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

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CALIBRATION

Valid To: March 31, 2025 Certificate Number: 2516.01

In recognition of the successful completion of the A2LA evaluation process, accreditation is granted to this laboratory to perform the following calibrations[1, 12]:

I. Chemical

Parameter/Equipment	Range	CMC[2, 13] (±)	Comments
pH – Measuring Equipment[3, 8]	≈4 pH ≈7 pH ≈10 pH	0.011 pH 0.011 pH 0.011 pH	Buffer solutions
Electrolytic Conductivity – Measuring Equipment	≈10 µS/cm ≈100 µS/cm ≈1000 µS/cm ≈10 000 µS/cm	0.62 µS/cm 2.1 µS/cm 4.6 µS/cm 40 µS/cm	Conductivity solutions

II. Dimensional

Parameter/Equipment	Range	CMC[2, 13] (±)	Comments
Angle – Measure[8]	Up to 60º	6.9” + 0.0010 ”/ ”	Gage blocks & sine bar
Angle – Measuring Equipment[8]	5º, 15º, 30º, 45º	6.8”	Angle blocks

Parameter/Equipment	Range	CMC[2] (±)	Comments
Bore Gages, Bore Micrometers & Holtests[3, 8]	Up to 8 in (8 to 20) in	67 µin + 6 µin/in 230 µin + 16 µin/in	Plain ring gages
Chamfer Gages[3, 8]	(0.188 to 0.750) in (0.750 to 1.000) in (1.000 to 2.000) in	580 µin 400 µin 220 µin + 83 µin/in	Master chamfer rings
Coordinate Measuring Machines[3, 8] –			
Repeatability	(0.75 to 1) in	67 µin	Sphere
Linear Accuracy	Up to 40 in	14 µin + 3.2 µin/in	Step gage/gage blocks
Squareness	Up to 18 in	72 µin + 1.8 µin/in	Square
Volumetric Performance	600 mm	88 µin	Ball bar[10]
Crimping Tools –			
Crimp Height	Up to 0.5 in	190 µin	Pin gages
Diameter, External[8] –	Up to 20 in	12 µin + 1.4 µin/in	ULM
Diameter, Internal[8] –	(0.13 to 1.0) in (1.0 to 20) in	8.2 µin + 0.26 µin/in 7.5 µin + 3.6 µin/in	Ring comparator ULM w/ gage blocks
Flatness[8]	3 in	3.2 µin	Optical flat
Gage Blocks	Up to 0.050 in (0.05 to 4) in	5.2 µin 2.4 µin + 1.2 µin/in	Comparison to gage blocks

Parameter/Equipment	Range	CMC[2] (±)	Comments
Hand Tools[3, 8]			
Indicators	(1 to 6) in	7.6 µin + 7 µin/in	Gage blocks
Micrometers	(1 to 80) in	11 µin + 7.5 µin/in	
Depth Gages	(1 to 80) in	11 µin + 8 µin/in	
Height Gages	(1 to 80) in	11 µin + 7.5 µin/in	
Calipers	(1 to 120) in	11 µin + 7 µin/in	
Height Master[3, 8] & Height Gages–			
Displacement – Length	Up to 24 in	14 µin + 3.6 µin/in	Gage blocks, linear amplifier
Height Master Micrometer Head	Up to 2 in	14 µin + 0.9 µin/in	Gage blocks, linear amplifier
Fixture Gages[8] (Inspection Fixtures, Hard Tooling, Functional Gages)			
1D	Up to 48 in	15 µin + 4 µin/in	Linear amplifier, gage blocks
	(48 to 60) in	340 µin + 2 µin/in	CMM
2D	X to Y: 24 in x 24 in	290 µin + 6 µin/in	CMM
	X to Z or Y to Z: 24 in x 20 in	290 µin + 6 µin/in	CMM
Volumetric	20 in x 20 in x 24 in	390 µin + 8 µin/in	CMM
Angle	360°	8.3”	CMM

Parameter/Equipment	Range	CMC[2] (±)	Comments
Linear Scales[3,8]			
Machine Tools & Linear Scales, Glass Scales, Optical Magnifiers	Up to 1 in (1 to 6) in (6 to 12) in (12 to 144) in	170 µin 200 µin + 21 µin/in 300 µin + 5 µin/in 440 µin + 32 µin/in	Optical comparator
ULM	Up to 40 in	2.4 µin + 4.7 µin/in	Gage blocks
1D Length	Up to 4 in [9]	13 µin + 2 µin/in	Gage blocks, linear amplifier
	(4 to 20) in	20 µin + 3.2 µin/in	ULM
	(20 to 80) in	86 µin + 3 µin/in	Gage blocks, linear amplifier
Optical Comparators[3, 8] –			
Linear Travel Angle	Up to 24 in Up to 360°	110 µin + 10 µin/in 1.4”	Glass scales Master balls
Surface Roughness Testers[3, 8]			
Profilometer Stylus Profilometer Linearity Profilometer Span	≈ 13 µin (Ra) ≈ 16 µin (Ra) ≈ 120 µin (Ra)	2.7 µin (Ra) 2.6 µin (Ra) 4.4 µin (Ra)	Surface roughness standards
Radius Gages[8]	Up to 1 in (1 to 6) in (6 to 12) in	180 µin 150 µin + 25 µin/in 310 µin + 5 µin/in	Optical comparator
Sieves & Sieve Cloths[8]	20 µm to 26.5 mm	3.6 µm	ASTM E11 w/ optical comparator

Parameter/Equipment	Range	CMC[2] (±)	Comments
Squareness[8]	90º	73 µin + 2 µin/in	Master square
Rules[8] & Tapes[3, 8]	Up to 100 ft	0.0018 in + 12 µin/in	Optical comparator, master tapes, & scales
Surface Finish Standards[3, 8]	≈ 16 µin (Ra) ≈ 120 µin (Ra)	4.8 µin (Ra) 12 µin (Ra)	Surface finish standards w/ surface texture analyzers
Surface Plates[3]			
Overall Flatness	Up to 170 in diagonal	4 µin + 3 µin/in	Laser doppler displacement meter
Repeat Readings	Up to 0.0002 inch	26 µin	Repeat-a-meter
	6” x 6”	310 µin	Gage amplifier
Thread Gauging, External[8] –			
Plug Gages, Discs Major Diameter	Up to 8 in	13 µin + 1 µin/in	ULM, master wires
Pitch Diameter: Up to 8 in	29 º (ACME) 55 º (Metric) 60 º (English) 7/45° (Buttress)	89 µin + 3.1 µin/in 10 µm + 1.8 µm 79 µin + 4.5 µin/in 99 µin + 3.6 µin/in	ULM, master wires
National Pipe (NPT) Pitch Diameter	Up to 3 in	76 µin + 3.6 µin/in	ULM, master wires
Step	Up to 4 in	23 µin + 1 µin/in	Gage blocks, linear amplifier

Parameter/Equipment	Range	CMC[2] (±)	Comments
Thread Gauging, Internal[8] –			
Ring Gages: Minor Diameter	Up to 0.5 in	260 µin	Hole micrometer, pins
	(0.50 to 0.75) in (0.75 to 1.68) in (1.68 to 2.00) in (2.00 to 2.40) in (2.40 to 2.80) in	160 µin + 24 µin/in 200 µin + 1 µin/in 360 µin 300 µin 320 µin	Hole micrometer, master ring
Pitch Diameter: Up to 8 in (Adj.)	29° 7/45°, 55 °, 60°	360 µin + 30 µin/in 140 µin + 29 µin/in	Master plug set (functional fit only)

