



# CERTIFICATE OF ACCREDITATION

## The ANSI National Accreditation Board

Hereby attests that

### **Transcat - Toronto**

1435 Norjohn Ct. #8-9  
Burlington, ON L7L 0E6  
Canada

Fulfills the requirements of

### **ISO/IEC 17025:2017**

and national standards

**ANSI/NCSL Z540-1-1994 (R2002)**

and

**ANSI/NCSL Z540.3-2006 (R2013)**

In the fields of

## **CALIBRATION AND DIMENSIONAL MEASUREMENT**

This certificate is valid only when accompanied by a current scope of accreditation document.

The current scope of accreditation can be verified at [www.anab.org](http://www.anab.org).

Jason Stine, Vice President

Expiry Date: 07 September 2025  
Certificate Number: AC-2489.23



This laboratory is accredited in accordance with the recognized International Standard ISO/IEC 17025:2017.  
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).

**SCOPE OF ACCREDITATION TO ISO/IEC 17025:2017**

**AND**

**ANSI/NCSL Z540-1-1994 (R2002)**

**ANSI/NCSL Z540.3-2006 (R2013)**

**Transcat-Toronto**

1435 Norjohn Ct. #8-9

Burlington, ON L7L 0E6

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**CALIBRATION AND DIMENSIONAL MEASUREMENT**

Valid to: **September 7, 2025**

Certificate Number: **AC-2489.23**

**CALIBRATION**

**Acoustics and Vibration**

<b>Parameter/Equipment</b>	<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>	<b>Reference Standard, Method, and/or Equipment</b>
Sound Level – Source <sup>1</sup>	125 Hz to 2 kHz (74 to 104) dB	0.45 dB	General Radio 1986 Sound Level Calibrator
	4 kHz (74 to 104) dB	0.72 dB	
	125 Hz to 2 kHz 114 dB	0.33 dB	
	4 kHz 114 dB	0.6 dB	
Sound Level – Measure <sup>1</sup>	125 Hz to 2 kHz (74 to 104) dB	0.46 dB	General Radio 1986 Sound Level Calibrator with Sound Level Meter
	4 kHz (74 to 104) dB	0.73 dB	
	125 Hz to 2 kHz 114 dB	0.35 dB	
	4 kHz 114 dB	0.61 dB	



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**Chemical Quantities**

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
pH Meters	4 pH 7 pH 10 pH	0.013 pH 0.012 pH 0.012 pH	Accredited Buffer Solutions
Conductivity Meters	1 μS/cm 10 μS/cm 100 μS/cm 1 000 μS/cm 10 000 μS/cm 100 000 μS/cm	0.63 μS/cm 0.63 μS/cm 2.1 μS/cm 4.8 μS/cm 43 μS/cm 370 μS/cm	Accredited Conductivity Solutions

**Electrical – DC/Low Frequency**

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Sine Wave Flatness – Measure <sup>1</sup>	Up to 3 V 10 Hz to 1 MHz (1 to 10) MHz (10 to 30) MHz (30 to 50) MHz (50 to 80) MHz (80 to 100) MHz	0.056 % of reading 0.069 % of reading 0.11 % of reading 0.19 % of reading 0.35 % of reading 0.46 % of reading	Thermal Voltage Converter, Keysight 3458A 8.5 Digit Multimeter
Capacitance – Source <sup>1</sup> (Simulation)	(220 to 400) pF 10 Hz to 10 kHz (0.4 to 1.1) nF 10 Hz to 10 kHz (1.1 to 3.3) nF 10 Hz to 3 kHz (3.3 to 11) nF 10 Hz to 3 kHz (11 to 33) nF 10 Hz to 1 kHz (33 to 110) nF 10 Hz to 1 kHz	0.4 % of reading + 7.8 pF 0.4 % of reading + 7.8 pF 0.4 % of reading + 7.8 pF 0.21 % of reading + 7.8 pF 0.2 % of reading + 78 pF 0.21 % of reading + 78 pF	Fluke 5522A Multiproduct Calibrator

**Electrical – DC/Low Frequency**

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Capacitance – Source <sup>1</sup> (Simulation)	(110 to 330) nF	0.2 % of reading + 0.2 nF	Fluke 5522A Multiproduct Calibrator
	10 Hz to 1 kHz	0.21 % of reading + 0.8 nF	
	(0.33 to 1.1) μF	0.21 % of reading + 2.3 nF	
	(10 to 600) Hz	0.2 % of reading + 7.8 nF	
	(1.1 to 3.3) μF	0.32 % of reading + 23 nF	
	(10 to 300) Hz	0.37 % of reading + 78 nF	
	(3.3 to 11) μF	0.38 % of reading + 0.2 μF	
	(10 to 150) Hz	0.35 % of reading + 0.8 μF	
	(11 to 33) μF	0.35 % of reading + 2.3 μF	
	(10 to 120) Hz	0.35 % of reading + 7.8 μF	
	(33 to 110) μF	0.58 % of reading + 23 μF	
	(10 to 80) Hz	0.85 % of reading + 78 μF	
	(110 to 330) μF		
	DC to 50 Hz		
	(0.33 to 1.1) mF		
DC to 20 Hz			
(1.1 to 3.3) mF			
DC to 6 Hz			
(3.3 to 11) mF			
DC to 2 Hz			
(11 to 33) mF			
DC to 0.6 Hz			
(33 to 110) mF			
DC to 0.2 Hz			
Capacitance – Measure <sup>1</sup>	0.1 pF	1.4 % of reading	Agilent E4980A Precision LCR Meter
	100 kHz	1.4 % of reading	
	1 pF	0.37 % of reading	
	10 kHz	1.4 % of reading	
	100 kHz	0.28 % of reading	
	10 pF	0.28 % of reading	
	1 kHz	2.1 % of reading	
	10 kHz	0.23 % of reading	
	100 kHz	0.18 % of reading	
	100 pF	0.21 % of reading	
	100 Hz		
	1 kHz		
	10 kHz		
	100 kHz		



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Electrical – DC/Low Frequency

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Capacitance – Measure <sup>1</sup>	1 nF		Agilent E4980A Precision LCR Meter
	20 Hz	1.8 % of reading	
	100 Hz	0.3 % of reading	
	1 kHz	0.1 % of reading	
	10 kHz	0.1 % of reading	
	100 kHz	0.1 % of reading	
	10 nF		
	20 Hz	0.31 % of reading	
	100 Hz	0.12 % of reading	
	1 kHz	0.09 % of reading	
	10 kHz	0.09 % of reading	
	100 kHz	0.09 % of reading	
	100 nF		
	20 Hz	0.16 % of reading	
	100 Hz	0.09 % of reading	
	1 kHz	0.09 % of reading	
	10 kHz	0.09 % of reading	
	100 kHz	0.18 % of reading	
	1 μF		
	20 Hz	0.15 % of reading	
	100 Hz	0.09 % of reading	
	1 kHz	0.09 % of reading	
	10 kHz	0.18 % of reading	
	100 kHz	0.25 % of reading	
10 μF			
20 Hz	0.15 % of reading		
100 Hz	0.09 % of reading		
1 kHz	0.16 % of reading		
10 kHz	0.28 % of reading		
100 kHz	0.73 % of reading		
100 μF			
20 Hz	0.16 % of reading		
100 Hz	0.17 % of reading		
1 kHz	0.29 % of reading		
10 kHz	0.8 % of reading		



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Electrical – DC/Low Frequency

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Capacitance – Measure <sup>1</sup>	Up to 2 nF (2 to 20) nF (20 to 200) nF (0.2 to 2) μF (2 to 20) μF (20 to 200) μF (0.2 to 2) mF (2 to 20) mF (20 to 200) mF	0.19 % of reading + 1 pF 0.081 % of reading + 2 pF 0.049 % of reading + 10 pF 0.041 % of reading + 0.1 nF 0.042 % of reading + 1 nF 0.061 % of reading + 10 nF 0.061 % of reading + 0.1 μF 0.071 % of reading + 1 μF 0.072 % of reading + 10 μF	Fluke 8588A 8.5 Digit Multimeter
AC Current – Source <sup>1</sup>	Up to 220 μA (10 to 20) Hz (20 to 40) Hz 40 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz (0.22 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 (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 (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 (0.22 to 2.2) A 10 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz	0.031 % of reading + 16 nA 0.019 % of reading + 10 nA 0.015 % of reading + 8 nA 0.03 % of reading + 12 nA 0.11 % of reading + 65 nA 0.03 % of reading + 40 nA 0.018 % of reading + 35 nA 0.013 % of reading + 35 nA 0.021 % of reading + 0.1 μA 0.11 % of reading + 0.65 μA 0.039 % of reading + 0.4 μA 0.019 % of reading + 0.35 μA 0.014 % of reading + 0.35 μA 0.021 % of reading + 0.55 μA 0.11 % of reading + 5 μA 0.033 % of reading + 4 μA 0.018 % of reading + 3.5 μA 0.014 % of reading + 2.5 μA 0.021 % of reading + 3.5 μA 0.11 % of reading + 10 μA 0.027 % of reading + 35 μA 0.046 % of reading + 80 μA 0.7 % of reading + 0.16 mA	Fluke 5720A Multiproduct Calibrator
AC Current – Source <sup>1</sup>	(2.2 to 11) A 40 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz	0.048 % of reading + 0.17 mA 0.096 % of reading + 0.38 mA 0.36 % of reading + 0.75 mA	Fluke 5720A Multiproduct Calibrator, Fluke 5725A Amplifier

**Electrical – DC/Low Frequency**

<b>Parameter/Equipment</b>	<b>Range</b>	<b>Expanded Uncertainty of Measurement (+/-)</b>	<b>Reference Standard, Method, and/or Equipment</b>
AC Current – Source <sup>1</sup>	(11 to 20.5) A (45 to 100) Hz 100 Hz to 1 kHz (1 to 5) kHz	0.09 % of reading + 4 mA 0.12 % of reading + 4 mA 2.3 % of reading + 4 mA	Fluke 5522A Multiproduct Calibrator
AC Current – Source <sup>1</sup>	(20.5 to 40) A (10 to 100) Hz 100 Hz to 1 kHz (1 to 5) kHz	0.14 % of reading + 11 mA 0.17 % of reading + 11 mA 2.3 % of reading + 11 mA	(2) Fluke 5520A Multiproduct Calibrators in Parallel
AC Current – Source <sup>1</sup> Extended Frequency Ranges	(29 to 330) $\mu$ A (10 to 30) kHz (0.33 to 3.3) mA (10 to 30) kHz (3.3 to 33) mA (10 to 30) kHz (33 to 330) mA (10 to 30) kHz	1.2 % of reading + 0.3 $\mu$ A 0.78 % of reading + 0.5 $\mu$ A 0.31 % of reading + 3.1 $\mu$ A 0.31 % of reading + 0.2 mA	Fluke 5522A Multiproduct Calibrator
AC Current – Source <sup>1</sup>	Up to 60 Hz Up to 20 A (20 to 100) A 60 Hz to 1 kHz Up to 20 A (20 to 100) A	0.12 % of reading + 3.5 mA 0.056 % of reading + 4.6 mA 0.056 % of reading + 1.2 mA 0.05 % of reading + 2.3 mA	Current Source, Ohms Labs CS-100 Current Shunt, Keysight 3458A 8.5 Digit Multimeter
AC Current – Source <sup>1</sup>	(10 to 65) Hz (20 to 33) A (33 to 40) A (40 to 60) A (60 to 100) A (65 to 300) Hz (20 to 33) A (33 to 60) A (60 to 100) A 300 Hz to 1 kHz (20 to 33) A (33 to 60) A (60 to 100) A	0.029 % of reading + 24 mA 0.037 % of reading + 36 mA 0.038 % of reading + 36 mA 0.034 % of reading + 36 mA 0.042 % of reading + 36 mA 0.05 % of reading + 45 mA 0.052 % of reading + 45 mA 0.12 % of reading + 0.12 A 0.12 % of reading + 0.12 A 0.12 % of reading + 0.12 A	Fluke 52120A Transconductance Amplifier, Fluke 5520A Multiproduct Calibrator
AC Clamp-on Ammeters (Toroidal Type) Transformer Type Sensor <sup>1</sup>	(20 to 150) A (45 to 65) Hz (65 to 440) Hz (150 to 1 000) A (45 to 65) Hz (65 to 440) Hz	0.3 % of reading + 26 mA 0.83 % of reading + 47 mA 0.35 % of reading + 0.1 A 1.1 % of reading + 0.2 A	Fluke 5522A Multiproduct Calibrator, 50-turn Coil

