



SCOPE OF ACCREDITATION TO ISO/IEC 17025:2005

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CALIBRATION

Valid To: March 31, 2020

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</sup>:

I. Chemical Quantities

Parameter/Equipment	Range	CMC <sup>2</sup> (±)	Comments
pH Indicator – Instrumental Error Linearity Repeatability	(0 to 14) pH units (0 to 14) pH units (0 to 14) pH units	0.0050 pH units 0.0050 pH units 0.0040 pH units	DC voltage
pH Detector – Instrumental Error Linearity Repeatability	4 pH units, 9 pH units 4 pH units, 7 pH units, 9 pH units 4 pH units 7 pH units 9 pH units	0.40 mV/pH 1.0 mV 0.90 mV 0.80 mV 1.9 mV	Standard solutions
pH Meters – Three-Point Calibration Instrumental Error	4 pH units 7 pH units 9 pH units	0.010 pH units 0.011 pH units 0.030 pH units	Standard solutions

Parameter/Equipment	Range	CMC <sup>2</sup> (±)	Comments
pH Meters –			Standard solutions
Two-Point Calibration Instrumental Error	4 pH units, 9 pH units 7 pH units	0.024 pH units 0.013 pH units	
One-Point Calibration Instrumental Error	4 pH units, 7 pH units, 9 pH units	0.19 pH units	

## II. Dimensional

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



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



Parameter/Equipment	Range	CMC <sup>2,4</sup> (±)	Comments
Electrical Comparators – (cont)			
Digital Resolution	$\leq 0.01 \mu\text{m}$ $\leq 0.1 \mu\text{m}$ $\leq 1.0 \mu\text{m}$	$0.09 \mu\text{m}$ $0.2 \mu\text{m}$ $2.0 \mu\text{m}$	Laser
Measuring Microscope <sup>3</sup> –			
Run & Parallelism	Up to 200 mm	$7.0 \mu\text{m}$	Glass line standard, scales, electrical comparators, square
Straightness	Up to 100 mm (> 100 to 200) mm	$1.8 \mu\text{m}$ $2.5 \mu\text{m}$	
Squareness	Up to 100 mm (> 100 to 200) mm	$1.7 \mu\text{m}$ $2.4 \mu\text{m}$	
Indication	Up to 100 mm (> 100 to 200) mm	$2.2 \mu\text{m}$ $2.5 \mu\text{m}$	
Measuring Projector <sup>3</sup> –			
Indication	Up to 200 mm	$3.8 \mu\text{m}$	Glass line standard, scales
Magnification	Up to 600 mm	0.04 % of nominal magnification	
Cylinder Gage <sup>3</sup>	Up to 1.2 mm	$5 \mu\text{m}$	Dial gage tester, dial gage
Universal Length Measuring Machine <sup>3</sup>	Up to 100 mm (> 100 to 200) mm  Up to 200 mm (> 200 to 3000) mm	$0.6 \mu\text{m}$ $0.8 \mu\text{m}$  $0.7 \mu\text{m}$ $(0.7 + L/1300) \mu\text{m}$	Gage blocks  Laser measurement system
Dial Depth Gage <sup>3</sup> –			
Dial & Digital (Resolution 0.01 mm)	Up to 200 mm	0.02 mm	Gage blocks

Parameter/Equipment	Range	CMC <sup>2</sup> (±)	Comments
Dial Depth Gage <sup>3</sup> – (cont) Digital (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 0.05 mm/m ≤ 0.02 mm/m	5.7" 2.9" 2.2"	Laser
Dial Gage Tester – Analog Digital	Up to 25 mm Up to 25 mm	0.7 μm 0.5 μm	Gage blocks, laser
Micrometer Heads – Analog Resolution ≤ 0.001 mm Resolution ≤ 0.002 mm Resolution ≤ 0.01 mm Digital Resolution ≤ 0.001 mm Resolution ≤ 0.002 mm Resolution ≤ 0.01 mm	Up to 50 mm	0.7 μm 2 μm 2 μm 0.5 μm 2 μm 2 μm	Gage blocks
Calipers <sup>3</sup> – Scale & Dial	Up to 600 mm (> 600 to 1000) mm (> 1000 to 1500) mm (> 1500 to 2000) mm	0.05 mm 0.10 mm 0.11 mm 0.13 mm	Step gages, gage blocks



Parameter/Equipment	Range	CMC <sup>2</sup> (±)	Comments
Calipers <sup>3</sup> – (cont)			
Digital	Up to 600 mm (> 600 to 1000) mm (> 1000 to 1500) mm (> 1500 to 2000) mm	0.03 mm 0.06 mm 0.07 mm 0.10 mm	Step gages, gage blocks
Dial Caliper Gages <sup>3</sup> –			
Dial Resolution 0.01 mm Resolution 0.05 mm Resolution 0.1 mm	Up to 200 mm	0.02 mm 0.05 mm 0.1 mm	Gage blocks
Digital Resolution 0.005 mm Resolution 0.01 mm Resolution 0.05 mm	Up to 200 mm	0.02 mm 0.02 mm 0.05 mm	
Height Gages <sup>3</sup> –			
Digital Resolution 0.001 mm	Up to 600 mm Up to 1000 mm	0.005 mm 0.006 mm	Step gages, gage blocks
Resolution 0.0001 mm	Up to 600 mm Up to 1000 mm	0.0045 mm 0.0053 mm	
Scale	Up to 1000 mm	0.04 mm	
Digital & Dial Resolution 0.01 mm	Up to 1000 mm	0.02 mm	
Hole Testers <sup>3</sup>	Up to 150 mm	3.0 µm	Master ring gages
Digital Indicators <sup>3</sup> –			
Resolution 0.01 mm Resolution 0.001 mm Resolution ≤ 0.0001 mm	Up to 100 mm	0.02 mm 0.002 mm 0.0013 mm	Gage blocks



Parameter/Equipment	Range	CMC <sup>2</sup> (±)	Comments
Thickness Gages <sup>3</sup> –  Dial Resolution 0.1 mm Resolution 0.01 mm Resolution 0.001 mm  Digital Resolution 0.01 mm Resolution 0.005 mm Resolution 0.001 mm	Up to 50 mm Up to 50 mm Up to 50 mm  Up to 50 mm Up to 50 mm Up to 50 mm	0.1 mm 0.01 mm 0.002 mm  0.02 mm 0.010 mm 0.002 mm	Gage blocks
Microindicators <sup>3</sup> –  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 –  Major Diameter Pitch Diameter  Major Diameter Pitch Diameter	Up to 120 mm   Up to 150 mm	1.1 μm 2.8 μm  3.4 μm 3.4 μm	ULM, thread wires   Contour measuring systems
Threads Wires –  Mean Diameter	Up to 5.05 mm	0.8 μm	ULM
Index Master – Fixed Point	Up to 250 μm	0.2 μm	Laser



Parameter/Equipment	Range	CMC <sup>2,4</sup> (±)	Comments
Surface Plate <sup>3</sup> (Flatness Only)	Up to 300 mm (Diagonal Line 430 mm)	3.5 µm	Electronic level
	(> 300 to 1000) mm (Diagonal Line 1250 mm)	3.9 µm	
	(> 1000 to 2000) mm (Diagonal Line 2500 mm)	4.8 µm	
Test Sieves –  Mesh  Line	Up to 2.36 mm (> 2.36 to 125) mm  Up to 1 mm (> 1 to 8) mm	9 µm 10 µm  9 µm 10 µm	Measuring microscope
Line Standard Scales	Up to 1 mm  (> 1 to 500) mm  (> 200 to 500) mm	0.4 µm  0.7 µm  1.3 µm	
Pattern	Up to 200 mm	1.0 µm	Laser measurement system
Coordinate Measuring Machines <sup>3</sup>	Up to 1000 mm	(1.9 + L/1200) µm	Step gage
	(> 1000 to 3000) mm	(0.7 + L/1300) µm	Laser measurement system
Protractors – Resolution 1' Resolution 5' Resolution 10' Resolution 30' Resolution 1°	Up to 360°	1.3' 1.7' 2.7' 7.1' 14'	Measuring microscope
Snap Gage	Up to 150 mm	2.6 µm	ULM, type IDM





Parameter/Equipment	Range	CMC <sup>2</sup> (±)	Comments
Screw Ring Gage – Pitch Diameter	Up to 150 mm	3.2 µm	Contour measuring systems
Contact Profilometry – Height Radius of Curvature Angle	Up to 300 mm Up to 100 mm Up to 180°	4.2 µm 3.2 µm 1.7'	Contour measuring systems
Test Bars – Diameter Run-out	Up to 100 mm	1.7 µm 1.5 µm	ULM Electric comparator
Microscope – Resolution 0.01 mm Resolution 0.02 mm Resolution 0.1 mm	Up to 10 mm	2.4 µm 2.6 µm 7 µm	Glass line standard, scales
Non-Contact Optical Type of Coordinate Measuring Machine <sup>3</sup> –  Probing Error Form Probing Error Size Length Measurement Error	Up to 2000 mm	6.4 µm 7.8 µm 30 µm	Artifact
R gage	Up to 150 mm	0.028 mm	Measuring microscope
Gage of Punch	Up to 200 mm	0.004 mm	Gage blocks
Extensometer <sup>3</sup>	Up to 600 mm	1.8 µm	Reference to ASTM E83, extensometer calibrator, gage blocks, digital linear height gage

III. Electrical – DC / Low Frequency

Parameter/Equipment	Range	CMC <sup>2,5,7</sup> (±)	Comments
DC Power – Generate <sup>3</sup> , 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 current coil: Fluke 5500A, 5520A, 5522A, 5700A, 5720A
0.2 W to 20 kW	(2 to 20) A	0.040 %	
2 W to 950 kW	(20 to 950) A, clamp type	0.35 %	
DC Energy– Generate <sup>3</sup>			Calibrator with current coil:
1 mWh to 2 kWh	1 mA to 2 A	0.080 %	Fluke 5500A, 5520A, 5522A, timer counter
0.2 Wh to 20 kWh	(2 to 20) A	0.12 %	
2 Wh to 950 kWh	(20 to 950) A, clamp type	0.35 %	
DC Power – Measure, 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 2 kW	(1 to 2) A	0.020 %	
0.2 W to 30 kW	(2 to 30) A	0.030 %	
3 W to 50 kW	(30 to 50) A	0.040 %	
DC Voltage – Generate	(0 to 1) mV (1 to 10) mV (10 to 100) mV (0.1 to 1) V (1 to 10) V 10 V (10 to 100) V (100 to 1000) V  (1 to 5) kV (5 to 50) kV  100 V to 30 kV	0.6 µV 0.036 % 48 µV/V 5.9 µV/V 1.8 µV/V 0.70 µV/V 1.9 µV/V 4.1 µV/V  0.050 % 0.070 %  1.6 %	Calibration of voltmeters using DC standard with Kelvin-Varley divider and calibrator  Voltage divider, DMM and AC/DC high voltage generator  Electrostatic meters

