AEROSPACE RECOMMENDED PRACTICE

ARP2654™ REV. A

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Superseding ARP2654

(R) Ultrasonic Thickness Testing

RATIONALE

ARP2654A is the result of a Five-Year Review and update of the document. Document and table formatting, metric additions, references, and other editorial changes have been made.

1. SCOPE

1.1 Purpose

To provide general instructions for accomplishing ultrasonic thickness measurements. Measurements can be made from one side of a material when access to the opposite side is restricted.

1.2 Application

This SAE Aerospace Recommended Practice (ARP) is intended for, but not limited to, use at maintenance and overhaul facilities to inspect aerospace structures and hardware for material loss or remaining thickness after rework or fabrication processes. Due to the number of variables which can affect the reliability of ultrasonic thickness measurements, it is only recommended for use when mechanical methods of measurement are not practical.

2. APPLICABLE DOCUMENTS

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of a conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

HS-1086 Metals and Alloys in the Unified Numbering System

TO PLACE A DOCUMENT ORDER: **Tel: 877-606-7323 (inside USA and Canada)**
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For more information on this standard, visit
https://www.sae.org/standards/content/ARP2654A/

2.2 AIA Publications

Available from Aerospace Industries Association, 1000 Wilson Boulevard, Suite 1700, Arlington, VA 22209-3928, Tel: 703-358-1000, www.aia-aerospace.org.

NAS410 Nondestructive Testing Personnel Qualification and Certification

2.3 America for Airlines (A4A) Publications

Available from Airlines for America (A4A), 1301 Pennsylvania Avenue, NW, Suite 1100, Washington, DC 20004, Tel: 202-626-4000, www.airlines.org.

Spec 105 Guidelines for Training and Qualifying Personnel in Nondestructive Testing

2.4 ASNT Publications

Available from American Society for Nondestructive Testing, 1171 Arlingate Lane, Columbus, OH 43228-0518, www.asnt.org.

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

2.5 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org.

ASTM E494 Measuring Ultrasonic Velocity in Materials by Comparative Pulse-Echo Method

3. BASIC THEORY

3.1 Ultrasonic thickness testing may be accomplished on any material in which ultrasonic waves will propagate at a constant velocity throughout the part and from which back surface reflections can be obtained and resolved.

3.2 Pulse-echo ultrasonic instruments measure the transit time of an ultrasonic pulse through a material. Thickness, when measured by the ultrasonic method, is a product of the velocity of sound in a material and one half the transit time (round trip) of the ultrasonic wave through the material.

3.3 The velocity of sound in the material under test is a function of the physical properties of the material. Velocities in liquids, gases, and homogenous solids such as metals or ceramics are generally assumed to be constant for a given material type and form. Approximate values for some materials are listed in Table 1. The values in this table are for reference only. Actual values may vary significantly due to variations in composition and manufacturing processes.

Table 1A - Acoustic properties of materials (inch/pound units)

