SCOPE OF ACCREDITATION TO ISO/IEC 17025:2017
& ANSI/NCSL Z540-1-1994

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CALIBRATION

Valid To: May 31, 2027 Certificate Number: 1078.01

In recognition of the successful completion of the A2LA evaluation process (including an assessment of the organization's compliance with R205 – A2LA's Calibration Program Requirements), accreditation is granted to this laboratory to perform the following calibrations[1, 15]:

I. Acoustical Quantities

Parameter/Equipment	Range	CMC[2, 8] (±)	Comments
Sound Pressure Level[3]			
Sound Level Calibrators	(85 to 140) dB 125 Hz to 4 kHz	0.20 dB + 0.032 %	Piston phone, transducer
Sound Level Meters	(94 & 114) dB 250 Hz, 1 kHz	0.4 dB	Sound level calibrator
Frequency Response[3] – Sound Level Meters	94 dB, 104 dB & 114 dB		Sound level calibrator
	31.5 Hz, 63 Hz, 125 Hz 250 Hz, 500 Hz, 1 kHz 2 kHz, 4 kHz 8 kHz 12.5 kHz, 16 kHz	0.59 dB 0.48 dB 0.7 dB 0.93 dB 1.2 dB	

II. Chemical

Parameter/Equipment	Range	CMC[2, 4, 8] (±)	Comments
Conductivity Meters	(1 to 10) µS/cm (50 to 100) µS/cm (1000 to 1413) µS/cm (5 to 100) mS/cm (150 to 200) mS/cm	0.34 µS/cm 0.96 µS/cm 5.5 µS/cm 750 µS/cm 1.5 mS/cm	Conductivity solutions
pH Meters[3]	4 pH 7 pH 10 pH	0.0.0 11 pH 0.00 11 pH 0.00 12 pH	Standard buffers
Refractometers[3]	(0 to 100) % Brix	0.2 % + 0.6R	Standard solutions

III. Dimensional

Parameter/Equipment	Range	CMC[2, 4, 13] (±)	Comments
Angle Blocks	Up to 60°	(0.36 + 1.1Θ/20) arcsec	Sine bar, gage blocks, gage amp & probe, where Θ = angle
Angle Plates[3]	Up to 48 in	65 µin or (12 µin/in + 30 µin), whichever is greater	Gage amp. probe, indi-square & test indicator
Angle – Measure	(20 to 360) °	0.061 °	Rotary encoder
Articulating Arm[3] (CMM) –			ASME B89.4.22-2004
Single Point Articulation	(2 to 10.5) ft	R_{sys}	R_{sys} is the std. dev. of repeated UUT test results during each test parameter
Effective Diameter	1 in (25.4 mm)	16 µin + R_{sys}	
Volumetric	Up to 76 in	(3.7L + 14) µin + R_{sys}	
Scanner Head	1 in (25.4 mm)	34 µin + R_{sys}	

Parameter/Equipment	Range	CMC[2, 4] (±)	Comments
Bench Center –			
Center Parallelism	Up to 24 in	(68 + 4*L*) µin	Gage amp w/ probe
Base Flatness & Base Parallelism	Up to 24 in	(62 + 2.5*L*) µin	
Bore Gages[3]	Up to 12 in	21 µin/in or 0.6*R* (Whichever is Greater)	SIP302M
Box Parallels –			
Parallelism	5 in × 10 in × 10 in	28 µin	Gage amp w/probe, square
Squareness	5 in × 10 in × 10 in	12 µin/in + 38 µin	
Calipers[3] (Including Intertest, Oditest, Snap Jaw & Other OD Calipers) –			
Resolution 0.0001 in	Up to 2 in (2 to 12) in	78 µin 70 µin + 4 µin/in	Gage blocks
Resolution 0.0005 in	Up to 24 in (24 to 60) in	450 µin 340 µin + 3.7 µin/in	
Resolution 0.001 in	Up to 30 in (30 to 100) in	840 µin 700 µin + 3.4 µin/in	
Chamfer Gages/Hole Gages[3]	Up to 12 in	20 µin + 0.6*R*	Cylindrical rings
Clinometers & Inclinometers, & Electronic Levels	Up to 360°	0.18 arcseconds + 37 parts in 10^6	Sine bar/gage blocks

Parameter/Equipment	Range	CMC[2, 4, 8] (±)	Comments
CMMs – Imaging (Video CMMs/Vision Systems)[3]	XY Diagonal Up to 36.5 in		ISO 10360-7 (Unidirectional)
Length Measurements:			
EUX, EUY, EUXY	Up to 24 in	(23 + 2.9*L*) µin	Glass scales
EUV	Up to 2 in	(15 + 2.9*L*) µin	Glass scales
EZ	Up to 8 in (Z-Axis)	(41 + 3.2*L*) µin	Gage blocks
Squareness – ESQ	Up to 8 in (Z-Axis)	(19 + 130*L*) µin	Ball bar
Probing Performance	Diameter Measured:		
PF2D, PFV2D	(0.012 to 0.12) in (0.12 to 0.4) in.	16 µin 25 µin	Test circles
CMMs[3] –			
Length Error (E_L)	Up to 52 in	40 µin + 5.2 min/in	ASME B89.4.1.10360.2, ISO 10360-2
Repeatability Range (R_0)	Up to 52 in	22 µin + 3 µin/in	
Coating Thickness Shims/Precision Shims	25 µin to 0.5 in	19 µin + 82 µin/in	ULM
Concentricity Gage	N/A	130 µin + 8 µin/in	Indicator, bench center
Cylindrical Plugs[3]	Up to 4 in (4 to 20) in	4 µin + 5 µin/in 4 µin + 5.4 µin/in	ULM, gage blocks
Cylindrical Rings[3]	(0.1 to 4) in (4 to 8.5) in (8.5 to 18) in (18 to 36) in	4 µin + 5 µin/in 4 µin + 5.4 µin/in 5.2 µin + 5.5 µin/in 50 µin + 3 µin/in	ULM, gage blocks
Displacement Velocity[3]	(0.1 to 40) in/min	0.13 %	String encoder, digital indicator, stopwatch; ASTM E2658

Parameter/Equipment	Range	CMC[2, 4] (±)	Comments
External Spline Gages[3] –			
Measurement Over Pins	Up to 8 in	(170 + 28*D*) µin	ULM
Circular Tooth Thickness	Up to 8 in	(110 + 16*L*) µin	Vision system
Major Diameter	Up to 8 in	(28 + 12*D*) µin	ULM
Includes Screw Pitch Gages, Drill Gages, Taper Gages, Center Gages, Sheet & Wire Gages, Angle Gages, Radius Gage, Functional Gages			
Fixtures, Gages & Parts			
1D – Distance			
X Axis Y Axis Z Axis	Up to 27.6 in Up to 39.36 in Up to 23.62 in	110 µin + 2.6 µin/in 110 µin + 2.9 µin/in 110 µin + 2.4 µin/in	CMM
2D – Angle, Angularity			
X & Y Axis Z & Y Axis Z & X Axis	Up to 360 °	5 arc-sec 6.7 arc-sec 6.7 arc-sec	
2D – Circularity, Circular Runout, Roundness, Diameter, Radius, Straightness, Parallelism, Perpendicularity			
X & Y Axis Z & Y Axis Z & X Axis	Up to (27.6 x 39.36 in) Up to (23.62 x 27.6) in Up to (23.62 x 39.36 in)	110 µin + 3.9 µin/in 110 µin + 2.4 µin/in 110 µin + 3.8 µin/in	
3D – Flatness, Cylindricity, Total Runout, Position, Concentricity, Coaxiality, Symmetry			
X & Y & Z Axis	Up to (23.62 x 27.6 x 39.36) in	110 µin + 4.6 µin/in	

Parameter/Equipment	Range	CMC[2, 4] (±)	Comments
Fixtures, Gages & Parts			
1D – Distance			
X Axis	Up to 11.81 in	94 µin + 4.6 µin/in	Vision system
Y Axis	Up to 7.87 in	94 µin + 4.6 µin/in	
Z Axis	Up to 5.91 in	130 µin + 5.7 µin/in	
2D – Angle, Angularity			
X & Y Axis	Up to 360 °	4.2 arc-sec	
Z & Y Axis		7.3 arc-sec	
Z & X Axis		3.7 arc-sec	
2D – Circularity, Circular Runout, Roundness, Diameter, Radius, Straightness, Parallelism, Perpendicularity			
X & Y Axis	Up to (11.81 x 7.87 in)	94 µin + 6.5 µin/in	
Z & X Axis	Up to (5.91 x 11.81) in	94 µin + 5.7 µin/in	
Z & Y Axis	Up to (5.91 x 7.87 in)	94 µin + 7.3 µin/in	
3D – Flatness, Cylindricity, Total Runout, Position, Concentricity, Coaxiality, Symmetry			
Z & X & Y Axis	Up to (5.91 x 7.87 x 11.81) in	94 µin + 8.6 µin/in	
Gage Amplifier & Probe(s)[3]			
Single Probe	Up to 0.025 in	8.9 µin	Gage blocks
Dual Probe	Up to 0.002 in	2.1 µin	
Gage Balls	Up to 4 in	(32 + 1.5*D*) µin	Universal length machine (ULM)

Parameter/Equipment	Range	CMC[2, 4] (±)	Comments
Gage Blocks	Up to 4 in (4 to 20) in	(3.1 + 3.2*L*) µin (3.3 + 3.2*L*) µin	Gage blocks & comparator
Height Gage[3]	Up to 20 in Up to 52 in	(7 + 4.6*H*) µin (7.7 + 6.2*H*) µin	Gage blocks, by request Reference stack, SOP
Height Measures[3]	Up to 0.0005 in (0.0005 to 2) in (0 to 24) in	13 µin (16 + 2.6*H*) µin (160 + 5.4*H*) µin	Heidenhain Certo Trimos Vertical 3
Indicators[3] – Dial, Digital, Test, & LVDTs LVDTs	Up to 4 in Up to 20 in	35 µin or 0.6*R* (Whichever is Greater) 77 µin + 150 µin/in	Indicator calibrator Gage blocks, digital multimeter, power supply
Indicator Calibrator[3]	Up to 4 in	12 µin + 0.6*R*	Gage blocks, amp w/probe
Laser Distance Meters	Up to 6.1 m	4.6 µm/m + 120 µm	ULM
Length & Thickness Standards, Feeler Gages[3] – Steel Field Calibration	 Up to 4 in (4 to 20) in (20 to 120) in Up to 16 in	 4 µin + 5 µin/in 4 µin + 5.4 µin/in 3.7 µin/in + 14 µin 5 µin + 14 µin/in + 4 µin/in/°C	 ULM, gage blocks ULM, gage blocks, Relative to 20/°C
Length – Air Amplifiers[3] Magnification: 10 000:1 and 16 000:1 8000:1 and 5000:1 4000:1 and 2500:1	 ± 0.0003 in ± 0.00075 in ± 0.0015 in	 14 µin (0.35 µm) 21 µin (0.53 µm) 21 µin (0.53 µm)	 Mahr Federal AMR series Restrictor kits

Parameter/Equipment	Range	CMC[2, 4, 8] (±)	Comments
Levels (Spirit, Bubble, Machinist)[3]	Up to 96 in	5.1 arcseconds + (37 x 10^{-6})	Surface plate & gage blocks
Linear Measurement of Machine Tools Scales[3]	Up to 20 ft	1.5 µin/in + 0.58 µin	Laser
Linear Scales/Reticles & Stage Micrometers –			
2D	Up to 12 in	(110 + 16*L*) µin	Vision system
1D	Up to 30 in	14µin + 1.5 µin/in	Gitterperioden interferometer
Micrometers[3] –			
Inside Depth Tri-Bores Outside Thread (Screw, Thread, Pitch, Point) & Groove	Up to 294 in Up to 24 in Up to 14 in Up to 80 in Up to 4 in	32 µin + 12 µin/in 14 µin + 6.7 µin/in 35 µin + 4 µin/in 7.3 µin + 6.1 µin/in 7.3 µin + 8.5 µin/in	ULM, gage blocks or rings
Microscopes[3] –			
Linear Accuracy	Up to 25 mm	0.25 µm + 5.7 µm/m	Glass scales, stage micrometers
Optical Comparator[3] –			
Linear	Up to 24 in	120 µin + 11 µin/in	Glass scale
Angle	(0 to 360)°	2’	Protractor
Magnification	10x, 20x, 50x, 62.5x, 100x, 200x	0.000 12 in	Calibration sphere

Parameter/Equipment	Range	CMC[2, 4] (±)	Comments
Optical Flats –			
Flatness	Up to 8 in	3.4 µin	Reference flat & monochromatic light source
Parallelism[11]	Up to 1.5 in Diameter & 1 in Thickness	3.1 µin	Gage block comparator
Parallels[3] –			
Parallelism	Up to 72 in	1 µin/in + 20 µin	Gage amp w/ probe
Pitch Micrometer Standards –			
Length	Up to 12 in	(22 + 6*L*) µin	UMM
Angle	Up to 60°	54″	Vision system
Precision Diameter Tapes	Up to 38 in (38 to 54) in (54 to 780) in	1.3 µin/in + 280 µin 7.5 µin/in + 250 µin 1.4 µin/in + 430 µin	Setting discs, ULM
Profilometers[3]	(15 to 150) µin Ra	2.8 µin	Roughness specimen
Protractor – Digital & Mechanical[3]	(0 to 180)°	0.0053° (19 arcsec)	Sine bar & gage blocks
Riser Blocks & Stands	Up to 24 in	2 µin/in + 23 µin	Gage amplifier w/ probe
Roundness Testers[3] –			
Coning Error	Up to 16 in	11 µin	Test ball & riser cylinder
Axial Error	Up to 16 in	11 µin	Test ball
Radial Accuracy	Up to 16 in	11 µin	Test ball
Z-Axis Straightness	(0.1 to 12) in	(14 + 12*H*) µin	Cylindrical square; in the CMC

Parameter/Equipment	Range	CMC[2, 4] (±)	Comments
Sine Plates/Bars[3] –			
Flatness/Parallelism & Parallelism Cylinder to Base	Up to 20 in	53 µin	Gage amp w/ probe, angle blocks & gage blocks
Angle Calibration Center of Rolls	(0 to 90)°	0.000 45° (1.6 arcsec, 16 µin/in)	
	Up to 20 in	17 µin/in (1.8 arcsec)	
Sand Sieves	20 µm to 125 mm 800 µin to 5 in	2.4 µm + 4.6 µm/m 94 µin + 4.6 µin/in	ASTM E11, vision system
Snap Gages[3] –			
Parallelism	Up to 20 in	97 µin	Box parallel with gage amp & probe
Linear Accuracy	Up to 20 in	1 µin/in + 49 µin	
Sphericity	Up to 4 in	17 µin	Spindle less sphericity fixture
Squares[3] –			
Master Squares (Class A Grade)	Up to 48 in	51 µin or (7 µin/in + 21 µin), (Whichever is Greater)	Indi-square & test indicator, gage amp & probe, gage locks
Granite, Steel, Cylindrical	Up to 48 in	65 µin or (12 µin/in + 30 µin), (Whichever is Greater)	
Straightness & Straight Edges[3]	Up to 72 in	1 µin/in + 19 µin	Gage amplifier w/ probe
	Up to 144 in	0.62 µin/in + 8 µin	Electronic levels
Step Gages, Step Bars, Reference Stacks	Up to 50 in	(9.7 + 3*H*) µin	Gage amp & probe, gage blocks