Parameter/Equipment	Range	CMC <sup>2, 5, 7</sup> ( $\pm$ )	Comments
DC Voltage – Generate <sup>3</sup>	(1 to 10) mV (10 to 100) mV (0.1 to 1) V (1 to 10) V 10 V (10 to 100) V (100 to 1000) V  (1 to 5) kV (5 to 50) kV	0.061 % + 3.7 $\mu$ V 0.013 % + 3.7 $\mu$ V 62 $\mu$ V/V + 6.1 $\mu$ V 62 $\mu$ V/V + 61 $\mu$ V 62 $\mu$ V/V + 61 $\mu$ V 68 $\mu$ V/V + 0.61 mV 68 $\mu$ V/V + 1.9 mV  0.050 % 0.070 %	Fluke 5500A,5520A, and 5522A       Resistance voltage divider, DMM and AC/DC high voltage generator
DC Voltage – Measure	(0 to 1) mV (1 to 10) mV (10 to 100) mV (0.1 to 1) V (1 to 10) V 10 V (10 to 100) V (100 to 1000) V  (1 to 5) kV (5 to 50) kV	0.7 $\mu$ V 0.036 % 48 $\mu$ V/V 5.9 $\mu$ V/V 1.8 $\mu$ V/V 0.70 $\mu$ V/V 1.9 $\mu$ V/V 4.1 $\mu$ V/V  0.050 % 0.070 %	Calibration of voltage generators using DC standard with Kelvin- Varley divider and calibrator      DMM with resistance voltage divider
DC Voltage – Measure <sup>3</sup>	(1 to 10) mV (10 to 100) mV (0.1 to 1) V (1 to 10) V 10 V (10 to 100) V (100 to 1000) V  (1 to 50) kV	0.047 % + 0.12 $\mu$ V 55 $\mu$ V/V + 0.12 $\mu$ V 18 $\mu$ V/V + 0.47 $\mu$ V 16 $\mu$ V/V + 2.4 $\mu$ V 16 $\mu$ V/V + 2.4 $\mu$ V 19 $\mu$ V/V + 47 $\mu$ V 19 $\mu$ V/V + 470 $\mu$ V  0.10 %	Multimeter        Resistance voltage divider RD5kV, RD50kV and multimeter



Parameter/Equipment	Range	CMC <sup>2, 5, 7</sup> (±)	Comments	
DC Current – Generate	(1 to 10) nA	0.12 %	Calibration of current measuring devices using:  Calibrator and standard resistor	
	(10 to 100) nA	0.12 %		
	100 nA to 1 µA	0.021 %		
	(1 to 10) µA	0.021 %		
	(10 to 100) µA	58 µA/A	DMM, resistance reference standards and secondary standards	
		0.1 mA to 2 A		35 µA/A
		(2 to 10) A		61 µA/A
	(10 to 20) A	0.013 %	DMM and shunt resistors	
		(20 to 50) A		0.014 %
		(50 to 200) A		0.015 %
		(200 to 300) A		0.030 %
		(300 to 500) A		0.036 %
		(500 to 1000) A		0.11 %
	Simulated Current	(30 to 100) A	0.39 %	Calibrator with current coil
(100 to 500) A		0.38 %		
(500 to 950) A		0.39 %		
(950 to 2500) A		0.58 %		
DC Current – Generate <sup>3</sup>	(0.1 to 3) mA	0.022 % + 0.07 µA	Calibration of current measuring devices using:  Fluke 5500A-5520A, and 5522A	
		(3 to 30) mA		0.018 % + 0.3 µA
		(30 to 300) mA		0.019 % + 4 µA
		(0.3 to 2) A		0.039 % + 54 µA
		(2 to 10) A		0.075 % + 400 µA
	(2 to 20) A	0.016 % + 0.003 mA	DMM and shunt resistors	
		(20 to 50) A		0.016 % + 0.012 mA
		(50 to 200) A		0.018 % + 0.058 mA
		(200 to 300) A		0.046 % + 0.35 mA
		(300 to 500) A		0.050 % + 0.58 mA
	(500 to 1000) A	0.11 % + 0.87 mA		
	Simulated Current	(30 to 100) A	0.39 % + 110 mA	Calibrator with current coil
		(100 to 500) A	0.38 % + 110 mA	
		(500 to 950) A	0.41 % + 120 mA	
(950 to 2000) A		0.38 % + 110 mA		
(2000 to 2500) A		0.58 % + 280 mA		

Parameter/Equipment	Range	CMC <sup>2, 5, 7</sup> (±)	Comments
DC Current – Measure	(1 to 10) nA (10 to 100) nA (0.1 to 1) μA (1 to 10) μA  (10 to 100) μA 100 μA to 2 A (2 to 10) A  (10 to 20) A (20 to 50) A (50 to 200) A (200 to 300) A (300 to 500) A (500 to 1000) A	0.17 % 0.13 % 0.042 % 0.023 %  58 μA/A 35 μA/A 61 μA/A  0.013 % 0.014 % 0.015 % 0.030 % 0.026 % 0.11 %	Calibration of current generators using:  Electrometer  DMM, resistance reference standards and secondary standards  DMM and shunt resistors
DC Current – Measure <sup>3</sup>	(10 to 100) μA (0.1 to 1) mA (1 to 10) mA (10 to 100) mA (0.1 to 1) A (1 to 2) A (2 to 20) A (20 to 50) A (50 to 200) A (200 to 300) A (300 to 500) A (500 to 1000) A	0.017 % + 0.012 nA 50 μA/A + 0.047 nA 50 μA/A + 0.47 nA 40 μA/A + 4.7 nA 0.017 % + 1.2 μA 0.016 % + 1.2 μA 0.020 % + 24 μA 0.016 % + 0.012 mA 0.018 % + 0.058 mA 0.046 % + 0.35 mA 0.050 % + 0.58 mA 0.11 % + 0.87 mA	Calibration of current generators using:  Multimeter with standard resistors and shunt resistors



Parameter/Equipment	Range	CMC <sup>2,5</sup> (±)	Comments
DC Resistance – Generate <sup>3</sup>			Calibration of resistance meters using:
Fixed Values	1 mΩ 0.01 Ω 0.1 Ω 1 Ω 10 Ω 100 Ω 1 kΩ 10 kΩ 100 kΩ 1 MΩ	18 μΩ/Ω 23 μΩ/Ω 9 μΩ/Ω 12 μΩ/Ω 9 μΩ/Ω 11 μΩ/Ω 11 μΩ/Ω 8 μΩ/Ω 15 μΩ/Ω 23 μΩ/Ω	Standard resistors using with multimeter and generator
Ranges	(1 to 10) mΩ (10 to 100) mΩ (0.1 to 1) Ω (1 to 10) Ω (10 to 100) Ω (0.1 to 1) kΩ (1 to 10) kΩ (10 to 100) kΩ (0.1 to 1) MΩ (1 to 100) MΩ (0.1 to 1) GΩ (1 to 10) GΩ (10 to 100) GΩ	0.11 % 0.026 % 0.012 % 70 μΩ/Ω 85 μΩ/Ω 40 μΩ/Ω 95 μΩ/Ω 70 μΩ/Ω 95 μΩ/Ω 0.014 % 0.50 % 0.50 % 0.43 %	Decade resistors          Decade resistors with Megohm bridge



Parameter/Equipment	Range	CMC <sup>2,5</sup> (±)	Comments
DC Resistance – Measure			Calibration of resistors using:
Fixed Values	1 mΩ 0.01 Ω 0.1 Ω 1 Ω 10 Ω 100 Ω 1 kΩ 10 kΩ 100 kΩ 1 MΩ	19 μΩ/Ω 18 μΩ/Ω 7.5 μΩ/Ω 7.3 μΩ/Ω 6.3 μΩ/Ω 6.4 μΩ/Ω 6.2 μΩ/Ω 6.2 μΩ/Ω 7.7 μΩ/Ω 5.6 μΩ/Ω	Resistance reference standards and multimeter
Ranges	(0.01 to 0.05) mΩ (0.05 to 0.1) mΩ (0.1 to 1) mΩ (1 to 10) mΩ (10 to 100) mΩ (0.1 to 1) Ω (1 to 10) Ω (10 to 100) Ω (0.1 to 1) kΩ (1 to 10) kΩ  (10 to 100) kΩ (0.1 to 1) MΩ (1 to 100) MΩ (0.1 to 1) GΩ (1 to 10) GΩ (10 to 100) GΩ	0.16 % 0.073 % 0.025 % 0.010 % 0.010 % 91 μΩ/Ω 31 μΩ/Ω 31 μΩ/Ω 31 μΩ/Ω 34 μΩ/Ω  54 μΩ/Ω 53 μΩ/Ω 0.011 % 0.12 % 0.17 % 0.53 %	Multimeter with fixed resistors           RB-22S Megohm bridge



Parameter/Equipment	Range	CMC <sup>2,5</sup> (±)	Comments
DC Resistance – Measure <sup>3</sup>			Calibration of resistors using:
Fixed Values	1 mΩ 0.01 Ω 0.1 Ω 1 Ω 10 Ω 100 Ω 1 kΩ 10 kΩ 100 kΩ 1 MΩ	0.013 % 95 μΩ/Ω 90 μΩ/Ω 90 μΩ/Ω 90 μΩ/Ω 90 μΩ/Ω 90 μΩ/Ω 90 μΩ/Ω 90 μΩ/Ω 90 μΩ/Ω	Multimeter with standard resistors
Ranges	(0.1 to 1) Ω (1 to 10) Ω (10 to 100) Ω (0.1 to 1) kΩ (1 to 10) kΩ (10 to 100) kΩ 100 kΩ to 1 MΩ	0.013 % 0.010 % 0.010 % 0.010 % 0.010 % 0.010 % 0.010 %	