Material	Acoustic Velocities (in/μs) V1 & V2 (Long.)	V3 (Shear)	V4 (Surface)	Acoustic-Impedance (lbs/ft²/μs)	Density (lbs/ft³)
METALS					
Aluminum	0.2488	0.1232		3.50	168.58
Al 1100 (2S)	0.2484	0.1213		3.50	169.21
Al 1100-0 (2S0)	0.2500	0.1220	0.1142	3.52	169.21
Al 2014	0.2508	0.1209		3.65	174.83
Al 2024-T4	0.2508	0.1244	0.1161	3.61	172.96
Al 2117-T4	0.2559	0.1228	0.1098	3.73	174.83
Bearing Babbit	0.0906			4.75	630.63
Beryllium	0.5079	0.3496	0.3098	4.81	113.64
Brass (Naval)	0.1744	0.0835	0.0768	7.58	525.73
Brass (Half Hard)	0.1508	0.0807		6.35	505.75
Bronze, Phosphor (5%)	0.1390	0.0878	0.0791	6.41	553.21
Cadmium	0.1095	0.0591		4.92	539.47
Copper	0.1835	0.0890	0.0760	8.52	557.58
Gold	0.1278	0.0472		12.82	1206.31
Hafnium	0.1512	0.0594		10.38	823.90
Inconel	0.2252	0.1189	0.1098	12.80	527.61
Lead Antimony (6%)	0.0850	0.0319	0.0291	4.83	680.58
Magnesium (Am35)	0.2280	0.1221	0.1130	2.07	108.64
Magnesium (ZK-60A-T5)	0.2250	0.1201		2.05	114.26
Mercury	0.0559			4.04	846.67
Monel	0.2370	0.1071	0.0772	10.90	551.33
Molybdenum	0.2476	0.1319	0.1224	13.15	636.87
Nickel	0.2217	0.1165	0.1039	10.24	554.46
Platinum	0.1559	0.0658		17.35	1336.19
Silver-Nickel (18Ni-5Zn-77Cu)	0.1819	0.0913	0.0665	8.28	546.34
Steel, 302 Cres	0.2228	0.1228	0.1228	9.30	501.38
Steel, 347 Cres	0.2260	0.1217		9.30	493.89
Steel, 410 Cres	0.2122	0.1177	0.0850	8.46	478.90
Steel, 1020	0.2319	0.1276		9.30	481.40
Steel, 1095	0.2323	0.1256		9.42	487.02
Steel, 4150 HRc14	0.2307	0.1098		9.40	489.52
Steel, 4150 HRc18	0.2319	0.1252		9.42	488.27
Steel, 4150 HRc43	0.2311	0.1260		9.38	487.65
Steel, 4150 HRc64	0.2291	0.1091		9.32	487.02
Steel, 4340	0.2303	0.1276		10.45	487.02
Titanium (Ti150A)	0.2402	0.1230	0.1098	5.67	283.47
Tungsten	0.2039	0.1130	0.1043	20.42	1201.94
Vanadium	0.2362	0.1094		7.42	376.51
POWDERED METAL MATERIALS					
Rene					
R-41 (53Ni-19Cr-11Co-10Mo)	0.2378	0.1260	0.1169	10.20	390.24
R-77 (55Ni-15Co-15Cr)	0.2441	0.1295	0.1201	10.06	494.51
R-80 (60.5Ni-9.9Co-14Cr)	0.2339	0.1272			
R-95 (61Ni-8Co-14Cr)	0.2350			10.02	511.37
-60 Mesh	0.2319			9.75	504.50
-As HIP'd	0.2382	0.1189			
-Cast & Wrought	0.2350	0.1157		10.02	511.37
-HIP'd & Forged	0.2339				
-150 Mesh	0.2374	0.1260	0.1169	10.24	518.24
-As HIP'd	0.2413	0.1260			

Table 1A - Acoustic properties of materials (inch/pound units) continued

Material	Acoustic Velocities (in/µs) V1 & V2 (Long.)	V3 (Shear)	V4 (Surface)	Acoustic-Impedance (lbs/ft²/µs)	Density (lbs/ft³)
PLASTIC, RESINS, AND PHENOLICS					
Acrylic Resin	0.1050	0.0440		0.645	73.68
Bakelite	0.1020			0.744	87.41
Boron Epoxy	0.1310			1.309	119.88
Carbon Graphite Epoxy Laminate	0.1150			0.948	99.28
Fiberglass Epoxy Laminate	0.1150			1.239	119.88
Hysol	0.1090			0.737	81.17
Lucite	0.1050	0.0500		0.647	73.68
Micarta, Glass/Epoxy (G11)	0.1160			1.108	115.51
Micarta, Linen/Phenolic (LE)	0.1050			0.717	82.42
Phenolic Resin	0.0560			0.389	83.67
PLEXIGLASS					
1. UVA	0.1090			0.713	79.30
2. UVAII	0.1080	0.0560		0.656	73.68
Teflon	0.0530			0.615	137.37
LIQUIDS					
Glycerin	0.0757			0.496	78.67
Mercury	0.0560			4.036	864.78
Motor Oil SAE20	0.0685			0.309	54.32
Propylene Glycol	0.0594			0.322	64.94
Ultragel II	0.0650			0.369	68.06
Water	0.0584			0.303	62.44

NOTE: The values in this table are for reference only. Actual values may vary significantly due to variations in composition and manufacturing processes.