Parameter/Equipment	Range	CMC[2, 4] (±)	Comments
Surface Flatness	Up to 600 µin TIR Up to 2000 µin TIR Up to 0.006 in TIR Up to 0.02 in TIR	18 µin 72 µin 140 µin 710 µin	Gage amplifier w/ probe TIR = Total Indicated Reading
Surface Plates[3] –			
Flatness	18 in x 24 in to 72 in x 144 in	$8\sqrt{D}$ µin	Electronic levels
Repeatability	Up to 72 in x 144 in	34 µin	Repeat-o-meter
Surface Roughness[3]	(15 to 150) µin (Ra, Rz, Rt, Rp)	3.4 µin	Verification of specimens per ASME B46.1
Tape Measures, Rulers[3]	Up to 10 ft (10 to 300) ft	1200 µin + 2.1 µin/in 220 µin + 6.8 µin/in	ULM
Tapered Plugs[3] –			
Simple Pitch Diameter	Up to 18 in	(100 + 8*D*) µin	Thread wires/UMM
Notch Height	Up to 18 in	13 µin/in + 94 µin	Height measuring machine
Tapered Rings[3] –			
Taper	Up to 18 in	400 µin	NPT master plug, ULM
Standoff & Thickness	Up to 18 in	120 µin	NPT master plug & height measuring machine
Functional Diameter	Up to 2 in	(300 + 8*D*) µin	
Thread Plugs[3] –			
Simple Pitch Diameter	Up to 20 in	82 µin + 6.8 µin/in	3-wire method
Major Diameter	Up to 4 in (4 to 8.5) in (8.5 to 20) in	4 µin + 5 µin/in 4 µin + 5.4 µin/in 5.2 µin + 5.5 µin/in	ULM, gage blocks

Parameter/Equipment	Range	CMC[2, 4, 8] (±)	Comments
Thread Rings[3] –			
Simple Pitch Diameter	Up to 18 in	(140 + 9*D*) µin	ULM
Minor Diameter	Up to 2 in	(70 + 13*D*) µin	
Functional Diameter	Up to 18 in	(100 + 8*D*) µin	w/ set plug
Thread Wires	Up to 0.5 in	(8.5 + 7*D*) µin	ULM, gage blocks
Universal Length Machines[3] (ULMs)	Up to 4 in (4 to 24) in Up to 120 in	1.5 µin + 1.2 µin/in 1.3 µin + 1.8 µin/in 0.69 µin + 0.51 µin/in	Gage blocks Laser interfermometer
V-Blocks –			
Parallelism Side	8 in × 8 in × 8 in	28 µin	Gage amp w/ probe
V Parallelism	8 in × 8 in × 8 in	1 µin/in + 28 µin	Cylindrical square
Squareness	8 in × 8 in × 8 in	9.7 µin/in + 48 µin	Cylindrical plug
Wire Crimpers[3] –			
Crimp Height	Up to 00 Gauge	0.0024 in	Micrometer
Crimping Chamber	Up to 00 Gauge	(10 + 19*D*) µin	Pin
Ratchet Inspection	Up to 00 Gauge	120 µin	Feeler gage
Crimp Dies	Up to 1 in (25 mm)	94 µin + 4.6 µin/in	Vision system
Crimper & Banding Tool Break Force	Up to 150 lbf	0.33 lbf + 0.41 %	Pull tester

IV. Electrical – DC/Low Frequency

Parameter/Range	Frequency	CMC[2, 7, 8, 14] (±)	Comments
AC Current – Generate & Measure[3]			Max frequency up to 3 mA is 30 kHz.
10 µA to 20 A	10 Hz to 50 kHz[3]	See Table IV.a	Fluke 5790A, 5700A/EP, A40s, standard resistors
(20 to 70) A	10 Hz	85 µA/A	Fluke 52120A, A40B-100, DMM
(20 to 100) A	55 Hz	0.013 %	
	300 Hz	0.012 %	
	1 kHz	0.012 %	
	5 kHz	0.036 %	
(20 to 80) A	6 kHz	0.039 %	
(20 to 50) A	10 kHz	0.092 %	
Measure Only[3]			
(1 to 10) A	Up to 1 kHz	0.02 %	Ohm Labs CS-10
(1 to 20) A	Up to 1 kHz	0.026 %	Ohm Labs CS-20
(1 to 500) A	Up to 60 Hz	0.023 %	Ohm Labs CS-500
(0 to 20.2) A	1 Hz to 2 kHz	0.66 mA + 0.8 mA/A	Fluke 8588A
	(2 to 10) kHz	0.64 mA + 0.8 mA/A	
(0 to 30.2) A	1 Hz to 2 kHz	12 mA + 0.8 mA/A	
	(2 to 10) kHz	12 mA + 1.2 mA/A	
(100 to 1000) A	60 Hz	0.5 %	Current clamp-on meter
Generate Only–Turn Amps[3]			
(20 to 120) A	(50 to 400) Hz	0.055 % + 0.6 A	Fluke 55120A w/ 52120-3k & 52120-6k coils
(120 to 6000) A		0.80 % - 1.6 A	
(20 to 120) A	1000 Hz	0.24 % + 0.24 A	
AC Current – 50 Turn Coils			
Effective Current Transfer Ratio	25 Turn Amps, 50 Hz, 400 Hz	0.11 % of ratio	Comparison to standard coil
	500 Turn Amps, 50 Hz, 400 Hz	0.12 % of ratio	
	800 Turn Amps, 400 Hz	0.14 % of ratio	
	1000 Turn Amps, 50 Hz	0.14 % of ratio	

TABLE IV.a AC Current Generate / Measure[3] – CMCs

Current Range	10 Hz	20 Hz	40 Hz
(10 to 300) µA	170 µA/A + 0.03 nA	67 µA/A + 0.03 nA	37 µA/A + 0.03 nA
300 µA to 3 mA	170 µA/A + 0.3 nA	60 µA/A + 0.3 nA	29 µA/A + 0.3 nA
(3 to 10) mA	170 µA/A + 1 nA	69 µA/A + 1 nA	37 µA/A + 1 nA
(10 to 20) mA	170 µA/A + 2 nA	69 µA/A + 2 nA	37 µA/A + 2 nA
(20 to 30) mA	170 µA/A + 3 nA	69 µA/A + 3 nA	37 µA/A + 3 nA
(30 to 50) mA	170 µA/A + 5 nA	69 µA/A + 5 nA	37 µA/A + 5 nA
(50 to 100) mA	170 µA/A + 60 nA	69 µA/A + 60 nA	37 µA/A + 60 nA
(100 to 200) mA	170 µA/A + 120 nA	72 µA/A + 120 nA	37 µA/A + 120 nA
(200 to 300) mA	170 µA/A + 180 nA	72 µA/A + 180 nA	37 µA/A + 180 nA
(300 to 500) mA	170 µA/A + 300 nA	72 µA/A + 300 nA	37 µA/A + 300 nA
500 mA to 1 A	170 µA/A + 6 µA	72 µA/A + 6 µA	41 µA/A + 6 µA
(1 to 2) A	170 µA/A + 12 µA	75 µA/A + 12 µA	42 µA/A + 12 µA
(2 to 3) A	180 µA/A + 18 µA	81 µA/A + 18 µA	58 µA/A + 18 µA
(3 to 5) A	190 µA/A + 30 µA	85 µA/A + 30 µA	58 µA/A + 30 µA
(5 to 10) A	190 µA/A + 60 µA	100 µA/A + 60 µA	73 µA/A + 60 µA
(10 to 20) A	220 µA/A + 12 µA	130 µA/A + 12 µA	86 µA/A + 12 µA

Current Range	400 Hz	1 kHz	5 kHz
(10 to 300) µA	37 µA/A + 0.03 nA	37 µA/A + 0.03 nA	46 µA/A + 0.03 nA
300 µA to 3 mA	29 µA/A + 0.3 nA	30 µA/A + 0.3 nA	30 µA/A + 0.3 nA
(3 to 10) mA	35 µA/A + 1 nA	35 µA/A + 1 nA	36 µA/A + 1 nA
(10 to 20) mA	35 µA/A + 2 nA	35 µA/A + 2 nA	36 µA/A + 2 nA
(20 to 30) mA	35 µA/A + 3 nA	35 µA/A + 3 nA	36 µA/A + 3 nA
(30 to 50) mA	35 µA/A + 5 nA	35 µA/A + 5 nA	36 µA/A + 5 nA
(50 to 100) mA	35 µA/A + 60 nA	35 µA/A + 60 nA	36 µA/A + 60 nA
(100 to 200) mA	35 µA/A + 120 nA	35 µA/A + 120 nA	36 µA/A + 120 nA
(200 to 300) mA	35 µA/A + 180 nA	35 µA/A + 180 nA	36 µA/A + 180 nA
(300 to 500) mA	35 µA/A + 300 nA	35 µA/A + 300 nA	36 µA/A + 300 nA
500 mA to 1 A	39 µA/A + 6 µA	39 µA/A + 6 µA	40 µA/A + 6 µA
(1 to 2) A	40 µA/A + 12 µA	39 µA/A + 12 µA	40 µA/A + 12 µA
(2 to 3) A	56 µA/A + 18 µA	56 µA/A + 18 µA	56 µA/A + 18 µA
(3 to 5) A	56 µA/A + 30 µA	56 µA/A + 30 µA	56 µA/A + 30 µA
(5 to 10) A	72 µA/A + 60 µA	71 µA/A + 60 µA	72 µA/A + 60 µA
(10 to 20) A	85 µA/A + 12 µA	84 µA/A + 12 µA	85 µA/A + 12 µA

TABLE IV.a (cont) AC Current Generate / Measure[3] - CMCs

Current Range	10 kHz	20 kHz	50 kHz
(10 to 300) µA	46 µA/A + 0.03 nA	62 µA/A + 0.03 nA	79 µA/A + 0.03 nA
300 µA to 3 mA	30 µA/A + 0.3 nA	45 µA/A + 0.3 nA	48 µA/A + 0.3 nA
(3 to 10) mA	36 µA/A + 1 nA	36 µA/A + 1 nA	60 µA/A + 1 nA
(10 to 20) mA	36 µA/A + 2 nA	36 µA/A + 2 nA	63 µA/A + 2 nA
(20 to 30) mA	36 µA/A + 3 nA	36 µA/A + 3 nA	63 µA/A + 3 nA
(30 to 50) mA	36 µA/A + 5 nA	36 µA/A + 5 nA	63 µA/A + 5 nA
(50 to 100) mA	36 µA/A + 60 nA	39 µA/A + 60 nA	68 µA/A + 60 nA
(100 to 200) mA	36 µA/A + 120 nA	39 µA/A + 120 nA	68 µA/A + 120 nA
(200 to 300) mA	36 µA/A + 180 nA	39 µA/A + 180 nA	72 µA/A + 180 nA
(300 to 500) mA	36 µA/A + 300 nA	39 µA/A + 300 nA	72 µA/A + 300 nA
500 mA to 1 A	40 µA/A + 6 µA	52 µA/A + 6 µA	110 µA/A + 6 µA
(1 to 2) A	40 µA/A + 12 µA	52 µA/A + 12 µA	110 µA/A + 12 µA
(2 to 3) A	56 µA/A + 18 µA	61 µA/A + 18 µA	120 µA/A + 18 µA
(3 to 5) A	56 µA/A + 30 µA	70 µA/A + 30 µA	160 µA/A + 30 µA
(5 to 10) A	72 µA/A + 60 µA	89 µA/A + 60 µA	130 µA/A + 60 µA
(10 to 20) A	85 µA/A + 12 µA	110 µA/A + 12 µA	150 µA/A + 12 µA

Parameter/Range	Frequency	CMC[2, 8, 14] (±)	Comments
AC Power – Generate[3]	See Table below	See Table below	Fluke 5560A

(65 to 500) Hz	(12.2 to 122) W	(0.122 to 1.22) kW	(1.22 to 3.16) kW	(3.16 to 12.2) kW	(12.2 to 30.8) kW
Ø 60 ° PF=0.500	0.61 %				
Ø 70 ° PF=0.342	0.96 %				
Ø 80 ° PF=0.174	2 %				
500 Hz to 1 kHz	(12.2 to 122) W	(0.122 to 1.22) kW	(1.22 to 3.16) kW	(3.16 to 12.2) kW	(12.2 to 30.8) kW
Ø 0 ° PF=1.000	0.029 %	0.034 %	0.048 %	0.04 %	0.11 %
Ø 10 ° PF=0.985	0.13 %				0.16 %
Ø 20 ° PF=0.940	0.26%				0.28 %
Ø 30 ° PF=0.866	0.41%				0.42 %
Ø 40 ° PF=0.766	0.59 %				0.6 %
Ø 50 ° PF=0.643	0.83 %				
Ø 60 ° PF=0.500	1.2 %				

<table>
<tr><td>Parameter/Range</td><td colspan="2">Frequency</td><td>CMC[2, 8, 14] (±)</td><td colspan="2">Comments</td></tr>
<tr><td>AC Power – Generate[3]</td><td colspan="2">See Table below</td><td>See Table below</td><td colspan="2">Fluke 5560A</td></tr>
<tr><td>500 Hz to 1 kHz</td><td>(12.2 to 122) W</td><td>(0.122 to 1.22) kW</td><td>(1.22 to 3.16) kW</td><td>(3.16 to 12.2) kW</td><td>(12.2 to 30.8) kW</td></tr>
<tr><td>Ø 70 °
PF=0.342</td><td colspan="5">1.9 %</td></tr>
<tr><td>Ø 80 °
PF=0.174</td><td colspan="5">4 %</td></tr>
<tr><td>(1 to 5) kHz</td><td colspan="2">(6 to 60) W</td><td colspan="2">(60 to 600) W</td><td>(0.6 to 1.55) kW</td></tr>
<tr><td>Ø 0 °
PF=1.000</td><td colspan="3">0.071 %</td><td colspan="2">0.082 %</td></tr>
<tr><td>Ø 10 °
PF=0.985</td><td colspan="5">0.64 %</td></tr>
<tr><td>Ø 20 °
PF=0.940</td><td colspan="5">1.3 %</td></tr>
<tr><td>Ø 30 °
PF=0.866</td><td colspan="5">2 %</td></tr>
<tr><td>Ø 40 °
PF=0.766</td><td colspan="5">2.8 %</td></tr>
<tr><td>Ø 50 °
PF=0.643</td><td colspan="5">4 %</td></tr>
<tr><td>(5 to 10) kHz</td><td colspan="3">(3 to 30) W</td><td colspan="2">(30 to 300) W</td></tr>
<tr><td>Ø 0 °
PF=1.000</td><td colspan="3">0.28 %</td><td colspan="2">0.34 %</td></tr>
<tr><td>Ø 10 °
PF=0.985</td><td colspan="5">1.4 %</td></tr>
<tr><td>(5 to 10) kHz</td><td colspan="3">(3 to 30) W</td><td colspan="2">(30 to 300) W</td></tr>
<tr><td>Ø 20 °
PF=0.940</td><td colspan="5">2.7 %</td></tr>
<tr><td>Ø 30 °
PF=0.866</td><td colspan="5">4.2 %</td></tr>
<tr><td>(10 to 30) kHz</td><td colspan="5">(3 to 300) W</td></tr>
<tr><td>Ø 0 °
PF=1.000</td><td colspan="5">1.1 %</td></tr>
<tr><td>Ø 10 °
PF=0.985</td><td colspan="5">3.4 %</td></tr>
<tr><td>Ø 20 °
PF=0.940</td><td colspan="5">5.9 %</td></tr>
<tr><td colspan="2">Phase Shift – Generate
(PF=1)

± (0 to 90) ° LEAD/LAG</td><td colspan="2">(3 to 65) Hz
(65 to 500) Hz
500 Hz to 1 kHz
(1 to 5) kHz
(5 to 10) kHz
(10 to 30) kHz</td><td colspan="2">Ø 0.1 °
Ø 0.2 °
Ø 0.4 °
Ø 1.9 °
Ø 3.9 °
Ø 7.8 °</td><td>Fluke 5560A</td></tr>
</table>