Parameter/Range	Frequency	CMC <sup>2,5</sup> (±)	Comments
AC Voltage – Generate			Calibration of AC voltmeters using:
(300 to 700) mV	(10 to 50) Hz	0.026 %	Fluke 792A, DT 72A
700 mV to 2 V	(10 to 50) Hz	0.035 %	
300 mV to 1 V	(10 to 30) kHz	38 µV/V	
	(30 to 100) kHz	43 µV/V	
	100 kHz to 1 MHz	0.041 %	
(2 to 200) V	(10 to 50) Hz	0.029 %	
(1 to 10) V	(10 to 30) kHz	37 µV/V	
	(30 to 100) kHz	37 µV/V	
	100 kHz to 1 MHz	68 µV/V	
(10 to 20) V	100 kHz to 1 MHz	0.011 %	
(10 to 100) V	(10 to 30) kHz	48 µV/V	
	(30 to 100) kHz	48 µV/V	
(100 to 600) V	(30 to 100) kHz	68 µV/V	
(0.1 to 1) kV	(10 to 30) kHz	81 µV/V	
(1 to 10) mV (10 to 100) mV (0.1 to 1) V	50 Hz to 1 kHz (except 50, 60, 400 Hz)	0.032 %	
		0.016 %	
		85 µV/V	
(1 to 10) V (10 to 100) V (0.1 to 1) kV	50 Hz to 1 kHz (except 50, 60, 400 Hz)	55 µV/V	
		50 µV/V	
		70 µV/V	
(1 to 10) mV (10 to 100) mV (100 to 300) mV	(1 to 10) kHz	0.031 %	
		0.026 %	
		0.019 %	
(0.3 to 1) V (1 to 10) V (10 to 100) V (0.1 to 1) kV	(1 to 10) kHz	50 µV/V	
		50 µV/V	
		45 µV/V	
		55 µV/V	
(1 to 10) mV (10 to 100) mV (0.1 to 1) V	(50, 60, 400) Hz	0.029 %	
		75 µV/V	
		75 µV/V	



Parameter/Range	Frequency	CMC <sup>2, 5, 7</sup> ( $\pm$ )	Comments
AC Voltage – Generate (cont)			Calibration of AC voltmeters using:
(1 to 10) V (10 to 100) V (0.1 to 1) kV	(50, 60, 400) Hz	50 $\mu$ V/V 55 $\mu$ V/V 55 $\mu$ V/V	Fluke 792A, DT 72A
(1 to 30) kV	(50, 60) Hz	0.17 % + 3.5 V	Multimeter, voltage divider and AC/DC high voltage generator
AC Voltage – Generate <sup>3</sup>			Calibration of AC voltmeters using:
(10 to 100) mV (0.1 to 1) V	50 Hz to 1 kHz	0.079 % + 25 $\mu$ V 0.039 % + 73 $\mu$ V	Fluke 5500A5520A, and 5522A
(1 to 10) V (10 to 100) V (0.1 to 1) kV	50 Hz to 1 kHz	0.05 % + 0.73 mV 0.062 % + 8 mV 0.062 % + 100 mV	
(10 to 100) mV (100 to 300) mV	(1 to 10) kHz	0.08 % + 25 $\mu$ V 0.043 % + 73 $\mu$ V	
(0.3 to 1) V (1 to 10) V (10 to 100) V (0.1 to 1) kV	(1 to 10) kHz	0.043 % + 73 $\mu$ V 0.050 % + 0.73 mV 0.098 % + 19 mV 0.25 % + 0.61 V	
(1 to 5) kV	(50, 60) Hz	0.23 % + 3.5 V	Multimeter with RD5kV, RD50kV and potential transformer
AC Voltage – Measure			Calibration of voltage generators using:
(300 to 700) mV	(10 to 50) Hz	0.026 %	Fluke 792A, DT 72A
700 mV to 2 V	(10 to 50) Hz	0.035 %	
300 mV to 1 V	(10 to 30) kHz (30 to 100) kHz 100 kHz to 1 MHz	38 $\mu$ V/V 43 $\mu$ V/V 0.041 %	
(2 to 200) V	(10 to 50) Hz	0.029 %	



Parameter/Range	Frequency	CMC <sup>2, 5, 7</sup> (±)	Comments
AC Voltage – Measure (cont)			Calibration of voltage generators using:
(1 to 10) V	(10 to 30) kHz (30 to 100) kHz 100 kHz to 1 MHz	37 µV/V 37 µV/V 68 µV/V	Fluke 792A, DT 72A
(10 to 20) V	100 kHz to 1 MHz	0.011 %	
(10 to 100) V	(10 to 30) kHz (30 to 100) kHz	48 µV/V 48 µV/V	
(100 to 600) V	(30 to 100) kHz	68 µV/V	
(0.1 to 1) kV	(10 to 30) kHz	81 µV/V	
1 mV to 0.01 V (0.01 to 0.1) V (0.1 to 1) V	50 Hz to 1 kHz (except 50, 60, 400 Hz)	0.032 % 0.016 % 85 µV/V	
(1 to 10) V (10 to 100) V (0.1 to 1) kV	50 Hz to 1 kHz (except 50, 60, 400 Hz)	55 µV/V 50 µV/V 70 µV/V	
1 mV to 0.01 V (0.01 to 0.1) V (0.1 to 0.3) V	(1 to 10) kHz	0.031 % 0.026 % 0.019 %	
(0.3 to 1) V (1 to 10) V (10 to 100) V (0.1 to 1) kV	(1 to 10) kHz	50 µV/V 50 µV/V 45 µV/V 55 µV/V	
1 mV to 0.01 V (0.01 to 0.1) V (0.1 to 1) V	(50, 60, 400) Hz	0.029 % 75 µV/V 75 µV/V	
(1 to 10) V (10 to 100) V (0.1 to 1) kV	(50, 60, 400) Hz	50 µV/V 55 µV/V 55 µV/V	
(1 to 30) kV	(50, 60) Hz	0.17 % + 3.5 V	Multimeter, voltage divider and AC/DC high voltage generator



Parameter/Range	Frequency	CMC <sup>2,5,7</sup> (±)	Comments
AC Voltage – Measure <sup>3</sup>			Calibration of voltage generators using:
(10 to 100) mV (0.1 to 0.3) V (0.3 to 1) V	50 Hz to 1 kHz (except 50, 60, 400 Hz)	0.027 % + 4.8 μV 0.020 % + 24 μV 0.020 % + 66 μV	Multimeter
(1 to 10) V (10 to 100) V (0.1 to 1) kV	50 Hz to 1 kHz (except 50, 60, 400 Hz)	0.019 % + 0.24 mV 0.020 % + 2.4 mV 0.020 % + 33 mV	
(10 to 100) mV (100 to 300) mV	(1 to 10) kHz	0.032 % + 4.8 μV 0.025 % + 24 μV	
(0.3 to 1) V (1 to 10) V (10 to 100) V (0.1 to 1) kV	(1 to 10) kHz	0.020 % + 66 μV 0.020 % + 0.24 mV 0.020 % + 2.4 mV 0.020 % + 34 mV	
(10 to 100) mV (0.1 to 0.3) V (0.3 to 1) V	(50, 60, 400) Hz	0.032 % + 4.8 μV 0.022 % + 24 μV 0.020 % + 24 μV	
(1 to 10) V (10 to 100) V (0.1 to 1) kV	(50, 60, 400) Hz	0.021 % + 0.24 mV 0.021 % + 2.4 mV 0.021 % + 33 mV	
(1 to 5) kV (5 to 30) kV	(50, 60) Hz	0.23 % + 3.5 V 0.52 % + 3.5 V	Multimeter with RD5kV, RD50kV
AC Current – Generate			Calibration of AC current measuring devices using:
(2 to 500) mA (0.5 to 1) A (1 to 2) A (2 to 10) A (10 to 20) A	50 Hz to 1 kHz	70 μA/A 75 μA/A 70 μA/A 0.010 % 0.020 %	Fluke 792A with current shunt A40
100 μA to 2 mA (20 to 120) A	50 Hz to 1 kHz (50, 60) Hz	0.014 % 0.14 %	Digital voltmeter, current transformer and current resistor shunt



Parameter/Range	Frequency	CMC <sup>2,5,7</sup> (±)	Comments
AC Current – Generate (cont)  (50 to 100) A (100 to 500) A (500 to 950) A (950 to 2000) A (2000 to 3000) A	(50, 60) Hz	0.39 % 0.38 % 0.39 % 0.38 % 0.58 %	Calibrator with current coil
AC Current – Generate <sup>3</sup>  100 µA to 2 mA (2 to 3) mA (3 to 30) mA (30 to 100) mA (100 to 300) mA (0.3 to 2) A (2 to 5) A (5 to 10) A (10 to 20) A  (20 to 120) A  (50 to 100) A (100 to 500) A (500 to 950) A (950 to 2000) A (2000 to 3000) A	50 Hz to 1 kHz          (50, 60) Hz  (50, 60) Hz	0.13 % + 0.40 µA 0.13 % + 0.40 µA 0.12 % + 3.7 µA 0.12 % + 37 µA 0.12 % + 37 µA 0.13 % + 0.37 mA 0.13 % + 2.5 mA 0.13 % + 2.5 mA 0.15 % + 6.1 mA  0.16 % + 2.4 mA  0.39 % + 110 mA 0.38 % + 110 mA 0.41 % + 110 mA 0.39 % + 220 mA 0.58 % + 280 mA	Calibration of AC current measuring devices using:  Fluke 5500A-5520A, and 5522A          Fluke 52120A  Calibrator with current coil (ex. clamp meter)
AC Current – Measure  (2 to 500) mA (0.5 to 1) A (1 to 2) A (2 to 5) A (5 to 10) A (10 to 20) A  100 µA to 2 mA (20 to 120) A  Current Coil Turns (10 to 50) Turns	50 Hz to 1 kHz          (50, 60) Hz	70 µA/A 75 µA/A 70 µA/A 0.010 % 95 µA/A 0.019 %  0.014 % 0.14 %  0.13 %	Calibration of current generators using:  Fluke 792A and current shunt A40       Digital voltmeter, current transformer and current resistor shunt  Calibrator



