



# CERTIFICATE OF ACCREDITATION

## The ANSI National Accreditation Board

Hereby attests that

**Transcat – Los Angeles**  
**1503 E. Orangethorpe Ave., Unit A**  
**Fullerton, CA 92831**

Fulfills the requirements of

**ISO/IEC 17025:2017**

and national standard

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

In the field of

**CALIBRATION**

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).

R. Douglas Leonard Jr., VP, PILR SBU

Expiry Date: 07 September 2021  
Certificate Number: AC-2489.08



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)

**Transcat – Los Angeles**  
1503 E. Orangethorpe Ave., Unit A  
Fullerton, CA 92831  
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### CALIBRATION

Valid to: **September 7, 2021**

Certificate Number: **AC-2489.08**

#### Acoustics and Vibration

| Parameter/Equipment                                                        | Range                                                                   | Expanded Uncertainty of Measurement (+/-)                                  | Reference Standard, Method, and/or Equipment         |
|----------------------------------------------------------------------------|-------------------------------------------------------------------------|----------------------------------------------------------------------------|------------------------------------------------------|
| Acceleration – Dynamic<br>Amplitude<br>(1 to 10) g<br>Sensitivity: 10 mV/g | (20 to 99) Hz<br>100 Hz to 2.5 kHz<br>(2.5 to 10) kHz<br>(10 to 20) kHz | 1.5 % of reading<br>1.4 % of reading<br>2.3 % of reading<br>5 % of reading | Comparison to Master Accelerometer                   |
| Sound Level Calibrators<br>31.5 Hz to 16 kHz                               | (94, 104, and 114) dB                                                   | 0.6 dB                                                                     | Bruel & Kjaer 4226 Multifunction Acoustic Calibrator |

#### Chemical Quantities

| Parameter/Equipment                   | Range                                                                | Expanded Uncertainty of Measurement (+/-)                    | Reference Standard, Method, and/or Equipment |
|---------------------------------------|----------------------------------------------------------------------|--------------------------------------------------------------|----------------------------------------------|
| pH – Measuring Equipment <sup>1</sup> | 4 pH<br>7 pH<br>10 pH                                                | 0.011 pH<br>0.011 pH<br>0.012 pH                             | Standard Buffer Solutions                    |
| Conductivity Meters                   | 10 µS/cm<br>100 µS/cm<br>1000 µS/cm<br>10 000 µS/cm<br>100 000 µS/cm | 0.5 µS/cm<br>2.2 µS/cm<br>3.7 µS/cm<br>36 µS/cm<br>440 µS/cm | Standard Solutions                           |

## Electrical – DC/Low Frequency

| Parameter/Equipment                                                           | Range                                                                                                                                                                                  | Expanded Uncertainty of Measurement (+/-)                                                                                                                                                                                                                        | Reference Standard, Method, and/or Equipment       |
|-------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------|
| Sine Wave Flatness <sup>1</sup>                                               | Up to 3 V<br>10 Hz to 1 MHz<br>(1 to 10) MHz<br>(10 to 30) MHz<br>(30 to 50) MHz<br>(50 to 80) MHz<br>(80 to 100) MHz                                                                  | 0.06 % of reading<br>0.1 % of reading<br>0.18 % of reading<br>0.41 % of reading<br>0.71 % of reading<br>0.84 % of reading                                                                                                                                        | Thermal Voltage Converters                         |
| DC Current – Measure/Source <sup>1</sup>                                      | (0 to 100) $\mu$ A<br>100 $\mu$ A to 1 mA<br>(1 to 10) mA<br>(10 to 100) mA<br>100 mA to 1 A                                                                                           | 26 $\mu$ A/A + 0.92 nA<br>26 $\mu$ A/A + 5.8 nA<br>26 $\mu$ A/A + 58 nA<br>43 $\mu$ A/A + 0.58 $\mu$ A<br>0.01 % + 12 $\mu$ A                                                                                                                                    | Agilent 3458A Multimeter w/ Current Source         |
|                                                                               | (1 to 100) A                                                                                                                                                                           | 0.01 % of reading + 0.5 mA                                                                                                                                                                                                                                       | Ohms Labs CS-100 Precision Shunt w/ Agilent 3458A  |
|                                                                               | (100 to 300) A                                                                                                                                                                         | 0.05 % of reading                                                                                                                                                                                                                                                | DC Current Shunts w/ DMM and Current Source        |
| DC Current – Source <sup>1</sup>                                              | (0 to 220) $\mu$ A<br>220 $\mu$ A to 2.2 mA<br>(2.2 to 22) mA<br>(22 to 220) mA<br>0.22 A to 2.2 A<br>(2.2 to 11) A                                                                    | 41 $\mu$ A/A + 6 nA<br>36 $\mu$ A/A + 7 nA<br>36 $\mu$ A/A + 40 nA<br>57 $\mu$ A/A + 0.7 $\mu$ A<br>0.2 mA/A + 12 $\mu$ A<br>0.4 mA/A + 0.5 mA                                                                                                                   | Fluke 5700A-EP Multimeter w/ Fluke 5725A Amplifier |
|                                                                               | (11 to 20) A                                                                                                                                                                           | 0.1 % of reading + 0.58 mA                                                                                                                                                                                                                                       | Fluke 5522A                                        |
| DC Clamp-on Ammeters (Non-Toroidal Type) Transformer Type Sensor <sup>1</sup> | (20 to 150) A<br>(150 to 1 000) A                                                                                                                                                      | 0.2 % of reading + 0.14 A<br>0.52 % of reading + 0.52 A                                                                                                                                                                                                          | Fluke 5520A/1100 Calibrator w/ Fluke 5500A/Coil    |
| AC Current – Measure <sup>1</sup>                                             | Up to 100 $\mu$ A<br>(10 to 20) Hz<br>(20 to 45) Hz<br>(45 to 100) Hz<br>100 Hz to 5 kHz<br>100 $\mu$ A to 1 mA<br>(10 to 20) Hz<br>(20 to 45) Hz<br>(45 to 100) Hz<br>100 Hz to 5 kHz | 0.46 % of reading + 35 nA<br>0.17 % of reading + 35 nA<br>0.07 % of reading + 35 nA<br>0.07 % of reading + 35 nA<br>0.46 % of reading + 0.23 $\mu$ A<br>0.17 % of reading + 0.23 $\mu$ A<br>0.07 % of reading + 0.23 $\mu$ A<br>0.04 % of reading + 0.23 $\mu$ A | Agilent 3458A Multimeter                           |

## Electrical – DC/Low Frequency

| Parameter/Equipment               | Range                                                                                                  | Expanded Uncertainty of Measurement (+/-)                                                                                                                   | Reference Standard, Method, and/or Equipment            |
|-----------------------------------|--------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------|
| AC Current – Measure <sup>1</sup> | (1 to 10) mA<br>(10 to 20) Hz<br>(20 to 45) Hz<br>(45 to 100) Hz<br>100 Hz to 5 kHz                    | 0.46 % of reading + 2.3 $\mu$ A<br>0.17 % of reading + 2.3 $\mu$ A<br>0.07 % of reading + 2.3 $\mu$ A<br>0.04 % of reading + 2.3 $\mu$ A                    | Agilent 3458A Multimeter                                |
|                                   | (10 to 100) mA<br>(10 to 20) Hz<br>(20 to 45) Hz<br>(45 to 100) Hz<br>100 Hz to 5 kHz                  | 0.46 % of reading + 23 $\mu$ A<br>0.17 % of reading + 23 $\mu$ A<br>0.07 % of reading + 23 $\mu$ A<br>0.04 % of reading + 23 $\mu$ A                        |                                                         |
|                                   | 100 mA to 1 A<br>(10 to 20) Hz<br>(20 to 45) Hz<br>(45 to 100) Hz<br>100 Hz to 5 kHz                   | 0.46 % of reading + 0.23 mA<br>0.19 % of reading + 0.23 mA<br>0.1 % of reading + 0.23 mA<br>0.12 % of reading + 0.23 mA                                     |                                                         |
| AC Current – Measure <sup>1</sup> | 0 A to 10 A<br>50 Hz to 1 kHz<br>1 kHz                                                                 | 0.05 % of reading + 1.3 mA<br>0.12 % of reading + 1.3 mA                                                                                                    | Ohms Labs CS-100<br>Precision Shunt<br>w/ Agilent 3458A |
|                                   | 10 A to 100 A<br>(50 to 100) Hz<br>100 Hz to 1 kHz<br>1 kHz                                            | 0.04 % of reading + 2.3 mA<br>0.04 % of reading + 2.3 mA<br>0.13 % of reading + 2.3 mA                                                                      |                                                         |
| AC Current – Source <sup>1</sup>  | Up to 220 $\mu$ A<br>(10 to 20) Hz<br>(20 to 40) Hz<br>40 Hz to 1 kHz<br>(1 to 5) kHz<br>(5 to 10) kHz | 0.03 % of reading + 16 nA<br>0.02 % of reading + 10 nA<br>0.01 % of reading + 8 nA<br>0.03 % of reading + 10 nA<br>0.11 % of reading + 65 nA                | Fluke 5700A-EP Calibrator                               |
|                                   | (0.22 to 2.2) mA<br>(10 to 20) Hz<br>(20 to 40) Hz<br>40 Hz to 1 kHz<br>(1 to 5) kHz<br>(5 to 10) kHz  | 0.03 % of reading + 40 nA<br>0.02 % of reading + 35 nA<br>0.01 % of reading + 35 nA<br>0.02 % of reading + 0.11 $\mu$ A<br>0.11 % of reading + 0.65 $\mu$ A |                                                         |

## Electrical – DC/Low Frequency

| Parameter/Equipment                                              | Range                                                                                                                                                                                                                                                                            | Expanded Uncertainty of Measurement (+/-)                                                                                                                                                                                                                                                                                                                                                                                                                  | Reference Standard, Method, and/or Equipment                                     |
|------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------|
| AC Current – Source <sup>1</sup>                                 | (2.2 to 22) mA<br>(10 to 20) Hz<br>(20 to 40) Hz<br>40 Hz to 1 kHz<br>(1 to 5) kHz<br>(5 to 10) kHz<br>(22 to 220) mA<br>(10 to 20) Hz<br>(20 to 40) Hz<br>40 Hz to 1 kHz<br>(1 to 5) kHz<br>(5 to 10) kHz<br>(0.22 to 2.2) A<br>20 Hz to 1 kHz<br>(1 to 5) kHz<br>(5 to 10) kHz | 0.04 % of reading + 0.4 $\mu$ A<br>0.02 % of reading + 0.35 $\mu$ A<br>0.01 % of reading + 0.35 $\mu$ A<br>0.02 % of reading + 0.55 $\mu$ A<br>0.11 % of reading + 5 $\mu$ A<br>0.03 % of reading + 4 $\mu$ A<br>0.02 % of reading + 3.5 $\mu$ A<br>0.01 % of reading + 2.5 $\mu$ A<br>0.02 % of reading + 3.5 $\mu$ A<br>0.11 % of reading + 10 $\mu$ A<br>0.03 % of reading + 35 $\mu$ A<br>0.05 % of reading + 80 $\mu$ A<br>0.7 % of reading + 0.16 mA | Fluke 5700A-EP Calibrator                                                        |
| AC Current – Source <sup>1</sup>                                 | (2.2 to 11) A<br>40 Hz to 1 kHz<br>(1 to 5) kHz<br>(5 to 10) kHz                                                                                                                                                                                                                 | 0.05 % of reading + 0.17 mA<br>0.1 % of reading + 0.38 mA<br>0.36 % of reading + 0.75 mA                                                                                                                                                                                                                                                                                                                                                                   | Fluke 5700A-EP Calibrator<br>w/ Fluke 5725A Amplifier                            |
| AC Current – Source <sup>1</sup>                                 | (11 to 20.5) A<br>(45 to 100) Hz<br>100 Hz to 1 kHz<br>(1 to 5) kHz                                                                                                                                                                                                              | 0.09 % of reading + 3.9 mA<br>0.12 % of reading + 3.9 mA<br>2.3 % of reading + 3.9 mA                                                                                                                                                                                                                                                                                                                                                                      | Fluke 5522A Calibrator                                                           |
| AC Current – Source <sup>1</sup>                                 | Up to 10 A<br>50 Hz to 1 kHz<br>1 kHz<br>(10 to 100) A<br>(50 to 100) Hz<br>(100 to 999) Hz                                                                                                                                                                                      | 0.05 % of reading + 1.3 mA<br>0.12 % of reading + 1.3 mA<br>0.04 % of reading + 2.3 mA<br>0.42 % of reading + 2.3 mA                                                                                                                                                                                                                                                                                                                                       | Ohms Labs CS-100<br>Precision Shunt<br>w/ Agilent 3458A<br>Multimeter and Source |
| AC Current – Source<br>Extended Frequency<br>Ranges <sup>1</sup> | 29 $\mu$ A to 329.99 $\mu$ A<br>(10 to 30) kHz<br>330 $\mu$ A to 3.299 mA<br>(10 to 30) kHz<br>3.3 mA to 32.99 mA<br>(10 to 30) kHz<br>33 mA to 329.99 mA<br>(10 to 30) kHz                                                                                                      | 1.2 % of reading + 0.31 $\mu$ A<br>0.78 % of reading + 0.47 $\mu$ A<br>0.31 % of reading + 3.1 $\mu$ A<br>0.31 % of reading + 0.16 mA                                                                                                                                                                                                                                                                                                                      | Fluke 5522A Calibrator                                                           |

