



The American Association for Laboratory Accreditation

World Class Accreditation

Accredited Laboratory

A2LA has accredited

PRECISION METROLOGY, INC.

Milwaukee, WI

for technical competence in the field of

Calibration

This laboratory is accredited in accordance with the recognized International Standard ISO/IEC 17025:2005 *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 5th day of August 2008.





Peter Abney

President & CEO
For the Accreditation Council
Certificate Number 1078.01
Valid to August 31, 2010
Revised July 20, 2010

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

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

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CALIBRATION

Valid To: August 31, 2010

Certificate Number: 1078.01

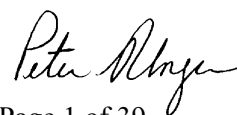
In recognition of the successful completion of the A2LA evaluation process, accreditation is granted to this laboratory to perform the following calibrations¹:

I. Acoustical Quantities

Parameter/Equipment	Range	CMC ² (±)	Comments
Sound Level	(0 to 140) dB	0.16 dB + 0.032 % rdg	Piston phone
	(0 to 140) dB	0.44 dB	Sound level calibrator
Sound Level ³	(0 to 140) dB	0.5 dB	Sound level calibrator

II. Chemical

Parameter/Equipment	Range	CMC ² (±)	Comments
pH Meters	(4, 7, 10) pH units	0.01 pH units	Standard buffers
Conductivity	10 µS/cm	0.64 µS/cm + 0.6R	Conductivity solutions
	100 µS/cm	1.2 µS/cm + 0.6R	
	1000 µS/cm	5.5 µS/cm + 0.6R	
	1400 µS/cm	9.2 µS/cm + 0.6R	
	10 000 µS/cm	35µS/cm + 0.6R	



Parameter/Equipment	Range	CMC ^{2,4} (±)	Comments
Gage Blocks – Steel Non-Steel	Up to 20 in Up to 20 in	(2.8 + 1.6L) μin (4.4 + 2.2L) μin	Gage blocks
Length Standards ³	Up to 18 in	(18 + 8L) μin	UMM
Length Standards	(18 to 120) in	(180 + 12L) μin	UMM
Indicators ³ – Dial Test	Up to 4 in Up to 0.060 in	0.6R + (10L) μin 0.0001 in	Indicator calibrator
Bore Gages ³	Up to 12 in	0.6R + (10L) μin	Gage blocks
Height Gages ³	Up to 48 in	0.6R + (10L) μin	Gage blocks
Calipers ³	Up to 80 in	0.6R + (10L) μin	Gage blocks
Micrometers ³ – Inside Depth Tri-Bores Outside Groove	Up to 294 in Up to 12 in Up to 6 in Up to 42 in Up to 4 in	0.6R + (10L) μin 0.6R + (10L) μin 0.6R + (10L) μin 0.6R + (10L) μin 0.6R + (18L) μin	Gage blocks; <i>L</i> is the measured displacement in inches.
Snap Gages ³	Up to 3 in	0.00017 in	Box parallel with gage amp and probe
Reference Stacks	50 in	(15 + 9L) μin	Gage blocks

Parameter/Equipment	Range	CMC ^{2,4} (±)	Comments
Thread Micrometers ³ (Screw thread, Pitch, Point)	Up to 4 in	$0.6R + (10L) \mu\text{in}$	Pitch standard; L is the measured displacement in inches.
Surface Plates ³ – Flatness	6 in × 6 in to 72 in × 144 in	$8\sqrt{D}$	Electronic levels D is the length of the plate diagonal in inches.
Rules/Scales ³	Up to 100 in	$(96 + 16L) \mu\text{in}$	Universal measuring machine (UMM)
Tape Measures ³	Up to 300 ft	0.06 in	Universal measuring machine (UMM)
Linear Measurement of Machine Tools ³	Up to 20 ft	$42 \mu\text{in} + 0.5 \mu\text{in/in}$	Laser
Height Measures ³	Up to 24 in	$(130 + 10L) \mu\text{in}$	Height gage
Plain Ring Gages ³	(0.1 to 14) in (14 to 36) in	$(33 + 3D) \mu\text{in}$ $(50 + 3D) \mu\text{in}$	UMM
Threaded Rings ³ – Pitch Diameter Functional Diameter	Up to 18 in Up to 18 in	$(140 + 8D) \mu\text{in}$ $(300 + 8D) \mu\text{in}$ (with set plug)	UMM

Parameter/Equipment	Range	CMC ^{2,4} (±)	Comments
Plain Plug Gages ³	Up to 20 in	(10 + 2D) μin	UMM
Threaded Plug Gages ³ – Pitch Diameter Major Diameter	Up to 18 in Up to 18 in	(100 + 8D) μin (20 + 2D) μin	UMM, thread wires (best thread wire size)
NPT Plugs ³ – Pitch Diameter Taper	Up to 18 in Up to 18 in	(100 + 12D) μin (360 + 10D) μin	Thread wires/UMM Height measuring machine
NPT Rings ³ – Pitch Diameter Taper Standoff and Thickness	Up to 18 in Up to 18 in Up to 18 in	(400 + 13D) μin (240 + 13D) μin 120 μin	NPT master plug NPT master plug NPT master plug and height measuring machine
Benchmics ³	Up to 2 in	30 μin	Gage blocks
CMMs ³ – Length Volume Probing Analysis Bi-directional	(0 to 72) in on each axis To 36 in for shortest axis --- ---	(42 + 5L) μin (120 + 5L) μin 2 μm 50 μin	ASME B89.4.1 w/ Step gage Ball bar Test probe

Parameter/Equipment	Range	CMC ^{2,4} (±)	Comments
Depth Gage ³	Up to 8 in	0.6R + (10L) μin	Gage blocks or depth mikemaster
Optical Comparator ³ Linear Angle Magnification	Up to 12 in 0° to 360° 10x, 20x, 50x, 62.5x, 100x, 200x	0.0002 in 2' 0.00012 in	Glass scale Calibration sphere Calibration sphere
Optical Flats	Up to 8 in	2.8 μin	Reference flat and monochromatic light source
Angle Plates ³	Up to 24 in / 24 in	0.00017 in / 24 in	Indi-square and test indicator
Roundness Testers ³ – Coning Error Axial Error Radial Accuracy Z-Axis straightness	(0.1 to 12) in	11 μin 11 μin 11 μin (24 + 8H) μin	Test ball and riser cylinder Test ball Test ball Cylindrical square; In the CMC, <i>H</i> is the height of the cylinder from the base in inches.
Angle Blocks	0° to 90°	7''	Measuring machine
Protractor – Digital and Mechanical ³	0° to 180°	0.08R + 0.08 ° / 180 °	Angle blocks
Levels (Machinist) ³	Up to 96 in	0.00015 in per foot	Sine plate

Parameter/Equipment	Range	CMC ^{2,4} (±)	Comments
Radius Gage	Up to 5 in	0.00026 in	Optical comparator
Feeler/Thickness Gage ³	Up to 0.2 in	36 μin	UMM
Thread Wires	Up to 0.5 in	(19 + 8D) μin	UMM
Fixed Gaging – Screw Pitch Gages, Drill Gages, Taper Gages, Center Gages, Sheet and Wire Gages, Angle Gages	---	0.0002 in (length measures) 2' (angular)	Measuring machine/optical comparator
Precision Diameter Tapes	Up to 48 in (48 to 780) in	200 μin + 4 μin/in 0.0013 in + 6 μin/in	UMM
Parallels ³ – Steel Granite	1.5 in × 6 in 8 in × 48 in	(8.8 + 6L) μin (8.8 + 3.6) μin	Gage amp with probe; <i>L</i> is the distance between the parallel surfaces.
Groove Micrometers ³	Up to 4 in	0.6R + 18 μin/in	Gage blocks
Snap (Jaw) Calipers ³	Up to 12 in	0.6R + 86 μin/in	Gage blocks
Intertest Calipers ³	Up to 4 in	0.6R + 40 μin	Micrometer
Oditest Calipers ³	Up to 4 in	0.6R + 40 μin	Gage blocks
Sine Plates/Bars ³ – Flatness/Parallelism & Parallelism Cylinder to Base Angle Calibration	Up to 20 in 0° to 90°	50 μin 16''	Gage amp with probe and angle blocks

