



## Accredited Laboratory

A2LA has accredited

### NOVASTAR METROLOGY

*Livonia, MI*

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/NCCL Z540-1-1994 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 10<sup>th</sup> day of April 2019.

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

Vice President, Accreditation Services  
For the Accreditation Council  
Certificate Number 1277.01  
Valid to March 31, 2021

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



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

NOVASTAR METROLOGY  
35200 Plymouth Road  
Livonia, MI 48150  
Guy Howe Phone: 734 453 8003

CALIBRATION

Valid To: March 31, 2021

Certificate Number: 1277.01

In recognition of the successful completion of the A2LA evaluation process, accreditation is granted to this laboratory to perform the following calibrations<sup>1,9</sup>:

I. Acoustical Quantities

Parameter/Range	Frequency	CMC <sup>2</sup> (±)	Comments
Microphone Acoustic Level –  Sensitivity: ¼ in ½ in 1 in  Frequency Response: ¼ in ½ in 1 in	   114 dB @ 250 Hz 114 dB @ 250 Hz 114 dB @ 250 Hz  20 Hz to 126 kHz 20 Hz to 20 kHz 20 Hz to 20 kHz	   0.20 dB 0.22 dB 0.22 dB  0.49 dB 0.21 dB 0.20 dB	   2900 B Larson Davis sound level calibration system (comparison method)
Sound Level Calibrators –  (94 to 114) dB	  (0.25 to 1) kHz	  0.27 dB	  2900 B Larson Davis sound level calibration system (comparison method)

Parameter/Range	Frequency	CMC <sup>2</sup> (±)	Comments
Sound Level Meters – (94 to 114) dB	(0.125 to 2) kHz	0.64 dB	Acoustic method
	(0.02 to 20) kHz	0.12 dB	Electrical method

## II. Chemical

Parameter/Equipment	Range	CMC <sup>2, 6, 10</sup> (±)	Comments
pH – Measuring Equipment	4.01 pH unit 7.01 pH unit 10.01 pH unit	0.012 pH unit + 0.6R 0.016 pH unit + 0.6R 0.018 pH unit + 0.6R	Accredited solutions
Conductance – Measuring Equipment	1.015 mS/cm 1.408 mS/cm 12.85 mS/cm 111.3 mS/cm	0.0058 mS/cm + 0.6R 0.010 mS/cm + 0.6R 0.087 mS/cm + 0.6R 0.88 mS/cm + 0.6R	Accredited solutions

## III. Dimensional

Parameter/Equipment	Range	CMC <sup>2, 6</sup> (±)	Comments
Micrometers <sup>3</sup>	Up to 36 in	(4.6 + 5.0L) μin + 0.6R	Gage blocks
Tri-Bore	Up to 5 in	(6.4 + 4.4L) μin/in	Ring gage set
Calipers <sup>3</sup>	Up to 36 in	(2.9 + 11L) μin + 0.6R	Gage blocks
Angle	Up to ±90 °	3.7'	Optical protractor
	Up to 60 °	0.000 048 °/°	Sine bar/gage blocks

Parameter/Equipment	Range	CMC <sup>2,6</sup> ( $\pm$ )	Comments
Optical Comparators <sup>3</sup> – Magnification	10 $\times$ to 100 $\times$	420 $\mu$ in	Magnification scale
Linear Accuracy	(0.001 to 6) in	150 $\mu$ in + 0.6R	Glass scale
Angle	(30/60/90/120/150) $^{\circ}$	0.0048 $^{\circ}$ + 0.6R	
Cylindrical Gages – Pins, Plugs, Discs	(0.003 to 4.0) in	(13 + 1.1L) $\mu$ in	ULM and gage blocks
Height Gages <sup>3,8</sup>	Up to 48 in	(25 + 4.9L) $\mu$ in	Gage blocks
Indicators <sup>3</sup> – Dial and Digital	Up to 4 in Up to 100 mm	(1.4 + 4.5L) $\mu$ in + 0.6R (54 + 7.6L) nm + 0.6R	Gage blocks
Gage Blocks	(0.01 to 4) in (0.5 to 100) mm (4 to 8) in	(1.6 + 3.7L) $\mu$ in (89 + 3.4L) nm (16 + 2L) $\mu$ in	Twin head comparison ULM
Linear Displacement	Up to 1600 in	(23 + 1.1L) $\mu$ in	Renishaw laser system
Radius Gage	(0.005 to 5) in	0.0031 in	Optical comparator
Threaded Plug Gages – Pitch diameter (5 to 80 TPI)	Up to 8 in	(31 + 1.3L) $\mu$ in	ULM, thread wires
Major Diameter	Up to 4 in	(13 + 1.1L) $\mu$ in	ULM and gage blocks
Thread rings – Pitch diameter (5 to 80 TPI)	Up to 6.5 in	(30 + 4.6L) $\mu$ in	ULM, Tee ball probes
Gage Balls	Up to 4 in	(11 + 3.9L) $\mu$ in	ULM
Ring Gages	Up to 8 in	(5 + 2.4L) $\mu$ in	ULM, master rings and gage blocks

Parameter/Equipment	Range	CMC <sup>2,6</sup> (±)	Comments
Foils and Thickness Gages	Up to 8 in	(16 + 1.9L) μin	ULM
Linear Scales/Reticles and Stage Micrometers	Up to 12 in	0.000 63 in	Optical comparator
Durometers –	Types A,B,C,D,E,O, and DO		ASTM D2240
Indenter Shape and Extension:	Indenter extension length	12 μm	Gage blocks
	Tip radius	12 μm	Optical comparator
Spring Force	All scales	0.0047 N	Dual pan balance and weights

