



SCOPE OF ACCREDITATION TO ISO/IEC 17025:2005  
ANSI/NCSL Z540-1-1994 & ANSI/NCSL Z540.3-2006

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CALIBRATION

Valid To: *See Footnote 9*

Certificate Number: 1022.01

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

I. Acoustics

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

II. Chemical

| Parameter/Equipment                   | Range            | CMC <sup>2</sup> (±) | Comments         | Location        |
|---------------------------------------|------------------|----------------------|------------------|-----------------|
| pH <sup>3</sup> – Measuring Equipment | (4, 7, 10) units | 0.016 units          | Buffer solutions | DET, CHIC, CLEV |

| Parameter/Equipment  | Range   | CMC <sup>2</sup> (±)                             | Comments               | Locations       |
|--|---|--|------------------------|-----------------|
| Electrolytic Conductivity <sup>3</sup> – Measuring Equipment | 10 μS/cm<br>100 μS/cm<br>1000 μS/cm<br>10 000 μS/cm | 0.41 μS/cm<br>1.1 μS/cm<br>5.3 μS/cm<br>49 μS/cm | Conductivity solutions | DET, CHIC, CLEV |

### III. Dimensional

| Parameter/Equipment                        | Range   | CMC <sup>2, 4, 6</sup> (±)   | Comments   | Location  |
|--|---|--|--|---|
| Angle <sup>3</sup> – Measuring Equipment   | Up to 360°<br>(0 to 60)°<br>90° ± 3'                              | 7.1"<br>8.7"<br>2.8"   | Angle encoder<br>Gage blocks w/ sine bar<br>Cylinder square  | DET, CHIC, CLEV<br>DET, CHIC, CLEV<br>DET, CLEV |
| Angle <sup>3</sup> – Measure               | (0 to 60)°  | 8.1"   | Gage blocks, sine bar & comparator   | DET, CLEV                                       |
| Flatness <sup>3</sup>                      | Up to 4 in diameter   | 5.6 μin  | Optical flats  | DET, CHIC, CLEV                                 |
| Gage Blocks                                | Up to 12 in<br><br>Up to 1 in<br>(1 to 4) in<br><br>(4 to 8) in   | 1.9 μin/in + 3.8 μin<br><br>3.0 μin<br>(4.5L + 2.2) μin<br><br>(1.4L + 21) μin | Master gage blocks and laser interferometer<br><br>Master gage blocks and comparator<br><br>LMM                        | DET<br><br>CLEV<br><br>CLEV                     |
| Length Standards, Foils & Thickness Gauges | Up to 12 in<br>(>12 to 48) in<br><br>Up to 8 in<br><br>Up to 8 in | 1.9 μin/in + 3.8 μin<br><br>2 μin/in + 22 μin<br><br>(1.4L + 21) μin           | Master gage blocks and laser interferometer<br><br>Master gage blocks and USM<br><br>Master gage blocks and comparator | DET<br><br>DET<br><br>CLEV                      |

| Parameter/Equipment  | Range                       | CMC <sup>2, 4, 5</sup> ( $\pm$ )                 | Comments   | Location               |
|--|-----------------------------|--|--|------------------------|
| Hand Tools <sup>3</sup> –<br>Calipers<br>Indicators<br>Micrometers<br>Height Gages | Up to 2 in<br>(>1 to 72) in | 8 $\mu$ in<br>2.7 $\mu$ in/in + 3.8 $\mu$ in     | Gage blocks (68° room)                               | DET, CLEV<br>DET, CLEV |
|  | Up to 1 in<br>(>1 to 40) in | 25 $\mu$ in/in<br>2.5 $\mu$ in/in + 0.8 $\mu$ in | Gage blocks (normal room)                            | CHIC<br>CHIC           |
| Linear Displacement <sup>3</sup> –<br>Measuring Equipment                          | Up to 24 in                 | 60 $\mu$ in/in + 0.0014 in                       | Height gage, linear encoder, gage blocks, steel tape | DET                    |
|  | Up to 24 in                 | 60 $\mu$ in/in + 0.0027 in                       | Height gage, steel tape                              | CLEV, CHIC             |
| Optical Comparators <sup>3</sup> –<br><br>Linear Travel                            | Up to 30 in                 | 180 $\mu$ in                                     | Glass scales, magnification checker, spheres         | DET                    |
|  | Up to 30 in                 | (3L + 130) $\mu$ in                              |  | CLEV, CHIC             |
| Optical Comparators –<br><br>Magnification   | 10x to 100x                 | 0.11 %   | Glass scales, magnification checker, spheres         | DET                    |
|  | 10x to 100x                 | 0.17 %   |  | CLEV, CHIC             |
| Plain Diameter –<br>Internal & External  | Up to 4 in<br>(4 to 12) in  | (16 + 3D) $\mu$ in<br>(28 + 3D) $\mu$ in         | Master gage blocks and laser interferometer          | DET<br>DET             |
|  | (0.125 to 8) in             | (28 + 3D) $\mu$ in                               | Master rings and USM                                 | CLEV                   |
| Plain Diameter –<br>External   | (0.003 to 0.5) in           | 31 $\mu$ in                                      | Laser micrometer                                     | CLEV, CHIC             |
| Steel Tapes <sup>3</sup>   | (1 to 100) ft               | 0.063 in   | Steel tape   | DET, CHIC, CLEV        |

| Parameter/Equipment  | Range                         | CMC <sup>2, 4, 5</sup> ( $\pm$ ) | Comments   | Location |
|--|-------------------------------|----------------------------------|--|----------|
| Surface Plate Flatness <sup>3</sup>                            | (4 to 16) ft Diagonal         | (70 + 6.5Di) $\mu$ in            | Electronic leveling system                         | CHIC     |
|  | ( $\geq$ 2 to 16) ft Diagonal | (70 + 6.5Di) $\mu$ in            |  | CLEV     |
|  | (4 to 16) ft Diagonal         | (70 + 6.5Di) $\mu$ in            |  | DET      |
|  | < 24 x 36 in                  | 43 $\mu$ in                      | Planekator   | DET      |
|  | < 36 x 48 in                  | 43 $\mu$ in                      |  | DET      |
|  | < 48 x 96 in                  | 63 $\mu$ in                      |  | DET      |
| Threaded Plug Gages – Simple Pitch Diameter, (4 TPI to 80 TPI) | (0.1 to 6.5) in               | (76 + 9D) $\mu$ in               | Gage blocks, thread wires and laser interferometer | DET      |
|  | (0.1 to 8) in                 | (77 + 2D) $\mu$ in               | Gage blocks, thread wires and USM                  | CLEV     |

#### IV. Dimensional Testing/Calibration<sup>8</sup>

| Parameter/Equipment | Range             | CMC <sup>2, 4</sup> ( $\pm$ ) | Comments           | Location |
|---------------------|-------------------|-------------------------------|--------------------|----------|
| Length – 1D         | Up to 8 in        | 0.06 % + 350 $\mu$ in         | Optical comparator | CLEV     |
|                     | Up to 8 in x 4 in | 0.085 % + 490 $\mu$ in        |                    | CLEV     |

#### V. Electrical – DC/Low Frequency

| Parameter/Equipment                | Range   | CMC <sup>2, 6, 7</sup> ( $\pm$ )  | Comments                   | Location        |
|------------------------------------|---|---|----------------------------|-----------------|
| DC Voltage <sup>3</sup> – Generate | (0 to 220) mV<br>(0.22 to 2.2) V<br>(2.2 to 11) V<br>(11 to 22) V<br>(22 to 220) V<br>(220 to 1100) V | 6.8 $\mu$ V/V + 0.4 $\mu$ V<br>3.7 $\mu$ V/V + 0.7 $\mu$ V<br>4.9 $\mu$ V/V + 2.9 $\mu$ V<br>4.9 $\mu$ V/V + 4.3 $\mu$ V<br>3.7 $\mu$ V/V + 48 $\mu$ V<br>4.6 $\mu$ V/V + 0.48 mV | Fluke 5720A                | DET, CLEV, CHIC |
| DC Voltage – Measure & Generate    | Up to 200 mV<br>200 mV to 2 V<br>(2 to 1000) V  | 0.49 $\mu$ V/V + 0.06 $\mu$ V<br>0.30 $\mu$ V/V + 0.2 $\mu$ V<br>0.30 $\mu$ V/V + 2 $\mu$ V   | Fluke 732B w/ 720A & 8508A | DET             |

| Parameter/Equipment                              | Range   | CMC <sup>2, 6, 7</sup> (±)   | Comments  | Location  |
|--|---|--|---|---|
| DC Voltage –<br>Generate, Fixed Points           | 100 mV<br>1 V<br>10 V<br>100 V<br>1000 V  | 2.5 µV/V<br>2.5 µV/V<br>2.5 µV/V<br>2.5 µV/V<br>2.5 µV/V   | Fluke 732, 752A   | CLEV  |
| DC Voltage –<br>Generate, Fixed Points           | 10 V  | 11 µV  | Fluke 732   | CHIC  |
| DC Voltage <sup>3</sup> –<br>Measure             | (0 to 7) mV<br><br>(7 to 100) mV<br>(0.1 to 1) V<br>(1 to 10) V<br>(10 to 100) V<br>(100 to 1000) V                             | 60 µV/V + 0.04 µV<br><br>9.5 µV/V + 0.37 µV<br>6.1 µV/V + 0.37 µV<br>5.8 µV/V + 0.59 µV<br>8.7 µV/V + 37 µV<br>8.7 µV/V + 0.12 mV  | Agilent 34420A<br><br>Agilent 3458A opt<br>002  | DET, CHIC, CLEV                                       |
| DC High Voltage –<br><br>Measure<br><br>Generate | Up to 1400 V<br>(>1.4 to 35) kV<br>(>35 to 100) kV<br><br>Up to 1400 V<br>(>1.4 to 35) kV<br>(>35 to 40) kV<br><br>(1 to 40) kV | 0.035 % + 13 mV<br>0.047 % + 130 mV<br>0.059 % + 1.3 V<br><br>0.035 % + 13 mV<br>0.047 % + 130 mV<br>0.059 % + 1.3 V<br><br>0.13 % | Vitretek 4700 w/ HVL-<br>100 and HVP-35<br><br><br><br>Ross divider and<br>voltage source | DET, CHIC, CLEV<br><br><br><br><br><br><br>CLEV, CHIC |