Table 1B - Acoustic properties of materials (SI units)

Material	Acoustic Velocities (cm/μs) V1 & V2 (Long.)	V3 (Shear)	V4 (Surface)	Acoustic-Impedance (gm/cm²/μs)	Density (gm/cm³)
METALS					
Aluminum	0.6320	0.3129		1.71	2.70
Al 1100 (2S)	0.6309	0.3081		1.71	2.71
Al 1100-0 (2S0)	0.6350	0.3099	0.2901	1.72	2.71
Al 2014	0.6370	0.3071		1.78	2.80
Al 2024-T4	0.6370	0.3160	0.2949	1.76	2.77
Al 2117-T4	0.6500	0.3119	0.2789	1.82	2.80
Bearing Babbit	0.2301			2.32	10.10
Beryllium	1.2901	0.8880	0.7869	2.35	1.82
Brass (Naval)	0.4430	0.2121	0.1951	3.70	8.42
Brass (Half Hard)	0.3830	0.2050		3.10	8.10
Bronze, Phosphor (5%)	0.3531	0.2230	0.2009	3.13	8.86
Cadmium	0.2781	0.1501		2.40	8.64
Copper	0.4661	0.2261	0.1930	4.16	8.93
Gold	0.3246	0.1199		6.26	19.32
Hafnium	0.3840	0.1508		5.07	13.20
Inconel	0.5720	0.3020	0.2789	6.25	8.45
Lead Antimony (6%)	0.2159	0.0810	0.0739	2.36	10.90
Magnesium (Am35)	0.5791	0.3101	0.2870	1.01	1.74
Magnesium (ZK-60A-T5)	0.5715	0.3051		1.00	1.83
Mercury	0.1420			1.97	13.56
Monel	0.6020	0.2720	0.1961	5.32	8.83
Molybdenum	0.6289	0.3350	0.3109	6.42	10.20
Nickel	0.5631	0.2959	0.2639	5.00	8.88
Platinum	0.3960	0.1674		8.47	21.40
Silver-Nickel (18Ni-5Zn-77Cu)	0.4620	0.2319	0.1689	4.04	8.75
Steel, 302 Cres	0.5659	0.3119	0.3119	4.54	8.03
Steel, 347 Cres	0.5740	0.3091		4.54	7.91
Steel, 410 Cres	0.5390	0.2990	0.2159	4.13	7.67
Steel, 1020	0.5890	0.3241		4.54	7.71
Steel, 1095	0.5900	0.3190		4.60	7.80
Steel, 4150 HRc14	0.5860	0.2789		4.59	7.84
Steel, 4150 HRc18	0.5890	0.3180		4.60	7.82
Steel, 4150 HRc43	0.5870	0.3200		4.58	7.81
Steel, 4150 HRc64	0.5819	0.2771		4.55	7.80
Steel, 4340	0.5850	0.3241		5.10	7.80
Titanium (Ti150A)	0.6101	0.3124	0.2789	2.77	4.54
Tungsten	0.5179	0.2870	0.2649	9.97	19.25
Vanadium	0.5999	0.2779		3.62	6.03
POWDERED METAL MATERIALS					
Rene					
R-41 (53Ni-19Cr-11Co-10Mo)	0.6040	0.3200	0.2969	4.98	6.25
R-77 (55Ni-15Co-15Cr)	0.6200	0.3289	0.3051	4.91	7.92
R-80 (60.5Ni-9.9Co-14Cr)	0.5941	0.3231			
R-95 (61Ni-8Co-14Cr)	0.5969			4.89	8.19
-60 Mesh	0.5890			4.76	8.08
-As HIP'd	0.6050	0.3020			
-Cast & Wrought	0.5969	0.2939		4.89	8.19
-HIP'd & Forged	0.5941				
-150 Mesh	0.6030	0.3200	0.2969	5.00	8.30
-As HIP'd	0.6129	0.3200			