Parameter/Equipment	Range	CMC ^{2,4} (±)	Comments
Thickness Gages ³ – Dial and Digital	Up to 1 in	0.6R + 52 μin	Gage blocks
Chamfer Gages/Hole Gages ³	Up to 12 in	0.6R + 20 μin/in	Cylindrical rings
Gage Amplifier and Probe ³	---	0.6R + 5 μin	Gage blocks
Riser Blocks and Stands	Up to 24 in	(13 + 8H) μin	Gage amplifier with probe
Clinometers and Inclinometers	Up to 360°	0.6R + 16"	Sine bar/gage blocks
Cylindrical Squares	Up to 12 in	(35 + 8H) μin	Gage amplifier with probe; In the CMC, <i>H</i> is the height of the cylinder from the base in inches.
Straightness and Straight Edges ³	Up to 60 in	0.6R + 10 μin	Gage amplifier with probe
V-Blocks – Parallelism Side V Squareness	8 in × 8 in × 8 in	14 μin 20 μin (25 + 20H) μin	Gage amplifier with probe Cylindrical square Cylindrical plug
Box Parallels – Parallelism Squareness	5 in × 10 in × 10 in	(12 + 20H) μin (18 + 20H) μin	Gage amp with probe, cylindrical square

Parameter/Equipment	Range	CMC ^{2,4} (±)	Comments
Indicator Calibrator ³	---	0.6R + 12 μin	Gage blocks
Indirect Verification of Profilometers ³	20 μin Ra 120 μin Ra 400 μin Rz	0.6R + 4.6 μin 0.6R + 4.6 μin 0.6R + 16 μin	Roughness specimen
Surface Roughness ³	(15 to 150) μin Ra	5 % rdg + 0.6R	Verification of specimens per ASME B46.1 Type C using profilometers; <i>R</i> is the resolution of the profilometers in microinches.
Wire Crimpers ³ – Crimp Height Crimping Chamber Ratchet Inspection	---	0.0024 in (10 + 19 <i>D</i>) μin 120 μin	Micrometer Pin; <i>D</i> is the diameter of the pin. Feeler gage
Microscopes ³ – Reticule Magnification	(0 to 25) mm Up to 1000x	23 μm 2.4 % rdg	Stage micrometer
Squares ³ – Master Granite Steel	Up to 24 in Up to 24 in Up to 24 in	0.00015 in 0.00017 in 0.00017 in	Gage amp and probe Indi-square and test indicator Master square and gage blocks
Concentricity	N/A	130 μin + 8 μin/in	Indicator, bench center

Parameter/Equipment	Range	CMC ^{2,4} (±)	Comments
Universal Measuring Machines ³ (UMMs)	Up to 20 in	(6 + 8L) μin	Gage blocks, dynamometer, optical flats
External Spline Gages ³ –			
Measurement over Pins	Up to 8 in	(170+ 28D) μin	UMM
Circular Tooth Thickness		0.0002 in	Optical comparator
Major Diameter		(42 + 12D) μin	UMM
Extensometers ³	Up to 4 in	120 μin	Extensometer verification device (micrometer)
Vision Systems ³ –			
X-Y Linear Accuracy	Up to 24 in	(110 + 13L) μin	Glass scale
Z-Axis Linear Accuracy	Up to 20 in	(74 + 11L) μin	Gage blocks
Linear Scales/Reticles	Up to 12 in	(17 + 7L) μin	Laser, optical comparator

III. Dimensional Testing

Parameter/Equipment	Range	CMC ^{2,4} (±)	Comments
Linear Measure	(0 to 30) in	(140 + 10L) μin	CMM
Linear Measure ³	(0 to 24) in	0.00013 in	Height gage

IV. Electrical – DC/Low Frequency

Parameter/Equipment	Range	CMC ^{2,5,6} (±)	Comments
DC Voltage – Generate, Fixed Points	(1.018, 10) V	1.6 parts in 10 ⁶	Fluke 732B
DC Voltage – Generate	(0 to 220) mV 220 mV to 220 V (220 to 1100) V	9 μV/V + 1 μV 5 μV/V + 40 μV 6 μV/V + 200 μV	Fluke 5700A
DC Voltage – Measure ³	Up to 100 mV 100 mV to 1 V (1 to 10) V (10 to 100) V (100 to 1000) V	4.2 μV/V + 3.4 parts in 10 ⁶ 4 μV/V + 0.34 parts in 10 ⁶ 3.4 μV/V + 0.06 parts in 10 ⁶ 5.4 μV/V + 0.34 parts in 10 ⁶ 5.4 μV/V + 0.12 parts in 10 ⁶	HP 3458A
DC Voltage – Measure	(0 to 100) V (100 to 1000) V	2.2 μV/V 2.3 μV/V	Fluke 732B, 752A, Agilent 34420A
DC High Voltage – Measure ³	(1 to 70) kV	0.05 % rdg + 0.023 % rng	Vitrek 4600A

Parameter/Equipment	Range	CMC ^{2, 5, 6} (\pm)	Comments
DC Current – Generate ³	(0 to 100) nA 100 nA to 1 μ A (1 to 10) μ A (10 to 220) μ A 220 μ A to 2.2 mA (2.2 to 22) mA (22 to 220) mA 220 mA to 2.2 A (2.2 to 11) A (11 to 20.5) A	11 μ A/A 3.6 μ A/A 4.3 μ A/A 35 μ A/A + 6 nA 30 μ A/A + 7 nA 30 μ A/A + 40 nA 40 μ A/A + 0.7 μ A 60 μ A/A + 12 μ A 0.035 % + 0.48 mA 0.1 % + 0.75 mA	Fluke 5720A Fluke 5520A
DC Current – Generate and Measure	(0 to 1) nA 1 nA to 1 μ A (1 to 10) μ A (10 to 100) μ A (0.1 to 10) mA (10 to 100) mA (0.1 to 1) A (1 to 20) A	34 μ A/A + 230 μ A/A 22 μ A/A + 46 μ A/A 18 μ A/A + 12 μ A/A 18 μ A/A + 9.2 μ A/A 18 μ A/A + 5.8 μ A/A 34 μ A/A + 5.8 μ A/A 0.012 % + 16 μ A/A 0.012 % + 12 μ A/A	Fluke 5720 (generate), HP 3458A and standard resistors (measure)
DC Current – Measure ³	(0 to 100) nA (0.1 to 1) μ A 1 μ A to 10 mA (10 to 100) mA (0.1 to 1) A (3 to 20) A (20 to 300) A (300 to 1000) A	36 μ A/A + 460 μ A/A 23 μ A/A + 46 μ A/A 23 μ A/A + 12 μ A/A 40 μ A/A + 6 μ A/A 0.013 % + 12 μ A/A 0.012 % + 12 μ A/A 0.04 % 0.25 %	HP 3458A with shunts
Resistance – Measure	(0 to 10) Ω (10 to 100) Ω 100 Ω to 100 k Ω 100 k Ω to 1 M Ω (1 to 10) M Ω (10 to 100) M Ω 100 M Ω to 1 G Ω	18 $\mu\Omega/\Omega$ + 6 $\mu\Omega/\Omega$ 13 $\mu\Omega/\Omega$ + 6 $\mu\Omega/\Omega$ 10 $\mu\Omega/\Omega$ + 0.58 $\mu\Omega/\Omega$ 16 $\mu\Omega/\Omega$ + 2 $\mu\Omega/\Omega$ 60 $\mu\Omega/\Omega$ + 12 $\mu\Omega/\Omega$ 0.058 % + 12 $\mu\Omega/\Omega$ 0.58 % + 12 $\mu\Omega/\Omega$	HP 3458A and standard resistors
Inductance ³ – Measure	50 μ H to 10 H	0.02 % rdg + 26 μ H/H	GR1689 RLC bridge
Generate – Fixed Points	100 μ H (1, 5, 10, 100) mH 1 H 2H, 5H	0.25 % rdg 0.1 % rdg 0.1 % rdg 0.11 % rdg	Standard inductors

