



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

ELEMENT - WARREN
 27485 George Merrelli Drive
 Warren, MI 48092
 Mike Trombley Phone: 586 754 9000
 Email: michael.trombley@element.com

CALIBRATION

Valid until: December 31, 2012

Certificate Number: 0038.05

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 Measuring Equipment ³	(0 to 14) units	0.02 units	Solutions
Conductivity – Fixed Values ³	(10 to 1 000) µS (1 000 to 110 000) µS	0.63 % of reading 0.29 % of reading	Solutions

II. Dimensional

Parameter/Equipment	Range	CMC ² (±)	Comments
Flatness ^{3,7}	(0.125 to 2) in	5.3 µin	Optical flats
Optical Flats	(0.5 to 2) in	4 µin	Grade 1 optical flats, monochromatic light

Parameter/Equipment	Range	CMC ^{2,4} (\pm)	Comments
Inside Micrometers ³	(0.2 to 20) in	$(27 + 4.2L) \mu\text{in}$	Gage blocks
Outside Micrometers ³	(0.001 to 6) in (6 to 36) in	$(33 + 2.9L) \mu\text{in}$ $(690 + 0.6L) \mu\text{in}$	Gage blocks, length standards, D5947, D3767
Depth Micrometers ³	(0.001 to 12) in	$(27 + 4.3L) \mu\text{in}$	Gage blocks
Calipers	(0.001 to 18) in (18 to 72) in	$(42 + 12.9L) \mu\text{in}$ $(250 + 2.6L) \mu\text{in}$	Gage blocks
Calipers ³ Field only	(0.001 to 18) in (18 to 36) in	$(42 + 12.9L) \mu\text{in}$ $(690 + 9.6L) \mu\text{in}$	Gage blocks
Dial Indicators ³	Up to 6 in	$(35 + 2.9L) \mu\text{in}$	Gage blocks, micrometer head
Indicators/Gage Heads ³	(-0.5 to 0.5) in	15 μin	Gage blocks
Dial Indicator Calibrators	(0.00005 to 6) in	$(30 + 6.8L) \mu\text{in}$	Gage blocks
Height Gages ^{3,7}	(0.001 to 24) in (24 to 36) in	$(27 + 6.5L) \mu\text{in}$ $(29 + 3.6L) \mu\text{in}$	Gage blocks
Height Gages ³ Field only	(0.001 to 24) in	$(27 + 6.5L) \mu\text{in}$	Gage blocks
Rulers ^{3,7}	0.5 in to 6.0 ft	0.013 in	Standard rule
Tape Measure	0.5 in to 12 ft (12 to 24) ft	0.051 in 0.081 in	Standard rule
Length Standards	(0.25 to 12) in	$(7.4 + 4.4L) \mu\text{in}$	Gage head and gage blocks

Parameter/Equipment	Range	CMC ^{2,4} (±)	Comments
Riser Blocks	(0.25 to 12) in	(7.4 + 4.4L) μin	Gage head and gage blocks
Angle ^{3, 7}	0.01° to 60° 0° to 360°	0.003° 4.4'	Angle sine plate, gage blocks Optical comparator
Radius	(0 to 12) in	410 μin	Optical comparator/ overlays
Parallels/1-2-3 blocks	Up to 12 in	(17 + 3.8L) μin	Gage head and gage blocks
Shims	(0.002 to 0.25) in	(11 + 6.4L) μin	Gage head and gage blocks
Pins/Plug Gages ³	(0.05 to 1) in	52 μin	Micrometer

III. Dimensional Testing/Calibration

Parameter/Equipment	Range	CMC ² (±)	Comments
Angle ¹⁰	(0 to 360) °	4.4'	Optical comparator
Height ^{3, 7, 10}	Up to 24 in	(20 + 7.1L) μin	Gage head, gage blocks and surface plate
1D Length ^{3, 7, 10}	Up to 24 in (24 to 40) in	(20 + 7.1L) μin (310 + 21L) μin	Gage head, gage blocks and surface plate Calipers
Radius ¹⁰	(0.01 to 4) in	410 μin	Optical comparator
Radius ^{3, 7, 10}	(0.01 to 0.5) in	0.002 in	Radius gage set

IV. Electrical – DC/Low Frequency

Parameter/Equipment	Range	CMC ^{2, 5, 6, 8} (±)	Comments
DC Current – Measure ^{3, 7}	(10 to 100) nA 100 nA to 1 µA (1 to 10) µA (10 to 100) µA 100 µA to 1 mA (1 to 10) mA (10 to 100) mA 100 mA to 1 A (1 to 3) A (3 to 1000) A	36 µA/A + 55 pA 24 µA/A + 55 pA 24 µA/A + 300 pA 24 µA/A + 2.9 nA 24 µA/A + 19 nA 24 µA/A + 120 nA 41 µA/A + 1.2 µA 0.013 % + 39 µA 0.14 % + 240 µA 0.012 % + 2.4 mA	HP 3458A HP 34401 HP 3458A opt 2 w/current shunt
DC Current – Generate ⁷	(0 to 2.2) mA (2.2 to 22) mA (22 to 220) mA 220 mA to 1 A (1 to 2.2) A (2.2 to 11) A (20 to 300) A	46 µA/A + 7.9 nA 41 µA/A + 13 nA 41 µA/A + 1 µA 52 µA/A + 1.3 µA 93 µA/A + 17 µA 0.042 % + 560 µA 0.086 % + 2.4 mA	Fluke 5700A, 5725A Power supply w/shunt and DMM See Footnote 3,7
DC Current – Generate ³	(0 to 330) µA 330 µA to 3.3 mA (3.3 to 33) mA (33 to 330) mA 330 mA to 1.1 A (1.1 to 2.9) A (2.9 to 11) A (11 to 20) A (20 to 160) A (160 to 525) A (525 to 1000) A	0.018 % + 0.024 µA 0.012 % + 0.066 µA 0.012 % + 0.45 µA 0.012 % + 8.5 µA 0.023 % + 50 µA 0.044 % + 200 µA 0.058 % + 900 µA 0.12 % + 2.3 mA 0.27 % + 14 mA 0.26 % + 130 mA 0.26 % + 290 mA	Fluke 5520A Fluke 5520A/Fluke 50- turn coil

