SCOPE OF ACCREDITATION TO ISO/IEC 17025-2005,
ANSI/NCSL Z540-1-1994 & ANSI/NCSL Z540.3-2006

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CALIBRATION

Valid To: May 31, 2012 Certificate Number: 1022.01

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

I. Acoustics

Parameter/Equipment	Range	CMC[2] (±)	Comments
Acoustics – Measure	20 Hz to 8 kHz 250 Hz reference	0.12 dB 0.12 dB	Standard reference microphone
Acoustics[3] – Measuring Equipment	124 dB @ 250 Hz 114 dB @ 1 kHz 94 dB @ 1 kHz 5 Hz to 50 kHz 5 Hz to 100 kHz	0.32 dB 0.48 dB 0.48 dB 0.38 dB 0.60 dB	Standard pistonphone Acoustical calibrator Electrostatic actuator

II. Chemical

Parameter/Equipment	Range	CMC[2] (±)	Comments
pH[3] – Measuring Equipment	(4, 7, 10) units	0.016 units	Buffer solutions

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Parameter/Equipment	Range	CMC[2] (±)	Comments
Electrolytic Conductivity[3] – Measuring Equipment	10 µS/cm 100 µS/cm 1000 µS/cm 10 000 µS/cm	0.52 µS/cm 2.4 µS/cm 23 µS/cm 230 µS/cm	Conductivity solutions

III. Dimensional

Parameter/Equipment	Range	CMC[2, 4, 8] (±)	Comments
Gage Blocks, Foils & Thickness Gauges	Up to 2 in (2 to 4) in (4 to 6) in (6 to 8) in (8 to 10) in (10 to 12) in	8 µin 10 µin 16 µin 19 µin 23 µin 26 µin	Master gage blocks & laser interferometer
Length Standards	(0.05 to 12) in (> 12 to 48) in	4 µin/in + 26 µin 2 µin/in + 30 µin	Master gage blocks & laser interferometer Gage blocks & height comparator
Linear Displacement[3] – Measuring Equipment	(0 to 67) in (0 to 24) in (1 to 91) ft (0 to 72) in	60 µin/in + 0.0031 in 60 µin/in + 0.0027 in 0.007 % + 0.05 ft 11 µin/in + 0.6*R*	Mitutoyo 539-134-10 Mitutoyo 570-314 Starrett 530-30CME Gage blocks
Plain, External Diameter[3]	(0.03 to 2.36) in	21 µin	Laser micrometer
Plain Diameter – Internal & External	Up to 4 in (4 to 12) in	(16 + 3*D*) µin (28 + 3*D*) µin	Master gage blocks & laser interferometer
Threaded Plug Gages – Simple Pitch Diameter, (4 TPI to 80 TPI)	(0.1 to 6.5) in	(76 + 9*D*) µin	Master gage blocks w/ master thread wires & laser interferometer

Parameter/Equipment	Range	CMC[2, 4, 8] (±)	Comments
Surface Plate Flatness[3] –			
Grade AA	< 24 in × 36 in	43 µin	24-inch Planekator
Grade A	< 36 in × 48 in		
Grade B	< 48 in × 96 in	63 µin	48-inch Planekator
	(4 to 16) ft diagonal	(70 + 7.5*Di*) µin	Electronic leveling system
Calipers[3]	(0.001 to 72) in	6 µin/in + 50 µin	Gage blocks
Indicators[3]	(0.001 to 6) in	6 µin/in + 10 µin	Gage blocks
Micrometers[3]	(0.001 to 72) in	6 µin/in + 5 µin	Gage blocks
Height Gages[3]	(0.001 to 48) in	6 µin/in + 50 µin	Gage blocks
Angle[3] – Measuring Equipment	Up to 360° (0 to 60)° 90° ± 3’	7.1” 8.7” 2.8”	Angle encoder Gage blocks w/ sine bar Cylinder square
Angle[3] – Measure	(0 to 60)°	8.1”	Gage blocks, sine bar & electronic level
Optical Comparators[3] –			Comparison to master
Linear Travel	Up to 30 in	120 µin	Scales
Magnification	10x to 100x	0.11 %	Magnification checker & spheres
Flatness[3]	Up to 4 in diameter	5.6 µin	Optical flats
Steel Tapes[3]	(1 to 100) ft	0.08 in	Master tape

IV. Electrical – DC/Low Frequency

Parameter/Equipment	Range	CMC[2, 5, 6, 8] (±)	Comments
DC Voltage[3] – 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	7.2 µV/V + 0.4 µV 4.5 µV/V + 0.8 µV 3.6 µV/V + 2.8 µV 3.6 µV/V + 4.8 µV 4.6 µV/V + 48 µV 5.6 µV/V + 0.46 mV	Fluke 5720A w/ 5725A
DC Voltage – Measure & Generate	0.1 mV to 1100 V	0.9 µV/V + 0.2 µV	Fluke 732B w/ 720A & Agilent 3458A Opt 002
DC High Voltage – Measure Generate	 (1 to 60) kV (1 to 40) kV	 0.13 % 0.13 %	 Ross divider & DVM
DC Voltage[3] – Measure	(0 to 7) mV (7 to 100) mV (0.1 to 1) V (1 to 10) V (10 to 100) V (100 to 1000) V	60 µV/V + 0.04 µV 9.5 µV/V + 0.4 µV 6 µV/V + 0.4 µV 4.7 µV/V + 0.6 µV 6.9 µV/V + 35 µV 7.9 µV/V + 0.12 mV	Agilent 34420A Agilent 3458A Opt 002
DC Current[3] – Generate	0.1 nA 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 (11 to 20.5) A (10 to 100) A (100 to 1000) A	44 µA/A + 8 nA 38 µA/A + 10 nA 38 µA/A + 48 nA 48 µA/A + 0.81 µA 74 µA/A + 14 µA 0.041 % + 0.56 mA 0.12 % + 0.87 mA 33 µA/A 0.3 % + 60 mA	Fluke 5720A w/ 5725A Fluke 5520A Agilent 3458A w/ Fluke 5520A & L&N 4361 Fluke 5500A/coil
DC Current – Generate	(100 to 1000) A	0.13 %	Sorensen DCR 20-1000 & Empro shunt