III. Electrical – DC/Low Frequency

Parameter/Equipment	Range	CMC[2, 5, 6, 7] (±)	Comments
DC Voltage[3, 8] – Generate	0 to 220 mV (0.22 to 2.2) V (2.2 to 11) V (11 to 22) V (22 to 220) V (220 to 1100) V	0.49 µV + 5.7 nV/mV 0.8 µV + 3.5 µV/V 2.9 µV + 2.5 µV/V 4.3 µV + 2.5 µV/V 43 µV + 3.5 µV/V 0.42 mV + 4.5 µV/V	Fluke 5720A
DC Voltage[3, 8] – Generate, Fixed Points	1.018 V 10 V	7.1 µV 23 µV	Fluke 732B
DC Voltage – Generate & Measure[3, 8]	Up to 1000 V	4.5 µV/V	Fluke 732B w/ 752A & Agilent 3458A
DC Voltage– Measure[3, 8]	Up to 100 mV (0.1 to 1) V (1 to 10) V (10 to 100) V (100 to 1000) V	0.33 µV + 13 nV/mV 0.52 µV + 4 µV/V 1.6 µV + 4 µV/V 35 µV + 6 µV/V 0.2 mV + 8 µV/V	Agilent 3458A
DC High Voltage[3, 8] – Measure	(1 to 120) kV	0.12 %	Ross VD120 w/ Fluke 189

Parameter/Equipment	Range	CMC[2, 5, 6, 7] (±)	Comments
DC Current[3, 8] – Generate	Up to 2 pA (2 to 20) pA (20 to 200) pA	12 fA + 6.6 fA/pA 24 fA + 4.2 fA/pA 95 fA + 3 fA/pA	Keithley 263
	0 to 220 µA (0.22 to 2.2) mA (2.2 to 22) mA (22 to 220) mA (0.22 to 2.2) A (2.2 to 11) A	6 nA + 35 pA/µA 7.1 nA + 30 nA/mA 41 nA + 30 nA/mA 0.73 µA + 50 nA/mA 12 µA + 0.11 mA/A 0.49 mA + 0.34 mA/A	Fluke 5720A
Clamp-Meters	(11 to 20.5) A	9.4 mA + 0.8 mA/A	Fluke 5520A
	(10 to 16.5) A (16.5 to 150) A (150 to 1025) A	50 mA + 6.5 mA/A 0.18 A + 3.4 mA/A 0.83 A + 3.3 mA/A	Fluke 5520A w/ coil
	(0.1 to 5) kA	1.2 A + 4.6 mA/A	Fluke 5522A, 52120A w/ coil
DC Current[3, 8] – Measure	(0 to 200) pA (0.2 to 200) nA	15 fA + 19 fA/pA 27 pA + 2.9 pA/nA	Keithley 617
	0 to 100 nA (0.1 to 1) µA (1 to 10) µA (10 to 100) µA (0.1 to 1) mA (1 to 10) mA (10 to 100) mA (0.1 to 1) A	41 pA + 89 fA/nA 41 pA + 28 pA/µA 0.4 nA + 24 pA/µA 0.83 nA + 22 pA/µA 5.8 nA + 24 nA/mA 53 nA + 21 nA/mA 0.53 µA + 37 nA/mA 10 µA + 0.11 mA/A	Agilent 3458A
	(1 to 10) A (10 to 100) A	0.0031 % 0.0033 %	w/ L&N 4222 w/ L&N 4223
	(100 to 1000) A	0.0087 %	w/ Empro 1000-100
	(1 to 10) A (10 to 100) A (100 to 300) A	0.0025 % 0.0052 % 0.0054 %	Guildline 9211A

Parameter/Equipment	Range	CMC[2, 5, 7] (±)	Comments
Resistance[3, 8] – Generate	(0 to 10.9999) Ω (11 to 32.9999) Ω (33 to 109.9999) Ω (110 to 329.9999) Ω (0.33 to 1.099 999) kΩ (1.1 to 3.299 999) kΩ (3.3 to 10.999 99) kΩ (11 to 32.999 99) kΩ (33 to 109.9999) kΩ (110 to 329.9999) kΩ (0.33 to 1.099 999) MΩ (1.1 to 3.299 999) MΩ (3.3 to 10.999 99) MΩ (11 to 32.999 99) MΩ (33 to 109.9999) MΩ (110 to 329.9999) MΩ (330 to 1100) MΩ	1.2 mΩ + 24 μΩ/Ω 1.5 mΩ + 24 μΩ/Ω 1.9 mΩ + 22 μΩ/Ω 4.1 mΩ + 22 μΩ/Ω 9.1 mΩ + 22 μΩ/Ω 41 mΩ + 22 μΩ/Ω 92 mΩ + 22 μΩ/Ω 0.41 Ω + 22 μΩ/Ω 0.9 Ω + 22 μΩ/Ω 8.4 Ω + 26 μΩ/Ω 14 Ω + 26 μΩ/Ω 93 Ω + 48 μΩ/Ω 0.4 kΩ + 0.1 mΩ/Ω 4.4 kΩ + 0.2 mΩ/Ω 16 kΩ + 0.4 mΩ/Ω 0.35 MΩ + 2.4 mΩ/Ω 4.4 MΩ + 12 mΩ/Ω	Fluke 5520A
Fixed Points	0.1 mΩ 1 mΩ 10 mΩ 100 mΩ	0.62 μΩ 0.24 μΩ 0.48 μΩ 8.4 μΩ	Empro HA500-50 shunt L&N 4223 L&N 4222 L&N 4221
	1 Ω 1.9 Ω 10 Ω 100 Ω 1 kΩ 10 kΩ 19 kΩ 100 kΩ 1 MΩ 10 MΩ 19 MΩ	30 μΩ 22 μΩ 0.16 mΩ 1.2 mΩ 10 mΩ 55 mΩ 0.11 Ω 0.81 Ω 14 Ω 112 Ω 245 Ω	Fluke 742A series
	0 Ω 1 Ω 1.9 Ω 10 Ω 19 Ω 100 Ω 190 Ω 1 k Ω 1.9 kΩ 10 kΩ 19 kΩ 100 kΩ	50 μΩ 95 μΩ 0.18 mΩ 0.26 mΩ 0.48 mΩ 1.1 mΩ 2.1 mΩ 9 mΩ 17 mΩ 90 mΩ 0.17 Ω 1.1 Ω	Fluke 5720A

Parameter/Equipment	Range	CMC[2, 5, 6, 7] (±)	Comments
Resistance[3, 8] – Generate (cont)			
Fixed Points	190 kΩ 1 MΩ 1.9 MΩ 10 MΩ 19 MΩ 100 MΩ 100 MΩ 1 GΩ 10 GΩ 100 GΩ	2.1 Ω 18 Ω 36 Ω 0.36 kΩ 0.89 kΩ 10 kΩ 1.2 MΩ 12 MΩ 0.12 GΩ 1.2 GΩ	Fluke 5720A IET HRRS-F-6-1M-5kV
DC Resistance[3, 8] – Measure	333 μΩ 1 mΩ 10 mΩ 100 mΩ 1 Ω 10 Ω 100 Ω 1 kΩ 10 kΩ	0.0047 % 0.0046 % 0.002 % 0.002 % 0.0015 % 0.0015 % 0.0015 % 0.0015 % 0.0015 %	Current transfer method using Guildline 9211, Agilent 3458A
Resistance[3, 8] – Measure	(0 to 10) Ω (10 to 100) Ω (100 to 1000) Ω (1 to 10) kΩ (10 to 100) kΩ (100 to 1000) kΩ (1 to 10) MΩ (10 to 100) MΩ (0.1 to 1) GΩ (0.1 to 1) Ω (1 to 1.9) Ω (1.9 to 10) Ω (10 to 100) Ω (0.1 to 1) kΩ (1 to 10) kΩ (10 to 19) kΩ (19 to 100) kΩ (0.1 to 1) MΩ (1 to 10) MΩ (10 to 19) MΩ	55 μΩ + 15 μΩ/ Ω 0.52 mΩ + 13 μΩ/Ω 0.53 mΩ + 10 μΩ/Ω 5.3 mΩ + 10 μΩ/Ω 53 mΩ + 11 μΩ/Ω 2.3 Ω + 17 μΩ/Ω 0.1 kΩ + 55 μΩ/Ω 1 kΩ + 0.52 mΩ/Ω 10 kΩ + 5.1 mΩ/Ω 29 μΩ 53 μΩ 0.26 mΩ 2 mΩ 10 mΩ 55 mΩ 0.11 Ω 0.81 Ω 14 Ω 0.11 kΩ 0.25 kΩ	Agilent 3458A Resistance transfer method using Fluke 742A reference resistors