Parameter/Equipment	Range	CMC ² (±)	Comments
Resistance – Generate, Fixed Points ³	1 mΩ 10 mΩ	0.13 % rdg 0.047 % rdg	L&N 4361 L&N 4363
	0.1 Ω (1, 10, 100) Ω (1, 10) kΩ 100 kΩ 1 MΩ (10, 100) MΩ 1 GΩ	10 parts in 10 ⁶ 10 parts in 10 ⁶ 7 parts in 10 ⁶ 5 parts in 10 ⁶ 7 parts in 10 ⁶ 13 parts in 10 ⁶ 28 parts in 10 ⁶	Fluke 742A, standard resistors
	0.1 Ω 1 Ω 10Ω 100 Ω 1kΩ 10kΩ 100 kΩ	4 μΩ 16 μΩ 0.15 mΩ 0.44 mΩ 14 mΩ 0.1 Ω 1.2 Ω	L&N resistors
	1MΩ 10MΩ	11 Ω 50 Ω	Guildline resistors
	100 MΩ 1 GΩ 10 GΩ 100 GΩ 1 TΩ 10 TΩ	0.015 % 0.038 % 0.21 % 0.42 % 2.5 % 5.5 %	IET high resistance standard
Capacitance ³ –			
	Measure		
	1 pF to 1μF 1 μF to 25 μF (25 to 100) μF 100 μF to 7 mF (7 to 110) mF	14 μF/F 0.02 % rdg + 80 μF/F 0.03 % rdg + 80 μF/F 0.02 % rdg 0.012 % rdg	AH 2500A, 1689 RLC bridge, Fluke 5700A and Agilent 3458A
	Generate – Fixed Points		
	100 pF 0.001 μF 0.002 μF (0.01, 0.02, 0.05) μF (0.1, 0.5, 1) μF	0.054 % rdg 0.068 % rdg 0.056 % rdg 0.055% rdg 0.055 % rdg	Standard capacitors

Parameter/Equipment	Range	CMC ^{2,6} (±)	Comments
DC Power ³	(0 to 15) W (15 to 200) W 200 W to 1 kW (1 to 20) kW	0.028 % + 8 μW/W 0.04 % + 8 μW/W 0.06 % + 8 μW/W 0.11 % + 8 μW/W	Fluke 5520A/5720A
AC Power ³ –			
(0 to 200) W	60 Hz 400 Hz	0.14 % + 82 μW/W 0.14 % + 82 μW/W	Fluke 5520A/5720A
200 W to 1 kW	60 Hz 400 Hz	0.2 % + 82 μW/W 0.28 % + 82 μW/W	
(1 to 20) kW	60 Hz 400 Hz	0.29 % + 82 μW/W 0.35 % + 82 μW/W	
Oscilloscope Calibration ³ –			
Squarewave Signal 50 Ω at 1 kHz Source	(1 to 110) mV 110 mV to 2.2 V (2.2 to 11) V (11 to 1100) V	0.28 % + 48 μV 0.28 % + 120 μV 0.28 % + 1.2 mV 0.28 % + 12 mV	Fluke 5520A/SC1100 scope option
Squarewave Signal 1 MΩ at 1 kHz Source	(1 to 110) mV 110 mV to 2.2 V (2.2 to 11) V (11 to 1100) V	0.12 % + 48 μV 0.12 % + 120 μV 0.12 % + 1.2 mV 0.12 % + 12 mV	
Leveled Sine Wave Amplitude	50 kHz reference 50 kHz to 100 MHz (100 to 300) MHz (300 to 600) MHz (600 to 1100) MHz	2 % + 300 μV 3.5 % + 300 μV 4 % + 300 μV 6 % + 300 μV 7 % + 300 μV	
Leveled Sine Wave Flatness (relative to 50 kHz)	50 kHz to 100 MHz (100 to 300) MHz (300 to 600) MHz (600 to 1100) MHz	1.5 % + 100 μV 2 % + 100 μV 4 % + 100 μV 5 % + 100 μV	
Time Marker 50 Ω Source and Period	5 s to 50 ms 20 ms to 2 ns	26 parts in 10 ⁶ + 0.07 ms 2.6 parts in 10 ⁶	
Rise Time	≤ 300 ps	+0 / -100 ps	

Parameter/Equipment	Range	CMC ^{2,6} (±)	Comments
Edge Characteristics – Amplitude Equivalent Rise Time	100 mV to 10 VDC ≥ 20 ps/div	6.2 parts in 10 ⁶ 8 ps + 0.1 % of time interval	HP 3458A TDS 8000, equivalent rise time determined using sine wave
Phase – (0.01 to 0.1) V _{rms} (0.1 to 100) V _{rms} (100 to 120) V _{rms}	10 Hz to 10 kHz (10 to 50) kHz (50 to 100) kHz 1 Hz to 1 kHz (1.001 to 6.25) kHz (6.25 to 50) kHz (50.01 to 100) kHz 10 Hz to 50 kHz (50 to 100) kHz	0.24° 0.42° 0.82° 15 m° 16 m° 31 m° 56 m° 0.06° 0.42°	KH 6620 phase meter Clark-Hess 5000 KH 6620 phase meter
Leveled Sine Wave ³ – Frequency Harmonics Flatness – High Frequency	50 kHz to 500 MHz 0.1 MHz to 8 GHz (8 to 13) GHz (13 to 18) GHz 0.1 MHz to 8 GHz	1.6 parts in 10 ⁶ 0.75 dBc + 3 % 0.75 dBc + 4 % 0.75 dBc + 5 % 0.04 dBc + 3 %	Agilent 53131 L1500A E4418 power meter and 8418D and 8482A power sensors
Electrical Calibration of Thermocouple Indicating Devices ³ – Type E	-250 °C to -100 °C -100 °C to 650 °C 650 °C to 1000 °C	0.5 °C 0.15 °C 0.21 °C	Fluke 5520A

Parameter/Equipment	Range	CMC ² (±)	Comments
Electrical Calibration of Thermocouple Indicating Devices ³ (cont.) –			
Type J	-210 °C to -100 °C -100 °C to 760 °C 760 °C to 1200 °C	0.28 °C 0.16 °C 0.23 °C	Fluke 5520A
Type K	-200 °C to -100 °C -100 °C to 120 °C 120 °C to 1000 C 1000 °C to 1372 °C	0.34 °C 0.17 °C 0.26 °C 0.4 °C	
Type S	0 °C to 250 °C 250 °C to 1400 °C 1400 °C to 1767 °C	0.47 °C 0.37 °C 0.46 °C	
Type T	-250 °C to -150 °C -150 °C to 0 °C 0 °C to 400 °C	0.63 °C 0.24 °C 0.15 °C	
Electrical Calibration of RTD Indicating Devices ³ –			
Pt 395, 100 Ω	-200 °C to 0 °C 0 °C to 100 °C 100 °C to 300 °C 300 °C to 400 °C 400 °C to 630 °C 630 °C to 800 °C	0.05 °C 0.07 °C 0.09 °C 0.1 °C 0.12 °C 0.14 °C	Fluke 5520A
Pt 3926, 100 Ω	-200 °C to 0 °C 0 °C to 100 °C 100 °C to 300 °C 300 °C to 400 °C 400 °C to 630 °C	0.05 °C 0.07 °C 0.09 °C 0.1 °C 0.26 °C	
PtNi 385, 120 Ω	-80 °C to 100 °C 100 °C to 260 °C	0.08 °C 0.16 °C	