Parameter/Equipment	Range	CMC[2, 5, 6, 8] (±)	Comments
DC Current[3] – Measure	Up to 20 pA (20 to 200) pA (0.2 to 2) nA (2 to 20) nA (20 to 200) nA (10 to 100) µA (0.1 to 1) mA (1 to 10) mA (10 to 100) mA (0.1 to 1) A (1 to 10) A (10 to 100) A (30 to 300) A (300 to 1200) A	3.5 % 0.63 % 0.20 % 0.23 % 0.085 % 19 µA/A + 1 nA 19 µA/A + 10 nA 21 µA/A + 70 nA 40 µA/A + 0.6 µA 0.012 % + 16 µA 0.31 mA 33 µA/A 0.011 % 0.05 %	Keithley 487 Agilent 3458A opt 002 w/ L&N 4222 w/ L&N 4361 w/ L&N 4363 w/ RAM shunt
DC Resistance[3] – Generate, Fixed Points	1 Ω 1.9 Ω 10 Ω 19 Ω 100 Ω 190 Ω 1 kΩ 1.9 kΩ 10 kΩ 19 kΩ 100 kΩ 190 kΩ 1 MΩ 1.9 MΩ 10 MΩ 19 MΩ 100 MΩ 1 GΩ 10 GΩ 100 GΩ	95 µΩ/Ω 97 µΩ/Ω 26 µΩ/Ω 26 µΩ/Ω 12 µΩ/Ω 13 µΩ/Ω 10 µΩ/Ω 10 µΩ/Ω 10 µΩ/Ω 10 µΩ/Ω 13 µΩ/Ω 13 µΩ/Ω 21 µΩ/Ω 22 µΩ/Ω 40 µΩ/Ω 49 µΩ/Ω 0.014 % 0.11 % 2.3 % 3.6 %	Fluke 5720A Keithley resistors

Parameter/Equipment	Range	CMC[2, 5, 6, 8] (±)	Comments
DC Resistance – Generate, Fixed Points	0.001 Ω 0.01 Ω 0.1 Ω (1, 1.9, 10) Ω 100 Ω, 1 kΩ (10, 19) kΩ 100 kΩ 1 MΩ 10 MΩ 19 MΩ	90 parts in 10^6 94 parts in 10^6 84 parts in 10^6 9 parts in 10^6 7 parts in 10^6 5 parts in 10^6 8 parts in 10^6 11 parts in 10^6 16 parts in 10^6 26 parts in 10^6	L&N fixed resistors Fluke 742A series fixed resistors
Resistance – Generate[3]	Up to 10.99 Ω 11 Ω to 1.099 kΩ (1.1 to 10.99) kΩ (11 to 109.99) kΩ (0.11 to 1.099) MΩ (1.1 to 3.299) MΩ (3.3 to 10.99) MΩ (11 to 32.99) MΩ (33 to 109.99) MΩ (110 to 330) MΩ (330 to 1100) MΩ	41 μΩ/Ω + 0.001 Ω 32 μΩ/Ω + 0.002 Ω 30 μΩ/Ω + 0.02 Ω 30 μΩ/Ω + 0.2 Ω 36 μΩ/Ω + 2.3 Ω 78 μΩ/Ω + 39 Ω 0.014 % + 52 Ω 0.026 % + 2.6 kΩ 0.052 % + 3.2 kΩ 0.31 % + 100 kΩ 1.6 % + 520 kΩ	Fluke 5520A, 4-wire Fluke 5520A, 2-wire
DC Resistance[3] – Measure	(0 to 1) Ω (1 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 1 GΩ to 1 TΩ	82 μΩ/Ω + 2.4 μΩ 18 μΩ/Ω + 64 μΩ 17 μΩ/Ω + 0.59 mΩ 12 μΩ/Ω + 0.58 mΩ 9.6 μΩ/Ω + 5.8 mΩ 9.7 μΩ/Ω + 58 mΩ 15 μΩ/Ω + 2.4 Ω 59 μΩ/Ω + 120 Ω 0.058 % + 1.2 kΩ 0.59 % + 12 kΩ 0.45 %	Agilent 34420A Agilent 3458A Keithley 487

Parameter/Equipment	Range	CMC[2, 5, 6, 8] (±)	Comments
DC Resistance – Measure	(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 (19 to 100) MΩ	60 μΩ/Ω 16 μΩ/Ω 13 μΩ/Ω 14 μΩ/Ω 14 μΩ/Ω 4.8 μΩ/Ω 4.8 μΩ/Ω 4.9 μΩ/Ω 7.3 μΩ/Ω 10 μΩ/Ω 13 μΩ/Ω 20 μΩ/Ω	Fluke 5720A, Agilent 3458A & 742A series resistors

Parameter/Range	Frequency	CMC[2, 5] (±)	Comments
AC Voltage[3] – Generate			
Up 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 (0.5 to 1) MHz (1 to 10) MHz (10 to 20) MHz (20 to 30) MHz	0.027 % + 5 μV 0.010 % + 5 μV 0.009 % + 5 μV 0.022 % + 5 μV 0.054 % + 6 μV 0.11 % + 12 μV 0.14 % + 23 μV 0.29 % + 23 μV 0.35 % + 6.1 μV 0.58 % + 6.1 μV 1.8 % + 6.1 μV	Fluke 5720A/5725A
(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 (0.5 to 1) MHz (1 to 10) MHz (10 to 20) MHz (20 to 30) MHz	0.027 % + 5 μV 0.01 % + 5 μV 90 μV/V + 5 μV 0.022 % + 5 μV 0.054 % + 6 μV 0.11 % + 12 μV 0.14 % + 23 μV 0.29 % + 23 μV 0.23% + 6.1 μV 0.46 % + 6.1 μV 1.2 % + 6.1 μV	

Parameter/Range	Frequency	CMC[2, 5] (±)	Comments
AC Voltage[3] – Generate (cont)			
(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 (0.5 to 1) MHz (1 to 10) MHz (10 to 20) MHz (20 to 30) MHz	0.027 % + 14 µV 0.01 % + 8 µV 87 µV/V + 8 µV 0.022 % + 8 µV 0.05 % + 20 µV 0.088 % + 23 µV 0.023 % + 29 µV 0.29 % + 52 µV 0.23 % + 6.1 µV 0.46 % + 6.1 µV 1.2 % + 6.1 µV	Fluke 5720A/5725A
(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 (0.5 to 1) MHz (1 to 10) MHz (10 to 20) MHz (20 to 30) MHz	0.026 % + 46 µV 0.01 % + 17 µV 51 µV/V + 9 µV 81 µV/V + 12 µV 0.012 % + 35 µV 0.039 % + 92 µV 0.11 % + 0.23 mV 0.17 % + 0.35 mV 0.23 % + 6.1 µV 0.46 % + 6.1 µV 1.15 % + 6.1 µV	
(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 (0.5 to 1) MHz	0.025 % + 0.46 mV 95 µV/V + 0.17 mV 51 µV/V + 0.06 mV 83 µV/V + 0.12 mV 0.011 % + 0.23 mV 0.03 % + 0.7 mV 0.11 % + 2.3 mV 0.15 % + 3.7 mV	
< 3 V	(1 to 10) MHz (10 to 20) MHz (20 to 30) MHz	0.23 % + 6.1 µV 0.46 % + 6.1 µV 1.2 % + 6.1 µV	
(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 (0.5 to 1) MHz	0.025 % + 4.6 mV 0.011 % + 1.7 mV 54 µV/V + 0.69 mV 0.013 % + 1.2 mV 0.022 % + 2.9 mV 0.094 % + 19 mV 0.49 % + 47 mV 0.81 % + 93 mV	