| Parameter/Equipment                   | Range   | CMC <sup>2, 6, 7</sup> ( $\pm$ )  | Comments   | Location        |
|---------------------------------------|---|---|--|-----------------|
| DC Current <sup>3</sup> –<br>Generate | 0.1 nA to 220 $\mu$ A<br>(0.22 to 2.2) mA<br>(2.2 to 22) mA<br>(22 to 220) mA<br>(0.22 to 2.2) A<br>(2.2 to 11) A | 35 $\mu$ A/A + 6 nA<br>31 $\mu$ A/A + 7 nA<br>30 $\mu$ A/A + 41 nA<br>41 $\mu$ A/A + 0.70 $\mu$ A<br>77 $\mu$ A/A + 12 $\mu$ A<br>0.034 % + 0.48 mA | Fluke 5720A w/ 5725A                                   | DET, CLEV, CHIC |
|                                       | (11 to 20.5) A  | 0.10 % + 0.90 mA  | Fluke 5520A  |                 |
|                                       | (10 to 300) A   | 76 $\mu$ A/A  | Agilent 3458A w/<br>Honeywell 1168                     |                 |
|                                       | (100 to 800) A  | 0.06 %  | Empro shunt and<br>Sorensen DCR20-1000                 |                 |
|                                       | (100 to 1000) A   | 0.59 % + 0.58 A   | Fluke 5500A/coil                                       |                 |
| DC Current <sup>3</sup> –<br>Measure  | Up to 20 pA<br>(20 to 200) pA<br>(0.2 to 2) nA<br>(2 to 20) nA<br>(20 to 200) nA                                  | 3.5 %<br>0.63 %<br>0.20 %<br>0.23 %<br>0.085 %  | Keithley 617   | DET, CLEV, CHIC |
|                                       | (10 to 100) $\mu$ A<br>(0.1 to 1) mA<br>(1 to 10) mA<br>(10 to 100) mA<br>(0.1 to 1) A                            | 17 $\mu$ A/A + 0.80 nA<br>17 $\mu$ A/A + 5 nA<br>17 $\mu$ A/A + 50 nA<br>31 $\mu$ A/A + 0.5 $\mu$ A<br>0.010 % + 10 $\mu$ A                         | Agilent 3458A opt 002                                  |                 |
|                                       | (1 to 2) A<br>(2 to 20) A   | 0.019 % + 20 $\mu$ A<br>0.04 % + 0.40 mA  | Fluke 8508A  | DET             |
|                                       | (1 to 10) A<br>(10 to 100) A<br>(100 to 300) A<br>(300 to 1200) A   | 0.31 mA<br>33 $\mu$ A/A<br>0.010 %<br>0.05 %  | Agilent 3458A with<br>shunts and standard<br>resistors | DET, CLEV, CHIC |
|                                       |   |   |  |                 |
|                                       |   |   |  |                 |



| Parameter/Equipment                | Range   | CMC <sup>2, 6, 7</sup> ( $\pm$ )  | Comments   | Location        |
|------------------------------------|---|---|--|-----------------|
| DC Resistance – Measure            | (0 to 1) $\Omega$<br>(0 to 10) $\Omega$<br>(10 to 100) $\Omega$<br>(0.1 to 1) k $\Omega$<br>(1 to 10) k $\Omega$<br>(10 to 100) k $\Omega$<br>(0.1 to 1) M $\Omega$<br>(1 to 10) M $\Omega$<br>(10 to 100) M $\Omega$<br>(0.1 to 1) G $\Omega$  | 82 $\mu\Omega/\Omega$ + 2.4 $\mu\Omega$<br>17 $\mu\Omega/\Omega$ + 58 $\mu\Omega$<br>12 $\mu\Omega/\Omega$ + 0.58 m $\Omega$<br>9.4 $\mu\Omega/\Omega$ + 0.58 m $\Omega$<br>9.5 $\mu\Omega/\Omega$ + 5.8 m $\Omega$<br>9.7 $\mu\Omega/\Omega$ + 58 m $\Omega$<br>15 $\mu\Omega/\Omega$ + 2.3 $\Omega$<br>58 $\mu\Omega/\Omega$ + 0.12 k $\Omega$<br>0.058 % + 1.2 k $\Omega$<br>0.6 % + 12 k $\Omega$   | Agilent 34420A and 3458A                               | DET, CLEV, CHIC |
| Resistance <sup>3</sup> – Generate | Up to 10.99 $\Omega$<br>(11 to 32.999) $\Omega$<br>(33 to 109.9999) $\Omega$<br>(0.11 to 1.09999) k $\Omega$<br>330 $\Omega$ to 1.099999 k $\Omega$<br>(1.1 to 3.299999) k $\Omega$<br>(3.3 to 10.99999) k $\Omega$<br>(11 to 32.99999) k $\Omega$<br>(33 to 109.9999) k $\Omega$<br>(110 to 329.9999) k $\Omega$<br><br>330 k $\Omega$ to 1.09999 M $\Omega$<br>(1.1 to 3.29999) M $\Omega$<br>(3.3 to 10.9999) M $\Omega$<br>(11 to 32.9999) M $\Omega$<br>(33 to 109.9999) M $\Omega$<br>(110 to 329.999) M $\Omega$<br>(330 to 1100) M $\Omega$ | 40 $\mu\Omega/\Omega$ + 1.0 m $\Omega$<br>30 $\mu\Omega/\Omega$ + 1.5 m $\Omega$<br>28 $\mu\Omega/\Omega$ + 1.4 m $\Omega$<br>28 $\mu\Omega/\Omega$ + 2.0 m $\Omega$<br>28 $\mu\Omega/\Omega$ + 2.0 m $\Omega$<br>28 $\mu\Omega/\Omega$ + 20 m $\Omega$<br>28 $\mu\Omega/\Omega$ + 20 m $\Omega$<br>28 $\mu\Omega/\Omega$ + 0.21 $\Omega$<br>28 $\mu\Omega/\Omega$ + 0.21 $\Omega$<br>32 $\mu\Omega/\Omega$ + 2.0 $\Omega$<br><br>32 $\mu\Omega/\Omega$ + 2.1 $\Omega$<br>60 $\mu\Omega/\Omega$ + 30 $\Omega$<br>0.013 % + 50 $\Omega$<br>0.025 % + 2.5 k $\Omega$<br>0.050 % + 3.0 k $\Omega$<br>0.30 % + 0.10 M $\Omega$<br>1.5 % + 0.50 M $\Omega$ | Fluke 5520A, 4-wire<br><br>Fluke 5520A, 2-wire         | DET, CLEV, CHIC |
| Resistance – Measure               | Up to 2 $\Omega$<br>(2 to 20) $\Omega$<br>(20 to 200) $\Omega$<br>(0.2 to 2) k $\Omega$<br>(2 to 20) k $\Omega$<br>(20 to 200) k $\Omega$<br>(0.2 to 2) M $\Omega$<br>(2 to 20) M $\Omega$<br>(20 to 200) M $\Omega$<br>200 M $\Omega$ to 2 G $\Omega$<br>(2 to 20) G $\Omega$<br>20 G $\Omega$ to 1 T $\Omega$   | 3.2 $\mu\Omega/\Omega$ + 4 $\mu\Omega$<br>2.6 $\mu\Omega/\Omega$ + 14 $\mu\Omega$<br>2.5 $\mu\Omega/\Omega$ + 30 $\mu\Omega$<br>3.2 $\mu\Omega/\Omega$ + 0.3 m $\Omega$<br>3.2 $\mu\Omega/\Omega$ + 3.0 m $\Omega$<br>5.6 $\mu\Omega/\Omega$ + 30 m $\Omega$<br>11 $\mu\Omega/\Omega$ + 3 $\Omega$<br>30 $\mu\Omega/\Omega$ + 10 $\Omega$<br>0.035 % + 100 $\Omega$<br>0.041 % + 10 k $\Omega$<br>0.15 % + 10 M $\Omega$<br>0.45 %  | Resistance transfer<br><br>Fluke 8508A<br>Keithley 487 | DET             |



| Parameter/Equipment  | Range   | CMC <sup>2,6</sup> (±)   | Comments                               | Location   |
|----------------------|---|--|--|------------|
| Resistance – Measure | (0 to 1) Ω<br>(1 to 1.9) Ω<br>(1.9 to 10) Ω<br>(10 to 100) kΩ<br>(1 to 1.9) kΩ<br>(1.9 to 10) kΩ<br>(10 to 19) kΩ<br>(19 to 100) kΩ<br>(0.1 to 1) MΩ<br>(1 to 10) MΩ<br>(10 to 19) MΩ<br>(19 to 100) MΩ | 60 μΩ/Ω<br>16 μΩ/Ω<br>13 μΩ/Ω<br>14 μΩ/Ω<br>14 μΩ/Ω<br>4.8 μΩ/Ω<br>4.8 μΩ/Ω<br>4.9 μΩ/Ω<br>7.3 μΩ/Ω<br>10 μΩ/Ω<br>13 μΩ/Ω<br>20 μΩ/Ω | Fluke 5700A, 742A<br>and Agilent 3458A | CLEV, CHIC |

| Parameter/Range                    | Frequency   | CMC <sup>2,7</sup> (±)  | Comments  | Location        |
|------------------------------------|---|---|---|-----------------|
| AC Voltage <sup>3</sup> – Generate |   |   |   |                 |
| Up to 2.2 mV                       | (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>(0.5 to 1) MHz<br>(1 to 10) MHz<br>(10 to 20) MHz<br>(20 to 30) MHz | 0.022 % + 4 μV<br>0.009 % + 4 μV<br>0.008 % + 4 μV<br>0.018 % + 4 μV<br>0.046 % + 5 μV<br>0.09 % + 10 μV<br>0.12 % + 20 μV<br>0.25 % + 20 μV<br>0.30 % + 3.0 μV<br>0.50 % + 3.0 μV<br>1.5 % + 3.0 μV  | Fluke 5720A/5725A;<br>frequencies ≥ 1 MHz<br>are referenced to 1<br>kHz | DET, CLEV, CHIC |
| (2.2 to 22) mV                     | (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>(0.5 to 1) MHz<br>(1 to 10) MHz<br>(10 to 20) MHz<br>(20 to 30) MHz | 0.022 % + 4 μV<br>0.009 % + 4 μV<br>0.008 % + 4 μV<br>0.018 % + 4 μV<br>0.046 % + 5 μV<br>0.090 % + 10 μV<br>0.12 % + 20 μV<br>0.25 % + 20 μV<br>0.20 % + 3.0 μV<br>0.40 % + 3.0 μV<br>1.0 % + 3.0 μV |   |                 |