**Electrical – DC/Low Frequency**

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Clamp-on Ammeters (Non-Toroidal Type) Hall Effect Sensor <sup>1</sup>	(20 to 150) A (45 to 65) Hz (65 to 440) Hz (150 to 1 000) A (45 to 65) Hz (65 to 440) Hz	0.57 % of reading + 0.2 A 1 % of reading + 0.2 A  0.6 % of reading + 0.9 A 1.3 % of reading + 0.9 A	Fluke 5522A Multiproduct Calibrator, 50-turn Coil
AC Clamp-on Ammeters (Non-Toroidal Type) Hall Effect Sensor <sup>1</sup>	(1 000 to 6 000) A (10 to 300) Hz (300 to 440) Hz	0.77 % of reading 0.77 % of reading	Fluke 52120A Transconductance Amplifier, Fluke 5520A Multiproduct Calibrator, 3 kA or 6 kA Coil
AC Current – Measure <sup>1</sup>	(1 to 20) A (50 to 100) Hz (100 to 300) Hz 300 Hz to 1 kHz (1 to 3) kHz (3 to 4) kHz (4 to 5) kHz	0.02 % of reading 0.03 % of reading 0.03 % of reading 0.06 % of reading 0.07 % of reading 0.09 % of reading	Fluke Y5020 Precision AC Current Shunt, Precision Digital Multimeter
AC Current – Measure <sup>1</sup>	Up to 60 Hz Up to 20 A (20 to 100) A 60 Hz to 1 kHz Up to 20 A (20 to 100) A	0.12 % of reading + 3.5 mA 0.056 % of reading + 4.6 mA  0.056 % of reading + 1.2 mA 0.05 % of reading + 2.3 mA	Ohms Labs CS-100 Current Shunt, Keysight 3458A 8.5 Digit Multimeter
AC High Current – Measure <sup>1</sup>	(1 to 6 000) A 60 Hz	0.17 % of reading	Rocoil 6142 (SX-170) Rogowski Coil with Integrator
AC Current – Measure <sup>1</sup>	Up to 100 $\mu$ A (10 to 20) Hz (20 to 45) Hz (45 to 100) Hz 100 Hz to 5 kHz	0.46 % of reading + 35 nA 0.17 % of reading + 35 nA 0.072 % of reading + 35 nA 0.072 % of reading + 35 nA	Agilent 3458A 8.5 Digit Multimeter



**Electrical – DC/Low Frequency**

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Current – Measure <sup>1</sup>	(0.1 to 1) mA (10 to 20) Hz (20 to 45) Hz (45 to 100) Hz 100 Hz to 5 kHz (1 to 10) mA (10 to 20) Hz (20 to 45) Hz (45 to 100) Hz 100 Hz to 5 kHz (10 to 100) mA (10 to 20) Hz (20 to 45) Hz (45 to 100) Hz 100 Hz to 5 kHz 100 mA to 1 A (10 to 20) Hz (20 to 45) Hz (45 to 100) Hz 100 Hz to 5 kHz	0.46 % of reading + 0.23 μA 0.17 % of reading + 0.23 μA 0.071 % of reading + 0.23 μA 0.038 % of reading + 0.23 μA 0.46 % of reading + 2.3 μA 0.17 % of reading + 2.3 μA 0.071 % of reading + 2.3 μA 0.038 % of reading + 2.3 μA 0.46 % of reading + 23 μA 0.17 % of reading + 23 μA 0.071 % of reading + 23 μA 0.037 % of reading + 23 μA 0.46 % of reading + 0.23 mA 0.19 % of reading + 0.23 mA 0.097 % of reading + 0.23 mA 0.12 % of reading + 0.23 mA	Agilent 3458A 8.5 Digit Multimeter
AC Current – Measure <sup>1</sup>	(0.2 to 20) μA 1 Hz to 2 kHz (2 to 10) kHz (10 to 30) kHz (20 to 200) μA 1 Hz to 2 kHz (2 to 10) kHz (10 to 30) kHz (30 to 100) kHz (0.2 to 2) mA 1 Hz to 2 kHz (2 to 10) kHz (10 to 30) kHz (30 to 100) kHz (2 to 20) mA 1 Hz to 2 kHz (2 to 10) kHz (10 to 30) kHz (30 to 100) kHz	0.2 % of reading + 2.5 nA 0.2 % of reading + 2.5 nA 0.2 % of reading + 2.5 nA 0.28 mA/A + 5 nA 0.53 mA/A + 5 nA 0.74 mA/A + 5 nA 4.1 mA/A + 10 nA 0.28 mA/A + 50 nA 0.53 mA/A + 50 nA 0.74 mA/A + 50 nA 4.1 mA/A + 0.1 μA 0.28 mA/A + 0.5 μA 0.53 mA/A + 0.5 μA 0.74 mA/A + 0.5 μA 4.1 mA/A + 1 μA	Fluke 8588A 8.5 Digit Multimeter

**Electrical – DC/Low Frequency**

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Current – Measure <sup>1</sup>	(20 to 200) mA 1 Hz to 2 kHz (2 to 10) kHz (10 to 30) kHz (0.2 to 2) A 1 Hz to 2 kHz (2 to 10) kHz (10 to 30) kHz (2 to 20) A 10 Hz to 2 kHz (2 to 10) kHz (20 to 30) A 10 Hz to 2 kHz (2 to 10) kHz	0.28 mA/A + 5 μA 0.52 mA/A + 5 μA 0.74 mA/A + 5 μA 0.3 mA/A + 0.1 mA 0.56 mA/A + 0.1 mA 0.8 mA/A + 0.1 mA 0.84 mA/A + 0.5 mA 0.86 mA/A + 0.5 mA 0.84 mA/A + 12 mA 1.2 mA/A + 12 mA	Fluke 8588A 8.5 Digit Multimeter
DC Current – Source <sup>1</sup>	Up to 220 μA (0.22 to 2.2) mA (2.2 to 22) mA (22 to 220) mA (0.22 to 2.2) A	0.004 % of reading + 6 nA 0.003 6 % of reading + 7 nA 0.003 5 % of reading + 40 nA 0.004 8 % of reading + 0.7 μA 0.008 4 % of reading + 12 μA	Fluke 5720A Multiproduct Calibrator
DC Current – Source <sup>1</sup>	(2.2 to 11) A	0.036 % of reading + 0.48 mA	Fluke 5720A Multiproduct Calibrator, Fluke 5725A Amplifier
DC Current – Source <sup>1</sup>	(11 to 20.5) A	0.093 % of reading + 0.58 mA	Fluke 5520 Multiproduct Calibrator
DC Current – Source <sup>1</sup>	(20.5 to 22) A (22 to 40) A	0.072 % of reading + 0.55 mA 0.13 % of reading + 0.82 mA	(2) Fluke 5520A Multiproduct Calibrators in Parallel
DC Current – Source <sup>1</sup>	Up to 100 A	0.008 7 % of reading + 0.58 mA	Current Source, Ohms Labs CS-100 Current Shunt, Keysight 3458A 8.5 Digit Multimeter
DC Current – Source <sup>1</sup>	(11 to 100) A	0.012 % of reading + 5 mA	Fluke 5520A Multiproduct Calibrator, Fluke 52120A Transconductance Amplifier
DC Clamp-on Ammeter (Non-Toroidal Type) Hall Effect Sensor <sup>1</sup>	(20 to 150) A (150 to 1 000) A	0.51 % of reading + 0.14 A 0.51 % of reading + 0.5 A	Fluke 5520A Multiproduct Calibrator, 50-turn Coil

**Electrical – DC/Low Frequency**

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
DC Clamp-on Ammeter (Non-Toroidal Type) Hall Effect Sensor <sup>1</sup>	(1 000 to 5 000) A	0.58 % of reading	Fluke 5520A Multiproduct Calibrator, Fluke 52120A Transconductance Amplifier, 3 kA or 6 kA Coil
DC Current – Measure <sup>1</sup>	Up to 100 $\mu$ A (0.1 to 1) mA (1 to 10) mA (10 to 100) mA (0.1 to 1) A	0.003 3 % of reading + 0.92 nA 0.002 9 % of reading + 5.8 nA 0.002 9 % of reading + 58 nA 0.004 6 % of reading + 0.58 $\mu$ A 0.013 % of reading + 12 $\mu$ A	Agilent 3458A 8.5 Digit Multimeter
DC Current – Measure <sup>1</sup>	Up to 20 $\mu$ A (20 to 200) $\mu$ A (0.2 to 2) mA (2 to 20) mA (20 to 200) mA (0.2 to 2) A (2 to 20) A (20 to 30) A	29 $\mu$ A/A + 0.4 nA 10 $\mu$ A/A + 0.39 nA 9.9 $\mu$ A/A + 3.9 nA 15 $\mu$ A/A + 39 nA 58 $\mu$ A/A + 1 $\mu$ A 0.13 mA/A + 0.1 mA 0.23 mA/A + 0.4 mA 0.55 mA/A + 4.4 mA	Fluke 8588A 8.5 Digit Multimeter
DC Current – Measure <sup>1</sup>	1 $\mu$ A to 100 mA 100 mA to 1 A (1 to 10) A (10 to 100) A (100 to 300) A	0.013 % of reading 0.015 % of reading 0.015 % of reading 0.042 % of reading 0.058 % of reading	Guideline 9211A Current Shunt, Agilent 3458A 8.5 Digit Multimeter
DC Current – Measure <sup>1</sup>	(50 to 667) A	0.12 % of reading	Empro LAB-1000-100 Current Shunt, Agilent 3458A 8.5 Digit Multimeter
DC Current – Measure <sup>1</sup>	Up to 100 A	0.008 7 % of reading + 0.58 mA	Ohms Labs CS-100 Current Shunt, Keysight 3458A 8.5 Digit Multimeter
DC High Current – Measure <sup>1</sup>	(100 to 3 000) A	0.17 % of reading + 0.36 A	Canadian Shunt 90000-1400 Current Shunt, Keysight 34470A 7.5 Digit Multimeter



ANSI National Accreditation Board

Electrical – DC/Low Frequency

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Inductance – Measure <sup>1,6</sup>	1 $\mu$ H		Agilent E4980A Precision LCR Meter
	10 kHz	1.6 % of reading	
	100 kHz	0.36 % of reading	
	10 $\mu$ H		
	10 kHz	0.37 % of reading	
	100 kHz	0.2 % of reading	
	100 $\mu$ H		
	1 kHz	0.41 % of reading	
	10 kHz	0.2 % of reading	
	100 kHz	0.12 % of reading	
	1 mH		
	100 Hz	0.56 % of reading	
	1 kHz	0.19 % of reading	
	10 kHz	0.12 % of reading	
	100 kHz	0.1 % of reading	
	10 mH		
	20 Hz	0.86 % of reading	
	100 Hz	0.22 % of reading	
	1 kHz	0.1 % of reading	
	10 kHz	0.1 % of reading	
	100 kHz	0.11 % of reading	
	100 mH		
	20 Hz	0.28 % of reading	
	100 Hz	0.11 % of reading	
1 kHz	0.1 % of reading		
10 kHz	0.1 % of reading		
100 kHz	0.21 % of reading		
1 H			
20 Hz	0.17 % of reading		
100 Hz	0.1 % of reading		
1 kHz	0.1 % of reading		
10 kHz	0.11 % of reading		
100 kHz	0.31 % of reading		