Parameter/Range	Frequency	CMC <sup>2, 5, 7</sup> ( $\pm$ )	Comments
AC Current – Measure <sup>3</sup>			Calibration of current generators using:
100 $\mu$ A to 2 mA (2 to 10) mA (10 to 100) mA (0.1 to 1) A (1 to 2) A (2 to 20) A	50 Hz to 1 kHz	0.050 % + 24 nA 0.041 % + 0.24 $\mu$ A 0.044 % + 2.4 $\mu$ A 0.047 % + 48 $\mu$ A 0.047 % + 96 $\mu$ A 0.048 % + 0.96 mA	Multimeter with shunts and current transformer
(20 to 120) A	(50, 60) Hz	0.16 % + 2.4 mA	
AC Power – Generate <sup>3</sup>			Calibration of watt meters & power analyzers using:
10 W to 6 kW	(50, 60) Hz	0.060 %	Watt converter
$\leq 1000$ V, $\leq 50$ A PF: 1	(50, 60) Hz Single Phase Three Phase – Three Wire Three Phase – Four Wire	0.11 % 0.11 % 0.11 %	Multimeter, calibrator, current transformer and phase meter
$\leq 1000$ V, $\leq 50$ A PF: 0(lag) ~ 1 ~ 0(lead)	Single Phase Three Phase – Three Wire Three Phase – Four Wire	1.1 mW/(V·A) 1.1 mW/(V·A) 1.1 mW/(V·A)	Multimeter, calibrator, current transformer and phase meter
$\leq 1000$ V, $\leq 950$ A PF: 1, with current coil	Single Phase Three Phase – Three Wire Three Phase – Four Wire	0.37 % 0.32 % 0.37 %	Multimeter, calibrator, current transformer, phase meter and current coil
$\leq 1000$ V, $\leq 950$ A PF: 0(lag) ~ 1 ~ 0(lead), with current coil	Single Phase Three Phase – Three Wire Three Phase – Four Wire	3.7 mW/(V·A) 3.2 mW/(V·A) 3.7 mW/(V·A)	Multimeter, calibrator, current transformer, phase meter and current coil



Parameter/Range	Frequency	CMC <sup>2,5</sup> (±)	Comments
AC Energy – Generate <sup>3</sup>			Calibration of watt meters & power analyzers using:
≤ 1000 V, ≤ 50 A PF: 1	(50, 60) Hz Single Phase Three Phase – Three Wire Three Phase – Four Wire	0.16 % 0.15 % 0.16 %	Multimeter, calibrator, current transformer, phase meter and time counter
≤ 1000 V, ≤ 50 A PF: 0(lag) ~ 1 ~ 0 (lead)	Single phase Three Phase – Three Wire Three Phase – Four Wire	1.6 mW·h/(V·A·h) 1.5 mW·h/(V·A·h) 1.6 mW·h/(V·A·h)	Multimeter, calibrator, current transformer, phase meter and time counter
≤ 1000 V, ≤ 500 A PF: 1, with current coil	Single Phase Three Phase – Three Wire Three Phase – Four Wire	0.39 % 0.34 % 0.39 %	Multimeter, calibrator, current transformer, phase meter, current coil and time counter
≤ 1000 V, ≤ 500 A PF: 0 (lag) ~ 1 ~ 0 (lead), with current coil	Single Phase Three Phase – Three Wire Three Phase – Four Wire	3.9 mW·h/(V·A·h) 3.4 mW·h/(V·A·h) 3.9 mW·h/(V·A·h)	Multimeter, calibrator, current transformer, phase meter, current coil and time counter
AC Power – Measure			Calibration of Watt generators & power analyzers using:
1 mW to 10 W	(50, 60) Hz	0.10 % + 0.1 mW	Fluke 792A and current shunt A40
10 W to 6 kW		0.060 %	Watt converter
(6 to 20) kW		0.060 %	Calibrator multimeter and shunt resistor
(20 to 50) kW		0.070 %	Calibrator multimeter and CT

Parameter/Range	Frequency	CMC <sup>2,5</sup> (±)	Comments
AC Resistance – Generate <sup>3</sup>			Calibration of AC resistance meters using:
Impedance Fixed Points			Standard AC resistors
0.001 Ω	50 Hz to 1 kHz	0.031 %	
0.01 Ω		0.031 %	
0.02 Ω		0.031 %	
0.1 Ω		0.031 %	
0.2 Ω		0.031 %	
1 Ω		0.031 %	
10 Ω		0.031 %	
	1 kHz	0.014 %	
	1 kHz to 1 MHz	0.051 %	
	(1 to 2) MHz	0.075 %	
	(2 to 3) MHz	0.080 %	
	(3 to 4) MHz	0.096 %	
	(4 to 5) MHz	0.13 %	
	(5 to 10) MHz	0.47 %	
	(10 to 13) MHz	0.73 %	
100 Ω	50 Hz to 1 kHz	0.031 %	
	1 kHz	0.013 %	
	1 kHz to 1 MHz	0.051 %	
	(1 to 5) MHz	0.066 %	
	(5 to 10) MHz	0.22 %	
	(10 to 13) MHz	0.32 %	
1 kΩ	50 Hz to 1 kHz	0.031 %	
	1 kHz	0.014 %	
	(1 to 100) kHz	0.056%	
	100 kHz to 3 MHz	0.057 %	
	(3 to 5) MHz	0.056 %	
	(5 to 10) MHz	0.22 %	
	(10 to 13) MHz	0.31 %	
10 kΩ	50 Hz to 1 kHz	0.031 %	
	1 kHz	0.013 %	
	(1 to 100) kHz	0.046 %	
	100 kHz to 1 MHz	0.055 %	
100 kΩ	1 kHz	0.014 %	
	(1 to 100) kHz	0.056 %	
	100 kHz to 1 MHz	0.073 %	





Parameter/Range	Frequency	CMC <sup>2,5</sup> (±)	Comments
AC Resistance – Generate <sup>3</sup> (cont)			Calibration of AC resistance meters using:
Ranges			
0.1 Ω to 10 kΩ	50 Hz to 1 kHz	0.031 %	Impedance meter with standard AC resistors
(10 to 100) kΩ	1 kHz	0.031 %	
10 Ω to 100 kΩ	1 kHz to 1 MHz	0.032 %	
Resistance			
Fixed Points			
10 Ω	1 kHz	0.013 %	
	1 kHz to 1 MHz	0.031 %	
	(1 to 2) MHz	0.056 %	
	(2 to 3) MHz	0.062 %	
	(3 to 4) MHz	0.074 %	
	(4 to 5) MHz	0.11 %	
	(5 to 10) MHz	0.42 %	
	(10 to 13) MHz	0.61 %	
100 Ω	1 kHz	0.013 %	
	1 kHz to 1 MHz	0.031 %	
	(1 to 5) MHz	0.052 %	
	(5 to 10) MHz	0.21 %	
	(10 to 13) MHz	0.31 %	
1 kΩ	1 kHz	0.013 %	
	(1 to 100) kHz	0.039 %	
	100 kHz to 3 MHz	0.040 %	
	(3 to 5) MHz	0.038 %	
	(5 to 10) MHz	0.21 %	
	(10 to 13) MHz	0.31 %	
10 kΩ	1 kHz	0.012 %	
	(1 to 100) kHz	0.022 %	
	100 kHz to 1 MHz	0.037 %	
100 kΩ	1 kHz	0.014 %	
	(1 to 100) kHz	0.039 %	
	100 kHz to 1 MHz	0.061 %	



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



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

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



Parameter/Range	Frequency	CMC <sup>2, 5, 7</sup> (±)	Comments
Capacitance – Generate (cont)			Calibration of capacitance meters using:
1000 pF to 0.01 μF (0.01 to 0.1) μF (0.1 to 1) μF	1 kHz	0.58 % 0.062 % 0.024 %	Standard capacitors and capacitance meters, Impedance meter
Capacitance – Measure			Calibration of capacitors using:
(1 to 10) pF	1 kHz 1 kHz to 1 MHz 1 MHz	0.019 % 0.030 % 0.026 %	Standard capacitors and capacitance meter, Impedance meter
(10 to 100) pF	1 kHz 1 kHz to 1 MHz 1 MHz	0.016 % 0.026 % 0.026 %	
(100 to 1000) pF	1 kHz 1 kHz to 1 MHz 1 MHz	0.016 % 0.039 % 0.027 %	
1000 pF to 0.01 μF	120 Hz 120 Hz to 1 kHz 1 kHz (1 to 10) kHz 10 kHz (10 to 100) kHz 100 kHz	0.011 % 0.026 % 0.016 % 0.026 % 0.026 % 0.033 % 0.026 %	
(0.01 to 0.1) μF	120 Hz 120 Hz to 1 kHz 1 kHz (1 to 10) kHz 10 kHz (10 to 100) kHz 100 kHz	0.026 % 0.027 % 0.016 % 0.026 % 0.011 % 0.27 % 0.011 %	
(0.1 to 1) μF	120 Hz 120 Hz to 1 kHz 1 kHz (1 to 10) kHz 10 kHz (10 to 100) kHz 100 kHz	0.026 % 0.026 % 0.012 % 0.076 % 0.026 % 2.8 % 0.027 %	
(1 to 10) μF 10 μF	1 kHz	0.19 % + 0.001 μF 0.11 %	

Parameter/Range	Frequency	CMC <sup>2, 5, 7</sup> (±)	Comments
Capacitance – Measure <sup>3</sup>  100 pF to 1 µF (1 to 10) µF	1 kHz	0.068 % 0.19 % + 0.001 µF	Calibration of capacitors using:  Capacitance meters
Inductance – Generate <sup>3</sup>  Fixed Points 100 µH 1 mH 10 mH 100 mH 1000 mH	1 kHz	0.51 % 0.11 % 0.11 % 0.11 % 0.11 %	Calibration of inductance meter using:  Standard inductor
Inductance – Measure <sup>3</sup>  Fixed Points 100 µH 1 mH 10 mH 100 mH 1000 mH	1 kHz	0.51 % 0.11 % 0.11 % 0.11 % 0.11 %	Calibration of inductor using:  Standard inductor



Parameter/Range	Frequency	CMC <sup>2,5</sup> (±)	Comments
Phase <sup>3</sup> (0 to 360)°	20 Hz to 2 kHz (2 to 5) kHz (5 to 10) kHz (10 to 50) kHz	0.028° 0.038° 0.049° 0.060°	Phase meter
Power Factor <sup>3</sup>	(50 to 60) Hz	$ \cos(A) - \cos(A + 0.028) $	Phase meter (A is the angle in degrees)

