



SCOPE OF ACCREDITATION TO ISO/IEC 17025:2005
& ANSI/NCSL Z540-1-1994

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CALIBRATION

Valid To: January 31, 2011

Certificate Number: 1625.01

In recognition of the successful completion of the A2LA evaluation process, accreditation is granted to this laboratory to perform the following calibrations¹:

I. Chemical

Parameter/Equipment	Range	CMC ² (±)	Comments
pH Meter/Probe Calibration ³	4, 7, 10 pH units	0.027 pH units	pH buffer
	0 to 14 pH units	0.068 pH units	Comparison to pH meter
Conductivity Meter/Probe Calibration ³ –			
Discrete points	10 µS 100 µS 1000 µS 10 000 µS 100 000 µS	0.71 µS 2.9 µS 5.1 µS 78 µS 370 µS	Conductivity solutions

II. Dimensional

Parameter/Equipment	Range	CMC ² (±)	Comments
Length Standards	(0 to 18) in (18 to 48) in	13 μin + 10 μin/in 42 μin + 5.5 μin/in	Measuring machine, gage blocks
Length Standards ³	(0 to 1) in (1 to 7) in (7 to 24) in	120 μin 130 μin 200 μin	Bench micrometer, gage blocks
Angle Blocks ³	0.25° to 60°	0.0043°	Gage blocks/sine bar, electronic probe
Cylindrical Diameter – Outside Inside	(0 to 5) in (5 to 18) in (18 to 24) in (0.1 to 0.5) in (0.5 to 2.5) in (2.5 to 8) in (8 to 48) in	24 μin + 0.43 μin/in 110 μin 290 μin 26 μin 18 μin + 1.5 μin/in 26 μin + 2 μin/in 250 μin + 2.4 μin/in	Measuring machine, plug gage Height gage Measuring machine, ring gage Gage blocks, universal comparator
Cylindrical Diameter ³ – Outside Inside	(0 to 24) in (8 to 48) in	480 μin 210 μin + 9 μin/in	Height gage Gage blocks, universal comparator
Protractors ³	0° to 90°	0.012°	Gage blocks/sine bar
Flatness Measurements ³	(0 to 2) in diameter To 10 in length	4 μin 35 μin	Optical flat Electronic probe
Parallel Measurements ³	(0 to 1) in diameter To 10 in length	5.7 μin 38 μin	Optical parallels Electronic probe

Parameter/Equipment	Range	CMC ^{2, 6} (±)	Comments
Surface Finish Meters ³ – Profilometers	(19 to 122) Ra	1.8 μin + 0.1 μin/μin	Roughness specimens
Micrometers ³ –	Up to 3 in (3 to 48) in	20 μin + 35 μin/in 64 μin + 1.5 μin/in	Gage blocks
Micrometer Heads		8.2 μin	Electronic probe
Laser Micrometers	Up to 2 in	32 μin	Pin / plug gages
Bore Micrometers	(0.25 to 5) in	8.5 μin/in + 60 μin	Ring gages
Bench Micrometers	(0 to 12) in	17 μin	Gage blocks
Gage Blocks	(0 to 1) in (2 to 4) in	3 μin + 0.5 μin/in 2.2 μin + 0.75 μin/in	Dimensional comparator
Surface Plates ³ –			
Flatness	Up to 107 <i>D</i> in	(23 + 0.69 <i>D</i>) μin	Electronic level system <i>D</i> = diagonal inches
Repeatability	Up to 0.015 in	30 μin	Repeatability gage
Levels – Electronic Level Systems	---	0.22 arc seconds	Gage blocks
Levels ³ – Bubble Vial	---	0.62 <i>R</i>	Gage blocks
Calipers ³	(0 to 12) in (12 to 72) in	540 μin 980 μin	Gage blocks
Height/Depth Gages	(0 to 24) in (24 to 72) in	(21 + 7 <i>L</i>) μin 150 μin + 16 μin/in	Gage blocks
Height/Depth Gages ³	(0 to 24) in (24 to 72) in	130 μin + 13 μin/in 150 μin + 16 μin/in	Gage blocks

Parameter/Equipment	Range	CMC ² (±)	Comments
Dial, Digital, and Test Indicators –	Resolution: 10 μin	6.5 μin	Measuring machine, gage blocks
Dial, Digital, and Test Indicators ³ –	Resolution: 50 μin 0.0001 in 0.0005 in 0.001 in	32 μin 58 μin 290 μin 580 μin	Gage blocks
Thread Plugs – Pitch Diameter Major Diameter	Up to 4 in Up to 4 in	120 μin 67 μin	Gage blocks, thread wires, measuring machine
Thread Plugs ³ – Pitch Diameter Major Diameter	Up to 2 in Up to 2 in	0.0002 in 0.0001 in	Gage blocks, thread wires, bench micrometer
Taper Thread Plug – Pitch Diameter Major Diameter Notch Length	(0 to 2) in (0 to 2) in (0 to 2) in	130 μin 90 μin 120 μin	Gage blocks, thread wires, measuring machine Height gage
Taper Thread Plug ³ – Pitch Diameter Major Diameter Notch Length	(0 to 2) in (0 to 2) in (0 to 2) in	200 μin 180 μin 120 μin	Gage blocks, thread wires, measuring machine Height gage

Parameter/Equipment	Range	CMC ² (±)	Comments
Thread Wires – Inch Metric	(4 to 80) tpi (0.2 to 10) pitch	27 μin 0.69 μm	UMM
Adjustable Thread Rings ³ – Pitch Diameter Minor Diameter	(0.25 to 0.5) in (0.25 to 0.5) in	300 μin 140 μin	Master set plugs and three point bore micrometer
Optical Comparators ³ – Length Radius / Diameter Angle Magnification	Up to 6 in Up to 1 in 0° to 360° 10× 20× 31.25× 50× 62.5× 100×	0.000 22 in 0.0005 in 0.014° 0.02× 0.014× 0.015× 0.011× 0.012× 0.016×	Glass artifact Glass artifact and glass magnification scale
Gage Block Comparator – Force	(0 to 200) μin (0 to 1.47) N	3 μin 0.029 N	Gage blocks Somfy force gage
Sine Bars – Length Parallelism	(5 to 10) in	70 μin 38 μin	UMM Electronic probe
Cylindrical Squares – Squareness	(4 to 20) in	25 μin	Electronic probe

Parameter/Equipment	Range	CMC ² (±)	Comments
Torque Arms	(2 to 24) in (24 to 48) in	250 μin + 2.4 μin/in 0.000 99 in	Dimensional comparison
Thickness Gages ³	(0.0009 to 0.06) in	20 μin + 0.035 in/in	Thickness films and gage blocks

III. Dimensional Testing

Parameter/Equipment	Range	CMC ² (±)	Comments
One Dimensional Length ³	Up to 12 in (12 to 72) in Up to 300 mm (300 to 1800) mm	0.0013 in 0.012 in 0.034 mm 0.59 mm	Digital scale Steel ruler Digital scale Steel ruler
Angle ³	(0 to 360)°	0.039°	Optical comparator
Diameter/Radius ³	Up to 6 in	0.000 29 in	Optical comparator
Wire Cloth and Sieves	(0.020 to 12.5) mm	4.4 μm	Optical comparator