#### IV. Electrical – DC/Low Frequency

Parameter/Range	Frequency	CMC <sup>2,4,10</sup> (±)	Comments
AC Current <sup>3</sup> – Generate			
(0 to 220) μA	(10 to 20) Hz (20 to 40) Hz (40 to 1000) Hz (1 to 5) kHz (5 to 10) kHz	0.082 % + 25 nA 0.041 % + 20 nA 0.017 % + 16 nA 0.073 % + 40 nA 0.19 % + 80 nA	Fluke 5700A
(0.22 to 2.2) mA	(10 to 20) Hz (20 to 40) Hz (40 to 1000) Hz (1 to 5) kHz (5 to 10) kHz	0.082 % + 40 nA 0.041 % + 20 nA 0.017 % + 35 nA 0.068 % + 400 nA 0.19 % + 800 nA	
(2.2 to 22) mA	(10 to 20) Hz (20 to 40) Hz (40 to 1000) Hz (1 to 5) kHz (5 to 10) kHz	0.082 % + 400 nA 0.041 % + 350 nA 0.017 % + 350 nA 0.068 % + 4 μA 0.19 % + 8 μA	

Parameter/Range	Frequency	CMC <sup>2, 4, 10</sup> ( $\pm$ )	Comments
AC Current <sup>3</sup> – Generate (cont)			
(22 to 220) mA	(10 to 20) Hz (20 to 40) Hz (40 to 1000) Hz (1 to 5) kHz (5 to 10) kHz	0.082 % + 4 $\mu$ A 0.041 % + 3.5 $\mu$ A 0.017 % + 3.5 $\mu$ A 0.068 % + 40 $\mu$ A 0.19 % + 80 $\mu$ A	Fluke 5700A
(0.22 to 2.2) A	(20 to 1000) Hz (1 to 5) kHz (5 to 10) kHz	0.077 % + 35 $\mu$ A 0.087 % + 80 $\mu$ A 1 % + 160 $\mu$ A	
(1.1 to 3) A	(10 to 45) Hz 45 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz	0.19 % + 0.1 mA 0.062 % + 0.1 mA 0.62 % + 1 mA 2.6 % + 5 mA	Fluke 5520A
(3 to 11) A	(45 to 100) Hz (0.1 to 1) kHz (1 to 5) kHz	0.062 % + 2 mA 0.1 % + 2 mA 2.6 % + 2 mA	
(11 to 20.5) A	(45 to 100) Hz (0.1 to 1) kHz (1 to 5) kHz	0.12 % + 5 mA 0.15 % + 5 mA 3.1 % + 5 mA	
(> 20.5 to 1025) A	(45 to 65) Hz (65 to 440) Hz	0.67 % + 0.9 A 1.2 % + 0.9 A	Fluke 552XA with Fluke 5500A/coil
AC Current <sup>3</sup> – Measure			
(0 to 100) $\mu$ A	(10 to 20) Hz (20 to 45) Hz (45 to 100) Hz 100 Hz to 1 kHz	0.51 % + 3 nA 0.21 % + 3 nA 0.13 % + 3 nA 0.13 % + 3 nA	HP 3458A, option II
(0.1 to 1) mA	(10 to 20) Hz (20 to 45) Hz (45 to 100) Hz 100 Hz to 5 kHz (5 to 20) kHz	0.49 % + 0.2 $\mu$ A 0.21 % + 0.2 $\mu$ A 0.1 % + 0.2 $\mu$ A 0.061 % + 0.2 $\mu$ A 0.085 % + 0.2 $\mu$ A	
(1 to 10) mA	(10 to 20) Hz	0.49 % + 2 $\mu$ A	

Parameter/Range	Frequency	CMC <sup>2, 4, 10</sup> ( $\pm$ )	Comments
AC Current <sup>3</sup> – Measure (cont)			
(1 to 10) mA	(20 to 45) Hz (45 to 100) Hz 100 Hz to 5 kHz (5 to 20) kHz	0.17 % + 2 $\mu$ A 0.085 % + 2 $\mu$ A 0.061 % + 2 $\mu$ A 0.069 % + 2 $\mu$ A	HP 3458A, option II
(10 to 100) mA	(10 to 20) Hz (20 to 45) Hz (45 to 100) Hz 100 Hz to 5 kHz (5 to 20) kHz	0.49 % + 20 $\mu$ A 0.18 % + 20 $\mu$ A 0.078 % + 20 $\mu$ A 0.061 % + 20 $\mu$ A 0.085 % + 20 $\mu$ A	
100 mA to 1 A	(10 to 20) Hz (20 to 45) Hz (45 to 100) Hz 100 Hz to 5 kHz	0.5 % + 0.2 mA 0.24 % + 0.2 mA 0.15 % + 0.2 mA 0.18 % + 0.2 mA	
(1 to 10) A	(45 to 1000) Hz (1 to 5) kHz	0.03 % 0.08 %	HP 3458A w/ Fluke Y5020A current shunt
AC Voltage <sup>3</sup> – Generate			
(0 to 2.2) mV	(10 to 20) Hz (20 to 40) Hz (40 to 20 000) Hz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz (500 to 1000) kHz	0.095 % + 4.5 $\mu$ V 0.073 % + 4.5 $\mu$ V 0.073 % + 4.5 $\mu$ V 0.12 % + 4.5 $\mu$ V 0.15 % + 7 $\mu$ V 0.21 % + 13 $\mu$ V 0.3 % + 25 $\mu$ V 0.54 % + 25 $\mu$ V	Fluke 5700A
(2.2 to 22) mV	(10 to 20) Hz (20 to 40) Hz (40 to 20 000) Hz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz (500 to 1000) kHz	0.064 % + 5 $\mu$ V 0.025 % + 5 $\mu$ V 0.015 % + 5 $\mu$ V 0.045 % + 5 $\mu$ V 0.1 % + 7 $\mu$ V 0.13 % + 12 $\mu$ V 0.2 % + 25 $\mu$ V 0.41 % + 25 $\mu$ V	