Parameter/Equipment	Range	CMC ² (±)	Comments
Electrical Calibration of RTD Indicating Devices ³ (cont) –			
Pt 385, 200 Ω	-200 °C to 100 °C	0.04 °C	Fluke 5520A
	100 °C to 260 °C	0.05 °C	
	260 °C to 300 °C	0.12 °C	
	300 °C to 400 °C	0.13 °C	
	400 °C to 600 °C	0.14 °C	
	600 °C to 630 °C	0.16 °C	
Pt 385, 500 Ω	-200 °C to -80 °C	0.04 °C	
	-80 °C to 100 °C	0.05 °C	
	100 °C to 260 °C	0.06 °C	
	260 °C to 400 °C	0.08 °C	
	400 °C to 600 °C	0.09 °C	
	600 °C to 630 °C	0.11 °C	
Pt 385, 1000 Ω	-200 °C to 0 °C	0.03 °C	
	0 °C to 100 °C	0.04 °C	
	100 °C to 260 °C	0.05 °C	
	260 °C to 300 °C	0.06 °C	
	300 °C to 600 °C	0.07 °C	
	600 °C to 630 °C	0.23 °C	
Pt 3916, 100 Ω	-200 °C to 0 °C	0.05 °C	
	0 °C to 100 °C	0.07 °C	
	100 °C to 300 °C	0.09 °C	
	300 °C to 400 °C	0.10 °C	
	400 °C to 630 °C	0.12 °C	
Thermocouples and Thermocouple Wire	-200 °C to 650 °C	0.42 °C	Comparison to SPRT with Agilent 3458

Parameter/Range	Frequency	CMC ^{2, 6, 7} (±)	Comments
AC Current – Generate			
10 mA to 2 A (2 to 20) A	10 Hz to 10 kHz 10 Hz to 10 kHz	0.008 % 0.009 %	Fluke 5790A, 5720A, 5520A, A40
Clamp-on Ammeter (20 to 1000) A	(10 to 20) Hz (20 to 40) Hz 40 Hz to 1 kHz	0.022 % 0.017 % 0.013 %	Fluke 5520 with 5500A coil
Applied Current (6 to 11) A (11 to 20) A	(1 to 10) kHz 40 Hz to 400 Hz	0.015 % 0.25 % 0.5 %	
AC Voltage – Generate ³			
(2.2 to 70) mV	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz 500 kHz to 1 MHz	0.021 % + 3.8 μV 94 μV/V + 3.8 μV 71 μV/V + 3.8 μV 88 μV/V + 3.8 μV 0.018 % + 4.6 μV 0.031 % + 9 μV 0.076 % + 19 μV 0.23 % + 19 μV	Fluke 5720A
(220 to 700) mV	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz 500 kHz to 1 MHz	0.021 % + 12 μV 94 μV/V + 6 μV 71 μV/V + 6 μV 88 μV/V + 3 μV 0.018 % + 15 μV 0.031 % + 19 μV 0.076 % + 23 μV 0.22 % + 46 μV	
(2.2 to 7) V	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz 500 kHz to 1 MHz	0.021 % + 38 μV 91 μV/V + 15 μV 58 μV/V + 8 μV 75 μV/V + 9 μV 94 μV/V + 30 μV 0.023 % + 76 μV 0.076 % + 190 μV 0.098 % + 300 μV	

Parameter/Range	Frequency	CMC ^{2,6} (±)	Comments
AC Voltage – Generate (cont), Fixed Points ³ (22 to 70) V	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz 500 kHz to 1 MHz	0.02 % + 0.38 mV 91 µV/V + 0.15 mV 58 µV/V + 0.052 mV 75 µV/V + 0.09 mV 91 µV/V + 0.19 mV 0.023 % + 0.61 mV 0.076 % + 1.9 mV 0.11 % + 3 mV	Fluke 5720A
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	0.021 % + 3.8 mV 91 µV/V + 1.5 mV 63 µV/V + 0.5 mV 78 µV/V + 0.9 mV 0.013 % + 2 mV 0.053 % + 15 mV 0.36 % + 38 mV	with 5725A
700 V	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz	0.021 % + 3.8 mV 91 µV/V + 1.5 mV 63 µV/V + 0.5 mV 78 µV/V + 0.9 mV 0.013 % + 2 mV	
750 V	(30 to 50) Hz (50 to 100) kHz	0.025 % + 8 mV 0.091 % + 34 mV	
1100 V	40 Hz to 1 kHz (1 to 20) kHz (20 to 30) kHz	65 µV/V + 3 mV 65 µV/V + 3 mV 94 µV/V + 4.6 mV	
AC High Voltage – Measure ³ (1 to 2) kV	(20 to 100) Hz (100 to 400) Hz	0.1 % rdg + 0.12 % rng 0.46 % rdg + 0.12 % rng	Vitrek 4600A
(2 to 20) kV	(2 to 100) Hz	0.23 % rdg + 0.12 % rng	
(20 to 70) kV	(50 to 60) Hz	0.46 % rdg + 0.17 % rng	

Parameter/Range	Frequency	CMC ^{2, 7} (±)	Comments
AC Voltage – Measure, Fixed Points			
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	0.13 % + 1 µV 0.058 % + 1 µV 0.035 % + 1 µV 0.063 % + 1.5 µV 0.092 % + 1.9 µV 0.18 % + 3 µV 0.19 % + 6 µV 0.27 % + 6 µV	Fluke 5790A, 5720A
7 mV	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz 500 kHz to 1 MHz	0.066 % + 1 µV 0.031 % + 1 µV 0.021 % + 1 µV 0.033 % + 1.5 µV 0.048 % + 1.9 µV 0.092 % + 3 µV 0.099 % + 6 µV 0.18 % + 6 µV	
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	0.026 % + 1 µV 0.02 % + 1 µV 0.016 % + 1 µV 0.027 % + 1.5 µV 0.027 % + 1.9 µV 0.063 % + 3 µV 0.069 % + 6 µV 0.13 % + 6 µV	
70 mV	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz 500 kHz to 1 MHz	0.023 % + 1.1 µV 0.016 % + 1.1 µV 0.014 % + 1.1 µV 0.017 % + 1.5 µV 0.024 % + 1.9 µV 0.04 % + 3 µV 0.053 % + 6 µV 0.084 % + 6 µV	
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	0.021 % + 1.1 µV 0.015 % + 1.1 µV 0.014 % + 1.1 µV 0.015 % + 1.5 µV 0.018 % + 1.9 µV 0.023 % + 3 µV 0.032 % + 6 µV 0.077 % + 6 µV	

Parameter/Range	Frequency	CMC ^{2, 7} (±)	Comments
AC Voltage – Measure (cont), Fixed Points			
700 mV	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz	0.022 % + 1.1 μV 0.017 % + 1.1 μV 0.016 % + 1.1 μV 0.016 % + 1.5 μV 0.017 % + 1.9 μV 0.02 % + 3 μV 0.028 % + 6 μV	Fluke 5790A, 5720A
2.2 V	(10 to 20) Hz 20 Hz to 100 kHz (100 to 300) kHz (300 to 500) kHz 500 kHz to 1 MHz	0.02 % 0.014 % 0.018 % 0.024 % 0.07 %	
7 V	(10 to 20) Hz 20 Hz to 50 kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz 500 kHz to 1 MHz	0.02 % 0.014 % 0.015 % 0.02 % 0.034 % 0.092 %	
(22 to 220) V	(10 to 20) Hz 20 Hz to 50 kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz 500 kHz to 1 MHz	0.02 % 0.014 % 0.015 % 0.02 % 0.033 % 0.092 %	
700 V	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz	0.022 % 0.017 % 0.016 % 0.018 % 0.034 %	
1000 V	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz	0.022 % 0.017 % 0.016 % 0.018 % 0.041 %	