Parameter/Equipment	Range	CMC ^{2, 5, 6, 8} (±)	Comments
DC Voltage –Generate ³	(0 to 220) mV 220 mV to 2.2 V (2.2 to 11) V (11 to 22) V (22 to 220) V (220 to 1100) V	10 μV/V + 1.2 μV 8.1 μV/V + 45 μV 8.1 μV/V + 45 μV 8.1 μV/V + 46 μV 9.3 μV/V + 660 μV 10 μV/V + 7.3 mV	Fluke 5700A/ 5725A
	(0 to 330) mV 330 mV to 3.3 V (3.3 to 33) V (33 to 330) V (330 to 1000) V	23 μV/V + 2.3 uV 13 μV/V + 9.6 uV 14 μV/V + 110 uV 21 μV/V + 1.1 mV 21 μV/V + 6.6 mV	Fluke 5520A
DC Voltage – Measure ^{3, 7}	(0 to 100) mV 100 mV to 1 V (1 to 10) V (10 to 100) V 100 V to 1 kV	6 μV/V + 580 nV 4.6 μV/V + 680 nV 4.6 μV/V + 5.2 μV 7 μV/V + 9.8 μV 7 μV/V + 2.1 mV	HP 3458A
	(1 to 2) kV (2 to 20) kV	0.058 % + 0.82 V 0.058 % + 8.2 V	Vahalla 4600 kilovolt meter, CMC is stated as percent of reading plus floor.

Parameter/Range	Frequency	CMC ^{2, 8} (±)	Comments
Capacitance – Generate ^{3, 7}			
Fixed Values, 0.001 μF 0.01 μF 1 μF	1 kHz 1 kHz 1 kHz	120 pF 170 pF 17 nF	Standard capacitors
Synthesized Capacitance			
(0.19 to 1.1) nF (1.1 to 3.3) nF (3.3 to 11) nF (11 to 33) nF (33 to 110) nF (110 to 330) nF (0.33 to 1.1) μF (1.1 to 3.3) μF (3.3 to 11) μF (11 to 33) μF	10 Hz to 10 kHz 10 Hz to 3 kHz 10 Hz to 1 kHz 10 Hz to 1 kHz 10 Hz to 1 kHz 10 Hz to 1 kHz 10 Hz to 600 Hz 10 Hz to 600 Hz 10 Hz to 150 Hz 10 Hz to 120 Hz	0.58 % + 0.012 nF 0.58 % + 0.012 nF 0.29 % + 0.014 nF 0.29 % + 0.12 nF 0.29 % + 0.14 nF 0.29 % + 0.39 nF 0.29 % + 1.4 nF 0.29 % + 4.00 nF 0.29 % + 15 nF 0.46 % + 43 nF	Fluke 5520A

Parameter/Range	Frequency	CMC ^{2, 8} (±)	Comments
Capacitance – Generate ^{3, 7} Synthesized Capacitance			
(33 to 110) μF	10 Hz to 80 Hz	0.52 % + 170 nF	Fluke 5520A
(110 to 330) μF	0 Hz to 50 Hz	0.52 % + 490 nF	
(0.33 to 1.1) mF	0 Hz to 20 Hz	0.52 % + 1.4 μF	
(1.1 to 3.3) mF	0 Hz to 6 Hz	0.52 % + 3.6 μF	
(3.3 to 11) mF	0 Hz to 2 Hz	0.52 % + 12.0 μF	
(11 to 33) mF	0 Hz to 0.6 Hz	0.52 % + 35 μF	
(33 to 110) mF	0 Hz to 0.2 Hz	1.30 % + 120 μF	

Parameter/Equipment	Range	CMC ^{2, 5, 6, 8} (±)	Comments
Resistance – Measure ^{3, 7}	(0 to 1) Ω (1 to 10) Ω (10 to 100) Ω 100 Ω to 1 kΩ (1 to 10) kΩ (10 to 100) kΩ 100 kΩ to 1 MΩ (1 to 10) MΩ (10 to 100) MΩ 100 MΩ to 1 GΩ	18 μΩ/Ω + 120 μΩ 18 μΩ/Ω + 750 μΩ 14 μΩ/Ω + 630 μΩ 14 μΩ/Ω + 6.4 mΩ 14 μΩ/Ω + 63 mΩ 12 μΩ/Ω + 140 mΩ 18 μΩ/Ω + 3.5 Ω 59 μΩ/Ω + 130 Ω 590 μΩ/Ω + 1.3 kΩ 0.59 % + 13 kΩ	HP 3458A
Resistance – Generate ^{3, 7} Fixed Values	0 Ω (1, 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	60 μΩ 120 μΩ 44 μΩ 60 μΩ 270 μΩ 230 μΩ 1.1 mΩ 2.0 mΩ 11 mΩ 23 mΩ 110 mΩ 300 mΩ 2.0 Ω 6.5 Ω 20 Ω 39 Ω 95 Ω	Fluke 5700A, fixed resistor

Parameter/Equipment	Range	CMC ^{2, 8} (±)	Comments
Resistance – Generate ^{3, 7} (cont)			
Fixed Values	1000 MΩ 2000 MΩ 3000 MΩ	5.9 MΩ 8.2 MΩ 10.1 MΩ	Fixed resistance value transfer through measurement
	(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 33 μΩ/Ω + 1.7 mΩ 33 μΩ/Ω + 3.1 mΩ 33 μΩ/Ω + 6.3 mΩ 33 μΩ/Ω + 41 mΩ 33 μΩ/Ω + 98 mΩ 33 μΩ/Ω + 410 mΩ 33 μΩ/Ω + 99 mΩ 37 μΩ/Ω + 3.42 Ω 37 μΩ/Ω + 9.1 Ω 70 μΩ/Ω + 49.4 Ω 0.015 % + 240 Ω 0.029 % + 3.7 kΩ 0.058 % + 9 kΩ 0.35 % + 130 kΩ 1.8 % + 1.1 MΩ	Fluke 5520A standard and decade resistors
Oscilloscopes ^{3, 7} –			
Bandwidth (50 kHz Reference)	10 Hz to 50 kHz 50 kHz to 100 MHz (100 to 300) MHz (300 to 600) MHz (600 to 1100) MHz	2.4 % + 120 μV 1.8 % + 120 μV 2.5 % + 120 μV 4.8 % + 120 μV 5.9 % + 120 μV	Fluke 5520A; reference set at 50 kHz
Risetime Into 50 Ω	Single Sided	120 ps	
Timing Markers	1 ns to 50 ms/div 50 ms to 5 s/div	2.9 ppm of output period + 0.6 Resolution 0.58 % of output period + 0.6 Resolution	