ANSI National Accreditation Board

Electrical – DC/Low Frequency

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment		
Inductance – Measure <sup>1,6</sup>	10 H		Agilent E4980A Precision LCR Meter		
	20 Hz	0.15 % of reading			
	100 Hz	0.1 % of reading			
	1 kHz	0.11 % of reading			
	10 kHz	0.21 % of reading			
	100 kHz	0.69 % of reading			
	100 H				
	20 Hz	0.15 % of reading			
	100 Hz	0.11 % of reading			
	1 kHz	0.15 % of reading			
	10 kHz	0.62 % of reading			
	Impedance – Measure <sup>1</sup>	0.1 Ω			Agilent E4980A Precision LCR Meter
		1 kHz		2 % of reading	
		10 kHz		1.2 % of reading	
100 kHz		1.1 % of reading			
1 Ω					
20 Hz		0.67 % of reading			
100 Hz		0.45 % of reading			
1 kHz		0.36 % of reading			
10 kHz		0.33 % of reading			
100 kHz		0.31 % of reading			
10 Ω					
20 Hz		0.29 % of reading			
100 Hz		0.2 % of reading			
1 kHz		0.17 % of reading			
10 kHz		0.18 % of reading			
100 kHz		0.18 % of reading			
100 Ω					
20 Hz		0.16 % of reading			
100 Hz		0.09 % of reading			
1 kHz		0.09 % of reading			
10 kHz		0.12 % of reading			
100 kHz		0.12 % of reading			
1 kΩ					
20 Hz		0.15 % of reading			
100 Hz		0.09 % of reading			
1 kHz		0.09 % of reading			
10 kHz		0.09 % of reading			
100 kHz		0.09 % of reading			



ANSI National Accreditation Board

Electrical – DC/Low Frequency

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Impedance – Measure <sup>1</sup>	10 kΩ	20 Hz 100 Hz 1 kHz 10 kHz 100 kHz	Agilent E4980A Precision LCR Meter
	100 kΩ	20 Hz 100 Hz 1 kHz 10 kHz 100 kHz	
DC Resistance – Source/Measure <sup>1</sup>	Up to 10 Ω	0.001 8 % of reading + 58 μΩ	Agilent 3458A 8.5 Digit Multimeter, Decade Resistor
	(10 to 100) Ω	0.001 5 % of reading + 0.58 mΩ	
	(0.1 to 1) kΩ	0.001 3 % of reading + 0.58 mΩ	
	(1 to 10) kΩ	0.001 2 % of reading + 5.8 mΩ	
	(10 to 100) kΩ	0.001 3 % of reading + 58 mΩ	
	(0.1 to 1) MΩ	0.002 1 % of reading + 2.3 Ω	
	(1 to 10) MΩ	0.006 2 % of reading + 0.12 kΩ	
DC Resistance – Source/Measure <sup>1</sup>	(10 to 100) MΩ	0.059 % of reading + 1.2 kΩ	Fluke 8588A 8.5 Digit Multimeter, Decade Resistor
	(0.1 to 1) GΩ	0.58 % of reading + 12 kΩ	
	Up to 2 Ω	16 μΩ/Ω + 4 μΩ	
	(2 to 20) Ω	10 μΩ/Ω + 14 μΩ	
	(20 to 200) Ω	9.2 μΩ/Ω + 47 μΩ	
	(0.2 to 2) kΩ	9.1 μΩ/Ω + 0.47 mΩ	
	(2 to 20) kΩ	9.2 μΩ/Ω + 4.7 mΩ	
	(20 to 200) kΩ	9.3 μΩ/Ω + 47 mΩ	
Low Current Resistance – Measure <sup>1</sup>	(0.2 to 2) MΩ	11 μΩ/Ω + 1 Ω	Fluke 8588A 8.5 Digit Multimeter
	(2 to 20) MΩ	19 μΩ/Ω + 0.10 kΩ	
	(20 to 200) MΩ	0.12 mΩ/Ω + 10 kΩ	
	(0.2 to 2) GΩ	0.13 % of reading + 1 MΩ	
	Up to 2 Ω	17 μΩ/Ω + 4 μΩ	
	(2 to 20) Ω	10 μΩ/Ω + 14 μΩ	
	(20 to 200) Ω	17 μΩ/Ω + 0.2 mΩ	
	(0.2 to 2) kΩ	18 μΩ/Ω + 2 mΩ	
	(2 to 20) kΩ	22 μΩ/Ω + 20 mΩ	
	(20 to 200) kΩ	22 μΩ/Ω + 62 mΩ	
Low Current Resistance – Measure <sup>1</sup>	(0.2 to 2) MΩ	26 μΩ/Ω + 1 Ω	Fluke 8588A 8.5 Digit Multimeter
	(2 to 20) MΩ	0.38 mΩ/Ω + 0.3 kΩ	
	(20 to 200) MΩ	0.13 % of reading + 10 kΩ	
Low Current Resistance – Measure <sup>1</sup>	(20 to 200) MΩ	0.13 % of reading + 10 kΩ	Fluke 8588A 8.5 Digit Multimeter
	(0.2 to 2) GΩ	0.13 % of reading + 1 MΩ	

**Electrical – DC/Low Frequency**

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
High Voltage Resistance – Measure <sup>1</sup>	(2 to 20) MΩ (20 to 200) MΩ (0.2 to 2) GΩ (2 to 20) GΩ	17 μΩ/Ω + 10 Ω 68 μΩ/Ω + 0.1 kΩ 0.23 mΩ/Ω + 0.1 MΩ 0.13 % of reading + 10 MΩ	Fluke 8588A 8.5 Digit Multimeter
Resistance – Measure <sup>1</sup>	Up to 1 Ω (1 to 10) Ω (10 to 100) Ω (0.1 to 1) kΩ (1 to 10) kΩ (10 to 100) kΩ (0.1 to 1) MΩ	0.008 2 % of reading + 2.3 μΩ 0.007 % of reading + 23 μΩ 0.007 % of reading + 0.23 mΩ 0.007 % of reading + 2.3 mΩ 0.007 % of reading + 0.023 Ω 0.007 % of reading + 0.46 Ω 0.008 4 % of reading + 4.6 Ω	Keysight 34420A 7.5 Digit Nanovoltmeter
DC Resistance – Source <sup>1</sup> (Fixed Artifact)	10 μΩ	30 nΩ	Canadian Shunts LAB-500-5 Current Shunt
DC Resistance – Source <sup>1</sup> (Fixed Artifact)	100 μΩ	0.13 μΩ	IET Labs DCCS/0.0001 Current Shunt
DC Resistance – Source <sup>1</sup> (Fixed Artifact)	1 mΩ	86 nΩ	Ohms Labs CS-100 Current Shunt
DC Resistance – Source <sup>1</sup> (Fixed Artifact)	10 mΩ	1.4 μΩ	Fluke Y5020 Precision Current Shunt
DC Resistance – Source <sup>1</sup> (Fixed Artifact)	1 Ω	10 μΩ	Fluke 742A-1 Standard Resistor
DC Resistance – Source <sup>1</sup> (Fixed Artifact)	10 Ω	0.37 mΩ	IET Labs SRX-10 Standard Resistor
DC Resistance – Source <sup>1</sup> (Fixed Artifact)	10 kΩ	52 mΩ	Fluke 742A-10k Standard Resistor
DC Resistance – Source <sup>1</sup> (Multi-tap Artifact)	333.33 μΩ 1 mΩ 10 mΩ 100 mΩ 1 Ω 10 Ω 100 Ω 1 kΩ 10 kΩ	0.19 μΩ 0.42 μΩ 1.7 μΩ 17 μΩ 0.15 mΩ 1.5 mΩ 15 mΩ 0.15 Ω 1.5 Ω	Guideline 9211A Multi-tap Current Shunt



ANSI National Accreditation Board

Electrical – DC/Low Frequency

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
DC Resistance – Source <sup>1</sup> (Variable Artifacts)	100 kΩ to 1 MΩ (1 to 10) MΩ (10 to 100) MΩ 100 MΩ to 1 GΩ (1 to 10) GΩ (10 to 100) GΩ 100 GΩ to 1 TΩ	0.035 % of reading 0.035 % of reading 0.12 % of reading 0.3 % of reading 0.58 % of reading 1.2 % of reading 2.6 % of reading	High Resistance Box (Up to 10 kV)
DC Resistance – Source <sup>1</sup> (Simulation)	Up to 11 Ω (11 to 33) Ω (33 to 111) Ω (110 to 330) Ω 330 Ω to 1.1kΩ (1.1 to 3.3) kΩ (3.3 to 11) kΩ (11 to 33) kΩ (33 to 110) kΩ (110 to 330) kΩ 330 kΩ to 1.19 MΩ (1.1 to 3.3) MΩ (3.3 to 11) MΩ (11 to 33) MΩ (33 to 110) MΩ (110 to 330) MΩ 330 MΩ to 1.1 GΩ	32 μΩ/Ω + 0.8 mΩ 24 μΩ/Ω + 1.2 mΩ 22 μΩ/Ω + 1.1 mΩ 22 μΩ/Ω + 1.6 mΩ 22 μΩ/Ω + 1.6 mΩ 22 μΩ/Ω + 1.6 mΩ 22 μΩ/Ω + 1.6 mΩ 22 μΩ/Ω + 0.2 Ω 22 μΩ/Ω + 0.2 Ω 27 μΩ/Ω + 1.6 Ω 26 μΩ/Ω + 1.6 Ω 66 μΩ/Ω + 23 Ω 0.1 mΩ/Ω + 39 Ω 0.2 mΩ/Ω + 1.9 kΩ 0.4 mΩ/Ω + 2.3 kΩ 0.23 % of reading + 78 kΩ 12 % of reading + 0.4 MΩ	Fluke 5522A Multiproduct Calibrator
AC Voltage – Source <sup>1</sup>	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 500 kHz to 1 MHz (2.2 to 22) mV (10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz 500 kHz to 1 MHz	0.16 % of reading + 4 μV 0.1 % of reading + 4 μV 0.078 % of reading + 4 μV 0.13 % of reading + 4 μV 0.17 % of reading + 5 μV 0.33 % of reading + 10 μV 0.47 % of reading + 20 μV 0.58 % of reading + 20 μV 0.042 % of reading + 4 μV 0.03 % of reading + 4 μV 0.014 % of reading + 4 μV 0.03 % of reading + 4 μV 0.058 % of reading + 5 μV 0.12 % of reading + 10 μV 0.16 % of reading + 20 μV 0.27 % of reading + 20 μV	Fluke 5720A Multiproduct Calibrator