Parameter/Range	Frequency	CMC ^{2, 5} (±)	Comments
AC Voltage – Measure ³ (cont)			
AC Bandwidth ≤ 2 MHz			
10 mV	(1 to 20) kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz	0.034 % + 0.034 % 0.12 % + 0.012 % 0.58 % + 0.012 % 4.6 % + 0.024 %	HP 3458A
100 mV to 10 V	1 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	0.008 % + 0.004 % 0.016 % + 0.0024 % 0.034 % + 0.0024 % 0.1 % + 0.0024 % 0.34 % + 0.012 % 1.2 % + 0.012 % 1.7 % + 0.012 %	
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 % + 0.004 % 0.024 % + 0.0024 % 0.04 % + 0.0024 % 0.14 % + 0.0024 % 0.46 % + 0.0012 % 1.7 % + 0.012 %	
1000 V	(1 to 40) Hz 40 Hz to 1 kHz (1 to 20) kHz (20 to 50) kHz (50 to 100) kHz	0.04 % + 0.004 % 0.04 % + 0.0024 % 0.07 % + 0.0024 % 0.14 % + 0.0024 % 0.34 % + 0.0024 %	
AC Bandwidth ≥ 2 MHz			
10 mV	45 Hz to 100 kHz 100 kHz to 1 MHz (1 to 4) MHz (4 to 8) MHz	0.1 % + 0.068 % 1.4 % + 0.058 % 3.4 % + 0.08 % 23 % + 0.09 %	
100 mV to 10 V	45 Hz to 100 kHz 100 kHz to 1 MHz (1 to 4) MHz (4 to 8) MHz (8 to 10) MHz	0.1 % + 0.068 % 2.4 % + 0.058 % 4.6 % + 0.08 % 4.6 % + 0.09 % 17 % + 0.012 %	
100 V	45 Hz to 100 kHz	0.14 % + 0.0024 %	
1000 V	45 Hz to 100 kHz	0.34 % + 0.012 %	

Parameter/Range	Frequency	CMC ^{2, 5, 6} (±)	Comments
AC Current – Measure ³			
(0 to 100) μA	(10 to 20) Hz (20 to 45) Hz (45 to 100) Hz 100 Hz to 5 kHz	0.46 % + 0.024 % 0.17 % + 0.024 % 0.068 % + 0.024 % 0.068 % + 0.024 %	HP 3458A
(0.1 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 % + 0.024 % 0.17 % + 0.024 % 0.68 % + 0.024 % 0.034 % + 0.024 % 0.068 % + 0.024 % 0.46 % + 0.046 % 0.64 % + 0.17 %	
(0.1 to 1) A	(10 to 20) Hz (20 to 45) Hz (45 to 100) Hz 100 Hz to 5 kHz (5 to 20) kHz (20 to 50) kHz	0.46 % + 0.024 % 0.18 % + 0.024 % 0.09 % + 0.024 % 0.012 % + 0.024 % 0.34 % + 0.024 % 0.12 % + 0.046 %	
AC Current – Generate ³			
(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	0.023 % + 16 nA 0.014 % + 10 nA 0.011 % + 8 nA 0.025 % + 12 nA 0.09 % + 65 nA	Fluke 5720A
	(10 to 30) kHz	1.6 % + 0.4 μA	Fluke 5520A
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	0.023 % + 40 nA 0.014 % + 35 nA 0.011 % + 0.35 nA 0.018 % + 0.1 μA 0.09 % + 0.65 μA	Fluke 5720A
	(10 to 30) kHz	1 % + 0.6 μA	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	0.023 % + 0.4 μA 0.014 % + 0.35 μA 0.011 % + 0.35 μA 0.018 % + 0.55 μA 0.09 % + 5 μA	Fluke 5720A
	(10 to 30) kHz	0.4 % + 4 μA	Fluke 5520A

Parameter/Range	Frequency	CMC ^{2, 5, 6} (\pm)	Comments
AC Current – Generate ³			
(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	0.023 % + 4 μ A 0.014 % + 3.5 μ A 0.011 % + 2.5 μ A 0.018 % + 3.5 μ A 0.09 % + 10 μ A	Fluke 5720A
	(10 to 30) kHz	0.4 % + 200 μ A	Fluke 5520A
220 mA to 2.2 A	(20 Hz to 1kHz (1 to 5) kHz (5 to 10) kHz	0.024 % + 35 μ A 0.039 % + 80 μ A 0.6 % + 0.16 mA	Fluke 5720A
(2.2 to 11) A	40 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz	0.04 % + 0.17 mA 0.085 % + 0.38 mA 0.33 % + 0.75 mA	Fluke 5720/5725
(11 to 20.5) A	(45 to 100) Hz 100 Hz to 1 kHz (1 to 5) kHz	0.12 % + 5 mA 0.15 % + 5 mA 3 % + 5 mA	Fluke 5520A
High Frequency Capacitance, Fixed Points ³			
1 pF	1 kHz 1 MHz 2 MHz 3 MHz 4 MHz 5 MHz 10 MHz 13 MHz	73 parts in 10 ⁶ 0.01 % rdg 0.023 % rdg 0.041 % rdg 0.063 % rdg 0.088 % rdg 0.26 % rdg 0.38 % rdg	HP 16380A series capacitors
10 pF	1 kHz (1, 2) MHz 3 MHz 4 MHz 5 MHz 10 MHz 13 MHz	62 parts in 10 ⁶ 62 parts in 10 ⁶ 64 parts in 10 ⁶ 67 parts in 10 ⁶ 72 parts in 10 ⁶ 0.013 % rdg 0.017 % rdg	

Parameter/Range	Frequency	CMC ^{2, 5, 6} (\pm)	Comments
High Frequency Capacitance, Fixed Points ³ (cont)			
100 pF	1 kHz 1 MHz 2 MHz 3 MHz 4 MHz 5 MHz 10 MHz 13 MHz	61 parts in 10 ⁶ 62 parts in 10 ⁶ 68 parts in 10 ⁶ 82 parts in 10 ⁶ 0.01 % rdg 0.014 % rdg 0.034 % rdg 0.05 % rdg	HP 16380A series capacitors
1000 pF	1 kHz 1 MHz 2 MHz 3 MHz 4 MHz 5 MHz 10 MHz 13 MHz	63 parts in 10 ⁶ 80 parts in 10 ⁶ 0.016 % rdg 0.028 % rdg 0.046 % rdg 0.064 % rdg 0.2 % rdg 0.29 % rdg	
0.01 μ F	(0.12, 1, 10, 100) kHz	63 parts in 10 ⁶	
0.1 μ F	(0.12, 1, 10, 100) kHz	63 parts in 10 ⁶	
1 μ F	0.12 kHz (1, 10) kHz 100 kHz	69 parts in 10 ⁶ 63 parts in 10 ⁶ 85 parts in 10 ⁶	

