



SCOPE OF ACCREDITATION TO ISO/IEC 17025:2017
ANSI/NCSL Z540-1-1994 & ANSI/NCSL Z540.3-2006

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CALIBRATION

Valid To: *See Footnote 9*

Certificate Number: 1022.01

In recognition of the successful completion of the A2LA evaluation process, accreditation is granted to this laboratory to perform the following calibrations^{1,10}:

I. Acoustics

Parameter/Equipment	Range	CMC ^{2, 11} (±)	Comments	Location
Acoustics – Measure	20 Hz to 8 kHz	0.16 dB	Standard reference microphone	DET
Acoustics ³ – Measuring Equipment	124 dB @ 250 Hz	0.20 dB	Standard pistonphone	DET
	114 dB @ 1 kHz 94 dB @ 1 kHz	0.12 dB 0.12 dB	Acoustical calibrator	DET
	5 Hz to 50 kHz 5 Hz to 100 kHz	0.45 dB 0.50 dB	Electrostatic actuator	DET

II. Chemical

Parameter/Equipment	Range	CMC ^{2, 11} (±)	Comments	Location
pH ³ – Measuring Equipment	(4, 7, 10) units	0.016 units	Buffer solutions	DET, CHIC, CLEV

Parameter/Equipment	Range	CMC ^{2, 11} (\pm)	Comments	Locations
Electrolytic Conductivity ³ – Measuring Equipment	10 μ S/cm 100 μ S/cm 1000 μ S/cm 10 000 μ S/cm	0.41 μ S/cm 1.1 μ S/cm 5.3 μ S/cm 49 μ S/cm	Conductivity solutions	DET, CLEV

III. Dimensional

Parameter/Equipment	Range	CMC ^{2, 4, 6, 11} (\pm)	Comments	Location
Angle ³ – Measuring Equipment	Up to 360° Up to 60° 90° \pm 3'	7.1" 8.7" 2.8"	Angle encoder Gage blocks w/ sine bar Cylinder square	DET, CHIC, CLEV DET, CHIC, CLEV DET, CLEV
Angle ³ – Measure	Up to 60°	8.1"	Gage blocks, sine bar & comparator	DET, CLEV
Flatness ³	Up to 4 in diameter	5.6 μ in	Optical flats	DET, CHIC, CLEV
Gage Blocks	Up to 12 in	1.9 μ in/in + 3.8 μ in	Master gage blocks and laser interferometer	DET
	Up to 1 in (1 to 4) in	3.0 μ in (4.5L + 2.2) μ in	Master gage blocks and comparator	CLEV
	(4 to 8) in	(1.4L + 21) μ in	LMM	CLEV
Length Standards, Foils & Thickness Gauges	Up to 12 in (>12 to 48) in	1.9 μ in/in + 3.8 μ in	Master gage blocks and laser interferometer	DET
	Up to 8 in	2 μ in/in + 22 μ in	Master gage blocks and USM	DET
	Up to 38 in	2 μ in/in + 12 μ in	Master gage blocks and comparator	CLEV

Parameter/Equipment	Range	CMC ^{2, 4, 5, 11} (\pm)	Comments	Location
Hand Tools ³ – Calipers Indicators Micrometers Height Gages	Up to 2 in (>1 to 72) in	8 μ in 2.7 μ in/in + 3.8 μ in	Gage blocks (68° room)	DET, CLEV DET, CLEV
	Up to 1 in (>1 to 40) in	25 μ in/in 14 μ in/in + 4.0 μ in	Gage blocks (normal room)	CHIC CHIC
Linear Displacement ³ – Measuring Equipment	Up to 24 in	60 μ in/in + 0.0014 in	Height gage, linear encoder, gage blocks, steel tape	DET
	Up to 24 in	60 μ in/in + 0.0027 in	Height gage, steel tape	CLEV, CHIC
Optical Comparators ³ – Linear Travel	Up to 30 in	180 μ in	Glass scales, magnification checker, spheres	DET
	Up to 30 in	(3L + 130) μ in		CLEV, CHIC
Optical Comparators – Magnification	10x to 100x	0.11 %	Glass scales, magnification checker, spheres	DET
	10x to 100x	0.17 %		CLEV, CHIC
Plain Diameter – Internal & External	Up to 4 in (4 to 12) in	(16 + 3D) μ in (28 + 3D) μ in	Master gage blocks and laser interferometer	DET DET
	(0.125 to 8) in	(28 + 3D) μ in	Master rings and USM	CLEV
Plain Diameter – External	(0.003 to 0.5) in	31 μ in	Laser micrometer	CLEV, CHIC
Steel Tapes ³	(1 to 100) ft	0.063 in	Steel tape	DET, CHIC, CLEV

Parameter/Equipment	Range	CMC ^{2,4,5} (\pm)	Comments	Location
Surface Plate Flatness ³	(4 to 16) ft Diagonal (≥ 2 to 16) ft Diagonal (4 to 16) ft Diagonal	(70 + 6.5Di) μ in (70 + 6.5Di) μ in (70 + 6.5Di) μ in	Electronic leveling system	CHIC CLEV DET
	< 24 x 36 in < 36 x 48 in < 48 x 96 in	43 μ in 43 μ in 63 μ in	Planekator	DET DET DET
Threaded Plug Gages – Simple Pitch Diameter, (4 TPI to 80 TPI)	(0.1 to 6.5) in	(76 + 9D) μ in	Gage blocks, thread wires and laser interferometer	DET
	(0.1 to 8) in	(77 + 2D) μ in	Gage blocks, thread wires and USM	CLEV
Adjustable Thread Rings	(0.04 to 3.125) in (4 to 30) mm	400 μ in 0.01mm	Set using master plug gages	CLEV

IV. Dimensional Testing/Calibration⁸

Parameter/Equipment	Range	CMC ^{2,4,11} (\pm)	Comments	Location
Length – 1D, Measure	Up to 8 in	0.06 % + 350 μ in	Optical comparator	CLEV
	Up to 8 in x 4 in	0.085 % + 490 μ in		CLEV

V. Electrical – DC/Low Frequency

Parameter/Equipment	Range	CMC ^{2,6,7} (\pm)	Comments	Location
DC Voltage ³ – Generate	(0 to 220) mV (0.22 to 2.2) V (2.2 to 11) V (11 to 22) V (22 to 220) V (220 to 1100) V	6.8 μ V/V + 0.4 μ V 3.7 μ V/V + 0.7 μ V 4.9 μ V/V + 2.9 μ V 4.9 μ V/V + 4.3 μ V 3.7 μ V/V + 48 μ V 4.6 μ V/V + 0.48 mV	Fluke 5720A	DET, CLEV, CHIC

Parameter/Equipment	Range	CMC ^{2, 6, 7} (\pm)	Comments	Location
DC Voltage – Measure & Generate	Up to 200 mV 200 mV to 2 V (2 to 1000) V	1.1 μ V/V + 0.06 μ V 1.1 μ V/V + 0.2 μ V 1.1 μ V/V + 0.30 mV	Fluke 732B w/ 720A & 8508A	DET
DC Voltage – Generate, Fixed Points	100 mV 1 V 10 V 100 V 1000 V	2.5 μ V/V 2.5 μ V/V 2.5 μ V/V 2.5 μ V/V 2.5 μ V/V	Fluke 732, 752A	CLEV
DC Voltage – Generate, Fixed Points	10 V	11 μ V	Fluke 732	CHIC
DC Voltage ³ – Measure	(0 to 7) mV (7 to 100) mV (0.1 to 1) V (1 to 10) V (10 to 100) V (100 to 1000) V	60 μ V/V + 0.04 μ V 9.5 μ V/V + 0.37 μ V 6.1 μ V/V + 0.37 μ V 5.8 μ V/V + 0.59 μ V 8.7 μ V/V + 37 μ V 8.7 μ V/V + 0.12 mV	Agilent 34420A Agilent 3458A opt 002	DET, CHIC, CLEV
DC High Voltage – Measure	Up to 1400 V (\geq 1.4 to 35) kV ($>$ 35 to 100) kV	0.035 % + 13 mV 0.047 % + 130 mV 0.059 % + 1.3 V	Vitretek 4700 w/ HVL-100 and HVP-35	DET, CHIC, CLEV
DC High Voltage – Generate	Up to 1400 V (\geq 1.4 to 35) kV ($>$ 35 to 40) kV (1 to 40) kV	0.035 % + 13 mV 0.047 % + 130 mV 0.059 % + 1.3 V 0.13 %	 Ross divider and voltage source	 CLEV, CHIC

Parameter/Equipment	Range	CMC ^{2,6,7} (\pm)	Comments	Location	
DC Current ³ – Generate	0.1 nA to 220 μ A (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	35 μ A/A + 6 nA 31 μ A/A + 7 nA 30 μ A/A + 41 nA 41 μ A/A + 0.70 μ A 77 μ A/A + 12 μ A 0.034 % + 0.48 mA	Fluke 5720A w/ 5725A	DET, CLEV, CHIC	
	(11 to 20.5) A	0.10 % + 0.90 mA	Fluke 5520A		
	(10 to 300) A	76 μ A/A	Agilent 3458A w/ Honeywell 1168		
	(100 to 800) A	0.06 %	Empro shunt and Sorensen DCR20-1000		
	(100 to 1000) A	0.59 % + 0.58 A	Fluke 5500A/coil		
DC Current ³ – Measure	Up to 20 pA (20 to 200) pA (0.2 to 2) nA (2 to 20) nA (20 to 200) nA	3.5 % 0.63 % 0.20 % 0.23 % 0.085 %	Keithley 487	DET, CLEV, CHIC	
	(10 to 100) μ A (0.1 to 1) mA (1 to 10) mA (10 to 100) mA (0.1 to 1) A	17 μ A/A + 0.80 nA 17 μ A/A + 5 nA 17 μ A/A + 50 nA 31 μ A/A + 0.5 μ A 0.010 % + 10 μ A	Agilent 3458A opt 002		
	(1 to 2) A (2 to 20) A	0.019 % + 20 μ A 0.04 % + 0.40 mA	Fluke 8508A		DET
	(1 to 10) A (10 to 100) A (100 to 300) A (300 to 1200) A	0.31 mA 33 μ A/A 0.010 % 0.05 %	Agilent 3458A w/ shunts and standard resistors		DET, CLEV, CHIC