Parameter/Range	Frequency	CMC[2, 5] (±)	Comments
AC Voltage[3, 8, 15] – Measure			
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 (1 to 1.2) MHz (1.2 to 2) MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz	1.3 µV + 1.7 µV/mV 1.3 µV + 0.75 µV/mV 1.3 µV + 0.43 µV/mV 2 µV + 0.83 µV/mV 2.5 µV + 1.2 µV/mV 4 µV + 2.3 µV/mV 8 µV + 2.6 µV/mV 8 µV + 5.1 µV/mV 1.4 µV + 0.75 µV/mV 1.4 µV + 0.75 µV/mV 2 µV + 1.8 µV/mV 2.8 µV + 3.1 µV/mV 6.3 µV + 7.2 µV/mV	Fluke 5790A w/ wideband opt 03
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 (1 to 1.2) MHz (1.2 to 2) MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz	3 µV + 0.86 µV/mV 2.1 µV + 0.38 µV/mV 1.7 µV + 0.22 µV/mV 2.8 µV + 0.42 µV/mV 3.7 µV + 0.62 µV/mV 6.4 µV + 1.2 µV/mV 11 µV + 1.4 µV/mV 15 µV + 3.6 µV/mV 2.4 µV + 0.73 µV/mV 2.4 µV + 0.73 µV/mV 3.1 µV + 1 µV/mV 4.5 µV + 1.8 µV/mV 8.7 µV + 3.9 µV/mV	
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 (1 to 1.2) MHz (1.2 to 2) MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz	3.1 µV + 0.3 µV/mV 2.5 µV + 0.2 µV/mV 2 µV + 0.12 µV/mV 3.3 µV + 0.21 µV/mV 4.4 µV + 0.31 µV/mV 9 µV + 0.83 µV/mV 14 µV + 1 µV/mV 24 µV + 2.6 µV/mV 4.4 µV + 0.73 µV/mV 4.4 µV + 0.73 µV/mV 6.3 µV + 1 µV/mV 11 µV + 1.8 µV/mV 23 µV + 3.8 µV/mV	

Parameter/Range	Frequency	CMC[2, 5] (±)	Comments
AC Voltage[3, 8, 15] – Measure (cont)			
70 mV	(9.5 to 10) Hz (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 (1 to 1.2) MHz (1.2 to 2) MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz	22 µV + 1 µV/mV 6.4 µV + 0.25 µV/mV 4.2 µV + 0.14 µV/mV 3 µV + 78 nV/mV 4.7 µV + 0.14 µV/mV 7.8 µV + 0.27 µV/mV 15 µV + 0.55 µV/mV 22 µV + 0.73 µV/mV 35 µV + 1.4 µV/mV 11 µV + 0.53 µV/mV 11 µV + 0.53 µV/mV 21 µV + 1 µV/mV 31 µV + 1.6 µV/mV 73 µV + 3.6 µV/mV	Fluke 5790A w/ wideband opt 03
220 mV	(9.5 to 10) Hz (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 (1 to 1.2) MHz (1.2 to 2) MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz	62 µV + 1 µV/mV 14 µV + 0.21 µV/mV 6.8 µV + 89 nV/mV 4.2 µV + 46 nV/mV 6.5 µV + 75 nV/mV 12 µV + 0.16 µV/mV 21 µV + 0.28 µV/mV 32 µV + 0.41 µV/mV 80 µV + 1.2 µV/mV 32 µV + 0.53 µV/mV 32 µV + 0.53 µV/mV 62 µV + 1 µV/mV 94 µV + 1.6 µV/mV 0.22 mV + 3.6 µV/mV	
700 mV	(9.5 to 10) Hz (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 (1 to 1.2) MHz (1.2 to 2) MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz	0.20 mV + 1 µV/mV 4.4 µV + 0.21 µV/mV 17 µV + 80 nV/mV 9.4 µV + 40 nV/mV 13 µV + 60 nV/mV 19 µV + 80 nV/mV 46 µV + 0.21 µV/mV 77 µV + 0.34 µV/mV 0.25 mV + 1.2 µV/mV 0.11 mV + 0.53 µV/mV 0.11 mV + 0.53 µV/mV 0.21 mV + 1 µV/mV 0.31 mV + 1.6 µV/mV 0.72 mV + 3.6 µV/mV	

Parameter/Range	Frequency	CMC[2, 5] (±)	Comments
AC Voltage[3, 15] – Measure (cont)			
2.2 V	(9.5 to 10) Hz (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 (1 to 1.2) MHz (1.2 to 2) MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz	0.6 mV + 1 mV/V 0.12 mV + 0.2 mV/V 44 µV + 69 µV/V 22 µV + 28 µV/V 34 µV + 510 µV/V 48 µV + 76 µV/V 0.12 mV + 0.2 mV/V 0.19 mV + 0.31 mV/V 0.72 mV + 1.2 mV/V 0.32 mV + 0.53 µV/V 0.32 mV + 0.53 µV/V 0.62 mV + 1 mV/V 0.94 mV + 1.6 mV/V 2.2 mV + 3.6 mV/V	Fluke 5790A w/ wideband opt 03
7 V	(9.5 to 10) Hz (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 (1 to 1.2) MHz (1.2 to 2) MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz	2 mV + 1 mV/V 0.4 mV + 0.2 mV/V 0.14 mV + 70 µV/V 61 µV + 30 µV/V 0.11 mV + 53 µV/V 0.17 mV + 86 µV/V 0.44 mV + 0.22 mV/V 0.94 mV + 0.47 mV/V 3 mV + 1.5 mV/V 1 mV + 0.52 mV/V 1.1 mV + 0.53 mV/V 2.1 mV + 1 mV/V 3.1 mV + 1.6 mV/V 7.3 mV + 3.6 mV/V	
22 V	(9.5 to 10) Hz (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	6 mV + 1 mV/V 1.2 mV + 0.2 mV/V 0.42 mV + 71 µV/V 0.19 mV + 32 µV/V 0.32 mV + 54 µV/V 0.51 mV + 86 µV/V 1.3 mV + 0.22 mV/V 2.8 mV + 0.47 mV/V 9 mV + 1.5 mV/V	

Parameter/Range	Frequency	CMC[2, 5] (±)	Comments
AC Voltage[3, 15] – Measure (cont)			
70 V	(9.5 to 10) Hz (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	20 mV + 1 mV/V 4 mV + 0.2 mV/V 1.5 mV + 73 µV/V 0.81 mV + 40 µV/V 1.3 mV + 64 µV/V 2.2 mV + 0.11 mV/V 4.4 mV + 0.22 mV/V 10 mV + 0.51 mV/V 30 mV + 1.5 mV/V	Fluke 5790A w/ wideband opt 03
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	12 mV + 0.2 mV/V 4.5 mV + 74 µV/V 2.4 mV + 40 µV/V 4.7 mV + 78 µV/V 6.7 mV + 0.11 mV/V 16 mV + 0.26 mV/V 42 mV + 0.7 mV/V	
700 V	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz	40 mV + 0.2 mV/V 23 mV + 0.11 mV/V 9.9 mV + 49 µV/V 30 mV + 0.15 mV/V 0.17 V + 0.85 mV/V	
1000 V	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz	0.12 V + 0.2 mV/V 68 mV + 0.11 mV/V 29 mV + 48 µV/V 91 mV + 0.15 mV/V 0.51 V + 0.085 mV/V	
Capacitance[3, 8] – Measure			
(1 to 10) pF (10 to 100) pF (100 to 1000) pF (1 to 10) nF (10 to 100) nF (100 to 1000) nF	(0.1 to 10) kHz	0.048 pF 0.2 pF 1.7 pF 39 pF 71 pF 0.28 nF	QuadTech 1689M CMC is stated at 1 kHz[9]

