



SCOPE OF ACCREDITATION TO ISO/IEC 17025:2017

JAPAN QUALITY ASSURANCE ORGANIZATION

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CALIBRATION

Valid To: March 31, 2026

Certificate Number: 1400.03

In recognition of the successful completion of the A2LA evaluation process, accreditation is granted to this laboratory at the location listed above as well as the satellite laboratory location listed below, to perform the following calibrations<sup>1, 11</sup>:

I. Chemical Quantities

| Parameter/Equipment | Range                                  | CMC <sup>2</sup> (±)       | Comments                          |
|---------------------|----------------------------------------|----------------------------|-----------------------------------|
| pH Indicator –      |                                        |                            |                                   |
| Instrumental Error  | (0 to 14) pH units                     | 0.005 pH units             | DC voltage                        |
| Linearity           | (0 to 14) pH units                     | 0.005 pH units             |                                   |
| Repeatability       | (0 to 14) pH units                     | 0.005 pH units             |                                   |
| pH Detector –       |                                        |                            |                                   |
| Instrumental Error  | 4 pH units, 9 pH units                 | 0.4 mV/pH                  | Standard solutions,<br>DC voltage |
| Linearity           | 4 pH units, 7 pH units,<br>9 pH units  | 1.1 mV                     |                                   |
| Repeatability       | 4 pH units<br>7 pH units<br>9 pH units | 1.1 mV<br>1.0 mV<br>2.0 mV |                                   |

| Parameter/Equipment                                                                                                                                                                                            | Range                  | CMC <sup>2</sup> (±)                                          | Comments                         |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------|---------------------------------------------------------------|----------------------------------|
| pH Detector <sup>3</sup> –<br><br>Instrumental Error<br>@4 pH units & 9 pH units<br><br>Linearity<br>@4 pH units, 7 pH units<br>& 9 pH units<br><br>Repeatability<br>@4 pH units<br>@7 pH units<br>@9 pH units | (-414.12 to 414.12) mV | 0.40 mV/pH<br><br>0.90 mV<br><br>0.90 mV<br>0.80 mV<br>1.9 mV | Standard solutions<br>DC voltage |

## II. Dimensional

| Parameter/Equipment                                                                                       | Range                                                                                                                | CMC <sup>2, 4</sup> (±)                                                              | Comments                                                                                                                |
|-----------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------|
| Gage Blocks                                                                                               | (0.1 to 100) mm<br>(> 100 to 500) mm<br><br>(0.1 to 100) mm<br>(> 100 to 500) mm                                     | 0.07 µm<br>(0.02 + L/2000) µm<br><br>0.08 µm<br>(0.025 + L/1800) µm                  | By mechanical<br>comparison<br><br>Note: chrome carbide<br>to chrome carbide<br><br>Note: chrome carbide<br>to ceramics |
| Step Gages –<br><br>Outside (Height)<br><br>Internal & Step<br>Caliper Checker<br><br>Depth-Micro-Checker | Up to 670 mm<br>(> 670 to 1000) mm<br><br>Up to 300 mm<br>(> 300 to 600) mm<br><br>Up to 150 mm<br>(> 150 to 300) mm | (0.6 + L/750) µm<br>(0.4 + L/600) µm<br><br>1.5 µm<br>2.1 µm<br><br>1.2 µm<br>1.5 µm | Gage blocks                                                                                                             |
| Ring Gages                                                                                                | Up to 100 mm<br><br>(> 100 to 150) mm                                                                                | (1.1 + L/500) µm<br><br>(1.1 + L/400) µm                                             | ULM, type IDM<br><br>Contour measuring<br>systems                                                                       |

| Parameter/Equipment                                                                                         | Range                                                                                                                | CMC <sup>2, 4</sup> (±)                                                                                           | Comments                                                        |
|-------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------|
| Plug Gages –<br><br>Diameter<br><br>Taper Angle                                                             | (1 to 100) mm                                                                                                        | 1.2 µm<br><br>1.8'                                                                                                | ULM, contour measuring systems<br><br>Contour measuring systems |
| Dial Gages <sup>3</sup>                                                                                     | Up to 10 mm<br>(> 10 to 25) mm<br>(> 25 to 100) mm                                                                   | 1.6 µm<br>1.8 µm<br>2.0 µm                                                                                        | Dial gage tester, gage blocks                                   |
| Micrometers <sup>3</sup> –<br><br>Outside<br><br>Inside<br><br>Bar Inside<br><br>Depth                      | Up to 500 mm<br>(>500 to 1000) mm<br><br>Up to 500 mm<br><br>Up to 1000 mm<br><br>Up to 500 mm                       | (2 + L/100) µm<br>(2 + L/90) µm<br><br>(2 + L/90) µm<br><br>(3 + L/60) µm<br><br>(2.5 + L/100) µm                 | Gage blocks                                                     |
| Pin Gages                                                                                                   | (0.1 to 40) mm<br>(> 40 to 100) mm                                                                                   | 0.8 µm<br>0.9 µm                                                                                                  | ULM                                                             |
| Standard Bars                                                                                               | Up to 500 mm<br>(> 500 to 1000) mm                                                                                   | (0.6 + L/1000) µm<br>(0.4 + L/600) µm                                                                             | Gage blocks, ULM                                                |
| Electrical Comparators –<br><br>Analog Graduation<br><br><br><br><br><br><br><br><br><br>Digital Resolution | ≤ 0.2 µm<br>0.5 µm<br>1.0 µm<br>2.0 µm<br>5.0 µm<br>10 µm<br>20 µm<br>50 µm<br><br>≤ 0.01 µm<br>≤ 0.1 µm<br>≤ 1.0 µm | 0.12 µm<br>0.23 µm<br>0.45 µm<br>0.9 µm<br>2.3 µm<br>4.5 µm<br>9.0 µm<br>23 µm<br><br>0.09 µm<br>0.2 µm<br>2.0 µm | Laser<br><br><br><br><br><br><br><br><br><br>Laser              |

| Parameter/Equipment                             | Range                                     | CMC <sup>2,4</sup> ( $\pm$ )          | Comments                                                    |
|-------------------------------------------------|-------------------------------------------|---------------------------------------|-------------------------------------------------------------|
| Measuring Microscope <sup>3</sup> –             |                                           |                                       |                                                             |
| Run & Parallelism                               | Up to 200 mm                              | 7.0 $\mu$ m                           | Glass line standard, scales, electrical comparators, square |
| Straightness                                    | Up to 100 mm<br>(> 100 to 200) mm         | 1.8 $\mu$ m<br>2.5 $\mu$ m            |                                                             |
| Squareness                                      | Up to 100 mm<br>(> 100 to 200) mm         | 1.7 $\mu$ m<br>2.4 $\mu$ m            |                                                             |
| Linear Accuracy                                 | Up to 100 mm<br>(> 100 to 200) mm         | 2.2 $\mu$ m<br>2.5 $\mu$ m            |                                                             |
| Measuring Projector <sup>3</sup> –              |                                           |                                       |                                                             |
| Linear Accuracy                                 | Up to 200 mm                              | 3.8 $\mu$ m                           | Glass line standard, scales                                 |
| Magnification                                   | Up to 600 mm<br>{Screen Size}             | 0.04 % of projected reading           |                                                             |
| Cylinder Gage <sup>3</sup>                      | Up to 1.2 mm                              | 5 $\mu$ m                             | Dial gage tester, dial gage                                 |
| Universal Length Measuring Machine <sup>3</sup> | Up to 100 mm<br>(> 100 to 200) mm         | 0.6 $\mu$ m<br>0.8 $\mu$ m            | Gage blocks                                                 |
|                                                 | Up to 200 mm<br>(> 200 to 3000) mm        | 0.7 $\mu$ m<br>(0.7 + L/1300) $\mu$ m | Laser measurement system                                    |
| Dial Depth Gage <sup>3</sup> –                  |                                           |                                       |                                                             |
| Dial & Digital<br>(Resolution 0.01 mm)          | Up to 200 mm                              | 0.02 mm                               | Gage blocks                                                 |
| Digital<br>(Resolution 0.001 mm)                | Up to 200 mm                              | 0.002 mm                              | Gage blocks                                                 |
| Depth Gages <sup>3</sup>                        | Up to 1000 mm                             | 0.02 mm                               | Step gages, gage blocks                                     |
| Precision Level                                 | 0.1 mm/m<br>0.05 mm/m<br>$\leq$ 0.02 mm/m | 5.7"<br>2.9"<br>2.2"                  | Laser                                                       |

| Parameter/Equipment                                                                                                                                                                                 | Range                                                                                                                                                                    | CMC <sup>2</sup> (±)                                                                     | Comments                                               |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------|--------------------------------------------------------|
| Dial Gage Tester –<br><br>Analog<br><br>Digital                                                                                                                                                     | Up to 25 mm<br><br>Up to 25 mm                                                                                                                                           | 0.7 µm<br><br>0.5 µm                                                                     | Gage blocks, laser                                     |
| Micrometer Heads –<br><br>Analog<br>Resolution ≤ 0.001 mm<br>Resolution ≤ 0.002 mm<br>Resolution ≤ 0.01 mm<br><br>Digital<br>Resolution ≤ 0.001 mm<br>Resolution ≤ 0.002 mm<br>Resolution ≤ 0.01 mm | Up to 50 mm                                                                                                                                                              | 0.7 µm<br>2 µm<br>2 µm<br><br>0.5 µm<br>2 µm<br>2 µm                                     | Gage blocks                                            |
| Calipers <sup>3</sup> –<br><br>Scale & Dial<br><br><br><br>Digital                                                                                                                                  | Up to 600 mm<br>(> 600 to 1000) mm<br>(> 1000 to 1500) mm<br>(> 1500 to 2000) mm<br><br>Up to 600 mm<br>(> 600 to 1000) mm<br>(> 1000 to 1500) mm<br>(> 1500 to 2000) mm | 0.05 mm<br>0.10 mm<br>0.11 mm<br>0.13 mm<br><br>0.03 mm<br>0.06 mm<br>0.07 mm<br>0.10 mm | Step gages, gage blocks<br><br>Step gages, gage blocks |
| Chamfer & Radius Calipers <sup>3</sup> –<br><br>Digital<br>Resolution 0.01 mm                                                                                                                       | Chamfer<br>Up to 15 mm<br>Radius<br>Up to 25 mm                                                                                                                          | 0.03 mm                                                                                  | Pin gages                                              |
| Chamfer Calipers <sup>3</sup> –<br>Analog<br>Resolution 0.1 mm<br><br>Digital<br>Resolution 0.01 mm                                                                                                 | Up to 15 mm<br><br>Up to 5 mm                                                                                                                                            | 0.2mm<br><br>0.03mm                                                                      | Pin gages                                              |

| Parameter/Equipment                                                                                                                                                                              | Range                                                                                                        | CMC <sup>2</sup> (±)                                                             | Comments                |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------|-------------------------|
| Dial Caliper Gages <sup>3</sup> –<br><br>Dial<br>Resolution 0.01 mm<br>Resolution 0.05 mm<br>Resolution 0.1 mm<br><br>Digital<br>Resolution 0.005 mm<br>Resolution 0.01 mm<br>Resolution 0.05 mm | Up to 200 mm<br><br><br><br><br>Up to 200 mm                                                                 | 0.02 mm<br>0.05 mm<br>0.1 mm<br><br>0.02 mm<br>0.02 mm<br>0.05 mm                | Gage blocks             |
| Height Gages <sup>3</sup> –<br><br>Digital<br>Resolution 0.001 mm<br><br>Resolution 0.0001 mm<br><br>Scale<br><br>Digital & Dial<br>Resolution 0.01 mm                                           | Up to 600 mm<br>Up to 1000 mm<br><br>Up to 600 mm<br>Up to 1000 mm<br><br>Up to 1000 mm<br><br>Up to 1000 mm | 0.005 mm<br>0.006 mm<br><br>0.0045 mm<br>0.0053 mm<br><br>0.04 mm<br><br>0.02 mm | Step gages, gage blocks |
| Hole Testers <sup>3</sup>                                                                                                                                                                        | Up to 150 mm                                                                                                 | 3.0 µm                                                                           | Master ring gages       |
| Digital Indicators <sup>3</sup> –<br><br>Resolution 0.01 mm<br>Resolution 0.001 mm<br>Resolution ≤ 0.0001 mm                                                                                     | Up to 100 mm                                                                                                 | 0.02 mm<br>0.002 mm<br>0.0013 mm                                                 | Gage blocks             |
| Thickness Gages <sup>3</sup> –<br><br>Dial<br>Resolution 0.1 mm<br>Resolution 0.01 mm<br>Resolution 0.001 mm<br><br>Digital<br>Resolution 0.01 mm<br>Resolution 0.005 mm<br>Resolution 0.001 mm  | Up to 50 mm<br>Up to 50 mm<br>Up to 50 mm<br><br>Up to 50 mm<br>Up to 50 mm<br>Up to 50 mm                   | 0.1 mm<br>0.01 mm<br>0.002 mm<br><br>0.02 mm<br>0.010 mm<br>0.002 mm             | Gage blocks             |

| Parameter/Equipment                                                                     | Range                                                                                                                                             | CMC <sup>2</sup> (±)                 | Comments                                           |
|-----------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------|----------------------------------------------------|
| Microindicators <sup>3</sup> –<br>Resolution ≤ 0.001 mm                                 | Up to 0.1 mm                                                                                                                                      | 0.5 µm                               | Laser                                              |
| Feeler Gages                                                                            | Up to 3 mm                                                                                                                                        | 1.4 µm                               | ULM                                                |
| Screw Threads –<br>Major Diameter<br>Pitch Diameter<br>Major Diameter<br>Pitch Diameter | Up to 120 mm<br><br><br>Up to 150 mm                                                                                                              | 1.1 µm<br>2.8 µm<br>3.4 µm<br>3.4 µm | ULM, thread wires<br><br>Contour measuring systems |
| Threads Wires –<br>Mean Diameter                                                        | Up to 5.05 mm                                                                                                                                     | 0.8 µm                               | ULM                                                |
| Index Master – Fixed Point                                                              | Up to 250 µm                                                                                                                                      | 0.2 µm                               | Laser                                              |
| Surface Plate <sup>3</sup><br>(Flatness Only)                                           | Up to 300 mm<br>(Diagonal Line 430 mm)<br><br>(> 300 to 1000) mm<br>(Diagonal Line 1250 mm)<br><br>(> 1000 to 2000) mm<br>(Diagonal Line 2500 mm) | 3.5 µm<br><br>3.9 µm<br><br>4.8 µm   | Electronic level                                   |
| Test Sieves –<br>Mesh<br><br>Line                                                       | Up to 2.36 mm<br>(> 2.36 to 125) mm<br><br>Up to 1 mm<br>(> 1 to 8) mm                                                                            | 9 µm<br>10 µm<br><br>9 µm<br>10 µm   | Measuring microscope                               |
| Line Standard Scales                                                                    | Up to 1 mm<br><br>(> 1 to 200) mm<br><br>(> 200 to 500) mm                                                                                        | 0.4 µm<br><br>0.7 µm<br><br>1.3 µm   | Laser measurement system                           |

| Parameter/Equipment                                                                                                                                 | Range                                | CMC <sup>2,4</sup> ( $\pm$ )                     | Comments                                    |
|-----------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------|--------------------------------------------------|---------------------------------------------|
| Pattern                                                                                                                                             | Up to 200 mm                         | 1.0 $\mu$ m                                      | Laser measurement system                    |
| Coordinate Measuring Machines <sup>3</sup>                                                                                                          | Up to 1000 mm<br>(> 1000 to 3000) mm | (1.9 + L/1200) $\mu$ m<br>(0.7 + L/1300) $\mu$ m | Step gage<br>Laser measurement system       |
| Protractors –<br><br>Resolution 1'<br>Resolution 5'<br>Resolution 10'<br>Resolution 30'<br>Resolution 1°                                            | Up to 360°                           | 1.3'<br>1.7'<br>2.7'<br>7.1'<br>14'              | Measuring microscope                        |
| Snap Gage                                                                                                                                           | Up to 150 mm                         | 2.6 $\mu$ m                                      | ULM, type IDM                               |
| Screw Ring Gage –<br><br>Pitch Diameter                                                                                                             | Up to 150 mm<br><br>Up to 100 mm     | 3.2 $\mu$ m<br><br>4.1 $\mu$ m                   | Contour measuring systems<br>Master scanner |
| Test Bars –<br><br>Diameter<br>Run-out                                                                                                              | Up to 100 mm                         | 1.7 $\mu$ m<br>1.5 $\mu$ m                       | ULM<br>Electric comparator                  |
| Microscope –<br><br>Resolution 0.01 mm<br>Resolution 0.02 mm<br>Resolution 0.1 mm                                                                   | Up to 10 mm                          | 2.4 $\mu$ m<br>2.6 $\mu$ m<br>7.0 $\mu$ m        | Glass line standard, scales                 |
| Non-Contact Optical Type of Coordinate Measuring Machine <sup>3</sup> –<br><br>Probing Error Form<br>Probing Error Size<br>Length Measurement Error | Up to 2000 mm                        | 6.4 $\mu$ m<br>7.8 $\mu$ m<br>30 $\mu$ m         | Artifact                                    |

| Parameter/Equipment                                                             | Range                                | CMC <sup>2</sup> (±) | Comments                                                                                            |
|---------------------------------------------------------------------------------|--------------------------------------|----------------------|-----------------------------------------------------------------------------------------------------|
| R gage                                                                          | Up to 150 mm                         | 0.028 mm             | Measuring microscope                                                                                |
| Gage of Punch                                                                   | Up to 200 mm                         | 0.004 mm             | Gage blocks                                                                                         |
| Surface of hole /<br>Chamfer —<br><br>Resolution 0.01 mm<br>Resolution 0.001 mm | Up to 40 mm                          | 0.02 mm<br>0.002 mm  | Master gage for<br>surface of hole /<br>chamfer                                                     |
| Extensometer <sup>3</sup>                                                       | Up to 100 mm<br><br>100 mm to 600 mm | 2.8 µm<br><br>13 µm  | Reference to ASTM<br>E83, extensometer<br>calibrator, gage<br>blocks, digital linear<br>height gage |

| Parameter/Equipment                                           | Range        | CMC <sup>2</sup> (±) | Comments               |
|---------------------------------------------------------------|--------------|----------------------|------------------------|
| Keyence Vision Systems <sup>3</sup><br>—                      |              |                      |                        |
| Model: IM<br>XY Plane Length<br>Measurement Error             | Up to 300 mm | 1.1 µm               | Dot photomask          |
| Image Probe Probing<br>Error                                  | Up to 300 mm | 1.4 µm               | Roundness<br>photomask |
| XY Plane Length<br>Measurement Error<br>(Light Probe Unit)    | Up to 300 mm | 2.7 µm               | Step gauge             |
| Image Probe Probing<br>Error (Light Probe Unit)               | Up to 40 mm  | 6.2 µm               | Ring gauge             |
| Z-Axis Unidirectional<br>Length Measurement<br>Error          | Up to 300 mm | 1.5 µm               | Step height gauge      |
| Model: LM<br>XY Plane Length<br>Measurement Error             | Up to 300 mm | 1.1 µm               | Dot photomask          |
| Image Probe Probing<br>Error                                  | Up to 300 mm | 1.3 µm               | Roundness photomask    |
| Z-Axis Unidirectional<br>Length Measurement<br>Error          | Up to 300 mm | 1.3 µm               | Step height gauge      |
| Model: LM-X<br>XY Plane<br>Length Measurement<br>Error        | Up to 325 mm | 1.2 µm               | Dot photomask          |
| Image Probe Probing<br>Error                                  | Up to 100 mm | 1.1 µm               | Roundness<br>photomask |
| XY Plane<br>Length Measurement<br>Error<br>(Touch Probe Unit) | Up to 210 mm | 0.5 µm               | Step gauge             |
| Image Probe Probing<br>Error<br>(Touch Probe Unit)            | Up to 40 mm  | 2.2 µm               | Ring gauge             |