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

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

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



| Parameter/Range                | Frequency   | CMC <sup>2, 6, 7</sup> ( $\pm$ )  | Comments  | Location        |
|--------------------------------|---|---|---|-----------------|
| AC Voltage –<br>Measure (cont) |   |   |   |                 |
| (220 to 700) mV                | (9.5 to 10) Hz<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>(0.5 to 1) MHz<br>(1 to 2) MHz<br>(2 to 10) MHz<br>(10 to 20) MHz<br>(20 to 30) MHz | 0.10 % + 1.5 $\mu$ V<br>0.021 % + 1.5 $\mu$ V<br>0.008 % + 1.5 $\mu$ V<br>0.003 % + 1.5 $\mu$ V<br>0.005 % + 2.0 $\mu$ V<br>0.008 % + 2.5 $\mu$ V<br>0.018 % + 4.0 $\mu$ V<br>0.030 % + 8.0 $\mu$ V<br>0.096 % + 8.0 $\mu$ V<br>0.05 % + 8.2 $\mu$ V<br>0.10 % + 8.2 $\mu$ V<br>0.15 % + 8.2 $\mu$ V<br>0.35 % + 8.2 $\mu$ V          | Fluke 5790A; frequencies<br>$\geq$ 1 MHz are referenced to<br>1 kHz | DET, CLEV, CHIC |
| 700 mV to 2.2 V                | (9.5 to 10) Hz<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>(0.5 to 1) MHz<br>(1 to 2) MHz<br>(2 to 10) MHz<br>(10 to 20) MHz<br>(20 to 30) MHz | 0.10 % + 0.08 $\mu$ V<br>0.020 % + 0.08 $\mu$ V<br>0.007 % + 0.08 $\mu$ V<br>0.002 % + 0.08 $\mu$ V<br>0.005 % + 0.08 $\mu$ V<br>0.007 % + 0.08 $\mu$ V<br>0.016 % + 0.08 $\mu$ V<br>0.026 % + 0.08 $\mu$ V<br>0.090 % + 0.08 $\mu$ V<br>0.05 % + 8.2 $\mu$ V<br>0.10 % + 8.2 $\mu$ V<br>0.15 % + 8.2 $\mu$ V<br>0.35 % + 8.2 $\mu$ V |   |                 |
| (2.2 to 7) V                   | (9.5 to 10) Hz<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>(0.5 to 1) MHz  | 0.10 % + 0.80 $\mu$ V<br>0.020 % + 0.80 $\mu$ V<br>0.007 % + 0.80 $\mu$ V<br>0.002 % + 0.80 $\mu$ V<br>0.005 % + 0.80 $\mu$ V<br>0.008 % + 0.80 $\mu$ V<br>0.019 % + 0.80 $\mu$ V<br>0.040 % + 0.80 $\mu$ V<br>0.12 % + 0.80 $\mu$ V  |   |                 |



| Parameter/Range                             | Frequency  | CMC <sup>2, 6, 7</sup> ( $\pm$ )   | Comments    | Location        |
|---|--|--|-------------|-----------------|
| AC Voltage <sup>3</sup> –<br>Measure (cont) |  |  |             |                 |
| (7 to 22) V                                 | (9.5 to 10) Hz<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>(0.5 to 1) MHz | 0.10 % + 0.80 $\mu$ V<br>0.020 % + 0.80 $\mu$ V<br>0.007 % + 0.80 $\mu$ V<br>0.003 % + 0.80 $\mu$ V<br>0.005 % + 0.80 $\mu$ V<br>0.008 % + 0.80 $\mu$ V<br>0.019 % + 0.80 $\mu$ V<br>0.040 % + 0.80 $\mu$ V<br>0.12 % + 0.80 $\mu$ V | Fluke 5790A | DET, CLEV, CHIC |
| (22 to 70) V                                | (9.5 to 10) Hz<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>(0.5 to 1) MHz | 0.10 % + 8.2 $\mu$ V<br>0.020 % + 8.2 $\mu$ V<br>0.007 % + 8.2 $\mu$ V<br>0.003 % + 8.2 $\mu$ V<br>0.006 % + 8.2 $\mu$ V<br>0.009 % + 8.2 $\mu$ V<br>0.020 % + 8.2 $\mu$ V<br>0.042 % + 8.2 $\mu$ V<br>0.12 % + 8.2 $\mu$ V          |             |                 |
| (70 to 220) V                               | (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                                     | 0.020 % + 8.2 $\mu$ V<br>0.007 % + 8.2 $\mu$ V<br>0.003 % + 8.2 $\mu$ V<br>0.007 % + 8.2 $\mu$ V<br>0.010 % + 8.2 $\mu$ V<br>0.021 % + 8.2 $\mu$ V<br>0.050 % + 8.2 $\mu$ V  |             |                 |
| (220 to 700) V                              | (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   | 0.020 % + 82 $\mu$ V<br>0.010 % + 82 $\mu$ V<br>0.004 % + 82 $\mu$ V<br>0.013 % + 82 $\mu$ V<br>0.050 % + 82 $\mu$ V   |             |                 |
| (700 to 1000) V                             | (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   | 0.020 % + 82 $\mu$ V<br>0.010 % + 82 $\mu$ V<br>0.004 % + 82 $\mu$ V<br>0.013 % + 82 $\mu$ V<br>0.050 % + 82 $\mu$ V   |             |                 |



| Parameter/Range                             | Frequency  | CMC <sup>2, 6, 7</sup> ( $\pm$ )   | Comments      | Location        |
|---|--|--|---------------|-----------------|
| AC Voltage <sup>3</sup> – Measure<br>(cont) |  |  |               |                 |
| (0.1 to 10) mV                              | (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                                   | 0.030 % + 3.3 $\mu$ V<br>0.020 % + 1.8 $\mu$ V<br>0.030 % + 1.8 $\mu$ V<br>0.10 % + 1.8 $\mu$ V<br>0.50 % + 1.8 $\mu$ V<br>4.0 % + 1.8 $\mu$ V   | Agilent 3458A | DET, CLEV, CHIC |
| (10 to 100) mV                              | (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>(0.3 to 1) MHz<br>(1 to 2) MHz | 0.007 % + 10 $\mu$ V<br>0.007 % + 2 $\mu$ V<br>0.014 % + 2 $\mu$ V<br>0.030 % + 2 $\mu$ V<br>0.080 % + 2 $\mu$ V<br>0.30 % + 10 $\mu$ V<br>1.0 % + 10 $\mu$ V<br>1.5 % + 10 $\mu$ V        |               |                 |
| 100 mV to 1V                                | (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>(0.3 to 1) MHz<br>(1 to 2) MHz | 0.007 % + 40 $\mu$ V<br>0.007 % + 20 $\mu$ V<br>0.014 % + 20 $\mu$ V<br>0.030 % + 20 $\mu$ V<br>0.080 % + 20 $\mu$ V<br>0.30 % + 100 $\mu$ V<br>1.0 % + 100 $\mu$ V<br>1.5 % + 100 $\mu$ V |               |                 |
| (1 to 10) V                                 | (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>(0.3 to 1) MHz<br>(1 to 2) MHz | 0.007 % + 0.40 mV<br>0.007 % + 0.20 mV<br>0.014 % + 0.20 mV<br>0.030 % + 0.20 mV<br>0.080 % + 0.20 mV<br>0.30 % + 1.0 mV<br>1.0 % + 1.0 mV<br>1.5 % + 1.0 mV                               |               |                 |
| (10 to 100) V                               | (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>(0.3 to 1) MHz                 | 0.02 % + 4.0 mV<br>0.02 % + 2.0 mV<br>0.02 % + 2.0 mV<br>0.04 % + 2.0 mV<br>0.12 % + 2.0 mV<br>0.40 % + 10 mV<br>1.5 % + 10 mV   |               |                 |
| (100 to 750) V                              | (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   | 0.04 % + 40 mV<br>0.04 % + 20 mV<br>0.06 % + 20 mV<br>0.12 % + 20 mV<br>0.30 % + 20 mV   |               |                 |