## Electrical – DC/Low Frequency

| Parameter/Equipment                                                       | Range                                                                                                                                                                                                                                              | Expanded Uncertainty of Measurement (+/-)                                                                                                                                                                                                                                                                                                                                  | Reference Standard, Method, and/or Equipment                |
|---------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------|
| AC Clamp-on Ammeters (Toroidal Type) Transformer Type Sensor <sup>1</sup> | (20 to 150) A<br>(45 to 65) Hz<br>(65 to 440) Hz<br>(150 to 1 000) A<br>(45 to 65) Hz<br>(65 to 440) Hz                                                                                                                                            | 0.34 % of reading + 35 mA<br>0.95 % of reading + 66 mA<br><br>0.38 % of reading + 0.17 A<br>1.2 % of reading + 0.29 A                                                                                                                                                                                                                                                      | Fluke 5522A Calibrator w/ Fluke 5500A/Coil                  |
| AC Clamp-on Ammeters (Non-Toroidal Type) Hall Effect Sensor <sup>1</sup>  | (20 to 150) A<br>(45 to 65) Hz<br>(65 to 440) Hz<br>(150 to 1 000) A<br>(45 to 65) Hz<br>(65 to 440) Hz                                                                                                                                            | 0.66 % of reading + 0.26 mA<br>1.2 % of reading + 0.29 A<br><br>0.68 % of reading + 1 A<br>1.4 % of reading + 1.1 A                                                                                                                                                                                                                                                        |                                                             |
| DC Resistance – Measure/Source <sup>1</sup>                               | (0 to 10) $\Omega$<br>(10 to 100) $\Omega$<br>100 $\Omega$ to 1 k $\Omega$<br>(1 to 10) k $\Omega$<br>(10 to 100) k $\Omega$<br>100 k $\Omega$ to 1 M $\Omega$<br>(1 to 10) M $\Omega$<br>(10 to 100) M $\Omega$<br>100 M $\Omega$ to 1 G $\Omega$ | 18 $\mu\Omega/\Omega$ + 58 $\mu\Omega$<br>15 $\mu\Omega/\Omega$ + 0.58 m $\Omega$<br>12 $\mu\Omega/\Omega$ + 0.58 m $\Omega$<br>12 $\mu\Omega/\Omega$ + 5.8 m $\Omega$<br>12 $\mu\Omega/\Omega$ + 58 m $\Omega$<br>19 $\mu\Omega/\Omega$ + 2.3 $\Omega$<br>62 $\mu\Omega/\Omega$ + 120 $\Omega$<br>0.06 % of reading + 1.2 k $\Omega$<br>0.58 % of reading + 12 k $\Omega$ | Agilent 3458A Multimeter w/ Decade Resistor                 |
| DC Resistance – Source Fixed <sup>1</sup>                                 | 1 m $\Omega$                                                                                                                                                                                                                                       | 9.8 $\mu\Omega/\Omega$                                                                                                                                                                                                                                                                                                                                                     | L&N 4223B Standard Resistor                                 |
|                                                                           | 10 m $\Omega$                                                                                                                                                                                                                                      | 30 $\mu\Omega/\Omega$                                                                                                                                                                                                                                                                                                                                                      | L&N 4222B Standard Resistor                                 |
|                                                                           | 100 m $\Omega$                                                                                                                                                                                                                                     | 34 $\mu\Omega/\Omega$                                                                                                                                                                                                                                                                                                                                                      | L&N 4015B Standard Resistor                                 |
| DC Resistance – Source Variable <sup>1</sup>                              | (2 to 10) G $\Omega$<br>(20 to 100) G $\Omega$<br>200 G $\Omega$ to 1 T $\Omega$                                                                                                                                                                   | 0.58 % of reading<br>1.2 % of reading<br>2.6 % of reading                                                                                                                                                                                                                                                                                                                  | IET HRRS-B-3-1G-5KV Decade Resistor                         |
| DC Resistance – RTD Measure <sup>1</sup>                                  | (0 to 25) $\Omega$<br>(25 to 400) $\Omega$<br>400 to 1 k $\Omega$<br>(1 to 40) k $\Omega$                                                                                                                                                          | 0.04 m $\Omega$<br>1.3 $\mu\Omega/\Omega$<br>4.1 $\mu\Omega/\Omega$<br>10 $\mu\Omega/\Omega$                                                                                                                                                                                                                                                                               | Hart 1590 Super Thermometer Readout                         |
| DC Voltage – Measure/Source <sup>1</sup>                                  | (0 to 100) mV<br>100 mV to 10 V<br>(10 to 100) V<br>(100 to 500) V<br>(500 to 800) V<br>(800 to 1 000) V                                                                                                                                           | 8.3 $\mu\text{V}/\text{V}$ + 0.5 $\mu\text{V}$<br>5.1 $\mu\text{V}/\text{V}$ + 0.5 $\mu\text{V}$<br>7.6 $\mu\text{V}/\text{V}$ + 35 $\mu\text{V}$<br>11 $\mu\text{V}/\text{V}$ + 0.12 mV<br>16 $\mu\text{V}/\text{V}$ + 0.12 mV<br>21 $\mu\text{V}/\text{V}$ + 0.12 mV                                                                                                     | Agilent 3458A opt 2 Multimeter w/ Fluke 5700A-EP Calibrator |



## Electrical – DC/Low Frequency

| Parameter/Equipment                    | Range                                                                                                                                                                                                                                                                                         | Expanded Uncertainty of Measurement (+/-)                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Reference Standard, Method, and/or Equipment         |
|----------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------|
| DC High Voltage – Measure <sup>1</sup> | (1 to 10) kV<br>(10 to 35) kV<br>(35 to 70) kV<br>(70 to 100) kV                                                                                                                                                                                                                              | 0.03 % of reading + 35 mV<br>0.06 % of reading + 81 mV<br>0.04 % of reading + 23 mV<br>0.17 % of reading + 1.3 V                                                                                                                                                                                                                                                                                                                                                                                  | Vitrek 4700 DVM<br>w/ Associated High Voltage Probes |
| AC Voltage – Measure <sup>1</sup>      | Up to 1 mV<br>100 kHz to 1 MHz<br>(1 to 3) MHz<br>(3 to 10) MHz<br>(10 to 20) MHz<br>(1 to 3) mV<br>100 kHz to 1 MHz<br>(1 to 3) MHz<br>(3 to 10) MHz<br>(10 to 20) MHz<br>(3 to 100) mV<br>100 kHz to 1 MHz<br>(1 to 3) MHz<br>(3 to 10) MHz<br>(10 to 20) MHz<br>(20 to 30) MHz             | 1.8 % of reading + 2.4 $\mu$ V<br>3.5 % of reading + 2.4 $\mu$ V<br>9.3 % of reading + 2.4 $\mu$ V<br>23 % of reading + 2.4 $\mu$ V<br>0.97 % of reading + 2 $\mu$ V<br>3.5 % of reading + 2 $\mu$ V<br>9.3 % of reading + 2 $\mu$ V<br>23 % of reading + 2 $\mu$ V<br>0.91 % of reading + 3 $\mu$ V<br>1.8 % of reading + 3 $\mu$ V<br>2.9 % of reading + 3 $\mu$ V<br>7 % of reading + 3 $\mu$ V<br>14 % of reading + 3 $\mu$ V                                                                 | Rohde & Schwarz URE3<br>RMS Voltmeter                |
| AC Voltage – Measure <sup>1</sup>      | Up to 10 mV<br>(1 to 40) Hz<br>40 Hz to 1 kHz<br>(1 to 20) kHz<br>(20 to 50) kHz<br>(50 to 100) kHz<br>(100 to 300) kHz<br>300 kHz to 1 MHz<br>(10 to 100) mV<br>(1 to 40) Hz<br>40 Hz to 1 kHz<br>(1 to 20) kHz<br>(20 to 50) kHz<br>(50 to 100) kHz<br>(100 to 300) kHz<br>300 kHz to 1 MHz | 0.04 % of reading + 3.5 $\mu$ V<br>0.04 % of reading + 1.2 $\mu$ V<br>0.04 % of reading + 1.2 $\mu$ V<br>0.15 % of reading + 1.2 $\mu$ V<br>0.59 % of reading + 1.2 $\mu$ V<br>4.6 % of reading + 2.3 $\mu$ V<br>1.5 % of reading + 5.8 $\mu$ V<br>0.01 % of reading + 4.6 $\mu$ V<br>0.01 % of reading + 2.3 $\mu$ V<br>0.02 % of reading + 2.3 $\mu$ V<br>0.04 % of reading + 2.3 $\mu$ V<br>0.09 % of reading + 2.3 $\mu$ V<br>0.36 % of reading + 12 $\mu$ V<br>1.2 % of reading + 12 $\mu$ V | Agilent 3458A Multimeter                             |

## Electrical – DC/Low Frequency

| Parameter/Equipment               | Range                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Expanded Uncertainty of Measurement (+/-)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Reference Standard, Method, and/or Equipment |
|-----------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------|
| AC Voltage – Measure <sup>1</sup> | 100 mV to 1 V<br>(1 to 40) Hz<br>40 Hz to 1 kHz<br>(1 to 20) kHz<br>(20 to 50) kHz<br>(50 to 100) kHz<br>(100 to 300) kHz<br>300 kHz to 1 MHz<br>(1 to 10) V<br>(1 to 40) Hz<br>40 Hz to 1 kHz<br>(1 to 20) kHz<br>(20 to 50) kHz<br>(50 to 100) kHz<br>(100 to 300) kHz<br>300 kHz to 1 MHz<br>(10 to 100) V<br>(1 to 40) Hz<br>40 Hz to 1 kHz<br>(1 to 20) kHz<br>(20 to 50) kHz<br>(50 to 100) kHz<br>(100 to 300) kHz<br>300 kHz to 1 MHz<br>(100 to 700) V<br>(1 to 40) Hz<br>40 Hz to 1 kHz<br>(1 to 20) kHz<br>(20 to 50) kHz<br>(50 to 100) kHz | 0.01 % of reading + 46 $\mu$ V<br>0.01 % of reading + 23 $\mu$ V<br>0.02 % of reading + 23 $\mu$ V<br>0.04 % of reading + 23 $\mu$ V<br>0.09 % of reading + 23 $\mu$ V<br>0.35 % of reading + 0.12 mV<br>1.2 % of reading + 0.12 mV<br>0.01 % of reading + 0.46 mV<br>0.01 % of reading + 0.23 mV<br>0.02 % of reading + 0.23 mV<br>0.04 % of reading + 0.23 mV<br>0.09 % of reading + 0.23 mV<br>0.35 % of reading + 1.2 mV<br>1.2 % of reading + 1.2 mV<br>0.02 % of reading + 4.6 mV<br>0.02 % of reading + 2.3 mV<br>0.02 % of reading + 2.3 mV<br>0.04 % of reading + 2.3 mV<br>0.14 % of reading + 2.3 mV<br>0.46 % of reading + 12 mV<br>1.7 % of reading + 12 mV<br>0.05 % of reading + 46 mV<br>0.05 % of reading + 23 mV<br>0.07 % of reading + 23 mV<br>0.14 % of reading + 23 mV<br>0.35 % of reading + 23 mV | Agilent 3458A Multimeter                     |
|                                   | (700 to 1 050) V<br>(1 to 10) Hz<br>(10 to 40) Hz<br>40 Hz to 10 kHz<br>(10 to 30) kHz<br>(30 to 100) kHz                                                                                                                                                                                                                                                                                                                                                                                                                                               | 0.02 % + 85 mV<br>0.02 % + 24 mV<br>0.02 % + 24 mV<br>0.03 % + 48 mV<br>0.06 % + 0.24 V                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                              |



## Electrical – DC/Low Frequency

| Parameter/Equipment                           | Range           | Expanded Uncertainty of Measurement (+/-) | Reference Standard, Method, and/or Equipment         |
|-----------------------------------------------|-----------------|-------------------------------------------|------------------------------------------------------|
| AC High Voltage – Measure/Source <sup>1</sup> | (1.05 to 10) kV |                                           | Vitrek 4700 DVM<br>w/ Associated High Voltage Probes |
|                                               | (10 to 200) Hz  | 0.14 % of reading + 0.12 V                |                                                      |
|                                               | (200 to 450) Hz | 0.46 % of reading + 0.12 V                |                                                      |
|                                               | (10 to 30) kV   |                                           |                                                      |
|                                               | (30 to 200) Hz  | 0.06 % of reading + 0.23 V                |                                                      |
|                                               | (200 to 450) Hz | 0.7 % of reading + 0.23 V                 |                                                      |
|                                               | (30 to 50) kV   |                                           |                                                      |
|                                               | (30 to 100) Hz  | 0.09 % of reading + 0.46 V                |                                                      |
|                                               | (100 to 450) Hz | 2.9 % of reading + 0.46 V                 |                                                      |
|                                               | (50 to 100) kV  |                                           |                                                      |
|                                               | 60 Hz           | 0.23 % of reading + 1.4 V                 |                                                      |