IV. Electrical – DC/Low Frequency

Parameter/Equipment	Range	CMC ^{2,4} (±)	Comments
DC Voltage – Measure, Fixed Point	10 V	1 μV/V	Zener array, scanner and detector
DC Voltage – Measure	(0 to 200) mV (0.2 to 2) V (2 to 20) V (20 to 200) V (200 to 1000) V	5.9 μV/V + 130 nV 3.6 μV/V + 480 nV 3.6 μV/V + 4.7 μV 5.3 μV/V + 50 μV 5.2 μV/V + 760 μV	Fluke 8508A

Parameter/Equipment	Range	CMC ^{2, 4, 5} (±)	Comments
DC Voltage ³ – Measure	(0 to 100) mV (0.1 to 1) V (1 to 10) V (10 to 100) V (100 to 1000) V	5.5 μV/V + 400 nV 4.2 μV/V + 840 nV 4.2 μV/V + 5.7 μV 6.5 μV/V + 89 μV 5.4 μV/V + 2.0 mV	HP 3458A, opt 002
DC Voltage ³ – HV Measure	(1 to 5) kV (5 to 50) kV (50 to 100) kV	0.083 kV 19 V + 16 V/kV 2.9 kV	Fluke 87 w/80K-40 Sensitive Research ESH Hipotronics KV100A
DC Voltage – 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 1 100) V	9.2 μV/V + 560 nV 5.8 μV/V + 880 nV 4 μV/V + 3.3 μV 4 μV/V + 5.3 μV 5.3 μV/V + 180 μV 7.3 μV/V + 730 μV	Fluke 5700A
Fixed Point	10 V	1 μV/V	Fluke 732A
DC Voltage ³ – Generate	(0 to 330) mV (0.33 to 3.3) V (3.3 to 33) V (33 to 330) V (330 to 1020) V	23 μV/V + 1.3 μV 13 μV/V + 2.5 μV 15 μV/V + 24 μV 22 μV/V + 190 μV 22 μV/V + 1.9 mV	Fluke 5520A
DC Current – Measure	(0 to 200) μA (0.2 to 2) mA (2 to 20) mA (20 to 200) mA (0.2 to 2) A (2 to 20) A (1 to 10) A (10 to 100) A	14 μA/A + 660 pA 15 μA/A + 5.0 nA 16 μA/A + 53 nA 43 μA/A + 200 nA 0.019 % + 28 μA 0.058 % + 1.9 mA 1.2 mA 13 mA	Fluke 8508A Valhalla 2575A

Parameter/Equipment	Range	CMC ^{2, 4, 5} (±)	Comments	
DC Current ³ – Measure	(0 to 100) µA (0.1 to 1) mA (1 to 10) mA (10 to 100) mA (0.1 to 1) A	20 µA/A + 1.5 nA 22 µA/A + 7.9 nA 22 µA/A + 81 nA 39 µA/A + 790 nA 0.011 % + 37 µA	HP 3458A, opt 002	
	(1 to 10) A	23 mA	Fluke 45	
	(100 to 1000) A	23 mA	Fluke 77 /80I-1010 clamp	
DC Current – Generate	(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	47 µA/A + 9.3 nA 47 µA/A + 9.5 nA 47 µA/A + 97 nA 53 µA/A + 950 nA 67 µA/A + 41 µA 0.04 % + 560 µA	Fluke 5700A	
	(20.5 to 100) A	1.3 A + 27 mA/A	Valhalla 2555A	
	(100 to 1000) A	1.5 A + 0.05 µA/A	Valhalla 2555A and 10 turn coil	
DC Current ³ – Generate	(0 to 330) µA (0.33 to 3.3) mA (3.3 to 33) mA (33 to 330) mA (0.33 to 1.1) A (1.1 to 3) A (3 to 11) A (11 to 20.5) A	0.018 % + 24 nA 0.012 % + 65 nA 0.012 % + 440 nA 0.01 % + 8.5 µA 0.023 % + 51 µA 0.04 % + 200 µA 0.055 % + 920 µA 0.11 % + 3 mA	Fluke 5520A	
DC Power ³ – Generate	(0.33 to 3.3) mA	(0.011 to 1.1) mW (0.11 to 11) mW (1.1 to 110) mW (0.011 to 1.1) W (0.11 to 3.3) W	0.043 % of rdg 94 µW/W 94 µW/W 95 µW/W 80 µW/W	Fluke 5520, opt PQ
	(3.3 to 33) mA	(0.11 to 11) mW (1.1 to 110) mW (0.011 to 1.1) W (0.11 to 11) W (1.1 to 33) W	0.043 % of rdg 90 µW/W 90 µW/W 91 µW/W 76 µW/W	

Parameter/Equipment	Range	CMC ^{2,5} (±)	Comments
DC Power ³ – Generate (cont)			
(33 to 330) mA	(1.1 to 110) mW (0.011 to 1.1) W (0.11 to 11) W (1.1 to 110) W (11 to 330) W	0.043 % of rdg 91 μW/W 91 μW/W 92 μW/W 77 μW/W	Fluke 5520, opt PQ
(0.33 to 3) A	(11 to 990) mW (0.11 to 9.9) W (1.1 to 99) W (11 to 990) W (0.11 to 3) kW	0.05 % of rdg 0.028 % of rdg 0.028 % of rdg 0.028 % of rdg 0.027 % of rdg	
(3 to 20.5) A	(0.099 to 6.7) W (0.99 to 6.7) W (9.9 to 670) W (0.099 to 6.8) kW (0.99 to 20.9) kW	0.082 % of rdg 0.071 % of rdg 0.071 % of rdg 0.071 % of rdg 0.07 % of rdg	
Thermocouple Indicators ³ –			
Type: B	(600 to 800) °C (800 to 1000) °C (1000 to 1550) °C (1550 to 1820) °C	0.52 °C 0.41 °C 0.36 °C 0.4 °C	Fluke 5520A
Type: C	(0 to 150) °C (150 to 650) °C (650 to 1000) °C (1000 to 1800) °C (1800 to 2316) °C	0.36 °C 0.32 °C 0.37 °C 0.59 °C 0.98 °C	
Type: E	(-250 to -100) °C (-100 to -25) °C (-25 to 350) °C (350 to 650) °C (650 to 1000) °C	0.59 °C 0.21 °C 0.19 °C 0.21 °C 0.26 °C	
Type: J	(-210 to -100) °C (-100 to -30) °C (-30 to 150) °C (150 to 760) °C (760 to 1200) °C	0.33 °C 0.21 °C 0.18 °C 0.22 °C 0.28 °C	
Type: K	(-200 to -100) °C (-100 to -25) °C (-25 to 120) °C (120 to 1000) °C (1000 to 1372) °C	0.4 °C 0.23 °C 0.21 °C 0.32 °C 0.47 °C	

Parameter/Equipment	Range	CMC ² (±)	Comments	
Thermocouple Indicators (cont) ³ –				
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 0.27 °C 0.24 °C 0.23 °C 0.33 °C	Fluke 5520A	
Type: R	(0 to 250) °C (250 to 400) °C (400 to 1000) °C (1000 to 1767) °C	0.67 °C 0.43 °C 0.41 °C 0.48 °C		
Type: S	(0 to 250) °C (250 to 1000) °C (1000 to 1400) °C (1400 to 1767) °C	0.56 °C 0.44 °C 0.45 °C 0.55 °C		
Type: T	(-250 to -150) °C (-150 to 0) °C (0 to 120) °C (120 to 400) °C	0.74 °C 0.29 °C 0.21 °C 0.19 °C		
Type: U	(-200 to 0) °C (0 to 600) °C	0.66 °C 0.33 °C		
RTD Indicators ³ –				
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	0.06 °C 0.059 °C 0.083 °C 0.11 °C 0.12 °C 0.12 °C 0.27 °C		Fluke 5520A
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	0.048 °C 0.048 °C 0.048 °C 0.06 °C 0.15 °C 0.16 °C 0.17 °C 0.19 °C		