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



| Parameter/Range                              | Frequency  | CMC <sup>2, 4, 6, 7</sup> ( $\pm$ )   | Comments                          | Location        |
|--|--|---|-----------------------------------|-----------------|
| AC Current <sup>3</sup> –<br>Generate (cont) |  |   |                                   |                 |
| (0.22 to 2.2) A                              | 20 Hz to 1 kHz<br>(1 to 5) kHz<br>(5 to 10) kHz                    | 0.024 % + 36 $\mu$ A<br>0.039 % + 80 $\mu$ A<br>0.60 % + 0.16 mA              | Fluke 5720A w/ 5725A              | DET, CLEC, CHIC |
| (2.2 to 11) A                                | 40 Hz to 1 kHz<br>(1 to 5) kHz<br>(5 to 10) kHz                    | 0.040 % + 0.18 mA<br>0.085 % + 0.39 mA<br>0.33 % + 0.75 mA                    | Fluke 5720A w/ 5725A              |                 |
| (11 to 20.5)                                 | (45 to 100) Hz<br>100 Hz to 1 kHz<br>(1 to 5) kHz                  | 0.12 % + 5.1 mA<br>0.15 % + 5.1 mA<br>3.0 % + 5.1 mA                          | Fluke 5520A                       |                 |
| 100 $\mu$ A to 20 A                          | 45 Hz to 5 kHz   | 0.016 %   | Fluke 5790A, 5720A,<br>A40 shunts |                 |
| (20 to 100) A                                | (25 to 500) Hz   | 1.0 %   | Fluke 5720A, 461CT &<br>1620A TCA |                 |
| (16 to 150) A                                | (45 to 65) Hz<br>(65 to 440) Hz                                    | 0.38 % + 0.029A<br>1.0 % + 0.031A   | Fluke 5520A,<br>5500A/coil        |                 |
| (150 to 1025) A                              | (45 to 65) Hz<br>(65 to 440) Hz                                    | 1.0 % + 0.031 A<br>1.0 % + 0.12 A   |                                   |                 |
| AC Current <sup>3</sup> –<br>Measure         |  |   |                                   |                 |
| (5 to 100) $\mu$ A                           | (10 to 20) Hz<br>(20 to 45) Hz<br>45 Hz to 5 kHz                   | 0.46 % + 0.035 $\mu$ A<br>0.18 % + 0.035 $\mu$ A<br>0.07 % + 0.035 $\mu$ A    | Agilent 3458A                     | DET, CLEV, CHIC |
| (0.1 to 100) mA                              | (10 to 20) Hz<br>(20 to 45) Hz<br>(45 to 100) Hz<br>(0.1 to 5) kHz | 0.46 % + 0.024 %<br>0.18 % + 0.024 %<br>0.07 % + 0.024 %<br>0.036 % + 0.024 % |                                   |                 |
| (0.1 to 1) A                                 | (10 to 20) Hz<br>(20 to 45) Hz<br>(45 to 100) Hz<br>(0.1 to 5) kHz | 0.46 % + 0.23 mA<br>0.19 % + 0.23 mA<br>0.093 % + 0.23 mA<br>0.12 % + 0.23 mA |                                   |                 |
| 100 mA to 20 A                               | Up to 1 kHz<br>(1 to 5) kHz  | 0.039 % + 0.032 % $\cdot F$<br>0.041 % + 0.032 % $\cdot F$                    | Y5020                             | DET, CLEV, CHIC |
| (20 to 800) A                                | (25 to 500) Hz   | 0.18 %  | Agilent 8508A & 461CT             | DET, CLEV, CHIC |

AC Current<sup>3</sup> – Measure (cont) w/ Fluke 5790A and A40 shunts  $\mu\text{A}/\text{A}$

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

| Parameter/Range                                       | Frequency              | CMC <sup>2, 6, 7</sup> ( $\pm$ ) | Comments                                  | Location        |
|---|------------------------|----------------------------------|---|-----------------|
| AC Impedance <sup>3</sup> –<br>Generate, Fixed Points |                        |                                  |   |                 |
| 0.1 $\Omega$  | $\leq 1 \text{ kHz}$   | 0.14 m $\Omega$                  | Agilent 16074A AC<br>resistance standards | DET, CLEV, CHIC |
| 1 $\Omega$  | $\leq 1 \text{ kHz}$   | 0.45 m $\Omega$                  |   |                 |
| 10 $\Omega$   | $\leq 13 \text{ MHz}$  | 4.2 m $\Omega$                   |   |                 |
| 100 $\Omega$  | $\leq 13 \text{ MHz}$  | 2.2 m $\Omega$                   |   |                 |
| 1 k $\Omega$  | $\leq 13 \text{ MHz}$  | 0.022 $\Omega$                   |   |                 |
| 10 k $\Omega$   | $\leq 1 \text{ MHz}$   | 0.22 $\Omega$                    |   |                 |
| 100 k $\Omega$  | $\leq 100 \text{ kHz}$ | 2.2 $\Omega$                     |   |                 |
| Capacitance <sup>3</sup> –<br>Generate                |                        |                                  |   |                 |
| (0.10 to 3.299) nF                                    | 10 Hz to 10 kHz        | 0.51 % + 12 pF                   | Fluke 5520A                               | DET, CLEV, CHIC |
| (0.33 to 10.999) nF                                   | (10 to 1000) Hz        | 0.26 % + 12 pF                   |   |                 |
| (11 to 109.999) nF                                    | (10 to 1000) Hz        | 0.26 % + 0.12 nF                 |   |                 |
| (110 to 329.99) nF                                    | (10 to 1000) Hz        | 0.26 % + 0.31 nF                 |   |                 |
| (0.33 to 1.0999) $\mu\text{F}$                        | (10 to 600) Hz         | 0.26 % + 1.2 nF                  |   |                 |
| (1.1 to 3.2999) $\mu\text{F}$                         | (10 to 300) Hz         | 0.26 % + 3.1 nF                  |   |                 |
| (3.3 to 10.999) $\mu\text{F}$                         | (10 to 150) Hz         | 0.26 % + 12 nF                   |   |                 |
| (11 to 32.999) $\mu\text{F}$                          | (10 to 120) Hz         | 0.42 % + 31 nF                   |   |                 |
| (33 to 109.99) $\mu\text{F}$                          | (10 to 80) Hz          | 0.46 % + 0.12 $\mu\text{F}$      |   |                 |



| Parameter/Range   | Frequency   | CMC <sup>2, 6, 7</sup> ( $\pm$ )  | Comments  | Location        |
|---|---|---|---|-----------------|
| Capacitance <sup>3</sup> – Generate<br>(cont)<br><br>(110 to 329.99) $\mu$ F<br>(0.33 to 1.0999) mF<br>(1.1 to 3.2999) mF<br>(3.3 to 10.999) mF<br>(11 to 32.999) mF<br>(33 to 110) mF<br><br>100 pF to 1.1 $\mu$ F | Up to 50 Hz<br>Up to 20 Hz<br>Up to 6 Hz<br>Up to 2 Hz<br>Up to 0.6 Hz<br>Up to 0.2 Hz<br><br>1 kHz   | 0.46 % + 0.31 $\mu$ F<br>0.46 % + 1.2 $\mu$ F<br>0.46 % + 3.1 $\mu$ F<br>0.46 % + 12 $\mu$ F<br>0.78 % + 31 $\mu$ F<br>1.2 % + 0.12 mF<br><br>0.03 %  | Fluke 5520A<br><br><br><br><br><br><br><br>Agilent 1423A  | DET, CLEV, CHIC |
| Capacitance <sup>3</sup> –<br>Generate, Fixed Points<br><br>1 pF<br>10 pF<br>100 pF<br>1000 pF<br>(10, 100, 1000) nF  | 1 kHz to 13 MHz<br>1 kHz to 13 MHz<br>1 kHz to 13 MHz<br>1 kHz to 13 MHz<br>120 Hz to 100 kHz   | 0.37 %<br>0.04 %<br>0.07 %<br>0.33 %<br>0.01 %  | Agilent 16380A and<br>16380C  | DET, CLEV, CHIC |
| Capacitance <sup>3</sup> – Measure<br><br>(1 to 10) pF<br><br>(10 to 100) pF<br><br>100 pF to 1 nF<br><br>(1 to 10) nF<br><br>(10 to 100) nF  | (1 to 2) kHz<br>5 kHz<br>10 kHz<br><br>150 Hz to 1 kHz<br>(1 to 2) kHz<br>5 kHz<br>10 kHz<br><br>(20 to 400) Hz<br>(1 to 2) kHz<br>5 kHz<br>10 kHz<br><br>(20 to 30) Hz<br>(1 to 2) kHz<br>5 kHz<br>10 kHz<br><br>(1 to 2) kHz<br>5 kHz<br>10 kHz | 0.012 %<br>0.035 %<br>0.092 %<br><br>0.41 % + $F_c$<br>0.012 %<br>0.023 %<br>0.058 %<br><br>0.41 % + $F_c$<br>0.012 %<br>0.023 %<br>0.058 %<br><br>0.41 % + $F_c$<br>0.012 %<br>0.023 %<br>0.058 %<br><br>0.012 %<br>0.035 %<br>0.081 % | GenRad 1615-A<br>capacitance bridge<br><br>$F_c = (0.01 \text{ pF}/f [\text{kHz}] + 0.01 \text{ pF})$ | DET             |

| Parameter/Range                              | Frequency  | CMC <sup>2, 6, 7</sup> (±)           | Comments                            | Location        |
|--|--|--------------------------------------|-------------------------------------|-----------------|
| Capacitance <sup>3</sup> – Measure<br>(cont) |  |                                      |                                     |                 |
| 100 nF to 1 µF                               | (1 to 2) kHz<br>5 kHz<br>10 kHz  | 0.023 %<br>0.081 %<br>0.32 %         | GenRad 1615-A<br>capacitance bridge | DET             |
| (1 to 10) µF                                 | (1 to 2) kHz<br>5 kHz<br>10 kHz  | 0.012 %<br>0.68 %<br>2.7 %           |                                     |                 |
| (10 to 100) µF                               | 1 kHz  | 0.012 %                              |                                     |                 |
| Capacitance <sup>3</sup> – Measure           |  |                                      |                                     |                 |
| (1 to 3) pF                                  | 500 Hz to 5 kHz<br>(5 to 100) kHz                                      | 12 %<br>1.2 %                        | Fluke PM6304C                       | DET, CLEV, CHIC |
| (10 to 30) pF                                | (150 to 500) Hz<br>500 Hz to 5 kHz<br>(5 to 20) kHz<br>(20 to 100) kHz | 12 %<br>1.2 %<br>0.12 %<br>0.46 %    |                                     |                 |
| (100 to 300) pF                              | (50 to 250) Hz<br>250 Hz to 1 kHz<br>(1 to 20) kHz<br>(20 to 100) kHz  | 12 %<br>1.2 %<br>0.12 %<br>0.46 %    |                                     |                 |
| (1 to 3) nF                                  | (50 to 250) Hz<br>250 Hz to 20 kHz<br>(20 to 100) kHz                  | 1.2 %<br>0.12 %<br>0.46 %            |                                     |                 |
| (10 to 30) nF                                | (50 to 500) Hz<br>500 Hz to 2 kHz<br>(2 to 20) kHz<br>(20 to 100) kHz  | 0.12 %<br>0.06 %<br>0.12 %<br>0.46 % |                                     |                 |
| (100 to 300) nF                              | (50 to 150) Hz<br>150 Hz to 2 kHz<br>(2 to 20) kHz<br>(20 to 100) kHz  | 0.12 %<br>0.06 %<br>0.12 %<br>0.46 % |                                     |                 |



