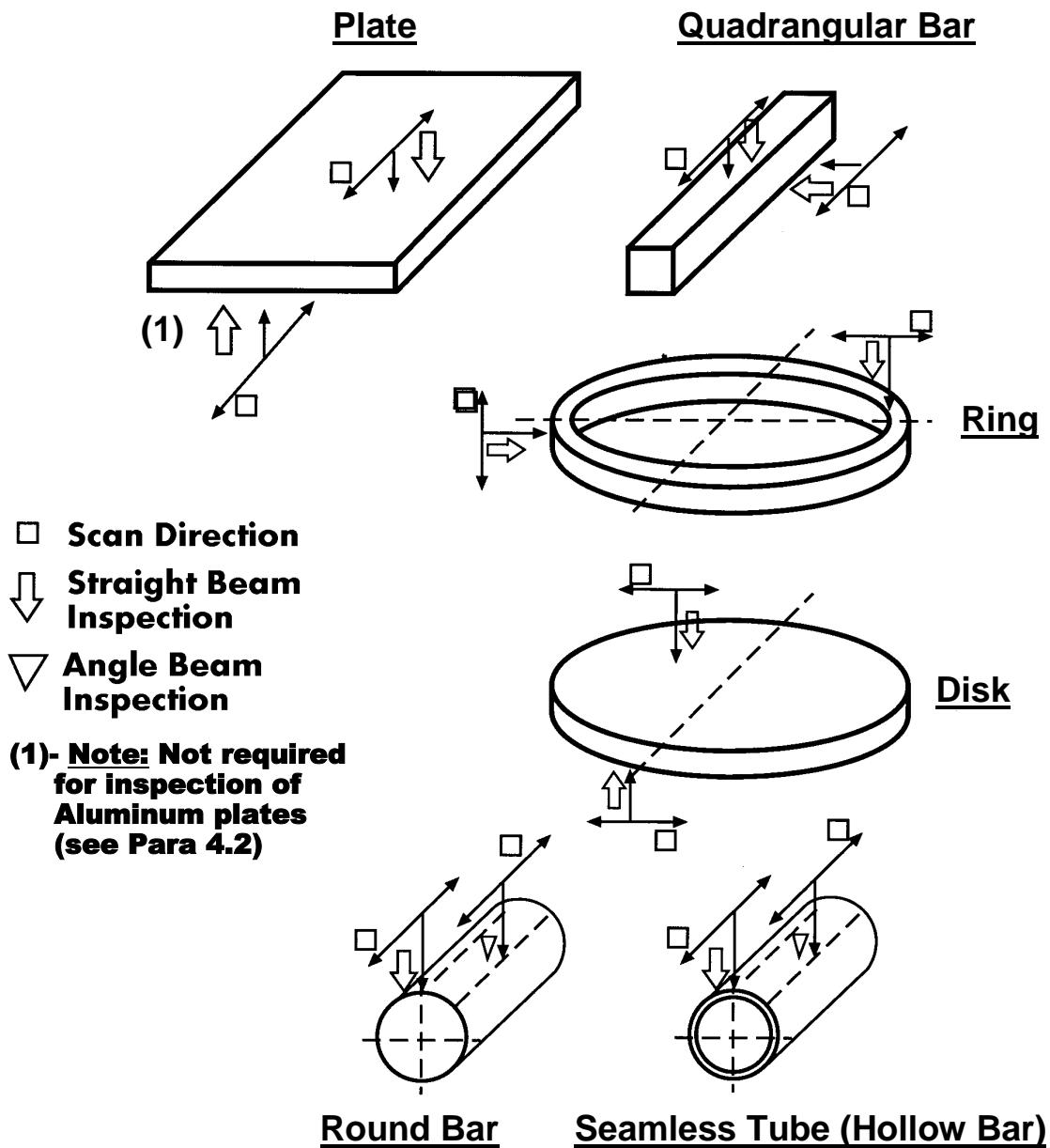
## 5. REPORTING

- 5.1 Items containing discontinuities exceeding the limits of the acceptance class shall be rejected.
- 5.2 The location and the estimated size of each indication exceeding 80% of the specified limits shall be reported also.