Table 1B - Acoustic properties of materials (SI units) continued

Material	Acoustic Velocities (cm/µs) V1 & V2 (Long.)	V3 (Shear)	V4 (Surface)	Acoustic-Impedance ($gm/cm^2/\mu s$)	Density (gm/cm^3)
PLASTIC, RESINS, AND PHENOLICS					
Acrylic Resin	0.2667	0.1118		0.315	1.18
Bakelite	0.2591			0.363	1.40
Boron Epoxy	0.3327			0.639	1.92
Carbon Graphite Epoxy Laminate	0.2921			0.463	1.59
Fiberglass Epoxy Laminate	0.2921			0.605	1.92
Hysol	0.2769			0.360	1.30
Lucite	0.2667	0.1270		0.316	1.18
Micarta, Glass/Epoxy (G11)	0.2946			0.541	1.85
Micarta, Linen/Phenolic (LE)	0.2667			0.350	1.32
Phenolic Resin	0.1422			0.190	1.34
PLEXIGLASS					
1. UVA	0.2769			0.348	1.27
2. UVAII	0.2743	0.1422		0.320	1.18
Teflon	0.1346			0.300	2.20
LIQUIDS					
Glycerin	0.1923			0.242	1.26
Mercury	0.1422			1.970	13.85
Motor Oil SAE20	0.1740			0.151	0.87
Propylene Glycol	0.1509			0.157	1.04
Ultragel II	0.1651			0.180	1.09
Water	0.1483			0.148	1.00

NOTE: The values in this table are for reference only. Actual values may vary significantly due to variations in composition and manufacturing processes.

3.3.1 SAE invites interested parties to submit corrections or new data for inclusion in Table 1. When doing so, the material should be identified in accordance with an industry-accepted standard (rather than by trade name) such as the Unified Numbering System (UNS) convention described in SAE HS-1086. In addition, include the method used for measuring the velocity such as those described in ASTM E494. Send information to SAE Aerospace, Technical Standards/Committee K, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

3.4 Velocities of composite materials such as fiberglass or graphite laminates can vary considerably (10% or more) due to variables in the manufacturing process. Such things as porosity, resin content, and cure pressures can affect velocities as well as the per ply thickness of a part (i.e., two parts with the same number of plies could have different physical measurements).

4. CAPABILITIES AND LIMITATIONS

4.1 Under ideal circumstances, accuracy on the order of ±0.001 inch (0.025 mm) can be achieved with ultrasonic thickness testing. Under normal circumstances encountered in aircraft maintenance, it is more realistic to expect less accuracy than ±0.001 inch (0.025 mm) or ±1% of actual material thickness when measuring metals. Numerous variables can significantly reduce this accuracy and it is imperative that these variables be considered when determining the adequacy of this technique for a given application.

4.2 Geometry

4.2.1 The highest level of accuracy is achieved on materials with parallel or concentric surfaces. In some cases, it is possible to obtain measurements from materials with non-parallel surfaces; however, the accuracy of the readings may be limited. Use of a standard with the same physical geometry should be used to maximize accuracy.

4.2.2 Convex or concave surfaces often require special techniques or equipment designed to fit the curvature and hold the transducer normal to the surface (or normal to the back surface) of the material. In some cases, rounded, radiused, or coned delay lines may facilitate inspection of irregularly shaped parts.

4.2.3 When measuring concave surfaces where a gap exists between the face of the transducer and the material being examined, that gap (if filled with couplant) may be included in the thickness measurement. This error can be significant, because most couplants have velocities about 1/4 that of most metals used in aircraft/engine fabrication. (0.001 inch [0.025 mm] of couplant will produce a reading of about 0.004 inch [0.10 mm]). This can be avoided if instruments having multi-echo measurement capabilities are used. If multi-echo mode is not used, Table 2 lists the maximum recommended transducer diameter to use based on the radius of curvature or blend radius to keep the couplant gap at less than 0.00025 inch (0.0064 mm) (0.001 inch [0.025 mm] maximum error in the above example).