Parameter/Equipment	Range	CMC ^{2, 5, 6, 7} (±)	Comments	Location
DC Resistance ³ – Generate, Fixed 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 1 GΩ 10 GΩ 100 GΩ 1 TΩ	40 μΩ 80 μΩ 0.15 mΩ 0.21 mΩ 0.40 mΩ 0.9 mΩ 1.7 mΩ 7.5 mΩ 14 mΩ 0.08 Ω 0.14 Ω 0.9 Ω 1.7 Ω 0.9 Ω 1.7 Ω 15 Ω 30 Ω 0.31 kΩ 0.11 % 62 MΩ 1.2 GΩ 2.3 GΩ	Fluke 5720A, standard resistors Keithley 289 resistors	DET, CLEV, CHIC
DC Resistance – Generate, Fixed Points	0.001 Ω 0.01 Ω 0.1 Ω (1, 1.9, 10, 100) Ω (1 kΩ, 10 kΩ) 19 kΩ 100 kΩ 1 MΩ 10 MΩ 19 MΩ	0.90 μΩ 0.94 μΩ 8.4 μΩ 2.5 μΩ/Ω 3.2 μΩ/Ω 0.095 Ω 0.56 Ω 11 Ω 300 Ω 0.78 kΩ	Fluke 742 and L&N standard resistors	DET, CLEV, CHIC
DC Resistance – Generate, Fixed Points	1 Ω 25 Ω 200 Ω 400 Ω	2.5 μΩ 0.088 mΩ 0.7 mΩ 1.4 mΩ	IET Resistors	DET



Parameter/Equipment	Range	CMC ^{2,6,7} (\pm)	Comments	Location
DC Resistance – Measure	(0 to 1) Ω (0 to 10) Ω (10 to 100) Ω (0.1 to 1) k Ω (1 to 10) k Ω (10 to 100) k Ω (0.1 to 1) M Ω (1 to 10) M Ω (10 to 100) M Ω (0.1 to 1) G Ω	82 $\mu\Omega/\Omega$ + 2.4 $\mu\Omega$ 17 $\mu\Omega/\Omega$ + 58 $\mu\Omega$ 12 $\mu\Omega/\Omega$ + 0.58 m Ω 9.4 $\mu\Omega/\Omega$ + 0.58 m Ω 9.5 $\mu\Omega/\Omega$ + 5.8 m Ω 9.7 $\mu\Omega/\Omega$ + 58 m Ω 15 $\mu\Omega/\Omega$ + 2.3 Ω 58 $\mu\Omega/\Omega$ + 0.12 k Ω 0.058 % + 1.2 k Ω 0.6 % + 12 k Ω	Agilent 34420A Agilent 3458A	DET, CLEV, CHIC
Resistance ³ – Generate	Up to 10.99 Ω (11 to 32.999) Ω (33 to 109.9999) Ω (110 to 329.999) Ω 330 Ω to 1.099999 k Ω (1.1 to 3.299999) k Ω (3.3 to 10.99999) k Ω (11 to 32.99999) k Ω (33 to 109.9999) k Ω (110 to 329.9999) k Ω 330 k Ω to 1.09999 M Ω (1.1 to 3.29999) M Ω (3.3 to 10.9999) M Ω (11 to 32.9999) M Ω (33 to 109.9999) M Ω (110 to 329.999) M Ω (330 to 1100) M Ω	40 $\mu\Omega/\Omega$ + 1.0 m Ω 30 $\mu\Omega/\Omega$ + 1.5 m Ω 28 $\mu\Omega/\Omega$ + 1.4 m Ω 28 $\mu\Omega/\Omega$ + 2.0 m Ω 28 $\mu\Omega/\Omega$ + 2.0 m Ω 28 $\mu\Omega/\Omega$ + 20 m Ω 28 $\mu\Omega/\Omega$ + 20 m Ω 28 $\mu\Omega/\Omega$ + 0.21 Ω 28 $\mu\Omega/\Omega$ + 0.21 Ω 32 $\mu\Omega/\Omega$ + 2.0 Ω 32 $\mu\Omega/\Omega$ + 2.1 Ω 60 $\mu\Omega/\Omega$ + 30 Ω 0.013 % + 50 Ω 0.025 % + 2.5 k Ω 0.050 % + 3.0 k Ω 0.30 % + 0.10 M Ω 1.5 % + 0.50 M Ω	Fluke 5520A, 4-wire Fluke 5520A, 2-wire	DET, CLEV, CHIC
Resistance – Measure	Up to 2 Ω (2 to 20) Ω (20 to 200) Ω (0.2 to 2) k Ω (2 to 20) k Ω (20 to 200) k Ω (0.2 to 2) M Ω (2 to 20) M Ω (20 to 200) M Ω 200 M Ω to 2 G Ω (2 to 20) G Ω 20 G Ω to 1 T Ω	3.2 $\mu\Omega/\Omega$ + 4 $\mu\Omega$ 2.6 $\mu\Omega/\Omega$ + 14 $\mu\Omega$ 2.5 $\mu\Omega/\Omega$ + 30 $\mu\Omega$ 3.2 $\mu\Omega/\Omega$ + 0.3 m Ω 3.2 $\mu\Omega/\Omega$ + 3.0 m Ω 5.6 $\mu\Omega/\Omega$ + 30 m Ω 11 $\mu\Omega/\Omega$ + 3 Ω 30 $\mu\Omega/\Omega$ + 10 Ω 0.035 % + 100 Ω 0.041 % + 10 k Ω 0.15 % + 10 M Ω 0.45 %	Resistance transfer with 8508A Keithley 487	DET

Parameter/Equipment	Range	CMC ^{2, 6, 7} (\pm)	Comments	Location
Resistance – Measure	(0 to 1) Ω (1 to 1.9) Ω (1.9 to 10) Ω (10 to 100) k Ω (1 to 1.9) k Ω (1.9 to 10) k Ω (10 to 19) k Ω (19 to 100) k Ω (0.1 to 1) M Ω (1 to 10) M Ω (10 to 19) M Ω (19 to 100) M Ω	60 $\mu\Omega/\Omega$ 16 $\mu\Omega/\Omega$ 12 $\mu\Omega/\Omega$ 14 $\mu\Omega/\Omega$ 14 $\mu\Omega/\Omega$ 5 $\mu\Omega/\Omega$ 5 $\mu\Omega/\Omega$ 5 $\mu\Omega/\Omega$ 7 $\mu\Omega/\Omega$ 10 $\mu\Omega/\Omega$ 13 $\mu\Omega/\Omega$ 20 $\mu\Omega/\Omega$	Fluke 5700A, 742A and Agilent 3458A	CLEV

Parameter/Range	Frequency	CMC ^{2, 7} (\pm)	Comments	Location
AC Voltage ³ – Generate				
Up to 2.2 mV	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz (0.5 to 1) MHz (1 to 10) MHz (10 to 20) MHz (20 to 30) MHz	0.022 % + 4 μ V 0.009 % + 4 μ V 0.008 % + 4 μ V 0.018 % + 4 μ V 0.046 % + 5 μ V 0.09 % + 10 μ V 0.12 % + 20 μ V 0.25 % + 20 μ V 0.30 % + 3.0 μ V 0.50 % + 3.0 μ V 1.5 % + 3.0 μ V	Fluke 5720A/5725A; frequencies \geq 1 MHz are referenced to 1 kHz	DET, CLEV, CHIC
(2.2 to 22) mV	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz (0.5 to 1) MHz (1 to 10) MHz (10 to 20) MHz (20 to 30) MHz	0.022 % + 4 μ V 0.009 % + 4 μ V 0.008 % + 4 μ V 0.018 % + 4 μ V 0.046 % + 5 μ V 0.090 % + 10 μ V 0.12 % + 20 μ V 0.25 % + 20 μ V 0.20 % + 3.0 μ V 0.40 % + 3.0 μ V 1.0 % + 3.0 μ V		

Parameter/Range	Frequency	CMC ^{2,6,7} (±)	Comments	Location
AC Voltage ³ – Generate (cont)				
(22 to 220) mV	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz (0.5 to 1) MHz (1 to 10) MHz (10 to 20) MHz (20 to 30) MHz	0.022 % + 12 µV 0.009 % + 7 µV 0.008 % + 7 µV 0.018 % + 7 µV 0.042 % + 17 µV 0.075 % + 20 µV 0.12 % + 25 µV 0.25 % + 45 µV 0.20 % + 3.0 µV 0.40 % + 3.0 µV 1.0 % + 3.0 µV	Fluke 5720A/5725A; frequencies ≥ 1 MHz are referenced to 1 kHz	DET, CLEV, CHIC
(0.22 to 2.2) V	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz (0.5 to 1) MHz (1 to 10) MHz (10 to 20) MHz (20 to 30) MHz	0.022 % + 40 µV 0.009 % + 15 µV 0.004 % + 8.0 µV 0.007 % + 10 µV 0.011 % + 30 µV 0.034 % + 80 µV 0.090 % + 0.20 mV 0.15 % + 0.30 mV 0.20 % + 6.5 µV 0.40 % + 6.5 µV 1.0 % + 6.5 µV		
(2.2 to 22) V	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz	0.022 % + 0.40 mV 0.008 % + 0.15 mV 0.004 % + 0.05 mV 0.007 % + 0.10 mV 0.010 % + 0.20 mV 0.026 % + 0.6 mV 0.090 % + 2.0 mV		
≤ 3 V	(0.5 to 1) MHz (1 to 10) MHz (10 to 20) MHz (20 to 30) MHz	0.13 % + 3.2 mV 0.20 % + 6.5 µV 0.40 % + 6.5 µV 1.0 % + 6.5 µV		
(22 to 220) V* *220 V range subject to 2.2E7 V-Hz limitation	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz (0.5 to 1) MHz	0.022 % + 4.0 mV 0.008 % + 1.5 mV 0.005 % + 0.60 mV 0.008 % + 1.0 mV 0.013 % + 2.5 mV 0.080 % + 16 mV 0.42 % + 40 mV 0.70 % + 80 mV		