Parameter/Equipment	Range	CMC <sup>2</sup> (±)	Comments
Electrical Calibration of Thermocouple Temperature Indicators <sup>3</sup> –			Calibration of temperature meters using:
Type K	(-200 to -170) °C (-170 to -100) °C (-100 to -20) °C (-20 to 1372) °C	0.63 °C 0.47 °C 0.42 °C 0.43 °C	Fluke 5500A, 5520A and 5522A
Type J	(-210 to -170) °C (-170 to -120) °C (-120 to -20) °C (-20 to 1200) °C	0.49 °C 0.46 °C 0.45 °C 0.44 °C	
Type E	(-250 to -220) °C (-220 to -180) °C (-180 to -70) °C (-70 to 1000) °C	0.61 °C 0.44 °C 0.40 °C 0.38 °C	
Type T	(-250 to -230) °C (-230 to -170) °C (-170 to -90) °C (-90 to -20) °C (-20 to 300) °C (300 to 400) °C	1.2 °C 0.62 °C 0.46 °C 0.42 °C 0.41 °C 0.40 °C	
Type R	(0 to 50) °C (50 to 250) °C (250 to 400) °C (400 to 800) °C (800 to 1760) °C	1.1 °C 0.80 °C 0.67 °C 0.63 °C 0.54 °C	



Parameter/Equipment	Range	CMC <sup>2</sup> (±)	Comments
Electrical Calibration of Thermocouple Temperature Indicators <sup>3</sup> – (cont)			Calibration of temperature meters using:
Type S	(0 to 50) °C (50 to 250) °C (250 to 400) °C (400 to 800) °C (800 to 1760) °C	1.1 °C 0.80 °C 0.67 °C 0.63 °C 0.59 °C	Fluke 5500A, 5520A and 5522A
Type N	(-200 to -170) °C (-170 to -100) °C (-100 to -20) °C (-20 to 410) °C (410 to 1300) °C	0.72 °C 0.44 °C 0.39 °C 0.37 °C 0.44 °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 -230) °C	0.94 °C	Multimeter and glass thermometers
	(-230 to -200) °C	0.50 °C	
	(-200 to -170) °C	0.30 °C	
	(-170 to -100) °C	0.27 °C	
	(-100 to -20) °C	0.20 °C	
	(-20 to 1200) °C	0.17 °C	
	(1200 to 1372) °C	0.18 °C	
Type J	(-210 to -170) °C	0.27 °C	
	(-170 to -120) °C	0.20 °C	
	(-120 to -20) °C	0.16 °C	
	(-20 to 1200) °C	0.15 °C	
Type E	(-270 to -250) °C	1.1 °C	
	(-250 to -220) °C	0.50 °C	
	(-220 to -180) °C	0.27 °C	
	(-180 to -70) °C	0.20 °C	
	(-70 to -20) °C	0.16 °C	
	(-20 to 1000) °C	0.14 °C	
Type T	(-270 to -230) °C	1.1 °C	
	(-230 to -170) °C	0.50 °C	
	(-170 to -90) °C	0.27 °C	
	(-90 to -20) °C	0.20 °C	
	(-20 to 300) °C	0.18 °C	
	(300 to 400) °C	0.15 °C	



Parameter/Equipment	Range	CMC <sup>2,5</sup> (±)	Comments
Electrical Calibration of Thermocouple Temperature Calibrators – (cont)			Calibration of temperature meter calibrators using:
Type R	(-50 to 0) °C (0 to 50) °C (50 to 250) °C (250 to 400) °C (400 to 800) °C (800 to 1760) °C	1.4 °C 0.98 °C 0.70 °C 0.55 °C 0.50 °C 0.39 °C	Multimeter and glass thermometers
Type S	(-50 to 0) °C (0 to 50) °C (50 to 250) °C (250 to 400) °C (400 to 800) °C (800 to 1760) °C	1.4 °C 0.98 °C 0.70 °C 0.55 °C 0.50 °C 0.46 °C	
Type N	(-270 to -230) °C (-230 to -170) °C (-170 to -100) °C (-100 to -20) °C (-20 to 1200) °C (1200 to 1370) °C	0.71 °C 0.50 °C 0.26 °C 0.22 °C 0.21 °C 0.18 °C	
Electrical Calibration of Strain Calibrators			Calibration of strain calibrator using:
	(20 000 to 200 000) × 10 <sup>-6</sup> (10 to 100) mV/V	0.010 %	Multimeter, voltage generator
	(2000 to 20 000) × 10 <sup>-6</sup> (1 to 10) mV/V	0.060 %	
	(20 to 2000) × 10 <sup>-6</sup> (0.01 to 1) mV/V	0.070 %	



Parameter/Equipment	Range	CMC <sup>2,5</sup> (±)	Comments
Electrical Calibration of Strain Indicators <sup>3</sup>	(20 000 to 200 000) × 10 <sup>-6</sup> (10 to 100) mV/V	0.020 % or one LSD, whichever is greater	Calibration of strain meter using:  Strain calibrator; LSD = least significant digit
	(2000 to 20 000) × 10 <sup>-6</sup> (1 to 10) mV/V	0.070 % or one LSD, whichever is greater	
	(20 to 2000) × 10 <sup>-6</sup> (0.01 to 1) mV/V	0.17 % or one LSD, whichever is greater	

#### IV. Electrical – RF/Microwave

Parameter/Range	Frequency	CMC <sup>2,5</sup> (±)	Comments
High Frequency Voltage – 0.5 V	(10 to 500) MHz	1.1 %	Bolometer mount, auto-balance bridge and DMM
	(500 to 1000) MHz	2.2 %	
(0.1 to 0.7) V	(10 to 500) MHz	1.3 %	Rohde & Schwartz URV5
	(500 to 1000) MHz	2.4 %	
(0.01 to 0.1) V	10 kHz to 1 MHz	0.80 %	Fluke A55
	(1 to 10) MHz	2.1 %	
(0.1 to 0.3) V	10 kHz to 1 MHz	0.80 %	Measuring receiver
	(1 to 10) MHz	1.1 %	
(0.3 to 0.5) V	(1 to 10) MHz	0.22 %	
	(1 to 10) MHz	0.21 %	
(0.5 to 3) V	(10 to 500) MHz	0.23 dB	
	(500 to 1000) MHz	0.28 dB	



Parameter/Range	Frequency	CMC <sup>2,5</sup> (±)	Comments
High Frequency Voltage <sup>3</sup> –			
(0.01 to 0.1) V	10 kHz to 1 MHz (1 to 10) MHz	1.8 % 2.6 %	Rohde & Schwartz URV5
(0.1 to 0.3) V	10 kHz to 1 MHz (1 to 10) MHz	1.8 % 2.0 %	
(10 to 120) dB/μV	(10 to 500) MHz (500 to 1000) MHz	0.25 dB 0.30 dB	Measuring receiver
High Frequency Power <sup>3</sup> –			
> 100 pW to 1 nW	(10 to 50) MHz 50 MHz to 6 GHz (6 to 12) GHz	1.8 % 2.2 % 2.4 %	Power meter, sensor, attenuator and signal calibrator with mixer
(> 1 to 100) nW	(9 to 10) kHz	2.0 %	
(> 1 to 10) nW	10 kHz to 10 MHz (10 to 50) MHz 50 MHz to 6 GHz (6 to 12) GHz (12 to 18) GHz	2.7 % 1.6 % 2.0 % 2.2 % 3.3 %	
> 100 nW to 100 mW	(9 to 10) kHz	1.4 %	
> 10 nW to 100 mW	10 kHz to 10 MHz (10 to 50) MHz 50 MHz to 6 GHz (6 to 12) GHz (12 to 18) GHz	2.1 % 1.5 % 1.9 % 2.1 % 3.3 %	
> 10 μW to 100 mW	(18 to 24) GHz (24 to 32) GHz (32 to 36) GHz (36 to 40) GHz	4.5 % 5.0 % 5.9 % 6.3 %	
1 mW	9 kHz to 10 MHz (10 to 50) MHz 50 MHz to 6 GHz (6 to 12) GHz (12 to 18) GHz (18 to 24) GHz (24 to 32) GHz (32 to 36) GHz (36 to 40) GHz	1.3 % 1.3 % 1.8 % 2.0 % 3.3 % 4.1 % 4.6 % 5.6 % 6.0 %	
> 100 mW to 100 W	10 MHz to 1 GHz	2.6 %	Power meter, sensor and directional coupler
(> 100 to 200) W	(10 to 250) MHz	2.6 %	



Parameter/Range	Frequency	CMC <sup>2, 5</sup> (±)	Comments
Modulation <sup>3</sup> —			
Amplitude Modulation	(20 to 100) %	2.1 %	Attenuator, HP 8902A
Frequency Modulation Deviation	(1 to 200) kHz	0.26 %	Tektronix AFG3022
Noise Level	9 kHz to 40 GHz	0.6 dB	Spectrum analyzer
Electromagnetic Wave Attenuation <sup>3</sup> — Generate			
(0 to 40) dB (40 to 60) dB	50 Hz to 1 kHz	0.01 dB 0.015 dB	Standard decade transformer
(0 to 20) dB (20 to 40) dB (40 to 60) dB	(1 to 10) kHz	0.01 dB 0.02 dB 0.07 dB	
(0 to 40) dB (40 to 50) dB (50 to 60) dB	10 kHz to 10 MHz	0.06 dB 0.08 dB 0.20 dB	Attenuator vector network analyzer
10 dB 50 dB 70 dB	10 MHz to 12 GHz	0.024 dB 0.024 dB 0.025 dB	Attenuator
10 dB 50 dB 60 dB	(12 to 18) GHz	0.027 dB 0.032 dB 0.032 dB	
(0 to 50) dB (> 50 to 100) dB	10 MHz to 12 GHz	0.03 dB 0.04 dB	Attenuation measurement equipment
(0 to 50) dB (> 50 to 100) dB	(12 to 18) GHz	0.04 dB 0.05 dB	
(0 to 60) dB	(18 to 40) GHz	0.20 dB	Measuring receiver