ANSI National Accreditation Board

Electrical – DC/Low Frequency

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage – Source <sup>1</sup>	(22 to 220) mV		Fluke 5720A Multiproduct Calibrator
	(10 to 20) Hz	0.028 % of reading + 12 μV	
	(20 to 40) Hz	0.011 % of reading + 7 μV	
	40 Hz to 20 kHz	0.008 5 % of reading + 7 μV	
	(20 o 50) kHz	0.021 % of reading + 7 μV	
	(50 to 100) kHz	0.047 % of reading + 17 μV	
	(100 to 300) kHz	0.091 % of reading + 20 μV	
	(300 to 500) kHz	0.14 % of reading + 25 μV	
	500 kHz to 1 MHz	0.28 % of reading + 45 μV	
	(0.22 to 2.2) V		
	(10 to 20) Hz	0.027 % of reading + 40 μV	
	(20 to 40) Hz	0.01 % of reading + 15 μV	
	40 Hz to 20 kHz	0.004 8 % of reading + 8 μV	
	(20 o 50) kHz	0.008 % of reading + 10 μV	
	(50 to 100) kHz	0.012 % of reading + 30 μV	
	(100 to 300) kHz	0.043 % of reading + 80 μV	
	(300 to 500) kHz	0.1 % of reading + 0.2 mV	
	500 kHz to 1 MHz	0.18 % of reading + 0.3 mV	
	(2.2 to 22) V		
	(10 to 20) Hz	0.028 % of reading + 0.4 mV	
	(20 to 40) Hz	0.01 % of reading + 0.15 mV	
	40 Hz to 20 kHz	0.004 9 % of reading + 50 μV	
	(20 o 50) kHz	0.008 3 % of reading + 0.1 mV	
	(50 to 100) kHz	0.011 % of reading + 0.2 mV	
(100 to 300) kHz	0.03 % of reading + 0.6 mV		
(300 to 500) kHz	0.1 % of reading + 2 mV		
500 kHz to 1 MHz	0.17 % of reading + 3.2 mV		
(22 to 220) V			
(10 to 20) Hz	0.028 % of reading + 4 mV		
(20 to 40) Hz	0.01 % of reading + 1.5 mV		
40 Hz to 20 kHz	0.005 6 % of reading + 0.6 mV		
(20 o 50) kHz	0.009 3 % of reading + 1 mV		
(50 to 100) kHz	0.016 % of reading + 2.5 mV		
(100 to 300) kHz	0.09 % of reading + 16 mV		
(300 to 500) kHz	0.44 % of reading + 40 mV		
500 kHz to 1 MHz	0.8 % of reading + 80 mV		
(220 to 1 100) V			
40 Hz to 1 kHz	0.011 % of reading + 4 mV		
(1 to 20) kHz	0.017 % of reading + 6 mV		
(20 to 30) kHz	0.061 % of reading + 11 mV		



ANSI National Accreditation Board

Electrical – DC/Low Frequency

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage – Source <sup>1</sup>	(220 to 750) V (30 to 50) kHz (50 to 100) kHz	0.061 % of reading + 11 mV 0.23 % of reading + 45 mV	Fluke 5720A Multiproduct Calibrator, Fluke 5725A Amplifier
AC Voltage – Measure <sup>1</sup>	Up to 1 mV 100 kHz to 1 MHz (1 to 3) MHz (3 to 10) MHz (10 to 20) MHz (1 to 3) mV 100 kHz to 1 MHz (1 to 3) MHz (3 to 10) MHz (10 to 20) MHz (3 to 100) mV 100 kHz to 1 MHz (1 to 3) MHz (3 to 10) MHz (10 to 20) MHz (20 to 30) MHz	1.8 % of reading + 2.4 μV 3.5 % of reading + 2.4 μV 9.3 % of reading + 2.4 μV 23 % of reading + 2.4 μV 1 % of reading + 2 μV 3.5 % of reading + 2 μV 9.3 % of reading + 2 μV 23 % of reading + 2 μV 0.9 % of reading + 3 μV 1.8 % of reading + 3 μV 2.9 % of reading + 3 μV 7 % of reading + 3 μV 14 % of reading + 3 μV	Rohde & Schwarz URE3 RMS Voltmeter
AC Voltage – Measure <sup>1</sup>	Up 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 300 kHz to 1 MHz (1 to 4) MHz (10 to 100) mV (1 to 40) Hz 40 Hz to 1 kHz (1 to 20) kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz 300 kHz to 1 MHz (1 to 2) MHz (2 to 4) MHz (4 to 8) MHz (8 to 10) MHz	0.04 % of reading + 3.5 μV 0.03 % of reading + 1.2 μV 0.04 % of reading + 1.2 μV 0.15 % of reading + 1.2 μV 0.59 % of reading + 1.2 μV 4.6 % of reading + 2.3 μV 1.5 % of reading + 5.8 μV 8.1 % of reading + 8.1 μV 0.013 % of reading + 4.6 μV 0.009 7 % of reading + 2.3 μV 0.017 % of reading + 2.3 μV 0.038 % of reading + 2.3 μV 0.093 % of reading + 2.3 μV 0.36 % of reading + 12 μV 1.2 % of reading + 12 μV 1.8 % of reading + 12 μV 4.7 % of reading + 81 μV 4.7 % of reading + 92 μV 17 % of reading + 0.12 mV	Agilent 3458A Opt 002 8.5 Digit Multimeter



ANSI National Accreditation Board

Electrical – DC/Low Frequency

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage – Measure <sup>1</sup>	(0.1 to 1) V		Agilent 3458A Opt 002 8.5 Digit Multimeter
	(1 to 40) Hz	0.008 8 % of reading + 46 μV	
	40 Hz to 1 kHz	0.008 3 % of reading + 23 μV	
	(1 to 20) kHz	0.017 % of reading + 23 μV	
	(20 to 50) kHz	0.036 % of reading + 23 μV	
	(50 to 100) kHz	0.093 % of reading + 23 μV	
	(100 to 300) kHz	0.35 % of reading + 0.12 mV	
	300 kHz to 1 MHz	1.2 % of reading + 0.12 mV	
	(1 to 2) MHz	1.8 % of reading + 0.12 mV	
	(2 to 4) MHz	4.6 % of reading + 0.81 mV	
	(4 to 8) MHz	4.6 % of reading + 0.92 mV	
	(8 to 10) MHz	17 % of reading + 1.2 mV	
	(1 to 10) V		
	(1 to 40) Hz	0.009 8 % of reading + 0.46 mV	
	40 Hz to 1 kHz	0.009 5 % of reading + 0.23 mV	
	(1 to 20) kHz	0.017 % of reading + 0.23 mV	
	(20 to 50) kHz	0.036 % of reading + 0.23 mV	
	(50 to 100) kHz	0.093 % of reading + 0.23 mV	
	(100 to 300) kHz	0.35 % of reading + 1.2 mV	
	300 kHz to 1 MHz	1.2 % of reading + 1.2 mV	
	(1 to 2) MHz	1.8 % of reading + 1.2 mV	
	(2 to 4) MHz	4.6 % of reading + 8.1 mV	
	(4 to 8) MHz	4.6 % of reading + 9.2 mV	
	(8 to 10) MHz	17 % of reading + 12 mV	
	(10 to 100) V		
	(1 to 40) Hz	0.024 % of reading + 4.6 mV	
	40 Hz to 1 kHz	0.024 % of reading + 2.3 mV	
	(1 to 20) kHz	0.024 % of reading + 2.3 mV	
(20 to 50) kHz	0.041 % of reading + 2.3 mV		
(50 to 100) kHz	0.14 % of reading + 2.3 mV		
(100 to 300) kHz	0.46 % of reading + 12 mV		
300 kHz to 1 MHz	1.7 % of reading + 12 mV		
(100 to 700) V			
(1 to 40) Hz	0.048 % of reading + 46 mV		
40 Hz to 1 kHz	0.048 % of reading + 23 mV		
(1 to 20) kHz	0.071 % of reading + 23 mV		
(20 to 50) kHz	0.14 % of reading + 23 mV		
(50 to 100) kHz	0.35 % of reading + 23 mV		



ANSI National Accreditation Board

Electrical – DC/Low Frequency

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage – Measure <sup>1</sup>	(0.1 to 10) mV		Fluke 8588A 8.5 Digit Multimeter
	1 Hz to 2 kHz	0.029 % of reading + 1.1 μV	
	(2 to 10) kHz	0.037 % of reading + 1.1 μV	
	(10 to 30) kHz	0.038 % of reading + 1.1 μV	
	(30 to 100) kHz	0.3 % of reading + 0.78 μV	
	(100 to 300) kHz	1 % of reading + 3.9 μV	
	300 kHz to 1 MHz	2 % of reading + 3.9 μV	
	(10 to 100) mV		
	1 Hz to 2 kHz	0.008 9 % of reading + 0.5 μV	
	(2 to 10) kHz	0.013 % of reading + 0.5 μV	
	(10 to 30) kHz	0.023 % of reading + 1 μV	
	(30 to 100) kHz	0.053 % of reading + 5 μV	
	(100 to 300) kHz	0.21 % of reading + 31 μV	
	300 kHz to 1 MHz	1 % of reading + 0.1 mV	
	(1 to 2) MHz	1.5 % of reading + 0.5 mV	
	(2 to 4) MHz	4.1 % of reading + 1 mV	
	(4 to 8) MHz	8.4 % of reading + 1 mV	
	(8 to 10) MHz	16 % of reading + 1 mV	
	(0.1 to 1) V		
	1 Hz to 2 kHz	0.007 7 % of reading + 5 μV	
	(2 to 10) kHz	0.012 % of reading + 5 μV	
	(10 to 30) kHz	0.023 % of reading + 10 μV	
	(30 to 100) kHz	0.053 % of reading + 50 μV	
	(100 to 300) kHz	0.21 % of reading + 0.31 mV	
	300 kHz to 1 MHz	1 % of reading + 1 mV	
	(1 to 2) MHz	1.5 % of reading + 5 mV	
	(2 to 4) MHz	4 % of reading + 10 mV	
	(4 to 8) MHz	8.2 % of reading + 10 mV	
(8 to 10) MHz	15 % of reading + 10 mV		
(1 to 10) V			
1 Hz to 2 kHz	0.007 6 % of reading + 50 μV		
(2 to 10) kHz	0.012 % of reading + 50 μV		
(10 to 30) kHz	0.023 % of reading + 0.1 mV		
(30 to 100) kHz	0.053 % of reading + 0.5 mV		
(100 to 300) kHz	0.21 % of reading + 3.1 mV		
300 kHz to 1 MHz	1 % of reading + 10 mV		
(1 to 2) MHz	1.5 % of reading + 50 mV		
(2 to 4) MHz	4 % of reading + 0.1 V		
(4 to 8) MHz	8.2 % of reading + 0.1 V		
(8 to 10) MHz	15 % of reading + 0.1 V		



ANSI National Accreditation Board

Electrical – DC/Low Frequency

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage – Measure <sup>1</sup>	(10 to 100) V 1 Hz to 2 kHz (2 to 10) kHz (10 to 30) kHz (30 to 100) kHz (100 to 300) kHz 300 kHz to 1 MHz (100 to 1 050) V 1 Hz to 2 kHz (2 to 10) kHz (10 to 30) kHz (30 to 100) kHz	0.009 % of reading + 0.5 mV 0.011 % of reading + 0.5 mV 0.023 % of reading + 1 mV 0.059 % of reading + 5 mV 0.37 % of reading + 47 mV 1 % of reading + 0.5 V 0.011 % of reading + 25 mV 0.011 % of reading + 25 mV 0.023 % of reading + 25 mV 0.059 % of reading + 0.1 V	Fluke 8588A 8.5 Digit Multimeter
AC High Voltage – Measure <sup>1</sup>	(0.7 to 10) kV (20 to 100) Hz (100 to 400) Hz (10 to 30) kV (30 to 70) Hz (70 to 200) Hz (200 to 450) Hz (30 to 50) kV (30 to 70) Hz (70 to 200) Hz (200 to 450) Hz (50 to 70) kV (30 to 70) Hz (70 to 200) Hz	0.14 % of reading + 0.4 V 0.48 % of reading + 0.2 V 0.11 % of reading + 2.4 V 0.7 % of reading + 2.4 V 1.4 % of reading + 2.4 V 0.13 % of reading + 2.5 V 0.7 % of reading + 2.5 V 2.9 % of reading + 2.5 V 0.16 % of reading + 2.6 V 1.2 % of reading + 2.6 V	Vitrek 4700 Digital HV Meter, Associated High Voltage Probes
AC High Voltage – Measure <sup>1</sup>	(1 to 60) kV 60 Hz (60 to 150) kV 60 Hz	0.77 % of reading + 29 V 0.77 % of reading + 0.29 kV	High Voltage Inc. DVR150 High Voltage Divider, Meter
DC Voltage – Source <sup>1</sup>	(0 to 220) mV (0.22 to 2.2) V (2.2 to 11) V (11 to 22) V (22 to 220) V	0.000 86 % of reading + 0.4 μV 0.000 51 % of reading + 0.7 μV 0.000 4 % of reading + 2.5 μV 0.000 39 % of reading + 4 μV 0.000 62 % of reading + 40 μV	Fluke 5720A Multiproduct Calibrator
DC Voltage – Source <sup>1</sup>	(220 to 1 100) V	0.000 76 % of reading + 0.4 mV	Fluke 5720A Multiproduct Calibrator, Fluke 5725A Amplifier