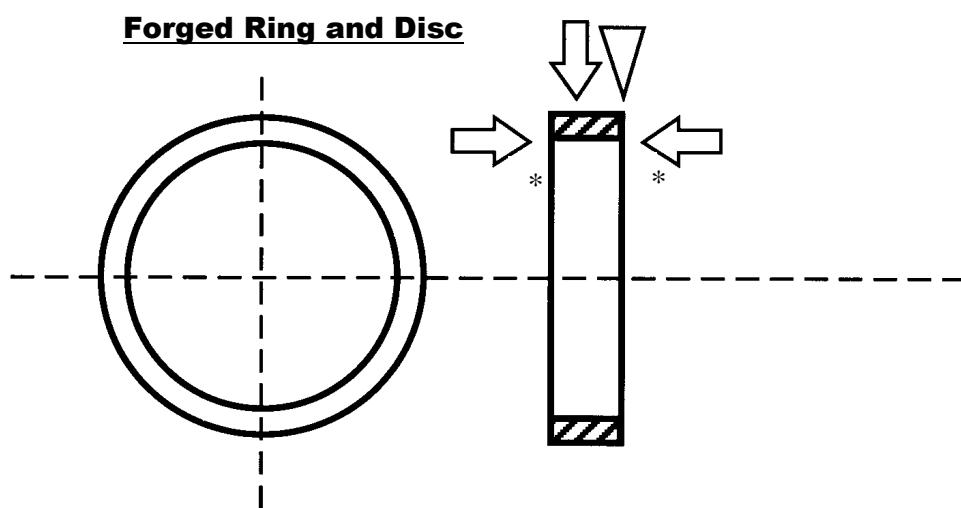
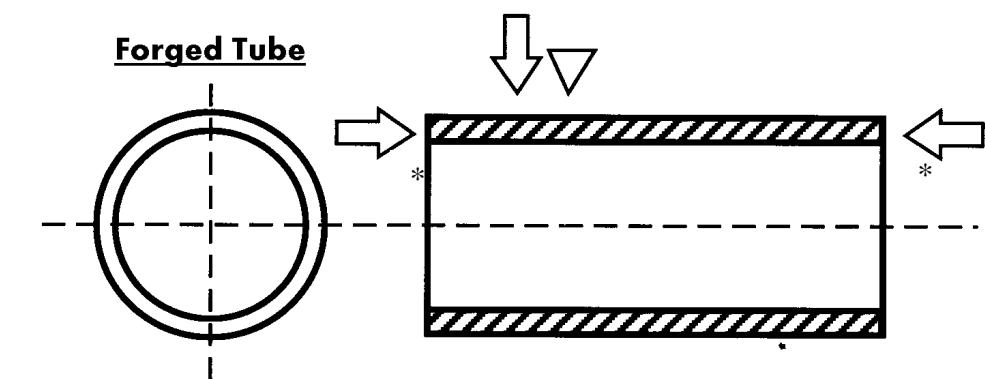
- 5.3 The results of the ultrasonic inspection shall be reported on the certificate of ultrasonic inspection form. A recommended form is attached in Appendix A.

*Note:* Another type of form for reporting may be used, as long as all parameters and requirements mentioned in the recommended form are carefully filled out.

- 5.4 The report should be written in English.
- 5.5 The Certificate of Ultrasonic Inspection should be regarded as part of the purchased material and should be fulfilled (see 5.3) and submitted to RAFAEL for review and approval prior to shipment.
- 5.6 Additional requirements for forging inspection reporting:  
(a) Each forging shall be marked and identified with its own serial number.  
(b) A separate Certificate of Ultrasonic Inspection shall be written for each forging.