Parameter/Range	Frequency	CMC <sup>2, 5</sup> (±)	Comments
Electromagnetic Wave Attenuation <sup>3</sup> – Measure			
(0 to 40) dB (40 to 60) dB	50 Hz to 1 kHz	0.01 dB 0.015 dB	Standard decade transformer
(0 to 20) dB (20 to 40) dB (40 to 60) dB	(1 to 10) kHz	0.01 dB 0.02 dB 0.07 dB	
(0 to 40) dB (40 to 50) dB (50 to 60) dB	10 kHz to 10 MHz	0.06 dB 0.08 dB 0.20 dB	Vector network analyzer
(0 to 50) dB (> 50 to 70) dB (> 70 to 80) dB (> 80 to 90) dB	10 MHz to 12 GHz	0.040 dB 0.050 dB 0.090 dB 0.63 dB	Attenuation measurement equipment
(0 to 90) dB	(12 to 18) GHz	0.15 dB	
(0 to 60) dB	(18 to 40) GHz	0.25 dB	Measuring receiver



Parameter/Range	Frequency	CMC <sup>2,5</sup> (±)	Comments
EMI Test Receiver <sup>3</sup> –			
Level	9 kHz to 5 MHz 5 MHz to 1 GHz (1 to 3) GHz (3 to 12) GHz (12 to 40) GHz	0.30 dB 0.50 dB 0.30 dB 0.40 dB 0.50 dB	Fluke 8920A, HP 8902A, E4418B&E4412A E4418B&8487A
Attenuation	(10 to 1300) MHz	0.20 dB	
Resolution BW	200 Hz to 1 MHz	5.0 %	
Impulse BW	1 MHz	5.0 %	Tektronix AFG3022
Center Frequency	9 kHz to 40 GHz	2.0 µHz/Hz	Advantest R5362B, 538B
Overall Selectivity (Pass-Band)	≤ 10 dB > 10 dB	1.5 % of Resolution Bandwidth	R&S FSMR
Impedance	≥ 10 dB 0 dB	3.0 % 5.0 %	Agilent 4294A Agilent E5061B HP4396B
Pulse Response (Relative Level)	(5 to 1000) Hz (1 to 2) Hz and Isolated Pulse	0.50 dB 0.70 dB	Schwarzbeck IGUU2916
Pulse Response (Absolute Level)	Band A: 25 Hz Band B, C, D: 100 Hz	0.50 dB 0.50 dB	Schwarzbeck IGUU2916
Noise Level	9 kHz to 40 GHz	0.6 dB	
Response to Intermittent, Unsteady and Drifting Narrowband Disturbances	9 kHz to 1 GHz	0.40 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 E5061B
Impedance (Phase)	9 kHz to 30 MHz (30 to 230) MHz	2° 3°	Agilent VNA E5061B, Rohde & Schwarz URV-5
Voltage Division Factor	9 kHz to 10 MHz (10 to 30) MHz (30 to 230) MHz	0.10 dB 0.20 dB 0.25 dB	
Isolation (0 to 60) dB (60 to 80) dB	9 kHz to 30 MHz	0.5 dB 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 230) MHz	5.0 %	Agilent VNA E5061B
Flicker Meter <sup>3</sup> –			
Perceptibility (Short term)	$\geq 0.4 P_{st}$	0.22 %	Fluke 5520A-PQ



Parameter/Range	Frequency	CMC <sup>2,5</sup> (±)	Comments
Pulse Generator <sup>3</sup> –			
Pulse Area	≥ 20 nV sec	5.0 %	Tektronix TDS7704B, Advantest TR5823H attenuator
Pulse Width	300 ps to 20 ms	5.0 %	
Pulse Amplitude	(10 to 70) dB	0.25 dB	
Repetition Frequency	(1 to 1000) Hz	3.0 parts in 10 <sup>7</sup>	
Spectrum Flatness	DC to 7 GHz	0.40 dB	
EFT/Burst Generator <sup>3</sup> –			
Peak Voltage (+ and –)			Tektronix TDS7704B, Schaffner INA265A (50Ω), 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	5 ns ± 30 %	100 ps	
1 kΩ Load	5 ns ± 30 %	100 ps	
Impulse Duration			
50 Ω Load	50 ns ± 30 %	1.0 ns	
1 kΩ Load	(50 to 15) ns / + 100 ns	1.0 ns	
Burst Duration	15 ms ± 20 % @ 5 kHz 0.75 ms ± 20 % @ 100 kHz	100 μs 1.0 μs	
Burst Period	300 ms ± 20 %	2.0 ms	
Repetition Frequency Up to 4 kV	5 kHz ± 20 % 100 kHz ± 20 %	0.50 % 0.50 %	



Parameter/Equipment	Range	CMC <sup>2,5</sup> (±)	Comments
ESD Targets –			
Low Frequency Transfer Function	1 A	0.13 %	IEC 61000-4-2, ISO 10605 Fuluke 5700A Wavetek 1281
Insertion Loss	10 MHz to 4 GHz	0.1 dB	Keysight E5071C
ESD Simulators <sup>3</sup> –			
Contact Voltage (+ and –)	(2 to 25) kV ± 5 %	2.0 %	Tektronix TDS7704B, Schaffner MD102, EMC Partner ESD- VERI-V
Rise Time	(0.7 to 1) ns	80 ps	
Peak Current	(7.5 to 30) A ± 10 % (30 to 112.5) A ± 10%	3.0 % 3.5 %	
30 ns Current	(4 to 16) A ± 30 % (16 to 60) A ± 30%	4.5 % 4.5 %	
60 ns Current	(2 to 8) A ± 30 % (8 to 30) A ± 30%	5.5 % 6.0 %	



Parameter/Equipment	Range	CMC <sup>2,5</sup> (±)	Comments	
Surge Simulators <sup>3</sup> –				
Open Circuit Voltage Waveform				
Peak Voltage Under / Overshoot Voltage	± (0.5 to 7) kV ± 10 % ± (0 to 2.1) kV	3.5 % 3.5 % of Peak Voltage	Schaffner MD200, MD300 Tektronix TDS 7704B, DPO 7254C, DPO 4032	
(1.2/50 µs) Front Time	1.2 µs ± 30 %	16 ns		
Rise Time	1 µs ± 30 %	16 ns		
Time to Half Value	50 µs +10 µs /-10 to -35 µs	0.35 µs		
Duration Time	50 µs ± 20 %	0.35 µs		
(10/700 µs) Front Time	10 µs ± 30 %	0.10 µs		
Rise Time	6.5 µs ± 30 %	0.10 µs		
Time to Half Value/ Duration Time	700 µs ± 20 % 700 µs ± 20 %	5.0 µs 5.0 µs		
Short Circuit Current Waveform				
Peak Current Under / Over Shoot Current	± (12.5 A to 3.5 kA) ± 10 % ± (0 to 1.05) kA	3.0 % 3.0 % of Peak Current		
(8/20 µs) Front Time	8 µs ± 20 % 2.5 µs ± 30 %	70 ns 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 % 16 µs ± 20 %	0.25 µs 0.15 µs		
(5/320 µs) Front Time	5 µs ± 20 %	50 ns		
Rise Time	4 µs ± 20 %	50 ns		
Time to Half Value	320 µs ± 20 %	3.0 µs		
Duration Time	300 µs ± 20 %	3.0 µs		
Phase Shifting	(0 to 360)°	0.78°		

Parameter/Equipment	Range	CMC <sup>2,4,5</sup> ( $\pm$ )	Comments
Surge Simulators <sup>3</sup> – (cont)			
Transient Voltage Surge			
Voltage	$\pm$ (1 to 600) V	1.5 %	Schaffner MD200, Tektronix TDS7704B, DPO 7254C, DPO 4032,
Rise Time	0.5 $\mu$ s to 10 ms 5ns $\pm$ 1.5 ns	1 % 3.5 %	
Duration Time	105 ns to 2.4 s	2 %	
Time ( $t_7, 8, 9, 10, 11, 12$ )	0.5 ms to 20 s	1 %	
Pulse Energy	105 ns to 2.4 s	4 %	
Voltage Dip Simulator <sup>3</sup> –			
AC Voltage	(0 to 230) V	0.20 %	Multimeter, differential probe & digital oscilloscope
Rise time Fall time	(1 to 5) $\mu$ s (1 to 5) $\mu$ s	0.50 $\mu$ s 0.30 $\mu$ s	
Phase Relationship	(0 to 360) $^\circ$ - 50 Hz (0 to 360) $^\circ$ - 60 Hz	3 $^\circ$ 4 $^\circ$	
RF Current Probes <sup>3</sup> –			
Bulk Current Injection Probes Insertion Loss	10 kHz to 400 MHz 400 MHz to 1 GHz	0.50 dB 0.70 dB	ISO11452-4 Agilent E5061B
Current Monitoring Probes Transfer Impedance	50 Hz to 400 MHz 400 MHz to 1 GHz	0.50 dB 0.70 dB	CISPR16-1-2 ISO11452-4 Agilent E5061B
Reflection Coefficient <sup>3</sup> – (0 to 0.3)	9 kHz to 3 GHz  (3 to 18) GHz	0.010 (Non-UNITS) Arcsin (0.010/  $\Gamma$  ) ( $^\circ$ )  0.020 (Non-UNITS) Arcsin (0.020/  $\Gamma$  ) ( $^\circ$ )	Agilent E5061B, E5071C, 85054D Wiltron 26N50 Anritsu 28NF50-2

Parameter/Equipment	Range	CMC <sup>2</sup> (±)	Comments
Monopole (Rod) Antenna <sup>3</sup>	9 kHz to 30 MHz	1.0 dB	CISPR16-1-6 Agilent E5061B
NSA Measurements <sup>3</sup>	(30 to 1000) MHz	1.4 dB	ANSI C63.4, CISPR 16-1-4, Network analyzer
SVSWR Validation Test <sup>3</sup>	(1 to 18) GHz	0.67 dB	CISPR 16-1-4, Network analyzer
Set-up Table Influences <sup>3</sup>	200 MHz to 18 GHz	0.39 dB	CISPR 16-1-4, Network analyzer