Parameter/Range	Frequency	CMC[2, 5] (±)	Comments
Capacitance[3, 8] – Generate			
(0.19 to 0.3999) nF			
(0.4 to 1.0999) nF	10 Hz to 10 kHz	8.7 pF + 4 pF/nF	Fluke 5520A
(1.1 to 3.299) nF	10 Hz to 10 kHz	9.7 pF + 4 pF/nF	
(3.3 to 10.999) nF	10 Hz to 10 kHz	13 pF + 4 pF/nF	
(11 to 32.9999) nF	(10 to 1000) Hz	15 pF + 2 pF/nF	
(33 to 109.999) nF	(10 to 1000) Hz	0.1 nF + 2 pF/nF	
(110 to 329.999) nF	(10 to 1000) Hz	0.15 nF + 2 pF/nF	
(0.33 to 1.099 99) µF	(10 to 1000) Hz	0.46 nF + 2 pF/nF	
(1.1 to 3.29999) µF	(10 to 600) Hz	1.5 nF + 2 nF/µF	
(3.3 to 10.9999) µF	(10 to 300) Hz	4.6 nF + 2 nF/µF	
(11 to 32.9999) µF	(10 to 150) Hz	15 nF + 2 nF/µF	
(33 to 109.999) µF	(10 to 120) Hz	59 nF + 3.2 nF/µF	
(110 to 329.999) µF	(10 to 80) Hz	0.2 µF + 3.6 nF/µF	
(0.33 to 1.099 99) mF	Up to 50 Hz	0.64 µF + 3.6 nF/µF	
(1.1 to 3.2999) mF	Up to 20 Hz	2 µF + 3.6 µF/mF	
(3.3 to 10.9999) mF	Up to 6 Hz	7 µF + 3.5 µF/mF	
(11 to 32.9999) mF	Up to 2 Hz	38 µF + 2.5 µF/mF	
(33 to 110) mF	Up to 0.6 Hz	90 µF + 6 µF/mF	
	Up to 0.2 Hz	0.37 mF + 8.8 µF/mF	
Fixed Points[3, 8]			
1 pF	1 kHz	0.35 fF	Agilent 16381A
	1 MHz	0.36 fF	
	2 MHz	0.42 fF	
	3 MHz	0.54 fF	
	4 MHz	0.72 fF	
	5 MHz	0.95 fF	
	10 MHz	2.5 fF	
	13 MHz	3.7 fF	
10 pF	1 kHz to 5 MHz	3.5 fF	Agilent 16382A
	10 MHz	3.7 fF	
	13 MHz	3.8 fF	
100 pF	1 kHz to 5 MHz	35 fF	Agilent 16383A
	10 MHz	48 fF	
	13 MHz	60 fF	

Parameter/Range	Frequency	CMC[2, 14] (±)	Comments
Capacitance[3, 8] – Generate			
Fixed Points[3, 8]			
1000 pF	1 kHz 1 MHz 2 MHz 3 MHz 4 MHz 5 MHz 10 MHz 13 MHz	0.35 pF 0.35 pF 0.38 pF 0.45 pF 0.56 pF 0.71 pF 1.9 pF 2.8 pF	Agilent 16384A
10 nF 100 nF 1000 nF	120 Hz to 120 kHz	0.79 pF 4.3 pF 71 pF	Agilent 16380C
Inductance[3, 8] – Measure			
Up to 1 mH (1 to 100) mH 100 mH to 1 H (1 to 10) H	(0.1 to 1) kHz	1.6 µH 94 µH + 0.6 µH/mH 1 mH + 1.1 mH/H 9.4 mH + 1.8 mH/H	QuadTech 1689M CMC is stated at 1 kHz[9]
Inductance[3, 8] – Generate			
Fixed Points 100 µH 1 mH 10 mH 100 mH 1 H 10 H	120 Hz to 100 kHz	0.11 µH 1 µH 9.8 µH 54 µH 0.57 mH 9.4 mH	General Radio 1482 series

Parameter/Range	Frequency	CMC[2, 5] (±)	Comments
AC Voltage[3, 8] – Generate			
(0 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	4 µV + 0.22 µV/mV 4 µV + 85 nV/mV 4 µV + 75 nV/mV 4 µV + 0.18 µV/mV 5 µV + 0.46 µV/mV 10 µV + 0.9 µV/mV 20 µV + 1.2 µV/mV 20 µV + 2.5 µV/mV	Fluke 5720A
(2.2 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	4.5 µV + 0.22 µV/mV 4.2 µV + 85 nV/mV 4.2 µV + 75 nV/mV 4.4µV + 0.18 µV/mV 6.1 µV + 0.46 µV/mV 12 µV + 0. 9 µV/mV 23 µV + 1.2 µV/mV 26 µV + 2.5 µV/mV	
(22 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	17 µV + 0.22 µV/mV 9 µV + 85 nV/mV 8.7 µV + 75 nV/mV 11 µV + 0.18 µV/mV 16 µV + 0.46 µV/mV 31 µV + 0.9 µV/mV 48 µV + 1.2 µV/mV 78 µV + 2.5 µV/mV	
(0.22 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	90 µV + 0.22 mV/V 34 µV + 79 µV/V 18 µV + 39 µV/V 26 µV + 70 µV/V 54 µV + 0.11 mV/V 0.16 mV + 0.34 mV/V 0.56 mV + 0.84 mV/V 0.64 mV + 1.5 mV/V	
(2.2 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	0.89 mV + 0.22 mV/V 0.33 mV + 80 µV/V 0.15 mV + 40 µV/V 0.26 mV + 70 µV/V 0.41 mV + 95 µV/V 1.2 mV + 0.26 mV/V 4 mV + 0.9 mV/V 6.1 mV + 1.3 mV/V	

Parameter/Range	Frequency	CMC[2, 5, 7] (±)	Comments
AC Voltage[3, 8] – Generate (cont)			
(22 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 500 kHz to 1 MHz	8.9 mV + 0.22 mV/V 3.4 mV + 80 µV/V 1.7 mV + 47 µV/V 3.5 mV + 72 µV/V 5.9 mV + 0.13 mV/V 34 mV + 0.8 mV/V 0.13 V + 4.2 mV/V 0.24 V + 7 mV/V	* 220 V range subject to 2.2E7 V-Hz limitation
(220 to 1100) V	(15 to 50) Hz ** 50 Hz to 1 kHz	74 mV + 0.26 mV/V 17 mV + 60 µV/V	** Max output 250 V from 15 Hz to 50 Hz
	40 Hz to 1 kHz (1 to 20) kHz (20 to 30) kHz	22 mV + 80 µV/V 34 mV + 0.13 mV/V 93 mV + 0.36 mV/V	w/ 5725A
(220 to 750) V	(30 to 50) kHz (50 to 100) kHz	93 mV + 0.36 mV/V 0.34 V + 1.3 mV/V	
AC High Voltage[3, 8] – Measure			
(1 to 85) kVrms	60 Hz	0.93 %	Ross VD120 w/ Fluke 189
AC Current[3, 8] – Generate			
(0 to 220) µA	(10 to 20) Hz (20 to 40) Hz 40 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz	63 nA + 0.13 nA/µA 12 nA + 0.14 nA/µA 9.2 nA + 0.11 nA/µA 15 nA + 0.25 nA/µA 75 nA + 0.9 nA/µA	Fluke 5720A
(29 to 329.99) µA	(10 to 30) kHz	0.69 µA + 13 nA/µA	5520A