Parameter/Range	Frequency	CMC[2, 7] (±)	Comments
AC Voltage – Measure & Generate[3]			
(0.6 to 2.2) mV	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz 500 kHz to 1 MHz	0.14 % + 1.1 µV 0.062 % + 1.1 µV 0.040 % + 1.1 µV 0.067 % + 1.6 µV 0.097 % + 2.0 µV 0.19 % + 3.2 µV 0.19 % + 6.3 µV 0.31 % + 6.3 µV	Fluke 5790A, 5720A
(2.2 to 7) mV	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz 500 kHz to 1 MHz	0.068 % + 1.1 µV 0.032 % + 1.1 µV 0.021 % + 1.1 µV 0.034 % + 1.6 µV 0.049 % + 2.0 µV 0.096 % + 3.2 µV 0.11 % + 6.3 µV 0.19 % + 6.3 µV	
(7 to 22) mV	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz 500 kHz to 1 MHz	0.024 % + 1.1 µV 0.016 % + 1.1 µV 0.0096 % + 1.1 µV 0.018 % + 1.6 µV 0.026 % + 2.0 µV 0.066 % + 3.2 µV 0.074 % + 6.3 µV 0.14 % + 6.3 µV	
(22 to 70) mV	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz 500 kHz to 1 MHz	0.022 % + 1.2 µV 0.012 % + 1.2 µV 0.0071 % + 1.2 µV 0.012 % + 1.6 µV 0.025 % + 2.0 µV 0.048 % + 3.2 µV 0.063 % + 6.3 µV 0.096 % + 6.3 µV	
(70 to 220) mV	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz 500 kHz to 1 MHz	0.017 % + 1.2 µV 0.0076 % + 1.2 µV 0.0037 % + 1.2 µV 0.0058 % + 1.6 µV 0.013 % + 2.0 µV 0.022 % + 3.2 µV 0.031 % + 6.3 µV 0.079 % + 6.3 µV	

Parameter/Range	Frequency	CMC[2, 7, 8] (±)	Comments
AC Voltage – Measure & Generate[3] (cont)			
(220 to 700) mV	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz 500 kHz to 1 MHz	0.017 % + 1.2 µV 0.0061 % + 1.2 µV 0.0029 % + 1.2 µV 0.0046 % + 1.6 µV 0.0063 % + 2.0 µV 0.017 % + 4.3 µV 0.025 % + 6.3 µV 0.074 % + 6.3 µV	Fluke 5790A, 5720A
(0.7 to 2.2) V	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz 500 kHz to 1 MHz	0.018 % 0.0061 % 0.0022 % 0.004 % 0.0057 % 0.015 % 0.023 % 0.074 %	
(2.2 to 7) V	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz 500 kHz to 1 MHz	0.016 % 0.0054 % 0.0024 % 0.0041 % 0.0065 % 0.018 % 0.035 % 0.097 %	
(7 to 22) V	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz 500 kHz to 1 MHz	0.016 % 0.0057 % 0.0030 % 0.0039 % 0.0065 % 0.018 % 0.033 % 0.097 %	
(22 to 70) V	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz 500 kHz to 1 MHz	0.016 % 0.0058 % 0.0034 % 0.0050 % 0.0075 % 0.016 % 0.032 % 0.09 %	

Parameter/Range	Frequency	CMC[2, 7, 14] (±)	Comments
AC Voltage – Measure & Generate[3] (cont)			
(70 to 220) V*	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz	0.016 % 0.0058 % 0.0034 % 0.0056 % 0.0080 % 0.017 % 0.039 %	Fluke 5790A, 5720A *Subject to 2.2 x 10^7 V-Hz limitation
(220 to 700) V	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz	0.016 % 0.0080 % 0.0038 % 0.011 % 0.040 %	Fluke 5790A, 5720A, 5725A
(700 to 1000) V**	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz	0.016 % 0.0080 % 0.0036 % 0.011 % 0.040 %	** Measure only
AC Voltage – Measure[3]			
(0 to 12.12) mV (12.12 to 1.212) V (1.212 to 12.12) V (12.12 to 121.2) V (121.2 to 1050) V	(1 to 10) Hz	1.3 µV + 67 µV/V 11 µV + 60 µV/V 0.14 mV + 62 µV/V 1.5 mV + 68 µV/V 34 mV + 90 µV/V	Fluke 8588A
AC High Voltage – Measure[3]			
(1 to 10) kV (10 to 100) kV	(50 to 60) Hz	9.6 V + 0.8 V/kV 61 V + 5.8 V/kV	Vitrek 4700A w/HVL-150 probe
AC High Voltage – Generate[3]			
(1 to 5) kV	60 Hz	0.24 % + 1 V	Assoc. Res. 3565D

Parameter/Range	Frequency	CMC[2, 5] (±)	Comments
AC Voltage – Measure[3] ≤2 MHz			
(0 to 10) mV	(1 to 40) Hz 40 Hz to 1 kHz (1 to 20) kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz	0.023 % + 2 µV 0.018 % + 0.74 µV 0.026 % + 0.74 µV 0.069 % + 0.74 µV 0.34 % + 0.74 µV 2.7 % + 1.4 µV	Agilent/HP 3458A
(10 to 100) mV	(1 to 40) Hz 40Hz to 1kHz (1 to 20) kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz 300 kHz to 1 MHz (1 to 2) MHz	0.033 % + 2.7 µV 0.014 % + 1.4 µV 0.019 % + 1.4 µV 0.037 % + 1.4 µV 0.067 % + 1.4 µV 0.22 % + 6.7 µV 0.68 % + 6.7 µV 1.1 % + 6.7 µV	
(0.1 to 1) V	(1 to 40) Hz 40 Hz to 1kHz (1 to 20) kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz 300 kHz to 1 MHz (1 to 2) MHz	0.0047 % + 27 µV 0.0047 % + 14 µV 0.0094 % + 14 µV 0.020 % + 14 µV 0.054 % + 14 µV 0.20 % + 67 µV 0.67 % + 67 µV 1.1 % + 67 µV	
(1 to 10) V	(1 to 40) Hz 40 Hz to 1 kHz (1 to 20) kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz 300 kHz to 1 MHz (1 to 2) MHz	0.0077 % + 0.27 mV 0.0062 % + 0.14 mV 0.0099 % + 0.14 mV 0.021 % + 0.14 mV 0.054 % + 0.14 mV 0.21 % + 0.67 mV 0.67 % + 0.67 mV 1.1 % + 0.67 mV	
(10 to 100) V	(1 to 40) Hz 40 Hz to 1 kHz (1 to 20) kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz 300 kHz to 1 MHz	0.025 % + 2.7 mV 0.016 % + 1.4 mV 0.014 % + 1.4 mV 0.025 % + 1.4 mV 0.082 % + 1.4 mV 0.27 % + 6.7 mV 1.1 % + 6.7 mV	
(100 to 700) V	(1 to 40) Hz 40 Hz to 1 kHz (1 to 20) kHz (20 to 50) kHz (50 to 100) kHz	0.033 % + 27 mV 0.027 % + 14 mV 0.041 % + 14 mV 0.081 % + 14 mV 0.21 % + 14 mV	

Parameter/Range	Frequency	CMC[2, 5, 7, 8, 14] (±)	Comments
Capacitance – Measure[3]			
1 pF 10 pF 100 pF to 1 µF	1 kHz	11 µF/F 13 µF/F 14 µF/F	AH2500A
(0.7 to 110) mF	DC	0.012 %	5700A w/ 3458A, charge method
10 pF to 0.1 F	12 Hz to 2 MHz	See Table IV.b	Quad tech 1689M, 7600
Capacitance – Measure[3]			
Up to 100 pF (0.1 to 1) nF (1 to 10) nF (10 to 100) nF (0.1 to 1) µF (1 to 10) µF (10 to 100) µF (0.1 to 1) mF (1 to 10) mF (10 to 100) mF	(1 to 12) Hz	13 % 13 % 2.1 % 2.1 % 0.55 % 0.38 % 0.38 % 0.37 % 0.58 % 0.7 %	Hioki IM 3533
Capacitance[3] – Generate			
200 pF to 1.2 nF (1.2 to 12) nF (>3 to 12) nF (12 to 120) nF (>30 to 120) nF (0.12 to 1.2) µF (1.2 to 12) µF (12 to 120) µF (0.12 to 1.2) mF (1.2 to 12) mF (12 to 120) mF	100 Hz to 10 kHz 150 Hz to 5 kHz (10 to 150) Hz 200 Hz to 1.3 kHz (10 to 200) Hz (2 to 310) Hz (0.5 to 110) Hz (0.5 to 40) Hz (0.1 to 11) Hz (0.03 to 4) Hz (0.01 to 1.3) Hz	2.4 pF + 0.86 mF/F 6.2 pF + 0.9 mF/F 7.8 pF + 0.9 mF/F 43 pF + 1 mF/F 61 pF + 1 mF/F 0.42 nF + 1 mF/F 4.2 nF + 1 mF/F 40 nF + 1.2 mF/F 0.48 µF + 1.9 mF/F 5.3 µF + 1.9 mF/F 77 µF + 3.9 mF/F	Fluke 5560A
Capacitance – Generate[3], Fixed Points			
100 pF 0.001 µF 0.002 µF (0.01, 0.02, 0.05) µF (0.1, 0.5, 1) µF	100 Hz, 1 kHz	0.054 % 0.068 % 0.048 % 0.055 % 0.055 %	Standard capacitors

Table IV.b: CMC (in %) for Capacitance Measured with 1689M & 7600 LCR Meter, Fixed Points

	10 pF	100 pF	1 nF	10 nF	100 nF	1 µF	10 µF	100 µF	0.001 F	0.01 F	0.1 F
12 Hz			3.1	5	1.5	0.79	0.93	0.14	0.11	0.46	4.5
20 Hz			1.9	3	0.63	0.48	0.49	0.11	0.11	0.76	
50 Hz		3.8	0.39	0.47	0.25	0.11	0.16	0.058	0.11	0.94	
100 Hz		1.4	0.16	0.21	0.15	0.047	0.067	0.047	0.16	1.4	
200 Hz		0.71	0.081	0.12	0.095	0.047	0.047	0.047	0.29	2.8	
500 Hz	1.9	0.2	0.035	0.042	0.058	0.035	0.035	0.058	0.48	4.4	
1 kHz	0.48	0.058	0.024	0.024	0.024	0.024	0.024	0.058	0.48	4.7	
2 kHz	0.71	0.081	0.047	0.035	0.035	0.041	0.035	0.17	1.2		
5 kHz	0.66	0.083	0.056	0.047	0.047	0.056	0.08	0.32	2.8		
10 kHz	0.42	0.07	0.056	0.055	0.055	0.06	0.11	0.6			
20 kHz	0.035	0.024	0.048	0.057	0.058	0.068	0.18	1.3			
50 kHz	0.024	0.024	0.066	0.066	0.07	0.11	0.46	4.1			
100 kHz	0.024	0.03	0.08	0.081	0.091	0.2	1.2				
200 kHz	0.27	0.11	0.11	0.12	0.15	0.46	3.7				
500 kHz	0.43	0.4	0.2	0.38	0.38	2.1					
1 MHz	0.36	0.35	0.35	0.41	1.1						
2 MHz	0.65	0.64	0.66	0.9	3.4						

Parameter/Range		Frequency		CMC[2, 8, 14] (±)		Comments	
Capacitance – Measure[3]		See Table Below		See Table Below		Keysight E4980A	
	(20 to 99.99) Hz	(100 to 999.9) Hz	(1 to 9.999) kHz	(10 to 99.99) kHz	(100 to 999.9) kHz	(1 to 1.999) MHz	2 MHz
Up to 10 pF	12 %	1.2 %	1.2 %	0.12 %	0.12 %	0.12 %	0.12 %
(10 to 100) pF	12 %	1.2 %	0.12 %	0.12 %	0.12 %	0.12 %	0.12 %
(100 to 1000) pF	1.2 %	0.12 %	0.06 %	0.06 %	0.06 %	0.12 %	0.12 %
(1 to 10) nF	0.35 %	0.12 %	0.06 %	0.06 %	0.06 %	0.12 %	0.12 %
(10 to 100) nF	0.06 %	0.06 %	0.06 %	0.06 %	0.12 %	0.12 %	0.35 %
(0.1 to 1) µF	0.06 %	0.06 %	0.06 %	0.12 %	0.12 %	0.35 %	1.2 %
(1 to 10) µF	0.06 %	0.06 %	0.12 %	0.12 %	0.35 %	1.2 %	1.2 %
(10 to 100) µF	0.06 %	0.12 %	0.12 %	0.35 %	1.2 %	12 %	12 %
(0.1 to 1) mF	0.12 %	0.35 %	0.35 %	1.2 %	12 %	--	--

Parameter/Equipment	Range	CMC[2, 5, 8, 14] (±)	Comments
DC Power[3] – Generate	Up to 1020 V		
Up to 120 µA	Up to 122 mW	0.015 %	Fluke 5560A
Up to 1.2 mA	(0.12 to 1.224) W	0.0092 %	
Up to 12 mA	(1.225 to 12.24) W	0.0087 %	
Up to 120 mA	(12.24 to 122.4) W	0.0087 %	
Up to 1.2 A	(0.1224 to 1.224) kW	0.013 %	
Up to 3.1 A	(1.224 to 3.162) kW	0.028 %	
Up to 12 A	(3.162 to 12.24) kW	0.025 %	
Up to 30.2 A	(12.24 to 30.8) kW	0.08 %	
DC Current[3] –			
Generate & Measure	(0 to 100) nA	30 µA/A + 0.027 nA	Agilent/HP 3458A/HFL, current source, standard resistors/current shunts
	(0.1 to 1) µA	18 µA/A + 0.027 nA	
	(1 to 10) µA	16 µA/A + 0.067 nA	
	(10 to 100) µA	5.2 µA/A + 0.01 nA	
	(0.1 to 1 mA	4.9 µA/A + 0.1 nA	
	(1 to 10) mA	5.1 µA/A + 1 nA	
	(10 to 100) mA	5.6 µA/A + 60 nA	
	(0.1 to 1) A	7.3 µA/A + 6 µA	
	(1 to 2) A	8.9 µA/A + 12 µA	
	(2 to 10) A	31 µA/A + 6 µA	
	(10 to 20) A	31 µA/A + 12 µA	
	(1 to 10) A	0.0013 %	Ohm Labs CS-10
	(1 to 20) A	0.0014 %	Ohm Labs CS-20
	(0 to 20.2) A	0.41 mA + 0.17 mA/A	Fluke 8588A
	(0 to 30.2) A	4.4 mA + 0.49 mA/A	
	(1 to 500) A	0.0049 %	Ohm Labs CS-500
	(0.01 to 100) mA	0.0021 %	Guildline 9211B
	(0.1 to 10) A	0.0025 %	
	(10 to 30) A	0.0071 %	
	(30 to 300) A	0.0063 %	
	(20 to 100) A	27 µA/A + 18 µA/°C	
	(100 to 300) A	0.011 % + 18 µA/°C	
	(300 to 1000) A	0.077 % + 18 µA/°C	
Generate Only Turn Amps	(20 to 100) A	0.09 % + 970 µA	Fluke 52120A w/ 52120-3k & 52120-6k coils
	(1000 to 3000) A	0.27 % + 470 mA	
	(3000 to 6000) A	0.38 % + 340 mA	

Parameter/Equipment	Range	CMC[2, 5, 8, 14] (±)	Comments
DC Voltage – Generate, Fixed Points	100 mV	0.82 µV/V	Fluke 732B, 752A, HP 34420A
	1 V	0.63 µV/V	Fluke 732B, 752A, HP 34420A
	10 V	0.55 µV/V	Fluke 732B
	19 V	1.1 µV/V	Fluke 732B, 720A, 752A, HP 34420A
	100 V	0.63 µV/V	Fluke 732B, 752A, HP 34420A
	1000 V	0.82 µV/V	Fluke 732B, 752A, HP 34420A
DC Voltage – Generate	(0 to 220) mV 220 mV to 2.2 V (2.2 to 11) V (11 to 22) V (22 to 220) V (220 to 1100) V	5.6 µV/V + 0.39 µV 3.2 µV/V + 0.63 mV 2.4 µV/V + 2.4 µV 2.4 µV/V + 3.9 µV 3.2 µV/V + 39 µV 4.8 µV/V + 390 µV	Fluke 5700A/EP
DC Voltage – Measure[3]	Up to 100 mV 100 mV to 1 V (1 to 10) V (10 to 100) V (100 to 1000) V	3.0 µV/V + 0.21 µV 2.1 µV/V + 0.21 µV 2.1 µV/V + 0.34 µV 3.5 µV/V + 21 µV 3.9 µV/V + 74 µV	Agilent/HP 3458A
DC High Voltage – Measure[3]	(1 to 10) kV (10 to 140) kV	3.2 V + 0.17 V/kV 12 V + 0.96 V/kV	Vitrek 4700A w/HVL-150 probe
DC High Voltage – Generate[3]	(1 to 6) kV	0.21 % + 1.1 V	Assoc. res. 3565D monitored with Vitrek 4700A
Edge Characteristics –			
Amplitude – Measure	(0 to 100) mV (0.1 to 1) V (1 to 10) V (10 to 100) V	3.0 µV/V + 0.21 µV 2.1 µV/V + 0.21 µV 2.1 µV/V + 0.34 µV 3.5 µV/V + 21 µV	Agilent/HP 3458A/HFL