**Electrical – DC/Low Frequency**

| Parameter/Equipment              | Range            | Expanded Uncertainty of Measurement (+/-) | Reference Standard, Method, and/or Equipment |
|----------------------------------|------------------|-------------------------------------------|----------------------------------------------|
| AC Voltage – Source <sup>1</sup> | Up to 2.2 mV     |                                           | Fluke 5700A-EP Calibrator                    |
|                                  | (10 to 20) Hz    | 0.04 % of reading + 4.1 $\mu$ V           |                                              |
|                                  | (20 to 40) Hz    | 0.03 % of reading + 4.1 $\mu$ V           |                                              |
|                                  | 40 Hz to 20 kHz  | 0.03 % of reading + 4.1 $\mu$ V           |                                              |
|                                  | (20 o 50) kHz    | 0.03 % of reading + 4.1 $\mu$ V           |                                              |
|                                  | (50 to 100) kHz  | 0.06 % of reading + 5.1 $\mu$ V           |                                              |
|                                  | (100 to 300) kHz | 0.13 % of reading + 10 $\mu$ V            |                                              |
|                                  | (300 to 500) kHz | 0.2 % of reading + 20 $\mu$ V             |                                              |
|                                  | 500 kHz to 1 MHz | 0.31 % of reading + 20 $\mu$ V            |                                              |
|                                  | (2.2 to 22) mV   |                                           |                                              |
|                                  | (10 to 20) Hz    | 0.04 % of reading + 4.1 $\mu$ V           |                                              |
|                                  | (20 to 40) Hz    | 0.03 % of reading + 4.1 $\mu$ V           |                                              |
|                                  | 40 Hz to 20 kHz  | 0.01 % of reading + 4.1 $\mu$ V           |                                              |
|                                  | (20 o 50) kHz    | 0.02 % of reading + 4.1 $\mu$ V           |                                              |
|                                  | (50 to 100) kHz  | 0.05 % of reading + 5.1 $\mu$ V           |                                              |
|                                  | (100 to 300) kHz | 0.11 % of reading + 10 $\mu$ V            |                                              |
|                                  | (300 to 500) kHz | 0.14 % of reading + 20 $\mu$ V            |                                              |
|                                  | 500 kHz to 1 MHz | 0.28 % of reading + 20 $\mu$ V            |                                              |
|                                  | (22 to 220) mV   |                                           |                                              |
|                                  | (10 to 20) Hz    | 0.02 % of reading + 12 $\mu$ V            |                                              |
|                                  | (20 to 40) Hz    | 0.01 % of reading + 7.1 $\mu$ V           |                                              |
|                                  | 40 Hz to 20 kHz  | 0.01 % of reading + 7.1 $\mu$ V           |                                              |
|                                  | (20 o 50) kHz    | 0.02 % of reading + 7.1 $\mu$ V           |                                              |
|                                  | (50 to 100) kHz  | 0.05 % of reading + 17 $\mu$ V            |                                              |
|                                  | (100 to 300) kHz | 0.09 % of reading + 20 $\mu$ V            |                                              |
|                                  | (300 to 500) kHz | 0.14 % of reading + 26 $\mu$ V            |                                              |
|                                  | 500 kHz to 1 MHz | 0.28 % of reading + 46 $\mu$ V            |                                              |
|                                  | 220 mV to 2.2 V  |                                           |                                              |
|                                  | (10 to 20) Hz    | 0.02 % of reading + 41 $\mu$ V            |                                              |
|                                  | (20 to 40) Hz    | 0.01 % of reading + 15 $\mu$ V            |                                              |
|                                  | 40 Hz to 20 kHz  | 0.05 % of reading + 8.2 $\mu$ V           |                                              |
|                                  | (20 o 50) kHz    | 0.01 % of reading + 10 $\mu$ V            |                                              |
|                                  | (50 to 100) kHz  | 0.01 % of reading + 31 $\mu$ V            |                                              |
|                                  | (100 to 300) kHz | 0.04 % of reading + 82 $\mu$ V            |                                              |
|                                  | (300 to 500) kHz | 0.1 % of reading + 0.2 mV                 |                                              |
|                                  | 500 kHz to 1 MHz | 0.17 % of reading + 0.31 mV               |                                              |

## Electrical – DC/Low Frequency

| Parameter/Equipment                         | Range                                                                                                                                                               | Expanded Uncertainty of Measurement (+/-)                                                                                                                                                                                                        | Reference Standard, Method, and/or Equipment          |
|---------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------|
| AC Voltage – Source <sup>1</sup>            | (2.2 to 22) V<br>(10 to 20) Hz<br>(20 to 40) Hz<br>40 Hz to 20 kHz<br>(20 to 50) kHz<br>(50 to 100) kHz<br>(100 to 300) kHz<br>(300 to 500) kHz<br>500 kHz to 1 MHz | 0.02 % of reading + 0.41 mV<br>0.01 % of reading + 0.15 mV<br>0.01 % of reading + 51 $\mu$ V<br>0.01 % of reading + 0.1 mV<br>0.01 % of reading + 0.2 mV<br>0.03 % of reading + 0.61 mV<br>0.1 % of reading + 2 mV<br>0.15 % of reading + 3.3 mV | Fluke 5700A-EP Calibrator                             |
|                                             | (22 to 220) V<br>(10 to 20) Hz<br>(20 to 40) Hz<br>40 Hz to 20 kHz<br>(20 to 50) kHz<br>(50 to 100) kHz<br>(100 to 300) kHz<br>(300 to 500) kHz<br>500 kHz to 1 MHz | 0.02 % of reading + 4.1 mV<br>0.01 % of reading + 1.5 mV<br>0.01 % of reading + 0.61 mV<br>0.01 % of reading + 1.0 mV<br>0.01 % of reading + 2.5 mV<br>0.09 % of reading + 16 mV<br>0.45 % of reading + 41 mV<br>0.82 % of reading + 82 mV       |                                                       |
| AC Voltage – Source <sup>1</sup>            | (220 to 1 100) V<br>40 Hz to 1 kHz<br>(1 to 20) kHz<br>(20 to 30) kHz<br>(30 to 50) kHz<br>(50 to 100) kHz                                                          | 0.01 % of reading + 4.1 mV<br>0.02 % of reading + 6.1 mV<br>0.06 % of reading + 11 mV<br>0.06 % of reading + 11 mV<br>0.24 % of reading + 46 mV                                                                                                  | Fluke 5700A-EP Calibrator<br>w/ Fluke 5725A Amplifier |
| Capacitance – Measure <sup>1</sup><br>1 kHz | Up to 10 pF<br>(10 to 100) pF<br>100 pF to 25 $\mu$ F<br>(25 to 100) $\mu$ F<br>(100 to 1 000) $\mu$ F                                                              | 0.47 % of reading + 0.05 pF<br>0.06 % of reading + 0.05 pF<br>0.02 % of reading + 0.05 pF<br>0.03 % of reading<br>0.24 % of reading                                                                                                              | GenRad 1689-9700<br>RLC Digibridge                    |

**Electrical – DC/Low Frequency**

| Parameter/Equipment   | Range   | Expanded Uncertainty of Measurement (+/-) | Reference Standard, Method, and/or Equipment |
|-----------------------|---------|-------------------------------------------|----------------------------------------------|
| Capacitance – Measure | 0.1 pF  |                                           | Agilent E4980A<br>LCR Meter                  |
|                       | 100 kHz | 1.4 % of reading                          |                                              |
|                       | 1 MHz   | 1.8 % of reading                          |                                              |
|                       | 1 pF    |                                           |                                              |
|                       | 10 kHz  | 1.4 % of reading                          |                                              |
|                       | 100 kHz | 0.37 % of reading                         |                                              |
|                       | 1 MHz   | 0.44 % of reading                         |                                              |
|                       | 2 MHz   | 1.1 % of reading                          |                                              |
|                       | 10 pF   |                                           |                                              |
|                       | 1 kHz   | 1.4 % of reading                          |                                              |
|                       | 10 kHz  | 0.28 % of reading                         |                                              |
|                       | 100 kHz | 0.28 % of reading                         |                                              |
|                       | 1 MHz   | 0.3 % of reading                          |                                              |
|                       | 2 MHz   | 0.75 % of reading                         |                                              |
|                       | 100 pF  |                                           |                                              |
|                       | 100 Hz  | 2.1 % of reading                          |                                              |
|                       | 1 kHz   | 0.23 % of reading                         |                                              |
|                       | 10 kHz  | 0.18 % of reading                         |                                              |
|                       | 100 kHz | 0.21 % of reading                         |                                              |
|                       | 1 MHz   | 0.23 % of reading                         |                                              |
|                       | 2 MHz   | 0.3 % of reading                          |                                              |
|                       | 1 nF    |                                           |                                              |
|                       | 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                          |                                              |
|                       | 1 MHz   | 0.14 % of reading                         |                                              |
|                       | 2 MHz   | 0.53 % of reading                         |                                              |
|                       | 10 nF   |                                           |                                              |
|                       | 20 Hz   | 0.31 % of reading                         |                                              |
|                       | 100 Hz  | 0.12 % of reading                         |                                              |
|                       | 1 kHz   | 0.1 % of reading                          |                                              |
|                       | 10 kHz  | 0.1 % of reading                          |                                              |
|                       | 100 kHz | 0.1 % of reading                          |                                              |
|                       | 1 MHz   | 0.25 % of reading                         |                                              |
|                       | 2 MHz   | 0.67 % of reading                         |                                              |

**Electrical – DC/Low Frequency**

| Parameter/Equipment                          | Range                 | Expanded Uncertainty of Measurement (+/-) | Reference Standard, Method, and/or Equipment |
|----------------------------------------------|-----------------------|-------------------------------------------|----------------------------------------------|
| Capacitance – Measure                        | 100 nF                |                                           | Agilent E4980A<br>LCR Meter                  |
|                                              | 20 Hz                 | 0.16 % of reading                         |                                              |
|                                              | 100 Hz                | 0.1 % of reading                          |                                              |
|                                              | 1 kHz                 | 0.1 % of reading                          |                                              |
|                                              | 10 kHz                | 0.1 % of reading                          |                                              |
|                                              | 100 kHz               | 0.18 % of reading                         |                                              |
|                                              | 1 MHz                 | 0.33 % of reading                         |                                              |
|                                              | 2 MHz                 | 0.97 % of reading                         |                                              |
|                                              | 1 $\mu$ F             |                                           |                                              |
|                                              | 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                         |                                              |
|                                              | 1 MHz                 | 0.79 % of reading                         |                                              |
|                                              | 10 $\mu$ F            |                                           |                                              |
|                                              | 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 $\mu$ F           |                                           |                                              |
|                                              | 20 Hz                 | 0.16 % of reading                         |                                              |
|                                              | 100 Hz                | 0.17 % of reading                         |                                              |
|                                              | 1 kHz                 | 0.29 % of reading                         |                                              |
|                                              | 10 kHz                | 0.8 % of reading                          |                                              |
| Capacitance – Source Simulation <sup>1</sup> | 190 pF to 1.1 nF      | 0.39 % of reading + 7.8 pF                | Fluke 5520A/1100<br>Calibrator               |
|                                              | (1.1 to 3.3) nF       | 0.39 % of reading + 7.8 pF                |                                              |
|                                              | (3.3 to 11) nF        | 0.2 % of reading + 7.8 pF                 |                                              |
|                                              | (11 to 110) nF        | 0.2 % of reading + 78 pF                  |                                              |
|                                              | (110 to 330) nF       | 0.2 % of reading + 0.23 nF                |                                              |
|                                              | 330 nF to 1.1 $\mu$ F | 0.2 % of reading + 0.78 nF                |                                              |
|                                              | (1.1 to 3.3) $\mu$ F  | 0.2 % of reading + 2.3 nF                 |                                              |
|                                              | (3.3 to 11) $\mu$ F   | 0.2 % of reading + 7.8 nF                 |                                              |
|                                              | (11 to 33) $\mu$ F    | 0.31 % of reading + 23 nF                 |                                              |
|                                              | (33 to 110) $\mu$ F   | 0.35 % of reading + 78 nF                 |                                              |
|                                              | (110 to 330) $\mu$ F  | 0.35 % of reading + 0.23 $\mu$ F          |                                              |
|                                              | 330 $\mu$ F to 1.1 mF | 0.35 % of reading + 0.78 $\mu$ F          |                                              |
|                                              | (1.1 to 3.3) mF       | 0.35 % of reading + 2.3 $\mu$ F           |                                              |
|                                              | (3.3 to 11) mF        | 0.35 % of reading + 7.8 $\mu$ F           |                                              |
|                                              | (11 to 33) mF         | 0.58 % of reading + 23 $\mu$ F            |                                              |
|                                              | (33 to 110) mF        | 0.86 % of reading + 78 $\mu$ F            |                                              |