#### V. Mechanical

Parameter/Equipment	Range	CMC <sup>2,5</sup> (±)	Comments
Pressure Gage Oil Pressure (Gage Pressure)	(0 to 2) MPa (2 to < 3) MPa (3 to < 4) MPa (4 to < 5) MPa (5 to < 5.5) MPa (5.5 to < 100) MPa  (100 to < 250) MPa	1.0 kPa 1.2 kPa 1.5 kPa 1.8 kPa 2.0 kPa 0.017 % or 3.4 kPa, whichever is larger  0.30 MPa	Pressure balance, digital pressure gauge
Pressure Gage Air Pressure (Gage Pressure)	(-100 to 0) kPa (0 to < 150) kPa (150 to < 200) kPa (200 to < 500) kPa (500 to < 1000) kPa (1000 to < 1500) kPa (1500 to < 2000) kPa (2000 to < 2500) kPa (2500 to < 3000) kPa (3000 to < 3500) kPa	25 Pa 13 Pa 16 Pa 0.0075 % 82 Pa 0.13 kPa 0.17 kPa 0.24 kPa 0.27 kPa 0.30 kPa	Pressure controller, pressure balance



Parameter/Equipment	Range	CMC <sup>2,5</sup> (±)	Comments
Pressure Gage –  Air Pressure Low Pressure (Gage Pressure and Differential Pressure)	(-20 to < -15) kPa (-15 to < -10) kPa (-10 to < -7.5) kPa (-7.5 to < -5) kPa (-5 to < -2.5) kPa (-2.5 to < -1) kPa (-1 to 0) kPa (0 to < 1) kPa (1 to < 2.5) kPa (2.5 to < 5) kPa (5 to < 7.5) kPa (7.5 to < 10) kPa (10 to < 15) kPa (15 to < 20) kPa	4.5 Pa 3.5 Pa 2.5 Pa 1.9 Pa 1.5 Pa 1.2 Pa 0.90 Pa 0.90 Pa 1.2 Pa 1.5 Pa 1.9 Pa 2.5 Pa 3.5 Pa 4.5 Pa	Low pressure controller;  [Line Pressure: 100 kPa ± 5kPa (absolute pressure)]
Pressure Gage –  Air Pressure (Absolute Pressure)	(8 to 75) kPa (75 to < 100) kPa (100 to < 150) kPa (150 to < 200) kPa (200 to < 250) kPa (250 to < 300) kPa (300 to < 350) kPa	27 Pa 29 Pa 36 Pa 44 Pa 53 Pa 61 Pa 71 Pa	Pressure controller, digital pressure gauge
Pressure Balance –  Oil Pressure (Gage Pressure)	(0.5 to 5) MPa (5 to < 10) MPa (10 to < 100) MPa	3.5 kPa 4.3 kPa 22 kPa or 0.044 %, whichever is larger	Digital pressure gauge



Parameter/Equipment	Range	CMC <sup>2</sup> (±)	Comments
Scales & Balances (Electric Type and Mechanical Type)	(< 500 to ≤ 600) kg	56 µg/g	Calibration using class E2, F1, F2, M1, and M2 weights
	(< 450 to ≤ 500) kg	52 µg/g	
	(< 400 to ≤ 450) kg	50 µg/g	
	(< 350 to ≤ 400) kg	46 µg/g	
	(< 300 to ≤ 350) kg	42 µg/g	
	(< 150 to ≤ 300) kg	16 µg/g	
	(< 12 to ≤ 150) kg	8.0 µg/g	
	(< 5 to ≤ 12) kg	8.0 µg/g	
	(< 2 to ≤ 5) kg	1.5 µg/g	
	(< 1 to ≤ 2) kg	2.3 µg/g	
	(< 90 to ≤ 1000) g	2.6 µg/g	
	(< 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		



Parameter/Equipment	Range	CMC <sup>2</sup> (±)	Comments
Scales & Balances (Electric Type and Mechanical Type) (cont)	(< 0.02 to ≤ 0.03) g	0.43 mg/g	Calibration using class E2, F1, F2, M1, and M2 weights
	(< 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		
Rotational Speed –			
Tachometers – Optical (Non-Contact)	(6 to 6000) rpm (6000 to 99 990) rpm (0.1 to 1000) rps (1000 to 1666.5) rps	0.060 rpm 0.070 rpm 0.010 rps 0.030 rps	Frequency counter
Tachometers – For Engine (Non-Contact)	(100 to 9990) rpm	0.60 rpm	
Tachometers – Digital/Mechanical (Contact)	(40 to 15 000) rpm (0.6667 to 250) rps	1.2 rpm 0.020 rps	Revolution generator







Parameter/Range	Frequency	CMC <sup>2,5</sup> (±)	Comments
Accelerometer Sensitivity Charge Sensitivity (10 <sup>-4</sup> to 10 <sup>6</sup> ) pC/(m/s <sup>2</sup> )	(20 to < 31.5) Hz	1.0 %	Laser interferometry (fringe-counting method)
	(31.5 to 160) Hz	0.90 %	
	(> 160 to 200) Hz	1.0 %	
	(> 200 to 250) Hz	1.1 %	
	(> 250 to 315) Hz	1.2 %	
	(> 315 to 400) Hz	1.6 %	
	(> 0.4 to 2) kHz (> 2 to 5) kHz (> 5 to 10) kHz	1.0 %	Laser interferometry (minimum-point method)
		1.2 %	
		1.6 %	
	(5 to 250) Hz (> 250 to 315) Hz (> 315 to < 500) Hz (500 to 2000) Hz (> 2 to 5) kHz (> 5 to 10) kHz	1.4 %	Secondary vibration calibration
		1.5 %	
		1.8 %	
1.3 %			
1.7 %			
2.0 %			
Vibration Meter –  (0.1 to 500) m/s <sup>2</sup>  (0.002 to 80) cm/s  0.1 μm to 10 mm (peak)	(5 to 5000) Hz (> 5 to 10) kHz	2.0 %	Secondary vibration calibration:  Acceleration or output voltage  Velocity or output voltage  Displacement or output voltage
		3.0 %	
	(5 to 5000) Hz (> 5 to 10) kHz	2.0 % 3.0 %	
(5 to 500) Hz	2.0 %		



Parameter/Range	Frequency	CMC <sup>2,5</sup> (±)	Comments
Vibration Exciter <sup>3</sup> –			Secondary vibration calibration:
(1 to 2000) m/s <sup>2</sup>	(5 to 5000) Hz (> 5 to 10) kHz	3.0 % 5.0 %	Acceleration
(1 to 200) cm/s	(5 to 315) Hz (> 315 to 1000) Hz (> 1000 to 2000) Hz (> 2 to 4) kHz (> 4 to 10) kHz	3.0 % 4.0 % 5.0 % 10 % 18 %	Velocity
(0.1 mm to 30 mm) (pk-pk)	(5 to 20) Hz (> 20 to 40) Hz (> 40 to 160) Hz (> 160 to 315) Hz	3.0 % 4.0 % 7.0 % 22 %	Displacement
	5 Hz to 10 kHz	0.010 %	Frequency
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	(588.4 to 1471) N (60 to 150) kgf	0.95 N	Verification of the test force by force-proving instruments per the method of ASTM E4
	(147.1 to 294.2) N (15 to 30) kgf	0.54 N	Verification of the test force by force-proving instruments per the method of ASTM E4
			Force-proving instruments
Verification of the Measuring Device	(0 to 250) µm	0.76 µm	Index-Master
	(0 to 100) µm	0.55 µm	Index-Master
			Note: not full verification

Parameter/Equipment	Range	CMC <sup>2</sup> (±)	Comments
Indirect Verification of Rockwell Hardness Testing Machines <sup>3</sup>	C scale		Indirect calibration method per JIS B 7726, test blocks
	Low	0.25 HRC	
	Medium	0.29 HRC	
	High	0.23 HRC	
	B scale		
	Low	0.61 HRB	
	Medium	0.36 HRB	
	High	0.40 HRB	
	A scale		
	Low	0.23 HRA	
	Medium	0.24 HRA	
	High	0.18 HRA	
	30N scale		
	Low	0.29 HR30N	
	Medium	0.38 HR30N	
	High	0.28 HR30N	
	30T scale		
	Low	0.39 HR30T	
	Medium	0.27 HR30T	
	High	0.28 HR30T	
	15N scale		
	Low	0.34 HR15N	
	Medium	0.33 HR15N	
	High	0.35 HR15N	
15T scale			
Low	0.40 HR15T		
Medium	0.39 HR15T		
High	0.39 HR15T		



Parameter/Equipment	Range	CMC <sup>2</sup> (±)	Comments
Indirect Verification of Rockwell Hardness Testing Machines <sup>3</sup>	C scale Low Medium High  B scale Low Medium High  A scale Low Medium High  30N scale Low Medium High  30T scale Low Medium High  15N scale Low Medium High  15T scale Low Medium High	0.25 HRC 0.29 HRC 0.23 HRC  0.61 HRBW 0.36 HRBW 0.40 HRBW  0.23 HRA 0.24 HRA 0.18 HRA  0.29 HR30N 0.38 HR30N 0.28 HR30N  0.39 HR30TW 0.27 HR30TW 0.28 HR30TW  0.34 HR15N 0.33 HR15N 0.35 HR15N  0.40 HR15TW 0.39 HR15TW 0.39 HR15TW	Indirect calibration method per ASTM E18 test blocks
Indirect Verification of MicroVickers Hardness Testing Machines <sup>3</sup>	(100 to 250) HV (> 250 to 650) HV (> 650 to 900) HV	3.2 HV 36 HV 10 HV	Indirect calibration method per JIS B 7725 or ASTM E384 or ASTM E92 standard blocks
Indirect Verification of Knoop Hardness Testing Machines <sup>3</sup>	(100 to 250) HK (> 250 to 650) HK (> 650 to 900) HK	21 HK 34 HK 51 HK	Indirect calibration method per JIS B 7734 or ASTM E384 or ASTM E92 standard blocks

Parameter/Equipment	Range	CMC <sup>2</sup> (±)	Comments
Direct Verification of MicroVickers and Knoop Hardness Testing Machines <sup>3</sup> –  Verification of the Test Force  Verification of the Measuring Device	98.07 mN to 19.61 N 10 gf to 2 kgf  (0 to 1) mm	0.037 N  1.3 µm	Direct calibration method per JIS B 7725 or JIS B 7734 or ASTM E384 or ASTM E92  Verification of the test force by force-proving instruments and electric balance Per the method of ASTM E4  Stage micrometer  Note: not full verification
Indirect Verification of Vickers Hardness Testing Machines <sup>3</sup>	(100 to 250) HV (> 250 to 650) HV (> 650 to 900) HV	6.0 HV 16 HV 20 HV	Indirect calibration method per JIS B 7725 or ASTM E384 or ASTM E92 standard blocks
Direct Verification of Vickers Hardness Testing Machines <sup>3</sup> –  Verification of the Test Force  Verification of the Measuring Device	(19.61 to 490.3) N (2 to 50) kgf  (0 to 1) mm	0.73 N  1.3 µm	Direct calibration method per JIS B 7725 or ASTM E384 or ASTM E92  Verification of the test force by force-proving instruments per the method of ASTM E4  Stage micrometer  Note: Not full verification
Indirect Verification of Brinell Hardness Testing Machines <sup>3</sup>	(250 to 450) HBW (100 to 250) HBW	5.0 HBW 3.5 HBW	Indirect calibration method per JIS B7724 standard blocks
Indirect Verification of Brinell Hardness Testing Machines <sup>3</sup>	(225 to 450) HBW (125 to 225) HBW	6.2 HBW 2.6 HBW	Indirect calibration method per ASTM E10 standard blocks