| Parameter/Equipment                                                                  | Range                        | CMC <sup>2</sup> (±)          | Comments                                                             |
|--------------------------------------------------------------------------------------|------------------------------|-------------------------------|----------------------------------------------------------------------|
| Keyence Vision Systems <sup>3</sup> –<br>(cont)                                      |                              |                               |                                                                      |
| Model: LM-X<br>Z-Axis Unidirectional<br>Length Measurement<br>Error (AF Height Unit) | Up to 60 mm                  | 1.3 µm                        | Step height gauge                                                    |
| Z-Axis Unidirectional<br>Length Measurement<br>Error (TP Height Unit)                | Up to 60 mm                  | 0.6 µm                        | Step height gauge                                                    |
| Z-Axis Unidirectional<br>Length Measurement<br>Error (Laser Height Unit)             | Up to 60 mm                  | 0.6 µm                        | Step height gauge                                                    |
| Roundness Measuring<br>Machine <sup>3</sup> –                                        |                              |                               |                                                                      |
| Relative Error of<br>Magnification                                                   | Up to 500 µm                 | 1.0 % of<br>measurement range | Gage blocks                                                          |
| Rotation Accuracy<br>Radial Direction                                                | Up to 500 µm                 | 0.03 µm                       | Master ball                                                          |
| Axial Direction                                                                      | Up to 500 µm                 | 0.11 µm                       | Optical flat                                                         |
| Column (Z-axis)<br>Straightness Accuracy                                             | Up to 140 mm                 | 0.11 µm                       | Optical flat                                                         |
| Column (Z-axis)<br>Parallelism                                                       | Up to 280 mm                 | 2.2 µm                        | Cylindrical square                                                   |
| R-axis (X-axis)<br>Straightness Accuracy                                             | Up to 140 mm                 | 0.12 µm                       | Optical flat                                                         |
| R-axis (X-axis)<br>Parallelism                                                       | Up to 140 mm                 | 0.37 µm                       | Optical flat                                                         |
| Contour Measuring<br>Systems <sup>3</sup> –                                          |                              |                               |                                                                      |
| Length<br>X-axis<br>Z-axis                                                           | Up to 200 mm<br>Up to 400 mm | 1.6 µm<br>1.6 µm              | Gage blocks, pin<br>gages,<br>angle gage blocks,<br>contour standard |
| Radius                                                                               | Up to R40 mm                 | 1.6 µm                        |                                                                      |
| Angle                                                                                | Up to 180°                   | 1.2'                          |                                                                      |

| Parameter/Equipment                    | Range                             | CMC <sup>2</sup> (±) | Comments                       |
|----------------------------------------|-----------------------------------|----------------------|--------------------------------|
| Contact Stylus Instrument <sup>3</sup> | Ra: Up to 3 µm<br>Rz: Up to 10 µm | 4 %<br>6 %           | Roughness measurement standard |

### III. Dimensional Testing/Calibration<sup>9</sup>

| Parameter/Equipment                                                       | Range                        | CMC <sup>2</sup> (±) | Comments                    |
|---------------------------------------------------------------------------|------------------------------|----------------------|-----------------------------|
| Length                                                                    | Up to 300 mm                 | 4.2 µm               | Contour measuring systems   |
| Radius of Curvature                                                       | Up to 100 mm                 | 3.2 µm               | Contour measuring systems   |
| Angle                                                                     | Up to 180°                   | 1.7'                 | Contour measuring systems   |
| Geometrical Deviations – Measure                                          |                              |                      | Roundness measuring machine |
| Rotational Measurement<br>Roundness, Coaxiality<br>Concentricity, Run-out | Up to 500 µm                 | 0.14 µm              |                             |
| Flatness                                                                  | Up to 140 mm<br>(Diameter)   | 0.17 µm              |                             |
| Linear Measurement<br>Straightness<br>Perpendicularity                    | Up to 140 mm<br>Up to 140 mm | 1.2 µm<br>2.0 µm     |                             |
| Rotational & Linear<br>Measurement<br>Parallelism Cylindricity            | Up to 140 mm                 | 2.4 µm               |                             |

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

| Parameter/Equipment                                    | Range                        | CMC <sup>2, 5, 7</sup> ( $\pm$ ) | Comments                                                 |
|--------------------------------------------------------|------------------------------|----------------------------------|----------------------------------------------------------|
| DC Power – Generate <sup>3</sup> ,<br>100 mV to 1000 V |                              |                                  | Calibration of DC power measuring devices using:         |
| 1 mW to 2 kW                                           | 1 mA to 2 A                  | 0.020 % + 0.1 mW                 | Calibrator with standard resistors, multimeter           |
| 0.2 W to 60 kW                                         | (2 to 60) A                  | 0.020 %                          |                                                          |
| 6 W to 200 kW                                          | (60 to 200) A                | 0.030 %                          |                                                          |
| 20 W to 500 kW                                         | (200 to 500) A               | 0.060 %                          |                                                          |
| 50 W to 1000 kW                                        | (500 to 1000) A              | 0.13 %                           | Calibrator with current coil: Fluke 55XXA, 57XXA, 52120A |
| 1 W to 1000 kW                                         | (10 to 1000) A, clamp type   | 0.35 %                           |                                                          |
| 100 W to 2000 kW                                       | (1000 to 2500) A, clamp type | 0.60 %                           |                                                          |
| DC Energy – Generate <sup>3</sup>                      |                              |                                  | Calibrator with current coil:                            |
| 1 mWh to 2 kWh                                         | 1 mA to 2 A                  | 0.080 %                          | Fluke 55XXA, 52120A, 2560A, timer counter                |
| 0.2 Wh to 20 kWh                                       | (2 to 20) A                  | 0.09 %                           |                                                          |
| 2 Wh to 100 kWh                                        | (20 to 100) A                | 0.10 %                           |                                                          |
| 2 Wh to 1000 kWh                                       | (20 to 1000) A, clamp type   | 0.35 %                           |                                                          |
| DC Power – Measure <sup>3</sup> ,<br>100 mV to 1000 V  |                              |                                  | Calibration of DC power generator using:                 |
| 1 mW to 1 kW                                           | 1 mA to 1 A                  | 0.010 % + 0.1 mW                 | Calibrator with standard resistors, multimeter           |
| 0.1 W to 30 kW                                         | (1 to 30) A                  | 0.020 %                          |                                                          |
| 3 W to 200 kW                                          | (30 to 200) A                | 0.030 %                          |                                                          |
| 3 W to 200 kW                                          | (200 to 500) A               | 0.060 %                          |                                                          |
| 3 W to 200 kW                                          | (500 to 1000) A              | 0.13 %                           |                                                          |

| Parameter/Equipment                | Range                                                                                                                                                                                                                         | CMC <sup>2, 5, 7</sup> ( $\pm$ )                                                                                                                                                                       | Comments                                                                                                                                                                                               |
|------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| DC Voltage – Generate <sup>3</sup> | (0 to 10) mV<br>(>10 to 100) mV<br>(>0.1 to < 1) V<br>(1 to <2.2) V<br>(2.2 to <10) V<br>10 V<br>(>10 to <22) V<br>(22 to <220) V<br>(220 to 1000) V<br><br>(1 to 5) kV<br>(5 to 50) kV<br><br>(10 to 1000) V<br>(1 to 30) kV | 0.24 $\mu$ V<br>0.39 $\mu$ V<br>3.9 $\mu$ V/V<br>2.5 $\mu$ V/V<br>1.5 $\mu$ V/V<br>0.51 $\mu$ V/V<br>0.57 $\mu$ V/V<br>0.58 $\mu$ V/V<br>2.7 $\mu$ V/V<br><br>0.050 %<br>0.070 %<br><br>1.4 %<br>1.6 % | Calibration of voltmeters using DC standard with Kelvin-Varley divider & calibrator<br><br><br><br><br><br><br><br>Voltage divider, DMM & AC/DC high voltage generator<br><br><br>Electrostatic meters |
| DC Voltage – Measure <sup>3</sup>  | (0 to <1) mV<br>(1 to 10) mV<br>(>10 to <100) mV<br>(100 to <200) mV<br>(0.2 to <1) V<br>(1 to <2) V<br>(2 to <10) V<br>10 V<br>(>10 to 100) V<br>(>100 to 1000) V<br><br>(1 to 5) kV<br>(5 to 50) kV                         | 0.45 $\mu$ V<br>0.32 $\mu$ V<br>0.43 $\mu$ V<br>4.4 $\mu$ V/V<br>3.3 $\mu$ V/V<br>2.4 $\mu$ V/V<br>1.4 $\mu$ V/V<br>0.52 $\mu$ V/V<br>0.57 $\mu$ V/V<br>2.7 $\mu$ V/V<br><br>0.050 %<br>0.070 %        | Keysight 3458A<br>Calibration of voltage generators using DC standard with Kelvin-Varley divider & calibrator<br><br><br><br><br><br><br>DMM with resistance voltage divider                           |
| DC Current – Generate <sup>3</sup> | (1 to 100) nA<br>100 nA to 10 $\mu$ A<br><br>0 A<br>10 $\mu$ A to 0.31 A<br>(0.31 to 3) A<br>(3 to 10) A<br>(10 to 20) A<br>(20 to 30) A<br>(30 to 40) A<br>(40 to 50) A<br>(50 to 60) A                                      | 77 $\mu$ A/A<br>34 $\mu$ A/A<br><br>0.063 nA<br>13 $\mu$ A/A<br>30 $\mu$ A/A<br>39 $\mu$ A/A<br>59 $\mu$ A/A<br>43 $\mu$ A/A<br>56 $\mu$ A/A<br>78 $\mu$ A/A<br>0.011 %                                | Calibration of current measuring devices using:<br><br>Calibrator & standard resistor<br><br>DMM, resistance reference standards and secondary standards                                               |

| Parameter/Equipment                             | Range                                                                                                                                  | CMC <sup>2, 5, 7</sup> (±)                                                                       | Comments                                                        |
|-------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------|-----------------------------------------------------------------|
| DC Current – Generate <sup>3</sup><br>(cont)    | (60 to 200) A<br>(200 to 300) A<br>(300 to 500) A<br>(500 to 1000) A                                                                   | 0.013 %<br>0.032 %<br>0.049 %<br>0.11 %                                                          | DMM & shunt resistors                                           |
| Simulated Current                               | (10 to 2000) A<br>(2000 to 2500) A                                                                                                     | 0.33 %<br>0.53 %                                                                                 | Calibrator with current coil                                    |
| DC Integrated Current–<br>Generate <sup>3</sup> |                                                                                                                                        |                                                                                                  | Calibration of current<br>generators using:                     |
| 2.8 µAh to 92 mAh                               | (1 to 330) mA                                                                                                                          | 0.05 %                                                                                           | Calibrator & time<br>counter                                    |
| 0.92 mAh to 0.83 Ah                             | 330 mA to 3 A                                                                                                                          | 0.08 %                                                                                           |                                                                 |
| 8.3 mAh to 3.1 Ah                               | (3 to 11) A                                                                                                                            | 0.12 %                                                                                           |                                                                 |
| 31 mAh to 5.6 Ah                                | (11 to 20) A                                                                                                                           | 0.16 %                                                                                           |                                                                 |
| DC Current – Measure <sup>3</sup>               |                                                                                                                                        |                                                                                                  | Calibration of current<br>generators using:                     |
|                                                 | (1 to 2) nA<br>(2 to 200) nA<br>(0.2 to 2) µA<br>(2 to 10) µA                                                                          | 0.13 %<br>0.054 %<br>0.025 %<br>0.018 %                                                          | Electrometer                                                    |
|                                                 | 0 A<br>10 µA to 0.31 A<br>(0.31 to 3) A<br>(3 to 10) A<br>(10 to 20) A<br>(20 to 60) A<br>(30 to 40) A<br>(40 to 50) A<br>(50 to 60) A | 0.056 nA<br>13 µA/A<br>30 µA/A<br>39 µA/A<br>59 µA/A<br>43 µA/A<br>56 µA/A<br>78 µA/A<br>0.011 % | DMM, resistance<br>reference standards &<br>secondary standards |
|                                                 | (60 to 200) A<br>(200 to 300) A<br>(300 to 500) A<br>(500 to 1000) A                                                                   | 0.012 %<br>0.032 %<br>0.049 %<br>0.11 %                                                          | DMM & shunt resistors                                           |

| Parameter/Range                       | Range                                                                                                                                                                                                                                                                                                                                  | CMC <sup>2, 5, 7</sup> ( $\pm$ )                                                                                                                                                                                                                                                                                                                                                    | Comments                                |
|---------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------|
| DC Resistance – Generate <sup>3</sup> |                                                                                                                                                                                                                                                                                                                                        |                                                                                                                                                                                                                                                                                                                                                                                     | Calibration of resistance meters using: |
| Fixed Values                          | 1 m $\Omega$<br>(2, 3, 5) m $\Omega$<br>0.01 $\Omega$<br>0.1 $\Omega$<br>1 $\Omega$<br>10 $\Omega$<br>100 $\Omega$<br>1 k $\Omega$<br>10 k $\Omega$<br>100 k $\Omega$<br>1 M $\Omega$<br>10 M $\Omega$<br>100 M $\Omega$<br>1 G $\Omega$<br>10 G $\Omega$<br>100 G $\Omega$<br>1 T $\Omega$                                            | 25 $\mu\Omega/\Omega$<br>0.017 %<br>13 $\mu\Omega/\Omega$<br>12 $\mu\Omega/\Omega$<br>1.0 $\mu\Omega/\Omega$<br>1.1 $\mu\Omega/\Omega$<br>1.0 $\mu\Omega/\Omega$<br>1.2 $\mu\Omega/\Omega$<br>1.4 $\mu\Omega/\Omega$<br>3.7 $\mu\Omega/\Omega$<br>4.3 $\mu\Omega/\Omega$<br>14 $\mu\Omega/\Omega$<br>33 $\mu\Omega/\Omega$<br>43 $\mu\Omega/\Omega$<br>0.013 %<br>0.038 %<br>0.51 % | Standard resistors                      |
| Ranges                                | (1 to 10) m $\Omega$<br>(10 to 100) m $\Omega$<br>(0.1 to 1) $\Omega$<br>(1 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 100) M $\Omega$<br>(0.1 to 10) G $\Omega$<br>(10 to 100) G $\Omega$<br>100 G $\Omega$ to 1 T $\Omega$ | 0.11 %<br>0.026 %<br>0.012 %<br>70 $\mu\Omega/\Omega$<br>85 $\mu\Omega/\Omega$<br>40 $\mu\Omega/\Omega$<br>95 $\mu\Omega/\Omega$<br>70 $\mu\Omega/\Omega$<br>95 $\mu\Omega/\Omega$<br>0.014 %<br>0.50 %<br>0.43 %<br>1.5 %                                                                                                                                                          | Decade resistors                        |
|                                       | (1 to 10) $\Omega$<br>(10 to 100) $\Omega$<br>(0.1 to 1) k $\Omega$<br>(1 to 10) k $\Omega$<br>10 k $\Omega$ to 1 M $\Omega$<br>(1 to 3.3) M $\Omega$<br>(3.3 to 10) M $\Omega$<br>(10 to 33) M $\Omega$<br>(33 to 100) M $\Omega$<br>(100 to 330) M $\Omega$<br>(0.33 to 1) G $\Omega$                                                | 0.018 %<br>0.013 %<br>42 $\mu\Omega/\Omega$<br>44 $\mu\Omega/\Omega$<br>61 $\mu\Omega/\Omega$<br>0.016 %<br>0.018 %<br>0.031 %<br>0.042 %<br>0.28 %<br>1.2 %                                                                                                                                                                                                                        | Calibrator (simulated)                  |



| Parameter/Range                                                                                                                                | Frequency                        | CMC <sup>2, 5, 7</sup> (±)                                                           | Comments                            |
|------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------|--------------------------------------------------------------------------------------|-------------------------------------|
| AC Voltage <sup>3</sup> – Generate                                                                                                             |                                  |                                                                                      | Calibration of AC voltmeters using: |
| (100 to <300) mV                                                                                                                               | (10 to <20) Hz<br>(20 to <50) Hz | 2.9 %<br>1.2 %                                                                       | URE3                                |
| (0.3 to 200) V                                                                                                                                 | (10 to <20) Hz<br>(20 to <40) Hz | 0.025 %<br>85 µV/V                                                                   | Fluke 792A, DT 72A                  |
| (0.3 to 20) V<br>(>20 to 200) V<br>(>200 to 1000) V                                                                                            | (40 to <50) Hz                   | 55 µV/V<br>50 µV/V<br>60 µV/V                                                        |                                     |
| (1 to <2) mV<br>(2 to <10) mV<br>(10 to <100) mV<br>100 mV to <0.3 V<br>(0.3 to 0.6) V<br>(>0.6 to 60) V<br>(>60 to 200) V<br>(>200 to 1000) V | 50 Hz to 1 kHz                   | 0.028 %<br>0.016 %<br>75 µV/V<br>60 µV/V<br>50 µV/V<br>40 µV/V<br>45 µV/V<br>50 µV/V |                                     |
| (1 to <2) mV<br>(2 to <10) mV<br>(10 to <100) mV<br>100 mV to <0.3 V                                                                           | (>1 to 5) kHz                    | 0.056 %<br>0.035 %<br>0.018 %<br>70 µV/V                                             |                                     |
| (1 to <2) mV<br>(2 to <10) mV<br>(10 to <100) mV<br>100 mV to <0.3 V                                                                           | (>5 to 10) kHz                   | 0.064 %<br>0.047 %<br>0.030 %<br>0.012 %                                             |                                     |
| (0.3 to 0.6) V<br>(>0.6 to 2) V<br>(>2 to 200) V<br>(>200 to 1000) V                                                                           | (>1 to 20) kHz                   | 50 µV/V<br>30 µV/V<br>40 µV/V<br>45 µV/V                                             |                                     |
| (0.3 to 0.6) V<br>(>0.6 to 200) V<br>(>200 to 1000) V                                                                                          | (>20 to 30) kHz                  | 75 µV/V<br>60 µV/V<br>90 µV/V                                                        |                                     |
| (0.3 to 0.6) V<br>(>0.6 to 200) V<br>(>200 to 600) V                                                                                           | (>30 to 50) kHz                  | 75 µV/V<br>60 µV/V<br>90 µV/V                                                        |                                     |
| (0.3 to 0.6) V<br>(>0.6 to 60) V<br>(>60 to 200) V<br>(>200 to 600) V                                                                          | (>50 to 100) kHz                 | 75 µV/V<br>65 µV/V<br>80 µV/V<br>0.012 %                                             |                                     |