## Electrical – DC/Low Frequency

| Parameter/Equipment                                  | Range                                                                                                                                                                                                                                  | Expanded Uncertainty of Measurement (+/-)                                                                                                                                                                                                                                                                                                                                                                  | Reference Standard, Method, and/or Equipment |
|------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------|
| Capacitance – Source <sup>1</sup><br>Fixed<br>1 kHz  | 1 nF<br>2 nF<br>5 nF<br>10 nF<br>20 nF<br>50 nF<br>0.1 $\mu$ F<br>0.2 $\mu$ F<br>0.5 $\mu$ F<br>1 $\mu$ F                                                                                                                              | 0.17 pF<br>0.34 pF<br>0.85 pF<br>1.7 pF<br>3.4 pF<br>8.5 pF<br>17 pF<br>34 pF<br>85 pF<br>0.17 nF                                                                                                                                                                                                                                                                                                          | GenRad 1409 Series<br>Standard Capacitors    |
| Inductance – Measure <sup>1</sup><br>100 Hz to 1 kHz | (1 to 10) mH<br>10 mH to 10 H                                                                                                                                                                                                          | 0.03 % of reading + 0.1 $\mu$ H<br>0.03 % of reading + 1.4 $\mu$ H                                                                                                                                                                                                                                                                                                                                         | GenRad 1689-9700<br>RLC Digibridge           |
| Inductance – Measure                                 | 1 $\mu$ H<br>10 kHz<br>100 kHz<br>1 MHz<br>2 MHz<br>10 $\mu$ H<br>10 kHz<br>100 kHz<br>1 MHz<br>2 MHz<br>100 $\mu$ H<br>1 kHz<br>10 kHz<br>100 kHz<br>1 MHz<br>2 MHz<br>1 mH<br>100 Hz<br>1 kHz<br>10 kHz<br>100 kHz<br>1 MHz<br>2 MHz | 1.6 % of reading<br>0.36 % of reading<br>0.27 % of reading<br>0.66 % of reading<br>0.37 % of reading<br>0.20 % of reading<br>0.20 % of reading<br>0.30 % of reading<br>0.40 % of reading<br>0.20 % of reading<br>0.12 % of reading<br>0.14 % of reading<br>0.72 % of reading<br>0.55 % of reading<br>0.18 % of reading<br>0.12 % of reading<br>0.09 % of reading<br>0.23 % of reading<br>0.88 % of reading | Agilent E4980A<br>LCR Meter                  |



**Electrical – DC/Low Frequency**

| Parameter/Equipment     | Range        | Expanded Uncertainty of Measurement (+/-) | Reference Standard, Method, and/or Equipment |
|-------------------------|--------------|-------------------------------------------|----------------------------------------------|
| Inductance – Measure    | 10 mH        |                                           | Agilent E4980AL<br>LCR Meter                 |
|                         | 20 Hz        | 0.85 % of reading                         |                                              |
|                         | 100 Hz       | 0.22 % of reading                         |                                              |
|                         | 1 kHz        | 0.09 % of reading                         |                                              |
|                         | 10 kHz       | 0.09 % of reading                         |                                              |
|                         | 100 kHz      | 0.10 % of reading                         |                                              |
|                         | 1 MHz        | 0.35 % of reading                         |                                              |
|                         | 2 MHz        | 1.3 % of reading                          |                                              |
|                         | 100 mH       |                                           |                                              |
|                         | 20 Hz        | 0.28 % of reading                         |                                              |
|                         | 100 Hz       | 0.10 % of reading                         |                                              |
|                         | 1 kHz        | 0.09 % of reading                         |                                              |
|                         | 10 kHz       | 0.09 % of reading                         |                                              |
|                         | 100 kHz      | 0.21 % of reading                         |                                              |
|                         | 1 MHz        | 0.88 % of reading                         |                                              |
|                         | 1 H          |                                           |                                              |
|                         | 20 Hz        | 0.16 % of reading                         |                                              |
|                         | 100 Hz       | 0.09 % of reading                         |                                              |
|                         | 1 kHz        | 0.09 % of reading                         |                                              |
|                         | 10 kHz       | 0.10 % of reading                         |                                              |
|                         | 100 kHz      | 0.31 % of reading                         |                                              |
|                         | 10 H         |                                           |                                              |
|                         | 20 Hz        | 0.15 % of reading                         |                                              |
|                         | 100 Hz       | 0.10 % 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       | 0.10 % of reading                         |                                              |
|                         | 1 kHz        | 0.15 % of reading                         |                                              |
|                         | 10 kHz       | 0.62 % of reading                         |                                              |
| AC Resistance – Measure | 0.1 $\Omega$ |                                           | Agilent E4980A<br>LCR Meter                  |
|                         | 1 kHz        | 1.8 % of reading                          |                                              |
|                         | 10 kHz       | 1.6 % of reading                          |                                              |
|                         | 100 kHz      | 1.0 % of reading                          |                                              |
|                         | 1 MHz        | 1.5 % of reading                          |                                              |

**Electrical – DC/Low Frequency**

| Parameter/Equipment     | Range         | Expanded Uncertainty of Measurement (+/-) | Reference Standard, Method, and/or Equipment |
|-------------------------|---------------|-------------------------------------------|----------------------------------------------|
| AC Resistance – Measure | 1 $\Omega$    |                                           | Agilent E4980A<br>LCR Meter                  |
|                         | 20 Hz         | 0.67 % of reading                         |                                              |
|                         | 100 Hz        | 0.43 % of reading                         |                                              |
|                         | 1 kHz         | 0.33 % of reading                         |                                              |
|                         | 10 kHz        | 0.32 % of reading                         |                                              |
|                         | 100 kHz       | 0.31 % of reading                         |                                              |
|                         | 1 MHz         | 0.38 % of reading                         |                                              |
|                         | 2 MHz         | 0.92 % of reading                         |                                              |
|                         | 10 $\Omega$   |                                           |                                              |
|                         | 20 Hz         | 0.29 % of reading                         |                                              |
|                         | 100 Hz        | 0.20 % of reading                         |                                              |
|                         | 1 kHz         | 0.17 % of reading                         |                                              |
|                         | 10 kHz        | 0.19 % of reading                         |                                              |
|                         | 100 kHz       | 0.19 % of reading                         |                                              |
|                         | 1 MHz         | 0.27 % of reading                         |                                              |
|                         | 2 MHz         | 0.67 % of reading                         |                                              |
|                         | 100 $\Omega$  |                                           |                                              |
|                         | 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 MHz         | 0.2 % of reading                          |                                              |
|                         | 2 MHz         | 0.53 % of reading                         |                                              |
|                         | 1 k $\Omega$  |                                           |                                              |
|                         | 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                         |                                              |
|                         | 1 MHz         | 0.14 % of reading                         |                                              |
|                         | 2 MHz         | 0.3 % of reading                          |                                              |
|                         | 10 k $\Omega$ |                                           |                                              |
|                         | 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       | 0.1 % of reading                          |                                              |
|                         | 1 MHz         | 0.29 % of reading                         |                                              |
|                         | 2 MHz         | 0.87 % of reading                         |                                              |

## Electrical – DC/Low Frequency

| Parameter/Equipment                                                                    | Range               | Expanded Uncertainty of Measurement (+/-) | Reference Standard, Method, and/or Equipment         |
|----------------------------------------------------------------------------------------|---------------------|-------------------------------------------|------------------------------------------------------|
| AC Resistance – Measure                                                                | 100 k $\Omega$      |                                           | Agilent E4980AL<br>LCR Meter                         |
|                                                                                        | 20 Hz               | 0.17 % of reading                         |                                                      |
|                                                                                        | 100 Hz              | 0.1 % of reading                          |                                                      |
|                                                                                        | 1 kHz               | 0.1 % of reading                          |                                                      |
|                                                                                        | 10 kHz              | 0.17 % of reading                         |                                                      |
|                                                                                        | 100 kHz             | 0.28 % of reading                         |                                                      |
|                                                                                        | 1 MHz               | 0.38 % of reading                         |                                                      |
| Inductance – Source <sup>1</sup>                                                       | 2 MHz               | 1.3 % of reading                          | Standard Inductors<br>w/ GenRad 1689-9700            |
|                                                                                        | 100 $\mu$ H         | 0.025 $\mu$ H                             |                                                      |
|                                                                                        | 1 mH                | 0.25 $\mu$ H                              |                                                      |
|                                                                                        | 10 mH               | 2.5 $\mu$ H                               |                                                      |
|                                                                                        | 100 mH              | 25 $\mu$ H                                |                                                      |
|                                                                                        | 1 H                 | 0.25 mH                                   |                                                      |
| Electrical Simulation of Thermocouple Indicating Devices – Measure/Source <sup>1</sup> | 10 H                | 2.5 mH                                    | Ectron 1140A<br>Thermocouple<br>Calibrator/Simulator |
|                                                                                        | Type B              |                                           |                                                      |
|                                                                                        | (250 to 350) °C     | 0.95 °C                                   |                                                      |
|                                                                                        | (350 to 445) °C     | 0.74 °C                                   |                                                      |
|                                                                                        | (445 to 580) °C     | 0.58 °C                                   |                                                      |
|                                                                                        | (580 to 750) °C     | 0.45 °C                                   |                                                      |
|                                                                                        | (750 to 1 000) °C   | 0.37 °C                                   |                                                      |
|                                                                                        | (1 000 to 1 820) °C | 0.29 °C                                   |                                                      |
|                                                                                        | Type C              |                                           |                                                      |
|                                                                                        | (0 to 250) °C       | 0.2 °C                                    |                                                      |
|                                                                                        | (250 to 1 000) °C   | 0.16 °C                                   |                                                      |
|                                                                                        | (1 000 to 1 500) °C | 0.18 °C                                   |                                                      |
|                                                                                        | (1 500 to 1 800) °C | 0.21 °C                                   |                                                      |
|                                                                                        | (1 800 to 2 000) °C | 0.23 °C                                   |                                                      |
|                                                                                        | (2 000 to 2 250) °C | 0.29 °C                                   |                                                      |
|                                                                                        | (2 250 to 2 315) °C | 0.32 °C                                   |                                                      |
|                                                                                        | Type E              |                                           |                                                      |
|                                                                                        | (-270 to -245) °C   | 1.2 °C                                    |                                                      |
|                                                                                        | (-245 to -195) °C   | 0.18 °C                                   |                                                      |
|                                                                                        | (-195 to -155) °C   | 0.11 °C                                   |                                                      |
|                                                                                        | (-155 to 1 000) °C  | 0.09 °C                                   |                                                      |
|                                                                                        | Type J              |                                           |                                                      |
|                                                                                        | (-210 to -180) °C   | 0.13 °C                                   |                                                      |
|                                                                                        | (-180 to -120) °C   | 0.11 °C                                   |                                                      |
|                                                                                        | (-120 to -50) °C    | 0.09 °C                                   |                                                      |
|                                                                                        | (-50 to 1 200) °C   | 0.08 °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   | 2.2 °C                                    |                                                |
|                                                                                        | (-255 to -195) °C   | 0.7 °C                                    |                                                |
|                                                                                        | (-195 to -115) °C   | 0.13 °C                                   |                                                |
|                                                                                        | (-115 to -55) °C    | 0.1 °C                                    |                                                |
|                                                                                        | (-55 to 1 000) °C   | 0.08 °C                                   |                                                |
|                                                                                        | (1 000 to 1 372) °C | 0.09 °C                                   |                                                |
|                                                                                        | Type N              |                                           |                                                |
|                                                                                        | (-270 to -260) °C   | 5 °C                                      |                                                |
|                                                                                        | (-260 to -200) °C   | 1 °C                                      |                                                |
|                                                                                        | (-200 to -140) °C   | 0.23 °C                                   |                                                |
|                                                                                        | (-140 to -70) °C    | 0.16 °C                                   |                                                |
|                                                                                        | (-70 to 25) °C      | 0.13 °C                                   |                                                |
|                                                                                        | (-25 to 1 300) °C   | 0.11 °C                                   |                                                |
|                                                                                        | Type R              |                                           |                                                |
|                                                                                        | (-50 to -30) °C     | 0.65 °C                                   |                                                |
|                                                                                        | (-30 to 45) °C      | 0.55 °C                                   |                                                |
|                                                                                        | (45 to 160) °C      | 0.40 °C                                   |                                                |
|                                                                                        | (160 to 775) °C     | 0.30 °C                                   |                                                |
|                                                                                        | (775 to 1 768) °C   | 0.22 °C                                   |                                                |
|                                                                                        | Type S              |                                           |                                                |
|                                                                                        | (-50 to -30) °C     | 0.62 °C                                   |                                                |
|                                                                                        | (-30 to 45) °C      | 0.56 °C                                   |                                                |
|                                                                                        | (45 to 105) °C      | 0.4 °C                                    |                                                |
|                                                                                        | (105 to 310) °C     | 0.33 °C                                   |                                                |
|                                                                                        | (310 to 1 768) °C   | 0.29 °C                                   |                                                |
|                                                                                        | Type T              |                                           |                                                |
|                                                                                        | (-270 to -255) °C   | 1.8 °C                                    |                                                |
|                                                                                        | (-255 to -240) °C   | 0.5 °C                                    |                                                |
|                                                                                        | (-240 to -210) °C   | 0.3 °C                                    |                                                |
|                                                                                        | (-210 to -150) °C   | 0.18 °C                                   |                                                |
|                                                                                        | (-150 to -40) °C    | 0.13 °C                                   |                                                |
|                                                                                        | (-40 to 100) °C     | 0.09 °C                                   |                                                |
|                                                                                        | (100 to 400) °C     | 0.08 °C                                   |                                                |
| Scope Voltage – Source <sup>1</sup><br>DC Signal                                       |                     |                                           | Fluke 9500B/3200 Oscilloscope Calibrator       |
| Into 50 Ω                                                                              | (-5 to 5) V         | 0.02 % of reading + 19 μV                 |                                                |
| Into 1 MΩ                                                                              | (-200 to 200) V     | 0.02 % of reading + 19 μV                 |                                                |