Parameter/Equipment	Range	CMC[2] (±)	Comments
Electrical Calibration of RTD Indicating Devices[3] –			
Pt 385, 100 Ω	(-200 to 0) °C (0 to 100) °C (100 to 300) °C (300 to 400) °C (400 to 630) °C (630 to 800) °C	0.05 °C 0.07 °C 0.09 °C 0.1 °C 0.12 °C 0.14 °C	Fluke 5520A
Pt 3926, 100 Ω	(-200 to 0) °C (0 to 100) °C (100 to 300) °C (300 to 400) °C (400 to 630) °C	0.05 °C 0.07 °C 0.09 °C 0.1 °C 0.26 °C	
PtNi 385, 120 Ω	(-80 to 100) °C (100 to 260) °C	0.08 °C 0.16 °C	
Pt 385, 200 Ω	(-200 to 100) °C (100 to 260) °C (260 to 300) °C (300 to 400) °C (400 to 600) °C (600 to 630) °C	0.04 °C 0.05 °C 0.12 °C 0.13 °C 0.14 °C 0.16 °C	
Pt 385, 500 Ω	(-200 to -80) °C (-80 to 100) °C (100 to 260) °C (260 to 400) °C (400 to 600) °C (600 to 630) °C	0.04 °C 0.05 °C 0.06 °C 0.08 °C 0.09 °C 0.11 °C	
Pt 385, 1000 Ω	(-200 to 0) °C (0 to 100) °C (100 to 260) °C (260 to 300) °C (300 to 600) °C (600 to 630) °C	0.03 °C 0.04 °C 0.05 °C 0.06 °C 0.07 °C 0.23 °C	
Pt 3916, 100 Ω	(-200 to -190) °C (-190 to -80) °C (-80 to 0) °C (0 to 100) °C (100 to 260) °C (260 to 300) °C (300 to 400) °C (400 to 600) °C (600 to 630) °C	0.25 °C 0.04 °C 0.05 °C 0.06 °C 0.07 °C 0.08 °C 0.09 °C 0.10 °C 0.23 °C	

Parameter/Equipment	Range	CMC[2] (±)	Comments
Electrical Calibration of Thermocouple Indicators[3]			
Type B	(250 to <350) °C (350 to <445) °C (445 to <580) °C (580 to <780) °C (750 to <1000) °C (1000 to 1820) °C	0.95 °C 0.74 °C 0.58 °C 0.46 °C 0.38 °C 0.3 °C	Ectron 1140A
Type C	(0 to <250) °C (250 to <1000) °C (1000 to <1500) °C (1500 to <1800) °C (1800 to <2000) °C (2000 to <2250) °C (2250 to 2315) °C	0.21 °C 0.17 °C 0.19 °C 0.22 °C 0.24 °C 0.3 °C 0.33 °C	
Type E	(-270 to < -245) °C (-245 to < -195) °C (-195 to < -155) °C (-155 to < -90) °C (-90 to <15) °C (15 to <890) °C (890 to 1000) °C	1.2 °C 0.18 °C 0.1 °C 0.082 °C 0.073 °C 0.063 °C 0.07 °C	
Type J	(-210 to < -180) °C (180 to < -120) °C (-120 to < -50) °C (-50 to <990) °C (990 to 1200) °C	0.12 °C 0.1 °C 0.083 °C 0.073 °C 0.07 °C	
Type K	(-270 to < -255) °C (-255 to < -195) °C (-195 to < -115) °C (-115 to < -55) °C (-55 to <1000) °C (1000 to 1372) °C	2.2 °C 0.7 °C 0.12 °C 0.092 °C 0.073 °C 0.083 °C	

Parameter/Equipment	Range	CMC[2] (±)	Comments
Electrical Calibration of Thermocouple Indicators[3] – cont.			
Type N	(-270 to < -260) °C (-260 to < -200) °C (-200 to < -140) °C (-140 to < -70) °C (-70 to 25) °C (25 to <160) °C (160 to 1300) °C	5 °C 1 °C 0.23 °C 0.16 °C 0.13 °C 0.11 °C 0.1 °C	Ectron 1140A
Type R	(-50 to < -30) °C (-30 to <45) °C (45 to <160) °C (160 to <380) °C (380 to <775) °C (775 to 1768) °C	0.65 °C 0.55 °C 0.41 °C 0.31 °C 0.27 °C 0.23 °C	
Type S	(-50 to < -30) °C (-30 to <45) °C (45 to <105) °C (105 to <310) °C (310 to <615) °C (615 to 1768) °C	0.62 °C 0.56 °C 0.41 °C 0.34 °C 0.3 °C 0.27 °C	
Type T	(-270 to < -255) °C (-255 to < -240) °C (-240 to < -210) °C (-210 to < -150) °C (-150 to < -40) °C (-40 to <100) °C (100 to 400) °C	1.8 °C 0.49 °C 0.3 °C 0.18 °C 0.12 °C 0.085 °C 0.08 °C	

Parameter/Range	Frequency	CMC[2, 8, 14] (±)	Comments
High Frequency Capacitance – Generate, Fixed Points[3] –			
1 pF	1 kHz 1 MHz 2 MHz 3 MHz 4 MHz 5 MHz 10 MHz 13 MHz	0.007 % 0.01 % 0.023 % 0.041 % 0.063 % 0.088 % 0.26 % 0.38 %	Agilent/HP 16380A series capacitors
10 pF	1 kHz (1, 2) MHz 3 MHz 4 MHz 5 MHz 10 MHz 13 MHz	62 parts in 10^6 62 parts in 10^6 64 parts in 10^6 67 parts in 10^6 72 parts in 10^6 0.013 % 0.017 %	
100 pF	1 kHz 1 MHz 2 MHz 3 MHz 4 MHz 5 MHz 10 MHz 13 MHz	61 parts in 10^6 62 parts in 10^6 68 parts in 10^6 82 parts in 10^6 0.01 % 0.014 % 0.034 % 0.049 %	
1000 pF	1 kHz 1 MHz 2 MHz 3 MHz 4 MHz 5 MHz 10 MHz 13 MHz	63 parts in 10^6 80 parts in 10^6 0.016 % 0.028 % 0.046 % 0.064 % 0.2 % 0.29 %	
0.01 µF	(0.12, 1, 10, 100) kHz	63 parts in 10^6	
0.1 µF	(0.12, 1, 10, 100) kHz	63 parts in 10^6	
1.0 µF	0.12 kHz (1, 10) kHz 100 kHz	69 parts in 10^6 63 parts in 10^6 85 parts in 10^6	

Parameter/Range	Frequency	CMC[2, 8, 14] (±)	Comments
Inductance[3] –			
Measure (12 Hz to 2 MHz)	0.1 µH to 10 H	See Table IV.c	LCR meters
Generate – Fixed Points	100 µH (1, 5, 10, 100) mH (1, 2, 5) H	0.026 % 0.11 % 0.11 %	Standard inductors

Table IVc: Inductance Measure CMC (in %) Measured with 1689M & 7600 LCR Meters

Freq.	0.1 µH	1 µH	10 µH	100 µH	1 mH	10 mH	100 mH	1 H	5 H	10 H
12 Hz						0.81	1.3	1.1	1.1	1.1
20 Hz					4.8	0.49	0.71	0.58	0.56	0.56
50 Hz					0.97	0.11	0.17	0.26	0.26	0.26
100 Hz				3.6	0.37	0.048	0.069	0.11	0.16	0.16
200 Hz				1.8	0.19	0.048	0.048	0.058	0.11	0.085
500 Hz			4.8	0.49	0.060	0.036	0.036	0.036	0.051	0.036
1 kHz			1.2	0.13	0.024	0.024	0.024	0.024	0.024	0.024
2 kHz			0.90	0.13	0.036	0.042	0.036	0.036	0.048	0.048
5 kHz		3.2	0.37	0.084	0.048	0.062	0.062	0.055	0.079	0.096
10 kHz		1.7	0.22	0.079	0.064	0.062	0.064	0.069	0.097	0.26
20 kHz		0.94	0.15	0.074	0.066	0.066	0.067	0.081	0.030	0.048
50 kHz	4.7	0.54	0.12	0.080	0.075	0.075	0.16	0.50	0.058	0.11
100 kHz	3.4	0.42	0.13	0.095	0.091	0.092	0.21	1.9	0.11	0.20
200 kHz	2.7	0.38	0.15	0.13	0.13	0.13	0.68	4.6		
500 kHz	2.4	0.44	0.25	0.23	0.46	0.50	1.9			
1 MHz	2.5	0.60	0.41	0.40	0.40	0.96				
2 MHz	2.7	0.92	0.75	0.73	0.76	4.3				

Parameter/Range		Frequency		CMC[2, 8, 14] (±)		Comments	
Inductance – Measure[3]		See Table Below		See Table Below		Keysight E4980A	
	(20 to 99.99) Hz	(100 to 999.9) Hz	(1 to 9.999) kHz	(10 to 99.99) kHz	(100 to 999.9) kHz	(1 to 1.999) MHz	2 MHz
Up to 1 µH	---	---	12 %	0.35 %	0.12 %	0.12 %	0.35 %
(1 to 10) µH	12 %	12 %	1.2 %	0.12 %	0.12 %	0.12 %	0.35 %
(10 to 100) µH	0.35 %	0.35 %	0.35 %	0.35 %	0.35 %	0.35 %	1.2 %
(0.1 to 1) mH	0.12 %	0.12 %	0.12 %	0.12 %	0.12 %	0.12 %	0.35 %
(1 to 10) mH	0.06 %	0.06 %	0.12 %	0.12 %	0.12 %	0.12 %	0.35 %
(10 to 100) mH	0.06 %	0.06 %	0.06 %	0.06 %	0.06 %	0.06 %	0.06 %
(0.1 to 1) H	0.06 %	0.06 %	0.06 %	0.06 %	0.06 %	0.12 %	0.12 %
(1 to 10) H	0.06 %	0.06 %	0.06 %	0.06 %	0.12 %	0.12 %	0.35 %
(10 to 100) H	0.12 %	0.12 %	0.12 %	0.12 %	0.12 %	0.35 %	1.2 %

Parameter/Range	Frequency	CMC[2, 8, 14] (±)	Comments
Low Frequency Capacitance & Inductance – Measure	CMC's are calculated per Fluke instructions & are specific to the calibration of the Fluke 5560A		Characterized Hioki IM3533 using capacitance, inductance & impedance artifacts

Capacitance	1 kHz	610 Hz	100 Hz	80 Hz	20 Hz	5 Hz	2 Hz	1 Hz
200 pF	0.01 %	----	----	----	----	----	----	----
1 nF	0.01 %	----	----	----	----	----	----	----
1.2 nF	0.01 %	----	----	----	----	----	----	----
10 nF	0.026 %	----	----	----	----	----	----	----
12.1 nF	----	0.026 %	----	----	----	----	----	----
20 nF	----	0.026 %	----	----	----	----	----	----
30 nF	----	0.012 %	----	----	----	----	----	----
50 nF	----	0.012 %	----	----	----	----	----	----
100 nF	----	0.012 %	----	----	----	----	----	----
121 nF	----	----	0.026 %	----	----	----	----	----
1 µF	----	----	0.012 %	----	----	----	----	----
1.21 µF	----	----	----	0.012 %	----	----	----	----
10 µF	----	----	----	0.027 %	----	----	----	----
12.1 µF	----	----	----	----	0.027 %	----	----	----
100 µF	----	----	----	----	0.01 %	----	----	----
121 µF	----	----	----	----	----	0.027 %	----	----
1 mF	----	----	----	----	----	0.01 %	----	----
1.21 mF	----	----	----	----	----	----	0.01 %	----
10 mF	----	----	----	----	----	----	0.026 %	----
12.1 mF	----	----	----	----	----	----	----	0.01 %
100 mF	----	----	----	----	----	----	----	0.026 %

Inductance	1 kHz	110 Hz	100 Hz	10 Hz	3 Hz	2 Hz
15 µH	0.011 %	----	----	----	----	----
100 µH	0.01 %	----	----	----	----	----
121 µH	0.01 %	----	----	----	----	----
1 mH	0.026 %	----	----	----	----	----
1.21 mH	----	0.01 %	----	----	----	----
2 mH	----	0.01 %	----	----	----	----
3 mH	----	0.026 %	----	----	----	----
5 mH	----	0.026 %	----	----	----	----
10 mH	----	0.026 %	----	----	----	----
12 mH	----	0.026 %	----	----	----	----
12.1 mH	----	----	0.026 %	----	----	----
100 mH	----	----	0.01 %	----	----	----
121 mH	----	----	----	0.026 %	----	----

Parameter/Range	Frequency	CMC[2, 8, 14] (±)	Comments
Low Frequency Capacitance & Inductance – Measure	CMC's are calculated per Fluke instructions & are specific to the calibration of the Fluke 5560A		Characterized Hioki IM3533 using capacitance, inductance & impedance srtifacts

Inductance	1 kHz	110 Hz	100 Hz	10 Hz	3 Hz	2 Hz
1 H	----	----	----	0.01 %	----	----
1.21 H	----	----	----	----	0.01 %	----
10 H	----	----	----	----	0.027 %	----
12.1 H	----	----	----	----	----	0.027 %
100 H	----	----	----	----	----	0.027 %

Inductance – Generate[3]			
(13 to 120) µH	(490 to 550) Hz (550 to 999) Hz 1 kHz (1.001 to 13) kHz (13 to 17) kHz	1.5 % 0.67 % 0.38 % 0.67 % 1.5 %	Fluke 5560A
(0.12001 to 1.2) mH	(260 to 330) Hz (330 to 999) Hz 1 kHz (1.001 to 1.6) kHz (1.6 to 2.5) kHz	1.4 % 0.49 % 0.2 % 0.49 % 1.4 %	
(1.2001 to 3.3) mH	(0.5 to 999) Hz 110 Hz (111 to 800) Hz (800 to 980) Hz	0.74 % 0.46 % 0.74 % 1.6 %	
(3.3 to 12) mH	(0.5 to 109) Hz 110 Hz (111 to 1000) Hz (1 to 1.4) kHz	0.49 % 0.2 % 0.49 % 1.4 %	
(12 to 83) mH	(0.1 to 99) Hz 100 Hz (101 to 180) Hz (180 to 230) Hz	0.53 % 0.25 % 0.53 % 1.4 %	
(83 to 120) mH	(0.1 to 99) Hz 100 Hz (101 to 320) Hz (320 to 1000) Hz	0.49 % 0.2 % 0.49 % 1.4 %	