Parameter/Range	Frequency	CMC ^{2, 6, 8} (±)	Comments
AC Current – 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	0.081 % + 93 nA 0.041 % + 91 nA 0.017 % + 90 nA 0.07 % + 120 nA 0.19 % + 160 nA	Fluke 5700A
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	0.081 % + 450 nA 0.041 % + 450 nA 0.017 % + 450 nA 0.07 % + 640 nA 0.19 % + 1 µA	
(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	0.081 % + 4.7 µA 0.041 % + 4.7 µA 0.017 % + 2.3 µA 0.07 % + 5.2 µA 0.19 % + 9.5 µA	
(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	0.081 % + 47 µA 0.041 % + 6.3 µA 0.017 % + 4.6 µA 0.07 % + 47 µA 0.19 % + 93 µA	
220 mA to 2.2 A	(20 to 40) Hz 40 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz	0.076 % + 41 µA 0.076 % + 93 µA 0.087 % + 93 µA 0.98 % + 190 µA	Fluke 5700A
(2.2 to 11) A	40 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz	0.054 % + 2.3 mA 0.11 % + 440 µA 0.42 % + 870 µA	Fluke 5700A/5725A
(20 to 110) A	10 Hz to 3 kHz	0.35 % + 580 mA	Fluke 5520A w/Fluke 50-turn coil

Parameter/Range	Frequency	CMC ^{2, 8} (±)	Comments
AC Current – Generate, Field Only ³			
(29 to 329) µA	(10 to 20) Hz (20 to 45) Hz (45 to 1000) Hz (1 to 5) kHz (5 to 10) kHz (10 to 30) kHz	0.23 % + 0.42 µA 0.17 % + 0.42 µA 0.17 % + 0.42 µA 0.35 % + 12 µA 0.92 % + 12 µA 1.9 % + 81 µA	Fluke 5520A
(0.33 to 3.3) mA	(10 to 20) Hz (20 to 45) Hz (45 to 1000) Hz (1 to 5) kHz (5 to 10) kHz (10 to 30) kHz	0.23 % + 0.55 µA 0.14 % + 0.55 µA 0.12 % + 0.50 µA 0.23 % + 12 µA 0.58 % + 12 µA 1.2 % + 81 µA	
(3.3 to 33) mA	(10 to 20) Hz (20 to 45) Hz (45 to 1000) Hz (1 to 5) kHz (5 to 10) kHz (10 to 30) kHz	0.21 % + 5.1 µA 0.10 % + 3.8 µA 0.05 % + 3.8 µA 0.09 % + 9.5 µA 0.23 % + 9.8 µA 0.46 % + 59 µA	
(33 to 330) mA	(10 to 20) Hz (20 to 45) Hz (45 to 1000) Hz (1 to 5) kHz (5 to 10) kHz (10 to 30) kHz	0.25 % + 42 µA 0.10 % + 31 µA 0.05 % + 31 µA 0.12 % + 62 µA 0.23 % + 120 µA 0.46 % + 250 µA	
(0.33 to 1.1) A	(10 to 45) Hz (45 to 1000) Hz (1 to 5) kHz (5 to 10) kHz	0.21 % + 180 µA 0.06 % + 140 µA 0.69 % + 4.8 mA 2.9 % + 24 mA	
(1.1 to 3) A	(10 to 45) Hz (45 to 1000) Hz (1 to 5) kHz (5 to 10) kHz	0.21 % + 400 µA 0.07 % + 260 µA 0.69 % + 3.7 mA 2.9 % + 19 mA	

Parameter/Range	Frequency	CMC ^{2, 5, 8} (±)	Comments
AC Current – Generate, Field Only ³ (cont)			
(3 to 11) A	(45 to 100) Hz (100 to 1000) Hz (1 to 5) kHz	0.07 % + 3.1 mA 0.12 % + 2.0 mA 3.5 % + 6.6 mA	Fluke 5520A
(11 to 20.5) A	(45 to 100) Hz (100 to 1000) Hz (1 to 5) kHz	0.14 % + 7.0 mA 0.17 % + 7.0 mA 3.5 % + 25 mA	
(20 to 110) A	10 Hz to 3 kHz	0.58 % + 7 mA	Fluke 5520A w/ Fluke 50-turn coil
(110 to 1000) A	(10 to 100) Hz	0.91 % + 70 mA	
(1000 to 2000) A	(10 to 100) Hz	1.1 % + 120 mA	100 Turn Coil
AC Current – Measure ^{3, 7}			
(5 to 100) µA	(10 to 20) Hz (20 to 45) Hz (45 to 100) Hz 100 Hz to 5 kHz	0.46 % + 53 nA 0.18 % + 53 nA 0.07 % + 53 nA 0.07 % + 53 nA	HP 3458A
100 µA 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	0.46 % + 310 µA 0.18 % + 400 µA 0.07 % + 310 µA 0.036 % + 310 µA 0.07 % + 310 µA 0.46 % + 480 µA 0.64 % + 1.8 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	0.46 % + 3.2 µA 0.18 % + 4.1 µA 0.07 % + 3.2 µA 0.036 % + 3.2 µA 0.07 % + 3.2 µA 0.46 % + 4.8 µA 0.64 % + 18 µA	
(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	0.46 % + 32 µA 0.18 % + 36 µA 0.07 % + 25 µA 0.036 % + 25 µA 0.07 % + 25 µA 0.46 % + 48 µA 0.64 % + 180 µA	

Parameter/Range	Frequency	CMC ^{2, 5, 8} (±)	Comments
AC Current – Measure (cont) ^{3, 7}			
100 mA 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	0.46 % + 320 µA 0.19 % + 360 µA 0.093 % + 250 µA 0.12 % + 250 µA 0.35 % + 250 µA 1.2 % + 250 µA	HP 3458A
(1 to 3) A	(3 to 5) Hz (5 to 10) Hz 10 Hz to 5 kHz	0.13 % + 700 µA 0.41 % + 710 µA 0.18 % + 710 µA	HP 34401
(3 to 1000) A	40 Hz to 400 Hz	0.085 % + 2.4 mA	HP 3458A opt 2 w/shunt
AC Voltage – Measure ^{3, 7}			
(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	0.036 % + 5.8 µV 0.025 % + 4.8 µV 0.036 % + 4.9 µV 0.12 % + 6.2 µV 0.58 % + 6.2 µV 1.4 % + 9.1 µV	HP 3458A opt 2
(10 to 100) 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 300 kHz to 1 MHz (1 to 2) MHz	0.006 % + 6.4 µV 0.01 % + 4.9 µV 0.017 % + 4.9 µV 0.035 % + 7.3 µV 0.093 % + 19 µV 0.35 % + 55 µV 1.2 % + 75 µV 1.8 % + 91 µV	