## Electrical – DC/Low Frequency

| Parameter/Equipment                                                                                                                 | Range                                                                                                                                                                   | Expanded Uncertainty of Measurement (+/-)                                                                               | Reference Standard, Method, and/or Equipment                                |
|-------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------|
| Scope Voltage – Source <sup>1</sup><br>Square Wave<br>10 Hz to 100 kHz<br>Into 50 $\Omega$                                          | 40 $\mu$ V p-p to 1 mV p-p<br>1 mV p-p to 5 V p-p                                                                                                                       | 0.78 % of reading + 7.8 $\mu$ V<br>0.08 % of reading + 7.8 $\mu$ V                                                      | Fluke 9500B/3200<br>Oscilloscope Calibrator<br>w/ Fluke 9530<br>Active Head |
| Scope Voltage – Source <sup>1</sup><br>Square Wave<br>10 Hz to 10 kHz<br>Into 1 M $\Omega$<br>10 Hz to 100 kHz<br>Into 1 M $\Omega$ | 40 $\mu$ V p-p to 1 mV p-p<br>1 mV p-p to 200 V p-p                                                                                                                     | 0.78 % of reading + 7.8 $\mu$ V<br>0.08 % of reading + 7.8 $\mu$ V                                                      | Fluke 9500B/3200<br>Oscilloscope Calibrator                                 |
| Scope – Time Markers <sup>1</sup><br>Into 50 $\Omega$<br>Square Wave<br>Sine Wave<br>Pulse<br>Triangle Wave                         | 9.0091 ns to 83 $\mu$ s<br>83 $\mu$ s to 55 s<br>450.5 ps to 9.009 ns<br>900.91 ns to 83 $\mu$ s<br>83 $\mu$ s to 55 s<br>900.91 ns to 83 $\mu$ s<br>83 $\mu$ s to 55 s | 0.19 $\mu$ s/s<br>2.3 $\mu$ s/s<br>0.19 $\mu$ s/s<br>0.19 $\mu$ s/s<br>2.3 $\mu$ s/s<br>0.19 $\mu$ s/s<br>2.3 $\mu$ s/s | Fluke 9500B/3200<br>Oscilloscope Calibrator                                 |
| Rise Time – Measure <sup>1</sup>                                                                                                    | $\geq 5$ ns                                                                                                                                                             | 0.41 ns                                                                                                                 | Rigol MSO8104<br>Oscilloscope                                               |
| Scope Rise Time – Source <sup>1, 4</sup><br>Into 50 $\Omega$<br>10 Hz to 2 MHz                                                      | 5 mV p-p to 3 V p-p<br>500 ps (Nominal)<br>150 ps (Nominal)                                                                                                             | 290 ps<br>35 ps                                                                                                         | Fluke 9500B/3200<br>Oscilloscope Calibrator<br>w/ Fluke 9530<br>Active Head |
| Scope Rise Time – Source <sup>1, 4</sup><br>Into 50 $\Omega$<br>10 Hz to 2 MHz                                                      | (425 to 575) mV p-p<br>25 ps (Nominal)                                                                                                                                  | 6.7 ps                                                                                                                  | Fluke 9500B/3200<br>Oscilloscope Calibrator                                 |
| Scope Leveled Sine Wave – Source <sup>1</sup><br>(50 kHz Ref. Frequency)<br>Into 50 $\Omega$                                        | 50 kHz to 10 MHz                                                                                                                                                        | 1.2 % of reading                                                                                                        | Fluke 9500B/3200<br>Oscilloscope Calibrator<br>w/ Fluke 9530<br>Active Head |

## Electrical – DC/Low Frequency

| Parameter/Equipment                                                                                                                                             | Range                                                                                                                                                                    | Expanded Uncertainty of Measurement (+/-)                                                                                                       | Reference Standard, Method, and/or Equipment                                |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------|
| Scope Bandwidth/Flatness – Source <sup>1</sup><br>Into VSWR (1.2:1)<br>(wrt Reference Frequency)                                                                | 5 mV p-p to 5 V p-p<br>0.1 Hz to 300 MHz<br>(300 to 550) MHz<br>5 mV p-p to 3 V p-p<br>550 MHz to 1.1 GHz<br>(1.1 to 2.5) GHz<br>5 mV p-p to 2 V p-p<br>(2.5 to 3.2) GHz | 1.6 % of reading<br>1.9 % of reading<br>2.7 % of reading<br>3.1 % of reading<br>3.1 % of reading                                                | Fluke 9500B/3200<br>Oscilloscope Calibrator<br>w/ Fluke 9530<br>Active Head |
| Scope Input Impedance – Source <sup>1</sup>                                                                                                                     | (10 to 40) $\Omega$<br>(40 to 90) $\Omega$<br>(90 to 150) $\Omega$<br>(50 to 800) k $\Omega$<br>800 k $\Omega$ to 1.2 M $\Omega$<br>(1.2 to 12) M $\Omega$               | 0.39 % of reading<br>0.08 % of reading<br>0.39 % of reading<br>0.39 % of reading<br>0.08 % of reading<br>0.39 % of reading                      | Fluke 9500B/3200<br>Oscilloscope Calibrator                                 |
| Scope Input Capacitance – Source <sup>1</sup>                                                                                                                   | (1 to 35) pF<br>(35 to 95) pF                                                                                                                                            | 1.6 % of reading + 0.19 pF<br>2.3 % of reading + 0.19 pF                                                                                        | Fluke 9500B/3200<br>Oscilloscope Calibrator                                 |
| LF Phase – Source <sup>1</sup>                                                                                                                                  | (0 to 90) °<br>(10 to 65) Hz<br>(65 to 500) Hz<br>500 Hz to 1 kHz<br>(1 to 5) kHz<br>(5 to 10) kHz<br>(10 to 30) kHz                                                     | 0.11 °<br>0.2 °<br>0.39 °<br>1.9 °<br>3.9 °<br>7.8 °                                                                                            | Fluke 5520A/1100<br>Calibrator                                              |
| DC Power – Source <sup>1</sup><br>330 $\mu$ A to 3.3 mA<br>(3.3 to 33) mA<br>(33 to 330) mA<br>330 mA to 1.1 A<br>(1.1 to 3) A<br>(3 to 11) A<br>(11 to 20.5) A | 11 $\mu$ W to 3.4 W<br>110 mW to 34 W<br>1.1 mW to 340 W<br>11 mW to 3.4 kW<br>36 mW to 3.1 kW<br>0.99 W to 11 kW<br>360 mW to 21 kW                                     | 0.02 % of reading<br>0.01 % of reading<br>0.01 % of reading<br>0.03 % of reading<br>0.03 % of reading<br>0.06 % of reading<br>0.09 % of reading | Fluke 5520A/1100<br>Calibrator                                              |

## Electrical – DC/Low Frequency

| Parameter/Equipment                        | Range                              | Expanded Uncertainty of Measurement (+/-) | Reference Standard, Method, and/or Equipment |
|--------------------------------------------|------------------------------------|-------------------------------------------|----------------------------------------------|
| AC Power – Source <sup>1,5</sup><br>PF = 1 |                                    |                                           |                                              |
| (3.3 to 9) mA                              | (45 to 65) Hz<br>0.11 mW to 9.2 W  | 0.09 % of reading                         | Fluke 5520A/11<br>Calibrator                 |
| (9 to 33) mA                               | (45 to 65) W<br>3 mW to 34 W       | 0.06 % of reading                         |                                              |
| (33 to 90) mA                              | (45 to 65) Hz<br>1.1 mW to 92 W    | 0.09 % of reading                         |                                              |
| (90 to 330) mA                             | (45 to 65) Hz<br>3 mW to 340 W     | 0.06 % of reading                         |                                              |
| 330 mA to 1.1 A                            | (45 to 65) Hz<br>11 mW to 1.1 kW   | 0.07 % of reading                         |                                              |
| (1.1 to 3) A                               | (45 to 65) Hz<br>36 mW to 3.1 kW   | 0.06 % of reading                         |                                              |
| (3 to 5.4) A                               | (45 to 65) Hz<br>99 mW to 5.5 kW   | 0.11 % of reading                         |                                              |
| (5.4 to 11) A                              | (45 to 65) Hz<br>180 mW to 11 kW   | 0.08 % of reading                         |                                              |
| (11 to 15) A                               | (45 to 100) Hz<br>360 mW to 15 kW  | 0.14 % of reading                         |                                              |
|                                            | 100 Hz to 1 kHz<br>360 mW to 15 kW | 0.16 % of reading                         |                                              |
| (15 to 20.5) A                             | (45 to 100) Hz<br>500 mW to 21 kW  | 0.13 % of reading                         |                                              |
|                                            | 100 Hz to 1 kHz<br>500 mW to 21 kW | 0.13 % of reading                         |                                              |



**Electrical – RF/Microwave**

| Parameter/Equipment               | Range            | Expanded Uncertainty of Measurement (+/-) | Reference Standard, Method, and/or Equipment           |
|-----------------------------------|------------------|-------------------------------------------|--------------------------------------------------------|
| Attenuation – Source <sup>1</sup> | DC to 12.4 GHz   |                                           | Agilent 8496H<br>Programmable Attenuator<br>w/ Type -N |
|                                   | 1 dB             | 0.3 dB                                    |                                                        |
|                                   | 2 dB             | 0.3 dB                                    |                                                        |
|                                   | 3 dB             | 0.4 dB                                    |                                                        |
|                                   | 4 dB             | 0.4 dB                                    |                                                        |
|                                   | 5 dB             | 0.5 dB                                    |                                                        |
|                                   | 6 dB             | 0.5 dB                                    |                                                        |
|                                   | 7 dB             | 0.6 dB                                    |                                                        |
|                                   | 8 dB             | 0.6 dB                                    |                                                        |
|                                   | 9 dB             | 0.6 dB                                    |                                                        |
|                                   | 10 dB            | 0.6 dB                                    |                                                        |
|                                   | 11 dB            | 0.7 dB                                    |                                                        |
|                                   | (12.4 to 18) GHz |                                           |                                                        |
|                                   | 1 dB             | 0.7 dB                                    |                                                        |
|                                   | 2 dB             | 0.7 dB                                    |                                                        |
|                                   | 3 dB             | 0.7 dB                                    |                                                        |
|                                   | 4 dB             | 0.7 dB                                    |                                                        |
|                                   | 5 dB             | 0.8 dB                                    |                                                        |
|                                   | 6 dB             | 0.8 dB                                    |                                                        |
|                                   | 7 dB             | 0.8 dB                                    |                                                        |
|                                   | 8 dB             | 0.8 dB                                    |                                                        |
|                                   | 9 dB             | 0.9 dB                                    |                                                        |
|                                   | 10 dB            | 0.9 dB                                    |                                                        |
|                                   | 11 dB            | 0.5 dB                                    |                                                        |
|                                   | DC to 12.4 GHz   |                                           |                                                        |
|                                   | 10 dB            | 0.5 dB                                    |                                                        |
|                                   | 20 dB            | 0.7 dB                                    |                                                        |
|                                   | 30 dB            | 0.9 dB                                    |                                                        |
|                                   | 40 dB            | 1.2 dB                                    |                                                        |
|                                   | 50 dB            | 1.5 dB                                    |                                                        |
|                                   | 60 dB            | 1.8 dB                                    |                                                        |
|                                   | 70 dB            | 2.1 dB                                    |                                                        |
|                                   | 80 dB            | 2.4 dB                                    |                                                        |
|                                   | 90 dB            | 2.7 dB                                    |                                                        |
|                                   | 100 dB           | 3.0 dB                                    |                                                        |
|                                   | 110 dB           | 3.3 dB                                    |                                                        |

## Electrical – RF/Microwave

| Parameter/Equipment                      | Range                              | Expanded Uncertainty of Measurement (+/-) | Reference Standard, Method, and/or Equipment                      |
|------------------------------------------|------------------------------------|-------------------------------------------|-------------------------------------------------------------------|
| Attenuation – Source <sup>1</sup>        | (12.4 to 18) GHz                   |                                           | Agilent 8496H<br>Programmable Attenuator<br>w/ Type-N             |
|                                          | 10 dB                              | 0.6 dB                                    |                                                                   |
|                                          | 20 dB                              | 0.8 dB                                    |                                                                   |
|                                          | 30 dB                              | 1.2 dB                                    |                                                                   |
|                                          | 40 dB                              | 1.6 dB                                    |                                                                   |
|                                          | 50 dB                              | 2.0 dB                                    |                                                                   |
|                                          | 60 dB                              | 2.4 dB                                    |                                                                   |
|                                          | 70 dB                              | 2.8 dB                                    |                                                                   |
|                                          | 80 dB                              | 3.2 dB                                    |                                                                   |
|                                          | 90 dB                              | 3.6 dB                                    |                                                                   |
|                                          | 100 dB                             | 4.0 dB                                    |                                                                   |
|                                          | 110 dB                             | 4.4 dB                                    |                                                                   |
| RF Absolute Power – Measure <sup>1</sup> | 10 Hz to 20 kHz<br>(-10 to 30) dBm | 0.13 % of reading                         | Fluke 8846A Multimeter                                            |
|                                          | 9 kHz to 18 GHz<br>(-60 to 20) dBm | 2.6 % of reading                          | Agilent E9304A-H18<br>RF Power Sensor<br>w/ RF Power Meter        |
|                                          | (18 to 40) GHz<br>(-70 to -30) dBm | 3.8 % of reading                          | Agilent 8487D<br>RF Power Sensor<br>w/ RF Power Meter             |
|                                          | (40 to 50) GHz<br>(-70 to -30) dBm | 5.5 % of reading                          |                                                                   |
|                                          | (18 to 40) GHz<br>(-30 to 20) dBm  | 4.4 % of reading                          | Agilent 8487D<br>RF Power Sensor<br>w/ RF Power Meter             |
|                                          | (40 to 50) GHz<br>(-30 to 20) dBm  | 5.5 % of reading                          |                                                                   |
|                                          | 30 MHz to 50 GHz<br>(20 to 30) dBm | 4.8 % of reading                          | Agilent E5532A-550<br>RF Power Sensor Module<br>w/ RF Power Meter |