Parameter/Range	Frequency	CMC <sup>2, 4, 10</sup> ( $\pm$ )	Comments
AC Voltage <sup>3</sup> – Generate (cont)			
(22 to 220) mV	(10 to 20) Hz (20 to 40) Hz (40 to 20 000) Hz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz (500 to 1000) kHz	0.064 % + 13 $\mu$ V 0.025 % + 8 $\mu$ V 0.013 % + 8 $\mu$ V 0.037 % + 8 $\mu$ V 0.1 % + 25 $\mu$ V 0.13 % + 25 $\mu$ V 0.2 % + 35 $\mu$ V 0.4 % + 80 $\mu$ V	Fluke 5700A
(0.22 to 2.2) V	(10 to 20) Hz (20 to 40) Hz (40 to 20 000) Hz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz (500 to 1000) kHz	0.06 % + 80 $\mu$ V 0.019 % + 25 $\mu$ V 0.0091 % + 6 $\mu$ V 0.014 % + 16 $\mu$ V 0.029 % + 70 $\mu$ V 0.05 % + 130 $\mu$ V 0.12 % + 350 $\mu$ V 0.26 % + 850 $\mu$ V	
(2.2 to 22) V	(10 to 20) Hz (20 to 40) Hz (40 to 20 000) Hz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz (500 to 1000) kHz	0.06 % + 800 $\mu$ V 0.019 % + 250 $\mu$ V 0.0091 % + 60 $\mu$ V 0.014 % + 160 $\mu$ V 0.029 % + 350 $\mu$ V 0.059 % + 1.5 mV 0.15 % + 4.3 mV 0.32 % + 8.5 mV	
(22 to 220) V*	(10 to 20) Hz (20 to 40) Hz (40 to 20 000) Hz (20 to 50) kHz (50 to 100) kHz	0.059 % + 8 mV 0.019 % + 2.5 mV 0.0096 % + 0.8 mV 0.025 % + 3.5 mV 0.059 % + 8 mV	*220V range subject to 2.2E7 V-Hz limitation
(220 to 1100) V**	(15 to 50) Hz (50 to 1000) Hz	0.046 % + 16 mV 0.0091 % + 3.5 mV	**1100 V range subject to 250 V limitation



Parameter/Range	Frequency	CMC <sup>2, 4, 10</sup> ( $\pm$ )	Comments
AC Voltage <sup>3</sup> – Measure			
(0 to 10) mV	(40 to 1000) Hz (1 to 20) kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz	0.023 % + 1.1 $\mu$ V 0.035 % + 1.1 $\mu$ V 0.12 % + 1.1 $\mu$ V 0.58 % + 1.1 $\mu$ V 4.6 % + 2 $\mu$ V	HP 3458A, option II
(10 to 100) mV	(40 to 1000) Hz (1 to 20) kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 1000) kHz (1 to 2) MHz	0.0087 % + 2 $\mu$ V 0.017 % + 2 $\mu$ V 0.035 % + 2 $\mu$ V 0.093 % + 2 $\mu$ V 0.35 % + 10 $\mu$ V 1.2 % + 10 $\mu$ V 1.7 % + 10 $\mu$ V	
100 mV to 1 V	(40 to 1000) Hz (1 to 20) kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 1000) kHz (1 to 2) MHz	0.0081 % + 20 $\mu$ V 0.016 % + 20 $\mu$ V 0.035 % + 20 $\mu$ V 0.092 % + 20 $\mu$ V 0.35 % + 0.1 mV 1.2 % + 0.1 mV 1.7 % + 0.1 mV	
(1 to 10) V	(40 to 1000) Hz (1 to 20) kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 1000) kHz	0.0081 % + 0.2 mV 0.016 % + 0.2 mV 0.035 % + 0.2 mV 0.92 % + 0.2 mV 0.35 % + 1 mV 1.2 % + 1 mV	
(10 to 100) V	(40 to 1000) Hz (1 to 20) kHz (20 to 50) kHz (50 to 100) kHz	0.023 % + 2 mV 0.023 % + 2 mV 0.040 % + 2 mV 0.14 % + 2 mV	
(100 to 1000) V	(40 to 1000) Hz	0.51 % + 20 mV	