Parameter/Range	Frequency	CMC ^{2, 6, 7} (\pm)	Comments	Location
AC Voltage ³ – Generate (cont)				
(220 to 1100) V	(15 to 50) Hz 50 Hz to 1 kHz (1 to 20) kHz (20 to 30) kHz	0.026 % + 16 mV 60 μ V/V + 3.5 mV 0.013 % + 6.0 mV 0.036 % + 11 mV	Fluke 5720A/5725A	DET, CLEV, CHIC
(220 to 750) V	(30 to 50) kHz (50 to 100) kHz	0.036 % + 11 mV 0.13 % + 45 mV		
AC Voltage – Measure				
(0.7 to 2.2) mV	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz (0.5 to 1) MHz (1 to 2) MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz	0.17 % + 1.3 μ V 0.074 % + 1.3 μ V 0.042 % + 1.3 μ V 0.081 % + 2.0 μ V 0.12 % + 2.5 μ V 0.23 % + 4.0 μ V 0.24 % + 8.0 μ V 0.35 % + 8.0 μ V 0.07 % + 1.0 μ V 0.17 % + 1.0 μ V 0.30 % + 1.0 μ V 0.70 % + 2.0 μ V	Fluke 5790A; frequencies \geq 1 MHz are referenced to 1 kHz	DET
(2.2 to 7) mV	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz (0.5 to 1) MHz (1 to 2) MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz	0.085 % + 1.3 μ V 0.037 % + 1.3 μ V 0.021 % + 1.3 μ V 0.040 % + 2.0 μ V 0.060 % + 2.5 μ V 0.12 % + 4.0 μ V 0.13 % + 8.0 μ V 0.23 % + 8.0 μ V 0.07 % + 1.0 μ V 0.10 % + 1.0 μ V 0.17 % + 1.0 μ V 0.37 % + 1.0 μ V		

Parameter/Range	Frequency	CMC ^{2, 6, 7} (\pm)	Comments	Location
AC Voltage – Measure (cont)				
(7 to 22) mV	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz (0.5 to 1) MHz (1 to 2) MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz	0.029 % + 1.3 μ V 0.019 % + 1.3 μ V 0.011 % + 1.3 μ V 0.021 % + 2.0 μ V 0.031 % + 2.5 μ V 0.081 % + 4.0 μ V 0.089 % + 8.0 μ V 0.17 % + 8.0 μ V 0.07 % + 0.08 μ V 0.10 % + 0.08 μ V 0.17 % + 0.08 μ V 0.37 % + 0.08 μ V	Fluke 5790A; frequencies \geq 1 MHz are referenced to 1 kHz	DET
(22 to 70) mV	(9.5 to 10) Hz (10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz (0.5 to 1) MHz (1 to 2) MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz	0.10 % + 1.5 μ V 0.024 % + 1.5 μ V 0.012 % + 1.5 μ V 0.007 % + 1.5 μ V 0.013 % + 2.0 μ V 0.026 % + 2.5 μ V 0.051 % + 4.0 μ V 0.067 % + 8.0 μ V 0.11 % + 8.0 μ V 0.05 % + 0.82 μ V 0.10 % + 0.82 μ V 0.15 % + 0.82 μ V 0.35 % + 0.82 μ V		
(70 to 220) mV	(9.5 to 10) Hz (10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz (0.5 to 1) MHz (1 to 2) MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz	0.10 % + 1.5 μ V 0.021 % + 1.5 μ V 0.009 % + 1.5 μ V 0.004 % + 1.5 μ V 0.007 % + 2.0 μ V 0.016 % + 2.5 μ V 0.025 % + 4.0 μ V 0.038 % + 8.0 μ V 0.10 % + 8.0 μ V 0.05 % + 0.82 μ V 0.10 % + 0.82 μ V 0.15 % + 0.82 μ V 0.35 % + 0.82 μ V		

Parameter/Range	Frequency	CMC ^{2, 6, 7} (\pm)	Comments	Location
AC Voltage – Measure (cont)				
(220 to 700) mV	(9.5 to 10) Hz (10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz (0.5 to 1) MHz (1 to 2) MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz	0.10 % + 1.5 μ V 0.021 % + 1.5 μ V 0.008 % + 1.5 μ V 0.003 % + 1.5 μ V 0.005 % + 2.0 μ V 0.008 % + 2.5 μ V 0.018 % + 4.0 μ V 0.030 % + 8.0 μ V 0.096 % + 8.0 μ V 0.05 % + 8.2 μ V 0.10 % + 8.2 μ V 0.15 % + 8.2 μ V 0.35 % + 8.2 μ V	Fluke 5790A; frequencies \geq 1 MHz are referenced to 1 kHz	DET
700 mV to 2.2 V	(9.5 to 10) Hz (10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz (0.5 to 1) MHz (1 to 2) MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz	0.10 % + 0.08 μ V 0.020 % + 0.08 μ V 0.007 % + 0.08 μ V 0.002 % + 0.08 μ V 0.005 % + 0.08 μ V 0.007 % + 0.08 μ V 0.016 % + 0.08 μ V 0.026 % + 0.08 μ V 0.090 % + 0.08 μ V 0.05 % + 8.2 μ V 0.10 % + 8.2 μ V 0.15 % + 8.2 μ V 0.35 % + 8.2 μ V		
(2.2 to 7) V	(9.5 to 10) Hz (10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz (0.5 to 1) MHz (1 to 2) MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz	0.10 % + 0.80 μ V 0.020 % + 0.80 μ V 0.007 % + 0.80 μ V 0.002 % + 0.80 μ V 0.005 % + 0.80 μ V 0.008 % + 0.80 μ V 0.019 % + 0.80 μ V 0.040 % + 0.80 μ V 0.12 % + 0.80 μ V 0.050 % + 0.66 mV 0.10 % + 0.27 mV 0.15 % + 0.51 mV 0.35 % + 0.60 mV		

Parameter/Range	Frequency	CMC ^{2, 6, 7} (\pm)	Comments	Location
AC Voltage ³ – Measure (cont)				
(7 to 22) V	(9.5 to 10) Hz (10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz (0.5 to 1) MHz	0.10 % + 0.80 μ V 0.020 % + 0.80 μ V 0.007 % + 0.80 μ V 0.003 % + 0.80 μ V 0.005 % + 0.80 μ V 0.008 % + 0.80 μ V 0.019 % + 0.80 μ V 0.040 % + 0.80 μ V 0.12 % + 0.80 μ V	Fluke 5790A	DET
(22 to 70) V	(9.5 to 10) Hz (10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz (0.5 to 1) MHz	0.10 % + 8.2 μ V 0.020 % + 8.2 μ V 0.007 % + 8.2 μ V 0.003 % + 8.2 μ V 0.006 % + 8.2 μ V 0.009 % + 8.2 μ V 0.020 % + 8.2 μ V 0.041 % + 8.2 μ V 0.12 % + 8.2 μ V		
(70 to 220) V	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz	0.020 % + 8.2 μ V 0.007 % + 8.2 μ V 0.003 % + 8.2 μ V 0.007 % + 8.2 μ V 0.010 % + 8.2 μ V 0.021 % + 8.2 μ V 0.050 % + 8.2 μ V		
(220 to 700) V	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz	0.020 % + 82 μ V 0.010 % + 82 μ V 0.004 % + 82 μ V 0.013 % + 82 μ V 0.050 % + 82 μ V		
(700 to 1000) V	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz	0.020 % + 82 μ V 0.010 % + 82 μ V 0.004 % + 82 μ V 0.013 % + 82 μ V 0.050 % + 82 μ V		

Parameter/Range	Frequency	CMC ^{2, 6, 7} (\pm)	Comments	Location
AC Voltage ³ – Measure (cont)				
(0.1 to 10) mV	(1 to 40) Hz 40 Hz to 1 kHz (1 to 20) kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz	0.030 % + 3.3 μ V 0.020 % + 1.8 μ V 0.030 % + 1.8 μ V 0.10 % + 1.8 μ V 0.50 % + 1.8 μ V 4.0 % + 1.8 μ V	Agilent 3458A	DET, CLEV, CHIC
(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 (0.3 to 1) MHz (1 to 2) MHz	0.007 % + 10 μ V 0.007 % + 2 μ V 0.014 % + 2 μ V 0.030 % + 2 μ V 0.080 % + 2 μ V 0.30 % + 10 μ V 1.0 % + 10 μ V 1.5 % + 10 μ V		
100 mV to 1V	(1 to 40) Hz 40 Hz to 1 kHz (1 to 20) kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (0.3 to 1) MHz (1 to 2) MHz	0.007 % + 40 μ V 0.007 % + 20 μ V 0.014 % + 20 μ V 0.030 % + 20 μ V 0.080 % + 20 μ V 0.30 % + 100 μ V 1.0 % + 100 μ V 1.5 % + 100 μ V		
(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 (0.3 to 1) MHz (1 to 2) MHz	0.007 % + 0.40 mV 0.007 % + 0.20 mV 0.014 % + 0.20 mV 0.030 % + 0.20 mV 0.080 % + 0.20 mV 0.30 % + 1.0 mV 1.0 % + 1.0 mV 1.5 % + 1.0 mV		
(10 to 100) V	(1 to 40) Hz 40 Hz to 1 kHz (1 to 20) kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (0.3 to 1) MHz	0.02 % + 4.0 mV 0.02 % + 2.0 mV 0.02 % + 2.0 mV 0.04 % + 2.0 mV 0.12 % + 2.0 mV 0.40 % + 10 mV 1.5 % + 10 mV		
(100 to 750) V	(1 to 40) Hz 40 Hz to 1 kHz (1 to 20) kHz (20 to 50) kHz (50 to 100) kHz	0.04 % + 40 mV 0.04 % + 20 mV 0.06 % + 20 mV 0.12 % + 20 mV 0.30 % + 20 mV		