| Parameter/Range                                         | Frequency         | CMC <sup>2, 5, 7</sup> ( $\pm$ ) | Comments                                                         |
|---------------------------------------------------------|-------------------|----------------------------------|------------------------------------------------------------------|
| AC Voltage <sup>3</sup> – Generate<br>(cont)            |                   |                                  |                                                                  |
| (0.3 to 0.6) V<br>(>0.6 to 20) V                        | (>100 to 500) kHz | 0.038 %<br>0.016 %               | Fluke 792A, DT 72A                                               |
| (0.3 to 0.6) V<br>(>0.6 to 20) V                        | 500 kHz to 1 MHz  | 0.057 %<br>0.017 %               |                                                                  |
| (0.3, 0.6, 1, 2, 6, 10, 20,<br>60, 100, 200) V          | 10 Hz             | 65 $\mu$ V/V                     |                                                                  |
| (0.3, 0.6, 1, 2, 6, 10, 20,<br>60, 100, 200) V          | 20 Hz             | 55 $\mu$ V/V                     |                                                                  |
| (0.3, 0.6, 1, 2, 6, 10, 20,<br>60, 100, 200) V<br>600 V | 50 kHz            | 40 $\mu$ V/V<br>85 $\mu$ V/V     |                                                                  |
| (0.3, 0.6, 1, 2, 6, 10, 20,<br>60, 100, 200) V<br>600 V | 100 kHz           | 50 $\mu$ V/V<br>95 $\mu$ V/V     |                                                                  |
| (0.3, 0.6, 1, 2, 6, 10, 20) V                           | 500 kHz           | 55 $\mu$ V/V                     |                                                                  |
| (0.3, 0.6) V<br>(1, 2, 6, 10, 20) V                     | 1 MHz             | 0.010 %<br>80 $\mu$ V/V          |                                                                  |
| (1 to 30) kV                                            | (50, 60) Hz       | 0.17 % + 3.5 V                   |                                                                  |
|                                                         |                   |                                  | Multimeter, voltage<br>divider & AC/DC high<br>voltage generator |
| AC Voltage – Generate <sup>3</sup>                      |                   |                                  | Calibration of AC<br>voltmeters using:                           |
| (1 to 5) kV                                             | (50, 60) Hz       | 0.23 % + 3.5 V                   | Multimeter with RD5kV,<br>RD50kV & potential<br>transformer      |

| Parameter/Range                                                                                                                                | Frequency                        | CMC <sup>2, 5, 7</sup> ( $\pm$ )                                                                                   | Comments                                 |
|------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------|--------------------------------------------------------------------------------------------------------------------|------------------------------------------|
| AC Voltage – Measure <sup>3</sup>                                                                                                              |                                  |                                                                                                                    | Calibration of voltage generators using: |
| (100 to <300) mV                                                                                                                               | (10 to <20) Hz<br>(20 to <50) Hz | 2.9 %<br>1.2 %                                                                                                     | URE3                                     |
| (0.3 to 200) V                                                                                                                                 | (10 to <20) Hz<br>(20 to <40) Hz | 0.025 %<br>85 $\mu$ V/V                                                                                            | Fluke 792A, DT 72A                       |
| (0.3 to 20) V<br>(>20 to 200) V<br>(>200 to 1000) V                                                                                            | (40 to <50) Hz                   | 55 $\mu$ V/V<br>50 $\mu$ V/V<br>60 $\mu$ V/V                                                                       |                                          |
| (1 to <2) mV<br>(2 to <10) mV<br>(10 to <100) mV<br>100 mV to <0.3 V<br>(0.3 to 0.6) V<br>(>0.6 to 60) V<br>(>60 to 200) V<br>(>200 to 1000) V | 50 Hz to 1 kHz                   | 0.029 %<br>0.016 %<br>75 $\mu$ V/V<br>60 $\mu$ V/V<br>50 $\mu$ V/V<br>40 $\mu$ V/V<br>45 $\mu$ V/V<br>50 $\mu$ V/V |                                          |
| (1 to <2) mV<br>(2 to <10) mV<br>(10 to <100) mV<br>100 mV to <0.3 V                                                                           | (>1 to 5) kHz                    | 0.056 %<br>0.035 %<br>0.018 %<br>70 $\mu$ V/V                                                                      |                                          |
| (1 to <2) mV<br>(2 to <10) mV<br>(10 to <100) mV<br>100 mV to <0.3 V                                                                           | (>5 to 10) kHz                   | 0.065 %<br>0.047 %<br>0.030 %<br>0.012 %                                                                           |                                          |
| (0.3 to 0.6) V<br>(>0.6 to 2) V<br>(>2 to 200) V<br>(>200 to 1000) V                                                                           | (>1 to 20) kHz                   | 50 $\mu$ V/V<br>30 $\mu$ V/V<br>40 $\mu$ V/V<br>45 $\mu$ V/V                                                       |                                          |
| (0.3 to 0.6) V<br>(>0.6 to 200) V<br>(>200 to 1000) V                                                                                          | (>20 to 30) kHz                  | 75 $\mu$ V/V<br>60 $\mu$ V/V<br>90 $\mu$ V/V                                                                       |                                          |
| (0.3 to 0.6) V<br>(>0.6 to 200) V<br>(>200 to 600) V                                                                                           | (>30 to 50) kHz                  | 75 $\mu$ V/V<br>60 $\mu$ V/V<br>90 $\mu$ V/V                                                                       |                                          |
| (0.3 to 0.6) V<br>(>0.6 to 60) V<br>(>60 to 200) V<br>(>200 to 600) V                                                                          | (>50 to 100) kHz                 | 75 $\mu$ V/V<br>65 $\mu$ V/V<br>80 $\mu$ V/V<br>0.012 %                                                            |                                          |

| Parameter/Range                                         | Frequency            | CMC <sup>2, 5, 7</sup> (±)       | Comments                                                         |
|---------------------------------------------------------|----------------------|----------------------------------|------------------------------------------------------------------|
| AC Voltage <sup>3</sup> – Measure<br>(cont)             |                      |                                  |                                                                  |
| (0.3 to 0.6) V<br>(>0.6 to 20) V                        | (>100 to 500) kHz    | 0.038 %<br>0.016 %               | Fluke 792A, DT 72A                                               |
| (0.3 to 0.6) V<br>(>0.6 to 20) V                        | 500 kHz to 1 MHz     | 0.057 %<br>0.017 %               |                                                                  |
| (0.3, 0.6, 1, 2, 6, 10, 20,<br>60, 100, 200) V          | 10 Hz                | 65 µV/V                          |                                                                  |
| (0.3, 0.6, 1, 2, 6, 10, 20,<br>60, 100, 200) V          | 20 Hz                | 55 µV/V                          |                                                                  |
| (0.3, 0.6, 1, 2, 6, 10, 20,<br>60, 100, 200) V<br>600 V | 50 kHz               | 40 µV/V<br>85 µV/V               |                                                                  |
| (0.3, 0.6, 1, 2, 6, 10, 20,<br>60, 100, 200) V<br>600 V | 100 kHz              | 50 µV/V<br>95 µV/V               |                                                                  |
| (0.3, 0.6, 1, 2, 6, 10, 20) V                           | 500 kHz              | 55 µV/V                          |                                                                  |
| (0.3, 0.6) V<br>(1, 2, 6, 10, 20) V                     | 1 MHz<br>(50, 60) Hz | 0.010 %<br>80 µV/V               |                                                                  |
| (1 to 30) kV                                            |                      | 0.17 % + 3.5 V                   |                                                                  |
|                                                         |                      |                                  | Multimeter, voltage<br>divider & AC/DC high<br>voltage generator |
| AC Voltage – Measure <sup>3</sup>                       |                      |                                  | Calibration of voltage<br>generators using:                      |
| (1 to 5) kV<br>(5 to 30) kV                             | (50, 60) Hz          | 0.23 % + 3.5 V<br>0.52 % + 3.5 V | Multimeter with<br>RD5kV, RD50kV                                 |
| AC Integrated Current –<br>Generate <sup>3</sup>        |                      |                                  | Calibration of current<br>generators using                       |
| 1 mA to 3 A<br>2.8 µAh to 0.83 Ah                       | 50 Hz to 1 kHz       | 0.17 %                           | Calibrator & time<br>counter                                     |
| (3 to 11) A<br>8.3 mAh to 3.1 Ah                        | 50 Hz to 1 kHz       | 0.23 %                           |                                                                  |
| (11 to 20) A<br>31 mAh to 5.6 Ah                        | 50 Hz to 1 kHz       | 0.26 %                           |                                                                  |

| Parameter/Range                                                                          | Frequency      | CMC <sup>2, 5, 7</sup> (±)                                     | Comments                                                                               |
|------------------------------------------------------------------------------------------|----------------|----------------------------------------------------------------|----------------------------------------------------------------------------------------|
| AC Current – Generate <sup>3</sup>                                                       |                |                                                                | Calibration of AC current measuring devices using:                                     |
| (2 to 500) mA<br>(0.5 to 1) A<br>(1 to 2) A<br>(2 to 10) A<br>(10 to 20) A               | 50 Hz to 1 kHz | 70 µA/A<br>75 µA/A<br>70 µA/A<br>0.010 %<br>0.020 %            | Fluke 792A with current shunt A40                                                      |
| 100 µA to 2 mA<br>(20 to 50) A                                                           | 50 Hz to 1 kHz | 0.014 %<br>0.42 %                                              | Digital voltmeter, current transformer & current resistor shunt                        |
| (20 to 120) A                                                                            | (50 to 60) Hz  | 0.08%                                                          |                                                                                        |
| (30 to 100) µA                                                                           | 50 Hz to 1 kHz | 0.49 %                                                         | Calibrator                                                                             |
| (10 to 2000) A<br>(2000 to 3000) A<br>(3000 to 6000) A                                   | (50 to 60) Hz  | 0.35 %<br>0.68 %<br>0.79 %                                     | Calibrator with current coil                                                           |
| AC Current – Measure <sup>3</sup>                                                        |                |                                                                | Calibration of current generators using:                                               |
| (2 to 500) mA<br>(0.5 to 1) A<br>(1 to 2) A<br>(2 to 5) A<br>(5 to 10) A<br>(10 to 20) A | 50 Hz to 1 kHz | 70 µA/A<br>75 µA/A<br>70 µA/A<br>0.010 %<br>95 µA/A<br>0.019 % | Fluke 792A & current shunt A40                                                         |
| (30 to 100) µA<br>100 µA to 2 mA<br>(10 to 50) A                                         | 50 Hz to 1 kHz | 0.49 %<br>0.014 %<br>0.42 %                                    | Calibrator, multimeter digital voltmeter, current transformer & current resistor shunt |
| (20 to 120) A                                                                            | (50 to 60) Hz  | 0.08 %                                                         |                                                                                        |
| Current Coil Turns<br>(10 to 50) Turns                                                   | (50 to 60) Hz  | 0.13 %                                                         | Calibrator                                                                             |

| Parameter/Range                                                             | Frequency                                                                            | CMC <sup>2, 5, 7</sup> ( $\pm$ )             | Comments                                                                |
|-----------------------------------------------------------------------------|--------------------------------------------------------------------------------------|----------------------------------------------|-------------------------------------------------------------------------|
| AC Power – Generate <sup>3</sup>                                            |                                                                                      |                                              | Calibration of watt meters & power analyzers using:                     |
| 10 W to 6 kW                                                                | (50 to 60) Hz                                                                        | 0.060 %                                      | Watt converter                                                          |
| $\leq 1000$ V, $\leq 120$ A<br>PF: 1                                        | (50 to 60) Hz<br>Single Phase<br>Three Phase – Three Wire<br>Three Phase – Four Wire | 0.11 %<br>0.11 %<br>0.11 %                   | Multimeter, calibrator, current transformer & phase meter               |
| $\leq 1000$ V, $\leq 120$ A<br>PF: 0(lag) ~ 1 ~ 0(lead)                     | Single Phase<br>Three Phase – Three Wire<br>Three Phase – Four Wire                  | 1.1 mW/(V·A)<br>1.1 mW/(V·A)<br>1.1 mW/(V·A) | Multimeter, calibrator, current transformer & phase meter               |
| $\leq 1000$ V, $\leq 1000$ A<br>PF: 1, with current coil                    | (50 to 60) Hz<br>Single Phase<br>Three Phase – Three Wire<br>Three Phase – Four Wire | 0.37 %<br>0.32 %<br>0.37 %                   | Multimeter, calibrator, current transformer, phase meter & current coil |
| $\leq 1000$ V, $\leq 1000$ A<br>PF: 0(lag) ~ 1 ~ 0(lead), with current coil | Single Phase<br>Three Phase – Three Wire<br>Three Phase – Four Wire                  | 3.7 mW/(V·A)<br>3.2 mW/(V·A)<br>3.7 mW/(V·A) | Multimeter, calibrator, current transformer, phase meter & current coil |
| $\leq 1000$ V, $\leq 2000$ A<br>PF: 1, with current coil                    | (50 to 60) Hz<br>Single Phase                                                        | 0.37 %                                       | Multimeter, calibrator, phase meter & current coil                      |
| $\leq 1000$ V, $\leq 2000$ A<br>PF: 0(lag) ~ 1 ~ 0(lead), with current coil | Single Phase                                                                         | 3.7 mW/(V·A)                                 |                                                                         |
| $\leq 1000$ V, $\leq 3000$ A<br>PF: 1, with current coil                    | Single Phase                                                                         | 0.69 %                                       |                                                                         |
| $\leq 1000$ V, $\leq 3000$ A<br>PF: 0(lag) ~ 1 ~ 0(lead), with current coil | Single Phase                                                                         | 6.9 mW/(V·A)                                 |                                                                         |
| $\leq 1000$ V, $\leq 6000$ A<br>PF: 1, with current coil                    | Single Phase                                                                         | 0.80 %                                       |                                                                         |
| $\leq 1000$ V, $\leq 6000$ A<br>PF: 0(lag) ~ 1 ~ 0(lead), with current coil | Single Phase                                                                         | 8.0 mW/(V·A)                                 |                                                                         |

| Parameter/Range                                                      | Frequency                                                                            | CMC <sup>2, 5</sup> (±)                                  | Comments                                                                              |
|----------------------------------------------------------------------|--------------------------------------------------------------------------------------|----------------------------------------------------------|---------------------------------------------------------------------------------------|
| AC Energy – Generate <sup>3</sup>                                    |                                                                                      |                                                          | Calibration of watt meters & power analyzers using:                                   |
| ≤ 1000 V, ≤ 120 A<br>PF: 1                                           | (50 to 60) Hz<br>Single Phase<br>Three Phase – Three Wire<br>Three Phase – Four Wire | 0.16 %<br>0.15 %<br>0.16 %                               | Multimeter, calibrator, current transformer, phase meter & time counter               |
| PF: 0(lag) ~ 1 ~ 0 (lead)                                            | Single phase<br>Three Phase – Three Wire<br>Three Phase – Four Wire                  | 1.6 mW·h/(V·A·h)<br>1.5 mW·h/(V·A·h)<br>1.6 mW·h/(V·A·h) | Multimeter, calibrator, current transformer, phase meter & time counter               |
| ≤ 1000 V, ≤ 1000 A<br>PF: 1,<br>with current coil                    | (50 to 60) Hz<br>Single Phase<br>Three Phase – Three Wire<br>Three Phase – Four Wire | 0.39 %<br>0.34 %<br>0.39 %                               | Multimeter, calibrator, current transformer, phase meter, current coil & time counter |
| PF: 0 (lag) ~ 1 ~ 0 (lead),<br>with current coil                     | Single Phase<br>Three Phase – Three Wire<br>Three Phase – Four Wire                  | 3.9 mW·h/(V·A·h)<br>3.4 mW·h/(V·A·h)<br>3.9 mW·h/(V·A·h) | Multimeter, calibrator, current transformer, phase meter, current coil & time counter |
| ≤ 1000 V, ≤ 2000 A<br>PF: 1, with current coil                       | (50 to 60) Hz<br>Single Phase                                                        | 0.42 %                                                   | Multimeter, calibrator, phase meter & current coil                                    |
| ≤ 1000 V, ≤ 2000 A<br>PF: 0(lag) ~ 1 ~ 0(lead),<br>with current coil | Single Phase                                                                         | 4.2 mW·h/(V·A·h)                                         |                                                                                       |
| ≤ 1000 V, ≤ 3000 A<br>PF: 1, with current coil                       | Single Phase                                                                         | 0.74 %                                                   |                                                                                       |
| ≤ 1000 V, ≤ 3000 A<br>PF: 0(lag) ~ 1 ~ 0(lead),<br>with current coil | Single Phase                                                                         | 7.4 mW·h/(V·A·h)                                         |                                                                                       |
| ≤ 1000 V, ≤ 6000 A<br>PF: 1, with current coil                       | Single Phase                                                                         | 0.85 %                                                   |                                                                                       |
| ≤ 1000 V, ≤ 6000 A<br>PF: 0(lag) ~ 1 ~ 0(lead),<br>with current coil | Single Phase                                                                         | 8.5 mW·h/(V·A·h)                                         |                                                                                       |

| Parameter/Range                                                                   | Frequency                                                                                                                                    | CMC <sup>2, 5</sup> (±)                                                                      | Comments                                                  |
|-----------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------|-----------------------------------------------------------|
| AC Power – Measure <sup>3</sup>                                                   |                                                                                                                                              |                                                                                              | Calibration of Watt generators & power analyzers using:   |
| 1 mW to 10 W                                                                      | (50 to 60) Hz                                                                                                                                | 0.10 % + 0.1 mW                                                                              | Fluke 792A & current shunt A40                            |
| 10 W to 6 kW                                                                      |                                                                                                                                              | 0.060 %                                                                                      | Watt converter                                            |
| (6 to 20) kW                                                                      |                                                                                                                                              | 0.060 %                                                                                      | Calibrator multimeter & shunt resistor                    |
| (20 to 50) kW                                                                     |                                                                                                                                              | 0.070 %                                                                                      | Calibrator multimeter & CT                                |
| ≤ 1000 V, ≤ 120 A<br>PF: 1                                                        | (50 to 60) Hz<br>Single phase<br>Three phase – three wire<br>Three phase – four wire                                                         | 0.11 %<br>0.11 %<br>0.11 %                                                                   | Multimeter, calibrator, current transformer & phase meter |
| ≤ 1000 V, ≤ 120 A<br>PF: 0(lag) ~ 1 ~ 0(lead)                                     | Single phase<br>Three phase – three wire<br>Three phase – four wire                                                                          | 1.1 mW/(V·A)<br>1.1 mW/(V·A)<br>1.1 mW/(V·A)                                                 | Multimeter, calibrator, current transformer & phase meter |
| Distortion–<br>Measure <sup>3</sup> / Generate <sup>3</sup>                       |                                                                                                                                              |                                                                                              |                                                           |
| (0.1 to 30) %                                                                     | 10 Hz to 60 kHz                                                                                                                              | 2.1 %                                                                                        | Distortion analyzer                                       |
| AC Resistance – Generate <sup>3</sup>                                             |                                                                                                                                              |                                                                                              | Calibration of AC resistance meters using:                |
| Impedance<br>Fixed Points<br>0.001 Ω<br>0.01 Ω<br>0.02 Ω<br>0.1 Ω<br>0.2 Ω<br>1 Ω | 50 Hz to 1 kHz                                                                                                                               | 0.031 %<br>0.031 %<br>0.031 %<br>0.031 %<br>0.031 %<br>0.031 %<br>0.014 %                    | Standard AC resistors                                     |
| 10 Ω                                                                              | 50 Hz to 1 kHz<br>1 kHz<br>1 kHz to 1 MHz<br>(1 to 2) MHz<br>(2 to 3) MHz<br>(3 to 4) MHz<br>(4 to 5) MHz<br>(5 to 10) MHz<br>(10 to 13) MHz | 0.013 %<br>0.013 %<br>0.031 %<br>0.056 %<br>0.062 %<br>0.074 %<br>0.11 %<br>0.42 %<br>0.61 % |                                                           |