**Electrical – RF/Microwave**

| Parameter/Equipment                                          | Range                | Expanded Uncertainty of Measurement (+/-) | Reference Standard, Method, and/or Equipment |
|--------------------------------------------------------------|----------------------|-------------------------------------------|----------------------------------------------|
| RF Absolute Power – Source <sup>1</sup>                      | (-70 to -10) dBm     |                                           | Agilent E8257D<br>Analog Signal Generator    |
|                                                              | 250 kHz to 2 GHz     | 0.8 dB                                    |                                              |
|                                                              | (2 to 20) GHz        | 1.1 dB                                    |                                              |
|                                                              | (20 to 40) GHz       | 1.2 dB                                    |                                              |
|                                                              | (40 to 50) GHz       | 1.8 dB                                    |                                              |
|                                                              | (-10 to 0) dBm       |                                           |                                              |
|                                                              | 250 kHz to 2 GHz     | 0.7 dB                                    |                                              |
|                                                              | (2 to 20) GHz        | 0.9 dB                                    |                                              |
|                                                              | (20 to 40) GHz       | 1.1 dB                                    |                                              |
|                                                              | (40 to 50) GHz       | 1.1 dB                                    |                                              |
|                                                              | (0 to 10 dBm)        |                                           |                                              |
|                                                              | 250 kHz to 2 GHz     | 0.7 dB                                    |                                              |
|                                                              | (2 to 20) GHz        | 0.9 dB                                    |                                              |
|                                                              | (20 to 40) GHz       | 1.1 dB                                    |                                              |
|                                                              | (40 to 50) GHz       | 1.5 dB                                    |                                              |
|                                                              | (10 to 14 dBm)       |                                           |                                              |
|                                                              | 250 kHz to 2 GHz     | 0.7 dB                                    |                                              |
|                                                              | (2 to 20) GHz        | 0.9 dB                                    |                                              |
|                                                              | (20 to 40) GHz       | 1.2 dB                                    |                                              |
|                                                              | (14 to 19 dBm)       |                                           |                                              |
|                                                              | 250 kHz to 2 GHz     | 0.9 dB                                    |                                              |
|                                                              | (2 to 20) GHz        | 0.9 dB                                    |                                              |
|                                                              | (20 to 40) GHz       | 1.2 dB                                    |                                              |
| RF Relative Power – Measure <sup>1</sup><br>(Tuned RF Level) | 100 kHz to 50 GHz    |                                           | Agilent E4448A<br>Spectrum Analyzer          |
|                                                              | (-10 to 0) dB        | 0.02 dB                                   |                                              |
|                                                              | (-20 to -10) dB      | 0.02 dB                                   |                                              |
|                                                              | (-30 to -20) dB      | 0.03 dB                                   |                                              |
|                                                              | (-40 to -30) dB      | 0.04 dB                                   |                                              |
|                                                              | (-50 to -40) dB      | 0.04 dB                                   |                                              |
|                                                              | (-60 to -50) dB      | 0.09 dB                                   |                                              |
|                                                              | (-70 to -60) dB      | 0.10 dB                                   |                                              |
|                                                              | (-80 to -70) dB      | 0.14 dB                                   |                                              |
|                                                              | (-90 to -80) dB      | 0.15 dB                                   |                                              |
|                                                              | 100 kHz to 45 GHz    |                                           |                                              |
|                                                              | (-100 to -90) dB     | 0.16 dB                                   |                                              |
|                                                              | (-110 to -100) dB    | 0.29 dB                                   |                                              |
|                                                              | 100 kHz to 31.15 GHz |                                           |                                              |
|                                                              | (-120 to -110) dB    | 0.29 dB                                   |                                              |
|                                                              | (-130 to -120) dB    | 0.29 dB                                   |                                              |

## Electrical – RF/Microwave

| Parameter/Equipment                                          | Range            | Expanded Uncertainty of Measurement (+/-) | Reference Standard, Method, and/or Equipment                                    |
|--------------------------------------------------------------|------------------|-------------------------------------------|---------------------------------------------------------------------------------|
| S11/S22 Reflection Magnitude – Measure <sup>1</sup> (Linear) | 9 kHz to 10 MHz  |                                           | Agilent E5071C Network Analyzer (Corrected with Agilent 85032F Calibration Kit) |
|                                                              | (0 to 0.5) lin   | 0.009                                     |                                                                                 |
|                                                              | (0.5 to 1) lin   | 0.019                                     |                                                                                 |
|                                                              | 10 MHz to 9 GHz  |                                           |                                                                                 |
|                                                              | (0 to 0.5) lin   | 0.012                                     | Agilent E5235A Network Analyzer (Corrected with Agilent 85056K Calibration Kit) |
|                                                              | (0.5 to 1) lin   | 0.022                                     |                                                                                 |
|                                                              | 50 MHz to 2 GHz  |                                           |                                                                                 |
|                                                              | (0 to 0.5) lin   | 0.015                                     |                                                                                 |
|                                                              | (0.5 to 1) lin   | 0.023                                     | Agilent E5235A Network Analyzer (Corrected with Agilent 85056K Calibration Kit) |
|                                                              | (2 to 40) GHz    |                                           |                                                                                 |
|                                                              | (0 to 0.5) lin   | 0.028                                     |                                                                                 |
|                                                              | (0.5 to 1) lin   | 0.04                                      |                                                                                 |
| S11/S21 Transmission Magnitude – Measure <sup>1</sup> (dB)   | 9 kHz to 10 MHz  |                                           | Agilent E5071C Network Analyzer (Corrected with Agilent 85032F Calibration Kit) |
|                                                              | (-30 to 0) dB    | 0.09 dB                                   |                                                                                 |
|                                                              | (-60 to -30) dB  | 0.45 dB                                   |                                                                                 |
|                                                              | 10 MHz to 9 GHz  |                                           |                                                                                 |
|                                                              | (-30 to 0) dB    | 0.09 dB                                   | Agilent E5235A Network Analyzer (Corrected with Agilent 85056K Calibration Kit) |
|                                                              | (-60 to -30) dB  | 0.26 dB                                   |                                                                                 |
|                                                              | (10 to 500) MHz  |                                           |                                                                                 |
|                                                              | (-30 to 0) dB    | 0.07 dB                                   |                                                                                 |
|                                                              | (-60 to -30) dB  | 1.6 dB                                    | Agilent E5235A Network Analyzer (Corrected with Agilent 85056K Calibration Kit) |
|                                                              | 500 MHz to 2 GHz |                                           |                                                                                 |
|                                                              | (-30 to 0) dB    | 0.05 dB                                   |                                                                                 |
|                                                              | (-60 to -30) dB  | 0.18 dB                                   |                                                                                 |
|                                                              | (2 to 50) GHz    |                                           | Agilent E5235A Network Analyzer (Corrected with Agilent 85056K Calibration Kit) |
|                                                              | (-30 to 0) dB    | 0.14 dB                                   |                                                                                 |
|                                                              | (-60 to -30) dB  | 0.55 dB                                   |                                                                                 |

## Electrical – RF/Microwave

| Parameter/Equipment                                                                | Range                                                       | Expanded Uncertainty of Measurement (+/-)              | Reference Standard, Method, and/or Equipment |
|------------------------------------------------------------------------------------|-------------------------------------------------------------|--------------------------------------------------------|----------------------------------------------|
| Amplitude Modulation – AM<br>Depth Measure <sup>1</sup><br>Rate: 100 kHz to 20 MHz | 50 Hz to 10 kHz<br>(5 to 99) % Depth                        | 0.9 % Depth                                            | Agilent E4448A<br>Spectrum Analyzer          |
| 10 MHz to 3 GHz                                                                    | 50 Hz to 100 kHz<br>(5 to 20) % Depth<br>(20 to 99) % Depth | 0.8 % Depth<br>2.6 % Depth                             |                                              |
| (3 to 26.5) GHz                                                                    | 50 Hz to 100 kHz<br>(5 to 20) % Depth<br>(20 to 99) % Depth | 1.6 % Depth<br>4.5 % Depth                             |                                              |
| (26.5 to 31.15) GHz                                                                | 50 Hz to 100 kHz<br>(5 to 20) % Depth<br>(20 to 99) % Depth | 2.1 % Depth<br>6.8 % Depth                             |                                              |
| (31.15 to 50) GHz                                                                  | 50 Hz to 100 kHz<br>(5 to 20) % Depth<br>(20 to 99) % Depth | 6 % Depth<br>26 % Depth                                |                                              |
| Amplitude Modulation<br>Distortion – Measure <sup>1</sup><br>100 kHz to 10 kHz     | 20 Hz to 1 kHz<br>> 1 %<br>> 3 %                            | 0.85 % of reading<br>0.42 % of reading                 |                                              |
| 10 MHz to 26.5 GHz                                                                 | 20 Hz to 1 kHz<br>> 1 %<br>> 3 %                            | 1 % of reading<br>0.5 % of reading                     |                                              |
| (26.5 to 50) GHz                                                                   | 20 Hz to 1 kHz<br>> 1 %<br>> 3 %<br>> 5 %                   | 6.2 % of reading<br>2 % of reading<br>1.5 % of reading |                                              |
| Amplitude Modulation – AM<br>Depth – Source <sup>1</sup><br>250 kHz to 50 GHz      | (0 to 90) % Depth                                           | 6.6 % Depth                                            | Agilent E8257D<br>Analog Signal Generator    |

## Electrical – RF/Microwave

| Parameter/Equipment                                                              | Range                                                  | Expanded Uncertainty of Measurement (+/-) | Reference Standard, Method, and/or Equipment |
|----------------------------------------------------------------------------------|--------------------------------------------------------|-------------------------------------------|----------------------------------------------|
| Frequency Modulation Deviation – Measure <sup>1</sup><br>Rate: 250 kHz to 10 MHz | 20 Hz to 10 kHz<br>Dev/Rate > 0.2<br>Dev/Rate > 1.2    | 1.5 % Deviation<br>1 % Deviation          | Agilent E4448A<br>Spectrum Analyzer          |
| 10 MHz to 6.6 GHz                                                                | 50 Hz to 200 kHz<br>Dev/Rate > 0.2<br>Dev/Rate > 0.45  | 1.5 % Deviation<br>1 % Deviation          |                                              |
| (6.6 to 13.2) GHz                                                                | 50 Hz to 200 kHz<br>Dev/Rate > 0.2<br>Dev/Rate > 8     | 2.5 % Deviation<br>1 % Deviation          |                                              |
| (13.2 to 31.15) GHz                                                              | 50 Hz to 200 kHz<br>Dev/Rate > 0.2<br>Dev/Rate > 16    | 3.8 % Deviation<br>1 % Deviation          |                                              |
| (31.5 to 50) GHz                                                                 | 50 Hz to 200 kHz<br>Dev/Rate > 0.2<br>Dev/Rate > 32    | 8.5 % Deviation<br>1 % Deviation          |                                              |
| Frequency Modulation Distortion – Measure <sup>1</sup><br>1 MHz to 6.6 GHz       | 20 Hz to 1 kHz<br>Dev 500 Hz to 2 kHz<br>Dev ≥ 2.0 kHz | 0.3 % of reading<br>0.11 % of reading     | Agilent E8257D<br>Analog Signal Generator    |
| (6.6 to 13.2) GHz                                                                | 20 Hz to 1 kHz<br>Dev > 2.3 kHz<br>Dev ≥ 4.5 kHz       | 0.3 % of reading<br>0.11 % of reading     |                                              |
| (13.2 to 31.15) GHz                                                              | 20 Hz to 1 kHz<br>Dev > 2.7 kHz<br>Dev ≥ 6.0 kHz       | 0.31 % of reading<br>0.12 % of reading    |                                              |
| (31.5 to 50) GHz                                                                 | 20 Hz to 1 kHz<br>Dev > 4.0 kHz<br>Dev ≥ 12.0 kHz      | 0.32 % of reading<br>0.14 % of reading    |                                              |
| Frequency Modulation – Deviation Source <sup>1</sup><br>250 kHz to 50 GHz        | DC to 10 MHz<br>Dev ≤ 128 MHz                          | 3.9 % Deviation                           |                                              |