Parameter/Range	Frequency	CMC[2, 5] (±)	Comments
AC Current[3, 8] – Generate (cont)			
220 µA to 2.2 mA	(10 to 20) Hz (20 to 40) Hz 40 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz	93 nA + 0.23 µA/mA 67 nA + 0.14 µA/mA 60 nA + 0.11 µA/mA 0.15 µA + 0.18 µA/mA 0.85 µA + 0.9 µA/mA	Fluke 5720A
(0.33 to 3.2999) mA	(10 to 30) kHz	3.3 µA + 8 µA/mA	5520A
(2.2 to 22) mA	(10 to 20) Hz (20 to 40) Hz 40 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz	0.92 µA + 0.23 µA/mA 0.69 µA + 0.14 µA/mA 0.6 µA + 0.11 µA/mA 0.95 µA + 0.18 µA/mA 7 µA + 0.9 µA/mA	5720
(3.3 to 32.999) mA	(10 to 30) kHz	14 µA + 3.2 µA/mA	5520A
(22 to 220) mA	(10 to 20) Hz (20 to 40) Hz 40 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz	9.3 µA + 0.23 µA/mA 6.8 µA + 0.14 µA/mA 5 µA + 0.11 µA/mA 7.5 µA + 0.18 µA/mA 30 µA + 0.9 µA/mA	5720A
(33 to 329.99) mA	(10 to 30) kHz	0.27 mA + 3.2 µA/mA	5520A
220 mA to 2.2 A	20 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz	89 µA + 0.24 mA/A 0.17 mA + 0.39 mA/A 1.5 mA + 6 mA/A	
(2.2 to 11) A	40 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz	1.1 mA + 0.4 mA/A 2.3 mA + 0.85 mA/A 8.0 mA + 3.3 mA/A	w/5725A
(11 to 20.5) A	(45 to 100) Hz 100 Hz to 1 kHz (1 to 5) kHz	15 mA + 0.96 mA/A 17 mA + 1.2 mA/A 0.27 A + 24 mA/A	Fluke 5520A
(0 to 20) A	(10 to 65) Hz (65 to 300) Hz 300 Hz to 1 kHz	11 mA + 0.15 mA/A 11 mA + 0.28 mA/A 13 mA + 0.9 mA/A	Fluke 52120A
(20 to 120) A	(10 to 65) Hz (65 to 300) Hz 300 Hz to 1 kHz	25 mA + 0.17 mA/A 38 mA + 0.28 mA/A 0.13 A + 0.9 mA/A	
120 A to 6 kA	(10 to 65) Hz (65 to 300) Hz 300 Hz to 1 kHz	1 A + 4.7 mA/A 1 A + 4.7 mA/A 1 A + 4.7 mA/A	Fluke 52120A w/ coil

Parameter/Range	Frequency	CMC[2, 5, 7] (±)	Comments
AC Current[3, 8] – Generate (cont)			
Toroidal:			
(10 to 16.5) A	(45 to 65) Hz	26 mA + 2.1 mA/A	Fluke 5520A w/ coil
(16.5 to 150) A		50 mA + 1.9 mA/A	
(150 to 1025) A		0.34 A + 1.9 mA/A	
(10 to 16.5) A	(65 to 440) Hz	60 mA + 6 mA/A	
(16.5 to 150) A		0.11 A + 5.3 mA/A	
(150 to 1025) A		0.86 A + 5.3 mA/A	
Non-Toroidal:			
(10 to 16.5) A	(45 to 65) Hz	60 mA/A + 3.8 mA/A	
(16.5 to 150) A		0.23 A + 3.7 mA/A	
(150 to 1025) A		1.2 A + 3.7 mA/A	
(10 to 16.5) A	(65 to 440) Hz	90 mA + 7.2 mA/A	
(16.5 to 150) A		0.28 A + 6.7 mA/A	
(150 to 1025) A		1.6 A + 6.7 mA/A	
AC Current[3, 8] – Measure			
10 mA to 5 A	(10 to 20) Hz	0.041 %	Fluke 5790A w/ A40's
10 A		0.047 %	
10 mA to 5 A	(20 to 40) Hz	0.026 %	
10 A		0.035 %	
10 mA to 5 A	40 Hz to 10 kHz	0.024 %	
10 A		0.033 %	
(1 to 2) A	< 1 kHz	0.029 %	Valhalla 2575
	(1 to 10) kHz	0.03 %	
(2 to 20) A	< 1 kHz	0.053 %	
	(1 to 10) kHz	0.054 %	
(20 to 100) A	< 1 kHz	0.067 %	

Parameter/Range	Frequency	CMC[2, 5] (±)	Comments
AC Current[3, 8] – Measure (cont)			
(5 to 100) µA	(10 to 20) Hz (20 to 45) Hz (45 to 100) Hz 100 Hz to 1 kHz	57 nA + 4 nA/µA 45 nA + 1.5 nA/µA 41 nA + 0.64 nA/µA 41 nA + 0.64 nA/µA	Agilent 3458A
(0.1 to 1) mA	(10 to 20) Hz (20 to 45) Hz (45 to 100) Hz 100 Hz to 5 kHz (5 to 20) kHz (20 to 50) kHz (50 to 100) kHz	0.43 µA + 4.1 µA/mA 0.31 µA + 1.6 µA/mA 0.26 µA + 0.67 µA/mA 0.25 µA + 0.37 µA/mA 0.26 µA + 0.67 µA/mA 0.63 µA + 4.1 µA/mA 1.8 µA + 5.6 µA/mA	
(1 to 10) mA	(10 to 20) Hz (20 to 45) Hz (45 to 100) Hz 100 Hz to 5 kHz (5 to 20) kHz (20 to 50) kHz (50 to 100) kHz	2.4 µA + 4.1 µA/mA 2.3 µA + 1.6 µA/mA 2.3 µA + 0.67 µA/mA 2.3 µA + 0.37 µA/mA 2.3 µA + 0.67 µA/mA 4.5 µA + 4.1 µA/mA 16 µA + 5.6 µA/mA	
(10 to 100) mA	(10 to 20) Hz (20 to 45) Hz (45 to 100) Hz 100 Hz to 5 kHz (5 to 20) kHz (20 to 50) kHz (50 to 100) kHz	42 µA + 4 µA/mA 30 µA + 1.5 µA/mA 25 µA + 0.6 µA/mA 24 µA + 0.3 µA/mA 25 µA + 0.6 µA/mA 62 µA + 4 µA/mA 0.18 mA + 5.5 µA/mA	
(0.1 to 1) A	(10 to 20) Hz (20 to 45) Hz (45 to 100) Hz 100 Hz to 5 kHz (5 to 20) kHz (20 to 50) kHz	0.42 mA + 4.1 mA/A 0.3 mA + 1.7 mA/A 0.26 mA + 0.9 mA/A 0.27 mA + 1.1 mA/A 0.37 mA + 3.1 mA/A 0.92 mA + 10 mA/A	

Parameter/Range	Frequency	CMC[2, 7, 14] (±)	Comments
AC Resistance[3, 8] – Generate			
0.1 Ω	DC to 5 MHz 10 MHz 13 MHz	0.13 % 0.17 % 0.23 %	Agilent 16074A
1 Ω	DC to 1 MHz 5 MHz 10 MHz 13 MHz	0.019 % 0.035 % 0.12 % 0.2 %	
10 Ω	DC to 1 MHz 5 MHz 10 MHz 13 MHz	0.012 % 0.031 % 0.12 % 0.2 %	
100 Ω	DC to 100 kHz 1 MHz 5 MHz 10 MHz 13 MHz	0.0017 % 0.002 % 0.029 % 0.12 % 0.2 %	
1 kΩ	DC to 100 kHz 1 MHz 5 MHz 10 MHz 13 MHz	0.0017 % 0.002 % 0.029 % 0.12 % 0.2 %	
10 kΩ	DC to 100 kHz 1 MHz 5 MHz 10 MHz 13 MHz	0.0016 % 0.002 % 0.029 % 0.12 % 0.2 %	
100 kΩ	DC to 100 kHz 1 MHz 5 MHz 10 MHz 13 MHz	0.002 % 0.0023 % 0.029 % 0.12 % 0.2 %	

Parameter/Equipment	Range	CMC[2, 7, 14] (±)	Comments
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
	15 ps 10 Hz to 1 MHz	8.4 ps	Tektronix, step gen. 067-1338-00
Risetime – Measure	Up to 50 GHz	11 ps	Tektronix 80E01
Time Marker	9 ns to 83 µs 83 µs to 55 s	0.000 047% 0.000 35%	Fluke 9500B
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 %	Fluke 9500B w/ active heads
	(6 to 18) GHz (18 to 26.5) GHz (26.5 to 50) GHz	4 % 4.1 % 4.4 %	Signal generator w/ power sensor E4412A E4413A N5532A