| Parameter/Range                                 | Frequency                                                                                                                  | CMC <sup>2, 5</sup> (±)                                                           | Comments                                      |
|-------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|-----------------------------------------------|
| AC Resistance – Generate <sup>3</sup><br>(cont) |                                                                                                                            |                                                                                   | Calibration of AC<br>resistance meters using: |
| 100 Ω                                           | 50 Hz to 1 kHz<br>1 kHz<br>1 kHz to 1 MHz<br>(1 to 5) MHz<br>(5 to 10) MHz<br>(10 to 13) MHz                               | 0.031 %<br>0.013 %<br>0.051 %<br>0.066 %<br>0.22 %<br>0.32 %                      | Standard AC resistors                         |
| 1 kΩ                                            | 50 Hz to 1 kHz<br>1 kHz<br>(1 to 100) kHz<br>100 kHz to 3 MHz<br>(3 to 5) MHz<br>(5 to 10) MHz<br>(10 to 13) MHz           | 0.031 %<br>0.014 %<br>0.056 %<br>0.057 %<br>0.056 %<br>0.22 %<br>0.31 %           |                                               |
| 10 kΩ                                           | 50 Hz to 1 kHz<br>1 kHz<br>(1 to 100) kHz<br>100 kHz to 1 MHz                                                              | 0.031 %<br>0.013 %<br>0.046 %<br>0.055 %                                          |                                               |
| 100 kΩ                                          | 1 kHz<br>(1 to 100) kHz<br>100 kHz to 1 MHz                                                                                | 0.014 %<br>0.056 %<br>0.073 %                                                     |                                               |
| Ranges                                          |                                                                                                                            |                                                                                   |                                               |
| 0.1 Ω to 10 kΩ                                  | 50 Hz to 1 kHz                                                                                                             | 0.031 %                                                                           | Impedance meter with<br>standard AC resistors |
| (10 to 100) kΩ                                  | 1 kHz                                                                                                                      | 0.031 %                                                                           |                                               |
| 10 Ω to 100 kΩ                                  | 1 kHz to 1 MHz                                                                                                             | 0.032 %                                                                           |                                               |
| Resistance<br>Fixed Points                      |                                                                                                                            |                                                                                   |                                               |
| 10 Ω                                            | 1 kHz<br>1 kHz to 1 MHz<br>(1 to 2) MHz<br>(2 to 3) MHz<br>(3 to 4) MHz<br>(4 to 5) MHz<br>(5 to 10) MHz<br>(10 to 13) MHz | 0.013 %<br>0.031 %<br>0.056 %<br>0.062 %<br>0.074 %<br>0.11 %<br>0.42 %<br>0.61 % |                                               |
| 100 Ω                                           | 1 kHz<br>1 kHz to 1 MHz<br>(1 to 5) MHz<br>(5 to 10) MHz<br>(10 to 13) MHz                                                 | 0.013 %<br>0.031 %<br>0.052 %<br>0.21 %<br>0.31 %                                 |                                               |

| Parameter/Range                                   | Frequency                                                                                                                  | CMC <sup>2, 5</sup> (±)                                                           | Comments                                                                |
|---------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|-------------------------------------------------------------------------|
| AC Resistance – Measure                           |                                                                                                                            |                                                                                   | Calibration of AC resistors using:                                      |
| Resistance<br>Fixed Points<br>10 Ω                | 1 kHz<br>1 kHz to 1 MHz<br>(1 to 2) MHz<br>(2 to 3) MHz<br>(3 to 4) MHz<br>(4 to 5) MHz<br>(5 to 10) MHz<br>(10 to 13) MHz | 0.013 %<br>0.031 %<br>0.056 %<br>0.062 %<br>0.074 %<br>0.11 %<br>0.42 %<br>0.61 % | DMM & AC current generator & impedance meter with standard AC resistors |
| 100 Ω                                             | 1 kHz<br>1 kHz to 1 MHz<br>(1 to 5) MHz<br>(5 to 10) MHz<br>(10 to 13) MHz                                                 | 0.013 %<br>0.031 %<br>0.052 %<br>0.21 %<br>0.31 %                                 |                                                                         |
| 1 kΩ                                              | 1 kHz<br>(1 to 100) kHz<br>100 kHz to 3 MHz<br>(3 to 5) MHz<br>(5 to 10) MHz<br>(10 to 13) MHz                             | 0.013 %<br>0.039 %<br>0.040 %<br>0.038 %<br>0.21 %<br>0.31 %                      |                                                                         |
| 10 kΩ                                             | 1 kHz<br>(1 to 100) kHz<br>100 kHz to 1 MHz                                                                                | 0.012 %<br>0.022 %<br>0.037 %                                                     |                                                                         |
| 100 kΩ                                            | 1 kHz<br>(1 to 100) kHz<br>100 kHz to 1 MHz                                                                                | 0.014 %<br>0.039 %<br>0.061 %                                                     |                                                                         |
| AC Resistance – Measure <sup>3</sup><br>Impedance |                                                                                                                            |                                                                                   | Calibration of AC resistors using:                                      |
| 0.001 Ω to 10 kΩ                                  | 50 Hz to 1 kHz                                                                                                             | 0.029 %                                                                           | DMM & AC current generator & impedance meter with standard AC resistors |
| (10 to 100) kΩ<br>10 Ω to 10 kΩ                   | 1 kHz<br>1 kHz to 1 MHz                                                                                                    | 0.029 %<br>0.054 %                                                                |                                                                         |

| Parameter/Range                   | Frequency                                                                                                                                    | CMC <sup>2,5</sup> (±)                                                                       | Comments                                                                    |
|-----------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------|
| AC Resistance – Measure           |                                                                                                                                              |                                                                                              | Calibration of AC resistors using:                                          |
| Impedance<br>Fixed Points<br>10 Ω | 50 Hz to 1 kHz<br>1 kHz<br>1 kHz to 1 MHz<br>(1 to 2) MHz<br>(2 to 3) MHz<br>(3 to 4) MHz<br>(4 to 5) MHz<br>(5 to 10) MHz<br>(10 to 13) MHz | 0.029 %<br>0.014 %<br>0.051 %<br>0.075 %<br>0.080 %<br>0.096 %<br>0.13 %<br>0.47 %<br>0.73 % | DMM and AC current generator and impedance meter with standard AC resistors |
| 100 Ω                             | 50 Hz to 1 kHz<br>1 kHz<br>1 kHz to 1 MHz<br>(1 to 5) MHz<br>(5 to 10) MHz<br>(10 to 13) MHz                                                 | 0.029 %<br>0.013 %<br>0.051 %<br>0.066 %<br>0.22 %<br>0.32 %                                 |                                                                             |
| 1 kΩ                              | 50 Hz to 1 kHz<br>1 kHz<br>(1 to 100) kHz<br>100 kHz to 3 MHz<br>(3 to 5) MHz<br>(5 to 10) MHz<br>(10 to 13) MHz                             | 0.029 %<br>0.014 %<br>0.056 %<br>0.057 %<br>0.056 %<br>0.22 %<br>0.31 %                      |                                                                             |
| 10 kΩ                             | 50 Hz to 1 kHz<br>1 kHz<br>(1 to 100) kHz<br>100 kHz to 1 MHz                                                                                | 0.029 %<br>0.013 %<br>0.046 %<br>0.055 %                                                     |                                                                             |
| 100 kΩ                            | 1 kHz<br>(1 to 100) kHz<br>100 kHz to 1 MHz                                                                                                  | 0.014 %<br>0.056 %<br>0.073 %                                                                |                                                                             |

| Parameter/Range                     | Frequency       | CMC <sup>2, 5</sup> (±) | Comments                                                  |
|-------------------------------------|-----------------|-------------------------|-----------------------------------------------------------|
| Capacitance – Generate <sup>3</sup> |                 |                         | Calibration of capacitance meters using:                  |
| Fixed Points                        |                 |                         |                                                           |
| 1 pF                                | 1 kHz           | 0.011 %                 | Standard capacitors & capacitance meters                  |
|                                     | 1 kHz to 1 MHz  | 0.018 %                 |                                                           |
|                                     | 1 MHz           | 0.011 %                 |                                                           |
| (10, 100) pF                        | 1 kHz           | 0.011 %                 |                                                           |
|                                     | 1 kHz to 1 MHz  | 0.011 %                 |                                                           |
|                                     | 1 MHz           | 0.011 %                 |                                                           |
| 1000 pF                             | 1 kHz           | 0.011 %                 |                                                           |
|                                     | 1 kHz to 1 MHz  | 0.031 %                 |                                                           |
|                                     | 1 MHz           | 0.012 %                 |                                                           |
| 0.01 µF                             | 120 Hz          | 0.011 %                 |                                                           |
|                                     | 120 Hz to 1 kHz | 0.012 %                 |                                                           |
|                                     | 1 kHz           | 0.012 %                 |                                                           |
|                                     | (1 to 10) kHz   | 0.011 %                 |                                                           |
|                                     | 10 kHz          | 0.011 %                 |                                                           |
|                                     | (10 to 100) kHz | 0.022 %                 |                                                           |
|                                     | 100 kHz         | 0.011 %                 |                                                           |
| 0.1 µF                              | 120 Hz          | 0.011 %                 |                                                           |
|                                     | 120 Hz to 1 kHz | 0.012 %                 |                                                           |
|                                     | 1 kHz           | 0.011 %                 |                                                           |
|                                     | (1 to 10) kHz   | 0.011 %                 |                                                           |
|                                     | 10 kHz          | 0.011 %                 |                                                           |
|                                     | (10 to 100) kHz | 0.27 %                  |                                                           |
|                                     | 100 kHz         | 0.011 %                 |                                                           |
| 1 µF                                | 120 Hz          | 0.011 %                 |                                                           |
|                                     | 120 Hz to 1 kHz | 0.011 %                 |                                                           |
|                                     | 1 kHz           | 0.011 %                 |                                                           |
|                                     | (1 to 10) kHz   | 0.072 %                 |                                                           |
|                                     | 10 kHz          | 0.011 %                 |                                                           |
|                                     | (10 to 100) kHz | 2.8 %                   |                                                           |
|                                     | 100 kHz         | 0.012 %                 |                                                           |
| 10 µF                               | 1 kHz           | 0.11 %                  |                                                           |
| Ranges                              |                 |                         |                                                           |
| 1000 pF to 0.01 µF                  | 1 kHz           | 0.58 %                  | Standard capacitors & capacitance meters, Impedance meter |
| (0.01 to 0.1) µF                    |                 | 0.062 %                 |                                                           |
| (0.1 to 1) µF                       |                 | 0.024 %                 |                                                           |

| Parameter/Range                    | Frequency                                                                                   | CMC <sup>2, 5, 7</sup> (±)                                                | Comments                                                 |
|------------------------------------|---------------------------------------------------------------------------------------------|---------------------------------------------------------------------------|----------------------------------------------------------|
| Capacitance – Measure              |                                                                                             |                                                                           | Calibration of capacitors using:                         |
| (1 to 10) pF                       | 1 kHz<br>1 kHz to 1 MHz<br>1 MHz                                                            | 0.019 %<br>0.030 %<br>0.026 %                                             | Standard capacitors & capacitance meter, Impedance meter |
| (10 to 100) pF                     | 1 kHz<br>1 kHz to 1 MHz<br>1 MHz                                                            | 0.016 %<br>0.026 %<br>0.026 %                                             |                                                          |
| (100 to 1000) pF                   | 1 kHz<br>1 kHz to 1 MHz<br>1 MHz                                                            | 0.016 %<br>0.039 %<br>0.027 %                                             |                                                          |
| 1000 pF to 0.01 µF                 | 120 Hz<br>120 Hz to 1 kHz<br>1 kHz<br>(1 to 10) kHz<br>10 kHz<br>(10 to 100) kHz<br>100 kHz | 0.011 %<br>0.026 %<br>0.016 %<br>0.026 %<br>0.026 %<br>0.033 %<br>0.026 % |                                                          |
| (0.01 to 0.1) µF                   | 120 Hz<br>120 Hz to 1 kHz<br>1 kHz<br>(1 to 10) kHz<br>10 kHz<br>(10 to 100) kHz<br>100 kHz | 0.026 %<br>0.027 %<br>0.016 %<br>0.026 %<br>0.011 %<br>0.27 %<br>0.011 %  |                                                          |
| (0.1 to 1) µF                      | 120 Hz<br>120 Hz to 1 kHz<br>1 kHz<br>(1 to 10) kHz<br>10 kHz<br>(10 to 100) kHz<br>100 kHz | 0.026 %<br>0.026 %<br>0.012 %<br>0.076 %<br>0.026 %<br>2.8 %<br>0.027 %   |                                                          |
| (1 to 10) µF<br>10 µF              | 1 kHz                                                                                       | 0.19 % + 0.001 µF<br>0.11 %                                               |                                                          |
| Capacitance – Measure <sup>3</sup> |                                                                                             |                                                                           | Calibration of capacitors using:                         |
| 100 pF to 1 µF<br>(1 to 10) µF     | 1 kHz                                                                                       | 0.068 %<br>0.19 % + 0.001 µF                                              | Capacitance meters                                       |

| Parameter/Range                                                                                    | Frequency                                                         | CMC <sup>2, 5, 7</sup> (±)                     | Comments                                                          |
|----------------------------------------------------------------------------------------------------|-------------------------------------------------------------------|------------------------------------------------|-------------------------------------------------------------------|
| Inductance – Generate <sup>3</sup><br><br>Fixed Points<br>100 µH<br>1 mH<br>10 mH<br>100 mH<br>1 H | 1 kHz                                                             | 0.51 %<br>0.11 %<br>0.11 %<br>0.11 %<br>0.11 % | Calibration of inductance meter using:<br><br>Standard inductor   |
| Inductance – Measure <sup>3</sup><br><br>Fixed Points<br>100 µH<br>1 mH<br>10 mH<br>100 mH<br>1 H  | 1 kHz                                                             | 0.51 %<br>0.11 %<br>0.11 %<br>0.11 %<br>0.11 % | Calibration of inductor using:<br><br>Standard inductor           |
| Phase <sup>3</sup><br>(0 to 360) °                                                                 | 20 Hz to 2 kHz<br>(2 to 5) kHz<br>(5 to 10) kHz<br>(10 to 50) kHz | 0.028°<br>0.038°<br>0.049°<br>0.060°           | Phase meter                                                       |
| Power Factor <sup>3</sup><br>(0 to 1)                                                              | (50 to 60) Hz                                                     | $ \cos(A) - \cos(A + 0.028) $                  | Phase meter<br>(A is the angle in degrees).<br>Unitless parameter |

| Parameter/Equipment                                                          | Range                                                                                             | CMC <sup>2</sup> (±)                                | Comments                                                    |
|------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------|-----------------------------------------------------|-------------------------------------------------------------|
| Electrical Calibration of Thermocouple Temperature Indicators <sup>3</sup> – |                                                                                                   |                                                     | Calibration of temperature meters using:<br><br>Fluke 55XXA |
| Type K                                                                       | (-200 to -100) °C<br>(-100 to -25) °C<br>(-25 to 120) °C<br>(120 to 1000) °C<br>(1000 to 1372) °C | 0.29 °C<br>0.18 °C<br>0.17 °C<br>0.24 °C<br>0.33 °C |                                                             |
| Type J                                                                       | (-210 to -100) °C<br>(-100 to -30) °C<br>(-30 to 150) °C<br>(150 to 760) °C<br>(760 to 1200) °C   | 0.26 °C<br>0.20 °C<br>0.19 °C<br>0.20 °C<br>0.23 °C |                                                             |
| Type E                                                                       | (-250 to -100) °C<br>(-100 to -25) °C<br>(-25 to 350) °C<br>(350 to 650) °C<br>(650 to 1000) °C   | 0.44 °C<br>0.20 °C<br>0.19 °C<br>0.20 °C<br>0.22 °C |                                                             |
| Type T                                                                       | (-250 to -150) °C<br>(-150 to -0) °C<br>(-0 to 120) °C<br>(120 to 400) °C                         | 0.53 °C<br>0.23 °C<br>0.17 °C<br>0.19 °C            |                                                             |
| Type R                                                                       | (0 to 250) °C<br>(250 to 400) °C<br>(400 to 1000) °C<br>(1000 to 1767) °C                         | 0.50 °C<br>0.31 °C<br>0.30 °C<br>0.38 °C            |                                                             |
| Type S                                                                       | (0 to 250) °C<br>(250 to 1000) °C<br>(1000 to 1400) °C<br>(1400 to 1767) °C                       | 0.43 °C<br>0.34 °C<br>0.34 °C<br>0.40 °C            |                                                             |
| Type N                                                                       | (-200 to -100) °C<br>(-100 to -25) °C<br>(-25 to 120) °C<br>(120 to 410) °C<br>(410 to 1300) °C   | 0.34 °C<br>0.21 °C<br>0.18 °C<br>0.18 °C<br>0.23 °C |                                                             |
| Electrical Calibration of RTDs <sup>3</sup> –                                |                                                                                                   |                                                     |                                                             |
| Pt385, 100 Ω & JPt-100                                                       | (-200 to 850) °C                                                                                  | 0.090 °C                                            | Decade resistors                                            |

| Parameter/Equipment                                              | Range                                                                                                                      | CMC <sup>2</sup> (±)                                          | Comments                                            |
|------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------|-----------------------------------------------------|
| Electrical Calibration of Thermocouple Temperature Calibrators – |                                                                                                                            |                                                               | Calibration of temperature meter calibrators using: |
| Type K                                                           | (-270 to -260) °C<br>(-260 to -250) °C<br>(-250 to -200) °C<br>(-200 to -100) °C<br>(-100 to 1372) °C                      | 0.80 °C<br>0.23 °C<br>0.15 °C<br>0.07 °C<br>0.06 °C           | Multimeter & glass thermometers                     |
| Type J                                                           | (-210 to 1200) °C                                                                                                          | 0.06 °C                                                       |                                                     |
| Type E                                                           | (-270 to -260) °C<br>(-260 to -250) °C<br>(-250 to -200) °C<br>(-200 to -100) °C<br>(-100 to 1000) °C                      | 0.60 °C<br>0.20 °C<br>0.15 °C<br>0.07 °C<br>0.06 °C           |                                                     |
| Type T                                                           | (-270 to -260) °C<br>(-260 to -250) °C<br>(-250 to -200) °C<br>(-200 to -100) °C<br>(-100 to 400) °C                       | 0.60 °C<br>0.20 °C<br>0.15 °C<br>0.07 °C<br>0.06 °C           |                                                     |
| Type R                                                           | (-50 to 0) °C<br>(0 to 100) °C<br>(100 to 1768) °C                                                                         | 0.20 °C<br>0.15 °C<br>0.10 °C                                 |                                                     |
| Type S                                                           | (-50 to 0) °C<br>(0 to 100) °C<br>(100 to 1768) °C                                                                         | 0.20 °C<br>0.15 °C<br>0.10 °C                                 |                                                     |
| Type N                                                           | (-270 to -260) °C<br>(-260 to -250) °C<br>(-250 to -240) °C<br>(-240 to -200) °C<br>(-200 to -100) °C<br>(-100 to 1370) °C | 1.7 °C<br>0.35 °C<br>0.20 °C<br>0.15 °C<br>0.08 °C<br>0.06 °C |                                                     |

| Parameter/Equipment                                        | Range                                                                                                                                                                                                                                                                                        | CMC <sup>2, 5</sup> (±)                                                                                                                       | Comments                                                                                        |
|------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------|
| Electrical Calibration of Strain Calibrators–              | $(10 \text{ to } 2\,000) \times 10^{-6}$<br>$(2\,000 \text{ to } 20\,000) \times 10^{-6}$<br>$(20\,000 \text{ to } 50\,000) \times 10^{-6}$<br>$(50\,000 \text{ to } 100\,000) \times 10^{-6}$<br>$(100\,000 \text{ to } 200\,000) \times 10^{-6}$                                           | $0.09 \times 10^{-6}$<br>$0.22 \times 10^{-6}$<br>$0.40 \times 10^{-6}$<br>$0.75 \times 10^{-6}$<br>$1.5 \times 10^{-6}$                      | Calibration of strain calibrator using:<br><br>Multimeter, voltage generator<br><br>mV/V(Ratio) |
| Electrical Calibration of Strain Indicators <sup>3</sup> – | $(10 \text{ to } 200) \times 10^{-6}$<br>$(200 \text{ to } 2\,000) \times 10^{-6}$<br>$(2\,000 \text{ to } 20\,000) \times 10^{-6}$<br>$(20\,000 \text{ to } 50\,000) \times 10^{-6}$<br>$(50\,000 \text{ to } 100\,000) \times 10^{-6}$<br>$(100\,000 \text{ to } 200\,000) \times 10^{-6}$ | $0.14 \times 10^{-6}$<br>$0.37 \times 10^{-6}$<br>$1.9 \times 10^{-6}$<br>$3.5 \times 10^{-6}$<br>$6.7 \times 10^{-6}$<br>$13 \times 10^{-6}$ | Calibration of strain meter using:<br><br>Strain calibrator<br><br>mV/V(Ratio)                  |