## Electrical – RF/Microwave

| Parameter/Equipment                                                           | Range           | Expanded Uncertainty of Measurement (+/-) | Reference Standard, Method, and/or Equipment |
|-------------------------------------------------------------------------------|-----------------|-------------------------------------------|----------------------------------------------|
| Phase Modulation Deviation – Measure <sup>1</sup><br>Rate: 100 kHz to 6.6 GHz | > 0.7 rad       | 1.1 % Deviation                           | Agilent E4448A<br>Spectrum Analyzer          |
| (6.6 to 13.2) GHz                                                             | > 0.3 rad       | 3.2 % Deviation                           |                                              |
| (13.2 to 26.5) GHz                                                            | > 2.0 rad       | 1.1 % Deviation                           |                                              |
| (26.5 to 31.15) GHz                                                           | > 0.6 rad       | 3.2 % Deviation                           |                                              |
| (31.15 to 50) GHz                                                             | > 4.0 rad       | 1.1 % Deviation                           |                                              |
|                                                                               | > 1.2 rad       | 3.2 % Deviation                           |                                              |
|                                                                               | > 4.0 rad       | 1.1 % Deviation                           |                                              |
|                                                                               | > 1.3 rad       | 3.2 % Deviation                           |                                              |
|                                                                               | > 8.0 rad       | 1.1 % Deviation                           |                                              |
|                                                                               | > 2.4 rad       | 3.2 % Deviation                           |                                              |
| Phase Modulation Distortion – Measure <sup>1</sup><br>1 MHz to 6.6 GHz        | (20 to 500) Hz  |                                           |                                              |
|                                                                               | > 0.8 rad       | 0.31 % of reading                         |                                              |
|                                                                               | ≥ 2.5 rad       | 0.13 % of reading                         |                                              |
|                                                                               | 500 Hz to 1 kHz |                                           |                                              |
|                                                                               | > 0.4 rad       | 0.31 % of reading                         |                                              |
|                                                                               | ≥ 1.0 rad       | 0.13 % of reading                         |                                              |
| (6.6 to 13.2) GHz                                                             | (20 to 500) Hz  |                                           |                                              |
|                                                                               | > 1.8 rad       | 0.31 % of reading                         |                                              |
|                                                                               | ≥ 5.5 rad       | 0.13 % of reading                         |                                              |
|                                                                               | 500 Hz to 1 kHz |                                           |                                              |
|                                                                               | ≥ 0.8 rad       | 0.31 % of reading                         |                                              |
|                                                                               | ≥ 2.5 rad       | 0.13 % of reading                         |                                              |
| (13.2 to 31.15) GHz                                                           | (20 to 500) Hz  |                                           |                                              |
|                                                                               | > 3.5 rad       | 0.31 % of reading                         |                                              |
|                                                                               | ≥ 10.0 rad      | 0.13 % of reading                         |                                              |
| (31.15 to 50) GHz                                                             | (20 to 500) Hz  |                                           |                                              |
|                                                                               | > 7.5 rad       | 0.31 % of reading                         |                                              |
|                                                                               | ≥ 19.0 rad      | 0.13 % of reading                         |                                              |
|                                                                               | 500 Hz to 1 kHz |                                           |                                              |
|                                                                               | > 3.0 rad       | 0.31 % of reading                         |                                              |
|                                                                               | ≥ 8.0 rad       | 0.13 % of reading                         |                                              |



## Electrical – RF/Microwave

| Parameter/Equipment                                                                                                                                                                       | Range                                                                                                                                                                                                                                                                                         | Expanded Uncertainty of Measurement (+/-)                                                                                                                        | Reference Standard, Method, and/or Equipment |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------|
| Phase Modulation Distortion – Source <sup>1</sup>                                                                                                                                         | (250 to 500) MHz<br>(0 to 10) rad<br>500 MHz to 1 GHz<br>(0 to 20) rad<br>(1 to 2) GHz<br>(0 to 40) rad<br>(2 to 3.2) GHz<br>(0 to 80) rad<br>(3.2 to 10) GHz<br>(0 to 160) rad<br>(10 to 20) GHz<br>(0 to 320) rad<br>(20 to 40) GHz<br>(0 to 640) rad<br>(40 to 50) GHz<br>(0 to 1 280) rad | 5.8 % of reading<br><br>5.8 % of reading<br><br>5.8 % of reading<br><br>5.8 % of reading<br><br>5.8 % of reading<br><br>5.8 % of reading<br><br>5.8 % of reading | Agilent E8257D<br>Analog Signal Generator    |
| Single Sideband Phase Noise – Measure <sup>1</sup><br>CW Frequency:<br>3 Hz to 3 GHz<br>(3 to 6.6) GHz<br>(6.6 to 22) GHz<br>(22 to 26.8) GHz<br>(26.8 to 31.15) GHz<br>(31.15 to 50) GHz | Markers:<br>100 Hz to 1 MHz<br>100 Hz to 1 MHz<br>100 Hz to 1 MHz<br>100 Hz to 1 MHz<br>100 Hz to 1 MHz<br>100 Hz to 1 MHz                                                                                                                                                                    | 0.6 dB<br>1 dB<br>1.6 dB<br>1.7 dB<br>1.1 dB<br>1.4 dB                                                                                                           | Agilent E4448A<br>Spectrum Analyzer          |
| Total Harmonic Distortion – Measure <sup>1</sup><br>(-100 to 0) dB                                                                                                                        | 10 Hz to 100 kHz<br>20 Hz to 20 kHz<br>(20 to 100) kHz                                                                                                                                                                                                                                        | 8.4 % of reading<br>1.1 dB<br>2 dB                                                                                                                               | Agilent U8903A<br>Audio Analyzer             |
| Total Harmonic Distortion – Measure <sup>1</sup><br>Rate: 5 Hz to 600 kHz<br>Level: (0.3 to 100) %                                                                                        | 10 Hz to 1 MHz<br>(1 to 3) MHz                                                                                                                                                                                                                                                                | 3 % of reading<br>6 % of reading                                                                                                                                 | Agilent 334A<br>Distortion Analyzer          |

## Length – Dimensional Metrology

| Parameter/Equipment                                                | Range                                                                          | Expanded Uncertainty of Measurement (+/-)                                    | Reference Standard, Method, and/or Equipment            |
|--------------------------------------------------------------------|--------------------------------------------------------------------------------|------------------------------------------------------------------------------|---------------------------------------------------------|
| Angles                                                             | < 90 °                                                                         | 4.1 "                                                                        | Sine Bar w/ Surface Plate                               |
|                                                                    | ≥ 90 °                                                                         | 1.4 "                                                                        | Master Square w/ Surface Plate                          |
| Micrometers and Calipers—<br>Outside, Inside, Depth <sup>1,2</sup> | (0 to 0.4) in<br>(0.4 to 1) in<br>(1 to 4) in<br>(4 to 15) in<br>(15 to 40) in | 13 μin<br>(13 + 1L) μin<br>(10 + 3.7L) μin<br>(12 + 4L) μin<br>(16 + 4L) μin | Comparison to Gage Blocks                               |
| Anvil Flatness <sup>1</sup>                                        | Up to 1 in Diameter                                                            | 6.5 μin                                                                      | Optical Flats                                           |
| Anvil Parallelism <sup>1</sup>                                     | Up to 1 in                                                                     | 5.9 μin                                                                      | Optical Parallels                                       |
| Linear Displacement <sup>2</sup>                                   | Up to 12 ft                                                                    | (1 + 2.1L) μin                                                               | Laser Interferometer                                    |
| Dial Indicators <sup>1,2</sup>                                     | Up to 0.1 in<br>(0.1 to 6) in                                                  | 4.5 μin<br>(4 + 4L) in                                                       | Comparison to Gage Blocks                               |
| Single Axis Length – Inside <sup>2</sup>                           | (0.06 to 4.7) in                                                               | (3 + 4L) in                                                                  | Horizontal Comparator                                   |
| Single Axis Length –<br>Outside <sup>2</sup>                       | (0.06 to 4.7) in                                                               | (3 + 4L) in                                                                  | Horizontal Comparator                                   |
|                                                                    | Up to 1 in<br>(1 to 10) in                                                     | (15 to 0.5L) in<br>(12 + 4L) in                                              | Super Micrometer                                        |
| Height Measuring<br>Equipment <sup>2</sup>                         | Up to 8 in<br>(8 to 26) in                                                     | (6 + 4L) μin<br>(12 + 4L) μin                                                | Gage Blocks<br>w/ Surface Plate                         |
| Measuring Tapes and Rulers <sup>2</sup>                            | Up to 6 ft<br>(6 to 12) ft<br>(12 to 100) ft                                   | (400 + 2L) μin<br>(400 + 7L) μin<br>(400 + 6L) μin                           | Accu-Gage                                               |
| Threaded Plug <sup>2</sup><br>Pitch Diameter                       |                                                                                | 83 μin                                                                       | Super Micrometer<br>w/ Thread Wires<br>Super Micrometer |
| Major Diameter                                                     | Up to 1 in<br>(1 to 6) in                                                      | (15 + 0.5L) μin<br>(12 + 4L) μin                                             |                                                         |
| Threaded Ring<br>Inner Pitch Diameter                              | Up to 6 in                                                                     | 150 μin                                                                      | Comparison to Set Plugs                                 |

## Mass and Mass Related

| Parameter/Equipment                    | Range                   | Expanded Uncertainty of Measurement (+/-) | Reference Standard, Method, and/or Equipment |
|----------------------------------------|-------------------------|-------------------------------------------|----------------------------------------------|
| Force Measuring Equipment <sup>1</sup> | (0.03 to 600) lbf       | 0.017 % of reading                        | Class F Weights                              |
|                                        | (0 to 500) lbf          | 0.035 lbf                                 | Load Cells                                   |
|                                        | (500 to 2 000) lbf      | 0.12 lbf                                  |                                              |
|                                        | (2 000 to 10 000) lbf   | 1.4 lbf                                   |                                              |
|                                        | (10 000 to 25 000) lbf  | 5.1 lbf                                   |                                              |
|                                        | (25 000 to 100 000) lbf | 28 lbf                                    |                                              |
| Mass Determination Metric              | 30 kg                   | 13 mg                                     | Echelon II                                   |
|                                        | 25 kg                   | 12 mg                                     |                                              |
|                                        | 20 kg                   | 10 mg                                     |                                              |
|                                        | 10 kg                   | 3.5 mg                                    |                                              |
|                                        | 5 kg                    | 1.6 mg                                    |                                              |
|                                        | 3 kg                    | 1.2 mg                                    |                                              |
|                                        | 2 kg                    | 0.66 mg                                   |                                              |
|                                        | 1 kg                    | 0.32 mg                                   |                                              |
|                                        | 500 g                   | 0.15 mg                                   |                                              |
|                                        | 300 g                   | 0.1 mg                                    |                                              |
|                                        | 200 g                   | 67 µg                                     |                                              |
|                                        | 100 g                   | 36 µg                                     |                                              |
|                                        | 50 g                    | 16 µg                                     |                                              |
|                                        | 30 g                    | 12 µg                                     |                                              |
|                                        | 20 g                    | 11 µg                                     |                                              |
|                                        | 10 g                    | 8.2 µg                                    |                                              |
|                                        | 5 g                     | 4.7 µg                                    |                                              |
|                                        | 3 g                     | 4.7 µg                                    |                                              |
|                                        | 2 g                     | 4.7 µg                                    |                                              |
|                                        | 1 g                     | 4.7 µg                                    |                                              |
|                                        | 500 mg                  | 2 µg                                      |                                              |
|                                        | 300 mg                  | 2 µg                                      |                                              |
|                                        | 200 mg                  | 2 µg                                      |                                              |
|                                        | 100 mg                  | 2 µg                                      |                                              |
|                                        | 50 mg                   | 2 µg                                      |                                              |
|                                        | 30 mg                   | 2 µg                                      |                                              |
|                                        | 20 mg                   | 2 µg                                      |                                              |
|                                        | 10 mg                   | 2 µg                                      |                                              |
|                                        | 5 mg                    | 2 µg                                      |                                              |
|                                        | 3 mg                    | 2 µg                                      |                                              |
|                                        | 2 mg                    | 2 µg                                      |                                              |
|                                        | 1 mg                    | 2 µg                                      |                                              |

## Mass and Mass Related

| Parameter/Equipment       | Range  | Expanded Uncertainty of Measurement (+/-) | Reference Standard, Method, and/or Equipment |
|---------------------------|--------|-------------------------------------------|----------------------------------------------|
| Mass Determination Metric | 50 kg  | 150 mg                                    | Echelon III                                  |
|                           | 30 kg  | 100 mg                                    |                                              |
|                           | 25 kg  | 100 mg                                    |                                              |
|                           | 20 kg  | 100 mg                                    |                                              |
|                           | 10 kg  | 12 mg                                     |                                              |
|                           | 5 kg   | 5.8 mg                                    |                                              |
|                           | 3 kg   | 4 mg                                      |                                              |
|                           | 2 kg   | 2.5 mg                                    |                                              |
|                           | 1 kg   | 1.1 mg                                    |                                              |
|                           | 500 g  | 0.51 mg                                   |                                              |
|                           | 300 g  | 0.37 mg                                   |                                              |
|                           | 200 g  | 0.21 mg                                   |                                              |
|                           | 100 g  | 0.1 mg                                    |                                              |
|                           | 50 g   | 45 µg                                     |                                              |
|                           | 30 g   | 30 µg                                     |                                              |
|                           | 20 g   | 27 µg                                     |                                              |
|                           | 10 g   | 24 µg                                     |                                              |
|                           | 5 g    | 12 µg                                     |                                              |
|                           | 3 g    | 12 µg                                     |                                              |
|                           | 2 g    | 12 µg                                     |                                              |
|                           | 1 g    | 12 µg                                     |                                              |
|                           | 500 mg | 4.9 µg                                    |                                              |
|                           | 300 mg | 4.9 µg                                    |                                              |
|                           | 200 mg | 4.9 µg                                    |                                              |
|                           | 100 mg | 4.9 µg                                    |                                              |
|                           | 50 mg  | 4.9 µg                                    |                                              |
|                           | 30 mg  | 4.9 µg                                    |                                              |
|                           | 20 mg  | 4.9 µg                                    |                                              |
|                           | 10 mg  | 4.9 µg                                    |                                              |
|                           | 5 mg   | 4.9 µg                                    |                                              |
|                           | 3 mg   | 4.9 µg                                    |                                              |
|                           | 2 mg   | 4.9 µg                                    |                                              |
|                           | 1 mg   | 4.9 µg                                    |                                              |