Parameter/Range	Frequency	CMC[2, 14] (±)	Comments
Phase Angle[3, 8] – Generate (0.0 to 360)º (0.05 to 120) V	 (1 to 1000) Hz (1.01 to 6.25) kHz (6.26 to 50) kHz (50.01 to 100) kHz	 5.9 mº 11 mº 28 mº 56 mº	 Clarke-Hess 5500, mº = milli degree
Phase – Measure[3, 8] (0 to 360) °	 101 Hz 1 kHz 100 kHz 1 MHz 13 MHZ	 0.0012 ° 0.0014 ° 0.092 ° 0.64 ° 8.3 °	 Agilent 53131A
Distortion[3, 8] – Measure	20 Hz to 20 kHz (20 to 100) kHz 100 kHz to 3 GHz (3 to 6.5) GHz (6.5 to 21.9) GHz (21.9 to 26.5) GHz (26.5 to 50) GHz	1.2 dB 2.3 dB 0.54 dB 1.8 dB 2.4 dB 3 dB 3.5 dB	Agilent 8903A Agilent E4448A

Parameter/Equipment	Range	CMC[2] (±)	Comments
Electrical Calibration of Thermocouple Indicators[3, 8]			
Type E	(-250 to -100) °C (-100 to -25) °C (-25 to 350) °C (350 to 650) °C (650 to 1000) °C	0.4 °C 0.13 °C 0.11 °C 0.13 °C 0.17 °C	Fluke 5520A
Type J	(-210 to -100) °C (-100 to -30) °C (-30 to 150) °C (150 to 760) °C (760 to 1200) °C	0.22 °C 0.13 °C 0.12 °C 0.14 °C 0.18 °C	
Type K	(-200 to -100) °C (-100 to -25) °C (-25 to 120) °C (120 to 1000) °C (1000 to 1372) °C	0.27 °C 0.14 °C 0.13 °C 0.21 °C 0.32 °C	
Type N	(-200 to -100) °C (-100 to -25) °C (-25 to 120) °C (120 to 410) °C (410 to 1300) °C	0.32 °C 0.18 °C 0.15 °C 0.15 °C 0.22 °C	
Type R	(0 to 250) °C (250 to 400) °C (400 to 1000) °C (1000 to 1767) °C	0.46 °C 0.28 °C 0.27 °C 0.33 °C	
Type S	(0 to 250) °C (250 to 1000) °C (1000 to 1400) °C (1400 to 1767) °C	0.38 °C 0.29 °C 0.3 °C 0.37 °C	
Type T	(-250 to -150) °C (-150 to 0) °C (0 to 120) °C (120 to 400) °C	0.51 °C 0.21 °C 0.15 °C 0.13 °C	
Type U	(-200 to 0) °C (0 to 600) °C	0.45 °C 0.22 °C	

Parameter/Equipment	Range	CMC[2] (±)	Comments
Electrical Calibration of RTDs[3, 8] Indicators			
Pt 385, 100 Ω	(-200 to -80) °C (-80 to 0) °C (0 to 100) °C (100 to 300) °C (300 to 400) °C (400 to 630) °C (630 to 800) °C	0.042 °C 0.041 °C 0.057 °C 0.073 °C 0.081 °C 0.097 °C 0.19 °C	Fluke 5520A
Pt 3926, 100 Ω	(-200 to -80) °C (-80 to 0) °C (0 to 100) °C (100 to 300) °C (300 to 400) °C (400 to 630) °C	0.041 °C 0.041 °C 0.057 °C 0.073 °C 0.081 °C 0.097 °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	0.2 °C 0.033 °C 0.042 °C 0.049 °C 0.057 °C 0.065 °C 0.073 °C 0.081 °C 0.18 °C	
Pt 385, 200 Ω	(-200 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	0.034 °C 0.034 °C 0.033 °C 0.042 °C 0.097 °C 0.11 °C 0.11 °C 0.13 °C	
Pt 385, 500 Ω	(-200 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	0.034 °C 0.042 °C 0.041 °C 0.05 °C 0.065 °C 0.065 °C 0.073 °C 0.089 °C	

Parameter/Equipment	Range	CMC[2, 7] (±)	Comments
Electrical Calibration of RTDs[3, 8] Indicators (cont)			Fluke 5520A
Pt 385, 1000 Ω	(-200 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	0.026 °C 0.026 °C 0.033 °C 0.042 °C 0.049 °C 0.057 °C 0.057 °C 0.19 °C	
Ni 120, 120 Ω	(-80 to 260) °C	0.01 °C	Fluke 7526A
Cu 427, 10 Ω	(-100 to 260) °C	0.12 °C	
SPRT[8]	(-200 to 660) °C	0.06 °C	
Electrical Conductivity Meters (IACS)	Titanium (< 4% IACS) Manganin (≈5% IACS) Bronze (≈18% IACS) Aluminum (≈30% IACS) Aluminum (≈32% IACS) Aluminum (> 40% IACS)	0.034 % 0.092 % 0.2 % 0.33 % 0.36 % 0.41 %	Conductivity standards

IV. Electrical – RF/Microwave

Parameter/Range	Frequency	CMC[2, 7] (±)	Comments
Power Meter[3, 8] – Power Reference, @ 1 mW	50 MHz	0.42 %	Agilent 432A w/ 478A, 3458A
Power Accuracy	3 µW to 100 mW	0.29 %	11683A-H01

Parameter/Range	Frequency	CMC[2, 7, 13] (±)	Comments
Power Sensor Calibration Factor	10 MHz 20 MHz (30 to 90) MHz (100 to 400) MHz (450 to 650) MHz 700 MHz to 3 GHz (3.1 to 5.4) GHz (5.6 to 6.4) GHz (6.6 to 9.2) GHz (9.4 to 13.5) GHz (13.75 to 17.5) GHz (17.75 to 22) GHz (23 to 26.5) GHz	2.1 % 1.7 % 1.6 % 1.6 % 1.6 % 1.6 % 1.7 % 1.8 % 1.9 % 2.1 % 2.6 % 2.7 % 3.1 %	Power sensor calibration system w/ Tegam 1830A power meter 1135B power reference
Relative Power (Tuned RF Level) [3, 8] – Measure (0 to -10) dB (-10 to -20) dB (-20 to -30) dB (-30 to -40) dB (-40 to -50) dB (-50 to -60) dB (-60 to -70) dB (-70 to -80) dB (-80 to -90) dB (-90 to -100) dB (-100 to -110) dB (-110 to -120) dB (-120 to -130) dB	100 kHz to 50 GHz	0.031 dB 0.035 dB 0.039 dB 0.058 dB 0.06 dB 0.064 dB 0.077 dB 0.082 dB 0.086 dB 0.10 dB 0.10 dB 0.11 dB 0.12 dB	Agilent E4448A
Displayed Average Noise Level[3, 8]	45 MHz to ≤ 2 GHz (2 to ≤ 3) GHz (3 to ≤ 8) GHz (8 to ≤ 20) GHz (20 to 26.5) GHz	0.63 dB 0.75 dB 0.73 dB 0.91 dB 0.98 dB	50 Ω termination

Parameter/Range	Frequency	CMC[2, 7, 13] (±)	Comments
Absolute Power[3, 8] – Measure			E4418B power meter w/ sensor
(0 to +20) dBm	9 kHz to 6 GHz	2.6 %	E9304A
(-10 to 0) dBm		3.3 %	
(-60 to -10) dBm		3.8 %	
(-30 to + 10) dBm	100 kHz to 4.2 GHz	1.7 %	8482A
(+10 to +20) dBm		3.9 %	
(-20 to +30) dBm	(4.2 to 18) GHz	4 %	N5532A
(-70 to -20) dBm	(4.2 to 18) GHz	3.9 %	E4412A
(-20 to +30) dBm	(18 to 26.5) GHz	4.1 %	N5532A
(-70 to -20) dBm	(18 to 26.5) GHz	4.7 %	E4413A
(-20 to +30) dBm	(26.5 to 50) GHz	4.4 %	N5532A
Return Loss (VSWR)[3, 8]	100 kHz to 45 MHz	0.6 dB	E4417A power meter, 8482A sensor, 8721A directional bridge E8364A VNA w/ cal kits
	45 MHz to 2 GHz	0.53 dB	85032B
	(2 to 6) GHz	0.51 dB	85032B
	(6 to 20) GHz	0.72 dB	85052C
	(20 to 26.5) GHz	0.72 dB	85052C
	(26.5 to 40) GHz	0.78 dB	85056D
	(40 to 50) GHz	1.1 dB	85056D
Transmission S_{12}/S_{21} – Measure			
Linear Magnitude	DC to 2 GHz	0.088 dB	E8364A VNA w/ cal kits
	(2 to 6) GHz	0.21 dB	
	(6 to 20) GHz	0.075 dB	
	(20 to 26.5) GHz	0.11 dB	
	(26.5 to 40) GHz	0.57 dB	
	(40 to 50) GHz	0.77 dB	
Linear Phase	DC to 2 GHz	1.7 °	
	(2 to 6) GHz	2.4 °	
	(6 to 8) GHz	1.5 °	
	(8 to 26.5) GHz	2.4 °	
	(26.5 to 40) GHz	4.1 °	
	(40 to 50) GHz	5.5 °	