ANSI National Accreditation Board

Electrical – DC/Low Frequency

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
DC Voltage – Measure <sup>1</sup>	Up to 1 mV (1 to 10) mV (10 to 100) mV (0.1 to 1) V (1 to 10) V (10 to 100) V	0.006 % of reading + 0.023 $\mu$ V 0.006 % of reading + 0.035 $\mu$ V 0.004 8 % of reading + 0.46 $\mu$ V 0.004 1 % of reading + 0.004 6 mV 0.003 5 % of reading + 0.046 mV 0.004 1 % of reading + 0.58 mV	Keysight 34420A 7.5 Digit Nanovoltmeter
DC Voltage – Measure <sup>1</sup>	(0 to 100) mV (0.1 to 1) V (1 to 10) V (10 to 100) V (100 to 500) V (500 to 800) V (800 to 1 000) V	0.000 83 % of reading + 0.58 $\mu$ V 0.000 69 % of reading + 0.58 $\mu$ V 0.000 53 % of reading + 0.58 $\mu$ V 0.000 77 % of reading + 35 $\mu$ V 0.001 4 % of reading + 0.12 mV 0.001 8 % of reading + 0.12 mV 0.002 1 % of reading + 0.12 mV	Agilent 3458A Opt 002 8.5 Digit Multimeter
DC Voltage – Measure <sup>1</sup>	Up to 200 mV (0.2 to 2) V (2 to 20) V (20 to 200) V (200 to 1 050) V	7.7 $\mu$ V/V + 0.2 $\mu$ V 2.9 $\mu$ V/V + 0.3 $\mu$ V 2.9 $\mu$ V/V + 0.47 $\mu$ V 4.3 $\mu$ V/V + 30 $\mu$ V 4.4 $\mu$ V/V + 0.5 mV	Fluke 8588A 8.5 Digit Multimeter
DC High Voltage – Measure <sup>1</sup>	(1 to 10) kV (10 to 20) kV (20 to 70) kV (70 to 100) kV	0.04 % of reading + 92 mV 0.09 % of reading + 2.4 V 0.09 % of reading + 2.4 V 0.17 % of reading + 2.5 V	Vitrek 4700 Digital HV Meter, Associated High Voltage Probes
DC High Voltage – Measure <sup>1</sup>	(1 to 5) kV (5 to 50) kV (50 to 100) kV	0.22 % of reading + 1.6 V 0.2 % of reading + 16 V 0.2 % of reading + 0.16 kV	Spellmann HVD100-1 High Voltage Divider, Meter
DC High Voltage – Measure <sup>1</sup>	(1 to 60) kV (60 to 150) kV	0.58 % of reading + 5.9 V 0.58 % of reading + 59 V	High Voltage Inc DVR150 High Voltage Divider, Meter



ANSI National Accreditation Board

Electrical – DC/Low Frequency

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment		
AC Power – Source <sup>1,3</sup> PF = 1	(3.3 to 9) mA (10 to 65) Hz (0.11 mW to 3) mW 3 mW to 9 W	0.13 % of reading 0.08 % of reading	Fluke 5522A Multiproduct Calibrator		
	(9 to 33) mA (10 to 65) Hz (0.3 to 10) mW 10 mW to 33 W	0.09 % of reading 0.08 % of reading			
	(33 to 90) mA (10 to 65) Hz (1 to 30) mW 30 mW to 90 W	0.07 % of reading 0.06 % of reading			
	(90 to 330) mA (10 to 65) Hz (3 to 100) mW 100 mW to 300 W	0.09 % of reading 0.08 % of reading			
	(0.33 to 0.9) A (10 to 65) Hz (11 to 300) mW (0.3 to 900) W	0.07 % of reading 0.08 % of reading			
	(0.9 to 2.2) A (10 to 65) Hz (30 to 720) mW 0.72 W to 2 kW	0.09 % of reading 0.08 % of reading			
	(2.2 to 4.5) A (10 to 65) Hz 80 mW to 1.4 W 1.4 W to 4.5 kW	0.09 % of reading 0.18 % of reading			
	(4.5 to 20.5) A (10 to 65) Hz 150 mW to 20 kW	0.17 % of reading			
	DC Power – Source <sup>1</sup>	(0.33 to 330) mA 11 μW to 1.1 mW (1.1 to 110) mW 110 mW to 110 W (110 to 330) W		0.02 % of reading 0.03 % of reading 0.02 % of reading 0.02 % of reading	Fluke 5522A Multiproduct Calibrator
		(0.33 to 3) A 11 μW to 110 mW 110 mW to 990 W 990 W to 3 kW		0.04 % of reading 0.05 % of reading 0.01 % of reading	
(3 to 20.5) A 99 mW to 0.99 W 0.99 W to 6.8 kW (6.8 to 20.5) kW		0.09 % of reading 0.07 % of reading 0.04 % of reading			



ANSI National Accreditation Board

Electrical – DC/Low Frequency

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Low Frequency Phase – Source <sup>1</sup>	Up to 179.99° (10 to 65) Hz (65 to 500) Hz 500 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz (10 to 30) kHz	0.1° 0.2° 0.4° 1.9° 3.9° 7.8°	Fluke 5522A Multiproduct Calibrator
Oscilloscopes <sup>1</sup> Amplitude – DC into 50 Ω load into 1 MΩ load Amplitude – Square Wave into 50 Ω load into 1 MΩ load Time Markers into 50 Ω load Rise Time into 50 Ω load Rate: 1 kHz to 2 MHz Rate: 2 MHz to 10 MHz	(-6 to 6) V (-130 to 130) V 10 Hz to 100 kHz 1 mVp-p to 6.6 Vp-p 10 Hz to 1 kHz 1 mVp-p to 130 Vp-p (1 kHz to 10) kHz 1 mVp-p to 130 Vp-p 1 ns to 20 ms 50 ms 0.1 s 0.2 s 0.5 s 1 s 2 s 5 s 5 mVp-p to 2.5 Vp-p 250 ps (nominal) 250 ps (nominal)	0.2 % of reading + 31 μV 0.04 % of reading + 31 μV 0.19 % of reading + 31 μV 0.08 % of reading + 31 μV 0.19 % of reading + 31 μV 0.000 22 % of reading 0.005 9 % of reading 0.009 8 % of reading 0.018 % of reading 0.041 % of reading 0.08 % of reading 0.16 % of reading 0.39 % of reading 51 ps 51 ps	Fluke 5520A/11 Multiproduct Calibrator



**Electrical – DC/Low Frequency**

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Oscilloscopes <sup>1,4</sup> Leveled Sine Wave into 50 Ω load	5 mVp-p to 5 Vp-p 50 kHz 50 kHz to 100 MHz (100 to 300) MHz (300 to 600) MHz (600 to 1 100) MHz	1.8 % of reading + 0.2 mV 2.8 % of reading + 0.2 mV 3.2 % of reading + 0.2 mV 4 % of reading + 0.2 mV 5.5 % of reading + 0.2 mV	Fluke 5520A/11 Multiproduct Calibrator
Bandwidth/Flatness (50 kHz Reference) into 50 Ω load	5 mVp-p to 5.5 Vp-p 50 kHz to 100 MHz (100 to 300) MHz (300 to 600) MHz (600 to 1 100) MHz	1.4 % of reading + 78 μV 1.8 % of reading + 78 μV 3.2 % of reading + 78 μV 3.9 % of reading + 78 μV	
Input Impedance – Measure	(40 to 60) Ω (0.5 to 1.5) MΩ	0.082 % of reading 0.081 % of reading	
Input Capacitance – Measure	(5 to 50) pF	3.9 % of reading + 0.4 pF	
Waveform Generator (Sine, Square, Triangle) Amplitude into 50 Ω load into 1 MΩ load	10 Hz to 10 kHz 1.8 mVp-p to 2.5 Vp-p 1.8 mVp-p to 55 Vp-p	2.3 % of reading + 78 μV 2.3 % of reading + 78 μV	
Frequency	10 Hz to 10 kHz	0.002 % of reading + 12 mHz	
Electrical Simulation of Thermocouple Indicating Devices – Measure/Source <sup>1</sup>	Type B (250 to 350) °C (350 to 445) °C (445 to 580) °C (580 to 750) °C (750 to 1 000) °C (1 000 to 1 820) °C	1.2 °C 0.9 °C 0.71 °C 0.55 °C 0.45 °C 0.35 °C	Ectron 1140A Thermocouple Calibrator/Simulator



ANSI National Accreditation Board

Electrical – DC/Low Frequency

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Electrical Simulation of Thermocouple Indicating Devices – Measure/Source <sup>1</sup>	Type C		Ectron 1140A Thermocouple Calibrator/Simulator
	(0 to 250) °C	0.24 °C	
	(250 to 1 000) °C	0.19 °C	
	(1 000 to 1 500) °C	0.21 °C	
	(1 500 to 1 800) °C	0.24 °C	
	(1 800 to 2 000) °C	0.27 °C	
	(2 000 to 2 250) °C	0.33 °C	
	(2 250 to 2 315) °C	0.37 °C	
	Type D		
	(0 to 100) °C	0.34 °C	
	(100 to 300) °C	0.28 °C	
	(300 to 1 400) °C	0.18 °C	
	(1 400 to 1 650) °C	0.19 °C	
	(1 650 to 1 930) °C	0.23 °C	
	(1 930 to 2 100) °C	0.28 °C	
	(2 100 to 2 200) °C	0.3 °C	
	(2 200 to 2 320) °C	0.34 °C	
	Type E		
	(-270 to -245) °C	1.6 °C	
	(-245 to -195) °C	0.24 °C	
	(-195 to -155) °C	0.12 °C	
	(-155 to -90) °C	0.095 °C	
	(-90 to 0) °C	0.08 °C	
	(0 to 15) °C	0.076 °C	
	(15 to 890) °C	0.064 °C	
	(890 to 1 000) °C	0.074 °C	
	Type G		
	(0 to 100) °C	1.6 °C	
(100 to 300) °C	0.5 °C		
(300 to 600) °C	0.35 °C		
(600 to 1 760) °C	0.18 °C		
(1 760 to 2 030) °C	0.2 °C		
(2 030 to 2 200) °C	0.25 °C		
(2 200 to 2 315) °C	0.27 °C		
Type J			
(-210 to -180) °C	0.15 °C		
(-180 to -120) °C	0.12 °C		
(-120 to -50) °C	0.093 °C		
(-50 to 990) °C	0.08 °C		
(990 to 1 200) °C	0.094 °C		