Parameter/Range	Frequency	CMC <sup>2, 4, 10</sup> (±)	Comments
Capacitance <sup>3</sup> – Generate  (0.19 to 0.4) nF (0.4 to 1.1) nF (1.1 to 3.3) nF (3.3 to 11) nF (11 to 33) nF (33 to 110) nF (110 to 330) nF (0.33 to 1.1) μF (1.1 to 3.3) μF (3.3 to 11) μF (11 to 33) μF (33 to 110) μF (110 to 330) μF (0.33 to 1.1) mF (1.1 to 3.3) mF (3.3 to 11) mF (11 to 33) mF (33 to 110) mF	10 Hz to 10 kHz 10 Hz to 10 kHz 10 Hz to 3 kHz 10 Hz to 1 kHz 10 Hz to 1 kHz 10 Hz to 1 kHz 10 Hz to 1 kHz (10 to 600) Hz (10 to 300) Hz (10 to 150) Hz (10 to 120) Hz (10 to 80) Hz (10 to 50) Hz (0 to 20) Hz (0 to 6) Hz (0 to 2) Hz (0 to 0.6) Hz (0 to 0.2) Hz	0.58 % + 0.01 nF 0.52 % + 0.01 nF 0.52 % + 0.01 nF 0.28 % + 0.01 nF 0.26 % + 0.1 nF 0.26 % + 0.1 nF 0.26 % + 0.3 nF 0.26 % + 1 nF 0.26 % + 3 nF 0.26 % + 10 nF 0.41 % + 30 nF 0.46 % + 0.1 μF 0.47 % + 0.3 μF 0.46 % + 1 μF 0.47 % + 3 μF 0.47 % + 10 μF 0.76 % + 30 μF 1.1 % + 0.10 mF	Fluke 5520A
Oscilloscopes –  Amplitude, DC Signal 50 Ω Load 1 MΩ Load  Amplitude, Square Wave 50 Ω Load  1 MΩ Load  Time Marker into 50 Ω Load-Source  Leveled Sine Wave Relative to 50 kHz [5 mV to 5.5 V] p-p	(-6.6 to 6.6) V (-130 to 130) V  ±1 mV to ±6.6 V <sub>p-p</sub> 10 Hz to 10 kHz  ±1 mV to ±130 V <sub>p-p</sub> 10 Hz to 1 kHz  5 s to 50 ms 20 ms to 2 ns  50 kHz to 100 MHz (100 to 300) MHz (300 to 600) MHz (550 to 1100) MHz (1.1 to 3.2) GHz (3.2 to 6.0) GHz	0.29 % IV + 40 μV 0.058 % IV + 40 μV  0.29 % IV + 40 μV  0.12 % IV + 40 μV  29 parts in 10 <sup>6</sup> + 1000 parts in 10 <sup>6</sup> /s 2.9 parts in 10 <sup>6</sup>  2.0 % 2.5 % 4.7 % 4.3 % 5.3 % 5.3 %	Fluke 5522A/SC1100              Fluke 9500B with active head(s)

Parameter/Equipment	Range	CMC <sup>2, 4, 10</sup> ( $\pm$ )	Comments
Oscilloscopes – (cont)			
Rise Time	10 Hz to 2 MHz (125 to 175) ps	20 ps	Fluke 9500B with active head(s)
	10 Hz to 1 MHz (59 to 81) ps	14 ps	
Capacitance – Fixed Points	100 pF 1 nF to 1 $\mu$ F	0.059 % 0.016 %	Standard capacitors
Capacitance – Measure	10 pF to 1.1 $\mu$ F	0.018 %	Gen Rad 1615A capacitance bridge
DC Current <sup>3</sup> – Generate	0.1 nA to 220 $\mu$ A (0.22 to 2.2) mA (2.2 to 22) mA (22 to 220) mA (0.22 to 2.2) A	130 $\mu$ A/A + 8 nA 130 $\mu$ A/A + 8 nA 130 $\mu$ A/A + 80 nA 150 $\mu$ A/A + 0.8 $\mu$ A 200 $\mu$ A/A + 25 $\mu$ A	Fluke 5700A
	(1.1 to 3) A (3 to 11) A (11 to 20) A	0.039 % + 40 $\mu$ A 0.052 % + 0.33 mA 0.1 % + 0.75 mA	Fluke 5520A
DC Current <sup>3</sup> – Measure	(10 to 100) $\mu$ A (0.1 to 1) mA (1 to 10) mA (10 to 100) mA (0.1 to 1) A	22 $\mu$ A/A + 0.8 nA 21 $\mu$ A/A + 5 nA 21 $\mu$ A/A + 50 nA 35 $\mu$ A/A + 0.5 $\mu$ A 0.011 % + 10 $\mu$ A	HP 3458A, option II
	(1 to 10) A (10 to 20) A	0.032 % + 0.6 mA 0.027 % + 3.3 mA	HP 3458A w/ Fluke Y5020 shunt
DC Voltage <sup>3</sup> – Measure	(0 to 100) mV (0.1 to 1) V (1.0 to 10) V (10 to 100) V (100 to 1000) V	5.2 $\mu$ V/V + 0.3 $\mu$ V 4.1 $\mu$ V/V + 0.3 $\mu$ V 4.0 $\mu$ V/V + 0.5 $\mu$ V 6.2 $\mu$ V/V + 30 $\mu$ V 63 $\mu$ V/V + 0.1 mV*	HP 3458A, option II  *Add 12 mV/V · (V <sub>in</sub> /1000) <sup>2</sup> for input >100 V