Parameter/Range	Frequency	CMC[2, 7, 13] (±)	Comments
Reflection S_{11}/S_{22} – Measure			
Linear Magnitude	DC to 2 GHz (2 to 6) GHz (6 to 20) GHz (20 to 26.5) GHz (26.5 to 40) GHz (40 to 50) GHz	0.0057 lin 0.0073 lin 0.0061 lin 0.0075 lin 0.016 lin 0.016 lin	E8364A VNA w/ cal kits
Linear Phase	DC to 2 GHz (2 to 6) GHz (6 to 8) GHz (8 to 26.5) GHz (26.5 to 40) GHz (40 to 50) GHz	2.1 ° 3.2 ° 1.7 ° 2.5 ° 9.5 ° 9.7 °	
Frequency Modulation[3, 8] – Measure			
Mod Rate: 20 Hz to 10 kHz Dev.: 200 Hz to 40 kHz (ß > 0.2)	250 kHz to 10 MHz	1.5 %	E4448A opt 233 ß is the ratio of the frequency deviation to the modulation rate
Mod Rate: 50 Hz to 200 kHz Dev.: 250 Hz to 400 kHz (ß > 0.2)	1 MHz to 6.6 GHz (6.6 to 13.2) GHz (13.2 to 31.15) GHz (31.15 to 50) GHz	1.5 % 2.5 % 3.8 % 8.9 %	

Parameter/Range	Frequency	CMC[2, 7, 13] (±)	Comments
Amplitude Modulation[3, 8] – Measure			
Depth:			
(5 to 99) %	100 kHz to 10 MHz	0.86 % of depth	E4448A opt 233
(5 to 20) %	10 MHz to 3 GHz	2.6 % of depth	
(20 to 99) %	10 MHz to 3 GHz	0.78 % of depth	
(5 to 20) %	(3 to 26.5) GHz	4.6 % of depth	
(20 to 99) %	(3 to 26.5) GHz	1.7 % of depth	
(5 to 20) %	(26.5 to 31.15) GHz	7.1 % of depth	
(20 to 99) %	(26.5 to 31.15) GHz	2.7 % of depth	
(5 to 20) %	(31.15 to 50) GHz	26 % of depth	
(20 to 99) %	(31.15 to 50) GHz	6.3 % of depth	
Phase Modulation[3, 8] –			
Mod Rate: (0.2 to 20) kHz			
0.3 rad < Dev ≤ 0.7 rad	100 kHz to 6.6 GHz	3 %	E4448A opt 233
Dev > 0.7 rad		1.1 %	
0.6 rad < Dev ≤ 2.0 rad	(6.6 to 13.2) GHz	3 %	
Dev > 2.0 rad		1.1 %	
1.2 rad < Dev ≤ 4.0 rad	(13.2 to 26.5) GHz	3 %	
Dev > 4.0 rad		1.1 %	
1.3 rad < Dev ≤ 4.0 rad	(26.5 to 31.5) GHz	3 %	
Dev > 4.0 rad		1.1 %	
2.4 rad < Dev ≤ 8.0 rad	(31.5 to 50) GHz	3 %	
Dev > 8.0 rad		1.1 %	

Parameter/Range	Frequency	CMC[2, 7, 13] (±)	Comments
Single Side-Band (SSB) Phase Noise[3, 8] – Measure	Carrier: 1 MHz to 50 GHz Offset Freq: 10 Hz 100 Hz 1 kHz 10 kHz 100 kHz 1 MHz 10 MHz 100 MHz	 4.4 dB 3.2 dB 2.8 dB 2.9 dB 2.6 dB 2.4 dB 2.4 dB 2.5 dB	 Agilent E4448A option 226

SSB Phase Noise Performance vs Center Frequency

Offset	Up to 600 MHz	(0.6 to 10.2) GHz	(10.2 to 25.2) GHz	(25.2 to 50) GHz
10 Hz	-105 dBc/Hz	-85 dBc/Hz	-76 dBc/Hz	-70 dBc/Hz
100 Hz	-105 dBc/Hz	-85 dBc/Hz	-76 dBc/Hz	-70 dBc/Hz
1 kHz	-111 dBc/Hz	-100 dBc/Hz	-92 dBc/Hz	-90 dBc/Hz
10 kHz	-120 dBc/Hz	-112 dBc/Hz	-105 dBc/Hz	-100 dBc/Hz
100 kHz	-125 dBc/Hz	-120 dBc/Hz	-112 dBc/Hz	-105 dBc/Hz
1 MHz	-150 dBc/Hz	-145 dBc/Hz	-138 dBc/Hz	-130 dBc/Hz
10 MHz	-158 dBc/Hz	-150 dBc/Hz	-140 dBc/Hz	-134 dBc/Hz
100 MHz	-158 dBc/Hz	-150 dBc/Hz	-140 dBc/Hz	-134 dBc/Hz

Digital Modulation FSK, MSK, PSK, QAM	Up to 50 GHz	0.42 % EVM (Error Vector Magnitude)	Agilent E4448A option 241

V. Fluid Quantities

Parameter/Equipment	Range	CMC [2, 7, 8, 13] (±)	Comments
Gas Flow – Measure	(1 to 10) sccm (10 to 100) sccm (0.1 to 1) SLPM (1 to 10) SLPM	0.41 % 0.4 % 0.4 % 0.63 %	DHI molbloc system

Parameter/Equipment	Range	CMC [2, 7, 8] (±)	Comments
Viscosity[3] – Ford, Dip & Other Viscosity Cups	Cup Nos. 1 through 5 (1 to 6) mm	3.3 %	Viscosity cups, stopwatch, 5616 PRT (ASTM D1200, D4212, ISO 2431)

VI. Magnetic Quantities

Parameter/Equipment	Range	CMC[2] (±)	Comments
DC Gauss Meters[3, 8]	10 G 20 G	0.58 G 0.66 G	R.B. Annis Gauss standards

VII. Mechanical

Parameter/Equipment	Range	CMC[2, 13] (±)	Comments
Mass Measurement[8]	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	6.2 µg 6.2 µg 6.6 µg 6.5 µg 6.1 µg 6.1 µg 6.2 µg 61 µg 61 µg 6.1 µg 6.1 µg 6.2 µg 12 µg 8.3 µg 8.6 µg 9.9 µg 16 µg 21 µg 27 µg 70 µg 72 µg 0.59 mg 0.59 mg 0.6 mg	Mass comparison to reference standards by substitution using NIST SOP 4 & NIST SOP 7

Parameter/Equipment	Range	CMC[2, 4, 13] (±)	Comments
Mass Measurement[8] (cont)	1 kg 2 kg 3 kg 5 kg 10 kg 20 kg 30 kg 50 kg Up to 220 g (220 to 2300) g (2.3 to 32) kg Up to 0.5 lb (0.5 to 5) lb (5 to 70) lb	5.8 mg 5.8 mg 5.8 mg 5.9 mg 6.2 mg 6.5 mg 6.8 mg 7.3 mg 0.27 mg 8.6 mg 72 mg 0.27 mg 8.6 mg 71 mg	Mass comparison to reference standards by substitution using NIST SOP 4 & NIST SOP 7 Direct weigh using precision balances
Balances[3, 8, 11] 0.0001 g Resolution (0.001 g Resolution 0.01 g Resolution 0.1 g, 1 g, 10 g Resolution Scales	 Up to 500 mg > 500 mg to 5 g > 5 g to 55 kg Up to 50 g (> 50 to 100) g (> 100 to 300) g > 300 g to 55 kg Up to 2 kg Up to 55 kg Up to 4800 lbs	 0.82 x *R* 0.91 x *R* 1.2 x *R* 0.83 x *R* 0.87 x *R* 1.0 x *R* 1.2 x *R* 0.83 x *R* 1.4 x *R* 0.82 x *R*	 Direct comparison to mass reference standards.