Table 2 - Maximum recommended transducer diameter to minimum bend radius

Xducer		Min Part or Blend	
Inches	**Millimeters**	**Inches**	**Millimeters**
0.060	1.52	1.5	38
0.080	2.03	3.2	81
0.100	2.54	5.0	127
0.125	3.18	8.0	203
0.187	4.75	17.5	444
0.250	6.35	32.0	813

4.2.4 On convex surfaces, rocking of the transducer can cause variations in the thickness reading. Generally, the transducer should be manipulated to obtain the thinnest reading.

4.3 Material Properties

4.3.1 The velocity of sound in most materials changes with both the heat treatment condition and material temperature. These changes are negligible on some materials, while on others, significant variations in thickness readings can occur. To minimize the effects of material heat treat condition and/or material temperature, calibration should be performed with the reference standard in the same heat treatment condition and at the same temperature as the material being inspected. In addition, if the reference standard is not fabricated from the same material as the part to be inspected, you must consider whether the velocity change is the same for both materials (same thermal coefficient of expansion for both the heat treatment condition and material temperature). A temperature response curve can also be developed to address the effect of part temperature. Material having high levels of porosity or attenuation or materials with rough surfaces should be examined using equipment having an A-scan display to minimize the possibility of errors (see 4.5).

4.3.2 If measurements are performed on multi-layer structures, only the layer in contact with the transducer can normally be measured. (Although not recommended, in the case of bonded structures, it is sometimes possible to measure each layer depending on the type and quality of the bond. This type of inspection should only be accomplished using a specific procedure.)

4.3.3 In the case of welded, clad, or brazed layers, both layers will normally be measured unless a disbond is present. Although not recommended, if this is being attempted, the material velocity and thickness of each layer (including the weld, clad or braze material) must be considered and represented in the calibration standard.

4.3.4 Surface coatings such as paint or plating will affect thickness readings. Although not recommended, if the thickness of the coating is known and is constant throughout the part being measured, it may be possible to fabricate a standard with a coating of equivalent thickness. Instruments having multi-echo measurement capabilities are recommended when measuring coated materials.

4.3.5 Ultrasonic thickness gauging is typically not recommended for measuring corroded material or material with extremely rough contact or back surfaces. This is due to attenuation and scattering which can occur, resulting in erroneous measurements. It is recommended that surfaces be blended smoothed and/or corrosion removed prior to taking measurements. If the measurement of corroded materials is necessary, the use of focused transducers and ultrasonic C-scan systems is recommended for best results.

4.3.6 Grain size and shape will affect the level of accuracy and may preclude the use of ultrasonic thickness testing methods. Materials exhibiting large, columnar type grain structures will yield a less accurate measurement than materials with small, equiaxed grain structures.

4.4 Operator Technique

4.4.1 Transducer handling pressures can affect the accuracy of thickness readings. An increase in pressure will produce thinner readings. The same contact pressure should be used during calibration and testing. Spring-loaded transducers can also be used to minimize this effect.

4.4.2 Transducers must be held so that the sound beam is directed normal (90 degrees) to the back surface of the material under inspection. As with non-parallel surfaces, changes in transducer contact angles can reduce the accuracy of readings due to both sine error (angular sound path) and distortion of the reflected sound beam.

4.5 Equipment Considerations

4.5.1 Direct-thickness readout instruments normally read the thickness at the first half cycle of a wave train which exceeds some set amplitude and fixed time. If the amplitude of the back reflection from the measured material is different from the amplitude of the back reflection from the calibration standard, the thickness reading may be taken on a different half cycle in the wave train, thereby producing an error. Signals from porosity can also produce erroneous thickness readings.

4.5.2 Direct-thickness readout instruments are not recommended for use when the calibration standard and the item to be inspected are from dissimilar materials or when the material to be inspected contains porosity as erroneous thickness readings may be obtained. Use of instruments with an A-scan display to monitor back wall reflections can minimize the potential for inaccurate results.