Parameter/Equipment	Range	CMC <sup>2, 4, 10</sup> ( $\pm$ )	Comments
DC Voltage <sup>3</sup> – Generate	(0 to 220) mV (0 to 2.2) V (2.2 to 11) V (11 to 22) V (22 to 220) V (220 to 1100) V	18 $\mu$ V/V + 0.6 $\mu$ V 21 $\mu$ V/V + 1 $\mu$ V 9 $\mu$ V/V + 3.5 $\mu$ V 18 $\mu$ V/V + 6.5 $\mu$ V 20 $\mu$ V/V + 80 $\mu$ V 12 $\mu$ V/V + 500 $\mu$ V	Fluke 5700A
Inductance – Measure  @ 100 Hz Fixed Values	100 $\mu$ H to 5 H	0.3 %	Standard inductor set with Gen Rad 1632A bridge as transfer standard
Inductance – Generate	100 $\mu$ H to 5.0 H	0.33 %	Gen Rad 1482 standard inductors
Resistance <sup>3</sup> – Measure	(0 to 10) $\Omega$ (10 to 100) $\Omega$ 100 $\Omega$ to 1 k $\Omega$ (1 to 10) k $\Omega$ (10 to 100) k $\Omega$ 100 k $\Omega$ to 1 M $\Omega$ (1 to 10) M $\Omega$ (10 to 100) M $\Omega$ 100 M $\Omega$ to 1 G $\Omega$	15 $\mu\Omega/\Omega$ + 0.05 m $\Omega$ 13 $\mu\Omega/\Omega$ + 0.50 m $\Omega$ 10 $\mu\Omega/\Omega$ + 5.0 m $\Omega$ 10 $\mu\Omega/\Omega$ + 50 m $\Omega$ 10 $\mu\Omega/\Omega$ + 50 m $\Omega$ 16 $\mu\Omega/\Omega$ + 2.0 $\Omega$ 52 $\mu\Omega/\Omega$ + 100 $\Omega$ 0.051 % + 1.0 k $\Omega$ 0.5 % + 10 k $\Omega$	HP 3458A, option II
Resistance <sup>3</sup> – Generate	(0 to 11) $\Omega$ (11 to 33) $\Omega$ (33 to 110) $\Omega$ (110 to 330) $\Omega$ (0.33 to 1.1) k $\Omega$ (1.1 to 3.3) k $\Omega$ (3.3 to 11) k $\Omega$ (11 to 33) k $\Omega$ (33 to 110) k $\Omega$ (110 to 330) k $\Omega$ (0.33 to 1.1) M $\Omega$ (0.50 to 3.3) M $\Omega$ (3.3 to 11) M $\Omega$ (11 to 33) M $\Omega$ (33 to 110) M $\Omega$ (110 to 330) M $\Omega$ (330 to 1100) M $\Omega$	46 $\mu\Omega/\Omega$ + 0.0010 $\Omega$ 32 $\mu\Omega/\Omega$ + 0.0015 $\Omega$ 30 $\mu\Omega/\Omega$ + 0.0015 $\Omega$ 29 $\mu\Omega/\Omega$ + 0.0020 $\Omega$ 29 $\mu\Omega/\Omega$ + 0.0020 $\Omega$ 29 $\mu\Omega/\Omega$ + 0.020 $\Omega$ 29 $\mu\Omega/\Omega$ + 0.020 $\Omega$ 29 $\mu\Omega/\Omega$ + 0.020 $\Omega$ 29 $\mu\Omega/\Omega$ + 0.2 $\Omega$ 29 $\mu\Omega/\Omega$ + 0.20 $\Omega$ 36 $\mu\Omega/\Omega$ + 2.0 $\Omega$ 39 $\mu\Omega/\Omega$ + 2.0 $\Omega$ 77 $\mu\Omega/\Omega$ + 30 $\Omega$ 0.016 % + 50 $\Omega$ 0.031 % + 2.5 k $\Omega$ 0.084 % + 3.0 k $\Omega$ 0.33 % + 0.10 M $\Omega$ 1.8 % + 0.50 M $\Omega$	Fluke 5520A

Parameter/Equipment	Range	CMC <sup>2, 4, 10</sup> ( $\pm$ )	Comments		
Resistance – Generate, Fixed Values	1 and 10 m $\Omega$	4.7 $\mu\Omega/\Omega$	L&N reference resistors		
	(0.1, 1, 10, 100) $\Omega$ (1, 10, 100, 1000) k $\Omega$	4.7 $\mu\Omega/\Omega$ 4.7 $\mu\Omega/\Omega$	ESI SR1010 reference resistors		
	0 $\Omega$	4.8 $\mu\Omega$	Copper shorting block		
	1 $\Omega$	120 $\mu\Omega$	Fluke 5700A		
	1.9 $\Omega$	210 $\mu\Omega$			
	10 $\Omega$	340 $\mu\Omega$			
	19 $\Omega$	620 $\mu\Omega$			
	100 $\Omega$	2 m $\Omega$			
	190 $\Omega$	3.8 m $\Omega$			
	1 k $\Omega$	15 m $\Omega$			
	1.9 k $\Omega$	29 m $\Omega$			
	10 k $\Omega$	140 m $\Omega$			
	19 k $\Omega$	270 m $\Omega$			
	100 k $\Omega$	1.6 $\Omega$			
	190 k $\Omega$	3.1 $\Omega$			
	1 M $\Omega$	23 $\Omega$			
	1.9 M $\Omega$	48 $\Omega$			
	10 M $\Omega$	480 $\Omega$			
	19 M $\Omega$	1.1 k $\Omega$			
	100 M $\Omega$	13 k $\Omega$			
Electrical Thermocouple <sup>3</sup> – Generate and Measure	Type C	(0 to 150) $^{\circ}\text{C}$		0.35 $^{\circ}\text{C}$	Fluke 5520A
		(150 to 650) $^{\circ}\text{C}$		0.3 $^{\circ}\text{C}$	
		(650 to 1000) $^{\circ}\text{C}$	0.36 $^{\circ}\text{C}$		
		(1000 to 1800) $^{\circ}\text{C}$	0.58 $^{\circ}\text{C}$		
		(1800 to 2316) $^{\circ}\text{C}$	0.97 $^{\circ}\text{C}$		
	Type E	(-250 to -100) $^{\circ}\text{C}$	0.76 $^{\circ}\text{C}$		
		(-100 to -25) $^{\circ}\text{C}$	0.32 $^{\circ}\text{C}$		
		(-25 to 350) $^{\circ}\text{C}$	0.25 $^{\circ}\text{C}$		
		(350 to 650) $^{\circ}\text{C}$	0.26 $^{\circ}\text{C}$		
		(650 to 1000) $^{\circ}\text{C}$	0.31 $^{\circ}\text{C}$		