Parameter/Range	Frequency	CMC[2, 5, 6] (±)	Comments
AC Voltage[3] – Generate (cont)			
(220 to 250) V	(15 to 40) Hz	0.03 % + 19 mV	Fluke 5720A/5725A
(220 to 750) V	(30 to 50) kHz (50 to 100) kHz	0.042 % + 13 mV 0.15 % + 52 mV	
(220 to 1100) V	(40 to 50) Hz 50 Hz to 1 kHz (1 to 20) kHz (20 to 30) kHz	92 µV/V + 4.7 mV 69 µV/V + 4.0 mV 0.014 % + 6.9 mV 0.042 % + 13 mV	
AC Voltage – Measure			
(0.7 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 (0.5 to 1) MHz (1 to 10) MHz (10 to 20) MHz (20 to 30) MHz	0.21 % + 1.6 µV 0.1 % + 1.6 µV 0.075 % + 1.6 µV 0.11 % + 2.4 µV 0.15 % + 2.9 µV 0.27 % + 4.6 µV 0.29 % + 9.2 µV 0.41 % + 9.2 µV 0.02 % + 1.2 µV 0.035 % + 1.2 µV 0.081 % + 1.2 µV	Fluke 5790A
(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 (0.5 to 1) MHz (1 to 10) MHz (10 to 20) MHz (20 to 30) MHz	0.1 % + 1.6 µV 0.048 % + 1.6 µV 0.032 % + 1.6 µV 0.051 % + 2.4 µV 0.072 % + 2.9 µV 0.14 % + 4.6 µV 0.15 % + 9.2 µV 0.27 % + 9.2 µV 0.012 % 0.02 % 0.043 %	

Parameter/Range	Frequency	CMC[2, 6] (±)	Comments
AC Voltage – Measure (cont)			
(7 to 22) mV	(10 to 20) Hz	0.034 % + 1.6 µV	Fluke 5790A
	(20 to 40) Hz	0.023 % + 1.6 µV	
	40 Hz to 20 kHz	0.017 % + 1.6 µV	
	(20 to 50) kHz	0.025 % + 2.4 µV	
	(50 to 100) kHz	0.037 % + 2.9 µV	
	(100 to 300) kHz	0.094 % + 4.6 µV	
	(300 to 500) kHz	0.1 % + 9.2 µV	
	(0.5 to 1) MHz	0.2 % + 9.2 µV	
	(1 to 10) MHz	0.012 % + 1.5 µV	
	(10 to 20) MHz	0.02 % + 1.5 µV	
	(20 to 30) MHz	0.043 % + 1.5 µV	
(22 to 70) mV	9.5 Hz	0.12 % + 1.8 µV	
	(10 to 20) Hz	0.028 % + 1.8 µV	
	(20 to 40) Hz	0.014 % + 1.8 µV	
	40 Hz to 20 kHz	80 µV/V + 1.8 µV	
	(20 to 50) kHz	0.015 % + 2.4 µV	
	(50 to 100) kHz	0.03 % + 2.9 µV	
	(100 to 300) kHz	0.059 % + 4.6 µV	
	(300 to 500) kHz	0.077 % + 9.2 µV	
	(0.5 to 1) MHz	0.13 % + 9.2 µV	
	(1 to 10) MHz	0.012 % + 1.5 µV	
	(10 to 20) MHz	0.02 % + 1.5 µV	
	(20 to 30) MHz	0.043 % + 1.5 µV	
(70 to 220) mV	9.5 Hz	0.12 % + 1.8 µV	
	(10 to 20) Hz	0.025 % + 1.8 µV	
	(20 to 40) Hz	98 µV/V + 1.8 µV	
	40 Hz to 20 kHz	43 µV/V + 1.8 µV	
	(20 to 50) kHz	80 µV/V + 2.4 µV	
	(50 to 100) kHz	0.018 % + 2.9 µV	
	(100 to 300) kHz	0.029 % + 4.6 µV	
	(300 to 500) kHz	0.049 % + 9.2 µV	
	(0.5 to 1) MHz	0.12 % + 9.2 µV	
	(1 to 10) MHz	0.012 % + 1.7 µV	
	(10 to 20) MHz	0.018 % + 1.7 µV	
	(20 to 30) MHz	0.041 % + 1.7 µV	

Parameter/Range	Frequency	CMC[2, 6] (±)	Comments
AC Voltage – Measure (cont)			
(220 to 700) mV	9.5 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 (0.5 to 1) MHz (1 to 10) MHz (10 to 20) MHz (20 to 30) MHz	0.12 % + 1.8 µV 0.025 % + 1.8 µV 0.011 % + 1.8 µV 43 µV/V + 1.8 µV 60 µV/V + 2.4 µV 93 µV/V + 2.9 µV 0.02 % + 4.6 µV 0.035 % + 9.2 µV 0.11 % + 9.2 µV 0.012 % + 1.7 µV 0.018 % + 1.7 µV 0.041 % + 1.7 µV	Fluke 5790A
700 mV to 2.2 V	9.5 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 (0.5 to 1) MHz (1 to 10) MHz (10 to 20) MHz (20 to 30) MHz	0.12 % 0.024 % 78 µV/V 28 µV/V 54 µV/V 84 µV/V 0.019 % 0.036 % 0.11 % 0.014 % + 1.5 µV 0.016 % + 1.5 µV 0.041 % + 1.7 µV	
(2.2 to 7) V	9.5 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 (0.5 to 1) MHz (1 to 10) MHz (10 to 20) MHz (20 to 30) MHz	0.12 % 0.023 % 78 µV/V 32 µV/V 56 µV/V 94 µV/V 0.022 % 0.046 % 0.14 % 0.012 % 0.018 % 0.041 %	