5. TECHNICAL REQUIREMENTS

5.1 Written Procedure Requirements

Ultrasonic thickness tests shall be done in accordance with this procedure or a detailed written procedure specific to the component being inspected. Because of the number of variables, when the measurement of the same component is to be conducted on a routine basis, a detailed procedure is recommended.

5.1.1 Procedures shall comply with the general requirements of this document and shall provide any additional specific information required to set up and calibrate the equipment and perform the tests.

5.1.2 Each procedure shall be verified and approved by certified ultrasonic Level III personnel.

5.1.3 Each procedure shall include not less than the following information:

5.1.3.1 A specific description of the area to be checked, the material type, nominal thickness, and acceptance criteria.

5.1.3.2 The required instrument, transducer, fixturing, reference standard, and couplant.

5.2 Equipment and Materials

5.2.1 Instruments

Thickness measurement instruments can be divided into four basic categories:

5.2.1.1 Flaw detectors with A-scan display (only).

NOTE: Flaw detectors without direct thickness readout are not recommended for precision thickness gauging.

5.2.1.2 Flaw detectors with A-scan display and direct thickness readout.

5.2.1.3 Digital thickness gauges with direct thickness readout.

5.2.1.4 Digital thickness gauges with A-scan display.

5.2.2 Transducers/Search Units

Most pulse-echo type search units (straight beam contact, delay line, and dual element) with frequency ranges between 2.25 MHz and 10 MHz are acceptable for use with flaw detectors with A-scan presentations. Highly damped, high frequency transducers (10 MHz or higher) are generally required for thicknesses less than about 0.025 inch (0.63 mm). Many digital thickness gauges require the use of a specific transducer or transducers to provide accurate measurements. Instrument manufacturers recommendations should be followed.

5.2.3 Reference Standards

Reference standards can be fabricated in a variety of configurations. Figures 1 and 2 provide examples of typical reference standards. Regardless of the configuration, reference standards shall meet the following criteria:

5.2.3.1 Metal standards must be identified as to their material type, alloy, and heat treat condition.

5.2.3.2 Nonmetallic standards (i.e., fiberglass and graphite) must be identified as to their material type, cure pressure, and cure temperature.

5.2.3.3 Each step used for calibration must be marked with its thickness, to the nearest 0.001 inch (0.025 mm).

5.2.3.4 Length and width of each step must be large enough to prevent interfering responses resulting from beam spread. Generally, 0.75 inch (19.0 mm) minimum is acceptable for thicknesses up to 1.0 inch (25.4 mm).

5.2.3.5 Surface finish should be representative of the item being tested.

5.2.4 Couplant

Low viscosity couplants are recommended. Water, propylene glycol, or any commercially available ultrasonic couplant compatible with the material to be inspected may be used.

5.3 Personnel Qualification

Personnel performing ultrasonic thickness testing shall be qualified in ultrasonic testing in accordance with Spec 105, NAS410, SNT-TC-1A, or other manner acceptable to local regulatory authority or as agreed upon between the supplier and customer.

5.4 Equipment Calibration

5.4.1 Instrument calibration can be divided into two separate categories:

5.4.1.1 Calibration of the display or analog portion of the instrument (applicable to instruments with A-scans only). Exact calibration of the display is generally not required.