Parameter/Range	Frequency	CMC ^{2, 6, 7} (\pm)	Comments	Location
AC High Voltage ³ – Measure				
Up to 1.4 kV	Up to 600 Hz	0.12 % + 13 mV	Vitrek 4700 w/ HVL-100 and HVP-35	DET, CLEV, CHIC
(1.4 to 35) kV	Up to 30 Hz (30 to 200) Hz (200 to 450) Hz (450 to 600) Hz	0.59 % + 0.13 V 0.12 % + 0.13 V 0.71 % + 0.13 V 1.5 % + 0.13 V		
(35 to 75) kV	Up to 30 Hz (30 to 70) Hz (70 to 200) Hz (200 to 450) Hz	0.35 % + 1.3 V 0.14 % + 1.3 V 1.2 % + 1.3 V 18 % + 1.3 V		
AC Current ³ – Generate				
(9 to 220) μ A	(10 to 20) Hz (20 to 40) Hz 40 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz (10 to 30) kHz	0.023 % + 16 nA 0.014 % + 10 nA 0.011 % + 8.0 nA 0.025 % + 12 nA 0.090 % + 65 nA 1.6 % + 0.40 μ A	Fluke 5720A w/ 5725A Fluke 5520A	DET, CLEV, CHIC
(0.22 to 2.2) mA	(10 to 20) Hz (20 to 40) Hz 40 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz (10 to 30) kHz	0.023 % + 41 nA 0.014 % + 36 nA 0.011 % + 36 nA 0.025 % + 0.11 μ A 0.090 % + 0.65 μ A 1.0 % + 0.60 μ A	Fluke 5720A w/ 5725A Fluke 5520A	
(2.2 to 22) mA	(10 to 20) Hz (20 to 40) Hz 40 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz (10 to 30) kHz	0.023 % + 0.40 μ A 0.014 % + 0.36 μ A 0.011 % + 0.36 μ A 0.025 % + 0.56 μ A 0.090 % + 5.0 μ A 0.40 % + 4.0 μ A	Fluke 5720A w/ 5725A Fluke 5520A	
(22 to 220) mA	(10 to 20) Hz (20 to 40) Hz 40 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz (10 to 30) kHz	0.023 % + 4.1 μ A 0.014 % + 3.6 μ A 0.011 % + 2.6 μ A 0.018 % + 3.6 μ A 0.09 % + 10 μ A 0.40 % + 0.20 mA	Fluke 5720A w/ 5725A Fluke 5520A	
(0.22 to 2.2) A	20 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz	0.024 % + 36 μ A 0.039 % + 80 μ A 0.60 % + 0.16 mA	Fluke 5720A w/ 5725A	DET, CLEV, CHIC

Parameter/Range	Frequency	CMC ^{2,4,6,7} (\pm)	Comments	Location
AC Current ³ – Generate (cont)				
(2.2 to 11) A	40 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz	0.040 % + 0.18 mA 0.085 % + 0.39 mA 0.33 % + 0.75 mA	Fluke 5720A w/ 5725A	DET, CLEV, CHIC
(11 to 20.5)	(45 to 100) Hz 100 Hz to 1 kHz (1 to 5) kHz	0.12 % + 5.1 mA 0.15 % + 5.1 mA 3.0 % + 5.1 mA	Fluke 5520A	
100 μ A to 20 A	45 Hz to 5 kHz	0.016 %	Fluke 5790A, 5720A, A40 shunts	DET
(20 to 100) A	(25 to 500) Hz	1.0 %	Fluke 5720A, 461CT & 1620A TCA	
(16 to 150) A	(45 to 65) Hz (65 to 440) Hz	0.38 % + 0.029A 1.0 % + 0.031A	Fluke 5520A, 5500A/coil	
(150 to 1025) A	(45 to 65) Hz (65 to 440) Hz	1.0 % + 0.031 A 1.0 % + 0.12 A		
AC Current ³ – Measure				
(5 to 100) μ A	(10 to 20) Hz (20 to 45) Hz 45 Hz to 5 kHz	0.40 % + 0.030 μ A 0.15 % + 0.030 μ A 0.060 % + 0.030 μ A	Agilent 3458A	DET, CLEV, CHIC
(0.1 to 100) mA	(10 to 20) Hz (20 to 45) Hz (45 to 100) Hz (0.1 to 5) kHz	0.40 % + 0.020 % 0.15 % + 0.020 % 0.060 % + 0.020 % 0.030 % + 0.020 %		
(0.1 to 1) A	(10 to 20) Hz (20 to 45) Hz (45 to 100) Hz (0.1 to 5) kHz	0.40 % + 0.20 mA 0.16 % + 0.20 mA 0.080 % + 0.20 mA 0.10 % + 0.20 mA		
100 mA to 20 A	Up to 1 kHz (1 to 5) kHz	0.039 % + 0.032 % $\cdot F$ 0.041 % + 0.032 % $\cdot F$	Y5020	DET, CLEV, CHIC
(20 to 800) A	(25 to 500) Hz	0.18 %	Agilent 3458A, Fluke Y5020 & 461CT	DET, CLEV, CHIC

AC Current^{3,7} – Measure (cont) w/ Fluke 5790A and A40 shunts $\mu\text{A/A}$

Calibrations performed at: DET location					
Frequency					
Range	DC	$\leq 1 \text{ kHz}$	$\leq 10 \text{ kHz}$	$\leq 30 \text{ kHz}$	$\leq 100 \text{ kHz}$
1 mA	21 $\mu\text{A/A}$	59 $\mu\text{A/A}$	78 $\mu\text{A/A}$	90 $\mu\text{A/A}$	170 $\mu\text{A/A}$
10 mA	21 $\mu\text{A/A}$	34 $\mu\text{A/A}$	34 $\mu\text{A/A}$	59 $\mu\text{A/A}$	93 $\mu\text{A/A}$
20 mA	21 $\mu\text{A/A}$	33 $\mu\text{A/A}$	33 $\mu\text{A/A}$	57 $\mu\text{A/A}$	79 $\mu\text{A/A}$
50 mA	21 $\mu\text{A/A}$	31 $\mu\text{A/A}$	31 $\mu\text{A/A}$	55 $\mu\text{A/A}$	75 $\mu\text{A/A}$
100 mA	21 $\mu\text{A/A}$	32 $\mu\text{A/A}$	32 $\mu\text{A/A}$	56 $\mu\text{A/A}$	74 $\mu\text{A/A}$
200 mA	21 $\mu\text{A/A}$	33 $\mu\text{A/A}$	33 $\mu\text{A/A}$	57 $\mu\text{A/A}$	75 $\mu\text{A/A}$
500 mA	22 $\mu\text{A/A}$	34 $\mu\text{A/A}$	34 $\mu\text{A/A}$	57 $\mu\text{A/A}$	76 $\mu\text{A/A}$
1 A	22 $\mu\text{A/A}$	34 $\mu\text{A/A}$	35 $\mu\text{A/A}$	58 $\mu\text{A/A}$	77 $\mu\text{A/A}$
2 A	22 $\mu\text{A/A}$	34 $\mu\text{A/A}$	36 $\mu\text{A/A}$	59 $\mu\text{A/A}$	85 $\mu\text{A/A}$
5 A	22 $\mu\text{A/A}$	37 $\mu\text{A/A}$	38 $\mu\text{A/A}$	64 $\mu\text{A/A}$	100 $\mu\text{A/A}$
10 A	27 $\mu\text{A/A}$	42 $\mu\text{A/A}$	63 $\mu\text{A/A}$	79 $\mu\text{A/A}$	120 $\mu\text{A/A}$
20 A	27 $\mu\text{A/A}$	48 $\mu\text{A/A}$	56 $\mu\text{A/A}$	86 $\mu\text{A/A}$	140 $\mu\text{A/A}$
50 A	33 $\mu\text{A/A}$	59 $\mu\text{A/A}$	83 $\mu\text{A/A}$	95 $\mu\text{A/A}$	160 $\mu\text{A/A}$
100 A	35 $\mu\text{A/A}$	68 $\mu\text{A/A}$	92 $\mu\text{A/A}$	110 $\mu\text{A/A}$	190 $\mu\text{A/A}$

Parameter/Range	Frequency	CMC ^{2,6,7} (\pm)	Comments	Location
AC Impedance ³ – Generate, Fixed Points				
0.1 Ω	$\leq 1 \text{ kHz}$	0.14 m Ω	Agilent 16074A AC resistance standards	DET, CLEV
1 Ω	$\leq 1 \text{ kHz}$	0.62 m Ω		
10 Ω	$\leq 13 \text{ MHz}$	8.2 m Ω		
100 Ω	$\leq 13 \text{ MHz}$	5.7 m Ω		
1 k Ω	$\leq 13 \text{ MHz}$	0.074 Ω		
10 k Ω	$\leq 1 \text{ MHz}$	0.56 Ω		
100 k Ω	$\leq 100 \text{ kHz}$	4.3 Ω		
Capacitance ³ – Generate				
(0.10 to 3.299) nF	10 Hz to 10 kHz	0.52 % + 12 pF	Fluke 5520A	DET, CLEV, CHIC
(0.33 to 10.999) nF	(10 to 1000) Hz	0.26 % + 12 pF		
(11 to 109.999) nF	(10 to 1000) Hz	0.26 % + 0.12 nF		
(110 to 329.99) nF	(10 to 1000) Hz	0.26 % + 0.31 nF		
(0.33 to 1.0999) μF	(10 to 600) Hz	0.26 % + 1.2 nF		
(1.1 to 3.2999) μF	(10 to 300) Hz	0.26 % + 3.1 nF		
(3.3 to 10.999) μF	(10 to 150) Hz	0.26 % + 12 nF		
(11 to 32.999) μF	(10 to 120) Hz	0.42 % + 31 nF		
(33 to 109.99) μF	(10 to 80) Hz	0.46 % + 0.12 μF		

Parameter/Range	Frequency	CMC ^{2, 6, 7} (\pm)	Comments	Location
Capacitance ³ – Generate (cont) (110 to 329.99) μ F (0.33 to 1.0999) mF (1.1 to 3.2999) mF (3.3 to 10.999) mF (11 to 32.999) mF (33 to 110) mF 100 pF to 1.1 μ F	Up to 50 Hz Up to 20 Hz Up to 6 Hz Up to 2 Hz Up to 0.6 Hz Up to 0.2 Hz 1 kHz	0.46 % + 0.31 μ F 0.46 % + 1.2 μ F 0.46 % + 3.1 μ F 0.46 % + 12 μ F 0.78 % + 31 μ F 1.2 % + 0.12 mF 0.030 %	Fluke 5520A Agilent 1423A	DET, CLEV, CHIC
Capacitance ³ – Generate, Fixed Points 1 pF 10 pF 100 pF 1000 pF (10, 100, 1000) nF	1 kHz to 13 MHz 1 kHz to 13 MHz 1 kHz to 13 MHz 1 kHz to 13 MHz 120 Hz to 100 kHz	0.37 % 0.040 % 0.067 % 0.33 % 0.010 %	Agilent 16380A and 16380C	DET, CLEV
Capacitance ³ – Measure (1 to 10) pF (10 to 100) pF 100 pF to 1 nF (1 to 10) nF (10 to 100) nF	(1 to 2) kHz 5 kHz 10 kHz 150 Hz to 1 kHz (1 to 2) kHz 5 kHz 10 kHz (20 to 400) Hz (1 to 2) kHz 5 kHz 10 kHz (20 to 30) Hz (1 to 2) kHz 5 kHz 10 kHz (1 to 2) kHz 5 kHz 10 kHz	0.012 % 0.035 % 0.092 % 0.41 % + F_c 0.012 % 0.023 % 0.058 % 0.41 % + F_c 0.012 % 0.023 % 0.058 % 0.41 % + F_c 0.012 % 0.023 % 0.058 % 0.012 % 0.035 % 0.081 %	Aberdeen Hagerling using 2700A with AH 1100 standard. This is the standard they have but need an exception to change GenRad 1615-A capacitance bridge $F_c = (0.01 \text{ pF}/f[\text{kHz}] +$ $0.01 \text{ pF})$	DET