| Parameter/Range   | Frequency   | CMC <sup>2, 6, 7</sup> ( $\pm$ )  | Comments           | Location        |
|---|---|---|--------------------|-----------------|
| Capacitance <sup>3</sup> – Measure<br>(cont)                                  |   |   |                    |                 |
| (1 to 3) $\mu$ F  | 50 Hz to 2 kHz<br>(2 to 20) kHz<br>(20 to 100) kHz                              | 0.06 %<br>0.12 %<br>0.46 %  | Fluke PM6304C      | DET, CLEV, CHIC |
| (10 to 30) $\mu$ F  | (50 to 1500) Hz<br>(1.5 to 15) kHz<br>(15 to 50) kHz<br>(50 to 100) kHz         | 0.06 %<br>0.12 %<br>1.2 %<br>12 %   |                    |                 |
| (30 to 100) $\mu$ F   | (50 to 1500) Hz<br>(1.5 to 15) kHz<br>(15 to 50) kHz                            | 0.12 %<br>1.2 %<br>12 %   |                    |                 |
| Phase Angle <sup>3</sup> – Generate   |   |   |                    |                 |
| (0 to 360) $^{\circ}$<br>50 mV to 120 V                                       | (1 to 1000) Hz<br>1001 Hz to 6.25 kHz<br>(6.26 to 50) kHz<br>(50.01 to 100) kHz | 6.2 m $^{\circ}$<br>12 m $^{\circ}$<br>30 m $^{\circ}$<br>58 m $^{\circ}$ | Clarke Hess 5000   | DET             |
| Phase Angle <sup>3</sup> – Measure<br>(0 to 360) $^{\circ}$<br>50 mV to 120 V | 20 Hz to 10 kHz<br>(10 to 40) kHz<br>(40 to 100) kHz                            | 0.081 $^{\circ}$<br>0.29 $^{\circ}$<br>0.98 $^{\circ}$                    | Krohn-Hite 6500    | DET             |
| Distortion <sup>3</sup>   | 20 Hz to 20 kHz<br>(20 to 100) kHz  | 0.63 dB<br>0.87 dB  | Agilent U8903A     | DET, CLEV, CHIC |
|   | 100 kHz to 2.5 GHz  | 1.8 dB  | Agilent 8566A      |                 |
|   | (2.5 to 26.5) GHz   | 2.6 dB  | Agilent 8563E      |                 |
| Risetime <sup>3</sup> – Measure   | > 7 ps  | 10 ps   | HP Sampling system | DET, CLEV, CHIC |

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

Inductance<sup>3,7</sup> – Generate w/ General Radio 1482 series inductors

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



Inductance<sup>3,7</sup> – Measure by Transfer Method w/ General Radio 1482 series inductors

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

| Parameter/Range                   | Frequency  | CMC <sup>2, 6, 7</sup> ( $\pm$ )              | Comments      | Location        |
|-----------------------------------|--|---|---------------|-----------------|
| Inductance <sup>3</sup> – Measure |  |   |               |                 |
| 1 $\mu$ H                         | 500 Hz to 1 kHz<br>(50 to 100) kHz   | 12 %<br>1.2 %                                 | Fluke PM6304C | DET, CLEV, CHIC |
| 10 $\mu$ H                        | (250 to 500) Hz<br>500 Hz to 20 kHz<br>(20 to 100) kHz                                 | 12 %<br>1.2 %<br>0.46 %                       |               |                 |
| 100 $\mu$ H                       | (75 to 250) Hz<br>(250 to 1500) Hz<br>(1.5 to 20) kHz<br>(20 to 100) kHz               | 12 %<br>1.2 %<br>0.12 %<br>0.46 %             |               |                 |
| 1 mH                              | (50 to 75) Hz<br>(75 to 250) Hz<br>250 Hz to 20 kHz<br>(20 to 100) kHz                 | 12 %<br>1.2 %<br>0.12 %<br>0.46 %             |               |                 |
| 10 mH                             | (50 to 75) Hz<br>(75 to 250) Hz<br>250 Hz to 2 kHz<br>(2 to 20) kHz<br>(20 to 100) kHz | 1.2 %<br>0.12 %<br>0.06 %<br>0.12 %<br>0.46 % |               |                 |
| 100 mH                            | (50 to 75) Hz<br>75 Hz to 2 kHz<br>(2 to 20) kHz<br>(20 to 100) kHz                    | 0.12 %<br>0.06 %<br>0.12 %<br>0.46 %          |               |                 |



| Parameter/Range                                  | Frequency  | CMC <sup>2, 6, 7</sup> (±)                               | Comments      | Location        |
|--|--|--|---------------|-----------------|
| Inductance <sup>3</sup> – Measure<br>(cont)      |  |  |               |                 |
| 1 H  | 50 Hz to 2 kHz<br>(2 to 20) kHz<br>(20 to 100) kHz     | 0.06 %<br>0.12 %<br>0.46 %                               | Fluke PM6304C | DET, CLEV, CHIC |
| 10 H   | (50 to 250) Hz<br>250 Hz to 20 kHz<br>(20 to 100) kHz  | 0.06 %<br>0.12 %<br>1.2 %                                |               |                 |
| 100 H  | (50 to 250) Hz<br>(2.5 to 15) kHz<br>(15 to 75) kHz    | 0.12 %<br>1.2 %<br>12 %                                  |               |                 |
| 1000 H   | (50 to 250) Hz<br>250 Hz to 2.5 kHz<br>(2.5 to 15) kHz | 0.12 %<br>1.2 %<br>13 %                                  |               |                 |
| Inductance – Generate                            |  |  |               |                 |
| 100 μH<br>1 mH<br>10 mH<br>100 mH<br>1 H<br>10 H | 400 Hz, 1 kHz  | 1.2 %<br>0.13 %<br>0.083 %<br>0.083 %<br>0.24 %<br>1.4 % | GenRad 1482   | CHIC            |
| Inductance – Generate                            |  |  |               |                 |
| 100 μH<br>10 mH<br>100 mH<br>10 H                | 400 Hz, 1 kHz  | 1.2 %<br>0.083 %<br>0.083 %<br>1.4 %                     | GenRad 1482   | CLEV            |



| Parameter/Equipment                                       | Range   | CMC <sup>2</sup> (±)  | Comments    | Location        |
|---|---|---|-------------|-----------------|
| Electrical Calibration of<br>RTDs <sup>3</sup> – Generate |   |   |             |                 |
| Pt 385, 100 Ω   | (-200 to 80) °C<br>(-80 to 100) °C<br>(100 to 300) °C<br>(300 to 400) °C<br>(400 to 600) °C<br>(600 to 800) °C                                      | 0.013 °C<br>0.02 °C<br>0.024 °C<br>0.026 °C<br>0.033 °C<br>0.038 °C                         | Fluke 7526A | DET, CLEV, CHIC |
| Pt 3926, 100 Ω  | (-200 to -80) °C<br>(-80 to 0) °C<br>(0 to 100) °C<br>(100 to 300) °C<br>(300 to 400) °C<br>(400 to 630) °C   | 0.013 °C<br>0.015 °C<br>0.017 °C<br>0.022 °C<br>0.026 °C<br>0.032 °C                        |             |                 |
| Pt 3916, 100 Ω  | (-200 to -190) °C<br>(-190 to -80) °C<br>(-80 to 0) °C<br>(0 to 100) °C<br>(100 to 300) °C<br>(300 to 400) °C<br>(400 to 600) °C<br>(600 to 630) °C | 0.01 °C<br>0.013 °C<br>0.015 °C<br>0.017 °C<br>0.022 °C<br>0.026 °C<br>0.031 °C<br>0.033 °C |             |                 |
| Pt 385, 200 Ω   | (-200 to -80) °C<br>(-80 to 0) °C<br>(0 to 100) °C<br>(100 to 260) °C<br>(260 to 300) °C<br>(300 to 400) °C<br>(400 to 630) °C                      | 0.053 °C<br>0.056 °C<br>0.06 °C<br>0.06 °C<br>0.069 °C<br>0.071 °C<br>0.088 °C              |             |                 |
| Pt 385, 500 Ω   | (-200 to 0) °C<br>(0 to 100) °C<br>(100 to 300) °C<br>(300 to 400) °C<br>(400 to 630) °C  | 0.026 °C<br>0.028 °C<br>0.034 °C<br>0.038 °C<br>0.045 °C                                    |             |                 |



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

| Parameter/Equipment   | Range   | CMC <sup>2</sup> (±)   | Comments    | Location        |
|---|---|--|-------------|-----------------|
| Thermocouple <sup>3</sup> –<br>Indicating Systems &<br>Measure (cont) |   |  |             |                 |
| Type L  | (-200 to -100) °C<br>(-100 to 900) °C   | 0.1 °C<br>0.09 °C  | Fluke 7526A | DET, CLEV, CHIC |
| Type N  | (-250 to -200) °C<br>(-200 to -100) °C<br>(-100 to 0) °C<br>(0 to 100) °C<br>(100 to 800) °C<br>(800 to 1300) °C                                      | 0.73 °C<br>0.23 °C<br>0.12 °C<br>0.11 °C<br>0.1 °C<br>0.12 °C                        |             |                 |
| Type R  | (50 to -25) °C<br>(-25 to 0) °C<br>(0 to 100) °C<br>(100 to 400) °C<br>(400 to 600) °C<br>(600 to 1000) °C<br>(1000 to 1600) °C<br>(1600 to 1767) °C  | 0.55 °C<br>0.45 °C<br>0.39 °C<br>0.28 °C<br>0.22 °C<br>0.21 °C<br>0.19 °C<br>0.23 °C |             |                 |
| Type S  | (-50 to -25) °C<br>(-25 to 0) °C<br>(0 to 100) °C<br>(100 to 400) °C<br>(400 to 600) °C<br>(600 to 1000) °C<br>(1000 to 1600) °C<br>(1600 to 1767) °C | 0.51 °C<br>0.43 °C<br>0.38 °C<br>0.29 °C<br>0.23 °C<br>0.22 °C<br>0.22 °C<br>0.26 °C |             |                 |
| Type T  | (-250 to -200) °C<br>(-200 to -100) °C<br>(-100 to 0) °C<br>(0 to 200) °C<br>(200 to 400) °C  | 0.35 °C<br>0.16 °C<br>0.11 °C<br>0.09 °C<br>0.09 °C                                  |             |                 |
| Type U  | (-200 to 0) °C<br>(0 to 200) °C<br>(200 to 600) °C  | 0.16 °C<br>0.1 °C<br>0.1 °C  |             |                 |