Parameter/Equipment	Range	CMC <sup>2,4</sup> (±)	Comments
Electrical Thermocouple <sup>3</sup> – Generate and Measure (cont)			
Type J	(-210 to -100) °C (-100 to -30) °C (-30 to 150) °C (150 to 760) °C (760 to 1200) °C	0.31 °C 0.19 °C 0.16 °C 0.2 °C 0.27 °C	Fluke 5520A
Type K	(-200 to -100) °C (-100 to -25) °C (-25 to 120) °C (120 to 1000) °C (1000 to 1372) °C	0.38 °C 0.21 °C 0.19 °C 0.3 °C 0.46 °C	
Type N	(-200 to -100) °C (-100 to -25) °C (-25 to 120) °C (120 to 410) °C (410 to 1300) °C	0.46 °C 0.25 °C 0.22 °C 0.21 °C 0.31 °C	
Type R	(0 to 250) °C (250 to 400) °C (400 to 1000) °C (1000 to 1767) °C	0.75 °C 0.48 °C 0.38 °C 0.47 °C	
Type S	(0 to 250) °C (250 to 1000) °C (1000 to 1400) °C (1400 to 1767) °C	0.54 °C 0.42 °C 0.4 °C 0.53 °C	
Type T	(-250 to -150) °C (-150 to 0) °C (0 to 120) °C (120 to 400) °C	0.73 °C 0.28 °C 0.19 °C 0.16 °C	
Type U	(-200 to 0) °C (0 to 600) °C	0.65 °C 0.31 °C	

Parameter/Equipment	Range	CMC <sup>2</sup> (±)	Comments
Electrical RTD Simulation <sup>3</sup> –			
Pt 385, 100 Ω	(-200 to -80) °C (-80 to 0) °C (0 to 100) °C (100 to 300) °C (300 to 400) °C (400 to 630) °C (630 to 800) °C	0.058 °C 0.058 °C 0.085 °C 0.1 °C 0.12 °C 0.12 °C 0.27 °C	Fluke 5520A
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	0.058 °C 0.058 °C 0.081 °C 0.1 °C 0.12 °C 0.14 °C	
Pt 3916, 100 Ω	(-200 to -190) °C (-190 to -80) °C (-80 to 0) °C (0 to 100) °C (100 to 260) °C (260 to 300) °C (300 to 400) °C (400 to 600) °C (600 to 630) °C	0.29 °C 0.046 °C 0.058 °C 0.069 °C 0.081 °C 0.092 °C 0.1 °C 0.12 °C 0.27 °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 600) °C (600 to 630) °C	0.046 °C 0.046 °C 0.046 °C 0.058 °C 0.14 °C 0.15 °C 0.16 °C 0.18 °C	
Pt 385, 500 Ω	(-200 to -80) °C (-80 to 0) °C (0 to 100) °C (100 to 260) °C (260 to 300) °C (300 to 400) °C (400 to 600) °C (600 to 630) °C	0.047 °C 0.058 °C 0.058 °C 0.069 °C 0.093 °C 0.093 °C 0.1 °C 0.13 °C	

Parameter/Equipment	Range	CMC <sup>2</sup> (±)	Comments
Electrical RTD Simulation <sup>3</sup> (cont) –			
Pt 385, 1000 Ω	(-200 to -80) °C (-80 to 0) °C (0 to 100) °C (100 to 260) °C (260 to 300) °C (300 to 400) °C (400 to 600) °C (600 to 630) °C	0.035 °C 0.035 °C 0.046 °C 0.058 °C 0.069 °C 0.081 °C 0.081 °C 0.27 °C	Fluke 5520A
PtNi 385, 120 Ω	(-80 to 0) °C (0 to 100) °C (100 to 260) °C	0.092 °C 0.092 °C 0.16 °C	
Cu 427, 10 Ω	(-100 to 260) °C	0.35 °C	

V. Electrical – RF/Microwave

Parameter/Range	Frequency	CMC <sup>2,4</sup> (±)	Comments
RF Absolute Power <sup>3,5</sup> – Measure			
1 mW Reference	50 MHz	0.45 %	HP 8478B sensor w/ HP 432A power meter and type N connector
(-20 to +10) dBm	(0.01 to 0.05) GHz (0.05 to 1) GHz (1 to 3) GHz (3 to 7) GHz (7 to 12.4) GHz (12.4 to 15) GHz (15 to 16) GHz (16 to 18) GHz	1.3 % + 0.6 μW 1.4 % + 0.6 μW 1.7 % + 0.6 μW 2.1 % + 0.6 μW 2.7 % + 0.6 μW 3.1 % + 0.6 μW 3.3 % + 0.6 μW 3.5 % + 0.6 μW	
(-20 to +30) dBm	100 kHz to 2.6 GHz	0.13 dB	HP 11722A sensor w/ HP 8902A, HP 11793A and type N connector



Parameter/Range	Frequency	CMC <sup>2,4,10</sup> ( $\pm$ )	Comments
RF Absolute Power <sup>3,5</sup> – Measure (cont)	50 MHz to 18 GHz	0.10 dB	HP 11792A sensor w/ HP 8902A, HP 11793A, and APC 3.5 mm connector
RF Absolute Power <sup>3,5</sup> – Generate			
Sine Wave into 50 $\Omega$			
(10 to 3) V <sub>p-p</sub>	(0.001 to 100) kHz 100 kHz to 20 MHz	0.12 dB 0.37 dB	HP 3325 synthesized function generator w/ BNC connector
2.99 V <sub>p-p</sub> to 1 mV <sub>p-p</sub>	0.001 Hz to 100 kHz 100 kHz to 10 MHz	0.26 dB 0.60 dB	
2.99 V <sub>p-p</sub> to 100 mV <sub>p-p</sub>	(10 to 20) MHz	0.60 dB	
(99.9 to 1) mV <sub>p-p</sub>	(10 to 20) MHz	0.60 dB	
(13.01 to -4.99) dBm	200 Hz to 80 MHz	0.19 dB	
(-6.99 to -44.99) dBm	200 Hz to 80 MHz	0.21 dB	
(-46.99 to -84.99) dBm	200 Hz to 80 MHz	0.29 dB	
RF Tuned Power – Measure			
(0 to -127) dB	(2.5 to 1300) MHz	0.11 dB + 0.000 83 %	HP 11722A/11792A sensors w/ HP 8902A, 11793A converter and type N or type APC 3.5 mm connectors
(0 to -127) dB	2.5 MHz to 18 GHz	0.11 dB + 0.004 %	