Parameter/Range	Frequency	CMC ^{2, 6, 7} (±)	Comments	Location
Capacitance ³ – Measure (cont)				
100 nF to 1 µF	(1 to 2) kHz 5 kHz 10 kHz	0.023 % 0.081 % 0.32 %	Aberdeen Hagerling using 2700A with AH 1100 standard. This is the standard they have but need an exception to change	DET
(1 to 10) µF	(1 to 2) kHz 5 kHz 10 kHz	0.012 % 0.68 % 2.7 %		
(10 to 100) µF	1 kHz	0.012 %		
Capacitance ³ – Measure				
Up to 1 pF	(0.5 to 5) kHz (>5 to 100) kHz	12 % + 0.37 pF 1.4 % + 0.37 pF	Fluke PM6304C	DET, CLEV, CHIC
(1 to 10) pF	(150 to 500) Hz (>0.5 to 5) kHz (>5 to 20) kHz (>20 to 100) kHz	12 % + 0.37 pF 1.2 % + 0.37 pF 0.12 % + 0.37 pF 0.46 % + 0.37 pF		
(10 to 100) pF	(50 to 250) Hz (>0.25 to 1) kHz (>1 to 20) kHz (>20 to 100) kHz	12 % + 0.37 pF 1.2 % + 0.37 pF 0.12 % + 0.37 pF 0.46 % + 0.37 pF		
(0.1 to 1) nF	(50 to 250) Hz (>0.25 to 20) kHz (>20 to 100) kHz	1.2 % + 0.00037 nF 0.12 % + 0.00037 nF 0.46 % + 0.00037 nF		
(1 to 10) nF	(50 to 500) Hz (>0.5 to 2) kHz (2 to 20) kHz (>20 to 100) kHz	0.12 % + 0.0037 nF 0.058 % + 0.0037 nF 0.12 % + 0.0037 nF 0.46 % + 0.0037 nF		
(10 to 100) nF	(50 to 150) Hz (>0.15 to 2) kHz (>2 to 20) kHz (> 20 to 100) kHz	0.12 % + 0.037 nF 0.06 % + 0.037 nF 0.12% + 0.037 nF 0.46 % + 0.037 nF		

Parameter/Range	Frequency	CMC ^{2,6,7} (\pm)	Comments	Location
Capacitance ³ – Measure (cont)				
(0.1 to 1) μ F	50 Hz to 2 kHz (2 to 20) kHz (>20 to 100) kHz	0.058 % + 0.00037 μ F 0.12 % + 0.00037 μ F 0.46 % + 0.00037 μ F	Fluke PM6304C	DET, CLEV, CHIC
(1 to 10) μ F	(50 to 1500) Hz (>1.5 to 15) kHz (>15 to 50) kHz (>50 to 100) kHz	0.060 % + 0.00069 μ F 0.14 % + 0.00069 μ F 1.2 % + 0.00069 μ F 12 % + 0.00069 μ F		
(10 to 100) μ F	(50 to 1500) Hz (>1.5 to 15) kHz (>15 to 50) kHz	0.12 % + 0.0058 μ F 1.2 % + 0.0058 μ F 12 % + 0.0058 μ F		
Phase Angle ³ – Generate				
(0 to 360) $^{\circ}$ 50 mV to 120 V	(1 to 1000) Hz 1001 Hz to 6.25 kHz (6.26 to 50) kHz (50.01 to 100) kHz	6.2 m $^{\circ}$ 12 m $^{\circ}$ 30 m $^{\circ}$ 58 m $^{\circ}$	Clarke Hess 5000	DET
Phase Angle ³ – Measure (0 to 360) $^{\circ}$ 50 mV to 120 V	20 Hz to 10 kHz (10 to 40) kHz (40 to 100) kHz	0.081 $^{\circ}$ 0.29 $^{\circ}$ 0.98 $^{\circ}$	Krohn-Hite 6500	DET
Distortion ³	20 Hz to 20 kHz (20 to 100) kHz 100 kHz to 2.5 GHz (2.5 to 26.5) GHz	0.63 dB 0.87 dB 1.8 dB 2.9 dB	Agilent U8903A Agilent 8566A Agilent 8563E	DET, CLEV, CHIC
Risetime ³ – Measure	Up to 26.5 GHz (>26.5 to 50) GHz	15 ps 8.6 ps	HP sampling system	DET

Parameter/Range	Frequency	CMC ^{2, 6, 7} (\pm)	Comments	Location
Oscilloscopes ³ –				
Risetime – Generate	(100 to 150) ps	40 ps	Fluke 5820A	DET, CLEV, CHIC
Flatness Up to 5 V	50 kHz to 100 MHz (100 to 300) MHz (300 to 500) MHz (500 to 600) MHz	1.8 % + 0.12 mV 2.4 % + 0.12 mV 4.1 % + 0.12 mV 4.7 % + 0.12 mV	Fluke 5820A	
Up to 3.5 V	(0.6 to 1.6) GHz (1.6 to 2.1) GHz	5.8 % + 0.12 mV 7.0 % + 0.12 mV		
Bandwidth	(2.1 to 4.2) GHz (4.2 to 18) GHz (18 to 26.5) GHz	0.31 dB 0.74 dB 0.84 dB	Agilent 8340A w/: 8482A, 11667A 8481A, 11667A 8485A, 11667B	

Inductance^{3, 7} – Generate w/ General Radio 1482 series inductors

Calibrations performed at DET location					
<i>Frequency</i>					
<i>Range</i>	≤ 100 Hz	≤ 200 Hz	≤ 400 Hz	≤ 1 kHz	≤ 10 kHz
100 μ H	0.36 %	0.15 %	0.061 %	0.081 %	0.066 %
200 μ H	0.44 %	0.43 %	0.31 %	0.20 %	0.28 %
500 μ H	0.016 %	0.10 %	0.068 %	0.054 %	0.10 %
1 mH	0.21 %	0.062 %	0.042 %	0.051 %	0.04 %
5 mH	0.21 %	0.063 %	0.12 %	0.11 %	0.04 %
10 mH	0.058 %	0.063 %	0.027 %	0.023 %	0.036 %
100 mH	0.021 %	0.062 %	0.042 %	0.038 %	0.049 %
500 mH	0.062 %	0.062 %	0.49 %	0.046 %	–
1 H	0.026 %	0.062 %	0.021 %	0.025 %	–
5 H	0.035 %	0.17 %	0.027 %	0.23 %	–
10 H	0.028 %	0.025 %	0.033 %	0.51 %	–

Inductance^{3,7} – Measure by Transfer Method w/ General Radio 1482 series inductors

Calibrations performed at: DET location					
Frequency					
Range	≤ 100 Hz	≤ 200 Hz	≤ 400 Hz	≤ 1 kHz	≤ 10 kHz
100 μH	0.48 %	0.18 %	0.074 %	0.095 %	0.076 %
200 μH	0.52 %	0.49 %	0.36 %	0.23 %	0.32 %
500 μH	0.019 %	0.12 %	0.078 %	0.062 %	0.12 %
1 mH	0.24 %	0.071 %	0.048 %	0.059 %	0.046 %
5 mH	0.24 %	0.074 %	0.14 %	0.12 %	0.047 %
10 mH	0.068 %	0.073 %	0.032 %	0.028 %	0.043 %
100 mH	0.025 %	0.071 %	0.048 %	0.044 %	0.057 %
500 mH	0.071 %	0.071 %	0.56 %	0.053 %	–
1 H	0.032 %	0.072 %	0.026 %	0.03 %	–
5 H	0.043 %	0.20 %	0.031 %	0.27 %	–
10 H	0.035 %	0.029 %	0.038 %	0.59 %	–

Parameter/Range	Frequency	CMC ^{2,6,7} (±)	Comments	Location
Inductance ³ – Measure				
1 μH	(1.5 to 20) kHz (>20 to 100) kHz	12 % + 0.013 μH 1.2 % + 0.059 μH	Fluke PM6304C	DET, CLEV, CHIC
10 μH	(250 to 1500) Hz (>1.5 to 20) kHz (>20 to 100) kHz	12 % + 0.013 μH 1.2 % + 0.013 μH 0.46 % + 0.013 μH		
100 μH	(75 to 200) Hz (>200 to 1500) Hz (>1.5 to 20) kHz (>20 to 100) kHz	12 % + 0.059 μH 1.2 % + 0.013 μH 0.12 % + 0.013 μH 0.46 % + 0.013 μH		
1 mH	(50 to 60) Hz (>60 to 200) Hz (>0.2 to 20) kHz (>20 to 100) kHz	12 % + 0.012 mH 1.2 % + 0.012 mH 0.12 % + 0.012 mH 0.46 % + 0.012 mH		
10 mH	(50 to 60) Hz (>60 to 200) Hz (>0.2 to 2) kHz (>2 to 20) kHz (>20 to 100) kHz	1.2 % + 0.012 mH 0.12 % + 0.012 mH 0.060% + 0.012 mH 0.12 % + 0.012 mH 0.46 % + 0.012 mH		
100 mH	(50 to 60) Hz (>60 to 2000) Hz (>2 to 20) kHz (>20 to 100) kHz	0.12 % + 0.12 mH 0.058 % + 0.12 mH 0.12 % + 0.12 mH 0.46 % + 0.12 mH		