Parameter/Range	Frequency	CMC[2, 6] (±)	Comments
AC Voltage[3] – Measure (cont)			
(7 to 22) V	9.5 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 (0.5 to 1) MHz	0.12 % 0.023 % 78 µV/V 32 µV/V 56 µV/V 96 µV/V 0.022 % 0.046 % 0.14 %	Fluke 5790A
(22 to 70) V	9.5 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 (0.5 to 1) MHz	0.12 % 0.023 % 79 µV/V 37 µV/V 66 µV/V 0.011 % 0.023 % 0.048 % 0.14 %	
(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	0.023 % 85 µV/V 42 µV/V 84 µV/V 0.012 % 0.024 % 0.058 %	
(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	0.023 % 0.012 % 49 µV/V 0.015 % 0.058 %	
(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	0.023 % 0.012 % 46 µV/V 0.015 % 0.058 %	

Parameter/Range	Frequency	CMC[2, 5, 6] (±)	Comments
AC Voltage[3] – Measure (cont)			
(0.1 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	0.035 % + 3.5 µV 0.024 % + 1.3 µV 0.035 % + 1.3 µV 0.12 % + 1.3 µV 0.58 % + 1.3 µV 4.6 % + 2.4 µV	Agilent 3458A
10 mV 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 (0.3 to 1) MHz (1 to 2) MHz	85 µV/V + 47 µV/V 92 µV/V + 24 µV/V 0.017 % + 24 µV/V 0.035 % + 24 µV/V 0.093 % + 24 µV/V 0.35 % + 0.012 % 1.2 % + 0.012 % 1.8 % + 0.012 %	
(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 (0.3 to 1) MHz	0.024 % + 4.7 mV 0.024 % + 2.3 mV 0.024 % + 2.3 mV 0.041 % + 2.3 mV 0.14 % + 2.3 mV 0.47 % + 12 mV 1.8 % + 12 mV	
(100 to 1000) V	(1 to 40) Hz 40 Hz to 1 kHz (1 to 20) kHz (20 to 50) kHz (50 to 100) kHz	0.047 % + 47 mV 0.047 % + 23 mV 0.07 % + 23 mV 0.14 % + 23 mV 0.35 % + 23 mV	
(1 to 42) kV	60 Hz	0.30 %	Ross divider & DVM
AC Current[3] – Generate			
(9 to 220) µA	(10 to 20) Hz (20 to 40) Hz 40 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz (10 to 30) kHz	0.027 % + 19 nA 0.016 % + 12 nA 0.013 % + 10 nA 0.029 % + 14 nA 0.1 % + 76 nA 1.8 % + 0.46 µA	Fluke 5720A w/ 5725A Fluke 5520A

Parameter/Range	Frequency	CMC[2, 5, 6, 8] (±)	Comments
AC Current[3] – Generate (cont)			
(0.22 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 (10 to 30) kHz	0.027 % + 47 nA 0.017 % + 41 nA 0.013 % + 41 nA 0.021 % + 0.13 µA 0.11 % + 0.76 µA 1.2 % + 0.69 µA	Fluke 5720A w/ 5725A Fluke 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 (10 to 30) kHz	0.027 % + 0.47 µA 0.017 % + 0.41 µA 0.013 % + 0.41 µA 0.021 % + 0.64 µA 0.11 % + 5.8 µA 0.46 % + 4.6 µA	Fluke 5720A w/ 5725A Fluke 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 (10 to 30) kHz	0.027 % + 4.7 µA 0.017 % + 4.1 µA 0.013 % + 2.9 µA 0.021 % + 4.1 µA 0.11 % + 12 µA 0.46 % + 0.23 mA	Fluke 5720A w/ 5725A Fluke 5520A
(0.22 to 2.2) A	20 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz	0.028 % + 41 µA 0.046 % + 93 µA 0.7 % + 190 µA	Fluke 5720A w/ 5725A
(2.2 to 11) A	40 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz	0.047 % + 0.2 mA 0.099 % + 0.44 mA 0.39 % + 0.87 mA	Fluke 5720A w/ 5725A
(11 to 20.5) A	(45 to 100) Hz 100 Hz to 1 kHz (1 to 5) kHz	0.14 % + 5.8 mA 0.18 % + 5.8 mA 3.5 % + 5.8 mA	Fluke 5520A
0.3 mA to 3 A	10 Hz to 10 kHz	70 µA/A	Fluke 5790A, 5720A, A40 shunts
(3 to 10) A	10 Hz to 10 kHz	0.012 %	
(10 to 20) A	45 Hz to 5 kHz	0.016 %	Fluke 5790A, 5520A, A40 shunts
(20 to 100) A	(25 to 500) Hz	1.1 %	Fluke 5720A & 461CT & 1620A

Parameter/Range	Frequency	CMC[2, 6, 8] (±)	Comments
AC Current[3] – Measure			
(5 to 100) µA	(10 to 20) Hz (20 to 45) Hz 45 Hz to 1 kHz	0.46 % + 0.035 µA 0.18 % + 0.035 µA 0.07 % + 0.035 µA	Agilent 3458A
(0.1 to 100) mA	(10 to 20) Hz (20 to 45) Hz (45 to 100) Hz (0.1 to 5) kHz	0.46 % + 0.024 % 0.18 % + 0.024 % 0.07 % + 0.024 % 0.036 % + 0.024 %	
(0.1 to 1) A	(10 to 20) Hz (20 to 45) Hz (45 to 100) Hz (0.1 to 5) kHz	0.46 % + 0.23 mA 0.19 % + 0.23 mA 0.093 % + 0.23 mA 0.12 % + 0.23 mA	
0.3 mA to 3 A (3 to 10) A (10 to 20) A	9.5 Hz to 10 kHz 10 Hz to 10 kHz 10 Hz to 10 kHz	0.007 % 0.012 % 0.016 %	Fluke 5790A w/ A40 shunts
(20 to 800) A	(25 to 500) Hz	0.18 %	Agilent 8508A & 461CT
AC Resistance[3] – Generate, Fixed Points			
0.1 Ω	100 Hz 1 kHz	0.15 % 0.14 %	Agilent 16074A AC resistance standards
1 Ω	100 Hz 1 kHz	0.024 % 0.062 %	
10 Ω	100 Hz to 13 MHz	0.082 %	
100 Ω	5 Hz 10 Hz 50 Hz to 1 MHz 5 MHz 10 MHz 13 MHz	0.28 % 0.13 % 0.015 % 0.21 % 0.44 % 0.57 %	