**Figure 1:** Ultrasonic Inspection Directions for Various Item Shapes  
(Note: They are not valid for forgings)

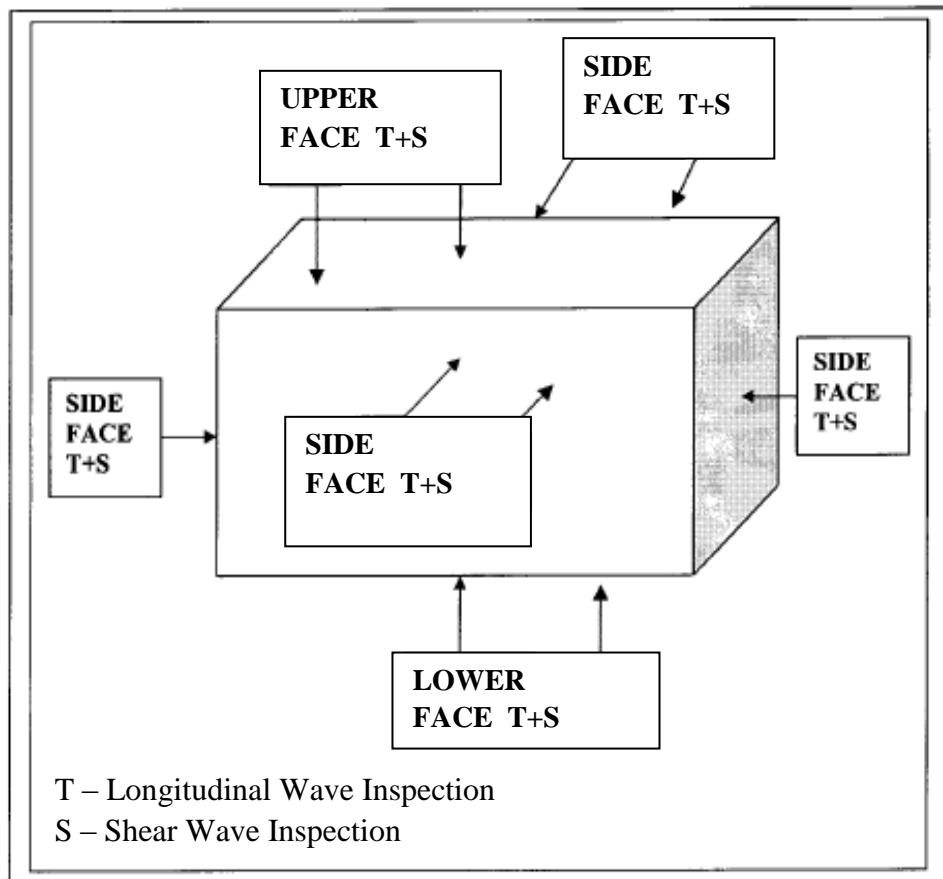


 - **Straight Beam Inspection**

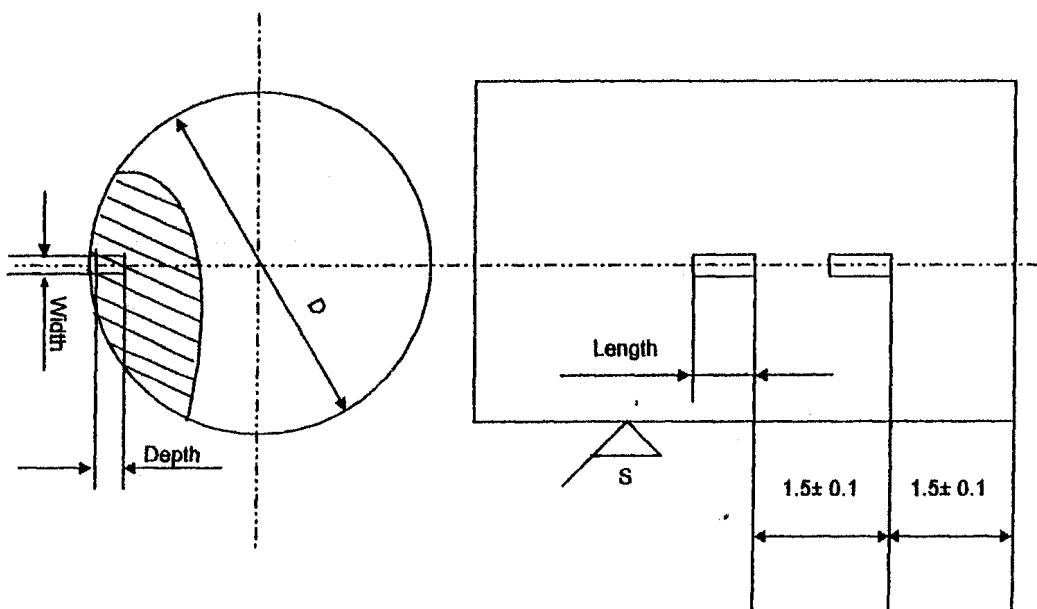
 - **Angle Beam Inspection**

 - **Straight Beam Inspection performing from the end sides,  
shall cover at least material length of 150 mm from each side**