Parameter/Equipment	Range	CMC ² (±)	Comments
RTD Indicators ³ (cont) –			
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	0.048 °C 0.06 °C 0.06 °C 0.071 °C 0.095 °C 0.095 °C 0.11 °C 0.13 °C	Fluke 5520A
Pt 385, 1 kΩ	(-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	0.036 °C 0.036 °C 0.048 °C 0.06 °C 0.071 °C 0.083 °C 0.083 °C 0.28 °C	
PtNi 385, 120 Ω	(-80 to 0) °C (0 to 100) °C (100 to 260) °C	0.095 °C 0.095 °C 0.017 °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	0.048 °C 0.048 °C 0.06 °C 0.071 °C 0.083 °C 0.095 °C 0.11 °C 0.12 °C 0.28 °C	
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	0.06 °C 0.06 °C 0.083 °C 0.11 °C 0.12 °C 0.15 °C	
Cu 427, 10 Ω	-100 °C to 260 °C	0.36 °C	

Parameter/Range	Frequency	CMC ^{2,4} (±)	Comments
AC Voltage – Measure			
(0 to 200) mV	(1 to 10) Hz (10 to 40) Hz (40 to 100) Hz (0.1 to 2) kHz (2 to 10) kHz (10 to 30) kHz (30 to 100) kHz	0.019 % + 18 μV 0.016 % + 5 μV 0.013 % + 5.2 μV 0.013 % + 2.5 μV 0.013 % + 5 μV 0.036 % + 9.5 μV 0.049 % + 130 μV	Fluke 8508A
(0.2 to 2) V	(1 to 10) Hz (10 to 40) Hz (40 to 100) Hz (0.1 to 2) kHz (2 to 10) kHz (10 to 30) kHz (30 to 100) kHz (100 to 300) kHz (0.3 to 1) MHz	0.016 % + 170 μV 0.012 % + 45 μV 0.011 % + 26 μV 78 μV/V + 25 μV 0.011 % + 25 μV 0.024 % + 52 μV 0.043 % + 740 μV 0.35 % + 2.4 mV 1.2 % + 24 mV	
(2 to 20) V	(1 to 10) Hz (10 to 40) Hz (40 to 100) Hz (0.1 to 2) kHz (2 to 10) kHz (10 to 30) kHz (30 to 100) kHz (100 to 300) kHz (0.3 to 1) MHz	0.016 % + 16 mV 0.013 % + 340 μV 0.011 % + 280 μV 78 μV/V + 260 μV 0.011 % + 250 μV 0.024 % + 480 μV 0.058 % + 2.5 mV 0.35 % + 24 mV 1.2 % + 240 mV	
(20 to 200) V	(1 to 10) Hz (10 to 40) Hz (40 to 100) Hz (0.1 to 2) kHz (2 to 10) kHz (10 to 30) kHz (30 to 100) kHz (100 to 300) kHz (0.3 to 1) MHz	0.017 % + 15 mV 0.013 % + 3.5 mV 0.011 % + 2.5 mV 85 μV/V + 2.4 mV 0.011 % + 2.5 mV 0.024 % + 4.8 mV 0.059 % + 24 mV 0.35 % + 240 mV 1.2 % + 2.4 V	
(200 to 1000) V	(1 to 10) Hz (10 to 40) Hz (0.04 to 10) kHz (10 to 30) kHz (30 to 100) kHz	0.018 % + 81 mV 0.015 % + 24 mV 0.012 % + 24 mV 0.024 % + 47 mV 0.061 % + 240 mV	

Parameter/Range	Frequency	CMC ^{2,4} (±)	Comments
AC Voltage ³ – Measure			
(0 to 10) mV	(1 to 40) Hz (0.04 to 1) kHz (1 to 20) kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz	0.034 % + 3.7 μV 0.023 % + 1.5 μV 0.034 % + 1.5 μV 0.12 % + 1.8 μV 0.58 % + 1.8 μV 4.6 % + 4.4 μV	HP 3458A, Opt 002
(10 to 100) mV	(1 to 40) Hz (0.04 to 1) kHz (1 to 20) kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (0.3 to 1) MHz	59 μV/V + 9 μV 58 μV/V + 6.1 μV 0.014 % + 5.6 μV 0.032 % + 5.8 μV 0.052 % + 62 μV 0.25 % + 140 μV 1.1 % + 160 μV	
(0.1 to 1) V	(1 to 40) Hz (0.04 to 1) kHz (1 to 20) kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (0.3 to 1) MHz	55 μV/V + 110 μV 70 μV/V + 40 μV 0.015 % + 39 μV 91 μV/V + 710 μV 0.065 % + 380 μV 0.32 % + 400 μV 1.2 % + 270 μV	
(1 to 10) V	(1 to 40) Hz (0.04 to 1) kHz (1 to 20) kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (0.3 to 1) MHz	54 μV/V + 1.1 mV 65 μV/V + 480 μV 0.015 % + 400 μV 0.029 % + 890 μV 0.09 % + 530 μV 0.34 % + 2.2 mV 1.2 % + 2.8 mV	
(10 to 100) V	(1 to 40) Hz (0.04 to 1) kHz (1 to 20) kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (0.3 to 1) MHz	0.021 % + 7.7 mV 0.022 % + 4 mV 0.022 % + 3.9 mV 0.04 % + 3.9 mV 0.14 % + 4.8 mV 0.46 % + 15 mV 1.8 % + 17 mV	
(100 to 700) V	(1 to 40) Hz (0.04 to 1) kHz (1 to 20) kHz (20 to 50) kHz (50 to 100) kHz	0.046 % + 55 mV 0.045 % + 37 mV 0.068 % + 38 mV 0.14 % + 43 mV 0.35 % + 43 mV	

Parameter/Range	Frequency	CMC ^{2,5} (±)	Comments
AC HV Voltage ³ –Measure			
(1 to 5) kV	Up to 60 Hz	0.15 kV	Fluke 77 w/80K-40
(5 to 50) kV	Up to 60 Hz	13 V + 21 V/kV	Sensitive Research ESH
(50 to 85) kV	Up to 60 Hz	3.5 kV	Hipotronics KV100A
AC Voltage – Generate			
(0.005 to 2.2) mV	(10 to 20) Hz (20 to 40) Hz (0.04 to 20) kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz (0.5 to 1) MHz	0.058 % + 5.2 μV 0.022 % + 5.2 μV 0.011 % + 5.2 μV 0.038 % + 5.3 μV 0.087 % + 8.1 μV 0.12 % + 15 μV 0.18 % + 29 μV 0.36 % + 29 μV	Fluke 5700A
(2.2 to 22) mV	(10 to 20) Hz (20 to 40) Hz (0.04 to 20) kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz (0.5 to 1) MHz	0.059 % + 5.9 μV 0.023 % + 5.8 μV 0.012 % + 5.8 μV 0.039 % + 5.9 μV 0.088 % + 8.1 μV 0.12 % + 16 μV 0.18 % + 30 μV 0.34 % + 37 μV	
(22 to 220) mV	(10 to 20) Hz (20 to 40) Hz (0.04 to 20) kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz (0.5 to 1) MHz	0.059 % + 16 μV 0.023 % + 10 μV 0.012 % + 10 μV 0.018 % + 62 μV 0.057 % + 130 μV 0.12 % + 38 μV 0.18 % + 41 μV 0.37 % + 93 μV	
(0.22 to 2.2) V	(10 to 20) Hz (20 to 40) Hz (0.04 to 20) kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz (0.5 to 1) MHz	0.052 % + 130 μV 0.016 % + 48 μV 75 μV/V + 13 μV 30 μV/V + 710 μV 0.016 % + 380 μV 0.046 % + 160 μV 0.12 % + 420 μV 0.23 % + 1 mV	