Parameter/Range	Frequency	CMC[2, 8] (±)	Comments
AC Resistance[3] – Generate, Fixed Points (cont)			
1 kΩ	5 Hz 10 Hz 50 Hz to 1 MHz 5 MHz 10 MHz 13 MHz	0.6 % 0.26 % 0.061 % 0.24 % 0.57 % 0.74 %	Agilent 16074A AC resistance standards
10 kΩ	5 Hz 10 Hz 50 Hz to 1 MHz	0.56 % 0.19 % 0.073 %	
100 kΩ	5 Hz 10 Hz 50 Hz to 100 kHz	0.43 % 0.32 % 0.07 %	
Capacitance[3] – Generate, Fixed Points			
(1, 10,100) pF and 1 nF	1 kHz to 13 MHz	0.036 %	Standard capacitors
(10, 100) nF and 1 μF	120 Hz to 100 kHz	0.037 %	
Capacitance[3] – Measure			
1 pF	(1 to 2) kHz 5 kHz 10 kHz	0.012 % 0.035 % 0.092 %	GenRad 1615-A capacitance bridge F_c = (0.01 pF/f [kHz] + 0.01 pF)
10 pF	150 Hz to 1 kHz (1 to 2) kHz 5 kHz 10 kHz	0.41 % + F_c 0.012 % 0.023 % 0.058 %	
100 pF	(20 to 400) Hz (1 to 2) kHz 5 kHz 10 kHz	0.41 % + F_c 0.012 % 0.023 % 0.058 %	

Parameter/Range	Frequency	CMC[2, 8] (±)	Comments
Capacitance[3] – Measure (cont)			
1 nF	(20 to 30) Hz (1 to 2) kHz 5 kHz 10 kHz	0.41 % + F_c 0.012 % 0.023 % 0.058 %	GenRad 1615-A capacitance bridge F_c = (0.01 pF/f [kHz] + 0.01 pF)
10 nF	(1 to 2) kHz 5 kHz 10 kHz	0.012 % 0.035 % 0.081 %	
100 nF	(1 to 2) kHz 5 kHz 10 kHz	0.023 % 0.081 % 0.32 %	
1 μF	(1 to 2) kHz 5 kHz 10 kHz	0.012 % 0.68 % 2.7 %	
10 μF	1 kHz	0.012 %	
1 pF	500 Hz to 5 kHz (5 to 100) kHz	12 % 1.2 %	Fluke PM6304C
10 pF	(150 to 500) Hz 500 Hz to 5 kHz (5 to 20) kHz (20 to 100) kHz	12 % 1.2 % 0.12 % 0.46 %	
100 pF	(50 to 250) Hz 250 Hz to 1 kHz (1 to 20) kHz (20 to 100) kHz	12 % 1.2 % 0.12 % 0.46 %	
1 nF	(50 to 250) Hz 250 Hz to 20 kHz (20 to 100) kHz	1.2 % 0.12 % 0.46 %	
10 nF	(50 to 500) Hz 500 Hz to 2 kHz (2 to 20) kHz (20 to 100) kHz	0.12 % 0.06 % 0.12 % 0.46 %	
100 nF	(50 to 150) Hz 150 Hz to 2 kHz (2 to 20) kHz (20 to 100) kHz	0.12 % 0.06 % 0.12 % 0.46 %	

Parameter/Range	Frequency	CMC[2, 8] (±)	Comments
Capacitance[3] – Measure (cont)			
1 µF	50 Hz to 2 kHz (2 to 20) kHz (20 to 100) kHz	0.06 % 0.12 % 0.46 %	Fluke PM6304C
10 µF	(50 to 1500) Hz (1.5 to 15) kHz (15 to 50) kHz (50 to 100) kHz	0.06% 0.12% 1.2 % 12%	
100 µF	(50 to 1500) Hz (1.5 to 15) kHz (15 to 50) kHz	0.12 % 1.2 % 12 %	
(100 to 200) µF (200 to 330) µF (0.33 to 110) mF	Direct Current Direct Current Direct Current	0.065 % 0.048 % 0.042 %	Time-charge method w/ Fluke 5720A & Agilent 3458A
Phase Angle[3] – Measuring Equipment			
(0 to 999.999)°	(1 to 1000) Hz 1001 Hz to 6.25 kHz (6.26 to 50) kHz (50.01 to 100) kHz	0.007° 0.013° 0.030° 0.060°	Clark Hess model 5000
Distortion[3]	20 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz	< 0.013 % < 0.038 % < 0.065 %	Agilent 8903A; single - sided
Inductance[3] – Generate, Fixed Points			
100 µH 200 µH, 1 H (0.5, 1, 5, 10, 100, 500) mH	400 Hz, 1 kHz	0.31 % 0.13 % 0.12 %	Standard inductors
10 H		0.24 %	

Parameter/Range	Frequency	CMC[2, 8] (±)	Comments
Inductance[3] – Measure			
1 µH	500 Hz to 1 kHz (50 to 100) kHz	12 % 1.2 %	Fluke PM6304C
10 µH	(250 to 500) Hz 500 Hz to 20 kHz (20 to 100) kHz	12 % 1.2 % 0.46 %	
100 µH	(75 to 250) Hz (250 to 1500) Hz (1.5 to 20) kHz (20 to 100) kHz	12 % 1.2 % 0.12 % 0.46 %	
1 mH	(50 to 75) Hz (75 to 250) Hz 250 Hz to 20 kHz (20 to 100) kHz	12 % 1.2 % 0.12 % 0.46 %	
10 mH	(50 to 75) Hz (75 to 250) Hz 250 Hz to 2 kHz (2 to 20) kHz (20 to 100) kHz	1.2 % 0.12 % 0.06 % 0.12 % 0.46 %	
100 mH	(50 to 75) Hz 75 Hz to 2 kHz (2 to 20) kHz (20 to 100) kHz	0.12 % 0.06 % 0.12 % 0.46 %	
1 H	50 Hz to 2 kHz (2 to 20) kHz (20 to 100) kHz	0.06 % 0.12 % 0.46 %	
10 H	(50 to 250) Hz 250 Hz to 20 kHz (20 to 100) kHz	0.06 % 0.12 % 1.2 %	
100 H	(50 to 2500) Hz (2.5 to 15) kHz (15 to 75) kHz	0.12 % 1.2 % 12 %	
1000 H	(50 to 250) Hz 250 Hz to 2.5 kHz (2.5 to 15) kHz	0.12 % 1.2 % 13 %	

Parameter/Range	Frequency	CMC[2, 8] (±)	Comments
Risetime[3] – Measure	Up to 50 GHz	10 ps	Tektronix TDS-8200 w/ 80E01
Oscilloscopes[3] –			
Risetime – Generate	Single Sided	< 150 ps ± 35 ps	Fluke 5820A
Bandwidth	50 kHz to 2.1 GHz	1.3 %	Fluke 5820A
	(2.1 to 4.2) GHz (4.2 to 18) GHz (18 to 26.5) GHz	0.31 dB 0.74 dB 0.84 dB	Agilent 8340A w/: 8482A, 11667A 8481A, 11667A 8485A, 11667B