Parameter/Range	Frequency	CMC[2, 8, 14] (±)	Comments
Inductance – Generate[3] (cont)			
(0.120 01 to 0.65) H	(0.05 to 9.9) Hz 10 Hz (10.1 to 30) Hz (30 to 50) Hz	0.61 % 0.32 % 0.6 % 1.5 %	Fluke 5560A
(0.65 to 1.2) H	(0.05 to 9.9) Hz 10 Hz (10.1 to 100) Hz (100 to 170) Hz	0.52 % 0.24 % 0.52 % 1.4 %	
(1.2001 to 5.5) H	(0.01 to 2.99) Hz 3 Hz (3.01 to 8) Hz (8 to 16) Hz	0.68 % 0.4 % 0.68 % 1.6 %	
(5.5 to 12) H	(0.01 to 2.99) Hz 3 Hz (3.01 to 19) Hz (19 to 37) Hz	0.57 % 0.28 % 0.57 % 1.4 %	
(12.001 to 30) H	(0.005 to 1.99) Hz 2 Hz (2.01 to 4) Hz (4 to 16) Hz	0.89 % 0.61 % 0.89 % 1.8 %	
(30 to 120) H	(0.005 to 1.99) Hz 2 Hz (2.01 to 7) Hz (7 to 14) Hz	0.61 % 0.32 % 0.6 % 1.5 %	
Phase – Generate	± 999.9999 °		
50 mV to 120 V	(1 to 1000) Hz (>1 to 6.25) kHz (>6.25 to 50) kHz (>50 to 200) kHz	0.006 ° 0.012 ° 0.018 ° 0.047 °	Clark-Hess 5600
50 mV to 8 V	>200 kHz to 1 MHz	0.076 ° + [0.000 28 ° x (F – 200)]	F = Frequency in kHz

Parameter/Range	Frequency	CMC[2, 8, 14] (±)	Comments
Phase – Measure			
(0.01 to 0.1) Vrms	10 Hz to 10 kHz (10 to 50) kHz (50 to 100) kHz	0.21° 0.36° 0.71°	KH 6620 phase meter
(0.1 to 120) Vrms	10 Hz to 50 kHz (50 to 100) kHz	0.054° 0.036°	
Oscilloscopes[3, 8] –			
Voltage			
DC into 1 MΩ	1 mV to 200 V	28 µV + 0.25 mV/V	Fluke 9500B
DC into 50 Ω	1 mV to 5 V	29 µV + 0.25 mV/V	
Squarewave into 1 MΩ	40 µV to 200 V_{p-p}	12 µV + 1 mV/V	
Squarewave into 50 Ω	40 µV to 5 V_{p-p}	12 µV + 1 mV/V	
Risetime – Generate	500 ps 10 Hz to 2 MHz	62 ps	w/ 9510 active head
	150 ps 10 Hz to 2 MHz	28 ps	w/9530 active head
	70 ps 10 Hz to 1 MHz	17 ps	w/ 9560 active head
Time Marker	9 ns to 83 µs 83 µs to 55 s	0.000 047 % 0.000 35 %	
Bandwidth	50 kHz to 300 MHz (300 to 550) MHz (0.55 to 1.1) GHz (1.1 to 3.2) GHz (3.2 to 6) GHz	3.3 % 3.4 % 4 % 4.4 % 5.8 %	w/ active heads
Rise Time – Generate	12.8 ps 8.8 ps	3.9 ps 3.6 ps	Tektronix 067-1338-00 Keysight N2806A
Rise Time – Measure	>5.4 ps	5.4 ps	Tektronix TDS8000 with 80E03

Parameter/Equipment	Range	CMC[2, 5, 8, 14] (±)	Comments
Resistance – Generate, Fixed Points[3]	100 µΩ 1 mΩ 10 mΩ 0.1 Ω 1 Ω 10 Ω 100 Ω 1 k Ω 10 kΩ 19 kΩ 100 kΩ 1 MΩ 10 MΩ 100 MΩ 1 GΩ 10 GΩ 100 GΩ 1 TΩ 10 TΩ	29 µΩ/Ω 14 µΩ/Ω 9.5 µΩ/Ω 6.5 µΩ/Ω 4.6 µΩ/Ω 4.2 µΩ/Ω 2.3 µΩ/Ω 2.5 µΩ/Ω 1.6 µΩ/Ω 4.7 µΩ/Ω 3.3 µΩ/Ω 4.5 µΩ/Ω 9.0 µΩ/Ω 22 µΩ/Ω 27 µΩ/Ω 0.13 % 0.22 % 0.34 % 1.2 %	Norma 80 L&N 4222B L&N 4223B L&N resistors Fluke 742A, standard resistors IET high resistance standard
Resistance[3] – Generate	(0 to 12) Ω (12 to 120) Ω 120 Ω to 1.2 kΩ (1.2 to 12) kΩ (12 to 120) kΩ 120 kΩ to 1.2 MΩ (1.2 to 12) MΩ (12 to 120) MΩ (120 to 1200) MΩ	1 mΩ + 19 µΩ/Ω 1.2 mΩ + 19 µΩ/Ω 4.4 mΩ + 19 µΩ/Ω 44 mΩ + 19 µΩ/Ω 0.44 Ω + 19 µΩ/Ω 4.4 Ω + 19 µΩ/Ω 63 Ω + 27 µΩ/Ω 6.5 kΩ + 0.33 mΩ/Ω 0.47 MΩ + 3.1 mΩ/Ω	Fluke 5560A
Resistance – Measure, DC	100 µΩ 100 µΩ to1 mΩ (1 to 10) mΩ (10 to 100) mΩ (0.1 to 1) Ω	85 µ Ω/Ω + 0.48 nΩ 12 µΩ/Ω + 4.8 nΩ 9.2 µ Ω/Ω + 4.8 nΩ 5.4 µ Ω/Ω + 48 nΩ 2.6 µ Ω/Ω + 0.48 µΩ	Stable current source, 3458A/HFL, standard resistors

Parameter/Equipment	Range	CMC[2, 8, 14] (±)	Comments
Resistance – Measure, DC (cont.)	(0 to 2) Ω (2 to 20) Ω (20 to 200) Ω 200 Ω to 2 kΩ (2 to 20) kΩ (20 to 200) kΩ 200 kW to 2 MΩ (2 to 20) MΩ (20 to 200) MΩ 200 MΩ to 2 GΩ (2 to 20) GΩ 100 MΩ to 1 GΩ (1 to 10) GΩ (10 to 100) GΩ 100 GΩ to 1 TΩ (1 to 10) TΩ (10 to 100) TΩ	3.4 μΩ/Ω + 4.4 μΩ 2.1 μΩ/Ω + 15 μΩ 2.6 μΩ/Ω + 33 μΩ 2.5 μΩ/Ω + 0.33 mΩ 1.5 μΩ/Ω + 3.3 mΩ 2.3 μΩ/Ω + 33 mW 4.4 μΩ/Ω + 1.1 Ω 4.4 μΩ/Ω + 11 Ω 8.3 μΩ/Ω + 110 Ω 28 μΩ/Ω + 110 kΩ 0.21 % + 1.1 MΩ 0.081 % 0.12 % 0.24 % 0.35 % 0.59 % 1.2 %	Fluke 8508A & standard resistors 6500A

Parameter/Range	Frequency	CMC[2, 8, 14] (±)	Comments
Resistance – Measure, AC	10 Hz to 2 MHz	See Table IV.d	LCR meters

Table IV.d: AC Resistance Measure CMC (in %) Measured with LCR Meters

	0.1 Ω	1 Ω	10 Ω	100 Ω	1 kΩ	10 kΩ	100 kΩ	200 kΩ	500 kΩ	1 MΩ
12 Hz		0.60	0.11	0.11	0.11	0.11	0.11	1.7		
20 Hz		0.60	0.11	0.11	0.11	0.11	0.11	0.85	2.8	4.6
50 Hz	3.1	0.31	0.058	0.058	0.058	0.058	0.058	0.38	1.3	2.0
100 Hz	2.3	0.23	0.047	0.047	0.047	0.047	0.047	0.23	0.70	1.2
200 Hz	2.3	0.23	0.047	0.047	0.047	0.047	0.047	0.15	0.44	0.70
500 Hz	1.5	0.16	0.035	0.035	0.035	0.035	0.035	0.10	0.29	0.44
1 kHz	0.77	0.09	0.024	0.024	0.024	0.024	0.024	0.082	0.24	0.35
2 kHz	1.0	0.15	0.035	0.035	0.035	0.035	0.047	0.075	0.21	0.31
5 kHz	0.90	0.14	0.047	0.047	0.047	0.047	0.063	0.072	0.20	0.30
10 kHz	1.0	0.14	0.062	0.055	0.055	0.055	0.063	0.073	0.21	0.30
20 kHz	1.1	0.16	0.066	0.057	0.057	0.057	0.067	0.077	0.22	0.33
50 kHz	1.4	0.19	0.077	0.066	0.065	0.066	0.31	0.37	1.1	1.7
100 kHz	1.9	0.26	0.10	0.081	0.079	0.081	0.40	0.47	1.5	2.2
200 kHz	3.0	0.39	0.14	0.11	0.11	0.12	0.56	0.68	2.2	3.4
500 kHz		0.79	0.26	0.20	0.20	0.26	1.1	1.4	4.2	
1 MHz		1.5	0.45	0.35	0.35	0.70	1.9	2.4		
2 MHz		2.8	0.85	0.65	0.64	1.4	3.5	4.5		

Parameter/Range		Frequency		CMC[2, 8, 14] (±)		Comments	
AC Impedance – Measure[3]		See Table Below		See Table Below		Keysight E4980A	
	(20 to 99.99) Hz	(100 to 999.9) Hz	(1 to 9.999) kHz	(10 to 99.99) kHz	(100 to 999.9) kHz	(1 to 1.999) MHz	2 MHz
Up to 10 mΩ	12 %	12 %	1.2 %	1.2 %	1.2 %	1.2 %	1.2 %
(10 to 100) mΩ	1.2 %	1.2 %	1.2 %	0.35 %	0.35 %	0.35 %	0.35 %
(0.1 to 1) Ω	0.35 %	0.35 %	0.35 %	0.35 %	0.35 %	0.35 %	1.2 %
(1 to 10) Ω	0.12 %	0.12 %	0.12 %	0.12 %	0.12 %	0.12 %	0.35 %
(10 to 100) Ω	0.06 %	0.06 %	0.12 %	0.12 %	0.12 %	0.12 %	0.35 %
(0.1 to 1) kΩ	0.06 %	0.06 %	0.06 %	0.06 %	0.06 %	0.06 %	0.06 %
(1 to 10) kΩ	0.06 %	0.06 %	0.06 %	0.06 %	0.06 %	0.12 %	0.12 %
(10 to 100) kΩ	0.06 %	0.06 %	0.06 %	0.06 %	0.12 %	0.12 %	0.35 %
(0.1 to 1) MΩ	0.12 %	0.12 %	0.12 %	0.12 %	0.12 %	0.35 %	1.2 %
(1 to 10) MΩ	1.2 %	1.2 %	0.35 %	0.35 %	0.35 %	1.2 %	12 %
(10 to 100) MΩ	12 %	12 %	1.2 %	1.2 %	1.2 %	12 %	12 %

V. Electrical – RF/Microwave

Parameter/Range	Frequency	CMC[2, 8, 14] (±)	Comments
Amplitude Modulation[3] –			
AM Accuracy:			
(0.15 to 10) MHz			
(5 to 40) % AM Depth	Rate:50 Hz to 10 kHz Rate: 20 Hz to 10 kHz	2.3 % + 0.012 % AM 3.5 % + 0.012 % AM	Measuring receiver
(40 to 99) % AM Depth	Rate 50 Hz to 10 kHz Rate: 20 Hz to 10 kHz	2.3 % + 0.12 % AM 3.5 % + 0.12 % AM	
(10 to 1300) MHz			
(5 to 40) % AM Depth	Rate: 50 Hz to 50 kHz Rate: 20 Hz to 100 kHz	1.2 % + 0.012 % AM 3.5 % + 0.012 % AM	
(40 to 99) % AM Depth	Rate: 50 Hz to 50 kHz Rate: 20 Hz to 100 kHz	1.2 % + 0.12 % AM 3.5 % + 0.12 % AM	
(1.3 to 26.5) GHz			
(5 to 40) % AM Depth	Rate: 50 Hz to 50 kHz Rate: 20 Hz to 100 kHz	1.2 % + 0.012 % AM 3.5 % + 0.012 % AM	Measuring receiver, down converter & local oscillator
(40 to 99) % AM Depth	Rate: 50 Hz to 50 kHz Rate: 20 Hz to 100 kHz	1.2 % + 0.12 % AM 3.5 % + 0.12 % AM	
AM Distortion:			
150 kHz to 1.3 GHz	<50 % AM Depth (50 to 95) % AM Depth	1.2 dB 2.3 dB	Measuring receiver & distortion analyzer
(1.3 to 26.5) GHz	<50 % AM Depth (50 to 95) % AM Depth	1.2 dB 2.3 dB	
AM Flatness:			
(0.01 to 26.5) GHz (20 to 80) % AM Depth	Rate: 90 Hz to 10 kHz	0.35 %	Measuring receiver
Distortion Accuracy – Measure[3]			
(0 to -70) dB	(2 to 20) Hz	0.43 dB	Low frequency signal analyzer
(-7 to -99.9) dB (-7 to -99.9) dB	20 Hz to 20 kHz (20 to 100) kHz	1.2 dB 2.3 dB	Distortion analyzer

Parameter/Range	Frequency	CMC[2, 8] (±)	Comments
Frequency Modulation[3] –			
FM Accuracy	Rate:		
(0.15 to 10) MHz			
<4 kHz FM peak Dev.	20 Hz to 10 kHz	2.4 % + 1.2 Hz	Measuring receiver
<40 kHz FM peak Dev.	20 Hz to 10 kHz	2.4 % + 12 Hz	
(10 to 1300) MHz			
<400 kHz FM pk Dev.	50 Hz to 100 kHz	1.3 % + 120 Hz	
	20 Hz to 200 kHz	5.8 % + 240 Hz	
(1.3 to 26.5) GHz			
<400 kHz FM pk Dev.	50 Hz to 100 kHz	1.3 % + 120 Hz	Measuring receiver & distortion analyzer
	20 Hz to 200 kHz	5.8 % + 240 Hz	
β (0 to 0.5)			
Rate: (1 to 3) Hz			
Peak Dev: 1 Hz to 1.3 GHz	1 Hz to 2.6 GHz	1.6 %	89441A
Rate: 3 Hz to 6.7 GHz			
Peak Dev: 3 Hz to 6.7 GHz	3 Hz to 13.2 GHz	1.5 %	E4445A
β 0.5 to 2			
Rate: (1 to 3) Hz			
Peak Dev: 1 Hz to 1.3 GHz	1 Hz to 2.6 GHz	2.1 %	89441A
Rate: 3 Hz to 6.7 GHz			
Peak Dev: 3 Hz to 6.7 GHz	3 Hz to 13.2 GHz	1.9 %	E4445A
β 2 to 10			
Rate: 1 Hz to 3 Hz			
Peak Dev: 1 Hz to 1.3 GHz	1 Hz to 2.6 GHz	1.2 %	89441A
Rate: 3 Hz to 6.7 GHz			
Peak Dev: 3 Hz to 6.7 GHz	3 Hz to 13.2 GHz	1.1 %	E4445A

Parameter/Range	Frequency	CMC[2, 8] (±)	Comments
Frequency Modulation[3] – (cont)			
β 10 to 100 Rate: 1 Hz to 3 Hz Peak Dev: 1 Hz to 1.3 GHz	1 Hz to 2.6 GHz	0.39 %	89441A
Rate: 3 Hz to 6.7 GHz Peak Dev: 3 Hz to 6.7 GHz	3 Hz to 13.2 GHz	0.36 %	E4445A
β 100 to 200 Rate: 1 Hz to 3 Hz Peak Dev: 1 Hz to 1.3 GHz	1 Hz to 2.6 GHz	0.09 %	89441A
Rate: 3 Hz to 6.7 GHz Peak Dev: 3 Hz to 6.7 GHz	3 Hz to 13.2 GHz	0.085 %	E4445A
β 200 to 500 Rate: 1 Hz to 13 MHz Peak Dev: 1 Hz to 1.3 GHz	1 Hz to 2.6 GHz	0.24 %	89441A
Rate: 1 Hz to 7 MHz Peak Dev: 1 Hz to 700 MHz	(2.6 to 18) GHz	0.24 %	89441A w/ mixer
β 500 to 5000 Rate: 1 Hz to 13 MHz Peak Dev: 1 Hz to 1.3 GHz	1 Hz to 2.6 GHz	0.14 %	89441A
Rate: 1 Hz to 7 MHz Peak Dev: 1 Hz to 700 MHz	(2.6 to 18) GHz	0.14 %	89441A w/ mixer
β 5000 to 6 000 000 Rate: 1 Hz to 13 MHz Peak Dev: 1 Hz to 1.3 GHz	1 Hz to 2.6 GHz	0.034 %	89441A
Rate: 1 Hz to 7 MHz Peak Dev: 1 Hz to 700 MHz	(2.6 to 18) GHz	0.034 %	89441A w/ mixer