Parameter/Range	Frequency	CMC ^{2,5} (±)	Comments
AC Voltage – Generate (cont)			
(2.2 to 22) V	(10 to 20) Hz (20 to 40) Hz (0.04 to 20) kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz (0.5 to 1) MHz	0.052 % + 1.2 mV 0.017 % + 380 μV 75 μV/V + 160 μV 0.011 % + 830 μV 0.025 % + 480 μV 0.053 % + 1.8 mV 0.14 % + 5.0 mV 0.3 % + 10 mV	Fluke 5700A
(22 to 220) V	(10 to 20) Hz (20 to 40) Hz (0.04 to 20) kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz (0.5 to 1) MHz	0.053 % + 11 mV 0.017 % + 3.9 mV 85 μV/V + 1.3 mV 0.023 % + 4.2 mV 0.053 % + 9.5 mV 0.17 % + 110 mV 0.53 % + 110 mV 1.3 % + 220 mV	
(220 to 1100) V	(15 to 50) Hz (0.050 to 1) kHz	0.043 % + 19 mV 80 μV/V + 9.3 mV	
AC Voltage ³ – Generate			
(1 to 33) mV	(10 to 45) Hz 45 Hz to 10 kHz (10 to 20) kHz (20 to 50) kHz (50 to 100) kHz (100 to 500) kHz	0.052 % + 33 μV 20 μV/V + 100 μV 24 μV/V + 120 μV 0.04 % + 70 μV 0.27 % + 80 μV 0.81 % + 110 μV	Fluke 5520A
(33 to 330) mV	(10 to 45) Hz 45 Hz to 10 kHz (10 to 20) kHz (20 to 50) kHz (50 to 100) kHz (100 to 500) kHz	0.036 % + 11 μV 0.015 % + 19 μV 31 μV/V + 250 μV 0.019 % + 140 μV 0.078 % + 100 μV 0.24 % + 87 μV	
(0.33 to 3.3) V	(10 to 45) Hz 45 Hz to 10 kHz (10 to 20) kHz (20 to 50) kHz (50 to 100) kHz (100 to 500) kHz	0.036 % + 60 μV 0.017 % + 130 μV 50 μV/V + 1.9 mV 0.016 % + 1.2 mV 0.074 % + 430 μV 0.28 % + 810 μV	

Parameter/Range	Frequency	CMC ^{2, 4, 5} (±)	Comments
AC Voltage ³ – Generate (cont)			
(3.3 to 33) V	(10 to 45) Hz 45 Hz to 10 kHz (10 to 20) kHz (20 to 50) kHz (50 to 100) kHz	0.036 % + 790 μV 0.018 % + 710 μV 0.028 % + 720 μV 0.041 % + 740 μV 0.11 % + 1.9 mV	Fluke 5520A
(33 to 330) V	45 Hz to 1 kHz (1 to 10) kHz (10 to 20) kHz (20 to 50) kHz (50 to 100) kHz	0.023 % + 3.1 mV 0.024 % + 7.2 mV 0.029 % + 11 mV 0.032 % + 20 mV 0.23 % + 63 mV	
(330 to 1020) V	45 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz	0.035 % + 20 mV 0.029 % + 20 mV 0.033 % + 32 mV	
AC Current – Measure			
(0 to 200) μA	(1 to 10) Hz (0.01 to 10) kHz (10 to 30) kHz (30 to 100) kHz	0.034 % + 25 nA 0.032 % + 26 nA 0.076 % + 28 nA 0.46 % + 39 nA	Fluke 8508A
(0.2 to 2) mA	(1 to 10) Hz (0.01 to 10) kHz (10 to 30) kHz (30 to 100) kHz	0.032 % + 300 nA 0.024 % + 550 nA 0.074 % + 280 nA 0.46 % + 470 nA	
(2 to 20) mA	(1 to 10) Hz (0.01 to 10) kHz (10 to 30) kHz (30 to 100) kHz	0.034 % + 2.4 μA 0.033 % + 2.4 μA 0.072 % + 3.2 μA 0.46 % + 2.7 μA	
(20 to 200) mA	(1 to 10) Hz (0.01 to 10) kHz (10 to 30) kHz	0.03 % + 36 μA 0.028 % + 29 μA 0.068 % + 28 μA	
(0.2 to 2) A	(0.01 to 2) kHz (2 to 10) kHz (10 to 30) kHz	0.067 % + 310 μA 0.081 % + 240 μA 0.35 % + 320 μA	
(2 to 20) A	(0.01 to 2) kHz (2 to 10) kHz	0.084 % + 4.6 mA 0.28 % + 5.6 mA	
(0.1 to 1) A (1 to 10) A (10 to 100) A	Up to 10 kHz Up to 10 kHz Up to 1 kHz	0.5 mA 5 mA 50 mA	Valhalla 2575A

Parameter/Range	Frequency	CMC ^{2, 4, 5} (±)	Comments
AC Current ³ – Measure			
(0 to 100) µA	(10 to 20) Hz (20 to 45) Hz (45 to 100) Hz (0.1 to 1) kHz	0.46 % + 42 nA 0.17 % + 41 nA 0.068 % + 38 nA 0.068 % + 38 nA	HP 3458A, Opt 002
(0.1 to 1) mA	(10 to 20) Hz (20 to 45) Hz (45 to 100) Hz (0.1 to 5) kHz	0.45 % + 360 nA 0.17 % + 310 nA 0.066 % + 280 nA 0.033 % + 280 nA	
(1 to 10) mA	(10 to 20) Hz (20 to 45) Hz (45 to 100) Hz (0.1 to 5) kHz	0.45 % + 3.6 µA 0.17 % + 3.0 µA 0.066 % + 2.8 µA 0.033 % + 2.8 µA	
(10 to 100) mA	(10 to 20) Hz (20 to 45) Hz (45 to 100) Hz (0.1 to 5) kHz	0.42 % + 71 µA 0.17 % + 32 µA 0.066 % + 28 µA 0.033 % + 28 µA	
(0.1 to 1) A	(10 to 20) Hz (20 to 45) Hz (45 to 100) Hz (0.1 to 5) kHz	0.46 % + 320 µA 0.18 % + 320 µA 0.089 % + 320 µA 0.12 % + 280 µA	
(100 to 1000) A	Up to 60 Hz	0.3 A	Fluke 77/80I-1010 Clamp
AC Current – Generate			
(0.02 to 220) µA	(10 to 20) Hz (20 to 40) Hz (0.04 to 1) kHz (1 to 5) kHz (5 to 10) kHz	0.071 % + 30 nA 0.036 % + 30 nA 0.014 % + 20 nA 0.058 % + 50 nA 0.17 % + 100 nA	Fluke 5700A
(0.22 to 2.2) mA	(10 to 20) Hz (20 to 40) Hz (0.04 to 1) kHz (1 to 5) kHz (5 to 10) kHz	0.065 % + 190 nA 0.022 % + 490 nA 0.014 % + 40 nA 0.058 % + 490 nA 0.17 % + 1 µA	
(2.2 to 22) mA	(10 to 20) Hz (20 to 40) Hz (0.04 to 1) kHz (1 to 5) kHz (5 to 10) kHz	0.07 % + 700 nA 0.036 % + 580 nA 0.014 % + 410 nA 0.057 % + 5.2 µA 0.17 % + 9.4 µA	