Parameter/Equipment	Range	CMC[2] (±)	Comments
Electrical Calibration of Thermocouples[3] – Generate and Measure			
Type E	(-250 to -100) °C (100 to -25) °C (-25 to 350) °C (350 to 650) °C (650 to 1000) °C	0.5 °C 0.16 °C 0.14 °C 0.16 °C 0.21 °C	Fluke 5520A
Type J	(-210 to -100) °C (-100 to -30) °C (-30 to 150) °C (150 to 760) °C (760 to 120) °C	0.27 °C 0.16 °C 0.14 °C 0.17 °C 0.23 °C	
Type K	(-200 to -100) °C (-100 to -25) °C (-25 to 120) °C (120 to 1000) °C (1000 to 1372) °C	0.33 °C 0.18 °C 0.16 °C 0.26 °C 0.4 °C	

Parameter/Equipment	Range	CMC[2] (±)	Comments
Electrical Calibration of Thermocouples[3] – Generate and Measure (cont)			
Type N	(-200 to -100) °C (-100 to -25) °C (-25 to 120) °C (120 to 410) °C (410 to 1300) °C	0.47 °C 0.36 °C 0.37 °C 0.46 °C 0.63 °C	Fluke 5520A
Type R	(0 to 250) °C (250 to 400) °C (400 to 1000) °C (1000 to 1767) °C	0.24 °C 0.16 °C 0.14 °C 0.40 °C	
Type S	(0 to 250) °C (250 to 400) °C (400 to 1000) °C (1000 to 1767) °C	0.22 °C 0.19 °C 0.18 °C 0.27 °C	
Type T	(-250 to -150) °C (-150 to 0) °C (0 to 120) °C (120 to 400) °C	0.57 °C 0.35 °C 0.33 °C 0.4 °C	
Electrical Calibration of RTDs[3] – Generate			
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	0.06 °C 0.07 °C 0.09 °C 0.10 °C 0.12 °C 0.23 °C	Fluke 5520A; 4-wire compensation
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 0.10 °C 0.12 °C	

Parameter/Equipment	Range	CMC[2, 4, 6] (±)	Comments
Electrical Calibration of RTDs[3] – Generate (cont)			
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	Fluke 5520A; 4-wire compensation
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 400) °C (400 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	
Ni 120, 120 Ω	(-80 to 100) °C (100 to 300) °C	0.08 °C 0.14 °C	
Cu 427, 10 Ω	(-100 to 260) °C	0.3 °C	
Electrical Calibration of Conductivity Indicating Systems[3]	1 µS/cm to 20 mS/cm	0.018 % + 0.6*R*	Agilent 3458A w/ ESI DB52 decade resistors

Parameter/Equipment	Range	CMC[2, 5, 6, 8] (±)	Comments
pH Indicating Systems[3]	(-2 to 16) units	0.016 %	Fluke 5500A
Thermocouple[3] – Indicating Systems & Measure	E, J, K, T R, S	0.053 % + 0.03 °C 0.053 % + 0.2 °C	Agilent 3458A w/ DCV source

V. Electrical – RF/Microwave – Signal Generators, Spectrum Analyzers, Network Analyzers, Power Sensors, LISNs

Parameter/Range	Frequency	CMC[2, 4, 6, 8] (±)	Comments
Power Meter[3] – Power Reference @ 1 mW	50 MHz	0.8 % + *M*	Power transfer using W&G EPM-1 & W&G TK-10
Power Sensor Calibration Factor[3] –			Agilent 438A w/:
(-30 to +20) dBm	100 kHz to 4.2 GHz	1.0 %	8482-H84
	10 MHz to 12 GHz (>12 to 18) GHz	1.0 % 1.3 %	8481A-H84
	(2 to 26.5) GHz	2.0 %	8485A-H84
Amplitude Modulation[3] –			
Carrier: (0.15 to 10) MHz Depth: Up to 99 %	(20 to 50) Hz 50 Hz to 100 kHz	3.5 % 2.5 %	Agilent 8902A
Carrier: 10 MHz to 1.3 GHz Depth: Up to 99 %	(20 to 50) Hz 50 Hz to 100 kHz	1.4 % 3.5 %	
Frequency Modulation[3] –			
Carrier: 250 kHz to 10 MHz Dev: Up to 40 kHz	20 Hz to 10 kHz	2.5 %	Agilent 8902A
Carrier: 10 MHz to 1.3 GHz Dev: Up to 400 kHz	(20 to 50) Hz 50 Hz to 100 kHz (100 to 200) kHz	5.9 % 1.4 % 5.9 %	

Parameter/Range	Frequency	CMC[2, 4, 6, 8] (±)	Comments
Phase Modulation[3] –			
Carrier: 150 kHz to 10 MHz	200 Hz to 10 kHz	4.7 %	Agilent 8902A
Carrier: 10 MHz to 1.3 GHz	200 Hz to 20 kHz	3.6 %	
Relative Power[3] – 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	10 MHz to 26.5 GHz	0.06 dB 0.07 dB 0.07 dB 0.11 dB 0.11 dB 0.12 dB 0.13 dB 0.19 dB 0.19 dB 0.35 dB	Agilent 8902A
Absolute Power[3] – Measure			Agilent E4448A or 438A:
(-70 to -30) dBm	10 MHz to 18 GHz	2.7 % + *M*	8484A, N-type
(-30 to +10) dBm	100 kHz to 4.2 GHz (4.2 to 18) GHz (18 to 26.5) GHz	1.9 % + *M* 3.1 % + *M* 2.6 % + *M*	8482A H85, N-type 8481A H85, N-type 8485A H85, 3.5 mm
(+10 to +20) dBm	100 kHz to 4.2 GHz (4.2 to 18) GHz (18 to 26.5) GHz	4 % + *M* 4.3 % + *M* 4.3 % + *M*	8482A H85, N-type 8481A H85, N-type 8485A H85, 3.5 mm
Reflection[3] S_{11}/S_{22} – Measure			Agilent 8753E w/:
Type-N connecters:			85032B & 85055A
30 kHz to 2 GHz	Linear Mag. Linear Phase	(± 0.015 to ± 0.030) dB (± 0.95 to ± 7.8)°	
(2 to 18) GHz	Linear Mag. Linear Phase	(± 0.026 to ± 0.053) dB (± 3.8 to ± 9.5)°	