**Figure 2:** Ultrasonic Inspection Directions for Forged Tubes, Rings and Discs.



**Figure 3:** Ultrasonic Inspection Directions for Forged Blocks



S - Surface finish: The surface roughness should be suitable for a reliable performance of the ultrasonic inspection

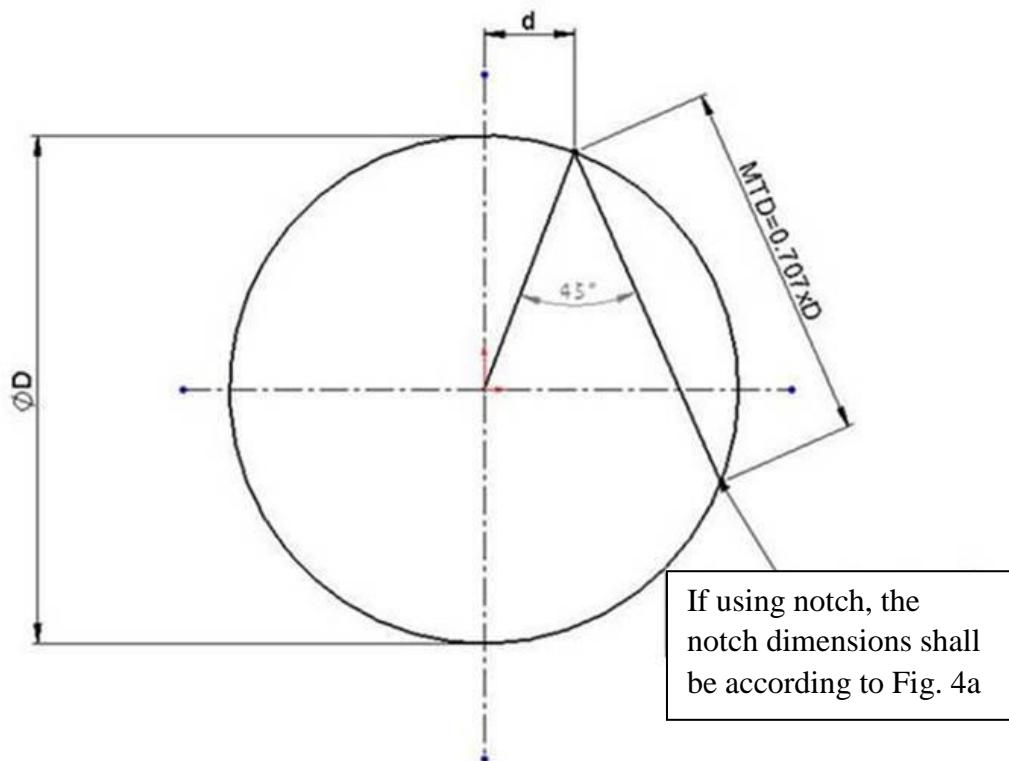
D – Nominal diameter of the inspected round bar

U.S. Class Level according to AMS-STD-2154	U.S. Class Level according to AMS 2631	Dimensions of Notch			F.B.H $\phi$ Equivalent [inch]
		Width [inch]	Depth [inch]	Length [inch]	
AA	AA	0.010	0.029 (4)	0.058 (4)	3/64 (4)
A	A1	0.010	0.029	0.058	3/64
B	A	0.010	0.049	0.098	5/64
C	B	0.010	0.078	0.157	8/64

Notes:

1. All dimensions are given in inches
2. Dimensions are  $\pm 0.002$  inches
3. The notches shall have a rectangular profile
4. Class AA for both Specs requires performing calibration on #2/64" FBH and to correlative notch area. When using #3/64" instead of #2/64" FBH it is required adding 7 dB for scanning and evaluation in longitudinal and in shear waves. It is possible, instead of 7dB addition, to use lowering gate to 18% FSH and detection of #2/64"FBH at 36%FSH. In this case, the report should include the note that the laboratory uses mentioned technique, instead 7dB addition, and the noise level during the test should be much lower than the gate position (<6%FSH).