Parameter/Range	Frequency	CMC ^{2,5} (±)	Comments
AC Current – Generate (cont)			
(22 to 220) mA	(10 to 20) Hz (20 to 40) Hz (0.04 to 1) kHz (1 to 5) kHz (5 to 10) kHz	0.061 % + 28 µA 0.032 % + 18 µA 0.015 % + 4.2 µA 0.058 % + 49 µA 0.16 % + 120 µA	Fluke 5700A
(0.22 to 2.2) A	(0.02 to 1) kHz (1 to 5) kHz (5 to 10) kHz	0.058 % + 200 µA 0.071 % + 240 µA 0.87 % + 720 µA	
(2.2 to 11) A	(0.04 to 1) kHz (1 to 5) kHz (5 to 10) kHz	0.025 % + 3.9 mA 0.068 % + 5.1 mA 0.3 % + 13 mA	
AC Current ³ – Generate			
(29 to 330) µA	(10 to 20) Hz (20 to 45) Hz 45 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz (10 to 30) kHz	0.24 % + 120 nA 0.18 % + 120 nA 0.15 % + 120 nA 0.35 % + 170 nA 0.93 % + 230 nA 1.9 % + 460 nA	Fluke 5520A
(0.33 to 3.3) mA	(10 to 20) Hz (20 to 45) Hz 45 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz (10 to 30) kHz	0.23 % + 280 nA 0.15 % + 220 nA 0.12 % + 170 nA 0.24 % + 230 nA 0.58 % + 350 nA 1.2 % + 690 nA	
(3.3 to 33) mA	(10 to 20) Hz (20 to 45) Hz 45 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz (10 to 30) kHz	0.21 % + 3.3 µA 0.11 % + 2.5 µA 0.049 % + 2.4 µA 0.096 % + 2.4 µA 0.24 % + 3.5 µA 0.47 % + 4.7 µA	
(33 to 330) mA	(10 to 20) Hz (20 to 45) Hz 45 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz (10 to 30) kHz	0.2 % + 70 µA 0.11 % + 28 µA 0.048 % + 24 µA 0.12 % + 58 µA 0.24 % + 120 µA 0.47 % + 240 µA	

Parameter/Range	Frequency	CMC ^{2,5} (±)	Comments
AC Current ³ – Generate (cont)			
(0.33 to 1.1) A	(10 to 45) Hz 45 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz	0.21 % + 190 µA 0.059 % + 120 µA 0.7 % + 1.2 mA 2.9 % + 5.8 mA	Fluke 5520A
(1.1 to 3) A	(10 to 45) Hz 45 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz	0.21 % + 190 µA 0.07 % + 120 µA 0.7 % + 1.2 mA 2.9 % + 5.8 mA	
(3 to 11) A	(45 to 100) Hz (0.1 to 1) kHz (1 to 5) kHz	0.057 % + 4.6 mA 0.094 % + 5.6 mA 0.34 % + 13 mA	
(11 to 20.5) A	(45 to 100) Hz (0.1 to 1) kHz (1 to 5) kHz	0.14 % + 7 mA 0.17 % + 7.7 mA 3.4 % + 14 mA	
(20 to 150) A (20 to 1000) A	(65 to 440) Hz (45 to 65) Hz	0.64 % + 0.85 A 0.39 % + 0.85 A	Fluke 5520A and 50 turn coil
AC Power ³ – Generate			
Watts ($\Phi = 0^\circ$) (10 to 65 Hz)			
(3.3 to 9) mA	(0.11 to 3.0) mW (0.001 to 9) W	0.089 % of rdg 0.082 % of rdg	Fluke 5520A, Opt PQ
(9 to 33) mA	(0.30 to 10) mW (0.003 m to 33) W	0.13 % of rdg 0.13 % of rdg	Note: Uncertainty is higher if Φ is non-zero or if frequency is greater than 65 Hz. (Upper frequency limit: 30 kHz)
(33 to 90) mA	(1 to 30) mW (0.01 to 90) W	0.089 % of rdg 0.082 % of rdg	
(90 to 330) mA	(3.0 to 100) mW (0.03 to 300) W	0.11 % of rdg 0.1 % of rdg	
(0.33 to 0.9) A	(11 to 300) mW (0.11 to 900) W	0.087 % of rdg 0.081 % of rdg	
(0.9 to 2.2) A	(30 to 720) mW (0.30 to 2000) W	0.09 % of rdg 0.084 % of rdg	
(2.2 to 4.5) A	(0.08 to 1.4) W (0.73 to 4500) W	0.16 % of rdg 0.16 % of rdg	
(4.5 to 20.5) A	(0.15 to 6.7) W (1.5 to 20 000) W	0.18 % of rdg 0.18 % of rdg	

Parameter/Equipment	Range	CMC ^{2, 4, 5} (±)	Comments
Inductance ³ – Generate (0.002 to 10) H (0.002 to 10) H	(100, 120) Hz 1 kHz	0.024 % + 2.2 μH 0.057 % + 1.6 μH	Genrad 1482 series standard inductors
Resistance – Measure	(0 to 2) Ω (2 to 20) Ω (20 to 200) Ω (0.2 to 2) kΩ (2 to 20) kΩ (20 to 200) kΩ (0.2 to 2) MΩ (2 to 20) MΩ (20 to 200) MΩ (0.2 to 2) GΩ	18 μΩ/Ω + 7.2 μΩ 13 μΩ/Ω + 25 μΩ 12 μΩ/Ω + 59 μΩ 11 μΩ/Ω + 730 μΩ 10 μΩ/Ω + 6.2 mΩ 8.6 μΩ/Ω + 120 mΩ 6.3 μΩ/Ω + 17 Ω 22 μΩ/Ω + 120 Ω 70 μΩ/Ω + 12 kΩ 0.061 % + 1.2 MΩ	Fluke 8508A
Resistance ³ – Measure	(0 to 10) Ω (10 to 100) Ω (0.1 to 1) kΩ (1 to 10) kΩ (10 to 100) kΩ (0.1 to 1) MΩ (1 to 10) MΩ (10 to 100) MΩ (0.1 to 1) GΩ	17 μΩ/Ω + 62 μΩ 14 μΩ/Ω + 590 μΩ 12 μΩ/Ω + 1 mΩ 11 μΩ/Ω + 11 mΩ 11 μΩ/Ω + 170 mΩ 8.8 μΩ/Ω + 18 Ω 54 μΩ/Ω + 170 Ω 0.051 % + 9.4 kΩ 0.55 % + 350 kΩ	HP 3458A, opt 002
Resistance ³ – Generate Synthesized Resistance Points	(0 to 11) Ω (11 to 33) Ω (33 to 110) Ω (110 to 330) Ω (0.33 to 1.1) kΩ (1.1 to 3.3) kΩ (3.3 to 11) kΩ (11 to 33) kΩ (33 to 110) kΩ (110 to 330) kΩ (0.33 to 1.1) MΩ (1.1 to 3.3) MΩ (3.3 to 11) MΩ (11 to 33) MΩ (33 to 110) MΩ (110 to 330) MΩ (0.33 to 1.1) GΩ	46 μΩ/Ω + 1.2 mΩ 35 μΩ/Ω + 1.8 mΩ 25 μΩ/Ω + 3.2 mΩ 29 μΩ/Ω + 4.2 mΩ 29 μΩ/Ω + 6.6 mΩ 29 μΩ/Ω + 41 mΩ 27 μΩ/Ω + 100 mΩ 29 μΩ/Ω + 400 mΩ 27 μΩ/Ω + 1 Ω 35 μΩ/Ω + 3.5 Ω 32 μΩ/Ω + 9.6 Ω 66 μΩ/Ω + 50 Ω 0.014 % + 250 Ω 0.027 % + 3.9 kΩ 0.052 % + 12 kΩ 0.35 % + 130 kΩ 1.7 % + 1.9 MΩ	Fluke 5520A