Parameter/Equipment	Range	CMC[2, 4, 7] (±)	Comments
Force[3, 8] – Tension & Compression	Up to 1400 lbf	0.0023 %	Deadweight method using Class F & Class F weights
	Up to 6000 lbf (6 to 25) klbf	4.3 lbf 21 lbf	Load cells
Torque[3, 8] –			
Tools (Gages & Drivers)	(0.5 to 42.5) ozf·in (2 to 5) lbf·in (5 to 50) lbf·in (50 to 300) lbf·in (25 to 150) lbf·ft (150 to 250) lbf·ft (250 to 1000) lbf·ft	0.23 % 0.68 % 0.3 % 0.32 % 0.32 % 0.31 % 1.2 %	Torque testers
Testers & Transducers	15 ozf·in to 150 lbf·in 150 lbf·in to 250 lbf·ft (250 to 1000) lbf·ft	0.035 % 0.034 % 0.033 %	Torque arms & Class 6 weights
Pressure[3, 8]			
Pneumatic	Up to ±5 inH_2O	0.0036 inH_2O	Heise HQS-1
	(0.5 to 23) psia	0.0034 psi + 0.000 048 psi/psi	RPM 4 A160Kp
	Up to 350 psig	0.039 psig + 0.000 13 psi/psi	Fluke P3031 DWT
	(8 to 17) psia (-15 to 100) psig (-15 to 757) psig (> 757 to 1500) psig	0.01 % 0.012 psi 0.076 psi 0.01 %	Mensor CPC 6050 (8 to 17) psi sensor (-15 to 100) psi sensor (-15 to 1000) psi sensor (-15 to 1000) psi sensor
Hydraulic	(1000 to 10 000) psig	0.51 psi + 0.000 14 psi/psi	Fluke P3214 DWT
	(10 000 to 30 000) psig	24 psi	Heise 901A pressure indicator

Parameter/Equipment	Range	CMC[2,] (±)	Comments
Hardness Testers – Rockwell, Indirect Verification	HRA: Low Medium High HRBW: Low Medium High HRC: Low Medium High HREW Low Medium High HR15N: Low Medium High HR15TW: Low Medium High HR30N: Low Medium High HR30TW: Low Medium High HR45N: Low Medium High HR45TW: Low Medium High	 1.1 HRA 1.1 HRA 0.57 HRA 1.6 HRBW 2.5 HRBW 1.1 HRBW 1.1 HRC 1.1 HRC 0.6 HRC 1.2 HREW 1.1 HREW 1.2 HREW 1.1 HR15N 1.1 HR15N 0.85 HR15N 1.6 HR15TW 1.1 HR15TW 1.1 HR15TW 1.1 HR30N 1.2 HR30N 0.9 HR30N 1.7 HR30TW 1.2 HR30TW 1.2 HR30TW 1.2 HR45N 1.1 HR45N 0.75 HR45N 1.7 HR45TW 1.2 HR45TW 1.1 HR45TW	ASTM E18 hardness blocks

Parameter/Equipment	Range	CMC[2, 7] (±)	Comments
Hardness Testers – Brinell Indirect Verification at Test Conditions[3]	(200 to 600) HBW	4.1% HBW	ASTM E10
Equotip (Leeb) Testers[3, 8]	≈ 800 Ld	17 Ld	ASTM A956

VIII. Thermodynamics

Parameter/Equipment	Range	CMC[2, 13] (±)	Comments
Temperature – Measure Equipment[3, 8]	(-95 to 140) °C (-95 to 35) °C (35 to 100) °C (100 to 225) °C (225 to 425) °C	0.24 °C 0.065 °C 0.067 °C 0.12 °C 0.24 °C	9190A well 1524 precision thermometer, 5615 PRT, calibration wells
Temperature[3, 8] – Measure	(-196 to 0) ºC (0 to 420) ºC (420 to 1000) ºC	0.027 °C 0.023 °C + 0.000 069 x $\Delta T_{\text{change from 0 °C}}$ 2.1 °C + 0.0044 x $\Delta T_{\text{change from 420 °C}}$	1524 precision thermometer, 5615 PRT Fluke 743B w/ Type K thermocouple
Infrared Thermometers[3, 8]	(-15 to < -12) °C (-12 to < -8) °C (-8 to -4) °C (-4 to 0) °C (0 to 120) °C (35 to 500) °C	0.51 °C 0.5 °C 0.49 °C 0.48 °C 0.6 °C + 0.0017 x $\Delta T_{\text{change from 0 °C}}$ 0.54 °C + 0.0042 x $\Delta T_{\text{change from 35 °C}}$	Hart 4180 black body Hart 4181 black body ε = 0.9 to 1.0 λ = (8 to 14) µm

Parameter/Equipment	Range	CMC[2, 13] (±)	Comments
Relative Humidity[3, 8] – Measuring Equipment	(10 to 95) % RH	0.63 % RH	Thunder Scientific 2500
Relative Humidity[3, 8] – Measure	(10 to 90) % RH (90 to 95) % RH	1.3 % RH 2.1 % RH	Vaisala HM70 / HMP 77

IX. Time & Frequency

Parameter/Equipment	Frequency	CMC[2, 13] (±)	Comments
Frequency – Measure [3, 8]	10 MHz	50 µHz	Frequency counter w/ GPS receiver
Frequency – Measuring Equipment[3, 8]	(0.1 to 20) MHz 20 MHz to 50 GHz	0.55 µHz + 27 pHz /Hz 0.58 mHz + 4.3 pHz/Hz	Synthesized function generator w/ GPS receiver Signal generator w/ GPS receiver
Frequency – Measure[3, 8]	0.1 Hz to 3 GHz (3 to 50) GHz	58 pHz + 12 pHz/Hz 0.12 Hz + 3 pHz/Hz	Counter locked to GPS10 MHz reference
RPM – Optical Measuring Equipment[3, 8]	(1 to 120 000) RPM	0.000 038 RPM + 0.000 046 RPM/RPM	Function generator
RPM – Mechanical Measuring Equipment [3, 8]	(55 to 350) RPM (350 to 40 000) RPM	0.6 RPM 0.012 %	GE H8224 tachometer tester
Stopwatches & Timers[3, 8]	± (0 to 19.99) sec/day	0.037 sec/day	Timometer

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

[2] Calibration and Measurement Capability (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. Calibration and Measurement Capabilities 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 of the device measured in inches; *R* is the value of the resolution of the device under test; *D* is the length of the diagonal in inches; *M* is the source of mismatch uncertainty

[5] The measurands stated are generated with the Fluke 5700A or 5520A 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.

[6] The measurands stated are measured with the Agilent 3458A. This capability is suitable for the calibration of the devices intended to generate the measurand in the ranges indicated. CMCs are expressed as either a specific value that covers the full range or as a combination of the fraction of the reading/output plus a range specification.

[7] In the statement of CMC, percentages are percentage of reading unless otherwise indicated.

[8] Uncertainty components that can be reasonably attributed to the Unit Under Test have not been utilized in the calculation of the CMC value for this measurement parameter.

[9] Measurement uncertainty at intermediate values is calculated using the Manufacturers Limits of Error Calculator

[10] Calibration method in accordance to ASME B89.4.1-1997

[11] 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.

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

[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] Values listed in Parameter/Range are for the range.

Accredited Laboratory

A2LA has accredited

TRESCAL, INC.

Irving, TX

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 20th day of July 2023.

Mr. Trace McInturff, Vice President, Accreditation Services
For the Accreditation Council
Certificate Number 2516.01
Valid to March 31, 2025

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