**Figure 4a:** Notches dimensions for Reference Standard for Angle Beam Inspection of Round Bars.



Note: The refracted shear waves inside the material inspected shall be with an angle of 45° only, either with FBH(s) or surface notches, for Reference Standard for Angle Beam Inspection of Round Bars

**Figure 4b:** The refracted shear waves inside the material inspected for Reference Standard for Angle Beam Inspection of Round Bars

**APPENDIX A: Recommended Certificate of Ultrasonic Inspection Form****RECOMMENDED CERTIFICATE OF ULTRASONIC INSPECTION FORM**

RAFAEL Purchase Order No. : \_\_\_\_\_

Date : \_\_\_\_\_

Inspected According to Specification : \_\_\_\_\_

Class : \_\_\_\_\_

Lab's Ultrasonic Scan Plan Procedure (Technical Sheet) No. and Rev.: \_\_\_\_\_

Raw Material Manufacturer/Supplier Details : \_\_\_\_\_

Name : \_\_\_\_\_

Address : \_\_\_\_\_  
\_\_\_\_\_**Ultrasonic Lab. Details:***Note:* To be filled out only if the ultrasonic inspection is performed by an external lab. as subcontractor

Name : \_\_\_\_\_

Address : \_\_\_\_\_  
\_\_\_\_\_

Lab's Test Certificate No. : \_\_\_\_\_

**MATERIAL/FORGING DATA**

Alloy and condition: \_\_\_\_\_ Procurement Specification: \_\_\_\_\_

Configuration: \_\_\_\_\_ Dimensions: \_\_\_\_\_

Surface Roughness: \_\_\_\_\_

Forging Serial No: \_\_\_\_\_ Forging Drawing No.: \_\_\_\_\_

Forging Dimensions:  $\varnothing_{\text{EXT}} \text{ max} = \underline{\hspace{2cm}}$ ,  $\varnothing_{\text{INT}} \text{ min} = \underline{\hspace{2cm}}$ , L=  $\underline{\hspace{2cm}}$

Date : \_\_\_\_\_  
 RAFAEL Purchase Order No. : \_\_\_\_\_  
 Lab's Test Certificate No. : \_\_\_\_\_

### REFERENCE STANDARD DATA

(A DRAWING OF THE REFERENCE STANDARD TO BE ATTACHED  
TO THE CERTIFICATE OF ULTRASONIC INSPECTION)

#### Reference Standard Configuration for Straight Beam Inspection

Reference Standard No.: \_\_\_\_\_  
 FBH Diameters: \_\_\_\_\_  
 Metal Travel Distances: \_\_\_\_\_  
 Alloy: \_\_\_\_\_  
 Surface Roughness: \_\_\_\_\_  
 Reference Thickness/Diameter: \_\_\_\_\_

#### Reference Standard Configuration for Angle Beam Inspection

Reference Standard No.: \_\_\_\_\_  
 FBH Diameters: \_\_\_\_\_  
 Notch Length (Fig. 4a): \_\_\_\_\_  
 Notch Depth (Fig. 4a): \_\_\_\_\_  
 Alloy: \_\_\_\_\_  
 Surface Roughness: \_\_\_\_\_  
 Reference Thickness/Diameter: \_\_\_\_\_

### TRANSDUCER DATA

#### Transducer Data for Straight Beam Inspection

Mfg.: \_\_\_\_\_  
 Element Diameter/Size\*: \_\_\_\_\_  
 Frequency: \_\_\_\_\_  
 Material: \_\_\_\_\_  
 Shape: Flat/Spherical/Cylindrical Focus  
 Focal Length: \_\_\_\_\_  
 Type: \_\_\_\_\_  
 Serial No.: \_\_\_\_\_

#### Transducer Data for Angle Inspection

Mfg.: \_\_\_\_\_  
 Element Diameter/Size\*: \_\_\_\_\_  
 Frequency: \_\_\_\_\_  
 Material: \_\_\_\_\_  
 Shape: Flat/Spherical/Cylindrical Focus  
 Focal Length: \_\_\_\_\_  
 Type: \_\_\_\_\_  
 Serial No.: \_\_\_\_\_