Parameter/Range	Frequency	CMC ^{2, 5, 8} (±)	Comments
AC Voltage – Measure (cont) ^{3, 7}			
100 mV to 1 V	(1 to 40) Hz 40 Hz to 1 kHz (1 to 20) kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz 300 kHz to 1 MHz (1 to 2) MHz	0.01 % + 63 μV 0.01 % + 49 μV 0.017 % + 49 μV 0.035 % + 71 μV 0.093 % + 71 μV 0.35 % + 200 μV 1.2 % + 550 μV 1.8 % + 910 μV	HP 3458A opt 2
(1 to 10) V	(1 to 40) Hz 40 Hz to 1 kHz (1 to 20) kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz 300 kHz to 1 MHz (1 to 2) MHz	0.01 % + 590 μV 0.01 % + 350 μV 0.017 % + 350 μV 0.035 % + 710 μV 0.093 % + 710 μV 0.35 % + 1.2 mV 1.2 % + 1.4 mV 1.8 % + 6 mV	
(10 to 100) V	(1 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz 300 kHz to 1 MHz	0.024 % + 5.8 mV 0.024 % + 4.2 mV 0.041 % + 9.7 mV 0.14 % + 9.7 mV 0.46 % + 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 % + 120 mV 0.047 % + 40 mV 0.07 % + 40 mV 0.14 % + 65 mV 0.35 % + 74 mV	
(1 to 2) kV	(20 to 100) Hz (100 to 400) Hz	0.12 % + 2.4 V 0.58 % + 12 V	Valhalla 4600 hi-voltage meter, uncertainties stated as percent of reading plus floor.
(2 to 15) kV	20 Hz to 60 Hz	0.58 % + 18 V	

Parameter/Range	Frequency	CMC ^{2,6,8} (±)	Comments
AC Level Flatness – Generate at 3 V ^{3,7}	10 Hz 100 Hz 10 kHz 30 kHz 100 kHz 300 kHz 1 MHz 3 MHz 8 MHz 10 MHz 20 MHz 30 MHz 50 MHz 70 MHz 80 MHz 100 MHz	0.054 % 0.023 % 0.018 % 0.016 % 0.031 % 0.07 % 0.043 % 0.091 % 0.20 % 0.32 % 0.75 % 0.45 % 0.43 % 1.6 % 2.3 % 1.7 %	Thermal converters and 1395A w/ HP 3458A and Fluke 5700A. CMC is % of applied value
Distortion Measure ^{3,7} – 20 Hz to 100 kHz (0 to 99.9) dB dist. 50 Hz to 100 kHz	< 0.1 % THD 0,1 to 3 % 3 % to 30 % > 30 % 20 Hz to 20 kHz (20 to 100) kHz	0.0012 % 0.0017 % 0.017 % 0.12 % 1.2 dB 2.3 dB	HP 8903A HP 8903A
AC Voltage – Generate ^{3,7} (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	0.064 % + 7.9 μV 0.025 % + 7.2 μV 0.013 % + 3.6 μV 0.043 % + 7.2 μV 0.099 % + 9.9 μV 0.13 % + 17 μV 0.2 % + 32 μV 0.4 % + 32 μV	Fluke 5700A series II/5725A amplifier

Parameter/Range	Frequency	CMC ^{2, 6, 8} (±)	Comments
AC Voltage – Generate ^{3, 7} (cont)			
(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	0.064 % + 9.5 μV 0.025 % + 8.1 μV 0.013 % + 7.4 μV 0.043 % + 8.1 μV 0.099 % + 14 μV 0.13 % + 21 μV 0.2 % + 38 μV 0.4 % + 41 μV	Fluke 5700A series II/5725A amplifier
(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	0.064 % + 47 μV 0.025 % + 21 μV 0.013 % + 14 μV 0.037 % + 25 μV 0.099 % + 44 μV 0.13 % + 120 μV 0.2 % + 140 μV 0.4 % + 170 μV	
220 mV to 2.2 V	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz 500 kHz to 1 MHz	0.058 % + 450 μV 0.019 % + 140 μV 87 μV/V + 26 μV 0.014 % + 90 μV 0.029 % + 140 μV 0.05 % + 310 μV 0.12 % + 1.1 mV 0.26 % + 1.4 mV	
(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	0.058 % + 1.7 mV 0.019 % + 730 μV 87 μV/V + 450 μV 0.014 % + 900 μV 0.029 % + 1.2 mV 0.058 % + 3.2 mV 0.15 % + 14 mV 0.32 % + 15 mV	
(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	0.056 % + 45 mV 0.019 % + 6.7 mV 92 μV/V + 6.7 mV 0.026 % + 14 mV 0.058 % + 24 mV 0.18 % + 110 mV 0.55 % + 120 mV 1.4 % + 250 mV	

Parameter/Range	Frequency	CMC ^{2, 6, 8} (±)	Comments
AC Voltage – Generate ^{3, 7} (cont)			
(220 to 750) V	40 Hz to 1 kHz (1 to 20) kHz (20 to 30) kHz (30 to 50) kHz (50 to 100) kHz	0.11 % + 28 mV 0.2 % + 29 mV 0.07 % + 43 mV 0.07 % + 47 mV 0.27 % + 74 mV	Fluke 5700A series II/5725A amplifier
(220 to 1100) V	40 Hz to 1 kHz (1 to 20) kHz (20 to 30) kHz	0.011 % + 23 mV 0.019 % + 46 mV 0.069 % + 54 mV	
Field Only ³			
(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	0.09 % + 9.9 μV 0.02 % + 7.7 μV 0.02 % + 7.7 μV 0.12 % + 8.6 μV 0.40 % + 17 μV 0.92 % + 63 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	0.03 % + 51 μV 0.02 % + 14 μV 0.02 % + 13 μV 0.04 % + 17 μV 0.09 % + 43 μV 0.23 % + 97 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	0.03 % + 480 μV 0.02 % + 110 μV 0.02 % + 110 μV 0.03 % + 160 μV 0.08 % + 260 μV 0.28 % + 1.2 mV	
(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	0.03 % + 4.8 mV 0.02 % + 1.1 mV 0.03 % + 1.1 mV 0.04 % + 1.6 mV 0.10 % + 3.0 mV	