**Electrical – DC/Low Frequency**

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Electrical Simulation of Thermocouple Indicating Devices – Measure/Source <sup>1</sup>	Type K		Ectron 1140A Thermocouple Calibrator/Simulator
	(-270 to -255) °C	2.5 °C	
	(-255 to -195) °C	0.85 °C	
	(-195 to -115) °C	0.16 °C	
	(-115 to -55) °C	0.12 °C	
	(-55 to 1 000) °C	0.087 °C	
	(1 000 to 1 372) °C	0.096 °C	
	Type N		
	(-270 to -260) °C	5.4 °C	
	(-260 to -200) °C	1.5 °C	
	(-200 to -140) °C	0.29 °C	
	(-140 to -70) °C	0.18 °C	
	(-70 to 25) °C	0.14 °C	
	(25 to 160) °C	0.12 °C	
	(160 to 1 300) °C	0.11 °C	
	Type PLII		
	(0 to 100) °C	0.1 °C	
	(100 to 925) °C	0.08 °C	
	(925 to 1 200) °C	0.1 °C	
	(1 200 to 1 395) °C	0.11 °C	
	Type R		
	(-50 to -30) °C	0.8 °C	
	(-30 to 45) °C	0.69 °C	
	(45 to 160) °C	0.49 °C	
	(160 to 380) °C	0.35 °C	
	(380 to 775) °C	0.3 °C	
	(775 to 1 768) °C	0.26 °C	
	Type S		
	(-50 to -30) °C	0.76 °C	
	(-30 to 45) °C	0.68 °C	
(45 to 105) °C	0.49 °C		
(105 to 310) °C	0.41 °C		
(310 to 615) °C	0.35 °C		
(615 to 1 768) °C	0.31 °C		
Type T			
(-270 to -255) °C	1.9 °C		
(-255 to -240) °C	0.6 °C		
(-240 to -210) °C	0.36 °C		
(-210 to -150) °C	0.22 °C		
(-180 to -40) °C	0.15 °C		
(-40 to 100) °C	0.095 °C		
(100 to 400) °C	0.08 °C		



ANSI National Accreditation Board

Electrical – DC/Low Frequency

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Electrical Simulation of RTD Indicators – Source <sup>1</sup>	Pt 385, 100 Ω		Fluke 5520A Multiproduct Calibrator
	(-200 to -80) °C	0.05 °C	
	(-80 to 0) °C	0.05 °C	
	(0 to 100) °C	0.07 °C	
	(100 to 300) °C	0.09 °C	
	(300 to 400) °C	0.1 °C	
	(400 to 630) °C	0.12 °C	
	(630 to 800) °C	0.23 °C	
	Pt 385, 200 Ω		
	(-200 to -80) °C	0.04 °C	
	(-80 to 0) °C	0.04 °C	
	(0 to 100) °C	0.04 °C	
	(100 to 260) °C	0.05 °C	
	(260 to 300) °C	0.12 °C	
	(300 to 400) °C	0.13 °C	
	(400 to 600) °C	0.14 °C	
	(600 to 630) °C	0.16 °C	
	Pt 385, 500 Ω		
	(-200 to -80) °C	0.04 °C	
	(-80 to 0) °C	0.05 °C	
	(0 to 100) °C	0.05 °C	
	(100 to 260) °C	0.06 °C	
	(260 to 300) °C	0.08 °C	
	(300 to 400) °C	0.08 °C	
(400 to 600) °C	0.09 °C		
(600 to 630) °C	0.11 °C		
Pt 385, 1 000 Ω			
(-200 to -80) °C	0.03 °C		
(-80 to 0) °C	0.03 °C		
(0 to 100) °C	0.04 °C		
(100 to 260) °C	0.05 °C		
(260 to 300) °C	0.06 °C		
(300 to 400) °C	0.07 °C		
(400 to 600) °C	0.07 °C		
(600 to 630) °C	0.23 °C		



ANSI National Accreditation Board

**Electrical – DC/Low Frequency**

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Electrical Simulation of RTD Indicators – Source <sup>1</sup>	Pt 3916, 100 Ω		Fluke 5520A Multiproduct Calibrator
	(-200 to -190) °C	0.25 °C	
	(-190 to -80) °C	0.04 °C	
	(-80 to 0) °C	0.05 °C	
	(0 to 100) °C	0.06 °C	
	(100 to 260) °C	0.07 °C	
	(260 to 300) °C	0.08 °C	
	(300 to 400) °C	0.09 °C	
	(400 to 600) °C	0.1 °C	
	(600 to 630) °C	0.23 °C	
	Pt 3926, 100 Ω		
	(-200 to -80) °C	0.05 °C	
	(-80 to 0) °C	0.05 °C	
	(0 to 100) °C	0.07 °C	
	(100 to 300) °C	0.09 °C	
(300 to 400) °C	0.1 °C		
(400 to 630) °C	0.12 °C		
PtNi 385, 120 Ω			
(-80 to 0) °C	0.08 °C		
(0 to 100) °C	0.08 °C		
(100 to 260) °C	0.14 °C		
Cu 427, 10 Ω			
(-100 to 260) °C	0.3 °C		

**Electrical – RF/Microwave**

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Relative RF Power <sup>1</sup>	100 kHz to 4.2 GHz	1.9 % of reading	Agilent 437B Power Meter, Agilent 8482A Power Sensor
	(-30 to -20) dB	1.8 % of reading	
	(-20 to -10) dB	1.8 % of reading	
Relative RF Power <sup>1</sup>	100 kHz to 4.2 GHz	1.8 % of reading	Agilent 437B Power Meter, Agilent 8482A Power Sensor
	(0 to 10) dB	1.8 % of reading	
	(10 to 20) dB	1.8 % of reading	
Harmonic Distortion – Measure <sup>1</sup>	20 Hz to 20 kHz	1.2 % of reading	HP 8903A Distortion Analyzer
	(20 to 100) kHz	2.3 % of reading	

**Length – Dimensional Metrology**

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment	
Gage Blocks <sup>2</sup> Length	Steel	(0.01 to 0.2) in	2.9 μin	Gage Block Comparator, Master Gage Blocks
		(0.2 to 1) in	(2.8 + 0.7L) μin	
		(1 to 4) in	(2 + 1.7L) μin	
	Chrome	(0.5 to 7.5) mm	83 nm	
		(7.5 to 30) mm	(0.075 + 0.001L) μm	
		(30 to 100) mm	(0.027 + 0.003L) μm	
		(0.01 to 0.2) in	3 μin	
		(0.2 to 1) in	(3 + 1L) μin	
		(1 to 4) in	(1 + 3L) μin	
	Ceramic	(0.5 to 6) mm	83 nm	
(6 to 30) mm		(0.072 + 0.002L) μm		
(30 to 100) mm		(0.05 + 0.003L) μm		
(0.01 to 0.2) in		3 μin		
Parallelism	(0.2 to 1) in	(2.8 + 1L) μin	Optical Parallels	
	(1 to 4) in	(1.8 + 2L) μin		
	(0.5 to 1.01) mm	95 nm		
	(1.01 to 30) mm	(0.09 + 0.001L) μm		
Flatness	(30 to 100) mm	(0.03 + 0.003L) μm	Optical Flats	
	(100 to 500) mm	(0.16 + 0.001L) μm		
Optical Flats and Parallels Flatness	Up to 1 inDL (25.4 mm)	1 μin (25 nm)	Master Optical Flat	
	Up to 4 in Diameter Up to 100 mm Diameter	3.5 μin 89 nm		
Parallelism	Up to 1 in Up to 25.4 mm	2.9 μin	P&W Measuring Machine	
		74 nm		

**Length – Dimensional Metrology**

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Angle Measuring Devices <sup>1,2</sup>	5° (5 to 20)° (20 to 35)° (35 to 45)° (45 to 60)° (60 to 75)° (75 to 85)° 90°	1.7" 2.4" 3.6" 4.6" 8.1" 17" 52" 1.1"	Sine Bar, Gage Blocks, Surface Plate, Granite Square
Calipers, Micrometers <sup>1,2</sup> Travel (Outside, Inside, Depth, Step)	Up to 0.5 in (0.5 to 1) in (1 to 4) in (4 to 15) in (15 to 40) in	13 μin 14 μin (10 + 3.6L) μin (11 + 4.2L) μin (11 + 4.4L) μin	ASME B89.1 Grade 0 Gage Blocks
Anvil Flatness	Up to 1 inDL	6.2 μin	Optical Flats
Anvil Parallelism	Up to 1 inDL	6.6 μin	Optical Parallels
Bore Gages <sup>1,2</sup>	(0.125 to 0.25) in (0.25 to 1) in (1 to 6) in	34 μin 36 μin (30 + 7L) μin	Characterized Ring Gages
Indicators <sup>1,2</sup> (Dial, Digital, Drop, Test)	Up to 6 in	(6.3 + 3.2L) μin	Gage Blocks, Surface Plate
Test Indicators	Up to 0.025 in	5.6 μin	Universal Length Measuring Machine
Wire Crimpers/Dies <sup>1</sup> Die Diameter 0.000 1 in step size 0.000 5 in step size 0.001 in step size	(0.011 to 0.625) in (0.011 to 0.625) in (0.011 to 0.625) in	150 μin 600 μin 1 200 μin	Pin Gages
Crimp Height	Up to 0.8 in	180 μin	Micrometer
Height Gages <sup>1,2</sup>	Up to 4 in (4 to 24) in	(26 + 0.5L) μin (16 + 3L) μin	Gage Blocks

**Length – Dimensional Metrology**

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Length – Single Axis <sup>2</sup> Outside Dimension  Inside Dimension	Up to 1 in (1 to 7) in (7 to 12) in  (0.04 to 1) in (1 to 2.5) in (2.5 to 10) in (10 to 14) in	(6 + 1L) μin (4 + 3.5 L) μin (4L) μin  11 μin 17 μin (18 + 3L) μin (38 + 3L) μin	Universal Length Measuring Machine
Surface Plates <sup>1,2</sup>  Overall Flatness  Local Area Flatness (Repeat Readings) Up to 12.37 inDL (12.37 to 18.25) inDL (18.97 to 30.59) inDL  > 16.97 inDL	Up to 250 inDL  Up to 0.001 in Up to 0.001 in Up to 0.001 in  Up to 0.001 in	(38 + 1√DL) μin  58 μin 65 μin 65 μin  33 μin	In accordance with ASME B89.3.7 using Wyler Levels  Gage Amp, Probe Level Plate, Surface Plate  Repeat-o-Meter
Optical Comparators <sup>1,2</sup> X-Y Length  Squareness  Magnification	Up to 6 in  (0.04 to 1) in  10X to 50X	(100 + 14L) μin  (120 + 1.5L) μin  (240 + 21L) μin	Calibration Grids  Calibration Grids  Magnification Checker
Optical Reference Plane <sup>1</sup>	Up to 6 in (6 to 12) in	51 μin 75 μin	Glass Scale, Calibration Grids
Laser Micrometers <sup>1,2</sup>	Up to 0.1 in (0.1 to 0.4) in (0.4 to 1) in	13 μin 8 μin (11 + 5L) μin	Characterized Master Pin Gages
Surface Roughness Testers <sup>1</sup>	Ra Rmax	70 nm (3 μin) 0.91 μm (36 μin)	Calibrated Specimen
Micrometer Head Spindle Displacement	Up to 1 in  Up to 25.4 mm	10 μin  0.26 μm	Laser Interferometer