IV. Electrical – Microwave/RF

Parameter/Equipment	Range	CMC ² (±)	Comments
RF Power ³	(-130 to 60) dBm	2.6 % rdg	HP 8902
Amplitude Modulation ³	(10 to 90) %	3.6 % rdg	HP 8902
Phase Modulation ³	150 kHz to 10 MHz (10 to 1300) MHz	4.6 % rdg 3.4 % rdg	HP 8902
Frequency Modulation ³ – Carrier Frequency: 250 kHz to 10 MHz (10 to 1300) MHz (10 to 1300) MHz (1.3 to 26.5) GHz	20 Hz to 10 kHz (50 to 100) kHz (20 to 200) kHz (20 to 200) kHz	2.4 % rdg 1.2 % rdg 5.8 % rdg 6 % rdg + 20 Hz	Agilent 8902
Spectrum Analyzers ³ – Frequency Range	9 kHz to 3.2 GHz	$3F \mu\text{Hz} + 1.2R$	Agilent 8648C; <i>F</i> is the frequency in hertz.
	250 kHz to 26.5 GHz	$0.15F \mu\text{Hz} + 1.2R$	Agilent E8244A; <i>F</i> is the frequency in hertz.
Residual FM	9 kHz to 26.5 GHz	7.6 Hz	HP 8648C or Agilent E8244A
Amplitude	(-130 to +30) dbm	0.15 dB	HP 436A or 8902
Resolution Bandwidth	1 kHz to 5 MHz	0.7 % (@ mdpt)	HP 8648C
Power Sensors, Fixed Points ³	100 kHz 300 kHz 1 MHz 50 MHz (100, 300, 500) MHz (1, 2) GHz 3 GHz (4, 4.2, 4.5)	3.8 % rdg 1.8 % rdg 1.3 % rdg 1.5 % rdg 1.2 % rdg 1.2 % rdg 1.5 % rdg 1.4 % rdg	Agilent 8482A with E4418B, reference to 50 MHz, 1μW

Parameter/Equipment	Range	CMC ² (±)	Comments
Power Sensors, Fixed Points ³ (cont)	5 GHz 6 GHz 7 GHz 8 GHz 9 GHz 10 GHz 11 GHz (12, 12.4) GHz 13 GHz (14, 15) GHz (16, 17) GHz 18 GHz	1.4 % rdg 1.6 % rdg 1.4 % rdg 1.9 % rdg 4.1 % rdg 3.6 % rdg 1.9 % rdg 1.5 % rdg 1.1 % rdg 2.8 % rdg 2.2 % rdg 2.5 % rdg	Agilent 8481A with E4418B, reference to 50 MHz, 1µW
Power Meters, Fixed Points ³ – Zero Set Instrument Accuracy	 3 µW 10 µW 30 µW (100, 300) µW (1, 2) mW (10, 30, 100) mW	 0.25 % rdg + 6.2 nW 1.6 % rdg 0.46 % rdg 0.28 % rdg 0.26 % rdg 0.28 % rdg 0.30 % rdg	 Range calibrator, Agilent 11683A or Agilent 8477A
Power Reference, Fixed Point ³ – at 1 mW	50 MHz	0.40 % rdg	Agilent 432A power meter with 8478 thermistor mount
Reflective Impedance – Measure	100 kHz to 0.3 GHz (0.3 to 2) GHz (2 to 8) GHz (8 to 21) GHz (21 to 26.5) GHz	8.5 mρ 9.4 mρ 17 mρ 30 mρ 45 mρ	Network analyzer 3577A with S parameter test set 35677 or network analyzer 8753ES with calibration kit or network analyzer 8510C with calibration kit

Parameter/Equipment	Range	CMC ² (±)	Comments	
Transmission S ₁₂ /S ₂₁ Magnitude and Phase – Measure	3.5 mm (0 to 20) dB	(1.5 to 26.5) GHz	(± 0.11 to ± 0.29) dB (± 1.2 to ± 12) deg	Agilent 85053B verification kit
		(20 to 40) dB	(1.5 to 26.5) GHz	
	(10 to -90) dB	300 kHz to 1.3 GHz	(± 0.3 to ± 6.0) dB (± 0.25 to ± 80) deg	Agilent 85029B verification kit
		(1.3 to 3.0) GHz	(± 0.04 to ± 6.0) dB (± 0.35 to ± 90) deg	
		(3.0 to 6.0) GHz	(± 0.06 to ± 9.0) dB (± 0.67 to ± 180) deg	
	7 mm (10 to -90) dB	300 kHz to 1.3 GHz	(± 0.03 to ± 5.0) dB (± 0.26 to ± 80) deg	
		(1.3 to 3.0) GHz	(± 0.03 to ± 5.0) dB (± 0.26 to ± 90) deg	
		(3.0 to 6.0) GHz	(± 0.05 to ± 10) dB (± 0.54 to ± 180) deg	
	N-Type (10 to -90) dB	300 kHz to 1.3 GHz	(± 0.03 to ± 6.0) dB (± 0.2 to ± 80) deg	
		(1.3 to 3.0) GHz	(± 0.04 to ± 6.0) dB (± 0.44 to ± 90) deg	
		(3.0 to 6.0) GHz	(± 0.1 to ± 9.0) dB (± 0.67 to ± 90) deg	

Parameter/Equipment	Range	CMC ² (±)	Comments
Reflection S _{11/22} Magnitude and Phase – Measure			
3.5 mm (0.01 to 1.0) lin (0 to 0.01) lin (0.01 to 0.1) lin (0.01 to 0.5) lin (0.5 to 1) lin	(1.5 to 26.5) GHz	(± 0.012 to ± 0.040) lin (± 7.4 to ± 180) deg (± 0.095 to ± 20) deg (± 0.54 to ± 2.3) deg (± 0.50 to ± 1.1) deg	Agilent 85053B verification kit
Magnitude (0 to 1) lin	300 kHz to 1.3 GHz (1.3 to 3.0) GHz (3.0 to 6.0) GHz	(± 0.005 to ± 0.015) lin (± 0.008 to ± 0.002) lin (± 0.015 to ± 0.032) lin	Agilent 85029B verification kit
Phase (0 to 0.2) lin	300 kHz to 1.3 GHz (1.3 to 3.0) GHz (3.0 to 6.0) GHz	(± 180 to ± 2) deg (± 180 to ± 3) deg (± 180 to ± 4.5) deg	
(0.2 to 1) lin	300 kHz to 1.3 GHz (1.3 to 3.0) GHz (3.0 to 6.0) GHz	(± 2 to ± 1) deg (± 3 to ± 1.5) deg (± 4.5 to ± 2) deg	
7 mm Magnitude (0 to 1) lin	300 kHz to 1.3 GHz (1.3 to 3.0) GHz (3.0 to 6.0) GHz	(± 0.001 to ± 0.006) lin (± 0.002 to ± 0.01) lin (± 0.005 to ± 0.018) lin	
Phase (0 to 0.2) lin	300 kHz to 1.3 GHz (1.3 to 3.0) GHz (3.0 to 6.0) GHz	(± 180 to ± 1) deg (± 180 to ± 1.5) deg (± 180 to ± 2) deg	
(0.2 to 1) lin	300 kHz to 1.3 GHz (1.3 to 3.0) GHz (3.0 to 6.0) GHz	(± 1 to ± 0.5) deg (± 1.5 to ± 0.5) deg (± 2 to ± 1) deg	

Parameter/Equipment	Range	CMC ² (±)	Comments
Reflection S _{11/22} Magnitude and Phase – Measure (cont)			
N-Type Magnitude (0 to 1) lin	300 kHz to 1.3 GHz (1.3 to 3.0) GHz (3.0 to 6.0) GHz	(± 0.005 to ± 0.018) lin (± 0.005 to ± 0.025) lin (± 0.01 to ± 0.05) lin	Agilent 85029B verification kit
Phase (0 to 0.2) lin	300 kHz to 1.3 GHz (1.3 to 3.0) GHz (3.0 to 6.0) GHz	(± 180 to ± 1.5) deg (± 180 to ± 2) deg (± 180 to ± 4) deg	
(0.2 to 1) lin	300 kHz to 1.3 GHz (1.3 to 3.0) GHz (3.0 to 6.0) GHz	(± 1.5 to ± 1) deg (± 2.0 to ± 1.5) deg (± 4 to ± 3) deg	