Parameter/Range	Frequency	CMC[2] (±)	Comments
Reflection[3] S_{11}/S_{22} – Measure (cont)			Agilent 8753E w/:
3.5 mm connectors:			85052C & 85053B
45 MHz to 2 GHz	Linear Mag. Linear Phase	(± 0.015 to ± 0.021) dB (± 0.99 to ± 3.9)°	
(2 to 20) GHz	Linear Mag. Linear Phase	(± 0.016 to ± 0.039) dB (± 2.3 to ± 6.2)°	
(20 to 26.5) GHz	Linear Mag. Linear Phase	(± 0.016 to ± 0.040) dB (± 2.4 to ± 6.7)°	
2.4 mm connectors:			85056A & 85057B
45 MHz to 2 GHz	Linear Mag. Linear Phase	(± 0.016 to ± 0.023) dB (± 1.2 to ± 7.3)°	
(2 to 20) GHz	Linear Mag. Linear Phase	(± 0.016 to ± 0.028) dB (± 1.5 to ± 7.5)°	
(20 to 40) GHz	Linear Mag. Linear Phase	(± 0.020 to ± 0.042) dB (± 2.5 to ± 7.7)°	
(40 to 50) GHz	Linear Mag. Linear Phase	(± 0.023 to ± 0.052) dB (± 3.1 to ± 8.0)°	

Parameter/Range	Frequency	CMC[2] (±)	Comments
Transmission[3] S_{12}/S_{21} – Measure			Agilent 8753E w/:
Type-N connecters			
30 kHz to 2 GHz	Linear Mag. Linear Phase	(± 0.063 to ± 8.162) dB (± 0.52 to ± 39)°	85032B & 85055A
(2 to 18) GHz	Linear Mag. Linear Phase	(± 0.191 to ± 1.942) dB (± 1.5 to ± 15)°	85054B & 85055A
3.5 mm connectors			
45 MHz to 2 GHz	Linear Mag. Linear Phase	(± 0.052 to ± 5.898) dB (± 0.40 to ± 76)°	85052C & 85053B
(2 to 20) GHz	Linear Mag. Linear Phase	(± 0.130 to ± 1.926) dB (± 1.2 to ± 15)°	
(20 to 26.5) GHz	Linear Mag. Linear Phase	(± 0.158 to ± 3.344) dB (± 1.7 to ± 28)°	
2.4 mm connectors			
45 MHz to 2 GHz	Linear Mag. Linear Phase	(± 0.052 to ± 8.162) dB (± 0.47 to ± 39)°	85056A & 85057B
(2 to 20) GHz	Linear Mag. Linear Phase	(± 0.093 to ± 1.916) dB (± 0.99 to ± 15)°	
(20 to 40) GHz	Linear Mag. Linear Phase	(± 0.166 to ± 3.372) dB (± 1.7 to ± 29)°	
(40 to 50) GHz	Linear Mag. Linear Phase	(± 0.268 to ± 3.754) dB (± 2.4 to ± 33)°	

Parameter/Equipment	Range	CMC[2] (±)	Comments
Single Side-Band Phase Noise[3, 7] – Measure			
Carrier: 50 kHz to 1.6 GHz			Agilent N5500A
Offset Freq:	Noise Floor:		
0.1 Hz	-70 dB	5 dB	
1 Hz	-130 dB	5 dB	
10 Hz	-140 dB	5 dB	
100 Hz	-150 dB	5 dB	
1 kHz	-160 dB	5 dB	
10 kHz	-170 dB	5 dB	
100 kHz	-170 dB	5 dB	
1 MHz	-170 dB	5 dB	
10 MHz	-170 dB	5 dB	
100 MHz	-170 dB	5 dB	
Carrier: (1.6 to 18) GHz			
Offset Freq:	Noise Floor:		
0.1 Hz	-55 dB	5 dB	
1 Hz	-115 dB	5 dB	
10 Hz	-125 dB	5 dB	
100 Hz	-135 dB	5 dB	
1 kHz	-145 dB	5 dB	
10 kHz	-155 dB	5 dB	
100 kHz	-160 dB	5 dB	
1 MHz	-160 dB	5 dB	
10 MHz	-160 dB	5 dB	
40 MHz	-160 dB	5 dB	
RF Power[3] – Measure			
100 kHz to 2.4 GHz	Up to 1500 W	16 W	Agilent 437B, 8482A, Bird 8890-300 w/ Werlatone C1460, C390B and AR DC7128M1

VI. Fluid Quantities

Parameter/Equipment	Range	CMC[2, 4, 8] (±)	Comments
Hydrometers[3]	(0.7 to 1.2) sp. gr. (1.2 to 2.0) sp. gr.	0.0007 sp. gr. 0.0012 sp. gr.	ASTM E126; by comparison using reference hydrometer
Gas Flow[3]	(1 to 1000) sccm (1000 to 10 000) sccm (10 000 to 50 000) sccm	0.38 % + 0.6*R* 0.39 % + 0.6*R* 0.44 % + 0.6*R*	Cal-Bench system
Volume[3] – To Contain (Beakers, Cylinders, Flasks, Proving Cans, etc) To Deliver (Burets, Dispensers, Pipettes, Syringes, Titrators)	 (0 to 4000) mL (4 to 30) L (0.1 to 1) mL (1 to 30) mL (30 to 160) mL	 0.05 mL + 0.6*R* 0.37 mL + 0.6*R* 0.042 mL 0.11 mL 0.39 mL	Gravimetric/electronic balances
Liquid Flow Systems	 ≤ 1 LPM (> 1 to ≤ 3) LPM (> 3 to ≤ 18) LPM (> 18 to ≤ 100) LPM	 1.3 % + 0.0098 LPM 0.59 % + 0.12 LPM 0.36 % + 0.12 LPM 1.2 % + 0.12 LPM	Direct comparison using Coriolis flow meters: CFM 025 CFM100

VII. Mechanical

Parameter/Equipment	Range	CMC[2, 4, 8] (±)	Comments
Mass Measurement	1 mg to 30 g (30 to 160) g (160 to 620) g (620 to 5000) g (5 to 55) kg	0.047 mg 0.38 mg 0.003 g 0.026 g 0.033 g	Electronic balance, mass comparison