**Length – Dimensional Metrology**

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Micrometer Standards <sup>2</sup>	Up to 36 in (36 to 80) in	$(30 + 4L) \mu\text{in}$ $(200 + 5L) \mu\text{in}$	P&W Measuring Machine
	Up to 900 mm (900 to 2 000) mm	$(0.8 + 0.004L) \mu\text{m}$ $(5 + 0.005L) \mu\text{m}$	
Pin Gages <sup>1</sup> (Non-contact)	(0.004 to 1) in	33 $\mu\text{in}$	Laser Micrometer
Plug Gages <sup>2</sup> (Outside Diameter)	Up to 1 in (1 to 7) in	12 $\mu\text{in}$ $(3 + 3D) \mu\text{in}$	Universal Length Measuring Machine
Measuring Rules <sup>2</sup>	Up to 48 in	$(30 + 8L) \mu\text{in}$	CSIP with Heidenhain LIP 401R Linear Encoder
Thread Wires	(2 to 120) TPI (0.008 33 to 0.5) in	12 $\mu\text{in}$	Universal Length Measuring Machine
	(2 to 120) TPI (0.211 6 to 12.7) mm	0.3 $\mu\text{m}$	
Cylindrical Ring Gages <sup>2</sup> Inside Diameter	(0.04 to 1) in (1 to 2.5) in (2.5 to 10) in (10 to 14) in	11 $\mu\text{in}$ 17 $\mu\text{in}$ $(18 + 3D) \mu\text{in}$ $(38 + 3D) \mu\text{in}$	Universal Length Measuring Machine
Thread Plug Gages <sup>2</sup> Pitch Diameter, 60° Thread	Up to 1 in (1 to 4) in (4 to 7) in	79 $\mu\text{in}$ 80 $\mu\text{in}$ 83 $\mu\text{in}$	Universal Length Measuring Machine, Thread Wires
Major Diameter	Up to 1 in (1 to 7) in	13 $\mu\text{in}$ $(10 + 3D) \mu\text{in}$	Universal Length Measuring Machine
Step Height	Up to 1 in	32 $\mu\text{in}$	Gage Amp, Probe, Gage Blocks
Thread Ring Gages Inner Pitch Diameter	Up to 1 in (1 to 4) in (4 to 7) in	79 $\mu\text{in}$ 80 $\mu\text{in}$ 83 $\mu\text{in}$	Master Thread Plug Uncertainty
Tapered Thread Plug Gages Pitch Diameter Taper	Up to 3 in	90 $\mu\text{in}$	Universal Length Measuring Machine, Thread Wires
Standoff	Up to 1 in	31 $\mu\text{in}$	Gage Amp, Probe, Gage Blocks

**Length – Dimensional Metrology**

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Tapered Thread Ring Gage	Up to 3 in	90 μin	Master Tapered Thread Plug Uncertainty
Thickness Foils, Feeler Gages <sup>2</sup>	Up to 1 in	(6 + 1L) μin	Universal Length Measuring Machine
Cylindrical Plug Gages, Cylindrical Ring Gages Diameter	(0.04 to 0.4) in (0.4 to 6) in  (1 to 10) mm (10 to 152) mm	45 μin (45 + 5D)  1.1 μin (1.1 + 0.005D)	MasterScanner XP16060 Master Scanner
Tapered Plug Gages, Tapered Ring Gages Diameter	(0.04 to 0.4) in (0.4 to 6) in  (1 to 10) mm (10 to 152) mm	48 μin (48 + 5L)  1.2 μm (1.2 + 0.005L)	MasterScanner XP16060 Master Scanner
Taper	-	0.1°	
Thread Plug Gages <sup>2,7</sup> Effective Pitch Diameter	(0.04 to 0.4) in (0.4 to 6) in  (1 to 10) mm (10 to 152) mm	87 μin (87 + 5L)  2.2 μm (2.2 + 0.005L)	
Major/Minor Diameter	(0.04 to 0.4) in (0.4 to 6) in  (1 to 10) mm (10 to 152) mm	49 μin (49 + 5L)  1.2 μm (1.2 + 0.005L)	MasterScanner XP16060 Master Scanner
Pitch	> 0 .004 in > 0.1 mm	30 μin 0.76 μm	
Flank Angle	Up to 60°	6'	

**Length – Dimensional Metrology**

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Tapered Plug Gages <sup>2,7</sup> Effective Pitch Diameter	(0.04 to 0.4) in (0.4 to 6) in	85 µin (85 + 5D)	MasterScanner XP16060 Master Scanner
Major/Minor Diameter	(1 to 10) mm (10 to 152) mm	2.2 µm (2.2 + 0.005D)	
Pitch	(0.04 to 0.4) in (0.4 to 6) in	51 µin (51 + 5D)	
Flank Angle	(1 to 10) mm (10 to 152) mm	1.3 µm (1.3 + 0.005D)	
Taper	> 0.004 in > 0.1 mm	30 µin 0.76 µm	
	Up to 60°	6'	
	Up to 60°	0.1°	

**Mass and Mass Related**

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Balances, Scales <sup>1,5</sup> Metric (SI)	Up to 500 mg 500 mg to 5 g (5 to 10) g (10 to 30) g (30 to 100) g 100 g to 5 kg (5 to 10) kg	12 µg 40 µg 61 µg 94 µg 0.000 9 % of reading 0.000 3 % of reading 0.000 3 % of reading	ASTM E617 Class 1 Weights and internal calibration procedure utilized for the calibration of the weighing system.
Balances, Scales <sup>1,5</sup> Metric (SI)	(5 to 50) mg (50 to 500) mg 500 mg to 5 g (5 to 10) g (10 to 20) g 20 g to 2 kg	16 µg 29 µg 63 µg 88 µg 0.12 mg 0.006 % of reading	ASTM E617 Class 2 Weights and internal calibration procedure utilized for the calibration of the weighing system.

**Mass and Mass Related**

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Balances, Scales <sup>1,5</sup> Metric (SI)  Avoirdupois	450 g to 27 kg  (1 to 62) lb	0.014 % of reading  0.014 % of reading	ASTM E617 Class 6 Weights and internal calibration procedure utilized for the calibration of the weighing system.
Balances, Scales <sup>1,5</sup> Metric (SI)  Avoirdupois	(450 to 211) kg  (1 to 466) lb	0.012 % of reading  0.012 % of reading	NIST Class F Weights and internal calibration procedure utilized for the calibration of the weighing system.
Rockwell Hardness and Superficial Testers <sup>1</sup>	HRA Scale (45 to 55) HRA (70 to 80) HRA (80 to 88) HRA HRBw Scale (44 to 49) HRBw (73 to 79) HRBw (88 to 99) HRBw HRC Scale (24 to 28) HRC (42 to 47) HRC (60 to 65) HRC HREw Scale (69 to 76) HREw (83 to 91) HREw (96 to 100) HREw HR15TW Scale (72 to 75) HR15TW (82 to 86) HR15TW (90 to 92) HR15TW HR30N Scale (45 to 48) HR30N (65 to 68) HR30N (76 to 78) HR30N HR30TW Scale (48 to 53) HR30TW (59 to 63) HR30TW (72 to 81) HR30TW HR45TW Scale (25 to 30) HR45TW (43 to 49) HR45TW (61 to 64) HR45TW	0.6 HRA 0.37 HRA 0.29 HRA 0.84 HRBw 0.75 HRBw 0.64 HRBw 0.44 HRC 0.42 HRC 0.38 HRC 0.62 HREw 0.63 HREw 0.59 HREw 0.64 HR15TW 0.64 HR15TW 0.45 HR15TW 0.63 HR30N 0.65 HR30N 0.51 HR30N 0.67 HR30TW 0.55 HR30TW 0.48 HR30TW 0.65 HR45TW 0.65 HR45TW 0.6 HR45TW	Indirect verification per ASTM E18 using hardness test blocks.

**Mass and Mass Related**

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Brinell Hardness Testers <sup>1</sup>	HBW Scale Low Medium High	1.4 HBW 4.2 HBW 5.3 HBW	Indirect verification per ASTM E10 using hardness test blocks.
Knoop Hardness Testers <sup>1</sup>	HK 0.1 Scale (858 to 886) HK	20 HK	Indirect verification per ASTM E384, ASTM E92 using hardness test blocks.
Leeb Hardness Testers <sup>1</sup>	HLD Scale (752 to 759) HLD (786 to 789) HLD	9.9 HLD 9.4 HLD	Indirect verification per ASTM A956 using hardness test blocks.
Vickers Hardness Testers <sup>1,7</sup>	HV 0.3 Scale (476 to 494) HV (747 to 757) HV HV 0.5 Scale (493 to 519) HV HV 1 Scale (460 to 468) HV (741 to 752) HV	10 HV 12 HV 12 HV 8 HV 13 HV	Indirect verification per ASTM E384, ASTM E92 using hardness test blocks.
Absolute Pressure <sup>1</sup> (Pneumatic)	Up to 5 psia Up to 10 psia Up to 15 psia Up to 30 psia (14.7 to 45) psia (14.7 to 65) psia (14.7 to 115) psia (14.7 to 165) psia (14.7 to 265) psia (14.7 to 315) psia (14.7 to 515) psia (14.7 to 765) psia (14.7 to 1 515) psia	0.000 61 psi 0.001 2 psi 0.001 8 psi 0.003 6 psi 0.005 3 psi 0.007 psi 0.012 psi 0.018 psi 0.031 psi 0.037 psi 0.062 psi 0.09 psi 0.19 psi	Mensor APC6000 Pressure Controller
Absolute Pressure <sup>1</sup> (Pneumatic)	Up to 62.5 psia (62.5 to 1 000) psia	0.006 3 psi 0.01 % of reading	Mensor CPC6050 Pressure Controller
Absolute Pressure <sup>1</sup> (Pneumatic)	(14.7 to 507.5) psia (507.5 to 1 015) psia (14.7 to 1 507.5) psia (1 507.5 to 3 015) psia (14.7 to 3 007.5) psia (3 007.5 to 6 015) psia	0.05 psi 0.01 % of reading + 0.001 5 psi 0.15 psi 0.01 % of reading + 0.001 5 psi 0.3 psi 0.01 % of reading + 0.001 5 psi	Mensor CPC8000 Pressure Controller



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Mass and Mass Related

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Gage Pressure <sup>1</sup> (Pneumatic)	Up to 0.5 psig	0.000 06 psi	Mensor APC6000 Pressure Controller
	Up to 1 psig	0.000 1 psi	
	Up to 5 psig	0.000 6 psi	
	Up to 10 psig	0.001 2 psi	
	Up to 15 psig	0.001 8 psi	
	Up to 30 psig	0.003 6 psi	
	Up to 50 psig	0.006 psi	
	Up to 100 psig Up to 150 psig	0.012 psi 0.018 psi	
Gage Pressure <sup>1</sup> (Pneumatic)	Up to 250 psig	0.031 psi	Mensor APC6000 Pressure Controller
	Up to 300 psig	0.037 psi	
	Up to 500 psig	0.062 psi	
	Up to 750 psig	0.093 psi	
	Up to 1 500 psig	0.19 psi	
Gage Pressure <sup>1</sup> (Pneumatic)	(-14.7 to 47.8) psig	0.006 3 psi	Mensor CPC6050 Pressure Controller
	(47.8 to 1 000.3) psig	0.01 % of reading	
Gage Pressure <sup>1</sup> (Pneumatic)	Up to 500 psig	0.05 psi	Mensor CPC8000 Pressure Controller
	(500 to 1 000) psig	0.01 % of reading	
	Up to 1 500) psig	0.15 psi	
	(1 500 to 3 000) psig	0.01 % of reading	
	Up to 3 000) psig (3 000 to 6 000) psig	0.3 psi 0.01 % of reading	
Gage Pressure <sup>1</sup> (Hydraulic)	Up to 10 000 psig	1.2 psi	Comparison to Mensor 2106 Digital Pressure Gage
Gage Pressure <sup>1</sup> (Hydraulic)	(100 to 16 000) psig	0.025 % of reading	Budenberg 580HXA Pressure Balance
Torque Drivers, Indicators <sup>1</sup>	(10 to 100) ozf·in	1.2 % of reading	CDI Torque Transducers
	(4 to 50) lbf·in	1.1 % of reading	
	(30 to 400) lbf·in	1.1 % of reading	
Torque Wrenches <sup>1</sup>	4 lbf·in to 250 lbf·ft	0.54 % of reading	CDI Torque Transducers
	(60 to 600) lbf·ft	0.49 % of reading	
Torque Analyzers, Torque Transducers	(2 to 40) ozf·in	0.13 % of reading	NIST Class F Weights, Torque Wheels, Torque Arm
	5 ozf·in to 25 lbf·in	0.085 % of reading	
	2.5 lbf·in to 150 lbf·ft	0.055 % of reading	
	50 lbf·in to 250 lbf·ft	0.053 % of reading	
	(25 to 1 000) lbf·ft	0.052 % of reading	