Parameter/Range	Frequency	CMC ^{2, 6, 7} (\pm)	Comments	Location
Inductance ³ – Measure (cont)				
1 H	50 Hz to 2 kHz (>2 to 20) kHz (>20 to 100) kHz	0.059 % + 0.12 mH 0.12 % + 0.12 mH 0.46 % + 0.12 mH	Fluke PM6304C	DET, CLEV, CHIC
10 H	(50 to 300) Hz >300 Hz to 20 kHz (>20 to 100) kHz	0.06 % 0.12 % 1.2 %		
100 H	(50 to 3000) Hz (>3 to 15) kHz (>15 to 75) kHz	0.12 % 1.2 % 12 %		
1000 H	(50 to 300) Hz (>0.3 to 3.0) kHz (>3.0 to 15) kHz	0.12 % 0.06 % 12 %		
Inductance – Generate				
100 μ H 1 mH 10 mH 100 mH 1 H 10 H	400 Hz, 1 kHz	1.2 % 0.13 % 0.083 % 0.083 % 0.24 % 1.4 %	GenRad 1482	CHIC
Inductance – Generate				
100 μ H 10 mH 100 mH 10 H	400 Hz, 1 kHz	1.2 % 0.083 % 0.083 % 1.4 %	GenRad 1482	CLEV

Parameter/Equipment	Range	CMC ² (±)	Comments	Location
Electrical Calibration of RTDs ³ – Generate				
Pt 385, 100 Ω	(-200 to 80) °C (-80 to 100) °C (100 to 300) °C (300 to 400) °C (400 to 600) °C (600 to 800) °C	0.013 °C 0.02 °C 0.024 °C 0.026 °C 0.033 °C 0.038 °C	Fluke 7526A	DET, CLEV, CHIC
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	0.013 °C 0.015 °C 0.017 °C 0.022 °C 0.026 °C 0.032 °C		
Pt 3916, 100 Ω	(-200 to -190) °C (-190 to -80) °C (-80 to 0) °C (0 to 100) °C (100 to 300) °C (300 to 400) °C (400 to 600) °C (600 to 630) °C	0.01 °C 0.013 °C 0.015 °C 0.017 °C 0.022 °C 0.026 °C 0.031 °C 0.033 °C		
Pt 385, 200 Ω	(-200 to -80) °C (-80 to 0) °C (0 to 100) °C (100 to 260) °C (260 to 300) °C (300 to 400) °C (400 to 630) °C	0.053 °C 0.056 °C 0.06 °C 0.06 °C 0.069 °C 0.071 °C 0.088 °C		
Pt 385, 500 Ω	(-200 to 0) °C (0 to 100) °C (100 to 300) °C (300 to 400) °C (400 to 630) °C	0.026 °C 0.028 °C 0.034 °C 0.038 °C 0.045 °C		

Parameter/Equipment	Range	CMC ² (±)	Comments	Location
Electrical Calibration of RTDs ³ – Generate (cont)				
Pt 385, 1000 Ω	(-200 to 0) °C (0 to 100) °C (100 to 300) °C (300 to 400) °C (400 to 630) °C	0.015 °C 0.018 °C 0.024 °C 0.026 °C 0.033 °C	Fluke 7526A	DET, CLEV, CHIC
Ni 120, 120 Ω	(-80 to 260) °C	0.009 °C		
Cu 427, 10 Ω	(-100 to 260) °C	0.11 °C		
SPRT	(-200 to 660) °C	0.06 °C		
Thermocouple ³ – Indicating Systems & Measure				
Type B	(600 to 800) °C (800 to 1550) °C 1550 to 1820) °C	0.35 °C 0.28 °C 0.22 °C	Fluke 7526A	DET, CLEV, CHIC
Type C	(0 to 1000) °C (1000 to 1800) °C (1800 to 2000) °C (2000 to 2316) °C	0.16 °C 0.23 °C 0.26 °C 0.35 °C		
Type E	(-250 to -200) °C (-200 to -100) °C (-100 to 0) °C (0 to 600) °C (600 to 1000) °C	0.25 °C 0.12 °C 0.09 °C 0.08 °C 0.1 °C		
Type J	(-210 to -100) °C (-100 to 800) °C (800 to 1200) °C	0.14 °C 0.09 °C 0.1 °C		
Type K	(-250 to -200) °C (-200 to -100) °C (-100 to 500) °C (500 to 800) °C (800 to 1372) °C	0.46 °C 0.16 °C 0.1 °C 0.1 °C 0.13 °C		

Parameter/Equipment	Range	CMC ² (±)	Comments	Location
Thermocouple ³ – Indicating Systems & Measure (cont)				
Type N	(-250 to -200) °C (-200 to -100) °C (-100 to 0) °C (0 to 100) °C (100 to 800) °C (800 to 1300) °C	0.73 °C 0.23 °C 0.12 °C 0.11 °C 0.1 °C 0.12 °C	Fluke 7526A	DET, CLEV, CHIC
Type R	(50 to -25) °C (-25 to 0) °C (0 to 100) °C (100 to 400) °C (400 to 600) °C (600 to 1000) °C (1000 to 1600) °C (1600 to 1767) °C	0.55 °C 0.45 °C 0.39 °C 0.28 °C 0.22 °C 0.21 °C 0.19 °C 0.23 °C		
Type S	(-50 to -25) °C (-25 to 0) °C (0 to 100) °C (100 to 400) °C (400 to 600) °C (600 to 1000) °C (1000 to 1600) °C (1600 to 1767) °C	0.51 °C 0.43 °C 0.38 °C 0.29 °C 0.23 °C 0.22 °C 0.22 °C 0.26 °C		
Type T	(-250 to -200) °C (-200 to -100) °C (-100 to 0) °C (0 to 200) °C (200 to 400) °C	0.35 °C 0.16 °C 0.11 °C 0.09 °C 0.09 °C		
Type U	(-200 to 0) °C (0 to 200) °C (200 to 600) °C	0.16 °C 0.1 °C 0.1 °C		CLEV

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

Parameter/Range	Frequency	CMC ^{2, 5, 6, 11} (±)	Comments	Location
Power Meter ³ – Power Reference @ 1 mW	50 MHz	0.34 % + 58 μW	N432A w/ 478A or 8478A	DET
	50 MHz	1.9 %	432B, 478A-H76	CLEV, CHIC
Power Accuracy	3 μW to 100 mW	0.29 %	Range calibrator	DET, CLEV, CHIC
Power Sensor Calibration Factor ³	100 kHz 200 kHz (0.2 to 1) MHz 1 MHz to 3 GHz (3 to 10) GHz (10 to 18) GHz (18 to 19) GHz (19 to 26.5) GHz	1.0 % CF 0.61 % CF 0.59 % CF 0.60 % CF 0.74 % CF 0.87 % CF 2.5 % CF 3.0 % CF	Power sensor calibration system w. Tegam F1130B and 1135B	DET CF = Calibration Factor
Amplitude Modulation ³ – Measure				
100 kHz to 10 MHz	Depth: (5 to 99) %	0.75 %	Measuring receiver system E44XA	DET
10 MHz to 3 GHz	(5 to 20) % (20 to 99) %	2.5 % 0.50 %		
(3 to 26.5) GHz	(5 to 20) % (20 to 99) %	4.5 % 1.5 %		
(26.5 to 31.15) GHz	(5 to 20) % (20 to 99) %	6.8 % 1.9 %		
(31.15 to 50) GHz	(5 to 20) % (20 to 99) %	26 % 6.0 %		
Amplitude Modulation ³ – Measure				
100 kHz to 26.5 GHz	Depth: (5 to 99) %	1.4 %	Agilent 8902A	CLEV, CHIC

Parameter/Range	Frequency	CMC ^{2, 5, 6, 11} (\pm)	Comments	Location
Frequency Modulation ³ – Measure Mod Rate: 20 Hz to 10 kHz Dev.: 200 Hz to 40 kHz ($\beta > 0.2$) Mod Rate: 50 Hz to 200 kHz Dev.: 250 Hz to 400 kHz ($\beta > 0.2$)	250 kHz to 10 MHz 10 MHz to 6.6 GHz (6.6 to 13.2) GHz (13.2 to 31.15) GHz (31.15 to 50) GHz	1.0 % 1.0 % 1.0 % 1.0 %	Measuring receiver system E444XA β is the ratio of the frequency deviation to the modulation rate	DET
Frequency Modulation ³ – Measure 100 kHz to 26.5 GHz Dev: Up to 400 kHz	(20 to 50) Hz 50 Hz to 100 kHz (100 to 200) kHz	5.8 % 1.4 % 5.8 %	Agilent 8902A	CLEV, CHIC
Phase Modulation ³ – Measure Mod Rate: (0.2 to 20) kHz 0.3 rad < Dev \leq 0.7 rad Dev > 0.7 rad 0.6 rad < Dev \leq 2.0 rad Dev > 2.0 rad 1.2 rad < Dev \leq 4.0 rad Dev > 4.0 rad 1.3 rad < Dev \leq 4.0 rad Dev > 4.0 rad 2.4 rad < Dev \leq 8.0 rad Dev > 8.0 rad	100 kHz to 6.6 GHz (6.6 to 13.2) GHz (13.2 to 26.5) GHz (26.5 to 31.5) GHz (31.5 to 50) GHz	3.0 % 1.0 % 3.0 % 1.0 % 3.0 % 1.0 % 3.0 % 1.0 %	Measuring receiver system E444XA	DET
Phase Modulation ³ – Measure 100 kHz to 26.5 GHz	200 Hz to 10 kHz 200 Hz to 20 kHz	4.7 % 3.5 %	Agilent 8902A	CLEV, CHIC

Parameter/Range	Frequency	CMC ^{2, 5, 6, 11} (±)	Comments	Location
Relative Power ³ – Measure (0 to -10) dB (-10 to -20) dB (-20 to -30) dB (-30 to -40) dB (-40 to -50) dB (-50 to -60) dB (-60 to -70) dB (-70 to -80) dB (-80 to -90) dB (-90 to -100) dB (-100 to -110) dB (-110 to -120) dB (-120 to -130) dB	100 kHz to 26.5 GHz	0.018 dB 0.019 dB 0.019 dB 0.056 dB 0.056 dB 0.057 dB 0.057 dB 0.094 dB 0.094 dB 0.095 dB 0.096 dB 0.096 dB 0.097 dB	Measuring receiver system, E444XA	DET
Relative Power ³ – Measure (0 to -10) dB (-10 to -20) dB (-20 to -30) dB (-30 to -40) dB (-40 to -50) dB (-50 to -60) dB (-60 to -70) dB (-70 to -80) dB (-80 to -90) dB (-90 to -100) dB (-100 to -110) dB (-110 to -120) dB	10 MHz to 26.5 GHz 10 MHz to 26.5 GHz 10 MHz to 26.5 GHz 10 MHz to 26.5 GHz 10 MHz to 26.5 GHz 10 MHz to 26.5 GHz 10 MHz to 26.5 GHz 10 MHz to 26.5 GHz 10 MHz to 26.5 GHz 10 MHz to 26.5 GHz 10 MHz to 26.5 GHz 10 MHz to 26.5 GHz	0.046 dB 0.053 dB 0.080 dB 0.098 dB 0.11 dB 0.12 dB 0.13 dB 0.17 dB 0.18 dB 0.19 dB 0.19 dB 0.21 dB	Agilent 8902A	CLEV, CHIC
Absolute Power ³ – Measure (-70 to -30) dBm (-30 to + 10) dBm (+10 to +20) dBm	10 MHz to 18 GHz 100 kHz to 4.2 GHz (4.2 to 18) GHz (18 to 26.5) GHz 100 kHz to 4.2 GHz (4.2 to 18) GHz (18 to 26.5) GHz	2.7 % 1.4 % 1.9 % 2.4 % 3.3 % 3.5 % 3.8 %	Power meter w/: 8484A, N-type 8482A H85, N-type 8481A H85, N-type 8485A H85, 3.5 mm 8482A H85, N-type 8481A H85, N-type 8485A H85, 3.5 mm	DET, CLEV, CHIC