#### V. Electrical – RF/Microwave

| Parameter/Range                                        | Frequency                                                                  | CMC <sup>2, 5</sup> (±)          | Comments                                                                    |
|--------------------------------------------------------|----------------------------------------------------------------------------|----------------------------------|-----------------------------------------------------------------------------|
| High Frequency Voltage – Measure / Measuring Equipment |                                                                            |                                  |                                                                             |
| 0.5 V                                                  | (10 to 500) MHz<br>(500 to 1000) MHz                                       | 1.1 %<br>2.2 %                   | Bolometer mount, auto-balance bridge & DMM<br><br><br>Rohde & Schwartz URE3 |
| (0.1 to 0.7) V                                         | (10 to 500) MHz<br>(500 to 1000) MHz                                       | 1.3 %<br>2.4 %                   |                                                                             |
| (1 to 3) mV                                            | (10 to 100) kHz<br>> 100 kHz to 1 MHz<br>(> 1 to 3) MHz<br>(> 3 to 10) MHz | 0.7 %<br>1.9 %<br>2.5 %<br>6.2 % |                                                                             |
| (> 3 to 10) mV                                         | (10 to 100) kHz<br>> 100 kHz to 1 MHz<br>(> 1 to 3) MHz<br>(> 3 to 10) MHz | 0.7 %<br>0.9 %<br>1.3 %<br>2.6 % |                                                                             |

| Parameter/Range                                                     | Frequency                                                                  | CMC <sup>2, 5</sup> (±)          | Comments                 |
|---------------------------------------------------------------------|----------------------------------------------------------------------------|----------------------------------|--------------------------|
| High Frequency Voltage –<br>Measure / Measuring<br>Equipment (cont) |                                                                            |                                  |                          |
| (> 0.01 to 0.3) V                                                   | (10 to 100) kHz<br>> 100 kHz to 1 MHz<br>(> 1 to 3) MHz<br>(> 3 to 10) MHz | 0.6 %<br>0.9 %<br>1.3 %<br>2.0 % |                          |
| (0.25 to 1) V                                                       | 100 kHz to 1 MHz<br>(> 1 to 10) MHz<br>(> 10 to 30) MHz                    | 0.08 %<br>0.24 %<br>0.47 %       | Fluke A55                |
| (> 1 to 3) V                                                        | 100 kHz to 1 MHz<br>(> 1 to 10) MHz<br>(> 10 to 30) MHz                    | 0.08 %<br>0.32 %<br>0.52 %       |                          |
| (10 to 120) dB/μV                                                   | (10 to 500) MHz<br>(500 to 1000) MHz                                       | 0.23 dB<br>0.29 dB               | Measuring receiver       |
| (1 to 3) mV                                                         | (10 to 100) kHz<br>>100 kHz to 1 MHz<br>(>1 to 3) MHz<br>(>3 to 10) MHz    | 1.2 %<br>2.1 %<br>2.7 %<br>6.2 % | Rohde & Schwartz<br>URE3 |
| (> 3 to 10) mV                                                      | (10 to 100) kHz<br>>100 kHz to 1 MHz<br>(>1 to 3) MHz<br>(>3 to 10) MHz    | 1.2 %<br>1.3 %<br>1.6 %<br>2.8 % |                          |
| (> 0.01 to 3) V                                                     | (10 to 100) kHz<br>>100 kHz to 1 MHz<br>(>1 to 3) MHz<br>(>3 to 10) MHz    | 1.1 %<br>1.3 %<br>1.6 %<br>2.3 % |                          |
| (0.3 to 3) V                                                        | (>10 to 30) MHz                                                            | 2.5 %                            | URV5                     |
| (> 3 to 200) V                                                      | 10 kHz to 100 kHz                                                          | 1.1 %                            | URE3                     |
| (10 to 120) dB/μV                                                   | (10 to 500) MHz<br>(500 to 1000) MHz                                       | 0.26 dB<br>0.30 dB               | Measuring receiver       |

| Parameter/Range                                                    | Frequency                                                                                                                                               | CMC <sup>2, 4, 5</sup> (±)                                                     | Comments                                                                           |
|--------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------|------------------------------------------------------------------------------------|
| High Frequency Power <sup>3</sup> –<br>Measuring Equipment         |                                                                                                                                                         |                                                                                |                                                                                    |
| 100 pW to 1 nW                                                     | (10 to 50) MHz<br>50 MHz to 6 GHz<br>(6 to 12) GHz                                                                                                      | 2.4 %<br>2.1 %<br>2.3 %                                                        | Power meter, sensor,<br>splitter, attenuator, &<br>signal calibrator with<br>mixer |
| (1 to 10) nW                                                       | 9 kHz to 10 MHz<br>(10 to 50) MHz<br>50 MHz to 6 GHz<br>(6 to 12) GHz<br>(12 to 18) GHz                                                                 | 1.8 %<br>2.2 %<br>2.0 %<br>2.2 %<br>4.1 %                                      |                                                                                    |
| > 10 nW to 100 mW                                                  | 9 kHz to 10 MHz<br>(10 to 50) MHz<br>50 MHz to 6 GHz<br>(6 to 12) GHz<br>(12 to 18) GHz                                                                 | 1.6 %<br>2.1 %<br>1.8 %<br>2.1 %<br>3.9 %                                      |                                                                                    |
| > 10 µW to 100 mW                                                  | (18 to 24) GHz<br>(24 to 32) GHz<br>(32 to 40) GHz                                                                                                      | 3.6 %<br>5.5 %<br>5.4 %                                                        |                                                                                    |
| 1 mW                                                               | 9 kHz to 10 MHz<br>(10 to 50) MHz<br>50 MHz<br>50 MHz to 6 GHz<br>(6 to 12) GHz<br>(12 to 18) GHz<br>(18 to 24) GHz<br>(24 to 32) GHz<br>(32 to 40) GHz | 1.4 %<br>1.8 %<br>0.68 %<br>1.5 %<br>1.8 %<br>2.3 %<br>2.4 %<br>4.3 %<br>4.2 % |                                                                                    |
| 100 mW to 100W                                                     | 10 MHz to 1 GHz                                                                                                                                         | 2.8 %                                                                          |                                                                                    |
| (> 100 to 200) W                                                   | (10 to 250) MHz                                                                                                                                         | 2.8 %                                                                          |                                                                                    |
| High Frequency Power <sup>3</sup> –<br>Calibration Factor,<br>1 mW | 9 kHz to 10 MHz<br>(10 to 50) MHz<br>50 MHz<br>50 MHz to 6 GHz<br>(6 to 12) GHz<br>(12 to 18) GHz<br>(18 to 24) GHz<br>(24 to 32) GHz<br>(32 to 0) GHz  | 1.4 %<br>1.8 %<br>0.68 %<br>1.5 %<br>1.8 %<br>2.3 %<br>2.4 %<br>4.3 %<br>4.2 % | Power meter, sensor,<br>splitter, attenuator, &<br>signal calibrator with<br>mixer |

|                                                                          |                                                                                                                                                       |                                                                               |                                                                                 |
|--------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------|---------------------------------------------------------------------------------|
| High Frequency Power <sup>3</sup> – Measure                              |                                                                                                                                                       |                                                                               |                                                                                 |
| 100 pW to 1 nW                                                           | 10 MHz to 4 GHz<br>(4 to 8) GHz<br>(8 to 12) GHz                                                                                                      | 3.1 %<br>3.6 %<br>3.7 %                                                       | Power meter, sensor,<br>attenuator, measuring<br>receiver                       |
| > 1 nW to 100 mW                                                         | 9 kHz to 1 MHz<br>1 MHz to 4 GHz<br>(4 to 8) GHz<br>(8 to 12) GHz<br>(12 to 18) GHz                                                                   | 3.0 %<br>3.1 %<br>3.6 %<br>3.7 %<br>5.9 %                                     |                                                                                 |
| > 10 µW to 100 mW                                                        | (18 to 24) GHz<br>(24 to 40) GHz                                                                                                                      | 6.5 %<br>11 %                                                                 |                                                                                 |
| 1 mW                                                                     | 9 kHz to 1 MHz<br>(1 to 30) MHz<br>(30 to 50) MHz<br>50 MHz<br>50 MHz to 8 GHz<br>(8 to 12) GHz<br>(12 to 18) GHz<br>(18 to 24) GHz<br>(24 to 40) GHz | 1.4 %<br>1.7 %<br>1.4 %<br>0.7 %<br>1.6 %<br>1.7 %<br>2.5 %<br>1.8 %<br>3.3 % |                                                                                 |
| Modulation <sup>3</sup> – Measure                                        |                                                                                                                                                       |                                                                               |                                                                                 |
| Amplitude Modulation<br>Freq: 100 kHz to 1 GHz<br>Rate: 50 Hz to 100 kHz | Modulation Depth<br>(20 to 99) %                                                                                                                      | 2.1 %                                                                         | Tektronix DPO4032,<br>Attenuator, modulation<br>meter/receiver                  |
| Frequency Modulation<br>Freq: 100 kHz to 1 GHz<br>Rate: 50 Hz to 100 kHz | Deviation<br>50 Hz to 200 kHz                                                                                                                         | 0.26 %                                                                        | Tektronix AFG3022,<br>modulation<br>meter/receiver                              |
| Modulation <sup>3</sup> – Measuring<br>Equipment                         |                                                                                                                                                       |                                                                               |                                                                                 |
| Amplitude Modulation<br>Freq: 100 kHz to 1 GHz<br>Rate: 50 Hz to 100 kHz | Modulation Depth<br>(20 to 99) %                                                                                                                      | 2.1 %                                                                         | Tektronix DPO4032<br>Attenuator                                                 |
| Frequency Modulation<br>Freq: 100 kHz to 1 GHz<br>Rate: 50 Hz to 100 kHz | Deviation<br>50 Hz to 200 kHz                                                                                                                         | 0.26%                                                                         | Bessel Null method<br>power splitter, signal<br>generator, spectrum<br>analyzer |

| Parameter/Range                                                                                        | Frequency        | CMC <sup>2, 4</sup> (±)          | Comments                                 |
|--------------------------------------------------------------------------------------------------------|------------------|----------------------------------|------------------------------------------|
| Display Average Noise Level<br>– Measuring Equipment<br><br>(-170 to 0) dBm<br>(-63 to 107) dB $\mu$ V | 9 kHz to 40 GHz  | 0.6 dB<br>0.6 dB                 | Terminations                             |
| Electromagnetic Wave<br>Attenuation– Generate <sup>3</sup><br><br>(0 to 60) dB                         | 50 Hz to 1 kHz   | 0.01 dB                          | Standard decade<br>transformer           |
| (0 to 20) dB<br>(20 to 40) dB<br>(40 to 60) dB                                                         | (1 to 10) kHz    | 0.01 dB<br>0.02 dB<br>0.18 dB    | Attenuator<br>vector network<br>analyzer |
| (0 to 40) dB<br>(40 to 50) dB<br>(50 to 60) dB                                                         | 9 kHz to 10 MHz  | 0.06 dB<br>0.08 dB<br>0.20 dB    | Attenuator                               |
| 10, 20, 30, 40, 50, 60 dB                                                                              | 10 kHz to 10 MHz | 0.04 dB                          |                                          |
| 10 dB<br>50 dB<br>70 dB                                                                                | 10 MHz to 12 GHz | 0.027 dB<br>0.034 dB<br>0.042 dB |                                          |
| 10 dB<br>50 dB<br>60 dB                                                                                | (12 to 18) GHz   | 0.05 dB<br>0.06 dB<br>0.06 dB    |                                          |
| (0 to 50) dB<br>(> 50 to 100) dB                                                                       | 10 MHz to 12 GHz | 0.05 dB<br>0.07 dB               |                                          |
| (0 to 50) dB<br>(> 50 to 100) dB                                                                       | (12 to 18) GHz   | 0.13 dB<br>0.18 dB               | Attenuation<br>measurement<br>equipment  |
| (0 to 60) dB                                                                                           | (18 to 40) GHz   | 0.25 dB                          | Measuring receiver                       |

| Parameter/Range                                                                                   | Frequency         | CMC <sup>2, 5</sup> (±)                                        | Comments                          |
|---------------------------------------------------------------------------------------------------|-------------------|----------------------------------------------------------------|-----------------------------------|
| Electromagnetic Wave Attenuation <sup>3</sup> – Measure                                           |                   |                                                                |                                   |
| (0 to 60) dB<br>(60 to 80) dB                                                                     | 50 Hz to 1 kHz    | 0.01 dB<br>0.015 dB                                            | Standard decade transformer       |
| (0 to 20) dB<br>(20 to 40) dB<br>(40 to 80) dB                                                    | (1 to 10) kHz     | 0.01 dB<br>0.02 dB<br>0.03 dB                                  |                                   |
| (0 to 40) dB<br>(40 to 50) dB<br>(50 to 60) dB                                                    | 9 kHz to 10 MHz   | 0.06 dB<br>0.08 dB<br>0.20 dB                                  | Vector network analyzer E5061B    |
| (0 to 50) dB<br>(50 to 70) dB<br>(70 to 80) dB<br>(80 to 90) dB                                   | 10 MHz to 12 GHz  | 0.06 dB<br>0.07 dB<br>0.12 dB<br>0.64 dB                       | Attenuation measurement equipment |
| (0 to 70) dB<br>(70 to 80) dB<br>(80 to 90) dB                                                    | (12 to 18) GHz    | 0.18 dB<br>0.28 dB<br>0.43 dB                                  |                                   |
| (0 to 60) dB                                                                                      | (18 to 40) GHz    | 0.25 dB                                                        | Measuring receiver                |
| (0 to 20) dB<br>(20 to 30) dB<br>(30 to 40) dB<br>(40 to 50) dB<br>(50 to 60) dB                  | 300 kHz to 10 MHz | 0.07 dB<br>0.15 dB<br>0.40 dB<br>1.2 dB<br>3.4 dB              | Vector network analyzer E5071C    |
| (0 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 | 10 MHz to 500 MHz | 0.05 dB<br>0.06 dB<br>0.07 dB<br>0.14 dB<br>0.35 dB<br>1.1 dB  |                                   |
| (0 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 | 500 MHz to 2 GHz  | 0.09 dB<br>0.11 dB<br>0.13 dB<br>0.16 dB<br>0.24 dB<br>0.67 dB |                                   |
| (0 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 | (2 to 6) GHz      | 0.09 dB<br>0.11 dB<br>0.13 dB<br>0.16 dB<br>0.28 dB<br>0.78 dB |                                   |

| Parameter/Range                                                       | Frequency                                                                           | CMC <sup>2, 5</sup> (±)                             | Comments                                           |
|-----------------------------------------------------------------------|-------------------------------------------------------------------------------------|-----------------------------------------------------|----------------------------------------------------|
| Electromagnetic Wave Attenuation <sup>3</sup> – Measure (cont)        |                                                                                     |                                                     |                                                    |
| (0 to 40) dB                                                          | (6 to 18) GHz                                                                       | 0.21 dB                                             | Vector network analyzer E5071C                     |
| (40 to 50) dB                                                         |                                                                                     | 0.26 dB                                             |                                                    |
| (50 to 60) dB                                                         |                                                                                     | 0.32 dB                                             |                                                    |
| (60 to 70) dB                                                         |                                                                                     | 0.43 dB                                             |                                                    |
| (70 to 80) dB                                                         |                                                                                     | 0.93 dB                                             |                                                    |
| (80 to 90) dB                                                         |                                                                                     | 2.6 dB                                              |                                                    |
| EMI Test Receiver <sup>3</sup> –                                      |                                                                                     |                                                     |                                                    |
| Level                                                                 | 9 kHz to 5 MHz<br>5 MHz to 1 GHz<br>(1 to 3) GHz<br>(3 to 12) GHz<br>(12 to 40) GHz | 0.30 dB<br>0.30 dB<br>0.30 dB<br>0.40 dB<br>0.50 dB | Fluke 8920A, HP 8902A, E4418B& E9304A E4418B&8487A |
| Attenuation                                                           | 10 MHz to 18 GHz                                                                    | 0.28 dB                                             |                                                    |
| Resolution BW                                                         | 200 Hz to 1 MHz                                                                     | 5.0 %                                               |                                                    |
| Impulse BW                                                            | 1 MHz                                                                               | 5.0 %                                               | Tektronix AFG3022, AFG3101                         |
| Center Frequency                                                      | 9 kHz to 40 GHz                                                                     | 0.30 µHz/Hz                                         | Advantest R5362B, MF2414C                          |
| Overall Selectivity (Pass-Band)                                       | ≤ 10 dB<br>> 10 dB                                                                  | 1.5 % of Resolution Bandwidth                       | JFW 50BR-017-N                                     |
| Impedance                                                             | ≥ 10 dB<br>0 dB                                                                     | 3.0 %<br>5.0 %                                      | Agilent E5061B, E5071C                             |
| Pulse Response (Relative Level)                                       | 5 Hz to 20 kHz<br>(1 to 2) Hz<br>& Isolated Pulse                                   | 0.50 dB<br>0.70 dB                                  | Schwarzbeck IGUU2916                               |
| Pulse Response (Absolute Level)                                       | Band A: 25 Hz<br>Band B, C/D: 100 Hz                                                | 0.50 dB<br>0.50 dB                                  | Schwarzbeck IGUU2916                               |
| Noise Level                                                           | 9 kHz to 40 GHz                                                                     | 0.6 dB                                              |                                                    |
| Response to Intermittent, Unsteady & Drifting Narrowband Disturbances | 9 kHz to 1 GHz                                                                      | 0.40 dB                                             |                                                    |
| Amplitude Relationship                                                | Band A: 25 Hz<br>Band B: 500 Hz<br>Band C/D: 5 kHz<br>Band E: 50 kHz                | 0.50 dB                                             |                                                    |