**Thermodynamic**

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Humidity – Humidity Controlled Chambers <sup>1</sup>	(-40 to -20) °C	1.7 % of reading + 1.8 %RH	Vaisala MI70/HMP76B Temp/Humidity Indicator/Probe
	(0 to 95) RH%	0.92 % of reading + 1.3 %RH	
	(-20 to 15) °C	1.3 RH%	
	(0 to 95) RH%	2 %RH	
Humidity – Humidity Controlled Chambers <sup>1</sup>	(15 to 25) °C	0.92 % of reading + 1.3 %RH	Vaisala MI70/HMP76B Temp/Humidity Indicator/Probe
	(0 to 90) RH%	1.7 % of reading + 1.8 %RH	
	(90 to 100) RH%		
Thermo-Hygrometers <sup>1</sup> Temperature	(25 to 40) °C		Kaymont 2000 Humidity Generator, Vaisala MI70/HMP76B Temp/Humidity Indicator/Probe
	(0 to 95) RH%	0.27 °C	
Humidity	(40 to 180) °C	0.92 % of reading + 1.3 %RH	
	(0 to 95) RH%	1.7 % of reading + 1.8 %RH	
	(18 to 25) °C		
Dry Blocks, Liquid Baths, Temperature Chambers, Furnaces, Ovens <sup>1</sup>	(5 to 95) %RH	1.4 %RH	
	(18 to 28) °C	2.1 %RH	
	(7 to 90) %RH		
Dry Blocks, Liquid Baths, Temperature Chambers, Furnaces, Ovens <sup>1</sup>	(90 to 100) %RH		
	(-195 to 0) °C	0.012 °C	
	(0 to 420) °C	0.026 °C	
Dry Blocks, Liquid Baths, Temperature Chambers, Furnaces, Ovens <sup>1</sup>	(420 to 660) °C	0.034 °C	SPRT, Temperature Indicator
	(600 to 1 093) °C	0.47 % of reading + 0.9 °C	
	(1 093 to 1 200) °C	0.47 % of reading + 1.9 °C	
Dry Blocks, Liquid Baths, Temperature Chambers, Furnaces, Ovens <sup>1</sup>	(600 to 1 093) °C	0.47 % of reading + 0.9 °C	Type N T/C Probe, Temperature Indicator
	(1 093 to 1 200) °C	0.47 % of reading + 1.9 °C	
	(615 to 1 093) °C	0.47 % of reading + 1.9 °C	
Dial/Digital Thermometers, RTD, PRT, Thermistor Probes	(1 093 to 1 200) °C	0.15 % of reading + 1 °C	Type K T/C Probe, Temperature Indicator
	(1 093 to 1 200) °C	0.15 % of reading + 1.9 °C	
Dial/Digital Thermometers, RTD, PRT, Thermistor Probes	0.01 °C	0.83 mK	Triple Point Water Cell
Dial/Digital Thermometers, RTD, PRT, Thermistor Probes <sup>1</sup>	(-30 to -20) °C	0.043 °C	Fluke 7320 Bath, Fluke 6102 Bath, SPRT, Temperature Indicator
	(-20 to 0) °C	0.018 °C	
	(0 to 150) °C	0.03 °C	
	(150 to 200) °C	0.05 °C	
Dial/Digital Thermometers, RTD, PRT, Thermistor Probes <sup>1</sup>	(50 to 100) °C	0.11 °C	Fluke 9173 Dry-well, SPRT, Temperature Indicator
	(100 to 420) °C	0.26 °C	
	(420 to 660) °C	0.41 °C	

**Thermodynamic**

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Thermocouple Wire, Thermocouple Probes (Types J, K, T, E)	(-30 to -20) °C (-20 to 0) °C (0 to 150) °C (150 to 200) °C (200 to 420) °C (420 to 660) °C	0.17 °C 0.15 °C 0.27 °C 0.32 °C 0.59 °C 0.87 °C	Comparison to Fluke 2560/5628 SPRT, Hart Black Stack, Ectron 1140A Thermocouple Calibrator/Simulator; Temperature Source
Infrared Thermometers <sup>1</sup>	(-15 to 0) °C (0 to 50) °C (50 to 100) °C (100 to 120) °C (120 to 200) °C (200 to 350) °C (350 to 500) °C	0.83 °C 0.65 °C 0.71 °C 0.76 °C 0.95 °C 1.6 °C 2 °C	Blackbody Source (Flat Plate) $\epsilon = (0.9 \text{ to } 1)$ $\lambda = (8 \text{ to } 14) \mu\text{m}$

**Time and Frequency**

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Reference Frequency (Source)	10 MHz	640 pHz/Hz	Rubidium Oscillator
Frequency – Measure <sup>1</sup>	10 MHz	0.21 $\mu\text{Hz/Hz}$	HP 53132A Opt 10 Universal Frequency Counter
Stopwatches, Timers <sup>1</sup>	Up to 599 s/mon	58 ms/day	Vibrograf 4500 Timometer
AC Duty Cycle – Source <sup>1</sup> Square Wave: < 3.3 Vp-p Freq: 0.1 Hz to 100 kHz	(1 to 10) % Duty Cycle 10 $\mu\text{s}$ to 100 s (10 to 49) % Duty Cycle 10 $\mu\text{s}$ to 100 s 50 % Duty Cycle 10 $\mu\text{s}$ to 100 s (51 to 90) % Duty Cycle 10 $\mu\text{s}$ to 100 s (90 to 99) % Duty Cycle 10 $\mu\text{s}$ to 100 s	0.62 % of reading + 78 ns 0.039 % of reading + 78 ns 0.016 % of reading + 78 ns 0.039 % of reading + 78 ns 0.62 % of reading + 78 ns	Fluke 55xxA Series Multiproduct Calibrator



## DIMENSIONAL MEASUREMENT

### 1 Dimensional

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Dimension Measurement – 1D	X-axis Up to 1 in (1 to 3) in (3 to 6) in  Y-axis Up to 2 in (2 to 3) in (3 to 5) in	210 μin 370 μin 480 μin  360 μin 410 μin 560 μin	Optical Comparator used as a Reference Standard for Dimensional Measurement. (Length)
Dimensional Measurement – 1D <sup>1,2</sup>	Up to 12 in	$(28 + 3.2L) \mu\text{in}$	Gage Amp, Probe, and Gage Blocks utilized as Reference Standards for Dimensional Measurement. (Height)
Dimensional Measurement – 1D <sup>1,2</sup>	Up to 4 inDL Up to 12.37 inDL (12.37 to 18.25) inDL (18.97 to 30.59) inDL	6.2 μin 35 μin 42 μin 46 μin	Optical Flats, Gage Amp, and Indicator utilized as Reference Standards for Dimensional Measurement. (Flatness)
Dimensional Measurement – 1D <sup>1,2</sup>	Up to 12.37 inDL (12.37 to 18.25) inDL (18.97 to 30.59) inDL	33 μin 40 μin 45 μin	Gage Amp and Indicator utilized as Reference Standards for Dimensional Measurement. (Parallelism)
Dimensional Measurement – 1D <sup>1,2</sup>	Up to 18 in	170 μin	Gage Amp, Surface Plate, and Granite Square utilized as Reference Standards for Dimensional Measurement. (Squareness)
Dimensional Measurement – 1D <sup>1,2</sup>	Up to 12 in (12 to 18) in (18 to 30) in	35 μin 42 μin 46 μin	Gage Amp and Indicator utilized as Reference Standards for Dimensional Measurement. (Straightness)

## 2 Dimensional

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Angle <sup>2</sup>	Up to 180°	29"	Optical Comparator utilized as Reference Standard for Dimensional Measurement.
Radius	Up to 1 in (1 to 3) in (3 to 6) in	260 μin 450 μin 590 μin	Optical Comparator utilized as Reference Standard for Dimensional Measurement.

## 3 Dimensional

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Dimensional Measurement – 3D <sup>2</sup>	X = Up to 2 500 mm Y = Up to 1 500 mm Z = Up to 1 000 mm	(6 + 0.009L) μm	Coordinate Measurement Machine utilized as Reference Standard for Dimensional Measurement.
Dimensional Measurement – 3D <sup>2</sup>	X = Up to 98.4 in Y = Up to 59 in Z = Up to 39.3 in	(240 + 0.4L) μin	Coordinate Measurement Machine utilized as Reference Standard for Dimensional Measurement.

Calibration and Measurement Capability (CMC) is expressed in terms of the measurement parameter, measurement range, expanded uncertainty of measurement and reference standard, method, and/or equipment. The expanded uncertainty of measurement is expressed as the standard uncertainty of the measurement multiplied by a coverage factor of 2 ( $k=2$ ), corresponding to a confidence level of approximately 95%.

Notes:

1. On-site calibration service is available for this parameter, since on-site conditions are typically more variable than those in the laboratory, larger measurement uncertainties are expected on-site than what is reported on the accredited scope.
2.  $L$  = length in measurand unit (inches or millimeters);  $D$  = diameter in measured unit (inches or millimeters); ' = arc-minute; " = arc-second;  $DL$  = diagonal length.
3. The uncertainties shown are for the most favorable conditions. There is an increase in uncertainty that corresponds to the laboratory's AC voltage and current uncertainties at different frequencies other than the ones shown. Power factors (PF) other than the one shown contribute to the power uncertainty. PF is related to the cosine of phase. Therefore, uncertainties track the laboratory's phase uncertainty closely at PF near one, but are magnified heavily as PF approaches zero. The lab may also report reactive power, apparent power, and power factor under this accreditation. If needed, contact laboratory for more information regarding uncertainties at frequency and power factor combinations other than the ones shown.
4. The stated uncertainty is the laboratory's ability to source a fast rise pulse that is approximately 250 ps. In the typical application of measuring rise time of an oscilloscope, this value is one of the contributing factors, but other factors are derived from the DUT.
5. The measurement uncertainty for scales and balances is highly dependent upon the resolution of the unit under test. The uncertainty presented here does not include the resolution of the unit under test. The resolution will be included in the reported measurement uncertainty at the time of calibration.
6. As frequency & amplitude deviate from the listed values, uncertainty may be higher than stated. If needed, contact the laboratory for more information regarding uncertainties at frequency and range combinations other than the ones shown.
7. Pitch is the distance from a point on the screw thread to a corresponding point on the next thread measured parallel to the axis. Pitch Diameter is the simple effective diameter of screw thread, approximately halfway between the major and minor diameters.
8. The legal entity for this location is Transcat, Inc.
9. This scope is formatted as part of a single document including Certificate of Accreditation No. AC-2489.23.



Jason Stine, Vice President