Parameter/Range	Frequency	CMC ^{2, 8} (±)	Comments
AC Voltage – Generate, Field Only ³ (cont)			
(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	0.02 % + 10 mV 0.02 % + 12 mV 0.03 % + 12 mV 0.03 % + 31 mV 0.23 % + 140 mV	Fluke 5520A
(330 to 1020) V	45 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz	0.035 % + 34 mV 0.03 % + 34 mV 0.035 % + 34 mV	
DC Power – Generate ^{3, 7}			
33 mV to 1020 V	(3.3 to 330) mA (0.3 to 3.3) A (3.3 to 20.5) A	0.03 % + 17 µA 0.03 % + 190 µA 0.084 % + 2.1 mA	Fluke 5520A
AC Power – Generate ^{3, 7}			
(45 to 65) Hz			
(33 to 330) mV	(3.3 to 9) mA (9 to 33) mA (33 to 90) mA (90 to 330) mA (0.33 to 9) A (0.9 to 2.1) A (2.1 to 4.5) A (4.5 to 20.5) A	0.24 % + 17 µA 0.13 % + 17 µA 0.17 % + 20 µA 0.19 % + 20 µA 0.17 % + 77 µA 0.15 % + 77 µA 0.17 % + 20 µA 0.15 % + 20 µA	Fluke 5520A
33 mV to 1020 V	(3.3 to 9) mA (9 to 33) mA (33 to 90) mA (90 to 330) mA (0.33 to 9) A (0.9 to 2.1) A (2.1 to 4.5) A (4.5 to 20.5) A	0.23 % + 17 µA 0.20 % + 17 µA 0.16 % + 77 µA 0.12 % + 20 µA 0.13 % + 77 µA 0.16 % + 20 µA 0.17 % + 20 µA 0.15% + 20 µA	

Parameter/Equipment	Range	CMC ² (±)	Comments
Phase Angle - Generate ^{3,7} (0 to 360) °	(10 to 65) Hz (65 to 500) Hz 500 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz (10 to 30) kHz	0.13 ° 0.30 ° 0.58 ° 2.90 ° 5.80 ° 12 °	Fluke 5520A
Electrical Calibration of RTD Indicating Devices ^{3,7} –			
Pt 385 200 Ω	(-200 to 100) °C (100 to 260) °C (260 to 300) °C (300 to 600) °C (600 to 630) °C	0.06 °C 0.07 °C 0.14 °C 0.17 °C 0.19 °C	Fluke 5520A
500 Ω	(-200 to 100) °C (100 to 260) °C (260 to 600) °C (600 to 630) °C	0.07 °C 0.08 °C 0.10 °C 0.14 °C	
1000 Ω	(-200 to 100) °C (100 to 260) °C (260 to 600) °C (600 to 630) °C	0.07 °C 0.08 °C 0.10 °C 0.28 °C	
PtNi 385 120Ω (Ni120)	(-80 to 100) °C (100 to 260) °C	0.90 °C 0.17 °C	
Cu 427, 10 Ω	(-100 to 260) °C	0.35 °C	
Pt 395, 100 Ω	(-200 to 0) °C (0 to 100) °C (100 to 400) °C (400 to 630) °C (630 to 800) °C	0.07 °C 0.09 °C 0.12 °C 0.15 °C 0.27 °C	
Pt 3916, 100 Ω	(-200 to -190) °C (-190 to 0) °C (0 to 260) °C (260 to 600) °C (600 to 630) °C	0.29 °C 0.07 °C 0.09 °C 0.12 °C 0.27 °C	
Pt 3926, 100 Ω	(-200 to 0) °C (0 to 100) °C (100 to 400) °C (400 to 630) °C	0.7 °C 0.09 °C 0.12 °C 0.15 °C	

Parameter/Equipment	Range	CMC ² (±)	Comments
Calibration of Thermocouple Indicators, Sensors and Sensing Systems ^{3,7} –			
Type B	(600 to 800) °C (800 to 1000) °C (1000 to 1550) °C (1550 to 1820) °C	0.53 °C 0.42 °C 0.36 °C 0.40 °C	Fluke 5520A
Type C	(0 to 150) °C (150 to 650) °C (650 to 1000) °C (1000 to 1800) °C (180 to 2316) °C	0.36 °C 0.41 °C 0.38 °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 0.22 °C 0.20 °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 0.19 °C 0.22 °C 0.28 °C	
Type K	(-200 to -100) °C (-100 to 120) °C (120 to 1000) °C (1000 to 1372) °C	0.41 °C 0.24 °C 0.32 °C 0.48 °C	
Type L	(-200 to -100) °C (-100 to 800) °C (800 to 900) °C	0.44 °C 0.32 °C 0.23 °C	
Type N	(-200 to -100) °C (-100 to -25) °C (-25 to 120) °C (120 to 410) °C (410 to 1300) °C	0.48 °C 0.28 °C 0.25 °C 0.24 °C 0.34 °C	
Type R	(0 to 250) °C (250 to 400) °C (400 to 1000) °C (1000 to 1767) °C	0.67 °C 0.43 °C 0.40 °C 0.48 °C	

Parameter/Equipment	Range	CMC ^{2, 5, 8} (±)	Comments
Calibration of Thermocouple Indicators, Sensors and Sensing Systems ^{3, 7} –			
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	Fluke 5520A
Type T	(-250 to -150) °C (-150 to 0) °C (0 to 120) °C (120 to 400) °C	0.74 °C 0.30 °C 0.22 °C 0.20 °C	
Type U	(200 to 0) °C (0 to 600) °C	0.66 °C 0.34 °C	
Type J	-210 °C to 760 °C	0.068 °C	HP 3458A opt 2, junction at ice point, ice bath
Type K	-270 °C to 1370 °C	0.063 °C	
Type T	-270 °C to 400 °C	0.072 °C	

V. Fluid Quantities

Parameter/Equipment	Range	CMC ^{2, 8} (±)	Comments
Fluid Quantity	(0 to 150) gpm (0 to 1250) lb/min	0.054 % 0.054 %	Primary piston style flow stand
Fluid Quantity ³	(0 to 100) gpm	0.26 %	Coriolis flow meter and indicator