Parameter/Equipment	Range	CMC <sup>2,5</sup> (±)	Comments
Direct Verification of Brinell Hardness Testing Machines <sup>3</sup> –			Direct calibration method per JIS B7724 force-proving instruments
Verification of the Test Force	(4.903 to 29.42) kN (500 to 3000) kgf	0.085 kN	Stage micrometer
Verification of the Measuring Device	(0 to 8) mm	4.3 µm	Note: not full verification
Direct Verification of Brinell Hardness Testing Machines <sup>3</sup>	(4.903 to 29.42) kN (500 to 3000) kgf  (0 to 8) mm	2.6 HBW	Direct calibration method per ASTM E10 verification of the test force by force-proving instruments and stage micrometer per the method of ASTM E4  Conversion to HBW Note: not full verification
Shore Hardness Testing Machine <sup>3</sup>	(25 to 100) HS (VHS)	0.62 HS	Indirect calibration method per JIS B7727  Standard blocks
Torque Measuring <sup>3</sup> Devices, Torque Wrench Tester, Torque Tester, Torque Driver Tester, Torque Meter, Torque Gauge, etc.	10 mN·m to 20 N·m  5 N·m to 1 kN·m	0.18 %  0.25 %	Lever-mass-system (moment-arm and weights)  Reference torque meter
Torque Tools <sup>3</sup> , Torque Wrench, Torque Screwdriver, Torque Gauge, etc.	100 mN·m to 1 kN·m	0.71 %	Torque wrench tester, torque tester, torque driver tester



Parameter/Equipment	Range	CMC <sup>2,5</sup> (±)	Comments
Spring Hammer	(≥0.2 to 1) J	0.010 J	Spring hammer calibration device
Uniaxial Testing Machines <sup>3</sup> –			
Tension Force	0.1 N to 100 kN	0.20 %	Calibration method per JIS B7721; Loop tester, load cells, and 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; Loop tester, load cells, and dead weights
Compression Force	0.1 N to 3 MN	0.23 %	
Graduated Cylinder	≤ 5 mL ≤ 20 mL ≤ 25 mL ≤ 50 mL ≤ 100 mL ≤ 200 mL ≤ 300 mL ≤ 500 mL ≤ 1000 mL ≤ 2000 mL	0.030 mL 0.067 mL 0.079 mL 0.16 mL 0.25 mL 0.51 mL 0.77 mL 1.6 mL 2.8 mL 5.1 mL	Mass method
Flask	≤ 10 mL ≤ 25 mL ≤ 50 mL ≤ 100 mL ≤ 200 mL ≤ 250 mL ≤ 300 mL ≤ 500 mL ≤ 1000 mL ≤ 2000 mL ≤ 2500 mL ≤ 3000 mL ≤ 5000 mL	0.017 mL 0.021 mL 0.031 mL 0.053 mL 0.073 mL 0.079 mL 0.11 mL 0.14 mL 0.26 mL 0.34 mL 0.57 mL 0.74 mL 1.1 mL	Mass method





Parameter/Equipment	Range	CMC <sup>2</sup> (±)	Comments
Volumetric Pipette	≤ 1 mL ≤ 2 mL ≤ 5 mL ≤ 10 mL ≤ 20 mL ≤ 25 mL ≤ 50 mL ≤ 100 mL ≤ 200 mL	0.0056 mL 0.0081 mL 0.016 mL 0.021 mL 0.023 mL 0.025 mL 0.030 mL 0.040 mL 0.056 mL	Mass method
Graduated Pipette	≤ 0.5 mL ≤ 1 mL ≤ 2 mL ≤ 5 mL ≤ 10 mL ≤ 25 mL ≤ 50 mL	0.0039 mL 0.0063 mL 0.0093 mL 0.019 mL 0.027 mL 0.049 mL 0.093 mL	Mass method
Burette	≤ 5 mL ≤ 10 mL ≤ 25 mL ≤ 50 mL ≤ 100 mL	0.0099 mL 0.020 mL 0.030 mL 0.042 mL 0.057 mL	Mass method

## VI. Optical Quantities

Parameter/Equipment	Range	CMC <sup>2,5</sup> (±)	Comments
Optical Power – Measuring Equipment <sup>3</sup>			
(10 to 50) μW (50 to 100) μW (100 to 500) μW	1310 nm	1.3 % 0.55 % 0.44 %	Optical power meter
(10 to 50) μW (50 to 100) μW (100 to 500) μW	1550 nm	1.3 % 0.55 % 0.44 %	



Parameter/Equipment	Range	CMC <sup>2,5</sup> (±)	Comments
Optical Time Domain Reflectometer <sup>3</sup>	1500 m 3000 m 7500 m 1300 m	0.05 % 0.05 % 0.05 % 0.05 %	Optical fiber
Illuminance Meter	(1 to 10) lx (10 to 1000) lx (1000 to 3000) lx (3000 to 10 000) lx	0.93 % 0.85 % 0.93 % 1.1 %	Photometer head and electrometer
Luminance Meter	(0.3 to 3000) cd/m <sup>2</sup>	1.8 %	Photometer head, electrometer and standard reflector

#### VII. Thermodynamics

Parameter/Equipment	Range	CMC <sup>2</sup> (±)	Comments
Digital Thermometer	(-80 to < 0) °C 0 °C (> 0 to 100) °C (> 100 to 200) °C (> 200 to 300) °C (> 300 to 400) °C (> 400 to 550) °C (> 550 to 650) °C (> 650 to 700) °C	0.054 °C 0.035 °C 0.043 °C 0.068 °C 0.11 °C 0.12 °C 0.15 °C 0.41 °C 0.76 °C	Standard digital thermometer, freezing point measurement device
Contact Thermometry	(-50 to 30) °C (> 30 to 100) °C (> 100 to 200) °C (> 200 to 300) °C (> 300 to 400) °C (> 400 to 500) °C	0.7 °C 0.8 °C 0.9 °C 0.9 °C 1.1 °C 1.6 °C	Standard digital thermometer, contact thermometer and surface plate; freezing point measurement device



Parameter/Equipment	Range	CMC <sup>2,5</sup> (±)	Comments
Liquid in Glass Thermometer <sup>6</sup>	(-80 to < 0) °C 0 °C (> 0 to 100) °C (> 100 to 200) °C (> 200 to 300) °C (> 300 to 350) °C	0.060 °C 0.030 °C 0.050 °C 0.070 °C 0.11 °C 0.13 °C	Standard digital thermometer, standard liquid in glass thermometer, freezing point measurement device
Mechanical Thermometer	(-80 to 300) °C (> 300 to 500) °C (> 500 to 600) °C (> 600 to 700) °C	0.70 °C 0.70 °C 0.80 °C 1.0 °C	Standard digital thermometer, freezing point measurement device
Thermocouple (K, E, J, T)	(-80 to 300) °C (> 300 to 500) °C (> 500 to 600) °C (> 600 to 700) °C	0.30 °C 0.50 °C 0.50 °C 0.80 °C	Standard digital thermometer, freezing point measurement device, multimeter
Radiation Thermometer	(-50 to < 0) °C 0 °C (0 to 50) °C (> 50 to 100) °C (> 100 to 200) °C (> 200 to 300) °C (> 300 to 400) °C (> 400 to 500) °C	1.0 °C $\epsilon = 0.997$ 0.88 °C $\epsilon = 0.997$ 0.87 °C $\epsilon = 0.95$ 0.74 °C $\epsilon = 0.95$ 1.2 °C $\epsilon = 0.95$ 1.7 °C $\epsilon = 0.95$ 2.4 °C $\epsilon = 0.95$ 2.5 °C $\epsilon = 0.95$	Blackbody, tammann tube (cavity), standard digital thermometer, freezing point measurement device;  $\epsilon =$ Emissivity
Hygrometer	30 % RH (> 30 to 40) % RH (> 40 to 70) % RH (> 70 to 80) % RH (> 80 to 95) % RH	0.8 % RH 1.1 % RH 1.6 % RH 1.8 % RH 2.1 % RH	Optical dew point meter



VIII. Time & Frequency

Parameter/Equipment	Range	CMC <sup>2</sup> (±)	Comments
Frequency	10 MHz	6.6 parts in 10 <sup>13</sup> Hz/Hz	GPS disciplined oscillator
	0.1 Hz to 3 GHz	8.8 parts in 10 <sup>13</sup> Hz/Hz	Counter, GPS disciplined oscillator
	(3 to 40) GHz	1.5 parts in 10 <sup>12</sup> Hz/Hz	
	(1, 5, 10) MHz	0.5 parts in 10 <sup>10</sup> Hz/Hz	Rubidium frequency standard FC 6017A, frequency difference meter
Frequency <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
Stopwatch <sup>3</sup>	Up to 86400 s	0.02 s/day	Watch tester, counter



Satellite Location:  
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I. Electrical – RF/Microwave<sup>1</sup>

Parameter/Range	Frequency	CMC <sup>2</sup> (±)	Comments
Antenna Factor – Loop Antenna			
Reference Antenna Method	(9, 10) kHz 150 kHz (0.5, 1, 5) MHz 15 MHz 30 MHz	3.4 dB 2.4 dB 2.2 dB 2.1 dB 1.9 dB	Standard reference loop antenna HFH2-Z2 6502
Antenna Factor – Horn Antenna			
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 ratio.

<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.

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## 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 17025:2005 *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 11<sup>th</sup> day of May 2018.

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President and CEO  
For the Accreditation Council  
Certificate Number 1400.03  
Valid to March 31, 2020

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