Parameter/Range	Frequency	CMC <sup>2, 4, 10</sup> ( $\pm$ )	Comments
Amplitude Modulation – Generate  AM Flatness Carrier Frequency  (11 to 13.5) MHz Depth: (0 to 99) %	Rate Frequency:  50 Hz to 50 kHz 20 Hz to 100 kHz	0.16 % 0.32 %	HP 11715A AM/FM test source
Amplitude Modulation – Measure  Carrier Frequency  (0.15 to 10) MHz Depth: (5 to 99) % (0 to 99) %  (10 to 1300) MHz Depth: (5 to 99) %  (1.3 to 18) GHz Depth: (5 to 99) %  10 MHz to 18 GHz Depth: (0 to 99) %	Rate Frequency:  50 Hz to 10 kHz 20 Hz to 10 kHz  50 Hz to 50 kHz  50 Hz to 50 kHz  20 Hz to 100 kHz	3.5 % + 1 digit 4.1 % + 1 digit  1.6 % + 1 digit  3.2 % + 1 digit  4.2 % + 1 digit	HP 8902A w/ HP 11722A and 11792A sensors and HP 11793A converter
Frequency Modulation – Measure  Carrier Frequency  (0.25 to 10) MHz $\leq$ 40 kHz Peak Deviation  10 MHz to 18 GHz $\leq$ 400 kHz Peak Deviation	Rate Frequency:  20 Hz to 10 kHz  50 Hz to 100 kHz 20 Hz to 400 kHz	2.3 % + 1 digit  3.0 % + 1 digit 6.7 % + 1 digit	HP 8902A w/ HP 11722A and 11792A sensors and 11793A converter

Parameter/Range	Frequency	CMC <sup>2, 4, 10</sup> (±)	Comments
Frequency Modulation – Generate  FM Flatness Carrier Frequency  (11 to 13.5) MHz  (88 to 108) MHz  (352 to 432) MHz	Rate Frequency:  DC to 100 kHz (100 to 200) kHz  DC to 100 kHz (100 to 200) kHz  DC to 100 kHz (100 to 200) kHz	  0.33 % 0.43 %  0.34 % 0.43 %  0.34 % 0.43 %	  HP 11715A AM/FM test source
Phase Modulation – Measure  Carrier Frequency  (0.15 to 10) MHz  10 MHz to 18 GHz	Rate Frequency:  200 Hz to 10 kHz  200 Hz to 20 kHz	  4.8 % + 1 digit  4.6 % + 1 digit	  HP 8902A w/ HP 11792A and 11722A sensors
RF Volts – Measure, Fixed Points  3 V	(1 to 10) MHz (10 to 30) MHz (30 to 50) MHz (50 to 70) MHz (70 to 80) MHz (80 to 100) MHz	 0.091 % 0.11 % 0.19 % 0.30 % 0.32 % 0.38 %	 HP 11049A thermal voltage converter

VI. Mechanical

Parameter/Equipment	Range	CMC <sup>2, 4, 6, 10</sup> (±)	Comments
Torque Wrench	(10 to 3120) in·lbf  (0 to 1000) in·ozf  (0 to 600) ft·lbf	0.24 % of IV from (10 to 100) % FS  0.49 % of IV (10 to 100) % of range  1.8 ft·lbf (10 to 100) % of range	Larson STWCS  Futek torque system
Torque – Measuring Equipment  Transducers	(0.6 to 42) ft·lbf (1.7 to 600) ft·lbf	0.032 % IV 0.042 % IV	Torque arm/dead weight
Acceleration/ Vibration – Measuring Equipment	(5 to 2000) Hz (2 to 10) kHz	1.3 % IV 1.1 % IV	Back to back comparison method
Pressure Gauges – Measuring Equipment  Pneumatic    Hydraulic	(-5 to 5) psig  (-15 to 50) psig  (-15 to 300) psig  (-14.5 to 1000) psig  (1000 to 10 000) psig  (0 to 10) in·H <sub>2</sub> O	0.0065 % IV + 0.0005 psig  0.0055 % IV + 0.0033 psig  0.0085 % IV + 0.015 psig  0.011 % IV + 0.051 psig  0.041 %  0.006 in·H <sub>2</sub> O	Pace 6000    Deadweight tester  Meriam manometer
Absolute Pressure – Measuring Equipment and Measure	(9 to 20) psia (0.5 to 80) psia (0.5 to 330) psia (0.5 to 1030) psia	0.0058 % IV 0.0058 % IV 0.0063 % IV 0.0064 % IV	Pace 6000