VI. Mechanical

Parameter/Equipment	Range	CMC ² (±)	Comments
Force – Tension and Compression	Up to 1000 lbf (1000 to 5000) lbf (5000 to 10 000) lbf (10 000 to 30 000) lbf	0.016 % 3.8 lbf 7.6 lbf 23 lbf	Dead weight ASTM E74 w/load cells, load cell calibrator
Force – Tension and Compression Field Only ³	Up to 1000 lbf (1000 to 5000) lbf (5000 to 10 000) lbf (10 000 to 30 000) lbf	0.016 % 5.3 lbf 11 lbf 32 lbf	Dead weight ASTM E74 w/load cells, load cell calibrator
Heat Deflection Testing Machines ^{3,7} –			
Support Spacing	(3.8 to 4.2) in	100 µin	ASTM D648
Heat Time	(1 to 180) min	1 Sec	
Support Radius	(0.09 to 0.15) in	0.002 in	
HDUL Load Radius	(0.05 to 0.20) in	0.002 in	
Vicat Needle	(0.04 to 0.05) in	60 µin	
LVDT Readings	(0 to 1) in	130 µin	
Dial Indicator	(0 to 1) in	420 µin	
Weight	(0 to 1200) g	0.27 g	
Temperature	To 300 °C	0.06 °C	
Bending Moment Machines ^{3,7} –			
Degrees Motion	(0 to 90) °	0.5°	ASTM D747
Stopwatch	(0 to 90) °	0.5 s	
Span	(0.1 to 3) in	0.0013 in	
Weight	(0 to 200) g	0.27 g	
Standard Shim (Load Scale Read)	(0.003 to 0.005) in	120 µin	

Parameter/Equipment	Range	CMC ^{2, 8} (±)	Comments
Verification of Tensile Testers ^{3, 7} –			
Displacement, Position	(0.01 to 4) in (4 to 72) in	(140 + 24L) μin 0.016 in	ASTM E4 w/
Crosshead Speed	(0.001 to 4) in/min	(0.02 % in/min) L	Digital indicator, precision rule, laser
	(4 to 60) in/min	(0.04 % in/min) L	Stopwatch, indicator/rule; L is the length of travel.
Tensile and Compressive Force	Up to 1000 lbf (1000 to 5000) lbf (5000 to 10 000) lbf (10 000 to 30 000) lbf	0.016 % Applied 5.3 lbf 11 lbf 32 lbf	Dead Weight Load cells
Verification of Extensometers ^{3, 7} –			ASTM E83 w/
Gage Length	(0.001 to 2) in (2 to 18) in	140 μin 0.0015 in	Micrometer head w/fixture
Strain Error	(0.001 to 4) in (4 to 24) in	130 μin 0.026 in	Micrometer head Steel rule
Mullen Burst Testers ^{3, 7} –			
Pressure Gages	(5 to 1500) lb	0.038 % + 0.5 psi	TAPPI T403/T-807/810 w/dead weight tester, caliper and functional verification w/SRM foils
Clamping Platen	(2 to 4) in	0.0013 in	
Specimen Upper Opening Diameter	(1.0 to 1.4) in	330 μin	
Lower Clamping Surface	(1.0 to 1.4) in	330 μin	
Diaphragm Distend Height	(0.30 to 0.40) in	0.0021 in	
Orifice	(0.2 to 1.25) in	620 μin	

Parameter/Equipment	Range	CMC ^{2,4} (±)	Comments
Flex Tester ^{3,7} – Stroke Distance Cycle Counter RPM Rate Oscillator Speed Angle	(0.5 to 2) in (0 to 9999) counts (450 to 550) rpm (20 to 180) osc/min (5 to 60) °	0.001 in 1.4 counts 0.032 rpm 0.7 % osc/min 0.5 °	ASTM D2097 ASTM D6182
Extrusion Plastometers ^{3,7} – Bore Measurement Piston Land Diameter Piston Foot Length Die Orifice Weight Height of Switch Switch Calibration Temperature Level Timer Go/No-Go Gage	(0.35 to 0.55) in (0.35 to 0.50) in (0.20 to 0.30) in (0.37 to 0.38) in (50 to 30 000) g (0.1 to 12) in (0.1 to 12) in (50 to 260) °C (260 to 420) °C (0 to 0.010) in/in (10 to 6000) sec (0.8 to 0.25) in	74 µin 76 µin 76 µin 76 µin 0.27 g 460 µin 460 µin 0.05 °C 0.08 °C 0.002 in/in 0.5 s 52 µin	ASTM D1238, ISO 1133
Impact Testing Machines ^{3,7} – Level Pendulum Straightness Striker Radius Striker Angle Vertical Fall Free Hang Weight Height Difference Striker Centered	(0 to 0.01) in/in (0.001 to 0.5) in (0.02 to 0.16) in (20 to 60) ° (0 to 25) in (0.5 to 1.2) in Up to 12 000 g ± 0.25 in ± 0.25 in	0.002 in/in 130 µin 0.006 in 0.5 ° (0.024 + 7.4L) in 0.0013 in 0.27 g 380 µin 0.003 in	ASTM D256 ISO 180
Wyzenbeek Oscillatory Abrasion Testers ^{3,7} – Cycle Rate Cycle Counter Specimen Tension/Force Pressure Pad Hardness	(80 to 100) osc/min (0 to 9999) counts (0.5 to 7) lbf (10 to 90) duro	0.62 counts 1.2 counts 0.09 lbf 1.4 duro units	Frequency counter Force gage Durometer