Parameter/Range	Frequency	CMC[2, 8, 14] (±)	Comments
Frequency Modulation[3] – (cont)			
FM Distortion			
400 kHz to 10 MHz Rate: 20 Hz to 10 kHz	<10 kHz FM Deviation	0.19 %	Measuring receiver
10 MHz to 26.5 GHz Rate: 20 Hz to 100 kHz	<100 kHz FM Deviation	0.3 %	
Residual FM			
Carrier Frequency (f)	Bandwidth:		Measuring receiver, local oscillator & distortion analyzer
<100 MHz	50 Hz to 3 kHz	1.2 Hz	
(100 to 1300) MHz		1.2 Hz + (5.7 x 10^{-9} x f)	
(1.3 to 26.5) GHz		9.3 Hz + (1.5 x 10^{-9} x f)	
Single Sideband Phase Noise – Measure			
	CF = 5 MHz		
Range:	Offset		
-110 dBc/Hz	20 Hz	1.6 dB	Agilent E8251A
-126 dBc/Hz	1 kHz	1.3 dB	Agilent E4408B
-131 dBc/Hz	20 kHz	1.0 dB	
-133 dBc/Hz	100 kHz	1.3 dB	HP 89441A w/
-139 dBc/Hz	1 MHz	1.3 dB	PMSSBPNMS
-140 dBc/Hz	5 MHz	1.4 dB	
	CF = 225 MHz		
	Offset		
-101 dBc/Hz	20 Hz	1.3 dB	
-114 dBc/Hz	1 kHz	1.0 dB	
-139 dBc/Hz	20 kHz	1.0 dB	
-140 dBc/Hz	100 kHz	1.1 dB	
-146 dBc/Hz	1 MHz	1.4 dB	
-148 dBc/Hz	10 MHz	1.4 dB	

Parameter/Range	Frequency	CMC[2, 14] (±)	Comments
Single Sideband Phase Noise – Measure (cont)			
	CF = 1 GHz		
Range:	Offset		
-89 dBc/Hz	20 Hz	1.6 dB	Agilent E8251A
-101 dBc/Hz	1 kHz	1.0 dB	Agilent E4408B
-131 dBc/Hz	20 kHz	0.9 dB	
-134 dBc/Hz	100 kHz	1.1 dB	HP 89441A w/
-145 dBc/Hz	1 MHz	1.4 dB	PMSSBPNMS
-147 dBc/Hz	10 MHz	1.4 dB	
	CF = 5 GHz		
	Offset		
-76 dBc/Hz	20 Hz	1.9 dB	
-88 dBc/Hz	1 kHz	1.4 dB	
-118 dBc/Hz	20 kHz	0.9 dB	
-119 dBc/Hz	100 kHz	1.0 dB	
-143 dBc/Hz	1 MHz	1.4 dB	
-149 dBc/Hz	10 MHz	2.0 dB	
	CF = 9.6 GHz		
	Offset		
-70 dBc/Hz	20 Hz	1.1 dB	
-82 dBc/Hz	1 kHz	1.2 dB	
-113 dBc/Hz	20 kHz	0.9 dB	
-116 dBc/Hz	100 kHz	1.0 dB	
-141 dBc/Hz	1 MHz	1.9 dB	
-144 dBc/Hz	10 MHz	3.0 dB	
	CF = 15 GHz		
	Offset		
-66 dBc/Hz	20 Hz	1.8 dB	
-77 dBc/Hz	1 kHz	1.2 dB	
-108 dBc/Hz	20 kHz	1.0 dB	
-110 dBc/Hz	100 kHz	1.0 dB	
-136 dBc/Hz	1 MHz	1.5 dB	
-145 dBc/Hz	10 MHz	3.5 dB	

Parameter/Range	Frequency	CMC[2, 8, 14] (±)	Comments
Single Sideband Phase Noise – Measure (cont) Range: -64 dBc/Hz -76 dBc/Hz -107 dBc/Hz -109 dBc/Hz -136 dBc/Hz -142 dBc/Hz	CF = 18 GHz <u>Offset</u> 20 Hz 1 kHz 20 kHz 100 kHz 1 MHz 10 MHz	 1.5 dB 1.4 dB 0.9 dB 1.0 dB 1.6 dB 3.0 dB	 Agilent E8251A Agilent E4408B HP 89441A w/ PMSSBPNMS
Phase Modulation[3] – (0.15 to 10) MHz <40 Radians (Peak) <400 Radians (Peak) (10 to 1300) MHz <4 Radians (Peak) <40 Radians (Peak) <400 Radians (Peak) (1.3 to 26.5) GHz <4 Radians (Peak) <40 Radians (Peak) <400 Radians (Peak)	 Rate: 200 Hz to 10 kHz Rate: 200 Hz to 20 kHz Rate: 200 Hz to 20 kHz	 4.7 % + 0.012 rad 4.6 % + 0.12 rad 3.5 % + 0.0012 rad 3.5 % + 0.012 rad 3.5 % + 0.12 rad 3.5 % + 0.0012 rad 3.5 % + 0.012 rad 3.5 % + 0.12 rad	 Measuring receiver Measuring receiver, down converter & local oscillator

Parameter/Equipment	Range	CMC[2, 14] (±)	Comments
Low Phase Noise RF Signal[3]– Generate	1 Hz offset 10 Hz offset 100 Hz offset 1 kHz offset 10 kHz offset 100 kHz offset	3 dB 3 dB 2.8 dB 2.5 dB 2.6 dB 2.4 dB	E8257D Opt UNX

Carrier Frequency	Offset from Carrier Frequency *Values below are in dBc/Hz (decibels below carrier in a 1-Hz bandwidth) which represents the approximate source phase noise at the specified offset from the Carrier Frequency. Stated values are informational only & serve as a guide for typical system performance. Actual performance may be better than what is stated.*					
	1 Hz	10 Hz	100 Hz	1 kHz	10 kHz	100 kHz
250 kHz to 250 MHz	-64	-92	-115	-123	-138	-141
(250 to 500) MHz	-67	-93	-111	-125	-138	-142
500 MHz to 1 GHz	-62	-91	-105	-121	-138	-138
(1 to 2) GHz	-57	-86	-100	-115	-133	-133
(2 to 3.2) GHz	-52	-81	-96	-111	-128	-128
(3.2 to 10) GHz	-43	-72	-85	-101	-120	-120
(10 to 20) GHz	-37	-66	-79	-95	-114	-114
(20 to 40) GHz	-31	-60	-73	-89	-108	-108

Parameter/Equipment	Range	CMC[2, 8] (±)	Comments
Range Calibration (Power Meters)[3] – Zero Set Instrument Accuracy	 (0.03 to 10) mW 3 µW 10 µW 30 µW (100, 300) µW (1, 2) mW (10, 30, 100) mW	 0.25 % + 6.2 nW 1.6 % 0.46 % 0.28 % 0.26 % 0.28 % 0.30 %	Range calibrator, Agilent 11683A or Agilent 8477A
Thermistor Mount – Calibration	50 MHz	0.3 %	Reference thermistor mount, digital multimeter, reference source

Parameter/Range	Frequency	CMC[2, 8, 14] (±)	Comments
RF Power Level[3] – Generate/Measure			
Absolute	0 dBm @ 50 MHz	0.41 %	Signal generator, power splitter, attenuator, standard sensors, & power meter
	(+20 to -128) dBm 0.9 MHz to 26.5 GHz	See Table Vc & Vd	
Relative	(+20 to -128) dBm 0.9 MHz to 26.5 GHz	See Table Va & Vb	E9304A, N8481A, 8485A, E4445A E8257A
Relative (Power Sensor Calibration Factors)	9 kHz 30 kHz 100 kHz 300 kHz 1 MHz 3 MHz 10 MHz 30 MHz 100 MHz 300 MHz 1 GHz 2 GHz 3 GHz 4 GHz 5 GHz 6 GHz 7 GHz 8 GHz 9 GHz 10 GHz 11 GHz 12 GHz 13 GHz 14 GHz 15 GHz 16 GHz 17 GHz 18 GHz 19 GHz 20 GHz 21 GHz 22 GHz 23 GHz 24 GHz 25 GHz 26 GHz 26.5 GHz	1 % 1 % 1 % 1 % 1 % 1 % 0.79 % 0.67 % 0.62 % 0.67 % 0.68 % 0.68 % 0.73 % 0.73 % 0.72 % 0.73 % 0.82 % 0.9 % 0.92 % 0.95 % 0.95 % 0.95 % 1.0 % 1.0 % 1.1 % 1.1 % 1.2 % 1.0 % 1.9 % 2.2 % 2.1 % 2.1 % 2.1 % 2.1 % 2.2 % 2.1 % 2.1 %	Power sensors, splitters, meters

Table V.a Power Measurement Relative (CMC in dBm, K=2)

		FREQUENCY						
		9 kHz to <10 MHz	10 MHz to <50 MHz	50 MHz	>50 MHz to 8 GHz	>8 GHz to 13.2 GHz	>13.2 GHz to 18 GHz	18 GHz to 26.5 GHz
Change From Reference	+20 dBm	0.007	0.006	0.008	0.007	0.007	0.010	0.008
	+10 dBm	0.007	0.005	0.006	0.006	0.006	0.010	0.006
	0 dBm	--- ref ---	--- ref ---	--- ref ---	--- ref ---	--- ref ---	--- ref ---	--- ref ---
	-10 dBm	0.006	0.006	0.005	0.005	0.006	0.005	0.006
	-20 dBm	0.006	0.006	0.006	0.006	0.006	0.006	0.005
	-30 dBm	0.007	0.007	0.007	0.006	0.007	0.006	0.006
	-40 dBm	0.008	0.007	0.006	0.006	0.008	0.005	0.006
	-50 dBm	0.008	0.007	0.006	0.006	0.008	0.007	0.006
	-60 dBm	0.009	0.008	0.007	0.008	0.009	0.008	0.008
	-70 dBm	0.010	0.009	0.008	0.009	0.011	0.009	0.008
	-80 dBm	0.010	0.009	0.008	0.008	0.009	0.007	0.008
	-90 dBm	0.011	0.010	0.010	0.011	0.011	0.009	0.010
	-100 dBm	0.016	0.013	0.012	0.013	0.014	0.012	0.010
	-110 dBm	0.015	0.011	0.013	0.035	0.031	0.012	0.014
	-120 dBm	0.025	0.013	0.019	0.090	0.040	0.014	0.045
	-128 dBm	0.041	0.020	0.053	0.11	0.17	0.056	0.095

Table V.b Power Source Relative (CMC in dBm, K=2)

		FREQUENCY						
		9 kHz to <10 MHz	10 MHz to <50 MHz	50 MHz	>50 MHz to 8 GHz	>8 GHz to 13.2 GHz	>13.2 GHz to 18 GHz	18 GHz to 26.5 GHz
Change From Reference	+20 dBm	0.009	0.007	0.011	0.010	0.010	0.014	0.011
	+10 dBm	0.008	0.006	0.006	0.006	0.008	0.015	0.008
	0 dBm	--- ref ---	--- ref ---	--- ref ---	--- ref ---	--- ref ---	--- ref ---	--- ref ---
	-10 dBm	0.007	0.006	0.006	0.006	0.008	0.005	0.007
	-20 dBm	0.008	0.007	0.007	0.008	0.007	0.006	0.006
	-30 dBm	0.009	0.009	0.009	0.007	0.008	0.007	0.007
	-40 dBm	0.011	0.010	0.008	0.007	0.011	0.006	0.007
	-50 dBm	0.012	0.010	0.008	0.007	0.012	0.009	0.007
	-60 dBm	0.012	0.011	0.009	0.010	0.014	0.010	0.010
	-70 dBm	0.013	0.011	0.010	0.013	0.015	0.011	0.010
	-80 dBm	0.013	0.012	0.010	0.010	0.012	0.008	0.009
	-90 dBm	0.013	0.011	0.011	0.013	0.014	0.010	0.012
	-100 dBm	0.023	0.017	0.016	0.017	0.018	0.015	0.012
	-110 dBm	0.024	0.015	0.020	0.064	0.055	0.017	0.022
	-120 dBm	0.042	0.018	0.030	0.17	0.073	0.021	0.081
	-128 dBm	0.073	0.032	0.096	0.20	0.33	0.10	0.18

Table V.c Power Measurement Absolute (CMC in dBm, K=2)

		FREQUENCY						
		9 kHz to <10 MHz	10 MHz to <50 MHz	50 MHz	>50 MHz to 8 GHz	>8 GHz to 13.2 GHz	>13.2 GHz to 18 GHz	18 GHz to 26.5 GHz
Change From Reference	+20 dBm	0.11	0.079	0.055	0.062	0.079	0.082	0.12
	+10 dBm	0.11	0.076	0.047	0.055	0.077	0.077	0.12
	0 dBm	0.10	0.076	0.047	0.054	0.078	0.078	0.12
	-10 dBm	0.10	0.076	0.048	0.055	0.078	0.078	0.12
	-20 dBm	0.10	0.076	0.048	0.055	0.078	0.078	0.12
	-30 dBm	0.10	0.077	0.048	0.055	0.078	0.078	0.12
	-40 dBm	0.10	0.077	0.048	0.055	0.078	0.078	0.12
	-50 dBm	0.10	0.077	0.048	0.055	0.078	0.078	0.12
	-60 dBm	0.10	0.077	0.048	0.055	0.079	0.078	0.12
	-70 dBm	0.10	0.077	0.048	0.055	0.079	0.078	0.12
	-80 dBm	0.10	0.077	0.048	0.055	0.079	0.078	0.12
	-90 dBm	0.11	0.077	0.048	0.055	0.079	0.078	0.12
	-100 dBm	0.11	0.077	0.049	0.056	0.079	0.078	0.12
	-110 dBm	0.11	0.077	0.049	0.065	0.084	0.079	0.12
	-120 dBm	0.11	0.077	0.051	0.11	0.088	0.083	0.12
	-128 dBm	0.12	0.079	0.071	0.12	0.19	0.088	0.15

Table V.d Power Source Absolute (CMC in dBm, K=2)

		FREQUENCY						
		9 kHz to <10 MHz	10 MHz to <50 MHz	50 MHz	>50 MHz to 8 GHz	>8 GHz to 13.2 GHz	>13.2 GHz to 18 GHz	18 GHz to 26.5 GHz
Change From Reference	+20 dBm	0.11	0.080	0.056	0.067	0.089	0.094	0.12
	+10 dBm	0.11	0.078	0.048	0.060	0.089	0.089	0.12
	0 dBm	0.11	0.078	0.049	0.059	0.091	0.090	0.12
	-10 dBm	0.11	0.077	0.048	0.055	0.080	0.078	0.12
	-20 dBm	0.11	0.078	0.049	0.056	0.080	0.079	0.12
	-30 dBm	0.11	0.079	0.050	0.056	0.080	0.079	0.12
	-40 dBm	0.11	0.079	0.049	0.056	0.081	0.078	0.12
	-50 dBm	0.11	0.079	0.049	0.056	0.082	0.080	0.12
	-60 dBm	0.11	0.080	0.050	0.057	0.083	0.081	0.12
	-70 dBm	0.11	0.079	0.050	0.059	0.083	0.081	0.12
	-80 dBm	0.11	0.080	0.050	0.056	0.081	0.079	0.12
	-90 dBm	0.11	0.078	0.050	0.058	0.081	0.079	0.12
	-100 dBm	0.11	0.082	0.052	0.060	0.084	0.081	0.12
	-110 dBm	0.11	0.081	0.056	0.094	0.11	0.084	0.12
	-120 dBm	0.12	0.082	0.062	0.19	0.12	0.090	0.16
	-128 dBm	0.15	0.090	0.12	0.21	0.35	0.14	0.24