Parameter/Equipment	Range	CMC ^{2,5} (±)	Comments
Resistance – Generate Discrete Resistance Points	0 Ω 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	59 μΩ 0.11 mΩ 0.21 mΩ 0.33 mΩ 0.58 mΩ 2 mΩ 3.8 mΩ 14 mΩ 27 mΩ 130 mΩ 250 mΩ 1.5 Ω 2.9 Ω 27 Ω 46 Ω 440 Ω 1.1 kΩ 15 kΩ	Fluke 5700A
pH Simulation ³ – Generate	(0 to 14) pH units	0.011 pH	Fluke 700 series process calibrator
Conductivity Simulation ³ – Generate	Up to 1 μS 1 μS to 10 mS	0.015 μS 16 μS	ESI DB 877 decade resistor
Oscilloscope Functions ³ – Rise/Fall Time Bandwidth	 Up to 600 MHz Up to 1.1 GHz	 1.7 ns 0.11 Division	 Fluke 5520A (scope option)

V. Fluid Quantities

Parameter/Equipment	Range	CMC ² (±)	Comments
Viscosity Meter Calibration ³	Up to 33 % of Scale (33 to 66) % of Scale (66 to 100) % of Scale	2.7 % of rdg 1.8 % of rdg 1.7 % of rdg	Viscosity oils

Parameter/Equipment	Range	CMC ² (±)	Comments
Refractometers –	1.336 59 n _D 1.344 01 n _D 1.355 68 n _D 1.469 90 n _D 1.522 56 n _D	0.000 42 n _D 0.000 42 n _D 0.000 42 n _D 0.000 48 n _D 0.000 49 n _D	Standard solutions

VI. Mechanical

Parameter/Equipment	Range	CMC ² (±)	Comments
Pressure – Pneumatic Gauge, Negative Gauge, and Absolute –	(0.07 to 0.2) psi (0.2 to 1000) psi	0.0062 psi 0.0025 % of rdg	PPC2+ Ruska 2465
Gauge Only	1000 to 15 000 psig	0.0075 % of rdg	Ruska 2475
Hydraulic	Up to 20 000 psig	0.0075 % of rdg	Ruska 2485
Pressure ³ – Pneumatic Gauge, Negative Gauge, and Absolute –	(0 to 2) inH ₂ O	0.0021 inH ₂ O	Microtector
Pressure – Gauge and Absolute	(0 to 200) psi (200 to 500) psi (500 to 1000) psi	0.42 psi 0.66 psi 2.1 psi	Pressure transducers
Pressure – Gauge Only	(1000 to 2000) psi (2000 to 5000) psi (5000 to 10 000) psi	4.2 psi 6.6 psi 22 psi	
Mass – Measure, Fixed Points	50 kg 30 kg 20 kg 10 kg 5 kg 3 kg 2 kg 1 kg 500 g 300 g 200 g 100 g 50 g 30 g 20 g	16 mg 5.4 mg 3.9 mg 2.8 mg 970 µg 780 µg 700 µg 600 µg 590 µg 590 µg 44 µg 40 µg 22 µg 19 µg 11 µg	Double substitution with air buoyancy correction; class E2 mass standards; Sartorius CC50, RC210P, CC5001, CC50002

Parameter/Equipment	Range	CMC ² (±)	Comments
Mass – Measure, Fixed Points (cont)	10 g 5 g 3 g 2 g 1 g 500 mg 300 mg 200 mg 100 mg 50 mg 30 mg 20 mg 10 mg 5 mg 3 mg 2 mg 1 mg	8.1 µg 5 µg 4.5 µg 3.2 µg 2.9 µg 2.8 µg 3.3 µg 2.6 µg 2.6 µg 2.1 µg 2.4 µg 2 µg 2 µg 1.5 µg 1.7 µg 1.5 µg 1.5 µg	Double substitution with air buoyancy correction; class E2 mass standards; Sartorius CC50, RC210P, CC5001, CC50002
Mass ³ – Measure	(0.2 to 3000) g (3 to 34) kg	10 mg 0.1 g	ASTM class 6/7, OIML class M2/M3, NIST class F by single substitution
Scales and Balances ³	(1 to 200) g (200 to 3000) g (3 to 5) kg (5 to 15) kg (15 to 34) kg (50 to 250) lbm (250 to 1000) lbm (1000 to 3000) lbm (3000 to 12 000) lbm	250 µg + 2.3 µg/g 880 µg + 120 µg/g 0.6 g 1.8 g 4.3 g 0.17 lbm 0.2 lbm 0.38 lbm 7.4 lbm	Certified weights, NIST Handbook 44 E2, Class 1
Force – Compression & Tension, Measure & Measuring Equipment	(200 to 5000) lbf (5000 to 20 000) lbf (20 000 to 60 000) lbf	1.2 lbf 4.6 lbf 15 lbf	Morehouse 1000 series proving rings
Force ³ – Compression & Tension, Measure & Measuring Equipment	(0 to 2.5) N (2.5 to 50) N (10 to 500) lbf (500 to 2000) lbf (2000 to 30 000) lbf	0.0011 N 0.011 N 0.18 lbf 3.0 lbf 21 lbf	Deadweights, load cells
Measure Only – Compression Only	(30 000 to 200 000) lbf	130 lbf	Load cell