Parameter/Equipment	Range	CMC ^{2,4} (±)	Comments
Plastic Impact Specimen Notcher & Plastic Impact Notches Specimen ^{3,7} – Notch Verification Device Notch Angle Notch Radius Thickness under Notch	(0 to 1) in (40 to 50) ° (0.005 to 0.015) R (0.3 to 0.5) in	38 μin 4.4 ° 410 μin 140 μin	ASTM D256
Gravelometer ^{3,7} – Pressure Time Orifice Distance Nozzle to Sample Distance Gun Barrel to Sample	(10 to 100) psi (5 to 15) s (0.261 to 0.271) in (21 to 22) in (13.45 to 14.05) in	0.59 psi 0.4 s 48 μin 0.012 in 0.012 in	SAE J400 w/ Pressure calibrator Stopwatch Plug gages
Gardner Impact Testers ^{3,7} – Weight Radius Impactor Insert Diameter Impactor Diameter Striker Penetration Depth Drop Height	Up to 12 kg (0.02 to 0.06) in (1.0 to 1.5) in (0.5 to 0.8) in (0.8 to 1.5) in (0 to 30) in (30 to 72) in	0.27 g 0.002 in 0.0006 in 320 μin 320 μin (690 + 1.3L) μin 0.016 in	ASTM D5420 Balance Radius gage Micrometer Micrometer/caliper Caliper Caliper Rule
Abrasion Testers ^{3,7} – Platform Speed Wheel Position Platform Flatness Arm Weight Add-on Weights Nozzle Flatness	(20 to 120) rpm (0.001 to 0.25) in ± 0.15 in (200 to 300) g (200 to 600) g (0.001 to 0.5) in	0.24 rpm 0.0012 in 750 μin 5.4 g 0.27 g 0.0012 in	Tachometer Caliper Indicator Load cell Balance

Parameter/Equipment	Range	CMC ^{2, 8} (±)	Comments
Pressure ^{3, 7} –			
Pneumatic	(0 to 40) inH ₂ O	0.002 in H ₂ O	Hook gage
	(0 to 15) psia/vac	0.004 % + 0.01 psia	Pressure transducer
	(0 to 5) psia/Pres	0.001 psia	Precision Pressure calibration System
	(5 to 11) psia/Pres	0.015 % applied	
	(11 to 17) psia/Pres	0.015 % applied	
	(17 to 24) psia/Pres	0.012 % applied	
	(24 to 60) psia/Pres	0.012 % applied	
	(60 to 150) psia/Pres	0.013 % applied	
	(150 to 715) psia/Pres	0.011 % applied	
	(715 to 1500) psia/Pres	0.011 % applied	
	(0 to 5) psi	0.002 psia	
	(5 to 11) psi	0.031 % applied	
	(11 to 17) psi	0.029 % applied	Precision Pressure calibration System
	(17 to 24) psi	0.016 % applied	
	(24 to 60) psi	0.016 % applied	
	(60 to 150) psi	0.017 % applied	
	(150 to 715) psi	0.016 % applied	
	(715 to 1500) psi	0.016 % applied	
Hydraulic	(5 to 100) psi	0.03 % + 0.001 psi	
	(100 to 10 000) psi	0.03 % + 0.001 psi	
Balances ^{3, 7} –			
1 mg to 11 kg	Readability: 0.001 mg 0.01 mg 0.1 mg 1 mg 10 mg 100 mg 1 g 10 g	0.0015 mg + 0.0039 % 0.015 mg + 0.0039 % 0.15 mg + 0.0039 % 1.5 mg + 0.0039 % 8.3 mg + 0.0039 % 83 mg + 0.0039 % 0.83 g + 0.0039 % 8.3 g + 0.0039 %	ASTM Class 1 weights, CMC stated as the base plus percent of applied load
Scales ^{3, 7}	(0.5 to 100) lb (100 to 500) lb	0.008 lb 0.033 lb	Class 5 weights
	(100 to 2000) lb (2000 to 4000) lb (4000 to 8000) lb	0.23 lb 0.31 lb 0.34 lb	Class 5, 6 weights using Handbook 44

Parameter/Equipment	Range	CMC ^{2, 8} (±)	Comments
Mass	(0.5, 1, 2) lb 5 lb 10 lb 20 lb 50 lb 100 lb	0.0083 oz 0.012 oz 0.015 oz 0.023 oz 0.006 oz 0.019 oz	Class 1, 5, 6 weights, direct comparison method using precision balance
Mass ^{3, 7}	(20 to 10 000) g (0 to 25) lb (0 to 12 500) g (25 to 50) lb (50 to 140) lb (12 500 to 22 700) g (22 700 to 140 000)g	15 mg 0.006 oz 0.16 g 0.01 oz 0.048 oz 1.2 g 1.5 g	Scale direct read using precision scales
Tachometers ^{3, 7} –			
Optical	(10 to 100 000) rpm	0.0006 % + 0.6R	Multifunction generator and LED
Mechanical Coupled	(55 to 10 000) rpm (10 000 to 40 000) rpm	0.024 rpm (0.17 + 0.007 % rdg) rpm	Tachometer calibrator GEC H8224/Strobotac and frequency counter
Linear Velocity	(175 to 188 000) in/min	0.1 in/min	
Shaft Speed ^{3, 7}	(0.01 to 1000) rpm (1000 to 25 000) rpm	0.24 rpm 0.63 rpm	Tachometer Shimpo DT 105A Strobotac and frequency counter
Linear Velocity – Measure ^{3, 7}	(0.6 to 10 000) in/min (10 000 to 100 000) in/min	(5.9 + 0.004 % rdg) in/min (7.6 + 0.09 % rdg) in/min	Tachometer Shimpo DT 105A
Linear Distance/ Length ^{3, 7}	(0.1 to 10 000) in (10 000 to 100 000) in	(8 + 0.09 % rdg) in (18 + 0.09 % rdg) in	Tachometer Shimpo DT 105A

Parameter/Equipment	Range	CMC ^{2, 8} (±)	Comments
Magnetic Wand Insertion Probe ^{3, 7}	(1 to 20) lbf	0.074 lbf	ASTM F2075 utilizing pull-test methods
Torque Wrenches ^{3, 7}	5 in·lb to 250 ft·lb (250 to 1000) ft·lb	0.33 % applied value 0.30 % applied value	Torque calibrator
Torque Transducers and Calibrators ^{3, 7} –			
Torque	(0 to 2000) ft·lb	0.08 % applied value	Torque arm, wheels, and Class 1,5, 6 weights
Speed	(0 to 1 000) rpm (1 000 to 10 000) rpm	0.3 rpm 0.7 rpm	Tachometer, strobotac, counter
Angle	(0 to 360) degrees	0.24”	Angle encoder
Indirect Verification of Rockwell Hardness and Rockwell Superficial Hardness Testers ^{3, 7}	HRB Low Middle High HRC Low Middle High HR15N Low Middle High	0.48 HRB 0.47 HRB 0.46 HRB 0.47 HRC 0.48 HRC 0.52 HRC 0.75 HR15N 0.45 HR15N 0.58 HR15N	ASTM E18