Parameter/Equipment	Range	CMC[2, 4, 8] (±)	Comments
Balances[3]	(0.001 to 7.4) kg 1 mg to 220 g 1 mg to 220 g	2.6 µg/g + 0.6*R* 5 µg/g + 0.6*R* 10 µg/g + 0.6*R*	Handbook 44 w/: Class 1 weights Class 2 weights Class 3 weights
Scales	2 mg to 38 kg 0.1 oz to 3700 lb	0.01 % + 0.6*R* 90 µg/g + 0.6*R*	Handbook 44 w/: Class F weights Class 6 weights
Force[3] – Compression & Tension			
Wheel Load Scales and Dynamometers	0.1 oz to 1000 lbf (1000 to 2000) lbf (2000 to 5000) lbf (5000 to 10 000) lbf (10 000 to 25 000) lbf (25 000 to 50 000) lbf	0.025 % 0.46 lbf 1.1 lbf 2.2 lbf 5.5 lbf 13 lbf	Class 6 weights/DMM Load cells
Torque[3] –			
Tools	(0.5 to 20) ozf·in (20 to 160) ozf·in (10 to 100) lbf·in (8 to 30) lbf·ft (30 to 300) lbf·ft (300 to 800) lbf·ft (800 to 1000) lbf·ft	0.25 % + 0.66 % of range 0.42 % + 0.01 ozf·in 0.3 % 0.21 % + 0.02 lbf·ft 0.24 % 0.23 % 4.2 lbf·ft	Waters 6500-T4 AKO TSD-650-P torque transducer calibration system Norbar torque transducer calibration system
Transducers	(2 to 100) ozf·in (6 to 250) lbf·in (20 to 250) lbf·ft (250 to 1000) lbf·ft (1000 to 5000) lbf·ft	0.13 % + 0.05 ozf·in 0.031 % 0.062 % 0.032 % + 0.14 lbf·ft 0.11 % + 2 lbf·ft	Class 6 weights and torque arms

Parameter/Equipment	Range	CMC[2, 4, 8] (±)	Comments
Pressure – Deadweight Testers, Transducers and Gages	(0 to 2) inH_2O (0.5 to 23) psia (23 to 1015) psia (0.2 to 600) psig (6 to 2400) psig (2400 to 12 000) psig	0.005 inH_2O 0.011 % + 0.0004 psi 0.011 % + 0.6*R* 0.0031 % + 0.6*R* 0.0054 % + 0.6*R* 0.0077 % + 0.6*R*	Dwyer 1430 DHI RPM 4 w/ PPC3 DHI PPC3 Ruska 2465 Ruska 2400
Accelerometers – Frequency Response	(5 to < 10) Hz 100 Hz (ref) 159 Hz ≥ 10 Hz to 10 kHz	7.1 % of full scale 2.2 % of full scale 2.0 % of full scale 2.8 % of full scale	Vibration transducer calibration system referenced @ 1 g
Accelerometers – Amplitude Response	(1 to 1000) g	0.82 %	Centrifugal calibration system
"Direct Verification" of Durometers[3] – Spring Force Indenter Shape	A, B, O, D, C, DO scales	0.6 points Pass/Fail	ASTM D2240 using Shore durocalibrator Microscope
Indirect Verification of Rockwell Hardness Testers[3]	HRBW: Low Mid High HRC: Low Mid High HREW: Mid High	 0.5 HRBW 0.3 HRBW 0.50 HRBW 0.53 HRC 0.54 HRC 0.43 HRC 0.20 HREW 0.20 HREW	ASTM E18 w/ traceable blocks

Parameter/Equipment	Range	CMC[2, 4, 8] (±)	Comments
Indirect Verification of Rockwell Hardness Testers[3] (cont)	HR30N: Low Mid High HR30TW: Low High	 0.2 HR30N 0.5 HR30N 0.3 HR30N 1.2 HR30TW 0.2 HR30TW	ASTM E18 w/ traceable bocks
Calibration of Optical Velocity Sensors[3] – Velocity Distance Sensing	(0.2 to 300) km/h	0.048 % of full scale	Speed and distance simulation with a rotating drum
Speed Measurement Systems[3]	(0.2 to 300) km/h	0.015 % full scale	Tapes, counter, stroboscope, DVM
Extrusion Plastometer[3] – Piston Diameter Cylinder/Bore Dia. Timer Mass Switch Travel Temperature	 --- --- --- --- --- < 300 °C ≥ 300 °C	 69 µin 120 µin 0.0023 s 0.04 g 0.0016 in 0.028 °C 0.037 °C	ASTM D1238 w/: Micrometer Micrometer Counter Digital balance Caliper PRT

VIII. Optical Quantities

Parameter/Equipment	Range	CMC[2] (±)	Comments
Gloss	20°, 60°, 85°	0.59 gloss units	Reference gloss standard

IX. Thermodynamics

Parameter/Equipment	Range	CMC[2, 8] (±)	Comments
Temperature[3] – Measuring Equipment	0.01 °C	0.003 °C	TPW cell
Temperature[3] – Measuring Equipment	-80 °C (-45 to 250) °C (250 to 660) °C	0.15 °C 0.0037 % + 0.014 °C 0.0037 % + 0.044 °C	Hart 5628 w/ 1502A
Temperature[3] – Measure	(-197 to 660) °C	0.0036 % + 0.012 °C	Hart 5628 w/ 1502A
Infrared – Measuring Equipment	(-30 to 150) °C (150 to 500) °C	0.5 °C 0.35 % + 0.5 °C	Hart 9133 Hart 4181
Relative Humidity[3] – Measure	(10 to 98) % RH	1.3 % RH	Thunder 5A-1MP psychrometer
Relative Humidity – Measuring Equipment	(15 to 95) % RH	0.7 % RH	Thunder 2500

X. Time & Frequency

Parameter/Equipment	Range	CMC[2, 4] (±)	Comments
Frequency Measuring Equipment[3]	1 mHz to 26.5 GHz	5 parts in 10^{12} + 0.6*R*	Agilent 3325B or 8340B
Frequency[3] – Measure	1 mHz to 26.5 GHz	5 parts in 10^{12} + 0.6*R*	Agilent 58503B & frequency comparison

[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. CMC's 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 and this laboratory meets A2LA *R104 – General Requirements: Accreditation of Field Testing and Field Calibration Laboratories* for these calibrations. 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; *D* is the numerical value of the nominal diameter of the device measured in inches; *R* is the numerical value of the resolution of the device in its respective units; *Di* is the numerical value of the nominal diagonal of the plate measured in feet; and *M* is the source mismatch uncertainty .

[5] The measurands stated are generated with the Fluke 732B, 742A, 5500A, 5520A, and 5720A 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 34410A, 3458A, 8902A, or Fluke 5790A instruments. 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 or a fraction of the range specification.

[7] Ranges are based upon the system combination used:

Single Side Band Phase Noise –

Carrier Frequency:

(50 to 100) kHz using 3325B

(> 100 to 250) kHz using 3325B
250 kHz to 6 GHz using ESG E4438C
(6 to 26.5) GHz using PSG E8257D opt UNX

Offsets:

< 100 kHz using 3561A

> 100 kHz using E4448A

- Noise floor at any given frequency may be degraded due to SSB noise floor of the reference generator.

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