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

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

| Parameter/Range           | Frequency        | CMC <sup>2, 5, 6</sup> (±) | Comments                        | Location          |
|---------------------------|------------------|----------------------------|---------------------------------|-------------------|
| Power Meter <sup>3</sup>  |                  |                            |                                 |                   |
| Power Reference<br>@ 1 mW | 50 MHz<br>50 MHz | 0.34 % + 1 μW<br>1.9 %     | N432A w/ 478A<br>432B, 478A-H76 | DET<br>CLEV, CHIC |
| Power Accuracy            | 3 μW to 100 mW   | 0.29 %                     | Range calibrator                | DET, CLEV, CHIC   |

| Parameter/Range                              | Frequency  | CMC <sup>2, 6, 7</sup> (±)   | Comments  | Location   |
|--|--|--|---|------------|
| Power Sensor Calibration Factor <sup>3</sup> | 100 kHz<br>200 kHz<br>(0.2 to 1) MHz<br>1 MHz to 3 GHz<br>(3 to 10) GHz<br>(10 to 18) GHz<br>(18 to 19) GHz<br>(19 to 26.5) GHz            | 1.0 %<br>0.61 %<br>0.59 %<br>0.60 %<br>0.74 %<br>0.87 %<br>2.5 %<br>3.0 %  | Power sensor calibration system   | DET        |
| Amplitude Modulation <sup>3</sup> – Measure  | Depth:<br>100 kHz to 10 MHz<br>10 MHz to 3 GHz<br>(3 to 26.5) GHz<br>(26.5 to 31.15) GHz<br>(31.15 to 50) GHz                              | (5 to 99) %<br>0.75 %<br>(5 to 20) %<br>2.5 %<br>(20 to 99) %<br>0.50 %<br>(5 to 20) %<br>4.5 %<br>(20 to 99) %<br>1.5 %<br>(5 to 20) %<br>6.8 %<br>(20 to 99) %<br>1.9 %<br>(5 to 20) %<br>2.6 %<br>(20 to 99) %<br>6.0 % | Measuring receiver system   | DET        |
| Amplitude Modulation <sup>3</sup> – Measure  | (20 to 50) kHz<br>(50 to 100) kHz  | 1.4 %<br>3.6 %   | Agilent 8902A   | CLEV, CHIC |
| Frequency Modulation <sup>3</sup> – Measure  | Mod Rate: 20 Hz to 10 kHz<br>Dev.: 200 Hz to 40 kHz<br>(β > 0.2)<br><br>Mod Rate: 50 Hz to 200 kHz<br>Dev.: 250 Hz to 400 kHz<br>(β > 0.2) | 250 kHz to 10 MHz<br><br>1.0 %<br><br>10 MHz to 6.6 GHz<br>(6.6 to 13.2) GHz<br>(13.2 to 31.15) GHz<br>(31.15 to 50) GHz<br>1.0 %<br>1.0 %<br>1.0 %<br>1.0 %   | Measuring receiver system<br><br>β is the ratio of the frequency deviation to the modulation rate | DET        |

| Parameter/Range  | Frequency   | CMC <sup>2, 5, 6</sup> (±)   | Comments                         | Location   |
|--|---|--|----------------------------------|------------|
| Frequency Modulation <sup>3</sup> – Measure<br><br>Dev: Up to 400 kHz  | (20 to 50) Hz<br>50 Hz to 100 kHz<br>(100 to 200) kHz   | 5.8 %<br>1.4 %<br>5.8 %  | Agilent 8902A                    | CLEV, CHIC |
| Phase Modulation <sup>3</sup> – Measure<br><br>Mod Rate: (0.2 to 20) kHz<br><br>0.3 rad < Dev ≤ 0.7 rad<br>Dev > 0.7 rad<br><br>0.6 rad < Dev ≤ 2.0 rad<br>Dev > 2.0 rad<br><br>1.2 rad < Dev ≤ 4.0 rad<br>Dev > 4.0 rad<br><br>1.3 rad < Dev ≤ 4.0 rad<br>Dev > 4.0 rad<br><br>2.4 rad < Dev ≤ 8.0 rad<br>Dev > 8.0 rad | 100 kHz to 6.6 GHz<br><br>(6.6 to 13.2) GHz<br><br>(13.2 to 26.5) GHz<br><br>(26.5 to 31.5) GHz<br><br>(31.5 to 50) GHz | 3.0 %<br>1.0 %<br><br>3.0 %<br>1.0 %<br><br>3.0 %<br>1.0 %<br><br>3.0 %<br>1.0 %<br><br>3.0 %<br>1.0 %   | Measuring receiver system        | DET        |
| Phase Modulation <sup>3</sup> – Measure  | 200 Hz to 10 kHz<br>200 Hz to 20 kHz  | 4.7 %<br>3.5 %   | Agilent 8902A                    | CLEV, CHIC |
| Relative Power <sup>3</sup> – Measure<br><br>(0 to -10) dB<br>(-10 to -20) dB<br>(-20 to -30) dB<br>(-30 to -40) dB<br>(-40 to -50) dB<br>(-50 to -60) dB<br>(-60 to -70) dB<br>(-70 to -80) dB<br>(-80 to -90) dB<br>(-90 to -100) dB<br>(-100 to -110) dB<br>(-110 to -120) dB<br>(-120 to -130) dB                    | 100 kHz to 26.5 GHz   | 0.018 dB<br>0.019 dB<br>0.019 dB<br>0.056 dB<br>0.056 dB<br>0.057 dB<br>0.057 dB<br>0.094 dB<br>0.094 dB<br>0.095 dB<br>0.096 dB<br>0.096 dB<br>0.097 dB | Measuring receiver system, E440A | DET        |

| Parameter/Range  | Frequency  | CMC <sup>2, 6, 7</sup> (±)   | Comments   | Location        |
|--|--|--|--|-----------------|
| <b>Relative Power<sup>3</sup> – Measure</b><br><br>(0 to -10) dB<br>(-10 to -20) dB<br>(-20 to -30) dB<br>(-30 to -40) dB<br>(-40 to -50) dB<br>(-50 to -60) dB<br>(-60 to -70) dB<br>(-70 to -80) dB<br>(-80 to -90) dB<br>(-90 to -100) dB<br>(-100 to -110) dB<br>(-110 to -120) dB | 10 MHz to 26.5 GHz<br>10 MHz to 26.5 GHz<br>10 MHz to 26.5 GHz<br>10 MHz to 26.5 GHz<br>10 MHz to 26.5 GHz<br>10 MHz to 26.5 GHz<br>10 MHz to 26.5 GHz<br>10 MHz to 26.5 GHz<br>10 MHz to 26.5 GHz<br>10 MHz to 26.5 GHz<br>10 MHz to 26.5 GHz<br>10 MHz to 26.5 GHz<br>10 MHz to 26.5 GHz | 0.046 dB<br>0.053 dB<br>0.080 dB<br>0.098 dB<br>0.11 dB<br>0.12 dB<br>0.13 dB<br>0.17 dB<br>0.18 dB<br>0.19 dB<br>0.19 dB<br>0.21 dB | Agilent 8902A  | CLEV, CHIC      |
| <b>Absolute Power<sup>3</sup> – Measure</b><br><br>(-70 to -30) dBm<br><br>(-30 to + 10) dBm<br><br>(+10 to +20) dBm   | 10 MHz to 18 GHz<br><br>100 kHz to 4.2 GHz<br>(4.2 to 18) GHz<br>(18 to 26.5) GHz<br><br>100 kHz to 4.2 GHz<br>(4.2 to 18) GHz<br>(18 to 26.5) GHz   | 2.7 %<br><br>1.4 %<br>1.9 %<br>2.4 %<br><br>3.3 %<br>3.5 %<br>3.8 %  | Power meter w/:<br><br>8484A, N-type<br><br>8482A H85, N-type<br>8481A H85, N-type<br>8485A H85, 3.5 mm<br><br>8482A H85, N-type<br>8481A H85, N-type<br>8485A H85, 3.5 mm | DET, CLEV, CHIC |

| Parameter/Equipment   | Range                               | CMC <sup>2, 6</sup> (±)   | Comments                                      | Location |
|---|-------------------------------------|---|---|----------|
| <b>Reflection<sup>3</sup> S<sub>11</sub>/S<sub>22</sub> – Measure</b><br><br>Type-N connectors:<br><br>Linear Mag.<br>Linear Phase<br>Linear Mag.<br>Linear Phase | 9 kHz to 2 GHz<br><br>(2 to 18) GHz | (± 0.004 to ± 0.014) dB<br>(± 0.75 to ± 8.0)°<br>(± 0.026 to ± 0.053) dB<br>(± 3.8 to ± 9.5)° | Vector network analyzer with calibration kits | DET      |



| Parameter/Range   | Frequency  | CMC <sup>2, 5, 6</sup> (±)   | Comments                                      | Location   |
|---|--|--|---|------------|
| Reflection <sup>3</sup> S <sub>11</sub> /S <sub>22</sub> – Measure (cont)<br><br>3.5 mm connectors:<br>45 MHz to 2 GHz<br>(2 to 20) GHz<br>(20 to 26.5) GHz<br><br>2.4 mm connectors:<br>45 MHz to 2 GHz<br>(2 to 20) GHz<br>(20 to 40) GHz<br>(40 to 50) GHz | Linear Mag.<br>Linear Phase<br>Linear Mag.<br>Linear Phase<br>Linear Mag.<br>Linear Phase<br><br>Linear Mag.<br>Linear Phase<br>Linear Mag.<br>Linear Phase<br>Linear Mag.<br>Linear Phase | (± 0.015 to ± 0.021) dB<br>(± 0.99 to ± 3.9) °<br>(± 0.016 to ± 0.039) dB<br>(± 2.3 to ± 6.2) °<br>(± 0.016 to ± 0.040) dB<br>(± 2.4 to ± 6.7) °<br><br>(± 0.016 to ± 0.023) dB<br>(± 1.2 to ± 7.3) °<br>(± 0.016 to ± 0.028) dB<br>(± 1.5 to ± 7.5) °<br>(± 0.020 to ± 0.042) dB<br>(± 2.5 to ± 7.7) °<br>(± 0.023 to ± 0.052) dB<br>(± 3.1 to ± 8.0) ° | Vector network analyzer with calibration kits | DET        |
| Reflection <sup>3</sup> S <sub>11</sub> /S <sub>22</sub> – Measure<br><br>Type N-Connectors:<br>30 kHz to 2 GHz<br>(2 to 6) GHz   | Linear Phase<br>Linear Mag.<br>Linear Phase<br>Linear Mag.   | (± 0.95 to ± 7.8) °<br>(± 0.018 to ± 0.031) dB<br>(± 3.9 to ± 9.5) °<br>(± 0.026 to ± 0.048) dB  | Vector network analyzer with calibration kits | CHIC       |
| Return Loss (VSWR)  | 5 MHz to 2 GHz<br>(2 to 12.5) GHz<br>(12.5 to 18) GHz  | 0.62 dB<br>0.72 dB<br>1.4 dB   | 8902A, SWR Bridges                            | CLEV, CHIC |