| Parameter/Range                            | Frequency                                            | CMC <sup>2, 5</sup> (±)       | Comments                                                              |
|--------------------------------------------|------------------------------------------------------|-------------------------------|-----------------------------------------------------------------------|
| AMN/LISN/ISN <sup>3</sup> –                |                                                      |                               |                                                                       |
| Impedance (Magnitude)                      | 9 kHz to 230 MHz                                     | 5.0 %                         | Agilent VNA E5061B                                                    |
| Impedance (Phase)                          | 9 kHz to 30 MHz<br>(30 to 230) MHz                   | 2 °<br>3 °                    |                                                                       |
| Voltage Division Factor                    | 9 kHz to 10 MHz<br>(10 to 30) MHz<br>(30 to 230) MHz | 0.10 dB<br>0.20 dB<br>0.25 dB |                                                                       |
| Isolation<br>(0 to 60) dB<br>(60 to 80) dB | 9 kHz to 30 MHz                                      | 0.5 dB<br>1 dB                |                                                                       |
| Insertion Loss                             | 150 kHz to 30 MHz                                    | 0.25 dB                       |                                                                       |
| Longitudinal Conversion Loss               | 150 kHz to 30 MHz                                    |                               |                                                                       |
| 55 dB                                      |                                                      | 0.3 dB                        |                                                                       |
| 65 dB                                      |                                                      | 0.5 dB                        |                                                                       |
| 75 dB                                      |                                                      | 1.5 dB                        |                                                                       |
| CDN <sup>3</sup> – Impedance               | (0.15 to 300) MHz                                    | 5.0 %                         | IEC 61000-4-6<br>Agilent VNA E5061B                                   |
| Pulse Generator <sup>3</sup> –             |                                                      |                               |                                                                       |
| Pulse Area                                 | (0.001 to 10) µV sec<br>Band A, B, C/D               | 5.0 %                         | CISPR16-1-1<br>Tektronix TDS7704B,<br>Advantest TR5823H<br>attenuator |
| Pulse Width                                | 300 ps to 20 ms                                      | 5.0 %                         |                                                                       |
| Pulse Amplitude                            | (10 to 70) dB                                        | 0.25 dB                       |                                                                       |
| Repetition Frequency                       | 1 Hz to 1 MHz                                        | 3.0 parts in 10 <sup>7</sup>  |                                                                       |
| Spectrum Flatness                          | DC to 7 GHz                                          | 0.40 dB                       |                                                                       |

| Parameter/Range                    | Frequency                                        | CMC <sup>2,5</sup> (±) | Comments                                                                                          |
|------------------------------------|--------------------------------------------------|------------------------|---------------------------------------------------------------------------------------------------|
| EFT/Burst Generator <sup>3</sup> – |                                                  |                        |                                                                                                   |
| Peak Voltage (+ & –)               |                                                  |                        | IEC 61000-4-4<br>Tektronix DPO7254C,<br>TDS7704B,<br>Schaffner<br>INA265A (50Ω),<br>INA266 (1 kΩ) |
| 50 Ω Load                          | (0.125 to 2) kV ± 10 %                           | 3.0 %                  |                                                                                                   |
| 1 kΩ Load                          | (0.24 to 3.8) kV ± 20 %                          | 4.0 %                  |                                                                                                   |
| Rise Time                          |                                                  |                        |                                                                                                   |
| 50 Ω Load                          | (3.5 to 7) ns                                    | 200 ps                 |                                                                                                   |
| 1 kΩ Load                          | 5 ns ± 30 %                                      | 200 ps                 |                                                                                                   |
| Impulse Duration                   |                                                  |                        |                                                                                                   |
| 50 Ω Load                          | (30 to 65) ns                                    | 1.0 ns                 |                                                                                                   |
| 1 kΩ Load                          | (35 to 150) ns                                   | 1.0 ns                 |                                                                                                   |
| Burst Duration                     | 15 ms ± 20 % @ 5 kHz<br>0.75 ms ± 20 % @ 100 kHz | 100 μs<br>1.0 μs       |                                                                                                   |
| Burst Period                       | 300 ms ± 20 %                                    | 2.0 ms                 |                                                                                                   |
| Repetition Frequency<br>Up to 4 kV | 5 kHz ± 20 %<br>100 kHz ± 20 %                   | 0.50 %<br>0.50 %       |                                                                                                   |
| Residual Voltage                   | (0 to 0.4) kV                                    | 2 % + 0.003kV          |                                                                                                   |
| ESD Targets –                      |                                                  |                        |                                                                                                   |
| Low Frequency Transfer<br>Function | @ 1 A applied input<br>Up to 1 V                 | 0.13 %                 | IEC 61000-4-2,<br>ISO 10605<br>Fluke 5700A, 8508A-01                                              |
| Insertion Loss                     | 10 MHz to 4 GHz<br>(0 to 50) dB<br>(50 to 70) dB | 0.1 dB<br>0.14 dB      | Keysight E5071C                                                                                   |

| Parameter/Equipment           | Range                                                      | CMC <sup>2, 5</sup> (±) | Comments                                                                                                      |
|-------------------------------|------------------------------------------------------------|-------------------------|---------------------------------------------------------------------------------------------------------------|
| ESD Simulators <sup>3</sup> – |                                                            |                         |                                                                                                               |
| Contact Voltage (+ & –)       | (2 to 25) kV, ± 5 %                                        | 2.0 %                   | IEC 61000-4-2<br>ISO 10605<br>Tektronix TDS7704B,<br>DPO7254C,<br>Teseq MD102A,<br>EMC Partner ESD-<br>VERI-V |
| Rise Time                     | (0.6 to 1) ns                                              | 180 ps                  |                                                                                                               |
| Peak Current                  | (7.5 to 30) A, -15 %/+30 %<br>(30 to 112.5) A, -15 %/+30 % | 4 %<br>4 %              |                                                                                                               |
| 30 ns Current                 | (4 to 16) A, ± 30 %<br>(16 to 60) A, ± 30%                 | 5.5 %<br>5.5 %          |                                                                                                               |
| 60 ns Current                 | (2 to 8) A, ± 30 %<br>(8 to 30) A, ± 30%                   | 6 %<br>6 %              |                                                                                                               |
| 65 ns Current                 | (4 to 16) A, ± 30 %<br>(16 to 60) A, ± 30%                 | 5 %<br>5 %              |                                                                                                               |
| 130 ns Current                | (2 to 8) A, ± 30 %<br>(8 to 30) A, ± 30%                   | 6 %<br>6 %              |                                                                                                               |
| 180 ns Current                | (0.55 to 2.2) A, ± 30 %<br>(2.2 to 8.25) A, ± 30 %         | 7 %<br>7 %              |                                                                                                               |
| 360 ns Current                | (0.3 to 1.2) A, ± 50 %<br>(1.2 to 4.5) A, ± 50 %           | 12 %<br>12 %            |                                                                                                               |
| 400 ns Current                | (0.55 to 2.2) A, ± 30 %<br>(2.2 to 8.25) A, ± 30 %         | 7 %<br>7 %              |                                                                                                               |
| 800 ns Current                | (0.3 to 1.2) A, ± 50 %<br>(1.2 to 4.5) A, ± 50 %           | 12 %<br>12 %            |                                                                                                               |

| Parameter/Equipment                           | Range                                            | CMC <sup>2, 5</sup> (±)           | Comments                                                                     |
|-----------------------------------------------|--------------------------------------------------|-----------------------------------|------------------------------------------------------------------------------|
| Surge Simulators <sup>3</sup> –               |                                                  |                                   |                                                                              |
| Open Circuit Voltage<br>Waveform              |                                                  |                                   |                                                                              |
| Peak Voltage<br>Under / Overshoot<br>Voltage  | ± (0.5 to 7) kV, ± 10 %<br>± (Up to 2.1) kV      | 3.5 %<br>3.5 % of Peak<br>Voltage | IEC 61000-4-5<br>Teseq MD210,<br>MD300<br>Tektronix<br>TDS7704B,<br>DPO7254C |
| (1.2 µs/50 µs)<br>Front Time                  | 1.2 µs ± 30 %                                    | 16 ns                             |                                                                              |
| Rise Time                                     | 1 µs ± 30 %                                      | 16 ns                             |                                                                              |
| Time to Half Value<br>Duration Time           | 50 µs +10 µs/-35 µs<br>50 µs ± 20 %              | 0.35 µs<br>0.35 µs                |                                                                              |
| (10 µs/700 µs)<br>Front Time                  | 10 µs ± 30 %                                     | 0.10 µs                           |                                                                              |
| Rise Time                                     | 6.5 µs ± 30 %                                    | 0.10 µs                           |                                                                              |
| Time to Half Value/<br>Duration Time          | 700 µs ± 20 %<br>700 µs ± 20 %                   | 5.0 µs<br>5.0 µs                  |                                                                              |
| Short Circuit Current<br>Waveform             |                                                  |                                   |                                                                              |
| Peak Current<br>Under / Over Shoot<br>Current | ± (12.5 A to 3.5 kA) ± 10 %<br>± (Up to 1.05) kA | 3.0 %<br>3.0 % of Peak<br>Current |                                                                              |
| (8 µs/20 µs)<br>Front Time                    | 8 µs ± 20 %<br>2.5 µs ± 30 %                     | 70 ns<br>80 ns                    |                                                                              |
| Rise Time                                     | 6.4 µs ± 20 %                                    | 70 ns                             |                                                                              |
| Time to Half Value                            | 20 µs ± 20 %                                     | 0.15 µs                           |                                                                              |
| Duration Time                                 | 25 µs ± 30 %<br>16 µs ± 20 %                     | 0.25 µs<br>0.15 µs                |                                                                              |
| (5 µs/320 µs)<br>Front Time                   | 5 µs ± 20 %                                      | 50 ns                             |                                                                              |
| Rise Time                                     | 4 µs ± 20 %                                      | 50 ns                             |                                                                              |
| Time to Half Value<br>Duration Time           | 320 µs ± 20 %<br>300 µs ± 20 %                   | 3.0 µs<br>3.0 µs                  |                                                                              |
| Phase Shifting                                | (0 to 360) °                                     | 0.78 °                            |                                                                              |

| Parameter/Equipment                                       | Range                                                                                                                           | CMC <sup>2, 4, 5</sup> (±)                                                                           | Comments                                                                              |
|-----------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|
| Surge Simulators <sup>3</sup> – (cont)                    |                                                                                                                                 |                                                                                                      |                                                                                       |
| Transient Voltage Surge                                   |                                                                                                                                 |                                                                                                      |                                                                                       |
| Voltage                                                   | ± (1 to 600) V                                                                                                                  | 1.5 %                                                                                                | ISO 7637-2<br>Teseq MD210,<br>Tektronix<br>TDS7704B,<br>DPO7254C                      |
| Rise Time                                                 | 0.5 µs to 10 ms<br>5 ns ± 1.5 ns                                                                                                | 1 %<br>3.5 %                                                                                         |                                                                                       |
| Duration Time                                             | 105 ns to 2.4 s                                                                                                                 | 2 %                                                                                                  |                                                                                       |
| Pulse Duration Time                                       | 0.5 ms to 20 s                                                                                                                  | 1 %                                                                                                  |                                                                                       |
| Pulse Energy                                              | 105 ns to 2.4 s<br>Up to 130 J                                                                                                  | 4 %                                                                                                  |                                                                                       |
| Voltage Dip Simulator <sup>3</sup> –                      |                                                                                                                                 |                                                                                                      |                                                                                       |
| AC Voltage                                                | (0 to 230) V                                                                                                                    | 0.20 %                                                                                               | IEC 61000-4-11<br>Multimeter,<br>differential probe &<br>digital oscilloscope         |
| Rise time                                                 | (1 to 5) µs                                                                                                                     | 0.50 µs                                                                                              |                                                                                       |
| Fall time                                                 | (1 to 5) µs                                                                                                                     | 0.30 µs                                                                                              |                                                                                       |
| Phase Relationship                                        | (0 to 360) ° at 50 Hz<br>(0 to 360) ° at 60 Hz                                                                                  | 3 °<br>4 °                                                                                           |                                                                                       |
| RF Current Probes <sup>3</sup> –                          |                                                                                                                                 |                                                                                                      |                                                                                       |
| Bulk Current Injection<br>Probes Insertion Loss           | 10 kHz to 400 MHz<br>400 MHz to 1 GHz                                                                                           | 0.50 dB<br>0.70 dB                                                                                   | ISO11452-4<br>Agilent E5061B                                                          |
| Current Monitoring<br>Probes Transfer<br>Impedance        | 50 Hz to 400 MHz<br>400 MHz to 1 GHz                                                                                            | 0.50 dB<br>0.70 dB                                                                                   | CISPR16-1-2<br>ISO11452-4<br>Agilent E5061B                                           |
| Reflection Coefficient <sup>3</sup><br>Mag(lin)/Phase (°) | 9 kHz to 3 GHz<br>Magnitude (0 to 0.3)<br>Phase (0 to 180) °<br><br>(3 to 18) GHz<br>Magnitude (0 to 0.3)<br>Phase (0 to 180) ° | 0.010<br>$\sin^{-1} (0.01/ I ) \times 180/\pi$<br><br>0.020<br>$\sin^{-1} (0.02/ I ) \times 180/\pi$ | Agilent E5061B,<br>85032F, E5071C,<br>85054D, 85054B,<br>Anritsu 28N50-2,<br>28NF50-2 |

| Parameter/Equipment                                                         | Range           | CMC <sup>2</sup> (±) | Comments                                              |
|-----------------------------------------------------------------------------|-----------------|----------------------|-------------------------------------------------------|
| Monopole (Rod) Antenna <sup>3</sup><br>Antennae Factor                      | 9 kHz to 30 MHz | 1.0 dB               | CISPR16-1-6<br>Agilent E5061B                         |
| SVSWR Validation Test <sup>3</sup><br>Vertical / Horizontal<br>polarization | (1 to 18) GHz   | 0.67 dB              | CISPR 16-1-4,<br>Network analyzer<br>Anechoic Chamber |

## VI. Mechanical

| Parameter/Equipment                                  | Range                                                                                                                       | CMC <sup>2, 5</sup> (±)                                                      | Comments                                    |
|------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------|---------------------------------------------|
| Pressure Gage –<br><br>Oil Pressure<br>Gage Pressure | (0 to 4) MPa<br>(> 4 to 5) MPa<br>(>5 to 6) MPa<br>(>6 to 8) MPa<br>(>8 to 10) MPa<br>(>10 to 100) MPa<br>(>100 to 250) MPa | 0.86 kPa<br>0.98 kPa<br>1.2 kPa<br>1.5 kPa<br>1.8 kPa<br>0.028 %<br>0.20 MPa | Pressure balance,<br>digital pressure gauge |
| Pressure Gage –<br><br>Air Pressure<br>Gage Pressure | (-100 to 0) kPa<br>(0 to 500) kPa<br><br>(>500 to 3500) kPa                                                                 | 0.022 kPa<br>Larger of 0.010 % or<br>0.010 kPa<br>0.010 %                    | Pressure controller,<br>pressure balance    |

| Parameter/Equipment                                                                                | Range                                                                                                                                                                                                                                                                       | CMC <sup>2, 5</sup> (±)                                                                                                           | Comments                                                                            |
|----------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|
| Pressure Gage – (cont)<br><br>Air Pressure<br>Low Pressure (Gage Pressure & Differential Pressure) | (-20 to < -15) kPa<br>(-15 to < -10) kPa<br>(-10 to < -7.5) kPa<br>(-7.5 to < -5) kPa<br>(-5 to < -2.5) kPa<br>(-2.5 to < -1) kPa<br>(-1 to 1) kPa<br>(> 1 to 2.5) kPa<br>(> 2.5 to 5) kPa<br>(> 5 to 7.5) kPa<br>(> 7.5 to 10) kPa<br>(> 10 to 15) kPa<br>(> 15 to 20) kPa | 2.8 Pa<br>2.2 Pa<br>1.7 Pa<br>1.2 Pa<br>1.1 Pa<br>0.96 Pa<br>0.80 Pa<br>0.96 Pa<br>1.1 Pa<br>1.2 Pa<br>1.7 Pa<br>2.2 Pa<br>2.8 Pa | Low pressure controller;<br><br>[Line Pressure: 100 kPa ± 5kPa (absolute pressure)] |
| Pressure Gage –<br><br>Air Pressure<br>Absolute Pressure                                           | (8 to 100) kPa<br>(> 100 to 150) kPa<br>(> 150 to 200) kPa<br>(> 200 to 250) kPa<br>(> 250 to 300) kPa<br>(> 300 to 350) kPa                                                                                                                                                | 0.025 kPa<br>0.031 kPa<br>0.038 kPa<br>0.045 kPa<br>0.053 kPa<br>0.061 kPa                                                        | Pressure controller, digital pressure gauge                                         |
| Pressure Balance –<br><br>Oil Pressure<br>Gage Pressure                                            | (0.5 to 5) MPa<br>(> 5 to 10) MPa<br>(> 10 to 100) MPa                                                                                                                                                                                                                      | 2.6 kPa<br>4.0 kPa<br>Larger of 0.046 % or 23 kPa                                                                                 | Digital pressure gauge                                                              |
| Scales & Balances <sup>3</sup><br>(Electric Type & Mechanical Type)                                | (< 500 to ≤ 600) kg<br>(< 450 to ≤ 500) kg<br>(< 400 to ≤ 450) kg<br>(< 350 to ≤ 400) kg<br>(< 300 to ≤ 350) kg<br>(< 150 to ≤ 300) kg<br>(< 12 to ≤ 150) kg<br><br>(< 5 to ≤ 12) kg<br>(< 2 to ≤ 5) kg<br>(< 1 to ≤ 2) kg                                                  | 56 µg/g<br>52 µg/g<br>50 µg/g<br>46 µg/g<br>42 µg/g<br>16 µg/g<br>8.0 µg/g<br><br>8.0 µg/g<br>1.5 µg/g<br>2.3 µg/g                |                                                                                     |