\*Note: For exceeding range 3/8"-1" transducers provide Rafael approval as a part of this report

### INSTRUMENT/SCAN

Instrument Mfg.: _____	Test Frequency: _____
Model: _____	Noise Level (1): _____
Test Method: _____	Scanning Speed: _____
Couplant: _____	Scanning Index: _____

Date : \_\_\_\_\_  
RAFAEL Purchase Order No. : \_\_\_\_\_  
Lab's Test Certificate No. : \_\_\_\_\_

Sketch of the part scanning sides

Date : \_\_\_\_\_  
 RAFAEL Purchase Order No. : \_\_\_\_\_  
 Lab's Test Certificate No. : \_\_\_\_\_

### CALIBRATION DATA

#### STRAIGHT BEAM CALIBRATION

FBH $\phi$ (x 1/64 in)	MTD (in / mm)	RESPONSE (% SCALE)	Alarm Level [% of scale]: _____
			Transfer Value (4) [db]: _____
			Back Reflection Response [% of Scale]: _____
			Dead Zone [in/mm]: _____
			Distance in the Material not Covered by the Alarm Gate: _____
			Noise Level (1) [% scale]: _____
			Noise Level (2) [% scale]: _____
			Water Path [mm]: _____

#### ANGLE BEAM CALIBRATION

FBH $\phi$ (x 1/64 in) or NOTCH (5) EQUIVALENT	MTD (in / mm)	RESPONSE (% SCALE)	Alarm Level [% of scale]: _____
			Transfer Value (4) [db]: _____
			Angle of Refracted Sound Beam in the Material Inspected $\Phi$ (3): _____
			Incident angle (3): _____
			Noise Level (1) [% scale]: _____
			Noise Level (2) [% scale]: _____
			The value of the distance "d" if performed according AMS-STD-2154 Fig. 10: _____
			Water Path [mm]: _____

Notes:

- (1) Average noise level (instrument + product) [% of scale].
- (2) Average noise level (instrument + reference standard) [% of scale].
- (3) See Figure 10 AMS-STD-2154 for incident and refracted angles of sound beam definition.
- (4) Transfer Value (AMD-STD-2154 Para 5.4.15): The gain difference in the response received from reference standard and the part to be inspected [db].
- (5) According to Fig. 4a of this Spec.

Date : \_\_\_\_\_  
RAFAEL Purchase Order No. : \_\_\_\_\_  
Lab's Test Certificate No. : \_\_\_\_\_

Reference Parts Sketches/Plans that were used for reported testing

Date : \_\_\_\_\_  
 RAFAEL Purchase Order No. : \_\_\_\_\_  
 Lab's Test Certificate No. : \_\_\_\_\_

**TEST RESULTS DATA**

ITEM/Part Serial No.	QTY	HEAT NO.	SURFACE FINISH	ACCEPT	REJECT

Observation Remarks:

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Inspected By: \_\_\_\_\_ Certification Level: \_\_\_\_\_  
 Approved By: \_\_\_\_\_ Certification Level: \_\_\_\_\_

*Note:* In case, when the ultrasonic inspection is performed by an external lab as subcontractor, the report should be authorized by the manufacturer.

Authorized By: \_\_\_\_\_ Certification Level: \_\_\_\_\_

Date : \_\_\_\_\_  
RAFAEL Purchase Order No. : \_\_\_\_\_  
Lab's Test Certificate No. : \_\_\_\_\_

Image/Sketch of rejected parts with marked rejected areas\*:

*\*Note:* Including reference surface (plate) /length axe (cylinder) and origin point for flaw position evaluation. The origin point and rejected areas should be physically marked on the part.

Date : \_\_\_\_\_  
RAFAEL Purchase Order No. : \_\_\_\_\_  
Lab's Test Certificate No. : \_\_\_\_\_

## Rejection report

Part number in tested lot	Flaw start point on length axe [mm]	Flaw length [mm]	Flaw radial position (degrees)	Flaw width [mm]	Flaw depth [mm]