Parameter/Equipment	Range	CMC ² (±)	Comments
Torque Wrenches	(8 to 80) in·ozf (5 to 20) in·lbf (20 to 50) in·lbf (4 to 100) ft·lbf (100 to 1000) ft·lbf	0.37 in·ozf 0.025 in·lbf 0.020 in·lbf 0.096 ft·lbf 0.25 ft·lbf	Torque transducers
Torque Wrenches ³	(45 to 450) in·lbf (74 to 740) in·lbf	0.26 in·lbf 1 ft·lbf	Torque transducers
Torque Tools ³	(16 to 160) in·lbf	1.4 in·lbf	Torque transducers
Torque Transducers	(4 to 80) in·ozf (5 to 60) in·lbf (5 to 250) ft·lbf (250 to 1000) ft·lbf	0.047 % of rdg 0.035 % of rdg 0.068 % of rdg 0.032 % of rdg	Torque arms and class F weights
Tachometers ³ –			
Contact	Up to 2000 rpm	3.9 rpm	Tachometer test station signal generator
Strobo	Up to 20 000 rpm	16 rpm	
Photo	Up to 99 999 rpm	0.013 rpm	
Indirect Verification of Rockwell Hardness Testers ³	HRB Low HRB Mid HRB High HRC Low HRC Mid HRC High HR15N Low HR15N Mid HR15N High HR30N Low HR30N Mid HR30N High HR45N Low HR45N Mid HR45N High HR15T Low HR15T Mid HR15T High	1.8 HRB 1.3 HRB 1.2 HRB 0.98 HRC 1.2 HRC 0.73 HRC 1.2 HR15N 1.2 HR15N 1.2 HR15N 1.2 HR30N 1.2 HR30N 1.2 HR30N 1.2 HR30N 1.2 HR45N 1.2 HR45N 1.2 HR45N 1.2 HR15T 1.2 HR15T 1.2 HR15T	ASTM E18

Parameter/Equipment	Range	CMC ² (±)	Comments
Indirect Verification of Rockwell Hardness Testers (cont) ³	HR30T Low HR30T Mid HR30T High HR45T Low HR45T Mid HR45T High	1.3 HR30T 1.2 HR30T 1.2 HR30T 1.3 HR45T 1.3 HR45T 1.2 HR45T	ASTM E18
Indirect Verification of Brinell Hardness Testers at Test Condition(s) ³ :			Indirect verification method per ASTM E10
10/500/15	Repeatability: > 65 to < 159 HBW	0.05 <i>d</i>	<i>d</i> is the mean of the <i>n</i> mean test diameters in millimeters. Uncertainty is stated as a percentage of the standardized test block hardness value.
10/3000/15	Error	3.4 % of rdg	
	Repeatability: 65 to < 159 HBW	0.04 <i>d</i>	
	Error	1.8 % of rdg	
Durometer Calibrators			
Beam Type	Type A Type D	0.014 % of rdg 0.012 % of rdg	Optical comparator and mass comparator
Indirect Verification of Microindentation Hardness Testers ³ (Knoop and Vickers)	Repeatability under forces <i>P</i> (gf): $1 \leq P < 1000$ $100 \leq HK \leq 270$ $100 \leq HV \leq 250$ $270 \leq HK \leq 720$ $250 \leq HV \leq 750$ Error	 4.3 % of rdg 3.7 % of rdg 1.8 % of rdg 3.6 % of rdg 0.91 μm	Indirect verification method per ASTM E384 Best uncertainty is stated as the repeatability as defined in E384
Linear Velocity ³	Up to 50 mm/min	0.033 mm/min	Linear scale and stopwatch

Parameter/Equipment	Range	CMC ² (±)	Comments
Extensometers ³	Up to 1 in (1 to 4) in (4 to 18) in	0.00045 in 0.0018 in 0.008 in	Measuring machine, gage blocks, micrometer, bench micrometer., linear encoder

VII. Optical Quantities

Parameter/Equipment	Range	CMC ² (±)	Comments
Gloss Meters ³	20° 60° 85°	0.66 GU 0.45 GU 0.44 GU	Gloss standards
Gloss Tiles ³	20° 60° 85°	0.64 GU 0.43 GU 0.43 GU	Comparison to gloss standards

VIII. Rubber and Plastics Industry Specific Equipment

Parameter/Equipment	Range	CMC ² (±)	Comments
Mooney Viscometers ³ , Stress Relaxation –			
Mooney Torque	(0 to 200) Mooney Units	0.08 MU	ASTM D 1646 Class F Weights
Rotor RPM	(0.01 to 100) rpm	0.25 % of rdg	Optical Encoder
Die Temperature	(0 to 400) °C	0.4 °C	ASTM D 1349 RTD with Indicator
Die Closing Force	(500 to 2700) lbf	28.5 lbf	ASTM E 4 Load Cell with Indicator
Rotor Dimensions	(0 to 2) in	300 μin	Measured at test temperatures with Micrometers
Rotor Eccentricity	(0 to 0.1) in	0.0016 in	Test Indicator

Parameter/Equipment	Range	CMC ² (±)	Comments
Oscillating Disc Rheometers ³ –			
Torque	(0 to 200) in·lbf	0.2 in·lbf	ASTM D2084, ISO 3417 OD Torsion Standard
Oscillatory Frequency	(0.016 to 33) Hz	0.01 Hz	Optical encoder
Oscillatory Amplitude	(-90 to 90) ° arc	37 arcseconds	Optical encoder
Die Temperature	(0 to 400) °C	0.4 °C	ASTM D 1349 RTD with Indicator
Die Closing Force	(500 to 2700) lbf	28.5 lbf	ASTM E 4 Load Cell with Indicator
Rotor Dimensions	(0 to 2) in	300 μin	Measured at test temperatures with Micrometers
Rotorless Cure Meters, Moving Die Rheometers, Rubber Process Analyzers ³ –			
Torque	(0 to 200) in·lbf	0.2 in·lbf	ASTM D 5289, ASTM D 6204, ASTM D6601 MD Torsion Standard (Dynamic)
Oscillatory Frequency	(0.016 to 33) Hz	0.01 Hz	Optical encoder
Oscillatory Amplitude	(-90 to 90) ° arc	37 arcseconds	Optical encoder
Die Temperature	(0 to 400) °C	0.4 °C	ASTM D 1349 Thermocouple or RTD with Indicator
Die Closing Force	(500 to 2700) lbf	28.5 lbf	ASTM E 4 Load Cell with Indicator
Extrusion Plastometers ^{3,7}	Cylinder Bore Piston Measurements Temperature Load to 3 kg Load (3 to 20) kg	0.0003 in 0.0005 in 0.09 °C 0.2 g 3.1 g	ASTM D1238

Parameter/Equipment	Range	CMC ² (±)	Comments
Direct Verification of Durometers Force Tip Angle Tip Diameter Tip Radius Indenter Diameter Indenter Length	Types A, B, E, & O Types C, D, & DO Types OO & OOO Type OOO-S Type M ----	0.63 Duro 0.61 Duro 1.5 Duro 1.3 Duro 1.9 Duro 0.01 ° 0.0041 mm 0.0038 mm 0.0043 mm 0.0043 mm	ASTM D2240, Durometer calibrator or balance Optical comparator
Durometer Test Blocks	Type A & D	1.4 Duro	Durometer
Capillary Rheometers – Polymeric (Plastic) Barrell Diameter and Uniformity Piston Tip Diameter and Length, Capillary Bore Length Temperature Accuracy Crosshead Speed Force Pressure	(6.35 to 19) mm (9 to 25.4) mm (180 to 300) °C (0 to 25.4) mm/min (0 to 5000) lbf (0 to 10 000) psi	0.0068 mm 0.005 mm 0.12 °C 0.3 % of rdg 8 lbf 0.12 % of rdg	ASTM D 3585 Bore micrometer Micrometer Digital thermometer Dial indicator/stopwatch Load cell Deadweight pressure tester