## Mass and Mass Related

| Parameter/Equipment               | Range                                                                                                        | Expanded Uncertainty of Measurement (+/-)                                                                                                                     | Reference Standard, Method, and/or Equipment |
|-----------------------------------|--------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------|
| Mass Determination<br>Avoirdupois | 50 lb<br>30 lb<br>20 lb<br>10 lb<br>5 lb<br>3 lb<br>2 lb<br>1 lb<br>8 oz<br>4 oz<br>2 oz<br>1 oz<br>0.5 oz   | 100 mg<br>13 mg<br>12 mg<br>5.8 mg<br>2.6 mg<br>1.2 mg<br>1.1 mg<br>0.51 mg<br>0.22 mg<br>0.1 mg<br>51 µg<br>36 µg<br>27 µg                                   | Echelon III                                  |
| Torque - Measure <sup>1</sup>     | 15 ozf·in to 2 000 lbf·ft                                                                                    | 1 % of reading                                                                                                                                                | CDI Torque Measuring System                  |
|                                   | (5 to 250) lbf·in                                                                                            | 1 % of reading                                                                                                                                                |                                              |
|                                   | (1 to 250) lbf·ft                                                                                            | 1 % of reading                                                                                                                                                |                                              |
|                                   | (500 to 10 000) lbf·ft                                                                                       | 1 % of reading                                                                                                                                                | Futek Sensor with Display                    |
| Torque Measuring Equipment        | (5 to 200) ozf·in<br>(4 to 400) lbf·in<br>(75 to 1 000) lbf·in<br>(25 to 250) lbf·ft<br>(60 to 2 000) lbf·ft | 0.06 % of reading<br>0.01 % of reading + 0.6R lbf·in<br>0.06 % of reading + 0.6R lbf·in<br>0.04 % of reading + 0.6R lbf·in<br>0.12 % of reading + 0.6R lbf·in | Torque Wheels w/ Weights                     |

## Mass and Mass Related

| Parameter/Equipment                                | Range                                                                                                                                              | Expanded Uncertainty of Measurement (+/-)                                                                                                                                         | Reference Standard, Method, and/or Equipment |
|----------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------|
| Balances <sup>1</sup><br>Metric                    | 5 kg<br>2 kg<br>1 kg<br>500 g<br>300 g<br>200 g<br>100 g<br>50 g<br>30 g<br>20 g<br>10 g<br>5 g<br>3 g<br>2 g<br>1 g<br>500 mg<br>200 mg<br>100 mg | 3.7 mg<br>1.4 mg<br>0.72 mg<br>0.38 mg<br>0.21 mg<br>0.14 mg<br>0.08 mg<br>42 µg<br>24 µg<br>20 µg<br>14 µg<br>8.3 µg<br>7.8 µg<br>7.7 µg<br>7.7 µg<br>2.4 µg<br>2.4 µg<br>2.4 µg | ASTM Class I Weights                         |
| Balances <sup>1</sup><br>Metric                    | 50 mg<br>20 mg<br>10 mg<br>5 mg<br>1 mg                                                                                                            | 2.4 µg<br>2.4 µg<br>2.4 µg<br>2.4 µg<br>2.4 µg                                                                                                                                    | ASTM Class I Weights                         |
| Balance/Scales <sup>1</sup><br>Avoirdupois         | 50 lb<br>30 lb<br>20 lb<br>10 lb<br>5 lb<br>3 lb<br>2 lb<br>1 lb<br>8 oz<br>4 oz<br>2 oz<br>1 oz<br>0.5 oz                                         | 2.3 g<br>1.4 g<br>0.91 g<br>0.45 g<br>0.23 g<br>0.14 g<br>91 mg<br>45 mg<br>23 mg<br>12 mg<br>5.7 mg<br>2.8 mg<br>1.4 mg                                                          | Class F Weights                              |
| Absolute Pressure –<br>Source/Measure <sup>1</sup> | (0 to 760) mmHg                                                                                                                                    | 0.005 mmHg                                                                                                                                                                        | Meriam Manometer                             |
|                                                    | (1 to 30) psia<br>(1 to 100) psia                                                                                                                  | 0.000 5 psi<br>0.001 6 psi                                                                                                                                                        | Mensor 2101 Digital Pressure Gauge           |

## Mass and Mass Related

| Parameter/Equipment                      | Range                                                                                                                                                                 | Expanded Uncertainty of Measurement (+/-)                                                                                                                                                                        | Reference Standard, Method, and/or Equipment      |
|------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------|
| Absolute Pressure – Source <sup>1</sup>  | (0 to 25) psia<br>(25 to 500) psia                                                                                                                                    | 0.001 9 psi<br>0.006 % of reading + 0.001 psi                                                                                                                                                                    | Fluke/Ruska 7250xi Pressure Controller/Calibrator |
| Pressure – Source Pneumatic <sup>1</sup> | (-14.7 to -0.5) psig<br>(0.5 to 3) psig<br>(3 to 500) psig                                                                                                            | 0.007 % of reading<br>0.007 % of reading<br>0.007 % of reading                                                                                                                                                   | Druck/Pressurements T3500 Deadweight Tester       |
| Pressure – Source <sup>6</sup>           | (1 to 100) psig                                                                                                                                                       | 0.019 psi                                                                                                                                                                                                        | Ametek MK 750B Deadweight Tester                  |
|                                          | (5 to 6 000) psig                                                                                                                                                     | 0.75 psi                                                                                                                                                                                                         | Ametek 10-10 Deadweight Tester                    |
|                                          | (5 to 10 000) psig                                                                                                                                                    | 1.4 psi                                                                                                                                                                                                          | Ametek 10-10525 Deadweight Tester                 |
|                                          | (5 to 10 000) psig                                                                                                                                                    | 2.7 psi                                                                                                                                                                                                          | Ametek DM-TQ-100 Deadweight Tester                |
|                                          | (60 to 11 000) psig                                                                                                                                                   | 1.6 psi                                                                                                                                                                                                          | Ametek TQ 100 Deadweight Tester                   |
|                                          | Up to 5.8 psig                                                                                                                                                        | 0.000 13 psi                                                                                                                                                                                                     | DHI 23111 Low Pressure Controller                 |
|                                          | (1 to 60) psig<br>(60 to 1 000) psig                                                                                                                                  | 0.017 psi<br>0.096 psi                                                                                                                                                                                           | Fluke/DHI 5201 Deadweight Tester                  |
|                                          | (200 to 10 000) psig                                                                                                                                                  | 1.4 psi                                                                                                                                                                                                          | Fluke/DHI 5203 Deadweight Tester                  |
|                                          | (1 000 to 20 000) psig                                                                                                                                                | 2 psi                                                                                                                                                                                                            | Fluke/DHI 5304 Deadweight Tester                  |
|                                          | (1 000 to 50 000) psig                                                                                                                                                | 17 psi                                                                                                                                                                                                           | Fluke/DHI 5305-02S Deadweight Tester              |
|                                          | Up to 2 000 psig                                                                                                                                                      | 0.15 psi                                                                                                                                                                                                         | Mensor CPG2500 Digital Pressure Indicator         |
|                                          | Up to 6000 psig                                                                                                                                                       | 0.56 psi                                                                                                                                                                                                         | Mensor 2101 Digital Pressure Indicator            |
|                                          | Up to 10 000 psig                                                                                                                                                     | 1.1 psi                                                                                                                                                                                                          |                                                   |
|                                          | (60 to 40 000) psig                                                                                                                                                   | 9 psi                                                                                                                                                                                                            | Fluke/Ruska 2450 Hydraulic Deadweight Tester      |
| Pressure – Source Pneumatic              | (-60 to -22) inH <sub>2</sub> O<br>(-22 to 22) inH <sub>2</sub> O<br>(22 to 60) inH <sub>2</sub> O<br>(60 to 72) inH <sub>2</sub> O<br>(72 to 804) inH <sub>2</sub> O | 0.009 % of reading + 0.000 15 inH <sub>2</sub> O<br>0.002 inH <sub>2</sub> O<br>0.009 % of reading + 0.000 15 inH <sub>2</sub> O<br>0.006 inH <sub>2</sub> O<br>0.009 % of reading + 0.000 15 inH <sub>2</sub> O | Fluke/DHI PPC4-ui Pressure Measurement System     |

### Mass and Mass Related

| Parameter/Equipment                      | Range                                       | Expanded Uncertainty of Measurement (+/-) | Reference Standard, Method, and/or Equipment |
|------------------------------------------|---------------------------------------------|-------------------------------------------|----------------------------------------------|
| Pressure – Source Hydraulic <sup>1</sup> | (5 to 1 500) psig<br>(1 500 to 15 000) psig | 0.008 % of reading<br>0.008 % of reading  | Ametek T-150<br>Dead Weight Tester           |

### Thermodynamic

| Parameter/Equipment                                       | Range                                                                | Expanded Uncertainty of Measurement (+/-)                                                                                        | Reference Standard, Method, and/or Equipment                                                                           |
|-----------------------------------------------------------|----------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------|
| Relative Humidity – Measure <sup>1</sup><br>(10 to 30) °C | (20 to 90) % RH                                                      | 1.3 % RH                                                                                                                         | Vaisala HMI41/HMP46<br>Thermohygrometer                                                                                |
| Relative Humidity – Source<br>(-10 to 70) °C              | (10 to 95) % RH                                                      | 0.5 % RH                                                                                                                         | Thunder Scientific 2500<br>Two-Pressure Humidity<br>Generator                                                          |
| Temperature – Measure <sup>1</sup>                        | (-195 to 660) °C                                                     | 0.003 % of reading + 0.009 °C                                                                                                    | Hart 5628 PRT<br>w/ Black Stack<br>Thermometer Indicator                                                               |
|                                                           | (600 to 1 000) °C<br>(1 000 to 1 200) °C                             | 0.93 °C<br>1.2 °C                                                                                                                | Accu-Mac AM1210<br>Type S Reference<br>Thermocouple<br>w/ Hart 2565<br>Thermocouple Module and<br>Black Stack          |
| Temperature – Source                                      | (-80 to 0) °C<br>(0 to 100) °C<br>(100 to 200) °C<br>(200 to 300) °C | 0.003 % of reading + 0.014 °C<br>0.003 % of reading + 0.017 °C<br>0.003 % of reading + 0.025 °C<br>0.003 % of reading + 0.035 °C | Hart 5628 PRT<br>w/ Black Stack and Fluke<br>7381, 7321, and 6331<br>Baths                                             |
|                                                           | (300 to 425) °C<br>(425 to 660) °C                                   | 0.003 % of reading + 0.043 °C<br>0.003 % of reading + 0.06 °C                                                                    | Hart 5628 PRT<br>w/ Black Stack and Fluke<br>9173 Dry Well                                                             |
|                                                           | (660 to 1 200) °C                                                    | 3.1 °C                                                                                                                           | Accu-Mac AM1210<br>Type S Reference<br>Thermocouple<br>w/ Hart 2565<br>Thermocouple Module,<br>Black Stack and Furnace |



## Time and Frequency

| Parameter/Equipment                                      | Range  | Expanded Uncertainty of Measurement (+/-) | Reference Standard, Method, and/or Equipment |
|----------------------------------------------------------|--------|-------------------------------------------|----------------------------------------------|
| Frequency – Measure and Measuring Equipment              | 10 MHz | $3.7 \times 10^{-12}$ Hz/Hz               | Fluke 910R GPS Frequency Secondary Standard  |
| Frequency – Measure and Measuring Equipment <sup>1</sup> | 10 MHz | $6.6 \times 10^{-9}$ Hz/Hz                | HP 53131A (10) Frequency Counter             |

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 inches
3. As frequency & amplitude deviate from the listed values, uncertainty may be higher than stated. If needed, contact laboratory for more information regarding uncertainties at frequency and range combinations other than the ones shown.
4. The stated uncertainty is the laboratory's ability to source a fast rise pulse that is approximately 500 ps, 125 ps, and 25 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. The known source rise time is mathematically removed from the total measured rise time measured on the DUT.
5. 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.
6. The reference standards found in this parameter are used for the calibration of pressure gages, pressure transducers, pressure transmitters and for cross-floating comparison calibration method for deadweight testers.
7. This scope is formatted as part of a single document including Certificate of Accreditation No. AC-2489.08.



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