Parameter/Equipment	Range	CMC ² (±)	Comments
Indirect Verification of Rockwell Hardness and Rockwell Superficial Hardness Testers ^{3,7}	HR30N Low Middle High	0.54 HR30N 0.45 HR30N 0.45 HR30N	ASTM E18
	HR15T Low Middle High	0.52 HR15T 0.47 HR15T 0.42 HR15T	ASTM E18, D785
	HR30T Low Middle High	0.57 HR30T 0.51 HR30T 0.51 HR30T	
	HRG Low Middle High	0.86 HRG 0.79 HRG 0.43 HRG	
	HRL High	0.48 HRL	
	HRM Middle High	0.63 HRM 0.6 HRM	
	HRR Middle High	0.48 HRR 0.41 HRR	
	Indirect Verification of Brinell Hardness Testers ^{3,7} – Brinell Scope	(50 to 200) HBW (200 to 400) HBW (400 to 600) HBW (0 to 7) mm	0.94 HBW 1.9 HBW 5.1 HBW 0.031 mm

Parameter/Equipment	Range	CMC ^{2, 8} (±)	Comments
Indirect Verification of Microindentation Hardness Testers –(Vickers and Knoop) ^{3, 7}	Repeatability under forces P (gf): 500 ≤ P < 1000 100 < HK < 250 100 < HV < 240 250 < HK < 650 240 < HV < 600	 3.2 HK 3.4 HV 8 HK 6.9 HV	ASTM E384 ASTM E92 CMC stated as the repeatability as defined in ASTM E384.
Direct Verification of Durometers – Verification of the Indentor Shape and Extension: 30° Cone 1.2 mm Radius Verification of the Durometer Spring	 Diameter of the base of the cone Cone angle Tip radius Indentor thickness Indentor radius Extension and range Type A, B, O Type C, D, DO Type M	 150 μin 4.5° 410 μin 150 μin 410 μin 290 μin 0.08 N 0.44 N 1° 1RHD	ASTM D2240 w/ Optical comparator Optical comparator/ radius gage set Gage blocks Durometer calibrator
Accelerometers	Reference (100 Hz) (3 to 10) Hz 10 Hz to 1 kHz (1 to 2) kHz (2 to 10) kHz	0.58 % 0.59 % 0.71 % 1.2 % 2.71 %	Vibration Calibration system referenced at 100 Hz or 160 Hz

VII. Optical Quantities

Parameter/Equipment	Range	CMC ² (±)	Comments
Gloss	(20, 60, 85) GU	1.2 GU	Reference gloss tiles

VIII. Thermodynamics

Parameter/Equipment	Range	CMC ² (±)	Comments
Relative Humidity – Measure and Measuring Equipment ^{3,7}	(0.5 to 95) % RH	1.5 % RH	Salts, chambers monitored with RH probe and indicator
Temperature – Measure ^{3,7}	-190 °C to 230 °C 230 °C to 660 °C 650 °C to 1400 °C	0.033 °C 0.048 °C 0.12 % + 1.17 °C	PRT Thermocouple
Ovens ^{3,7} – Temperature Uniformity Time Constant Ventilation Rate	40 °C to 500 °C 10 s to 60 m (1 to 600) exchanges	0.51 °C 0.4 s 2.8 % exchanges	ASTM E145, ISO 188 and other standard methods Multichannel scanner Scanner, power measurement system
Infrared Temperature – Measuring Equipment ^{3,7}	(23 to 100) °C (100 to 200) °C (200 to 300) °C (300 to 400) °C (400 to 500) °C	1.5 °C 1.6 °C 2.0 °C 2.6 °C 4.1 °C	Source target black box
Infrared – Measure ^{3,7}	(25 °C to 200) °C (200 to 300) °C (300 to 500) °C	2.1 °C 4.3 °C 7.1 °C	IR measurement gun

IX. Time and Frequency

Parameter/Equipment	Range	CMC ^{2,9} (\pm)	Comments
Frequency – Measure ^{3,7}	1 μ Hz to 1.3 GHz	$5 \times 10^{-12}f$	Frequency counter
Frequency – Measuring Equipment	1 μ Hz to 1.0 GHz	$5 \times 10^{-12}f$	GPS receiver
Frequency – Measuring Equipment ^{3,7}	1 μ Hz to 1.0 GHz	$1.6 \times 10^{-8}f$	Arbitrary generator/RF generator
Mechanical Timers/ Stop Watches ^{3,7}	5 s to 24 hr	0.4 s	Frequency counter
Electronic Timers/Stop Watches ^{3,7}	0.5 s to 24 hr	$4 \times 10^{-7}f$	Frequency counter

¹ This laboratory offers commercial calibration services as well as field calibration services, where noted.

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 L is the numerical value of the nominal length in inches unless otherwise noted. H is the numerical value of the nominal height in inches. R is the resolution of the unit under test.

⁵ Based on using the standard at the temperature the **HP 3458A** was calibrated ($t_{cal} \pm 5$ °C) and a auto-calibration (ACAL) was performed within the previous 24 hours (± 1 °C of ambient temperature). CMC is based upon 1-year specifications and is read as a fraction of the reading plus range error.

⁶ Based on using the standard at the temperature the **Fluke 5700A** was calibrated ($t_{cal} \pm 5 \text{ }^{\circ}\text{C}$) and assuming the instrument is zeroed at least every seven days or when the ambient temperature changes more than $5 \text{ }^{\circ}\text{C}$. For resistance, a zero calibration is performed at least every 12 hours within $\pm 1 \text{ }^{\circ}\text{C}$ of use. CMC is based upon 1-year specifications and is read as a fraction or percent output plus floor specification.

⁷ The CMC stated for calibrations performed in the laboratory is applicable for calibrations performed in the field.

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

⁹ In the statement of CMC, f is the frequency and t is the time.

¹⁰ This laboratory meets *R205 – Specific Requirements: Calibration Laboratory Accreditation Program* for the types of dimensional tests listed above and is considered equivalent to that of a calibration certificate.



The American Association for Laboratory Accreditation

World Class Accreditation

Accredited Laboratory

A2LA has accredited

ELEMENT - WARREN

Warren, MI

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 30th day of March 2011.



A handwritten signature in black ink, reading "Peter Abney".

President & CEO
For the Accreditation Council
Certificate Number 38.05
Valid to December 31, 2012
Revised May 7, 2012

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