| Parameter/Equipment  | Frequency   | CMC <sup>2, 6</sup> (±)  | Comments                                      | Location   |
|--|---|--|---|------------|
| Transmission <sup>3</sup> S <sub>12</sub> /S <sub>21</sub> – Measure<br><br>Type-N connectors<br><br>Linear Mag.<br>Linear Phase<br>Linear Mag.<br>Linear Phase<br><br>3.5 mm connectors<br><br>Linear Mag.<br>Linear Phase<br>Linear Mag.<br>Linear Phase<br>Linear Mag.<br>Linear Phase<br><br>2.4 mm connectors<br><br>Linear Mag.<br>Linear Phase<br>Linear Mag.<br>Linear Phase<br>Linear Mag.<br>Linear Phase<br>Linear Mag.<br>Linear Phase | 9 kHz to 2 GHz<br><br>(2 to 18) GHz<br><br>45 MHz to 2 GHz<br><br>(2 to 20) GHz<br><br>(20 to 26.5) GHz<br><br>45 MHz to 2 GHz<br><br>(2 to 20) GHz<br><br>(20 to 40) GHz<br><br>(40 to 50) GHz | (± 0.043 to ± 9.4) dB<br>(± 0.30 to ± 78) <sup>o</sup><br>(± 0.19 to ± 1.9) dB<br>(± 1.5 to ± 15) <sup>o</sup><br><br>(± 0.052 to ± 5.9) dB<br>(± 0.40 to ± 76) <sup>o</sup><br>(± 0.13 to ± 1.9) dB<br>(± 1.2 to ± 15) <sup>o</sup><br>(± 0.16 to ± 3.4) dB<br>(± 1.7 to ± 28) <sup>o</sup><br><br>(± 0.052 to ± 8.2) dB<br>(± 0.47 to ± 39) <sup>o</sup><br>(± 0.093 to ± 1.9) dB<br>(± 0.99 to ± 15) <sup>o</sup><br>(± 0.17 to ± 3.4) dB<br>(± 1.7 to ± 29) <sup>o</sup><br>(± 0.27 to ± 3.8) dB<br>(± 2.4 to ± 33) <sup>o</sup> | Vector network analyzer with calibration kits | DET        |
| Transmission S <sub>12</sub> /S <sub>21</sub> – Measure<br><br>Type-N connectors:<br><br>Linear Mag.<br>Linear Phase<br>Linear Mag.<br>Linear Phase  | 30 kHz to 2 GHz<br><br>(2 to 6) GHz   | (± 0.61 to ± 45) <sup>o</sup><br>(± 0.11 to ± 9.5) dB<br>(± 0.60 to ± 45) <sup>o</sup><br>(± 0.12 to ± 9.5) dB   | Vector network analyzer with calibration kits | CLEV, CHIC |



| Parameter/Equipment   | Range   | CMC <sup>2, 6</sup> (±)   | Comments  | Location |
|---|---|---|---|----------|
| Single Side-Band Phase Noise <sup>3</sup> – Measure<br><br>Noise Floor :<br><br>-110 dB<br>-110 dB<br>-130 dB<br>-140 dB<br>-150 dB<br>-155 dB<br>-155 dB<br>-155 dB                            | Carrier:<br>50 kHz to 26.5 GHz<br>Offset Freq:<br>10 Hz<br>100 Hz<br>1 kHz<br>10 kHz<br>100 kHz<br>1 MHz<br>10 MHz<br>100 MHz | <br><br><br>1.5 dB<br>1.5 dB<br>1.5 dB<br>1.5 dB<br>1.5 dB<br>1.5 dB<br>1.5 dB<br>1.5 dB      | Agilent E4448A<br>option 226  | DET      |
| Single Side-Band Phase Noise <sup>3</sup> – Measure<br><br>Noise Floor:<br>(approximately)<br><br>-80 dB<br>-95 dB<br>-110 dB<br>-118 dB<br>-118 dB<br>-118 dB<br>-118 dB<br>-145 dB<br>-150 dB | Carrier:<br>(1 to 26) MHz<br>Offset Freq:<br>10 Hz<br>100 Hz<br>1 kHz<br>10 kHz<br>100 kHz<br>1 MHz<br>10 MHz<br>100 MHz      | <br><br><br>3.0 dB<br>2.2 dB<br>1.1 dB<br>0.76 dB<br>0.87 dB<br>0.46 dB<br>0.46 dB<br>0.46 dB | Agilent E4440A opt.<br>226<br><br>Noise floor for any<br>given frequency may<br>be degraded due to<br>SSB noise floor of the<br>reference generator | CHIC     |

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



VII. Fluid Quantities

| Parameter/Equipment   | Range  | CMC <sup>2, 5, 6</sup> (±)  | Comments  | Location        |
|---|--|---|---|-----------------|
| Hydrometers <sup>3</sup>  | (0.7 to 1.2) sp. gr.<br>(1.2 to 2.0) sp. gr.   | 0.0007 sp. gr.<br>0.0012 sp. gr.  | ASTM E126; by comparison using reference hydrometer | DET, CLEV, CHIC |
| Gas Flow <sup>3</sup>   | (1 to 1000) sccm<br>(1000 to 10 000) sccm<br>(10 000 to 50 000) sccm                     | 0.38 % + 0.019 sccm<br>0.39 %<br>0.44 %   | Cal-bench system                                    | DET             |
| Gas Flow <sup>3</sup>   | (1 to 1000) sccm<br>(1 to 10) slm<br>(10 to 30) slm<br>(30 to 60) slm<br>(60 to 100) slm | 0.26 % + 0.02 % of FS<br>0.26 % + 0.02 % of FS<br>0.28 % + 0.02 % of FS<br>0.4 % + 0.03 % of FS<br>1.4 % + 0.03 % of FS | In the CMC, FS is Full Scale, DHI molbloc system    | CLEV            |
| Volume <sup>3</sup> –<br>To Contain (Beakers, Cylinders, Flasks, Proving Cans, etc)<br><br>To Deliver (Burets, Dispensers, Pipettes, Syringes, Titrators) | (0 to 4000) mL<br>(4 to 30) L<br><br>(0.1 to 30) mL<br>(30 to 160) mL                    | 0.05 mL<br>0.38 mL<br><br>0.047 mL<br>0.42 mL   | Gravimetric/<br>electronic<br>balances              | DET             |
| Volume  | Up to 400 mL<br>(400 to 4000) mL<br>(4 to 30) L  | 0.01 mL<br>0.05 mL<br>0.37 mL   | Gravimetric/<br>electronic<br>balances              | CLEV            |
| Viscosity <sup>3</sup> – Ford, Dip and Other Viscosity Cups   | Cup Nos. 1 through 5   | 2.8 %   | ASTM D1200, D4212, ISO-2431                         | DET, CLEV, CHIC |

VIII. Mechanical

| Parameter/Equipment                           | Range   | CMC <sup>2, 5, 6</sup> ( $\pm$ )   | Comments  | Location            |
|---|---|--|---|---------------------|
| Mass Measurement                              | Up to 200 g<br>200 g to 2.3 kg<br>2.3 kg to 32 kg                   | 1.2 $\mu$ g/g + 25 $\mu$ g<br>0.94 $\mu$ g/g + 0.80 mg<br>0.77 $\mu$ g/g + 11 mg | Electronic balance, mass comparison                                     | DET                 |
| Mass Measurement                              | Up to 400 g<br>(400 to 4000) g<br>(4 to 31) kg                      | 0.01 g<br>0.04 g<br>0.32 g   | Electronic balance  | CLEV                |
| Mass Measurement                              | Up to 4000 g<br>(4 to 31) kg  | 0.04 g<br>0.32 g   | Electronic balance  | CHIC                |
| Balances <sup>3</sup>                         | (0.001 to 7.4) kg<br>1 mg to 220 g<br>1 mg to 220 g                 | 5 $\mu$ g/g<br>10 $\mu$ g/g<br>20 $\mu$ g/g                                      | Handbook 44 w/<br>Class 1 weights<br>Class 2 weights<br>Class 3 weights | DET, CLEV, CHIC     |
| Scales  | 2 mg to 38 kg<br>Up to 1500 lbf<br>(1000 to 4000) lbf               | 0.020 %<br>0.022 %<br>0.11 %   | Handbook 44 w/<br>Class F weights<br>Class 6 weights                    | DET, CLEV, CHIC     |
| Force <sup>3</sup> – Compression & Tension    | 1000 lbf<br>1400 lbf<br>100 lbf                                     | 0.025 %<br>0.025 %<br>0.025%   | Deadweight<br>Deadweight<br>Deadweight                                  | DET<br>CLEV<br>CHIC |
| Force <sup>3</sup> – Compression & Tension    | (1000 to 50 000) lbf<br>(1400 to 50 000) lbf<br>(100 to 25 000) lbf | 0.025 %<br>0.038 %<br>0.034 %  | Standard cells<br>Standard cells<br>Standard cells                      | DET<br>CLEV<br>CHIC |
| Wheel Load Scales & Dynamometers <sup>3</sup> | (200 to 5000) lbf<br>(5000 to 10 000) lbf<br>(10 000 to 25 000) lbf | 0.70 lbf<br>1.3 lbf<br>7.2 lbf   | H-frame with standard load cells  | CLEV                |