Parameter/Equipment	Range	CMC ^{2, 6, 11} (\pm)	Comments	Location
Reflection ³ S ₁₁ /S ₂₂ – Measure				
Type-N connectors:				DET
Linear Mag.	9 kHz to 2 GHz	(± 0.004 to ± 0.014) dB	Vector network analyzer with E8364A and verification and calibration kits	
Linear Phase		(± 0.75 to ± 8.0) °		
Linear Mag.	(2 to 18) GHz	(± 0.026 to ± 0.053) dB		
Linear Phase		(± 3.8 to ± 9.5) °		
3.5 mm connectors:				
45 MHz to 2 GHz	Linear Mag.	(± 0.015 to ± 0.021) dB	Vector network analyzer with E8364A and verification and calibration kits	
	Linear Phase	(± 0.99 to ± 3.9) °		
(2 to 20) GHz	Linear Mag.	(± 0.016 to ± 0.039) dB		
	Linear Phase	(± 2.3 to ± 6.2) °		
(20 to 26.5) GHz	Linear Mag.	(± 0.016 to ± 0.040) dB		
	Linear Phase	(± 2.4 to ± 6.7) °		
2.4 mm connectors:				
45 MHz to 2 GHz	Linear Mag.	(± 0.016 to ± 0.023) dB		
	Linear Phase	(± 1.2 to ± 7.3) °		
(2 to 20) GHz	Linear Mag.	(± 0.016 to ± 0.028) dB		
	Linear Phase	(± 1.5 to ± 7.5) °		
(20 to 40) GHz	Linear Mag.	(± 0.020 to ± 0.042) dB		
	Linear Phase	(± 2.5 to ± 7.7) °		
(40 to 50) GHz	Linear Mag.	(± 0.023 to ± 0.052) dB		
	Linear Phase	(± 3.1 to ± 8.0) °		

Parameter/Range	Frequency	CMC ^{2, 5, 6, 11} (\pm)	Comments	Location
Return Loss (VSWR)	5 MHz to 2 GHz (2 to 12.5) GHz (12.5 to 18) GHz	0.62 dB 0.72 dB 1.4 dB	8902A, SWR Bridges	CLEV, CHIC
Transmission ³ S ₁₂ /S ₂₁ – Measure				
Type-N connectors				
Linear Mag.	9 kHz to 2 GHz	(\pm 0.043 to \pm 9.4) dB	Vector network analyzer with E8364A and verification and calibration kits	DET
Linear Phase		(\pm 0.30 to \pm 78) °		
Linear Mag.	(2 to 18) GHz	(\pm 0.19 to \pm 1.9) dB		
Linear Phase		(\pm 1.5 to \pm 15) °		
3.5 mm connectors				
Linear Mag.	45 MHz to 2 GHz	(\pm 0.052 to \pm 5.9) dB		
Linear Phase		(\pm 0.40 to \pm 76) °		
Linear Mag.	(2 to 20) GHz	(\pm 0.13 to \pm 1.9) dB		
Linear Phase		(\pm 1.2 to \pm 15) °		
Linear Mag.	(20 to 26.5) GHz	(\pm 0.16 to \pm 3.4) dB		
Linear Phase		(\pm 1.7 to \pm 28) °		
2.4 mm connectors				
Linear Mag.	45 MHz to 2 GHz	(\pm 0.052 to \pm 8.2) dB		
Linear Phase		(\pm 0.47 to \pm 39) °		
Linear Mag.	(2 to 20) GHz	(\pm 0.093 to \pm 1.9) dB		
Linear Phase		(\pm 0.99 to \pm 15) °		
Linear Mag.	(20 to 40) GHz	(\pm 0.17 to \pm 3.4) dB		
Linear Phase		(\pm 1.7 to \pm 29) °		
Linear Mag.	(40 to 50) GHz	(\pm 0.27 to \pm 3.8) dB		
Linear Phase		(\pm 2.4 to \pm 33) °		

Parameter/Equipment	Range	CMC ^{2, 6, 11} (\pm)	Comments	Location
Transmission S12/S21 – Measure Type-N connectors: Linear Mag. Linear Phase Linear Mag. Linear Phase	30 kHz to 2 GHz (2 to 6) GHz	(± 0.61 to ± 45) ^o (± 0.11 to ± 9.5) dB (± 0.60 to 45) ^o (± 0.12 to 9.5) dB	Vector network analyzer with calibration kits	CLEV, CHIC
Single Side-Band Phase Noise ³ – Measure Noise Floor: -110 dB -110 dB -130 dB -140 dB -150 dB -155 dB -155 dB -155 dB	Carrier: 50 kHz to 26.5 GHz Offset Freq: 10 Hz 100 Hz 1 kHz 10 kHz 100 kHz 1 MHz 10 MHz 100 MHz	5.3 dB 5.3 dB 5.3 dB 5.3 dB 5.3 dB 5.3 dB 5.3 dB 5.3 dB	Agilent E4448A option 226	DET
Single Side-Band Phase Noise ³ – Measure Noise Floor: (approximately) -80 dB -95 dB -110 dB -118 dB -118 dB -118 dB -145 dB -150 dB	Carrier: (1 to 26) MHz Offset Freq: 10 Hz 100 Hz 1 kHz 10 kHz 100 kHz 1 MHz 10 MHz 100 MHz	3.0 dB 2.2 dB 1.1 dB 0.76 dB 0.87 dB 0.46 dB 0.46 dB 0.46 dB	Agilent E4440A opt. 226 Noise floor for any given frequency may be degraded due to SSB noise floor of the reference generator	CHIC

Parameter/Equipment	Range	CMC ^{2, 5, 6} (±)	Comments	Location
ESD Guns –				
Contact Voltage (Positive & Negative)	(2 to 30) kV	2.3 %	ISO 10605 IEC/EN 61000-4-2 SAE J1113-13	DET
Peak Current	(2 to 16) kA	2.4 %		
Rise Time	1 ns pulse	50 ps		

VII. Fluid Quantities

Parameter/Equipment	Range	CMC ^{2, 5, 6, 11} (±)	Comments	Location
Hydrometers ³	(0.7 to 1.2) sp. gr. (1.2 to 2.0) sp. gr.	0.0007 sp. gr. 0.0012 sp. gr.	ASTM E126; by comparison using reference hydrometer	DET, CLEV
Gas Flow	(1 to 1000) sccm (1000 to 10 000) sccm (10 000 to 50 000) sccm	0.38 % + 0.019 sccm 0.39 % 0.44 %	Cal-bench system	DET
Gas Flow ³	(1 to 1000) sccm (1 to 10) slm (10 to 30) slm (30 to 60) slm (60 to 100) slm	0.26 % + 0.02 % of FS 0.26 % + 0.02 % of FS 0.28 % + 0.02 % of FS 0.4 % + 0.03 % of FS 1.4 % + 0.03 % of FS	In the CMC, FS is Full Scale, DHI molbloc system	CLEV
Volume ³ – To Contain (Beakers, Cylinders, Flasks, Proving Cans, etc)	(0 to 4000) mL (4 to 30) L	0.05 mL 0.38 mL	Gravimetric/ electronic balances	DET
To Deliver (Burets, Dispensers, Pipettes, Syringes, Titrators)	(0.1 to 30) mL (30 to 160) mL	0.047 mL 0.42 mL		
Volume	Up to 400 mL (400 to 4000) mL (4 to 30) L	0.01 mL 0.05 mL 0.37 mL	Gravimetric/ electronic balances	CLEV

Parameter/Equipment	Range	CMC ^{2, 5, 6, 11} (\pm)	Comments	Location
Viscosity ³ – Ford, Dip and Other Viscosity Cups	Cup Nos. 1 through 5	2.8 %	ASTM D1200, D4212, ISO-2431	DET, CLEV

VIII. Mechanical

Parameter/Equipment	Range	CMC ^{2, 5, 6, 11} (\pm)	Comments	Location
Mass Measurement	Up to 200 g 200 g to 2.3 kg (2.3 to 32) kg	1.2 μ g/g + 25 μ g 0.94 μ g/g + 0.80 mg 0.77 μ g/g + 11 mg	Electronic balance, mass comparison	DET
Mass Measurement	Up to 400 g (400 to 4000) g (4 to 31) kg	0.01 g 0.04 g 0.32 g	Electronic balance	CLEV
Mass Measurement	Up to 4000 g (4 to 31) kg	0.04 g 0.32 g	Electronic balance	CHIC
Balances ³	(0.001 to 7.4) kg 1 mg to 220 g 1 mg to 220 g	5 μ g/g 10 μ g/g 20 μ g/g	Class 1 weights Class 2 weights Class 3 weights	DET, CLEV, CHIC
Scales	2 mg to 38 kg Up to 1500 lbf (1000 to 4000) lbf	0.020 % 0.022 % 0.11 %	Class F weights Class 6 weights	DET, CLEV, CHIC
Force ³ – Compression & Tension	1000 lbf 1400 lbf 100 lbf	0.025 % 0.025 % 0.025%	Deadweight Deadweight Deadweight	DET CLEV CHIC
Force ³ – Compression & Tension	(1000 to 50 000) lbf (1400 to 50 000) lbf (100 to 25 000) lbf	0.025 % 0.038 % 0.034 %	Standard cells Standard cells Standard cells	DET CLEV CHIC
Wheel Load Scales & Dynamometers ³	(200 to 5000) lbf (5000 to 10 000) lbf (10 000 to 25 000) lbf	0.70 lbf 1.3 lbf 7.2 lbf	H-frame with standard load cells	CLEV