| Parameter/Equipment                                                             | Range                  | CMC <sup>2</sup> (±) | Comments                                                      |
|---------------------------------------------------------------------------------|------------------------|----------------------|---------------------------------------------------------------|
| Scales & Balances <sup>3</sup><br>(Electric Type &<br>Mechanical Type) - (cont) | (< 90 to ≤ 1000) g     | 2.6 µg/g             | Calibration using<br>class<br>E2, F1, F2, M1, &<br>M2 weights |
|                                                                                 | (< 50 to ≤ 90) g       | 3.9 µg/g             |                                                               |
|                                                                                 | (< 40 to ≤ 50) g       | 2.3 µg/g             |                                                               |
|                                                                                 | (< 30 to ≤ 40) g       | 5.1 µg/g             |                                                               |
|                                                                                 | (< 20 to ≤ 30) g       | 6.6 µg/g             |                                                               |
|                                                                                 | (< 10 to ≤ 20) g       | 5.1 µg/g             |                                                               |
|                                                                                 |                        |                      |                                                               |
|                                                                                 | (< 5 to ≤ 10) g        | 10 µg/g              |                                                               |
|                                                                                 | (< 3 to ≤ 5) g         | 19 µg/g              |                                                               |
|                                                                                 | (< 2 to ≤ 3) g         | 16 µg/g              |                                                               |
|                                                                                 | (< 1 to ≤ 2) g         | 12 µg/g              |                                                               |
|                                                                                 |                        |                      |                                                               |
|                                                                                 | (< 0.9 to ≤ 1) g       | 19 µg/g              |                                                               |
|                                                                                 | (< 0.7 to ≤ 0.9) g     | 50 µg/g              |                                                               |
|                                                                                 | (< 0.5 to ≤ 0.7) g     | 44 µg/g              |                                                               |
|                                                                                 | (< 0.4 to ≤ 0.5) g     | 33 µg/g              |                                                               |
|                                                                                 | (< 0.3 to ≤ 0.4) g     | 60 µg/g              |                                                               |
|                                                                                 | (< 0.2 to ≤ 0.3) g     | 86 µg/g              |                                                               |
|                                                                                 | (< 0.1 to ≤ 0.2) g     | 54 µg/g              |                                                               |
|                                                                                 |                        |                      |                                                               |
|                                                                                 | (< 0.09 to ≤ 0.1) g    | 0.13 mg/g            |                                                               |
|                                                                                 | (< 0.08 to ≤ 0.09) g   | 0.25 mg/g            |                                                               |
|                                                                                 | (< 0.07 to ≤ 0.08) g   | 0.27 mg/g            |                                                               |
|                                                                                 | (< 0.06 to ≤ 0.07) g   | 0.22 mg/g            |                                                               |
|                                                                                 | (< 0.05 to ≤ 0.06) g   | 0.24 mg/g            |                                                               |
|                                                                                 | (< 0.04 to ≤ 0.05) g   | 0.17 mg/g            |                                                               |
|                                                                                 | (< 0.03 to ≤ 0.04) g   | 0.36 mg/g            |                                                               |
|                                                                                 | (< 0.02 to ≤ 0.03) g   | 0.43 mg/g            |                                                               |
|                                                                                 | (< 0.01 to ≤ 0.02) g   | 0.36 mg/g            |                                                               |
|                                                                                 |                        |                      |                                                               |
|                                                                                 | (< 0.009 to ≤ 0.01) g  | 0.59 mg/g            |                                                               |
|                                                                                 | (< 0.008 to ≤ 0.009) g | 1.6 mg/g             |                                                               |
|                                                                                 | (< 0.007 to ≤ 0.008) g | 1.8 mg/g             |                                                               |
|                                                                                 | (< 0.006 to ≤ 0.007) g | 1.4 mg/g             |                                                               |
|                                                                                 | (< 0.005 to ≤ 0.006) g | 1.6 mg/g             |                                                               |
|                                                                                 | (< 0.004 to ≤ 0.005) g | 0.96 mg/g            |                                                               |
|                                                                                 | (< 0.003 to ≤ 0.004) g | 2.4 mg/g             |                                                               |
|                                                                                 | (< 0.002 to ≤ 0.003) g | 3.2 mg/g             |                                                               |
|                                                                                 | (< 0.001 to ≤ 0.002) g | 2.4 mg/g             |                                                               |
|                                                                                 | 0.001 g                | 4.8 mg/g             |                                                               |

| Parameter/Equipment                              | Range                                                                                                                                                                                   | CMC <sup>2,5</sup> (±)                                                             | Comments                      |
|--------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|-------------------------------|
| Rotational Speed –                               |                                                                                                                                                                                         |                                                                                    |                               |
| Tachometers –<br>Optical<br>(Non-Contact)        | (6 to 6000) rpm<br>(6000 to 100 000) rpm<br>(0.1 to 1000) rps<br>(1000 to 1666.5) rps                                                                                                   | 0.060 rpm<br>0.070 rpm<br>0.010 rps<br>0.030 rps                                   | Frequency counter             |
| Tachometers –<br>For Engine<br>(Non-Contact)     | (100 to 10 000) rpm                                                                                                                                                                     | 0.60 rpm                                                                           |                               |
| Tachometers –<br>Digital/Mechanical<br>(Contact) | (40 to 15 000) rpm<br>(0.6667 to 250) rps                                                                                                                                               | 1.2 rpm<br>0.020 rps                                                               | Revolution generator          |
| Speed Meter –<br>Digital/Mechanical<br>(Contact) | (1.3 to 100) m/min<br>(> 100 to 200) m/min<br>(> 200 to 470) m/min<br><br>(21 to 942) mm/sec<br>(> 942 to 2618) mm/sec<br>(> 2618 to 7854) mm/sec                                       | 0.30 m/min<br>0.60 m/min<br>1.4 m/min<br><br>3.0 mm/sec<br>8.0 mm/sec<br>22 mm/sec | Revolution generator          |
| Force Gage <sup>3</sup> ,<br>Push-Pull Gage      | 10 mN to 100 mN<br>100 mN to 2 kN<br>(Tension)<br><br>10 mN to 100 mN<br>100 mN to 0.5 kN<br>(Compression)<br><br>0.01 kN to 5 kN<br>(Tension)<br><br>0.01 kN to 50 kN<br>(Compression) | 0.20 %<br>0.10 %<br><br>0.20 %<br>0.10 %<br><br>0.20 %<br>0.20 %                   | Weights<br><br><br>Load cells |
| Tension Gage <sup>3</sup>                        | 10 mN to 2 kN                                                                                                                                                                           | 0.20 % F.S                                                                         | Weights                       |
| Compression Gage <sup>3</sup>                    | 10 mN to 0.5 kN                                                                                                                                                                         | 0.20 % F.S.                                                                        | Weights                       |

| Parameter/Range                                                                                                      | Frequency                                                                                                                                                                                                                   | CMC <sup>2, 5</sup> (±)                                                                                      | Comments                                                                                                                                                         |
|----------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Accelerometer Sensitivity<br>Charge Sensitivity<br>(10 <sup>-4</sup> to 10 <sup>2</sup> ) pC/(m/s <sup>2</sup> )     | (20 to < 31.5) Hz<br>(31.5 to 160) Hz<br>(> 160 to 200) Hz<br>(> 200 to 250) Hz<br>(> 250 to 315) Hz<br>(> 315 to 400) Hz<br><br>(> 0.4 to 2) kHz<br><br>(5 to < 2000) Hz<br>(2000) Hz<br>(> 2 to 5) kHz<br>(> 5 to 10) kHz | 1.0 %<br>0.90 %<br>1.0 %<br>1.1 %<br>1.2 %<br>1.6 %<br><br>1.0 %<br><br>1.4 %<br>1.5 %<br>1.7 %<br>2.0 %     | Laser interferometry<br>(fringe-counting method)<br><br><br><br><br><br>Laser interferometry<br>(minimum-point method)<br><br>Secondary vibration<br>calibration |
| Vibration Meter –<br><br>(0.1 to 500) m/s <sup>2</sup><br><br>(0.002 to 80) cm/s<br><br>0.1 µm to 10 mm              | <br><br>(5 to 5000) Hz<br>(> 5 to 10) kHz<br><br>(5 to 5000) Hz<br>(> 5 to 10) kHz<br><br>(5 to 500) Hz                                                                                                                     | <br><br>2.0 %<br>3.0 %<br><br>2.0 %<br>3.0 %<br><br>2.0 %                                                    | Secondary vibration<br>calibration:<br><br>Acceleration or output<br>voltage<br><br>Velocity or output<br>voltage<br><br>Displacement or output<br>voltage       |
| Vibration Exciter <sup>3</sup> –<br><br>(0.1 to 3000) m/s <sup>2</sup><br>(1 to 3000) cm/s<br><br>(0.1 mm to 100 mm) | <br><br>(5 to 5000) Hz<br><br>(5 to 4000) Hz<br>(> 4 to 5) kHz<br><br>(5 to 40) Hz<br>(> 40 to 315) Hz<br><br>(5 to 5000) Hz                                                                                                | <br><br>3.0 %<br><br>3.0 %<br>5.0 %<br><br>3.0 %<br>4.0 %<br><br>0.010 %                                     | Secondary vibration<br>calibration:<br><br>Acceleration<br><br>Velocity<br><br>Displacement<br><br>Frequency                                                     |
| Accelerometer Sensitivity<br>Voltage Sensitivity<br>(10 <sup>-6</sup> to 10) V/(m/s <sup>2</sup> )                   | (20 to < 31.5) Hz<br>(31.5 to 160) Hz<br>(> 160 to 200) Hz<br>(> 200 to 250) Hz<br>(> 250 to 315) Hz<br>(> 315 to 400) Hz<br><br>(> 0.4 to 2) kHz<br><br>(5 to < 2000) Hz<br>(2000) Hz<br>(> 2 to 5) kHz<br>(> 5 to 10) kHz | 0.70 %<br>0.60 %<br>0.70 %<br>0.80 %<br>1.0 %<br>1.4 %<br><br>0.70 %<br><br>1.2 %<br>1.4 %<br>1.6 %<br>2.0 % | Laser interferometry<br>(fringe-counting method)<br><br><br><br><br><br>Laser interferometry<br>(minimum-point method)<br><br>Secondary vibration<br>calibration |

| Parameter/Range                           | Frequency                                             | CMC <sup>2, 5</sup> (±) | Comments                                                            |
|-------------------------------------------|-------------------------------------------------------|-------------------------|---------------------------------------------------------------------|
| Vibration Calibrator                      | (20 to 500) Hz                                        | 0.004 %                 | Frequency                                                           |
|                                           | (1 to 100) m/s <sup>2</sup><br>(20 to 500) Hz         | 1.7 %                   | Acceleration                                                        |
|                                           | (1 to 10) cm/s<br>(20 to 500) Hz                      | 1.7 %                   | Velocity                                                            |
|                                           | (10 µm to 20 mm)<br>(20 to 315) Hz                    | 1.6 %                   | Displacement                                                        |
| Charge Amplifier & Other<br>Charge Device |                                                       |                         | Capacitor, multimeter                                               |
| Sensitivity                               | (2×10 <sup>-5</sup> to 10) V/pC                       |                         |                                                                     |
|                                           | (1.5 to <150) pC<br>(20 to <50) Hz<br>50 Hz to 10 kHz | 0.52 %<br>0.44 %        | Reading of output voltage                                           |
| Indication Value                          | (150 to 5000) pC<br>20 Hz to 10 kHz                   | 0.24 %                  |                                                                     |
|                                           | (1.5 to <150) pC<br>(20 to <50) Hz<br>50 Hz to 10 kHz | 0.58 %<br>0.50 %        | Reading of output voltage<br>with power supply                      |
|                                           | (150 to 5000) pC<br>20 Hz to 10 kHz                   | 0.36 %                  |                                                                     |
|                                           | (1.5 to <150) pC<br>(20 to <50) Hz<br>50 Hz to 10 kHz | 0.52 %<br>0.42 %        | Indicated value of<br>acceleration, velocity,<br>displacement, etc. |
|                                           | (150 to 5000) pC<br>20 Hz to 10 kHz                   | 0.22 %                  |                                                                     |

| Parameter/Equipment                                                      | Range                                                                                                                                                                                                | CMC <sup>2, 5</sup> (±)                                                                                                                                                                                      | Comments                                                                                            |
|--------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------|
| Direct Verification of Rockwell Hardness Testing Machines <sup>3</sup> – |                                                                                                                                                                                                      |                                                                                                                                                                                                              | Direct calibration method per JIS B 7726 or ASTM E18                                                |
| Verification of the Test Force                                           | 98.07 N (10 kgf)<br>(588.4 to 1471) N<br>(60 to 150) kgf                                                                                                                                             | 0.37 N<br>0.95 N                                                                                                                                                                                             | Verification of the test force by force-proving instruments per the method of JIS B 7721 or ASTM E4 |
|                                                                          | 29.42 N (3 kgf)<br>(147.1 to 294.2) N<br>(15 to 30) kgf                                                                                                                                              | 0.21 N<br>0.54 N                                                                                                                                                                                             | Force-proving instruments                                                                           |
| Verification of the Measuring Device                                     | (0 to 250) µm<br>(0 to 100) µm                                                                                                                                                                       | 0.76 µm<br>0.55 µm                                                                                                                                                                                           | Index-Master<br>Index-Master                                                                        |
|                                                                          |                                                                                                                                                                                                      |                                                                                                                                                                                                              | Note: not full verification                                                                         |
| Indirect Verification of Rockwell Hardness Testing Machines <sup>3</sup> | C scale<br>Low<br>Medium<br>High<br><br>B scale<br>Low<br>Medium<br>High<br><br>A scale<br>Low<br>Medium<br>High<br><br>30N scale<br>Low<br>Medium<br>High<br><br>30T scale<br>Low<br>Medium<br>High | 0.25 HRC<br>0.29 HRC<br>0.23 HRC<br><br>0.61 HRB<br>0.36 HRB<br>0.40 HRB<br><br>0.23 HRA<br>0.24 HRA<br>0.18 HRA<br><br>0.29 HR30N<br>0.38 HR30N<br>0.28 HR30N<br><br>0.39 HR30T<br>0.27 HR30T<br>0.28 HR30T | Indirect calibration method per JIS B 7726 or ASTM E18 standard blocks                              |

| Parameter/Equipment                                                                  | Range                                                                        | CMC <sup>2</sup> (±)                                                                 | Comments                                                                                                               |
|--------------------------------------------------------------------------------------|------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------|
| Indirect Verification of Rockwell Hardness Testing Machines <sup>3</sup> (cont)      | 15N scale<br>Low<br>Medium<br>High<br><br>15T scale<br>Low<br>Medium<br>High | 0.34 HR15N<br>0.33 HR15N<br>0.35 HR15N<br><br>0.40 HR15T<br>0.39 HR15T<br>0.39 HR15T | Indirect calibration method per JIS B 7726 or ASTM E18 standard blocks                                                 |
| Indirect Verification of MicroVickers Hardness Testing Machines <sup>3</sup>         | (100 to 250) HV<br>(> 250 to 650) HV<br>(> 650 to 900) HV                    | 3.2 HV<br>36 HV<br>10 HV                                                             | Indirect calibration method per JIS B 7725 or ASTM E92 standard blocks                                                 |
| Indirect Verification of Knoop Hardness Testing Machines <sup>3</sup>                | (100 to 250) HK<br>(> 250 to 650) HK<br>(> 650 to 900) HK                    | 21 HK<br>34 HK<br>51 HK                                                              | Indirect calibration method per JIS B 7734 or ASTM E92 standard blocks                                                 |
| Direct Verification of MicroVickers & Knoop Hardness Testing Machines <sup>3</sup> – |                                                                              |                                                                                      | Direct calibration method per JIS B 7725 or JIS B 7734 or ASTM E92                                                     |
| Verification of the Test Force                                                       | 98.07 mN to 19.61 N<br>10 gf to 2 kgf                                        | 0.037 N                                                                              | Verification of the test force by force-proving instruments & electric balance Per the method of JIS B 7721 or ASTM E4 |
| Verification of the Measuring Device                                                 | (0 to 1) mm                                                                  | 1.3 µm                                                                               | Stage micrometer<br>Note: not full verification                                                                        |
| Indirect Verification of Vickers Hardness Testing Machines <sup>3</sup>              | (100 to 250) HV<br>(> 250 to 650) HV<br>(> 650 to 900) HV                    | 6.0 HV<br>16 HV<br>20 HV                                                             | Indirect calibration method per JIS B 7725 or ASTM E92 standard blocks                                                 |

| Parameter/Equipment                                                     | Range                               | CMC <sup>2, 5</sup> ( $\pm$ ) | Comments                                                                                            |
|-------------------------------------------------------------------------|-------------------------------------|-------------------------------|-----------------------------------------------------------------------------------------------------|
| Direct Verification of Vickers Hardness Testing Machines <sup>3</sup> – |                                     |                               | Direct calibration method per JIS B 7725 or ASTM E92                                                |
| Verification of the Test Force                                          | (19.61 to 490.3) N<br>(2 to 50) kgf | 0.73 N                        | Verification of the test force by force-proving instruments per the method of JIS B 7721 or ASTM E4 |
| Verification of the Measuring Device                                    | (0 to 1) mm                         | 1.3 $\mu$ m                   | Stage micrometer<br>Note: Not full verification                                                     |
| Indirect Verification of Brinell Hardness Testing Machines <sup>3</sup> | (250 to 450) HBW<br>Under 250 HBW   | 6.2 HBW<br>3.7 HBW            | Indirect calibration method per JIS B7724 standard blocks                                           |
| Indirect Verification of Brinell Hardness Testing Machines <sup>3</sup> | (225 to 450) HBW<br>Under 225 HBW   | 6.2 HBW<br>3.7 HBW            | Indirect calibration method per ASTM E10 standard blocks                                            |
| Direct Verification of Brinell Hardness Testing Machines <sup>3</sup> – |                                     |                               | Direct calibration method per JIS B7724 or ASTM E10                                                 |
|                                                                         | 0.09807 kN~4.903 kN                 | 0.0012 kN                     | Verification of the test force by force-proving instruments per the method of JIS B 7721 or ASTM E4 |
| Verification of the Test Force                                          | 4.903 to 29.42 kN                   | 0.085 kN                      | Force-proving instruments                                                                           |
| Verification of the Measuring Device                                    | (0 to 8) mm                         | 4.3 $\mu$ m                   | Stage micrometer<br>Note: not full verification                                                     |
| Shore Hardness Testing Machine <sup>3</sup>                             | (25 to 100) HS (VHS)                | 0.86 HS                       | Indirect calibration method per JIS B7727<br>Standard blocks                                        |

| Parameter/Equipment                                                                                                                                | Range                                       | CMC <sup>2, 5</sup> (±) | Comments                                                                       |
|----------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------|-------------------------|--------------------------------------------------------------------------------|
| Leeb Hardness Testing Machine <sup>3</sup>                                                                                                         | 400 HLD to 800 HLD                          | 11 HLD                  | Indirect calibration method per ASTM A956/956M                                 |
| Torque Measuring Devices <sup>3</sup> ,<br>Torque Wrench Tester,<br>Torque Tester,<br>Torque Driver Tester,<br>Torque Meter,<br>Torque Gauge, etc. | 10 mN·m to 20 N·m<br><br>0.4 N·m to 2 kN·m  | 0.18 %<br><br>0.25 %    | Lever-mass-system (moment-arm & weights)<br><br>Reference torque meter         |
| Torque Tools <sup>3</sup> ,<br>Torque Wrench,<br>Torque Screwdriver,<br>Torque Gauge, etc.                                                         | 20 mN·m to 2 kN·m                           | 0.71 %                  | Torque wrench tester,<br>torque tester,<br>torque driver tester                |
| Spring Hammer                                                                                                                                      | (≥ 0.2 to 1) J                              | 0.010 J                 | Spring hammer calibration device                                               |
| Uniaxial Testing Machines <sup>3</sup><br>—                                                                                                        |                                             |                         |                                                                                |
| Tension Force                                                                                                                                      | 0.1 N to 100 kN                             | 0.20 %                  | Calibration method per JIS B7721;<br>Loop tester, load cells, & dead weights   |
| Compression Force                                                                                                                                  | 0.1 N to 3 MN                               | 0.20 %                  |                                                                                |
| Tension Force                                                                                                                                      | 0.1 N to 100 kN                             | 0.25 %                  | Calibration method per ASTM E4;<br>Loop tester, load cells, & dead weights     |
| Compression Force                                                                                                                                  | 0.1 N to 500 kN<br>500 kN to 3 MN           | 0.23 %<br>0.50 %        |                                                                                |
| Crosshead Speed                                                                                                                                    | (0.5 to 500) mm/min<br>(500 to 1000) mm/min | 0.40 %<br>1.3 %         | Height gauge or Digital (Dial) indicator & stopwatch, laser measurement system |
| Crosshead Distance                                                                                                                                 | (0.5 to 5) mm<br>(5 to 600) mm              | 1.1 %<br>0.40 %         | Height gauge, laser measurement system<br>Digital (Dial) indicator             |