| Parameter/Equipment                              | Range   | CMC <sup>2, 5, 6</sup> (±)  | Comments  | Location  |
|--|---|---|---|---|
| Torque – Tools                                   | Up to 215 ozf·in<br>Up to 800 lbf·ft<br>(800 to 1000) lbf·ft<br>(20 to 160) ozf·in<br>(8 to 30) lbf·in<br>(30 to 300) lbf·ft<br>(300 to 800) lbf·ft | 0.59 %<br>0.29 %<br>0.50 %<br>0.42 %<br>0.29 %<br>0.24 %<br>0.23 %                | Waters 6500<br>Digital torque tester<br>Digital torque tester<br>Digital torque tester<br>Digital torque tester<br>Digital torque tester<br>Digital torque tester | DET, CLEV, CHIC<br>DET<br>DET<br>CLEV, CHIC<br>CLEV, CHIC<br>CLEV, CHIC<br>CLEV |
| Torque – Measuring Equipment                     | (1 to 100) ozf·in<br>(4 to 200) lbf·in<br>(20 to 2000) lbf·in<br>(150 to 5000) lbf·ft   | 0.10 %<br>0.049 %<br>0.031 %<br>0.036 %   | Torque arms and masses  | DET   |
| Torque – Measuring Equipment                     | (0.5 to 125) ozf·in<br>(0.125 to 20) lbf·ft<br>(8 to 250) lbf·ft<br>(250 to 1000) lbf·ft  | 0.51 %<br>0.031 % + 0.011 lbf·ft<br>0.031 % + 0.09 lbf·ft<br>0.03 % + 0.23 lbf·ft | Torque arms and masses  | CLEV  |
| Pressure – Measure and Generate                  |   |   |   |   |
| Hydraulic  | (2400 to 12 000) psi<br>(6 to 2400) psi<br>(0 to 10 000) psi<br>(0 to 10 000) psi   | 0.0077 %<br>0.0054 %<br>0.068 %<br>0.12 %   | Ruska 2400HL DWT<br>Ruska 2400HL DWT<br>M&G TQ-100 DWT<br>M&G DM-T-100 DWT  | DET<br>DET<br>CLEV<br>CHIC  |
| Pneumatic  | (0.2 to 600) psig<br>(0.5 to 23) psia<br>(0 to 2) inH <sub>2</sub> O  | 0.0031 %<br>0.010 % + 0.00003 psi<br>0.005 in H <sub>2</sub> O                    | Ruska 2465 DWT<br>PPC3<br>Dwyer 1430 Hook Gage  | DET<br>DET<br>DET, CLEV, CHIC   |
| Pneumatic  | (23 to 1015) psia<br>(0.3 to 1000) psia<br>(-14.5 to 1000) psig<br>(0.5 to 1000) psia   | 0.01 %<br>0.02 %<br>0.018 %<br>0.018 % + 0.03 psi                                 | PPC3<br>PC2+<br>DPI515<br>DPI515  | DET<br>CLEV<br>CHIC<br>CHIC   |
| Direct Verification of Durometers <sup>3</sup> – |   |   | ASTM D2240 using  |   |
| Spring Force                                     | All scales  | 0.6 points  | Shore durocalibrator and scale  | DET, CLEV, CHIC   |
| Indenter Shape                                   |   | Pass/Fail   | Optical comparator  | DET, CLEV, CHIC   |

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

| Parameter/Equipment  | Range  | CMC <sup>2, 6</sup> ( $\pm$ )  | Comments                     | Location        |
|--|--|--|------------------------------|-----------------|
| Indirect Verification of Rockwell Hardness Testers <sup>3</sup> (cont) | HR30N:<br>High<br>Middle<br>Low<br><br>HR30TW:<br>High<br>Middle<br>Low<br><br>HR45N:<br>High<br>Middle<br>Low | 0.20 HR30N<br>0.50 HR30N<br>0.30 HR30N<br><br>1.2 HR30TW<br>0.6 HR30TW<br>0.2 HR30TW<br><br>0.81 HR45N<br>0.57 HR45N<br>0.61 HR45N | ASTM E18 w/ traceable blocks | DET, CLEV, CHIC |

#### IX. Optical Quantities

| Parameter/Equipment | Range         | CMC <sup>2</sup> ( $\pm$ ) | Comments                 | Location |
|---------------------|---------------|----------------------------|--------------------------|----------|
| Gloss               | 20°, 60°, 85° | 0.59 gloss units           | Reference gloss standard | DET      |

#### X. Thermodynamics

| Parameter/Equipment                            | Range            | CMC <sup>2, 5, 6</sup> ( $\pm$ ) | Comments                        | Location   |
|--|------------------|----------------------------------|---------------------------------|------------|
| Temperature <sup>3</sup> – Measuring Equipment | 0.01 °C          | 0.003 °C                         | TPW cell                        | DET        |
| Temperature <sup>3</sup> – Measuring Equipment | -80 °C           | 0.072 °C                         | Hart 5628 w/PRT                 | DET        |
| Temperature <sup>3</sup> – Measuring Equipment | (-197 to 660) °C | 0.0009 % + 0.008 °C              | PRT and HART 5609,<br>Dry wells | DET        |
|  | (-197 to 660) °C | 0.0036 % + 0.012 °C              | PRT and HART 1502,<br>Dry well  | CLEV, CHIC |

| Parameter/Equipment                       | Range   | CMC <sup>2,5,6</sup> ( $\pm$ )          | Comments                | Location        |
|---|---|---|-------------------------|-----------------|
| Infrared – Measuring Equipment            | (-30 to 150) °C<br>(150 to 500) °C                                      | 0.5 °C<br>0.35 % + 0.5 °C               | Hart 9133<br>Hart 4181  | DET, CLEV       |
| Infrared – Measuring Equipment            | (-30 to 150) °C<br>(50 to 100) °C<br>(100 to 300) °C<br>(300 to 500) °C | 0.51 °C<br>0.63 °C<br>0.83 °C<br>1.2 °C | Hart 9133 and 4181      | CHIC            |
| Relative Humidity <sup>3</sup> – Generate | (15 to 95) % RH   | 0.7 % RH                                | Thunder Scientific 2500 | DET             |
| Relative Humidity <sup>3</sup> – Generate | (10 to 95) % RH   | 1.3 % RH                                | Kaymont 2000            | DET, CLEV, CHIC |
| Relative Humidity <sup>3</sup> – Measure  | (10 to 98) % RH   | 1.2 % RH                                | Vaisala MI70            | DET, CLEV, CHIC |

#### XI. Time & Frequency

| Parameter/Equipment                          | Range   | CMC <sup>2,4</sup> ( $\pm$ )                              | Comments   | Location            |
|--|---|---|--|---------------------|
| Frequency – Measuring Equipment <sup>3</sup> | 1 mHz to 26.5 GHz<br>1 mHz to 50 GHz<br>1 mHz to 26.5 GHz | 5 pHz/Hz + 0.6R<br>590 pHz/Hz + 0.6R<br>590 pHz/Hz + 0.6R | GPS and signal generator<br>Rb oscillator and sig gen<br>Rb oscillator and sig gen | DET<br>CHIC<br>CLEV |
| Frequency <sup>3</sup> – Measure             | 1 mHz to 26.5 GHz<br>1 mHz to 40 GHz<br>1 mHz to 26.5 GHz | 5 pHz/Hz + 0.6R<br>590 pHz/Hz + 0.6R<br>590 pHz/Hz + 0.6R | GPS and signal generator<br>Rb oscillator and sig gen<br>Rb oscillator and sig gen | DET<br>CHIC<br>CLEV |

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

<sup>2</sup> Calibration and Measurement Capability Uncertainty (CMC) is the smallest uncertainty of measurement that a laboratory can achieve within its scope of accreditation when performing more or less routine calibrations of nearly ideal measurement standards or nearly ideal measuring equipment. CMC's represent expanded uncertainties expressed at approximately the 95 % level of confidence, usually using a coverage factor of  $k = 2$ . The actual measurement uncertainty of a specific calibration performed by the laboratory may be greater than the CMC due to the behavior of the customer's device and to influences from the circumstances of the specific calibration.



- <sup>3</sup> Field calibration service is available for this calibration and this laboratory meets A2LA R104 – *General Requirements: Accreditation of Field Testing and Field Calibration Laboratories* for these calibrations. Please note the actual measurement uncertainties achievable on a customer's site can normally be expected to be larger than the CMC found on the A2LA Scope. Allowance must be made for aspects such as the environment at the place of calibration and for other possible adverse effects such as those caused by transportation of the calibration equipment. The usual allowance for the actual uncertainty introduced by the item being calibrated, (e.g. resolution) must also be considered and this, on its own, could result in the actual measurement uncertainty achievable on a customer's site being larger than the CMC.
- <sup>4</sup> In the statement of CMC,  $L$  is the numerical value of the nominal length of the device measured in inches;  $D$  is the numerical value of the nominal diameter of the device measured in inches;  $Di$  is the numerical value of the nominal diagonal of the plate measured in feet;  $R$  is the numerical value of the resolution of the device in its respective units; and  $F$  is the applied frequency in kHz
- <sup>5</sup> In the statement of CMC, percentages are percentage of reading unless otherwise indicated.
- <sup>6</sup> CMC components that can be reasonably attributed to the Unit Under Test have not been utilized in the calculation of the CMC value for this measurement parameter.
- <sup>7</sup> The stated measured values are determined using the indicated instrument (see Comments). This capability is suitable for the calibration of the devices intended to measure or generate the measured value in the ranges indicated. CMC's are expressed as either a specific value that covers the full range or as a percent or fraction of the reading plus a fixed floor specification.
- <sup>8</sup> This laboratory meets R205 – Specific Requirements: Calibration Laboratory Accreditation Program for the types of dimensional tests listed above and is considered equivalent to that of a calibration.
- <sup>9</sup> The locations of the laboratories that can perform the calibrations are given by a three-letter code with valid to dates given in the table below:

| Location   | Code | Valid to Dates |
|--|------|----------------|
| 1200 North Old US, 23 PO Box 559, Hartland, MI 48353             | DET  | May 31, 2018   |
| 735 Beta Dr., PO Box 559, Cleveland, OH 44143                    | CLEV | May 31, 2018   |
| 718 West Algonquin Road, PO Box 559, Arlington Heights, IL 60005 | CHIC | May 31, 2018   |