Parameter/Equipment	Range	CMC ^{2, 5, 6, 11} (±)	Comments	Location
Torque – Tools	Up to 215 ozf·in Up to 800 lbf·ft (800 to 1000) lbf·ft (20 to 160) ozf·in (8 to 30) lbf·in (30 to 300) lbf·ft (300 to 800) lbf·ft	0.59 % 0.29 % 0.50 % 0.42 % 0.29 % 0.24 % 0.23 %	Waters 6500 Digital torque tester Digital torque tester Digital torque tester Digital torque tester Digital torque tester Digital torque tester	DET, CLEV, CHIC DET DET CLEV, CHIC CLEV, CHIC CLEV, CHIC CLEV
Torque – Measuring Equipment	(1 to 100) ozf·in (4 to 200) lbf·in (20 to 2000) lbf·in (150 to 5000) lbf·ft	0.10 % 0.049 % 0.031 % 0.036 %	Torque arms and masses	DET
Torque – Measuring Equipment	(0.5 to 125) ozf·in (0.125 to 20) lbf·ft (8 to 250) lbf·ft (250 to 1000) lbf·ft	0.51 % 0.031 % + 0.011 lbf·ft 0.031 % + 0.09 lbf·ft 0.03 % + 0.23 lbf·ft	Torque arms and masses	CLEV
Pressure – Measure and Generate				
Hydraulic	(2400 to 12 000) psi (6 to 2400) psi (0 to 10 000) psi (0 to 10 000) psi	0.0077 % 0.0054 % 0.068 % 0.12 %	Ruska 2400HL DWT Ruska 2400HL DWT M&G TQ-100 DWT M&G DM-T-100 DWT	DET DET CLEV CHIC
Pneumatic	(0.2 to 600) psig (0.5 to 23) psia (0 to 2) inH ₂ O	0.0031 % 0.010 % + 0.00003 psi 0.005 in H ₂ O	Ruska 2465 DWT PPC3 Dwyer 1430 Hook Gage	DET DET DET, CLEV, CHIC
Pneumatic	(23 to 1015) psia (0.02 to 1515) psia (-14.5 to 100) psig (0.5 to 100) psia	0.01 % 0.011 % 0.018 % 0.018 % + 0.03 psi	PPC3 Mensor CPC6000 DPI515 DPI515	DET CLEV CHIC CHIC
Direct Verification of Durometers ³ –				
Spring Force	All scales	0.6 points	Shore durocalibrator and scale	DET, CLEV
Indenter Shape		Pass/Fail	Optical comparator	DET, CLEV

Parameter/Equipment	Range	CMC ^{2, 5, 6} (±)	Comments	Location
Accelerometers – Frequency Response	100 Hz (ref) 159 Hz (ref) (5 to 100) Hz 100 Hz to 1 kHz (1 to 10) kHz	1.5 % 1.7 % 2.9 % 2.0 % 2.5 %	Vibration transducer calibration system referenced @ 1 g	DET
Accelerometers – Amplitude Response	(1 to 1000) g	0.82 %	Centrifugal calibration system	DET
Indirect Verification of Rockwell Hardness Testers ³	HRA: High Middle Low HRBW: High Middle Low HRC: High Middle Low HREW: High Middle Low HRRW High Middle HR15N High Middle Low HR15T High Middle Low	0.17 HRA 0.27 HRA 0.43 HRA 0.48 HRBW 0.63 HRBW 0.58 HRBW 0.22 HRC 0.39 HRC 0.97 HRC 1.1 HREW 0.83 HREW 1.1 HREW 0.29 HRRW 0.44 HRRW 0.22 HR15N 0.76 HR15N 0.86 HR15N 0.22 HR15T 0.76 HR15T 0.86 HR15T	ASTM E18 w/ traceable blocks	DET, CLEV, CHIC



Parameter/Equipment	Range	CMC ^{2,6} (±)	Comments	Location
Indirect Verification of Rockwell Hardness Testers ³ (cont)	HR30N: High Middle Low HR30TW: High Middle Low HR45N: High Middle Low	0.20 HR30N 0.50 HR30N 0.30 HR30N 1.2 HR30TW 0.6 HR30TW 0.2 HR30TW 0.81 HR45N 0.57 HR45N 0.61 HR45N	ASTM E18 w/ traceable blocks	DET, CLEV, CHIC

IX. Optical Quantities

Parameter/Equipment	Range	CMC ^{2,11} (±)	Comments	Location
Gloss	20°, 60°, 85°	0.59 gloss units	Reference gloss standard	DET

X. Thermodynamics

Parameter/Equipment	Range	CMC ^{2,5,6,11} (±)	Comments	Location
Temperature ³ – Measure	(-197 to 660) °C	0.0009 % + 0.008 °C	PRT and Burns 5610	DET
	(-197 to 660) °C	0.0036 % + 0.012 °C	PRT and HART 1502	CLEV, CHIC
Temperature ³ – Measuring Equipment	(-78 to 660) °C	0.0009 % + 0.008 °C	PRT and Burns 5610, dry wells, dry ice bath	DET
	(-78 to 660) °C	0.0036 % + 0.012 °C	PRT and HART 1502, dry well, dry ice bath	CLEV, CHIC

Parameter/Equipment	Range	CMC ^{2, 5, 6, 11} (\pm)	Comments	Location
Infrared Temperature – Measuring Equipment	(-30 to 150) °C (150 to 500) °C	0.5 °C 0.35 % + 0.5 °C	Hart 9133 Hart 4181 Hart 4180	DET, CLEV
Infrared Temperature – Measuring Equipment	(-30 to 150) °C (100 to 300) °C (300 to 500) °C	0.50 °C 0.83 °C 1.1 °C	Hart 9133 9132	CHIC
Relative Humidity – Measuring Equipment	(15 to 95) % RH	0.7 % RH	Thunder Scientific 2500	DET
Relative Humidity ³ – Measuring Equipment	(10 to 95) % RH	1.3 % RH	Kaymont 2000	DET, CLEV, CHIC
Relative Humidity ³ – Measure	(10 to 98) % RH	1.2 % RH	Vaisala MI70	DET, CLEV, CHIC

XI. Time & Frequency

Parameter/Equipment	Range	CMC ^{2, 4, 6, 11} (\pm)	Comments	Location
Frequency – Measuring Equipment ³	1 mHz to 26.5 GHz 1 mHz to 50 GHz 1 mHz to 26.5 GHz	5 pHz/Hz 590 pHz/Hz 590 pHz/Hz	GPS and signal generator Rb oscillator and sig gen Rb oscillator and sig gen	DET CHIC CLEV
Frequency ³ – Measure	1 mHz to 26.5 GHz 1 mHz to 40 GHz 1 mHz to 26.5 GHz	5 pHz/Hz 590 pHz/Hz 590 pHz/Hz	GPS and counter Rb oscillator and counter Rb oscillator and counter	DET CHIC CLEV

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

² Calibration and Measurement Capability Uncertainty (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. CMCs represent expanded uncertainties expressed at approximately the 95 % level of confidence, usually using a coverage factor of $k = 2$. The actual measurement uncertainty of a specific calibration performed by the laboratory may be greater than the CMC due to the behavior of the customer's device and to influences from the circumstances of the specific calibration.

³ Field calibration service is available for this calibration and this laboratory meets A2LA R104 – *General Requirements: Accreditation of Field Testing and Field Calibration Laboratories* for these calibrations. Please note the actual measurement uncertainties achievable on a customer's site can normally be expected to be larger than the CMC found on the A2LA Scope. Allowance must be made for aspects such as the environment at the place of calibration and for other possible adverse effects such as those caused by transportation of the calibration equipment. The usual allowance for the actual uncertainty introduced by the item being calibrated, (e.g. resolution) must also be considered and this, on its own, could result in the actual measurement uncertainty achievable on a customer's site being larger than the CMC.

⁴ In the statement of CMC, L is the numerical value of the nominal length of the device measured in inches; D is the numerical value of the nominal diameter of the device measured in inches; D_i is the numerical value of the nominal diagonal of the plate measured in feet; R is the numerical value of the resolution of the device in its respective units; and F is the applied frequency in kHz

⁵ In the statement of CMC, percentages are percentage of reading unless otherwise indicated.

⁶ CMC components that can be reasonably attributed to the Unit Under Test have not been utilized in the calculation of the CMC value for this measurement parameter.

⁷ The stated measured values are determined using the indicated instrument (see Comments). This capability is suitable for the calibration of the devices intended to measure or generate the measured value in the ranges indicated. CMC's are expressed as either a specific value that covers the full range or as a percent or fraction of the reading plus a fixed floor specification.

⁸ 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.

⁹ The locations of the laboratories that can perform the calibrations are given by a letter code with valid to dates given in the table below:

Location	Code	Valid to Dates
1200 North Old US, 23 PO Box 559, Hartland, MI 48353	DET	May 31, 2020
735 Beta Dr., PO Box 559, Cleveland, OH 44143	CLEV	May 31, 2020
718 West Algonquin Road, PO Box 559, Arlington Heights, IL 60005	CHIC	May 31, 2020

¹⁰ This scope meets A2LA's P112 *Flexible Scope Policy*.

¹¹ The type of instrument or material being calibrated is defined by the parameter. This indicates the laboratory is capable of calibrating instruments that measure or generate the values in the ranges indicated for the listed measurement parameter.



Accredited Laboratory

A2LA has accredited

TRESCAL, INC.

Cleveland, OH

for technical competence in the field of

Calibration

This laboratory is accredited in accordance with the recognized International Standard ISO/IEC 17025:2017 *General requirements for the competence of testing and calibration laboratories*. This laboratory also meets the requirements of ANSI/NCSLI Z540-1-1994 and the requirements of ANSI/NCSLI Z540.3-2006 and R205 – Specific Requirements: Calibration Laboratory Accreditation Program. This accreditation demonstrates technical competence for a defined scope and the operation of a laboratory quality management system (*refer to joint ISO-ILAC-IAF Communiqué dated April 2017*).



Presented this 9th day of May 2019.

A blue ink signature of the Vice President of Accreditation Services.

Vice President, Accreditation Services
For the Accreditation Council
Certificate Number 1022.02
Valid to May 31, 2020

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