Parameter/Equipment	Range	CMC ² (±)	Comments
Capillary Rheometers – Rubber			ASTM D 5099
Barrell Diameter and Uniformity	(9 to 22) mm	0.0068 mm	Bore micrometer
Piston Tip Diameter and Length, Capillary Bore Length	(9 to 25.4) mm	0.005 mm	Micrometer
Temperature Accuracy	(100 to 190) °C	0.12 °C	Digital thermometer
Crosshead Speed	(0 to 25.4) mm/min	0.3 % of rdg	Dial indicator/stopwatch
Force	(0 to 5000) lbf	8 lbf	Load cell
Pressure	(0 to 10 000) psi	0.12 % of rdg	Deadweight pressure tester
Injection Molders –			
Temperature Controller Accuracy (T/C)	(0 to 1200) °C	1.0 °C	TC calibrator
Thermocouple Accuracy	(0 to 350) °C	0.9 °C	Master temp probe and dry block calibrator
Screw Speed	(6 to 10 000) RPM	1.3 RPM	Tachometer
Pressure	(2 to 10 000) psi	0.12 % of rdg	Deadweight pressure tester
Plunger Linear Displacement	(0 to 300) mm (11 in) (300 to 1.8) m (70 in)	0.15 mm (0.006 in) 1.7 mm (0.07 in)	Comparison to length standards
Plunger Speed	(0 – 900) mm/min	0.35% of rdg	Length standards/stopwatch
Timer Accuracy	(0 to 7200) sec	1.6 sec	Comparison to stopwatch

Parameter/Equipment	Range	CMC ² (±)	Comments
Extruders			
Temperature Controller Accuracy (T/C)	(0 to 1200) °C	2.0 °C	TC calibrator
Thermocouple Accuracy	(0 to 350) °C	0.9 °C	Master temp probe and dry block calibrator
Screw Speed	(6 to 10 000) RPM	1.3 RPM	Tachometer
Pressure	(2 to 10 000) psi	0.12 % of rdg	Deadweight pressure tester
Takeoff Speed	(0 to 1000) in/min	1.3 in/min	Contact Tachometer with length wheel
Timer Accuracy	(0 to 7200) sec	1.6 sec	Comparison to stopwatch

X. Thermodynamics

Parameter/Equipment	Range	CMC ² (±)	Comments
IR Temperature ³ – Measuring Equipment	Ambient to 285 °C (285 to 800) °C	0.88 °C + 0.007 °C/°C 0.44 °C + 0.009 °C/°C	Blackbody source, IR thermometer
IR Temperature ³ – Measure Blackbody Sources	Ambient to 285 °C (285 to 800) °C	0.88 °C + 0.007 °C/°C 0.44 °C + 0.009 °C/°C	Blackbody source, IR thermometer

Parameter/Equipment	Range	CMC ² (±)	Comments
Temperature Measure – Temperature Baths, Dry Wells –			
Temperature Uniformity	(-200 to 150) °C	0.015 °C	PRT, digital thermometer
Temperature Accuracy	(-200 to 0) °C (0 to 660) °C	0.0053 °C 0.000 009 1 °C/°C + 0.0053 °C	SPRT, digital thermometer
	(660 to 1000) °C (1000 to 1450) °C	0.24 °C 2 °C	Characterized S thermocouple
Temperature Measure ³ – Temperature Baths, Dry Wells –			
Temperature Accuracy	(-200 to 0) °C (0 to 660) °C	0.000 019 °C/°C + 0.02 °C	SPRT, Digital Thermometer
	(660 to 1000) °C (1000 to 1450) °C	0.000 045 °C/°C + 0.02 °C	Characterized S thermocouple
		0.24 °C 2 °C	
Temperature Measuring Equipment – TC/RTD Probes, LIG Thermometers	0.01 °C	0.0053 °C	Triple point of water
	(-80 to 0) °C (0 to 150) °C (150 to 300) °C (300 to 400) °C	0.011 °C 0.015 °C 0.027 °C 0.028 °C	Comparison to reference probe and temperature baths
	(400 to 1000) °C (1000 to 1200) °C	3 °C 3.6 °C	Drywell and S thermocouple

Parameter/Equipment	Range	CMC ² (±)	Comments
Temperature Measuring Equipment ³ – TC/RTD Probes, LIG Thermometers	(-15 to 400) °C	0.5 °C	Comparison to reference probe and drywells
	(400 to 1000) °C	3 °C	Drywell and type S thermocouple
	(1000 to 1200) °C	3.6 °C	
Humidity ³ – Measure and Measuring Equipment	(9 to 95) % RH	1 % RH	Chilled mirror
		1 % RH	Thunder Scientific 2500
Ovens ³ – Temperature Uniformity System Accuracy Time Constant Ventilation Rate	Up to 1000 °C	2.2 °C	ASTM E145, ASTM 991, AMS 2750, HP 34970
	Up to 420 °C (420 to 1000) °C	0.59 °C 1.8 °C	RTD TC
	(5 to 800) s	5.8 s	Fluke 54 II
	(5 to 300) Air changes/hr	3.4 % of Air changes/hr	ASTM E145

X. Time and Frequency

Parameter/Equipment	Range	CMC ² (±)	Comments
Frequency Measuring Equipment ⁶	Up to 18 GHz	10 pHz/Hz + 0.58R	GPS disciplined receiver and signal generator
Frequency ^{3,6} – Measure	0.01 Hz to 18 GHz	10 pHz/Hz + 0.58R	EIP 545 and HP 5335A electronic counters
Timers/Stop Watches	(1 to 28 800) s	0.06 s/day	Timometer

Parameter/Equipment	Range	CMC ² (±)	Comments
Timers/Stop Watches ³	(1 to 28 800) s	0.049 s	Electronic counter
Tuning Fork	35 Hz to 22 kHz	1.2 mHz/Hz	Electronic counter
Tuning Fork ³	35 Hz to 22 kHz	0.12 % of rdg	Electronic counter

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 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 The measurands stated are measured with the Genrad 1692 RLC, Fluke 8508A, or HP 3458A. This capability is suitable for the calibration of the devices intended to generate the measurand in the ranges indicated. Calibration and Measurement Capabilities are expressed as either a specific value that covers the full range or as a combination of the fraction/percentage of the reading/output plus a range specification.

⁵ The measurands stated are generated with the Genrad 1482 series, 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. Calibration and Measurement Capabilities are expressed as either a specific value that covers the full range or as a fraction/percentage of the reading plus a fixed floor specification.

⁶ In the statement of Calibration and Measurement Capability, L is the length of the unit under test in inches. R is the resolution of the unit under test.

⁷ Using ASTM D1238 at 0 °C to 400 °C Temp, (0 to 20) kg force, and (0 to 2) in length.



World Class Accreditation

The American Association for Laboratory Accreditation

Accredited Laboratory

A2LA has accredited

RICHARD J. BAGAN, INC.

Columbia City, IN

for technical competence in the field of

Calibration

This laboratory is accredited in accordance with the recognized International Standard ISO/IEC 17025:2005 *General Requirements for the Competence of Testing and Calibration Laboratories*. This laboratory also meets the requirements of ANSI/NCSL Z540-1-1994 and any additional program requirements in the field of calibration. 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 8 January 2009*).

Presented this 17th day of February 2009.



A handwritten signature in black ink, appearing to read "Peter M. Boyer".

President & CEO
For the Accreditation Council
Certificate Number 1625.01
Valid to January 31, 2011
REVISED: September 28, 2009

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