Parameter/Range	Frequency	CMC[2] (±)	Comments
S-Parameters (Reflection & Transmission)	9 kHz to 18 GHz	See tables below (Interpolate CMC's between cardinal points listed)	Network analyzers: 8753ES, E5080A, 8510C calibration kits: 85032B, 85054D

Type N: Reflection S_{11}/S_{22} Linear Magnitude (ρ)

rho	(9 to 300) kHz	(0.3 to 10) MHz	(0.01 to 3) GHz	(3 to 6) GHz	(6 to 8) GHz	(8 to 9) GHz	(9 to 18) GHz
0.01	0.0031	0.0031	0.0045	0.0099	0.0099	0.02	0.02
0.1	0.0031	0.031	0.0045	0.0099	0.0099	0.02	0.02
0.2	0.0031	0.0032	0.0045	0.01	0.01	0.02	0.02
0.3	0.0032	0.0033	0.0047	0.01	0.01	0.02	0.02
0.4	0.0032	0.0034	0.0051	0.011	0.011	0.021	0.021
0.5	0.0033	0.0038	0.0059	0.013	0.013	0.022	0.022
0.6	0.0035	0.0043	0.0071	0.015	0.015	0.024	0.024
0.7	0.0037	0.0051	0.0086	0.018	0.018	0.027	0.027
0.8	0.0039	0.0061	0.011	0.021	0.021	0.031	0.031
0.9	0.0043	0.0072	0.013	0.024	0.024	0.036	0.036
1.0	0.0047	0.0086	0.015	0.028	0.028	0.041	0.041

Type N: Reflection S_{11}/S_{22} Phase (°)

rho	(9 to 300) kHz	(0.3 to 10) MHz	(0.01 to 3) GHz	(3 to 6) GHz	(6 to 8) GHz	(8 to 9) GHz	(9 to 18) GHz
0.01	18	18	2.7	5.7	80	---	---
0.1	1.8	0.9	2.6	5.7	5.7	12	12
0.2	0.9	0.9	1.3	2.9	2.9	5.8	6
0.3	0.6	0.62	0.9	2	2	3.9	4.2
0.4	0.46	0.49	0.74	1.6	1.6	3	2.3
0.5	0.38	0.43	0.68	1.5	1.5	2.5	2.8
0.6	0.33	0.41	0.67	1.4	1.4	2.3	2.6
0.7	0.3	0.42	0.7	1.4	1.4	2.2	2.5
0.8	0.28	0.43	0.75	1.5	1.5	2.2	2.5
0.9	0.27	0.46	0.81	1.6	1.6	2.3	2.6
1.0	0.27	0.49	0.88	1.7	1.7	2.4	2.7

Parameter/Range	Frequency	CMC[2] (±)	Comments
S-Parameters (Reflection & Transmission)	9 kHz to 18 GHz	See tables below (Interpolate CMC's between cardinal points listed)	Network analyzers: 8753ES, E5080A, 8510C calibration kits: 85032B, 85054D

Type N: Reflection S_{21}/S_{12} Linear Magnitude (dB)

dB	(9 to 300) kHz	(0.3 to 10) MHz	(0.01 to 3) GHz	(3 to 6) GHz	(6 to 8) GHz	(8 to 9) GHz	(9 to 18) GHz
10	0.036	0.031	0.036	0.085	0.085	0.11	0.11
0	0.024	0.016	0.025	0.028	0.028	0.081	0.081
-10	0.026	0.019	0.027	0.03	0.03	0.081	0.081
-20	0.027	0.021	0.028	0.031	0.031	0.081	0.081
-30	0.029	0.023	0.03	0.032	0.032	0.083	0.083
-40	0.033	0.026	0.032	0.044	0.044	0.096	0.096
-50	0.047	0.035	0.039	0.087	0.087	0.14	0.14
-60	0.012	0.084	0.082	0.11	0.11	0.18	0.37
-70	0.31	0.17	0.15	0.17	0.17	0.22	1.1
-80	0.88	0.43	0.33	0.33	0.33	0.36	---
-90	2.5	1.2	0.89	0.89	0.89	0.9	---

Type N: Reflection S_{21}/S_{12} Phase (°)

dB	(9 to 300) kHz	(0.3 to 10) MHz	(0.01 to 3) GHz	(3 to 6) GHz	(6 to 8) GHz	(8 to 9) GHz	(9 to 18) GHz
10	0.21	0.17	0.21	0.55	0.55	1	1
0	0.16	0.11	0.17	0.36	0.36	0.82	0.82
-10	0.17	0.12	0.17	0.37	0.37	0.82	0.82
-20	0.18	0.13	0.18	0.38	0.38	0.82	0.82
-30	0.19	0.14	0.19	0.38	0.38	0.83	0.83
-40	0.21	0.16	0.2	0.45	0.45	0.9	0.9
-50	0.31	0.22	0.25	0.57	0.57	1.1	1.2
-60	0.78	0.55	0.53	0.74	0.74	1.2	2.7
-70	2.1	1.1	0.98	1.1	1.1	1.4	7.1
-80	6.1	2.9	2.2	2.2	2.2	2.4	---
-90	20	8.7	6.2	6.2	6.2	6.3	---

Parameter/Range	Frequency	CMC[2] (±)	Comments
S-Parameters (Reflection & Transmission)	9 kHz to 26.5 GHz	See tables below (Interpolate CMC's between cardinal points listed)	Network analyzers: 8753ES, E5080A, 8510C calibration kits: 85052D

3.5 mm: Reflection S_{11}/S_{22} Linear Magnitude (ρ)

rho	(9 to 300) kHz	(0.3 to 10) MHz	(0.01 to 3) GHz	(3 to 6) GHz	(6 to 8) GHz	(8 to 9) GHz	(9 to 20) GHz	(20 to 26.5) GHz
0.01	0.0079	0.0079	0.013	0.013	0.013	0.016	0.016	0.032
0.1	0.008	0.008	0.013	0.013	0.013	0.016	0.016	0.032
0.2	0.008	0.008	0.013	0.013	0.013	0.016	0.016	0.032
0.3	0.0081	0.0081	0.013	0.013	0.013	0.016	0.016	0.032
0.4	0.0083	0.0083	0.013	0.013	0.013	0.017	0.017	0.032
0.5	0.0087	0.0087	0.014	0.014	0.014	0.019	0.019	0.034
0.6	0.0095	0.0095	0.016	0.016	0.016	0.021	0.021	0.038
0.7	0.011	0.011	0.019	0.019	0.019	0.024	0.024	0.041
0.8	0.012	0.012	0.022	0.022	0.022	0.029	0.029	0.046
0.9	0.014	0.014	0.026	0.026	0.026	0.035	0.034	0.053
1.0	0.016	0.016	0.031	0.031	0.031	0.041	0.04	0.062

3.5 mm: Reflection S_{11}/S_{22} Phase (°)

rho	(9 to 300) kHz	(0.3 to 10) MHz	(0.01 to 3) GHz	(3 to 6) GHz	(6 to 8) GHz	(8 to 9) GHz	(9 to 20) GHz	(20 to 26.5) GHz
0.01	---	53	---	---	---	---	---	---
0.1	4.6	4.6	7.2	7.2	7.2	9.1	9.4	19
0.2	2.3	2.3	3.6	3.6	3.6	4.6	4.9	9.5
0.3	1.5	1.5	2.4	2.4	2.4	3.1	3.4	6.5
0.4	1.2	1.2	1.9	1.9	1.9	2.4	2.7	5.1
0.5	1	1	1.7	1.7	1.7	2.1	2.4	4.3
0.6	0.9	0.9	1.6	1.6	1.6	2	2.3	3.9
0.7	0.86	0.86	1.5	1.5	1.5	2	2.3	3.7
0.8	0.86	0.86	1.6	1.6	1.6	2.1	2.4	3.7
0.9	0.89	0.89	1.7	1.7	1.7	2.2	2.5	3.8
1.0	0.93	0.93	1.8	1.8	1.8	2.4	2.7	3.9

Parameter/Range	Frequency	CMC[2] (±)	Comments
S-Parameters (Reflection & Transmission)	9 kHz to 26.5 GHz	See tables below (Interpolate CMC's between cardinal points listed)	Network analyzers: 8753ES, E5080A, 8510C calibration kits: 85052D

3.5 mm: Reflection S_{21}/S_{12} Linear Magnitude (dB)

dB	(9 to 300) kHz	(0.3 to 10) MHz	(0.01 to 3) GHz	(3 to 6) GHz	(6 to 8) GHz	(8 to 9) GHz	(9 to 20) GHz	(20 to 26.5) GHz
10	0.081	0.038	0.057	0.028	0.028	0.15	0.076	0.15
0	0.077	0.028	0.051	0.028	0.028	0.15	0.076	0.15
-10	0.077	0.029	0.052	0.03	0.03	0.15	0.076	0.15
-20	0.078	0.031	0.052	0.032	0.032	0.15	0.077	0.15
-30	0.079	0.032	0.053	0.033	0.033	0.15	0.078	0.16
-40	0.08	0.034	0.055	0.045	0.045	0.15	0.093	0.21
-50	0.087	0.042	0.059	0.089	0.089	0.15	0.14	0.43
-60	0.14	0.087	0.093	0.12	0.12	0.17	0.39	1.5
-70	0.32	0.17	0.16	0.17	0.17	0.21	1.2	5.2
-80	0.89	0.43	0.33	0.34	0.34	0.36	---	---
-90	2.5	1.2	0.89	0.9	0.9	0.9	---	---

3.5 mm: Reflection S_{21}/S_{12} Phase (°)

dB	(9 to 300) kHz	(0.3 to 10) MHz	(0.01 to 3) GHz	(3 to 6) GHz	(6 to 8) GHz	(8 to 9) GHz	(9 to 20) GHz	(20 to 26.5) GHz
10	0.53	0.23	0.37	0.36	0.36	0.99	0.81	1.4
0	0.51	0.19	0.35	0.36	0.36	0.98	0.8	1.4
-10	0.51	0.19	0.35	0.37	0.37	0.98	0.81	1.4
-20	0.51	0.2	0.36	0.38	0.38	0.98	0.81	1.4
-30	0.52	0.21	0.36	0.39	0.39	0.99	0.82	1.4
-40	0.53	0.22	0.37	0.45	0.45	0.99	0.89	1.7
-50	0.57	0.27	0.39	0.63	0.63	1	1.2	3.1
-60	0.92	0.57	0.61	0.78	0.78	1.1	2.8	9.9
-70	2.1	1.2	1	1.1	1.1	1.4	7.6	27
-80	6.2	2.9	2.2	2.3	2.3	2.4	---	---
-90	20	6.7	6.2	6.2	6.2	6.3	---	---

Parameter/Range	Frequency	CMC[2] (±)	Comments
S-Parameters (Reflection & Transmission)	9 kHz to 6 GHz	See tables below (Interpolate CMC's between cardinal points listed)	Network analyzers: 8753ES, E5080A calibration kits: 85031B

7 mm: Reflection S_{11}/S_{22} Linear Magnitude (ρ)

rho	(9 to 300) kHz	(0.3 to 10) MHz	(0.01 to 3) GHz	(3 to 6) GHz
0.01	0..017	0.0017	0.0026	0.0052
0.1	0.0017	0.0017	0.0027	0.0052
0.2	0.0017	0.0017	0.0027	0.0052
0.3	0.0017	0.0017	0.0027	0.0053
0.4	0.0017	0.0018	0.0028	0.0054
0.5	0.0018	0.0019	0.0029	0.0056
0.6	0.0019	0.002	0.003	0.006
0.7	0.002	0.0022	0.0032	0.0064
0.8	0.0021	0.0025	0.0035	0.007
0.9	0.0023	0.0028	0.0039	0.0079
1.0	0.0025	0.0032	0.0044	0.0088

7 mm: Reflection S_{11}/S_{22} Phase (°)

rho	(9 to 300) kHz	(0.3 to 10) MHz	(0.01 to 3) GHz	(3 to 6) GHz
0.01	---	9.7	---	31
0.1	0.95	0.97	1.5	3
0.2	0.48	0.49	0.77	1.5
0.3	0.32	0.33	0.52	1
0.4	0.25	0.26	0.4	0.77
0.5	0.2	0.21	0.33	0.64
0.6	0.18	0.19	0.29	0.56
0.7	0.16	0.18	0.27	0.52
0.8	0.15	0.18	0.26	0.5
0.9	0.14	0.18	0.25	0.5
1.0	0.14	0.18	0.25	0.5

Parameter/Range	Frequency	CMC[2] (±)	Comments
S-Parameters (Reflection & Transmission)	9 kHz to 6 GHz	See tables below (Interpolate CMC's between cardinal points listed)	Network analyzers: 8753ES, E5080A calibration kits: 85031B

7 mm: Reflection S_{21}/S_{12} Linear Magnitude (dB)

dB	(9 to 300) kHz	(0.3 to 10) MHz	(0.01 to 3) GHz	(3 to 6) GHz
10	0.029	0.027	0.028	0.037
0	0.013	0.009	0.011	0.027
-10	0.016	0.013	0.014	0.028
-20	0.018	0.016	0.017	0.03
-30	0.021	0.019	0.02	0.032
-40	0.025	0.022	0.023	0.034
-50	0.043	0.032	0.032	0.04
-60	0.11	0.083	0.078	0.082
-70	0.31	0.17	0.15	0.15
-80	0.88	0.43	0.33	0.33
-90	2.5	1.2	0.89	0.89

7 mm: Reflection S_{21}/S_{12} Phase (°)

dB	(9 to 300) kHz	(0.3 to 10) MHz	(0.01 to 3) GHz	(3 to 6) GHz
10	0.16	0.15	0.18	0.22
0	0.086	0.065	0.12	0.18
-10	0.098	0.081	0.13	0.18
-20	0.11	0.098	0.14	0.19
-30	0.13	0.12	0.15	0.2
-40	0.16	0.14	0.17	0.21
-50	0.27	0.21	0.2	0.26
-60	0.77	0.54	0.51	0.53
-70	2.1	1.1	0.97	0.98
-80	6.1	2.9	2.2	2.2
-90	20	8.7	6.2	6.2

VI. Fluid Quantities

Parameter/Equipment	Range	CMC[2, 8] (±)	Comments
Viscosity[3] –			
Dynamic (Meter)	(0 to 100 000) cP	0.83 %	Standard viscosity fluids, PRT, stopwatch
Kinematic (Cups)	(0 to 100 000) cP	0.24 % + 0.84 s	
Hydrometers – Direct Verification			Electronic balance, Class 0 weight set, master hydrometer
	(0.66 to 0.75) sp. gr.	0.000 31 sp. gr.	Petroleum solution
	(0.75 to 1.00) sp. gr.	0.000 34 sp. gr.	Alcohol solution
	(1.00) sp. gr.	0.000 21 sp. gr.	Distilled water
	(1.005 to 1.85) sp. gr.	0.000 26 sp. gr.	Sulfuric acid solution
Volumetric Calibration	Up to 250 mL (>250 to 1200) mL (>1.2 to 8.2) L (>8.2 to 32) L	0.08 % + 50 µL 330 µL 0.001 % + 920 µL 0.002 % + 780 µL	Gravimetric method

VII. Foundry-Industry Specific Calibrations

Parameter/Equipment	Range	CMC[2, 8] (±)	Comments
Welders[3]	(1 to 50) V (1 to 750) A	1.0 % 1.0 %	Loadbank & DMM

