



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

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Documents

Document Sharing Hub

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)			Acoustic-Impedance (lbs/ft ² /μs)	Density (lbs/ft ³)
	V1 & V2 (Long.)	V3 (Shear)	V4 (Surface)		
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 Babbitt	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)			Acoustic-Impedance (lbs/ft ² /μs)	Density (lbs/ft ³)
	V1 & V2 (Long.)	V3 (Shear)	V4 (Surface)		
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)			Acoustic-Impedance (gm/cm ² /μs)	Density (gm/cm ³)
	V1 & V2 (Long.)	V3 (Shear)	V4 (Surface)		
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 Babbitt	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	0.1671		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			