| Parameter/Equipment | Range                                                                                                                                                                                                          | CMC <sup>2</sup> (±)                                                                                                                             | Comments    |
|---------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------|-------------|
| Graduated Cylinder  | Up to 5 mL<br>Up to 20 mL<br>Up to 25 mL<br>Up to 50 mL<br>Up to 100 mL<br>Up to 200 mL<br>Up to 300 mL<br>Up to 500 mL<br>Up to 1000 mL<br>Up to 2000 mL                                                      | 0.030 mL<br>0.067 mL<br>0.079 mL<br>0.16 mL<br>0.25 mL<br>0.51 mL<br>0.77 mL<br>1.6 mL<br>2.8 mL<br>5.1 mL                                       | Mass method |
| Flask               | Up to 10 mL<br>Up to 25 mL<br>Up to 50 mL<br>Up to 100 mL<br>Up to 200 mL<br>Up to 250 mL<br>Up to 300 mL<br>Up to 500 mL<br>Up to 1000 mL<br>Up to 2000 mL<br>Up to 2500 mL<br>Up to 3000 mL<br>Up to 5000 mL | 0.017 mL<br>0.021 mL<br>0.031 mL<br>0.053 mL<br>0.073 mL<br>0.079 mL<br>0.11 mL<br>0.14 mL<br>0.26 mL<br>0.34 mL<br>0.57 mL<br>0.74 mL<br>1.1 mL | Mass method |
| Volumetric Pipette  | Up to 1 mL<br>Up to 2 mL<br>Up to 5 mL<br>Up to 10 mL<br>Up to 20 mL<br>Up to 25 mL<br>Up to 50 mL<br>Up to 100 mL<br>Up to 200 mL                                                                             | 0.0056 mL<br>0.0081 mL<br>0.016 mL<br>0.021 mL<br>0.023 mL<br>0.025 mL<br>0.030 mL<br>0.040 mL<br>0.056 mL                                       | Mass method |
| Graduated Pipette   | Up to 0.5 mL<br>Up to 1 mL<br>Up to 2 mL<br>Up to 5 mL<br>Up to 10 mL<br>Up to 25 mL<br>Up to 50 mL                                                                                                            | 0.0039 mL<br>0.0063 mL<br>0.0093 mL<br>0.019 mL<br>0.027 mL<br>0.049 mL<br>0.093 mL                                                              | Mass method |
| Burette             | Up to 5 mL<br>Up to 10 mL<br>Up to 25 mL<br>Up to 50 mL<br>Up to 100 mL                                                                                                                                        | 0.0099 mL<br>0.020 mL<br>0.030 mL<br>0.042 mL<br>0.057 mL                                                                                        | Mass method |

## VII. Optical Quantities

| Parameter/Equipment                                           | Range                                                                       | CMC <sup>2, 5</sup> ( $\pm$ )       | Comments                                                 |
|---------------------------------------------------------------|-----------------------------------------------------------------------------|-------------------------------------|----------------------------------------------------------|
| Optical Power –<br>Measuring Equipment <sup>3</sup>           |                                                                             |                                     |                                                          |
| 1310 nm                                                       | (10 to 50) $\mu$ W<br>(50 to 100) $\mu$ W<br>(100 to 500) $\mu$ W           | 1.3 %<br>0.55 %<br>0.40 %           | Calorimeter                                              |
|                                                               | 10 nW to 1 $\mu$ W<br>(1 to 500) $\mu$ W                                    | 0.63 %<br>0.56 %                    | Photodiode sensor                                        |
| 1550 nm                                                       | (10 to 50) $\mu$ W<br>(50 to 100) $\mu$ W<br>(100 to 500) $\mu$ W           | 1.3 %<br>0.55 %<br>0.40 %           | Calorimeter                                              |
|                                                               | 10 nW to 1 $\mu$ W<br>(1 to 500) $\mu$ W                                    | 0.63 %<br>0.56 %                    | Photodiode sensor                                        |
| Optical Time Domain<br>Reflectometer <sup>3</sup>             |                                                                             |                                     |                                                          |
| 1310 nm                                                       | 3000 m<br>7500 m<br>13000 m                                                 | 0.010 %<br>0.010 %<br>0.010 %       | Optical fiber                                            |
| Illuminance Meter                                             |                                                                             |                                     |                                                          |
| 2856 K<br>(400 to 720) nm                                     | (1 to 10) lx<br>(10 to 1000) lx<br>(1000 to 3000) lx<br>(3000 to 10 000) lx | 0.93 %<br>0.85 %<br>0.93 %<br>1.1 % | Photometer head &<br>electrometer                        |
| Luminance Meter<br>2856 K<br>(400 to 720) nm                  | (0.3 to 3000) cd/m <sup>2</sup>                                             | 1.8 %                               | Photometer head,<br>electrometer &<br>standard reflector |
| Chromaticity Coordinates <sup>3</sup> -<br>Light-Source Color | $0.4434 \leq x \leq 0.4494$<br>$0.4041 \leq y \leq 0.4101$                  | 0.0030<br>0.0030                    | Lamp A,<br>spectrophotometer                             |

| Parameter/Equipment                                                                         | Range                                                                                                                                                                                          | CMC <sup>2, 5</sup> ( $\pm$ )                                    | Comments                                                                                                                                        |
|---------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------|
| Chromaticity Coordinates <sup>3</sup><br>- Non-Luminous Object Color<br><br>(380 to 780) nm | $0.4445 \leq x \leq 0.4565$<br>$0.4029 \leq y \leq 0.4149$<br><br>$0.3078 \leq x \leq 0.3198$<br>$0.3143 \leq y \leq 0.3263$<br><br>$0.3104 \leq x \leq 0.3224$<br>$0.3271 \leq y \leq 0.3391$ | 0.0060<br>0.0060<br><br>0.0060<br>0.0060<br><br>0.0060<br>0.0060 | Color tile spectrophotometer<br>JIS Z 8722<br><br>Lamp A, spectrophotometer<br><br>Lamp C, spectrophotometer<br><br>Lamp D65, spectrophotometer |
| Gloss <sup>3</sup>                                                                          | (0 to 10) GU<br>(10 to 94) GU<br>(94 to 100) GU<br>(100 to 2000) GU                                                                                                                            | 0.45 GU<br>0.76 GU<br>0.68 GU<br>2.9 %                           | Gloss meter, gloss tile                                                                                                                         |

#### VIII. Thermodynamics

| Parameter/Equipment | Range                                                                                                                                                                                                                                    | CMC <sup>2</sup> ( $\pm$ )                                                                                                           | Comments                                                        |
|---------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------|
| Digital Thermometer | (-90 to < -80) °C<br>(-80 to < 0) °C<br>0 °C<br>(> 0 to 100) °C<br>(> 100 to 200) °C<br>(> 200 to 300) °C<br>(> 300 to 400) °C<br>(> 400 to 550) °C<br>(> 550 to 650) °C<br>(> 650 to 700) °C<br>(> 700 to 900) °C<br>(> 900 to 1000) °C | 0.072 °C<br>0.054 °C<br>0.035 °C<br>0.040 °C<br>0.062 °C<br>0.072 °C<br>0.072 °C<br>0.19 °C<br>0.42 °C<br>1.1 °C<br>1.8 °C<br>1.9 °C | Standard digital thermometer, freezing point measurement device |

| Parameter/Equipment                                                               | Range                                                                                                                                                                                                                             | CMC <sup>2</sup> (±)                                                                                                                                                                                                              | Comments                                                                                                                          |
|-----------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------|
| Contact Thermometer                                                               | (-50 to 30) °C<br>(> 30 to 100) °C<br>(> 100 to 200) °C<br>(> 200 to 300) °C<br>(> 300 to 400) °C<br>(> 400 to 500) °C                                                                                                            | 0.70 °C<br>0.90 °C<br>1.0 °C<br>1.2 °C<br>1.3 °C<br>1.5 °C                                                                                                                                                                        | Standard digital thermometer, contact thermometer & surface plate; freezing point measurement device                              |
| Liquid in Glass Thermometer <sup>6</sup>                                          | (-80 to < 0) °C<br>0 °C<br>(> 0 to 100) °C<br>(> 100 to 200) °C<br>(> 200 to 300) °C<br>(> 300 to 350) °C                                                                                                                         | 0.060 °C<br>0.060 °C<br>0.060 °C<br>0.070 °C<br>0.080 °C<br>0.10 °C                                                                                                                                                               | Standard digital thermometer, standard liquid in glass thermometer, freezing point measurement device                             |
| Mechanical Thermometer                                                            | (-80 to 300) °C<br>(> 300 to 550) °C<br>(> 550 to 650) °C<br>(> 650 to 700) °C                                                                                                                                                    | 0.70 °C<br>0.70 °C<br>0.80 °C<br>1.2 °C                                                                                                                                                                                           | Standard digital thermometer, freezing point measurement device                                                                   |
| Thermocouple<br><br>Type K, E, J, T<br><br><br><br><br><br><br><br><br><br>Type R | (-80 to 300) °C<br>(> 300 to 400) °C<br>(> 400 to 500) °C<br>(> 500 to 650) °C<br>(> 650 to 700) °C<br>(> 700 to 1000) °C<br><br>(-50 to < 0) °C<br>(0 to 300) °C<br>(> 300 to 650) °C<br>(> 650 to 700) °C<br>(> 700 to 1000) °C | 0.30 °C<br>0.30 °C<br>0.30 °C<br>0.50 °C<br>1.1 °C<br>2.0 °C<br><br>0.70 °C<br>0.50 °C<br>0.70 °C<br>1.1 °C<br>2.0 °C                                                                                                             | Standard digital thermometer, freezing point measurement device, Multimeter                                                       |
| Radiation Thermometer                                                             | (-50 to < 0) °C<br>0 °C<br>(0 to 50) °C<br>(> 50 to 100) °C<br>(> 100 to 200) °C<br>(> 200 to 300) °C<br>(> 300 to 400) °C<br>(> 400 to 500) °C                                                                                   | 1.0 °C $\epsilon = 0.997$<br>0.88 °C $\epsilon = 0.997$<br>0.87 °C $\epsilon = 0.95$<br>0.74 °C $\epsilon = 0.95$<br>1.2 °C $\epsilon = 0.95$<br>1.7 °C $\epsilon = 0.95$<br>2.4 °C $\epsilon = 0.95$<br>2.5 °C $\epsilon = 0.95$ | Blackbody, tammann tube (cavity), standard digital thermometer, freezing point measurement device;<br><br>$\epsilon$ = Emissivity |

| Parameter/Equipment                                                                                               | Range                                                                                               | CMC <sup>2</sup> (±)                                     | Comments                                                                                                    |
|-------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------|----------------------------------------------------------|-------------------------------------------------------------------------------------------------------------|
| Hygrometer                                                                                                        | (10 to 30) % RH<br>(> 30 to 40) % RH<br>(> 40 to 60) % RH<br>(> 60 to 80) % RH<br>(> 80 to 95) % RH | 0.8 % RH<br>1.2 % RH<br>1.6 % RH<br>1.9 % RH<br>2.3 % RH | Optical dew point meter                                                                                     |
| Humidity Controlled Chamber <sup>3, 10</sup>                                                                      | (10 to 98) % RH                                                                                     | 1.6 % RH                                                 | Dew point hygrometer & reference PRT JTM K09, JTM K07, IEC 60068-3-6, IEC60068-3-5                          |
| Temperature Installations-Furnaces, Ovens, Incubators, Stirred Water Baths, Fridges and Freezers <sup>3, 10</sup> | (-80 to < -50) °C<br>(-50 to 100) °C<br>(>100 to 300) °C<br>(>300 to 950) °C                        | 0.10 °C<br>0.05 °C<br>0.11 °C<br>2.5 °C                  | PRT (includes uncertainty of transfer from measurand) JTM K09, JTM K07, IEC 60068-3-6, IEC 60068-3-5, T/C's |

#### IX. Time & Frequency

| Parameter/Equipment                         | Range                                                                    | CMC <sup>2</sup> (±)                                                                                                                                                           | Comments                                                                                                                                      |
|---------------------------------------------|--------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------|
| Frequency                                   |                                                                          |                                                                                                                                                                                |                                                                                                                                               |
| Tension Meter–Sensor (Acceleration Pick-up) | (20 to 1000) Hz                                                          | 0.1 Hz                                                                                                                                                                         | Frequency counter                                                                                                                             |
| Tension Meter–Sensor (Microphone)           | (20 to 1500) Hz<br>(>1500 to 3600) Hz<br>(>3600 to 5000) Hz              | 0.1 Hz<br>0.2 Hz<br>0.3 Hz                                                                                                                                                     |                                                                                                                                               |
| Frequency – Measure / Measuring Equipment   | 10 MHz<br><br>0.1 Hz to 3 GHz<br><br>(3 to 40) GHz<br><br>(1, 5, 10) MHz | 6.6 parts in 10 <sup>13</sup> Hz/Hz<br><br>8.8 parts in 10 <sup>13</sup> Hz/Hz + 0.2 pHz<br><br>1.5 parts in 10 <sup>12</sup> Hz/Hz<br><br>0.5 parts in 10 <sup>10</sup> Hz/Hz | GPS disciplined oscillator<br><br>Counter, GPS disciplined oscillator<br><br>Rubidium frequency standard FC 6017A, frequency difference meter |

| Parameter/Equipment                                       | Range                                  | CMC <sup>2, 5</sup> (±)          | Comments                                                    |
|-----------------------------------------------------------|----------------------------------------|----------------------------------|-------------------------------------------------------------|
| Frequency – Measure /<br>Measuring Equipment <sup>3</sup> | (1, 10) MHz                            | 8 parts in 10 <sup>9</sup> Hz/Hz | Standard frequency counter SX-1016B                         |
|                                                           | 1 mHz to 1300 MHz                      | 3 parts in 10 <sup>7</sup> Hz/Hz | Frequency counter TR 5823H                                  |
|                                                           | 100 kHz to 40 GHz                      | 5 parts in 10 <sup>8</sup> Hz/Hz | Measuring receiver FSMR43                                   |
| Time Interval Measure                                     | 49.9 ns to 49.9 µs                     | 0.13 %                           | Rubidium frequency standard FC 6017A, Oscilloscope DPO7254C |
|                                                           | 49.9 µs to 499 µs<br>499 µs to 49.9 ms | 0.037 µs<br>0.019 µs             | Rubidium frequency standard FC 6017A, Phase Meter 6000A     |
| Pulse Width - Measure                                     | 5 ns to 1 µs                           | 0.54 %                           | Oscilloscope DPO7254C                                       |
| Stopwatch <sup>3</sup>                                    | Up to 64.8 s/day<br>Up to 388.8 s/day  | 0.02 s/day<br>0.03 s/day         | Watch tester, counter                                       |

## SATELLITE

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### I. Electrical – RF/Microwave

| Parameter/Range                                                           | Frequency                                                                         | CMC <sup>2</sup> (±)                           | Comments                                      |
|---------------------------------------------------------------------------|-----------------------------------------------------------------------------------|------------------------------------------------|-----------------------------------------------|
| Antenna Factor –<br>Loop Antenna                                          |                                                                                   |                                                |                                               |
| Reference Antenna<br>Method                                               | (9 to 150) kHz<br>(150 to 500) kHz<br>(0.5 to 15) MHz<br>(15 to 30) MHz<br>30 MHz | 3.4 dB<br>2.4 dB<br>2.2 dB<br>2.1 dB<br>1.9 dB | Standard reference<br>loop antenna<br>HFH2-Z2 |
| Standard Antenna<br>Method                                                | 9 kHz to 30 MHz                                                                   | 1.3 dB                                         | CISPR16-1-6                                   |
| Antenna Factor –<br>Horn Antenna<br>Vertical / Horizontal<br>Polarization |                                                                                   |                                                |                                               |
| Standard Site Method                                                      | (1 to 18) GHz                                                                     | 1.8 dB                                         | ANSI C63.5                                    |
| 1 m Distance                                                              | (1 to 18) GHz                                                                     | 1.2 dB                                         | SAE ARP958                                    |

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

<sup>2</sup> Calibration and Measurement Capability (CMC) uncertainty is the smallest uncertainty of measurement that a laboratory can achieve within its scope of accreditation when performing more or less routine calibrations of nearly ideal measurement standards or nearly ideal measuring equipment. CMCs represent expanded uncertainties expressed at approximately the 95 % level of confidence, usually using a coverage factor of  $k = 2$ . The actual measurement uncertainty of a specific calibration performed by the laboratory may be greater than the CMC uncertainty 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 uncertainty 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 uncertainty.
- <sup>4</sup> In the statement of CMC uncertainty,  $L$  is the numerical value of the nominal length of the device measured in mm.  $\Gamma$  represents a reflection coefficient. CMC uncertainty of high frequency power does not include mismatch contribution from the device-under-test.
- <sup>5</sup> Unless otherwise noted, in the statement of CMC uncertainty, % is the uncertainty percentage of the relative value of the reading, or the relative value of the reading plus floor specification.
- <sup>6</sup> The CMC uncertainty for liquid-in-glass thermometers is based on total immersion method. The liquid-in-glass thermometers calibrated by partial immersion method will have a larger CMC
- <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. CMCs 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 accreditation covers calibrations performed at all laboratory locations listed in this scope of accreditation.
- <sup>9</sup> This laboratory meets R205 – Specific Requirements: Calibration Laboratory Accreditation Program for the types of dimensional calibrations listed above and considered equivalent to that of a calibration.
- <sup>10</sup> The contributions from the “best existing device” are not included in the CMC claim.
- <sup>11</sup> This scope meets A2LA's *P112 Flexible Scope Policy*.
- <sup>12</sup> The type of instrument or material being calibrated is defined by the parameter. This indicates the laboratory is capable of calibrating instruments that measure or generate the values in the ranges indicated for the listed measurement parameter.



# Accredited Laboratory

A2LA has accredited

## JAPAN QUALITY ASSURANCE ORGANIZATION

Osaka, JAPAN

for technical competence in the field of

### Calibration

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



Presented this 4<sup>th</sup> of April, 2024.

A blue ink signature of Mr. Trace McInturff.

Mr. Trace McInturff, Vice President, Accreditation Services  
For the Accreditation Council  
Certificate Number 1400.03  
Valid to March 31, 2026

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