VIII. Mechanical

Parameter/Equipment	Range	CMC[2, 4, 8] (±)	Comments
Accelerometers[3]			
Frequency Response	(1 to 10) g, (5 to <10) Hz (1 to 10) g, (10 to <100) Hz (1 to 10) g, (100) Hz (1 to 10) g, (>100 to 920) Hz (1 to 10) g, >920 Hz to 5 kHz (1 to 10) g, (>5 to 10) kHz (1 to 10) g, (>10 to 15) kHz	1.8 % 1.3 % 0.9 % 1.1 % 1.5 % 2 % 2.3 %	9155C with 353B04
Voltage Sensitivity	(0.5 to 1000) mV/g, 100 Hz (0.5 to 1000) mV/g, 159 Hz	1.5 % 1.5 %	
Charge Sensitivity	(0.5 to 100) pC/g, 100 Hz (0.5 to 100) pC/g, 1 kHz	1.5 % 1.5 %	9155C with 353B04 & 422M184
Phase	± 360 °, (5 to <100) Hz ± 360 °, 100 Hz to <5 kHz	1.6 ° 1.4 °	9155C with 353B04
Air Velocity			Wind tunnel, thermometer, Flowkinetics manometer & pitot tube
Low Range High Range	(141 to 2829) FPM (895 to 17 892) FPM	0.43 % + 12 FPM 1.1 % + 63 FPM	
Cable Tensiometers/ Wire Tension Meters	Up to to 1000 lbf	1.1 lbf + 0.6*R*	Deadweights
Durometers[3] –	Types A, B, C, D, E, O & DO		ASTM D2240
	Pressure Foot Orifice Diameter	3.2 µm	
Indenter Shape & Extension	Indenter Extension Length	3.2 µm	Gage blocks
	Cone Angle Tip Radius Indenter Thickness	1 arcmin 3.2 µm 3.2 µm	Vision system
Durometer Spring	Up to 45 N	36 mN	Durometer calibrator
Display Linearity	(0.001 to 0.2) in	37 µin or 0.6*R*, (Whichever is Greater)	Gage blocks

Parameter/Equipment	Range	CMC[2, 8] (±)	Comments
Durometer Calibrator	Scales A, B, E, O & C, D, DO	0.20 %	Scale & CMM
Indirect Verification of Brinell Hardness Testers at Test Condition(s)[3] – (3000, 1500, 500) kg	10 mm/500 kg (50 to 70) HBW (71 to 90) HBW (91 to 109) HBW 10 mm/1500 kg (50 to 99) HBW (100 to 200) HBW (201 to 345) HBW 10 mm/3000 kg (100 to 199) HBW (200 to 499) HBW (500 to 650) HBW	 0.13 HBW 0.38 HBW 1.1 HBW 0.35 HBW 0.56 HBW 1.4 HBW 0.80 HBW 1.6 HBW 3.7 HBW	ASTM E10
Indirect Verification of Leeb Hardness Testers	HLD: Low Medium High	 8 HLD 9 HLD 10 HLD	ASTM A956
Indirect Verification of Microindentation Hardness Testers (Knoop & Vickers)[3] –	<u>Vickers, ≤1 kg</u> (100 to 240) HV (241 to 600) HV (600 to >650) HV <u>Knoop, ≤1 kg</u> (100 to 250) HK (251 to 650) HK (650 to >650) HK	 11 HV 11 HV 11 HV 5.3 HK 5.6 HK 5.2 HK	ASTM E384

Parameter/Equipment	Range	CMC[2] (±)	Comments
Indirect Verification of Rockwell Hardness & Rockwell Superficial Hardness Testers[3]	HRA: Low Mid High HRBW: Low Mid High HRC: Low Mid High HRE: Low Mid High HR15N: Low Mid High HR30N: Low Mid High HR45N: Low Mid High HR15T: Low Mid High HR30T: Low Mid High HR45T: Low Mid High	 0.29 HRA 0.56 HRA 0.24 HRA 0.94 HRB 0.69 HRB 0.62 HRB 0.78 HRC 0.92 HRC 0.39 HRC 0.92 HRE 1.1 HRE 0.89 HRE 0.76 HR15N 0.75 HR15N 1.1 HR15N 0.55 HR30N 0.48 HR30N 0.46 HR30N 0.68 HR45N 0.72 HR45N 0.66 HR45N 0.79 HR15T 0.52 HR15T 0.61 HR15T 0.70 HR30T 0.61 HR30T 0.42 HR30T 0.98 HR45T 0.78 HR45T 0.81 HR45T	ASTM E18

Parameter/Equipment	Range	CMC[2, 8] (±)	Comments
Load Cells & Transducers[3] – Load Cells, Force Gauges, Force Rings, & Dynamometers	Up to 3325 lbf Up to 40 ozf Up to 50 gf Up to 2.2 lbf Up to 11 lbf Up to 25 lbf Up to 500 lbf Up to 2000 lbf Up to 5000 lbf Up to 10 000 lbf Up to 25 000 lbf Up to 50 000 lbf	0.01 % 0.021 ozf + 0.32 % 0.17 gf 0.0013 lbf + 0.0041 % 0.0086 lbf + 0.0036 % 0.014 lbf + 0.004 % 0.23 lbf + 0.007 % 0.34 lbf + 0.013 % 0.83 lbf + 0.048 % 1.5 lbf + 0.05 % 8.1 lbf + 0.03 % 7.6 lbf + 0.039 %	Dead weights Comparison to master load cells
Mass	1 mg 2 mg 3 mg 5 mg 10 mg 20 mg 30 mg 50 mg 100 mg 200 mg 300 mg 500 mg 1 g 2 g 3 g 5 g 10 g 20 g 30 g 50 g 100 g 200 g 300 g 500 g 1 kg 2 kg 3 kg 5 kg 10 kg 20 kg 30 kg 32 kg	0.000 87 mg 0.0010 mg 0.000 94 mg 0.0012 mg 0.0011 mg 0.001 mg 0.0011 mg 0.0013 mg 0.0013 mg 0.0012 mg 0.0016 mg 0.0014 mg 0.0014 mg 0.0016 mg 0.0022 mg 0.0033 mg 0.0064 mg 0.0065 mg 0.0082 mg 0.013 mg 0.022 mg 0.055 mg 0.039 mg 0.043 mg 0.06 mg 0.28 mg 0.56 mg 0.84 mg 1.1 mg 11 mg 24 mg 24 mg	Mass by substitution comparison using NIST SOP 4 & NIST SOP 7. ASTM E617-18 Classes 3 to 7. NIST Class F.

Parameter/Equipment	Range	CMC[2, 8] (±)	Comments
Pressure/Vacuum Gauges & Transducers[3]	Up to 1 inH_2O (>1 to 5) inH_2O (>5 to 10) inH_2O (>10 to 100) inH_2O (>100 to 400) inH_2O ($1x10^{-9}$ to $2x10^{-4}$) Torr $2x10^{-4}$ Torr to Atmosphere (0.1 to 1000) Torr (-13.8 to 1500) psig (>1500 to 3000) psig (>3000 to 6000) psig (>6000 to 10 000) psig (10 000 to 15 000) psig	0.0006 inH_2O 0.0031 inH_2O 0.0061 inH_2O 0.0016 % + 0.0058 inH_2O 0.0015 % + 0.0015 inH_2O 9.2 % 2.1 % 0.6 Torr + 0.15 % Greater of (0.0092 % + 0.014 psig) or 0.075 psig 0.004 % + 0.24 psig 0.0007 % + 0.66 psig 0.0038 % + 0.75 psig 9.4 psi	Pressure calibrators & sensors
Barometric	(8 to 17) psig	0.0033 % + 0.0039 psia	
Balances[3, 11, 12]	Up to 30 kg	0.82 x UUT Resolution	Class 0, 1, 3 & 4 weight set
Scales[3, 12]	Up to 1000 lbs	0.82 x UUT Resolution	Class F weights
Torque			
Wrenches, Watches, & Indicators	Up to 1.5 lbf·in (>1.5 to 10) lbf·in (>10 to 100) lbf·in (>100 to 145) lbf·in (>145 to 3000) lbf·in (>3000 to 24 000) lbf·in	0.0076 lbf·in 0.17 % + 0.013 lbf·in 0.25 % + 0.008 lbf·in 0.38 lbf·in 0.28 % + 0.0058 lbf·in 0.25 % + 3 lbf·in	Torque calibrator
Testers, Analyzers & Transducers	Up to 2000 lbf·ft	0.05 %	Weights, loading arms
Ultrasonic Hardness Testers	HRC Low Mid High	 0.42 HRC 0.43 HRC 0.38 HRC	ASTM A1038
Ultrasonic Thickness Testers[3]	(0 to 10) in	25 µin/in + 850 µin	Standard thickness specimen

IX. Optical Quantities

Parameter/Equipment	Range	CMC[2] (±)	Comments
Gloss Meters[3]	20°, 90 ± 10 % *GU* 60°, 85°, 95 ± 10 % *GU*	0.73 *GU* 0.54 *GU*	Gloss standards; *GU* represents gloss units.

X. Thermodynamics

Parameter/Equipment	Range	CMC[2, 4. 8, 13] (±)	Comments
Dew Point	(-20 to 60) °C	0.44 °C + 0.6*R*	Thunder Scientific humidity chamber
Infrared Thermometers[3]	(-15 to 120) °C (35 to 500) °C (150 to 1200) °C	0.57 °C + 0.0017 °C/°C 0.47 °C + 0.0047 °C/°C 3.3 °C + 0.0049 °C/°C	Fluke 418x series Isotech Pegasus
Temperature Measuring Equipment – Indicators, RTD's, Thermocouples[3]	-80 °C, (-30 to 300) °C (300 to 650) °C (650 to 1100) °C	0.006 % + 0.017 °C 0.007 % + 0.039 °C 0.018 % + 0.41 °C but Not Less Than 0.02 °C	Temperature source, SPRT
Temperature – Measure[3]	(-196 to 660) °C (660 to 1450) °C	0.017 °C + 0.000 027 x $\Delta T_{\text{Change from -196 °C}}$ 0.94 °C + 0.002 x $\Delta T_{\text{Change from 660 °C}}$	Fluke 1560, 2560 & 5609 Fluke 5650 Type S Probe
Relative Humidity – Measure Generate Psychrometers	 (5 to 95) % RH (5 to 95) % RH (5 to 35) °C	 0.9 % + 0.072 % RH but Not Less Than 0.13 % RH 0.57 % 0.28 % + 0.44 % RH but Not Less Than 0.5 % RH 0.1 °C + 0.84*R*	 Chilled mirror, RH Systems 973 Pressure & temperature method Thunder Scientific 2500ST Comparison to SPRT in temp bath

XI. Time & Frequency

Parameter/Equipment	Range	CMC[2, 13] (±)	Comments
Frequency – Measuring Equipment & Measure	10 MHz 0.01 Hz to 6 GHz (6 to 26.5) GHz	3 parts in 10^{11} 3.1 parts in 10^{11} 6.7 parts in 10^{11} + 1 Hz	GPS Function generator, signal generator, frequency counter or spectrum analyzer with ext. GPS timebase
Stopwatches & Timers[3]	10 s to 24 hr Up to 19.99 s/day (86 400 s)	28 ms + 18 µs/s 0.037 s/day	Function generator, frequency counter Timometer – NIST SP 960-12
Tachometers[3] – Non-Contact Contact	 Up to 180 000 rpm Up to 5000 rpm (5000 to 15 000) rpm	 0.8*R* 0.024 % + 1.4 rpm 0.032 % + 0.84 rpm	 Calibrator, LED Tachometer calibrator
Rotational Speed[3] – Measure Optical Contact	 (5 to 99 999) rpm (0.5 to 15 000) rpm	 0.22 rpm + 0.000 61 rpm/rpm 1.7 rpm + 0.000 65 rpm/rpm	 Handheld tachometer

[1] This laboratory offers commercial calibration service and field calibration service.

[2] Calibration and Measurement Capability Uncertainty (CMC) is the smallest uncertainty of measurement that a laboratory can achieve within its scope of accreditation when performing more or less routine calibrations of nearly ideal measurement standards or nearly ideal measuring equipment. CMCs represent expanded uncertainties expressed at approximately the 95 % level of confidence, usually using a coverage factor of $k = 2$. The actual measurement uncertainty of a specific calibration performed by the laboratory may be greater than the CMC due to the behavior of the customer's device and to influences from the circumstances of the specific calibration.

[3] Field calibration service is available for this calibration. Please note the actual measurement uncertainties achievable on a customer's site can normally be expected to be larger than the CMC found on the A2LA Scope. Allowance must be made for aspects such as the environment at the place of calibration and for other possible adverse effects such as those caused by transportation of the calibration equipment. The usual allowance for the actual uncertainty introduced by the item being calibrated, (e.g. resolution) must also be considered and this, on its own, could result in the actual measurement uncertainty achievable on a customer's site being larger than the CMC.

[4] In the statement of CMC, *L* is the numerical value of the nominal length in inches; *R* is the resolution of the unit under test; *D* is the diameter in inches; *H* is the height of the unit under test (except where noted); and fs represents full scale. *Ra* is the numerical value of the nominal roughness of the surface measured in micrometer roughness, except where noted; the value is defined as the percentage of reading, unless otherwise noted.

[5] CMC for calibrations performed in the laboratory with the Agilent/HP 3458A/HFL is based upon 90-day specifications. CMC for calibrations performed field with the Agilent/HP 3458A is based upon 1-year specifications. The measurands stated are generated with the Agilent/HP 3458A. This capability is suitable for the calibration of the devices intended to measure the stated measurand in the ranges indicated. CMC are expressed as either a specific value that covers the full range or as a fraction of the reading plus a fixed floor specification. Unless otherwise noted, percentages are defined as percent of reading.

[6] CMC for calibrations performed with the Fluke 5520A is based upon 1-year specifications. CMC for calibrations performed with the Fluke 5720A/EP is based upon 90-day specifications. The measurands stated are generated with the Fluke 5500, 5700 and 732B series of instruments. This capability is suitable for the calibration of the devices intended to measure the stated measurand in the ranges indicated. CMC are expressed as either a specific value that covers the full range or as a fraction of the reading plus a fixed floor specification. Unless otherwise noted, percentages are defined as percent of reading.

[7] CMC for calibrations performed with the Fluke 5790A is based upon 1-year specifications. The measurands stated are generated with the Fluke 5700 series of instruments. This capability is suitable for the calibration of the devices intended to measure the stated measurand in the ranges indicated. CMCs are expressed as either a specific value that covers the full range or as a fraction of the reading plus a fixed floor specification. Unless otherwise noted, percentages are defined as percent of reading.

[8] In the statement of CMC, the value is defined as the percentage of reading, unless otherwise noted.

[9] This calibration is offered for "Field Service" only.

[10] Parallelism measurements apply only to optical parallels; calibrated for flatness and parallelism.

[11] Balance resolution is not included in the CMC. The uncertainty stated on the Certificate of Calibration will be larger than the CMC due to the resolution of the balance being included in the reported expanded uncertainty.

[12] Balances and scales are typically calibrated at the place of use. If a balance or scale is not calibrated at the place of use, the user is responsible to account for any gravitational or air buoyancy errors that may result.

[13] The type of instrument or material being calibrated is defined by the parameter. This indicates the laboratory is capable of calibrating instruments that measure or generate the values in the ranges indicated for the listed measurement parameter.

[14] The measurands stated are generated using the indicated instrument (see Comments). This capability is suitable for the calibration of the devices intended to measure the measurand in the ranges indicated. CMCs are expressed as either a specific value that covers the full range or as a fraction of the reading plus a fixed floor specification.

[15] This scope meets A2LA's *P112 Flexible Scope Policy.*

Accredited Laboratory

A2LA has accredited

TRESCAL, INC.

Milwaukee, WI

for technical competence in the field of

Calibration

This laboratory is accredited in accordance with the recognized International Standard ISO/IEC 17025:2017 *General requirements for the competence of testing and calibration laboratories*. This laboratory also meets the requirements of ANSI/NCSL Z540-1-1994 and R205 – Specific Requirements: Calibration Laboratory Accreditation Program. This accreditation demonstrates technical competence for a defined scope and the operation of a laboratory quality management system (*refer to joint ISO-ILAC-IAF Communiqué dated April 2017*).

Presented this 18th day of September 2025.

Mr. Trace McInturff, Vice President, Accreditation Services
For the Accreditation Council
Certificate Number 1078.01
Valid to May 31, 2027

For the calibrations to which this accreditation applies, please refer to the laboratory's Calibration Scope of Accreditation.