V. Fluid Quantities

Parameter/Equipment	Range	CMC ^{2,4} (±)	Comments
Flow ³	(0.1 to 10) sccm (10 to 1000) sccm (50 to 5000) sccm (1 to 100) slm 0.1 sccm to 750 slm	1.5 % rdg + 0.7 % fs 1.5 % rdg + 0.7 % fs 1.5 % rdg + 0.7 % fs 1.5 % rdg + 0.7 % fs 0.4 % of rdg	Flow rate monitor
Viscometers ³	(0 to 100 000) cps	1.6 % rdg + 1 cps	Standard viscosity fluids
Viscosity Cups ³	Zahn cups (1 to 5) Shell cups (1 to 6)	0.84 s + 0.24 % rdg	Portable temperature bath, viscosity oils
Volumetric Calibration	(0 to 400) mL (400 to 1200) mL (1200 to 8200) mL (1 to 10) gallon	0.01 mL 0.016 mL 0.084 mL 0.00062 gallon or 0.14 in ³	Gravimetric method

Parameter/Equipment	Range	CMC ^{2,4} (±)	Comments
Hydrometers –	Specific Gravity:		
Baume Lighter than Water	1.00	0.0058 % rdg + 0.6R	Distilled water
80.5 to 57 API 81 to 57	0.66 to 0.75	0.0072 % rdg + 0.6R	Petroleum based solutions
57 to 10 API 57 to 10	0.75 to 1	0.006 % rdg + 0.6R	Alcohol solutions
Heavier than Water			
0.72 to 21 API 10 to -11	1 to 1.17	0.0058 % rdg + 0.6R	Sulfuric acid and/or glycerine solutions
0.72 to 67	1 to 1.85	0.0058 % rdg + 0.6R	Sulfuric acid solutions

VI. Foundry-Industry Specific Calibrations

Parameter/Equipment	Range	CMC ^{2,4} (±)	Comments
Sand (Green) Strength Machine ³	(0 to 500) psi	2.3 % rdg + 3.4 psi	Master proving gage
Sand Rammer ³ (Compactability Tester)	---	0.6R + 0.0066 in	Impact rings
Sand Sieves –			ASTM E11, optical comparator
Brass Wire	Standard Sieve Designations	7 μm + 0.75 μm/m	
Steel Wire	125 mm to 20 μm	7 μm + 0.4 μm/m	
Permmeter ³	(0 to 500) perms	6.2 perms	Perm standard

Parameter/Equipment	Range	CMC ^{2,4} (±)	Comments
Moisture Teller ³	(0 to 300) °F	2 °F	Temperature calibrator
Mold Strength Tester ³	(0 to 50) psi	0.6R + 0.2 % rdg	Balances and weights
AFS Clay Tester ³	---	0.42 s	Stopwatch
Friability Tester ³	60 s	0.42 s	Stopwatch
Cone Jolt Toughness Tester ³ – Cam Measurement Rise in Cam Cone Weight	0.030 in 0.030 in (470 to 480) g	180 µin 200 µin 0.14 g	Micrometer Feeler gage Scale
Ultrasonic Cleaner/Scrubber ³ – Temperature Time	18 °F 30 min	0.64 °F 0.42 s	Thermometer Stopwatch
Moisture Teller ³	(0 to 300) °F	2 °F	Temperature calibrator
Mold Strength Tester ³	(0 to 50) psi	0.6R + 0.2 % rdg	Balances and weights
Wet Tensile Tester ³ – Load Temperature Load Rate Pressure	0.449 N/cm ² 300 °F to 320 °F 0.05 N/cm ² /s (4 to 5) bars	0.002 N/cm ² 0.7 °F 0.0017 N/cm ² /s 0.3 psi	Dead weight Thermometer Stopwatch Pressure calibrator
Melt Point Apparatus ³	200 °F to 220 °F	2.8 °F	Temperature measuring device

Parameter/Equipment	Range	CMC ^{2,4} (±)	Comments
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Hot Tensile Tester ³ –			
Load Temperature Gap Measure	130 psi 450 °F 0.030 in	0.38 psi 0.7 °F 200 µin	Dead weight Temperature measuring device Feeler gage
Sand Squeezer ³	(0 to 10 000) psi	1.2 % rdg + 1 psi	Pressure calibrator
Welders ³	(0 to 50) V (0 to 50) A	1 % rdg 1 % rdg	Loadbank and DMM

VII. Mechanical

Parameter/Equipment	Range	CMC ^{2,4} (±)	Comments
Scales ³	(0.5 to 5) lb (5 to 100) lb (100 to 1000) lb	0.002 lb 0.02 lb 0.2 lb	Verification with Class F weights
Scales and Balances ³	(1 to 500) mg 500 mg to 30 g 30 g to 8 kg (8 to 50) kg	0.003 mg 0.012 mg 1.1 mg 0.02 g	Verification with Class 1, 2, or 4 weights
Scales – Proportional Testing ³	Up to 750 lb (750 to 1500) lb (1500 to 3000) lb (3000 to 4500) lb (4500 to 6000) lb	0.2 lb + 0.6R 0.26 lb + 0.6R 0.32 lb + 0.6R 0.38 lb + 0.6R 0.44 lb + 0.6R	Class F weights
Mass	1 mg to 400 g 400 g to 1.2 kg (1.2 to 8.2) kg (8.2 to 30) kg	0.56 mg 3.2 mg 20 mg 0.2 g	By comparison
Mass ³	(2 to 30) kg	0.3 g	By comparison

Parameter/Equipment	Range	CMC ^{2,4} (±)	Comments
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Force Gages	(0 to 250) lbf (250 to 500) lbf (500 to 10 000) lbf	0.12 % rdg + 0.6R 1.2 % rdg + 0.6R 0.88 % rdg + 1.2 lbf	Deadweights Load cell
Force Gages ³	(0 to 250) lbf	0.12 % rdg + 0.6R	Deadweights
Tensile Testers ³	(0 to 30 000) lbf (30 000 to 50 000) lbf	0.4 % rdg + 0.08 % fs 0.8 % rdg + 0.08 % fs	Load cells
Torque Wrenches	Up to 1000 ft·lb (1000 to 2000) ft·lb	0.6 % rdg + 0.1 ft·lb 0.04 % rdg + 1.3 ft·lb	Torque calibrator
Torque – Calibration of Torque Meters and Sensors	(0.1 to 1000) ft·lb	0.14 % rdg	Weights
Torque Watches ³	(0.5 to 215) in·oz	0.48 % rdg + 0.52 in·oz	Torque calibrator
Tachometers ³ –			
Photo	(0 to 100 000) rpm	0.014 % rdg + 1.2R	Function generator
Contact	(0 to 5000) rpm (5000 to 15 000) rpm	1.3 rpm 0.032 % rdg + 0.6 rpm	Tachometer calibrator
Pressure/Vacuum Gauges ³	(-15 to 1000) psi Pneumatic	0.0022 psi + 0.012 % fs	Pressure calibrator
	(1000 to 5000) psi	0.9 psi + 0.026 %	Pressure transducers
	(5000 to 10 000) psi	1.8 psi + 0.026 % fs	
Pipettes	10 µL 20 µL 50 µL 100 µL 200 µL 500 µL 1000 µL (2000 to 5000) µL	3.1 % of rdg 1.6 % of rdg 0.64 % of rdg 0.33 % of rdg 0.19 % of rdg 0.14 % of rdg 0.08 % of rdg 0.06 % of rdg	Gravimetric method
Parameter/Equipment	Range	CMC ^{2,4} (±)	Comments