Parameter/Equipment	Range	CMC <sup>2,4,6</sup> (±)	Comments
Scales and Balances <sup>3</sup> – Analytical Balances <sup>3</sup>	(0.5 to 629) lb (20 to 100) mg (100 to 500) mg (1 to 10) g (10 to 100) g (0.1 to 3) kg	0.01 % + 0.6R 0.031 mg + 0.19 mg/g 0.043 mg + 0.076 mg/g 0.033 mg + 0.002 mg/g 0.03 mg + 0.0023 mg/g 0.0034 % + 0.6R	ASTM Class 6 weights ASTM Class 1 weights
Force <sup>3,7</sup> – Measuring Equipment	(0.5 to 500) lbf (100 to 1000) lbf (200 to 2000) lbf (500 to 5000) lbf (1000 to 10 000) lbf (2500 to 25 000) lbf (5000 to 50 000) lbf (10 000 to 100 000) lbf (50 000 to 500 000) lbf	0.01 % IV + 0.6R 0.061 % FS 0.050 % FS 0.049 % FS 0.049 % FS 0.056 % FS 0.049 % FS 0.064 % FS 0.05 % FS	ASTM Class 6 weights Load cells Compression only
Rockwell Hardness <sup>3</sup> – Indirect Verification of Superficial Hardness Testers	HRA: Low Medium High HRBW: Low Medium High HRC: Low Medium High	0.54 HRA 0.43 HRA 0.32 HRA 0.83 HRBW 1.0 HRBW 0.79 HRBW 0.86 HRC 1.0 HRC 0.44 HRC	ASTM E18

Parameter/Equipment	Range	CMC <sup>2,4</sup> (±)	Comments
Rockwell Hardness <sup>3</sup> – Indirect Verification of Superficial Hardness Testers (cont)	HRRW: HR15N: Low Medium High HR30N: Low Medium High HR15TW: Low Medium High HR30TW: Low Medium High	1.6 HRRW  0.99 HR15N 0.80 HR15N 0.97 HR15N  0.49 HR30N 0.78 HR30N 0.38 HR30N  0.52 HR15TW 0.59 HR15TW 0.48 HR15TW  0.97 HR30TW 0.77 HR30TW 0.57 HR30TW	ASTM E18
Universal Testing Machine, Compression Testing Machines, Tension Testing Machines <sup>3</sup>	(0.5 to 500) lbf (100 to 1000) lbf (200 to 2000) lbf (500 to 5000) lbf (1000 to 10 000) lbf  (2500 to 25 000) lbf (5000 to 50 000) lbf (10 000 to 100 000) lbf (50 000 to 500 000) lbf	0.011 % IV 0.061 % FS 0.050 % FS 0.058 % FS 0.049 % FS  0.056 % FS 0.056 % FS 0.056 % FS 0.056 % FS	ASTM E4, load cells and dead weights tension and compression  Compression only

VII. Thermodynamics

Parameter/Equipment	Range	CMC <sup>2, 4, 10</sup> (±)	Comments
Temperature <sup>3</sup> – Generate	(-40 to 150) °C	0.014 °C + 42 µ°C/°C	Fluke 1502 w/ 5628 PRT in bath
	(-50 to 660) °C	0.036 °C + 0.16 m°C/°C	Fluke 1502 w/ 5609 PRT
Infrared Temperature <sup>3</sup> – Measure	(25 to 400) °C	1.9 °C + 0.001 °C/°C	Black body
Temperature <sup>3</sup> – Measure	(-50 to 660) °C	0.031 °C + 72 µ°C/°C	Fluke 1502 w/ 5628 PRT
	(93 to 649) °C	1.4 °C + 3.3 m°C/°C	Type N thermocouple
Thermocouples – Types B, C, E, J, K N, R, S, T, U	(-50 to 660) °C	0.23 °C + 0.12 m°C/°C	Fluke 5520A/ Fluke 1502A/5628
RTDs –	(-50 to 660) °C	0.038 °C	HP3458A/Hart 1502A/ 5628
Relative Humidity – Generate	(10 to 95) % RH	0.7 % RH	Thunder Scientific 2500
Relative Humidity <sup>3</sup> – Measuring Equipment	11.3 % RH 33 % RH 75.5 % RH 97.7 % RH	1.6 % RH 1.6 % RH 2.0 % RH 2.6 % RH	Vaisala HMK15
Relative Humidity <sup>3</sup> – Measure	(11.3 to 90) % RH (90 to 97.7) % RH	1.9 % RH 2.5 % RH	Vaisala MI70/HMP77B

VIII. Time & Frequency

Parameter/Equipment	Range	CMC <sup>2, 10</sup> (±)	Comments
Frequency – Measuring Equipment	10 MHz	5.7 x 10 <sup>-12</sup> Hz/Hz	NOVAS WR 2410 GPS receiver
Frequency – Measure	0.01 Hz to 18 GHz	1.6 x 10 <sup>-9</sup> Hz/Hz	NOVAS WR 2410 GPS receiver with Frequency Counter
Period – Measure	1 µs to 1000 s	1.2 x 10 <sup>-9</sup> s/s	

Parameter/Equipment	Range	CMC <sup>2</sup> (±)	Comments
Stopwatches	24 hr (2 to 120) s	33 ms 0.039 s/day	NIST RP 960-12 Timometer

<sup>1</sup> This laboratory offers commercial calibration service and field calibration service.

<sup>2</sup> 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.

<sup>3</sup> 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.

<sup>4</sup> In the statement of CMC, the value is defined as the percentage of reading unless otherwise indicated; IV represents *Indicated Value* and FS represents *Full Scale*.

<sup>5</sup> The CMCs do not include mismatch.

<sup>6</sup> In the statement of CMC,  $L$  represents the length of the unit under test in inches or millimeters, where appropriate;  $R$  represents the resolution of the unit under test.

<sup>7</sup> Greater than 100 kN, field service available only.

<sup>8</sup> Repeatability of the Unit Under Test has not been utilized in the calculation of the CMC value for this measurement parameter.

<sup>9</sup> This scope meets A2LA's *P112 Flexible Scope Policy*.

<sup>10</sup> 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.