5.4.1.2 Calibration of the numeric display or digital portion of the instrument.

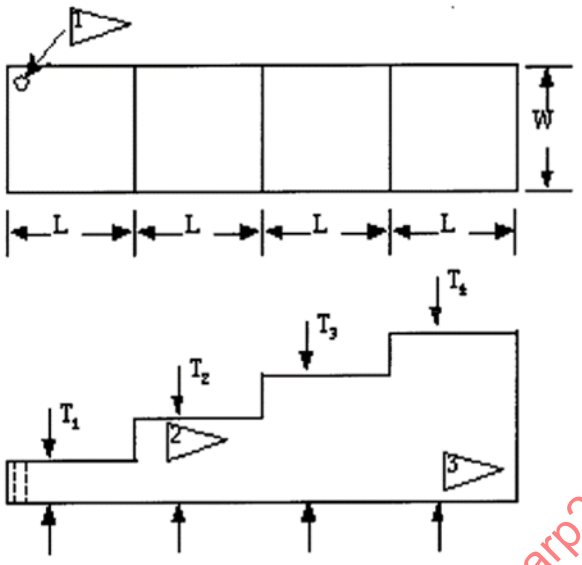

Table of Dimensions				
Four-Step Calibration Block				
	Dimension		Tolerance	
Legend	Inches	Millimeters	Inches	Millimeters
T_1	0.250	6.35	0.001	0.025
T_2	0.500	12.70	0.001	0.025
T_3	0.750	19.05	0.001	0.025
T_4	1.000	25.40	0.001	0.025
L	0.75	19.0	0.02	0.5
W	0.75	19.0	0.05	1.3

Notes	

• Material to be as specified.
• Surface finish:
  ○ "T" faces: 32 rms or better.
  ○ Other surfaces: 63 rms or better.
• All "T" dimensions to be after any specified plating or anodizing.
• Break sharp edges. Edges may be beveled or rounded providing the edge dimension is not reduced more than 0.020 inch (0.50 mm).	

1	Optional 1/16 inch (1.6 mm) diameter through hole used for block support during plating. Locate center 1/16 inch (1.6 mm) block from edge.
2	Indelibly mark the side of each step with actual thickness to nearest 0.001 inch (0.025 mm).
3	Indelibly mark the side of block with the following: • Metallic standards: Material type, alloy, and heat treatment. • Non-metallic standards (i.e., fiberglass and graphite): Material type, cure pressure, and cure temperature.

Figure 1 - Typical four-step calibration block

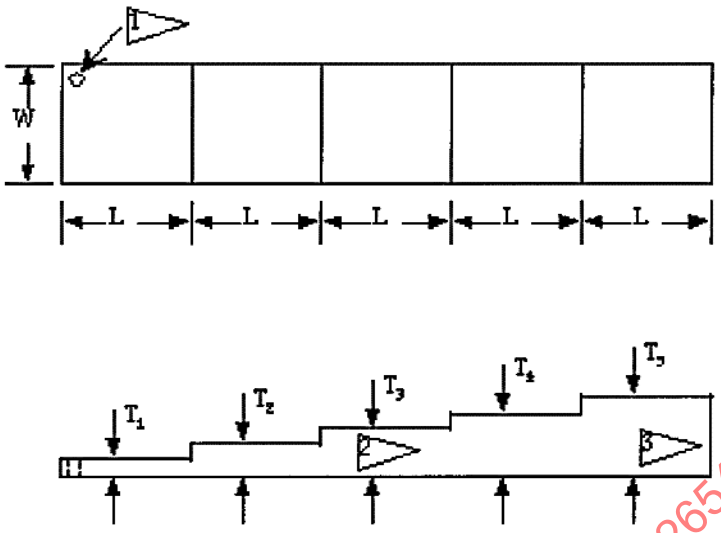

Table of Dimensions				
Thick Five-Step Calibration Block				
	Dimension		**Tolerance**	
Legend	**Inches**	**Millimeters**	**Inches**	**Millimeters**
T_1	0.100	2.54	0.001	0.025
T_2	0.200	5.08	0.001	0.025
T_3	0.300	7.62	0.001	0.025
T_4	0.400	10.16	0.001	0.025
T_5	0.500	12.70	0.001	0.025
L	0.75	19.0	0.02	0.5
W	0.75	19.0	0.05	1.3
Thin Five-Step Thick Calibration Block				
	Dimension		**Tolerance**	
Legend	**Inches**	**Millimeters**	**Inches**	**Millimeters**
T_1	0.020	0.51	0.001	0.025
T_2	0.040	1.02	0.001	0.025
T_3	0.060	1.52	0.001	0.025
T_4	0.080	2.03	0.001	0.025
T_5	0.100	2.54	0.001	0.025
L	0.75	19.0	0.02	0.5
W	0.75	19.0	0.05	1.3

NOTES:	

• Material to be as specified.
• Surface finish:
  ○ "T" faces: 32 rms or better.
  ○ Other surfaces: 63 rms or better.
• All "T" dimensions to be after any specified plating or anodizing.
• Break sharp edges. Edges may be beveled or rounded providing the edge dimension is not reduced more than 0.020 inch (0.50 mm).	