<p>Indirect Verification of Rockwell Hardness and Rockwell Superficial Hardness Testers³</p>	<p>HRA: Low, Middle, High</p> <p>HRB: Low, Middle, High</p> <p>HRC: Low, Middle, High</p> <p>HRE: Low, Middle, High</p> <p>HRF: Low, Middle, High</p> <p>HR15N: Low, Middle, High</p> <p>HR30N: Low, Middle, High</p> <p>HR45N: Low, Middle, High</p> <p>HR15T: Low, Middle, High</p> <p>HR30T: Low, Middle, High</p> <p>HR45T: Low, Middle, High</p>	<p>0.7 HRA</p> <p>0.7 HRB</p> <p>0.7 HRC</p> <p>0.7 HRE</p> <p>0.7 HRF</p> <p>0.7 HR15N</p> <p>0.7 HR30N</p> <p>0.7 HR45N</p> <p>0.7 HR15T</p> <p>0.7 HR30T</p> <p>0.7 HR45T</p>	<p>ASTM E18</p>
<p>Indirect Verification of Brinell Hardness Testers at Test Condition(s)³ –</p> <p>10/3000/15</p>	<p><u>(150 to 260) HBW</u></p>	<p>0.008<i>d</i></p>	<p>ASTM E10</p> <p><i>d</i> is the mean of the <i>n</i> mean test diameter in millimeters.</p>
<p>Durometer Calibrator</p>	<p>Scales A and D</p>	<p>0.36 units</p>	<p>Scale and linear measure, weights and moment arm</p>

Parameter/Equipment	Range	CMC ^{2,4} (±)	Comments
Indirect Verification of Microindentation Hardness Testers (Knoop and Vickers) ³ –	Repeatability under forces P (g) $1 \leq P < 500$ $100 \leq HK \leq 940$ $100 \leq HV \leq 940$	20 HK + 1.2 % 13 HV + 3 %	ASTM E384 CMC is stated as the repeatability as defined in E384.
Direct Verification of Durometers ³ – Verification of indenter shape and extension: Extension at zero reading Diameter of the base of the frustum Diameter of the top of the frustum Cone angle Tip radius Indenter thickness Indenter radius Verification of the durometer spring	----- -----	5 μm 5 μm 5 μm 0.03° 5 μm 5 μm 5 μm 62 mN	ASTM D2240 The dimensional characteristics of the indenters are verified by optical projection The durometer spring is verified with deadweights. This CMC applies to all durometer types.
Load Cells	(0 to 500) lbf (500 to 10 000) lbf	0.034 % rdg + 0.00044 lbf 0.04 % rdg + 0.38 lbf	Dead weights, comparison to master load cell
Load Cells ³	(0 to 10 000) lbf	0.1 % rdg + 0.002 lbf	Dead weights, comparison to master load cell

Parameter/Equipment	Range	CMC ^{2,4} (\pm)	Comments
Dynamometer and Force Rings ³	(0 to 10 000) lbf	0.18 % rdg + 0.6R	Load cells
Spring Testers ³ – Force Scale	(0 to 1000) lbf	0.6R + 0.02 %	Weights, load cells; <i>R</i> is the resolution of the force scale of the spring tester.
Deflection Accuracy	Up to 20 in	0.6R + 26 μ in	Gage blocks; <i>R</i> is the resolution of the deflection scale.
Cable Tensiometers/Wire Tension Meters	(0 to 1000) lb	0.6R + 1.1 lb	Weights
Accelerometers – Shear and Charge ³	(0.25 to 10) <i>g</i> (5 to 10 000) Hz	2.7 % rdg	Accelerometer; <i>g</i> is the acceleration due to gravity.
Refractometers ³	(0 to 100) %	0.28 % rdg + 0.6R	Standard solutions
Ultrasonic Thickness Testers ³	(0 to 10) in	(800 + 13L) μ in	Standard thickness specimen
Manometers	(0 to 24) inH ₂ O	0.00016 inH ₂ O	Hook gage
Deadweight Testers – Piston and Cylinder Area	(0 to 10 000) psi	(10 + 2D) μ in	UMM
Mass		0.2 g	Class F weights and scales
Performance Test (Cross-Float)		0.04 % rdg	Pressure calibrator with transducer

Parameter/Equipment	Range	CMC ^{2,4} (±)	Comments
Air Velocity	(100 to 4000) ft/min (4000 to 9000) ft/min	0.48 % of rdg + 5.5 ft/min 0.48 % of rdg + 39.4 ft/min	Flowkinetics manometer

VIII. Optical Quantities

Parameter/Equipment	Range	CMC ^{2,4} (±)	Comments
Gloss Meters ³	20 °, 60°, 85 °	(0.54 +0.6R) GU	Gloss standards; GU represents gloss units.

IX. Thermodynamics

Parameter/Equipment	Range	CMC ^{2,4} (±)	Comments
Liquid-in-Glass Thermometers and Temperature Measuring Devices	-40 °C to 150 °C 150 °C to 250 °C 250 °C to 300 °C	0.02 °C + 0.6R 0.03 °C + 0.6R 0.04 °C + 0.6R	Hart 7341 bath and SPRT
Temperature – Measuring Equipment ³	-10 °C to 650 °C	0.045 °C + 0.6R	Dry-wells
Infrared Thermometers – Measure ³	50°C to 500 °C 500 °C to 1100 °C	0.8°C + 0.6R 4.8 °C	Hart 9132 radiation source Isotech Pegasus 92R radiation source
Relative Humidity – Measure Hygrometer	15 % to 90 % RH	1.7 % RH + 0.6R	Dewpoint hygrometer Ultra DP5 and humidity chamber

Parameter/Equipment	Range	CMC ^{2,4} (±)	Comments
Relative Humidity – Measure (cont.) Psychrometer	5 °C to 35 °C	0.1 °C + 0.84R	Comparison to SPRT in temp bath
Dew Point	-20 to 60 °C	0.3 °C + 0.6R	Chilled mirror
Indirect Verification of Leeb Hardness Testers	Up to 800 HLD	7.4 HLD	Standard test block

X. Time & Frequency

Parameter/Equipment	Range	CMC ² (±)	Comments
Frequency	10 Hz to 10 GHz	3 parts in 10 ¹¹	GPS
Frequency – Measure ³	0.1 Hz to 5 GHz (5 to 20) GHz	2.5 parts in 10 ⁶ 5 parts in 10 ⁶	Agilent 53131, Agilent 5350B

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 In the statement of CMC, L is the numerical value of the nominal length in inches; R is the resolution of the unit under test; D is the diameter in inches; H is the height of the unit under test (except where noted).
- ⁵ CMC for calibrations performed in the laboratory with the HP 3458A is **based upon 90-day specifications** and is read as ppm or percent reading plus ppm or percent range. CMC for calibrations performed field with the HP 3458A is based upon 1-year specifications and is also read as ppm or percent reading plus ppm or percent range. Where “ppm” appears in the CMC, it is equivalent to that part in one million.
- ⁶ CMC for calibrations performed with the Fluke 5520A is based upon 1-year specifications and is read as ppm or percent reading plus ppm or percent range or as ppm or percent of reading plus floor specification. CMC for calibrations performed with the Fluke 5720A is **based upon 90-day specifications** and is also read as ppm or percent reading plus ppm or percent range or as ppm or percent of reading plus floor specification. Where “ppm” appears in the CMC, it is equivalent to that part in one million.
- ⁷ CMC for calibrations performed with the Fluke 5790A is based upon 1-year specifications and is read as ppm or percent reading plus floor specification. Where “ppm” appears in the CMC, it is equivalent to that part in one million.