1	Optional 1/16 inch (1.6 mm) diameter through hole used for block support during plating. Locate center 1/16 inch (1.6 mm) block from edge.
2	Indelibly mark the side of each step with actual thickness to nearest 0.001 inch (0.025 mm).
3	Indelibly mark the side of block with the following: • Metallic standards: Material type, alloy, and heat treatment. • Non-metallic standards (i.e., fiberglass and graphite): Material type, cure pressure, and cure temperature.

Figure 2 - Typical five-step calibration block

5.4.2 Obtain an appropriate calibration standard. Calibration must be performed using one of the following:

5.4.2.1 A reference standard as described in 5.2.3.

5.4.2.2 The item being tested (see Note).

5.4.2.3 Any material (i.e., raw stock or scrap hardware) of the same type (i.e., form, alloy, and condition) as the item being tested.

NOTE: At least two steps of known thickness must be used for calibration. One must be near the maximum thickness to be measured and one must be less than the minimum to be measured. As a general rule, the thin step should be no less than one-half the thickness and the thick step should be no greater than twice the thickness of the material to be measured.

5.4.3 Select an appropriate transducer. Unless specific transducers are required by the instrument manufacturer or written procedure, the following items should be considered when selecting a transducer:

NOTE: If transducers other than those specified by the manufacturer are used, erroneous readings can result.

5.4.3.1 Highly damped transducers with frequencies of 10 MHz or higher will provide the best resolution. Lower frequencies may be necessary when inspecting porous materials or materials with rough surfaces.

5.4.3.2 Transducers with larger contact areas will generally provide more stable readings; however, depending on part geometry, the guidelines of 4.2 should be used.

5.4.3.3 Delay line transducers are generally recommended for use on thin materials (less than 0.050 inch [1.27 mm]) because of “dead zone” effects or the ability to resolve the reflected sound beam from the initial pulse. This is a function of the transducer characteristics (damping, frequency, and diameter), as well as the material. The use of a water column can also reduce the dead zone of the transducers.

NOTE: Delay line transducers require couplant between the delay tip and transducer face as shown in Figure 3. Replace couplant any time the delay tip is removed, or difficulty obtaining thickness readings or back surface reflections is experienced.

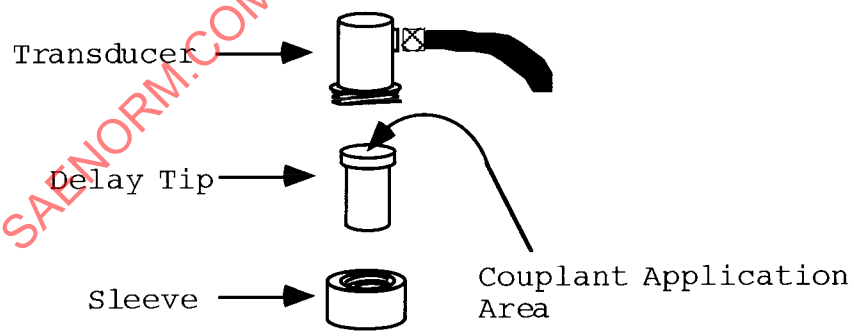

Figure 3 - Couplant application area

5.4.4 The basic analog and digital calibration sequence is outlined below. Because of differences in equipment, some of the steps described may not be applicable or may vary considerably. The equipment manufacturers manual should be referenced for specific calibration instructions:

NOTE: Different instrument manufacturers often use different terminology to describe the same control(s). The following instructions use the most common terminology.

5.4.4.1 Set instrument frequency to match the transducer.