

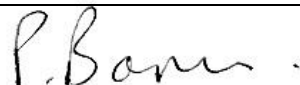
Laboratory Accreditation Programmes

Schedule to

CERTIFICATE OF ACCREDITATION

Laboratory	Callaghan Innovation Measurement Standards Laboratory of New Zealand
Address	PO Box 31310, Lower Hutt, 5040 69 Gracefield Road, Gracefield, Lower Hutt, 5010
Telephone	04 931-3000
URL	http://www.measurement.govt.nz/
Authorised Representative	Dr Blair Hall Principal Research Scientist and Quality Manager
Client No.	8
Programme	Metrology & Calibration Laboratory
Accreditation Number	1
Initial Accreditation Date	30 July 2004
Conformance Standard	ISO/IEC 17025:2017 General requirements for the competence of testing and calibration laboratories
Testing Services Summary	<p>5.01 Engineers' Limit Gauges</p> <p>5.02 Jigs, Fixtures, Cutting Tools and Components</p> <p>5.05 Geometric Form</p> <p>5.11 Working Standards of Length and Angle</p> <p>5.12 Precision Measuring Instruments</p> <p>5.14 Laser Frequency</p> <p>5.21 Masses</p> <p>5.31 Volumetric Equipment</p> <p>5.32 Density</p> <p>5.33 Hydrometers</p> <p>5.35 Hygrometry</p> <p>5.41 Barometers</p> <p>5.42 Differential Pressure Measuring Devices (including Manometers)</p> <p>5.43 Pressure Gauge Testers and Pressure Balances</p> <p>5.44 Pressure and Vacuum Measurement</p> <p>5.61 Temperature Measuring Equipment</p> <p>5.65 Photometers and Radiometers</p> <p>5.66 Lamps, LEDs, Lasers and Other Light Sources</p> <p>5.67 Colour of Light Sources and Colorimeters</p> <p>5.68 Optical Properties of Materials: Spectral</p> <p>5.69 Optical Properties of Materials: Spectrally integrated</p> <p>5.82 Resistors, Resistance Boxes and Potential Dividers</p> <p>5.84 Capacitors</p>

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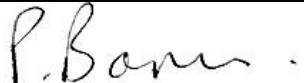
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	5.85 Inductors and Transformers
	5.86 Voltage Standards and Current Standards
	5.87 Transfer Instruments (AC/DC)
	5.88 Calibrators for Instrumentation
	5.89 Indicating Instruments and Recording Instruments
	5.90 Bridges, Potentiometers and Test Sets
	5.91 Frequency Measurement and Time Measurement
	5.92 Waveform Measurement
	5.93 Signal Sources
	5.97 High Voltage Testing
Signatories	<p>Dr Tim Armstrong 5.91, 5.92(a)(c), 5.93(a)</p> <p>Dr Laurie Christian 5.82, 5.85(d), 5.86, 5.87, 5.88, 5.89, 5.90, 5.92(b), 5.93(b), 5.97</p> <p>Dr Mark Clarkson 5.41, 5.42, 5.43, 5.44</p> <p>Mr David Cochrane 5.05(d)(ii)</p> <p>Dr Adam Dunford 5.91(a)(c)(d)(g), 5.92(a)(c), 5.93(a)</p> <p>Dr Murray Early 5.82, 5.86, 5.87, 5.88, 5.89(a-d,i), 5.90(a,f,g), 5.92(b), 5.93(b), 5.97</p> <p>Mr Hamish Edgar 5.61</p> <p>Dr Lucy Forde 5.02, 5.05(d)(ii)(h), 5.11(f)(i)(n), 5.12, 5.14</p> <p>Ms Eleanor Howick 5.01, 5.02, 5.05, 5.11, 5.12, 5.14</p> <p>Mr Darrin Jack 5.41, 5.42, 5.43, 5.44</p> <p>Mr Graeme Jonas 5.05(d)(ii)</p> <p>Mr Keith Jones 5.82, 5.84, 5.85, 5.86, 5.87, 5.88(a,c,e), 5.89(a,c,e,f,g,h,i,l), 5.90, 5.92(b), 5.93(b), 5.97</p> <p>Dr Annette Koo 5.68, 5.69</p> <p>Dr Tim Lawson 5.82(a), 5.86(b), 5.88(c), 5.89(c)</p> <p>Dr Jeremy Lovell-Smith 5.35</p> <p>Mr Ross Mason 5.35, 5.61(c)</p> <p>Mr Greg Reid 5.21, 5.31, 5.32, 5.33</p> <p>Dr Peter Saunders 5.61, 5.82(a), 5.90(a)(c)</p> <p>Dr Francois Shindo 5.65, 5.66, 5.67</p> <p>Mr Tom Stewart 5.82(a), 5.84, 5.85(a,d), 5.88(b,d,e,f), 5.89(a,b,c,d-h,l), 5.90(c,f,g)</p> <p>Dr Chris Sutton 5.21, 5.31, 5.32, 5.33, 5.41, 5.42, 5.43, 5.44</p> <p>Mr Neil Swift 5.05(d)(ii), 5.65, 5.66, 5.67, 5.68, 5.69</p> <p>Mr Yang Yenn Tan 5.65, 5.66(a)(e)(h), 5.68(a)(b)</p> <p>Dr Emile Webster 5.61(c)(p)</p> <p>Dr David Rodney White 5.35, 5.61, 5.82(a), 5.90(a)(c)</p> <p>Mr Chris Young 5.01, 5.02, 5.05, 5.11, 5.12, 5.14</p>

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The uncertainty of a Calibration and Measurement Capability (CMC) is expressed as an expanded uncertainty with a level of confidence of approximately 95% Note1.

Measurement results are traceable to the International System of Units (SI)

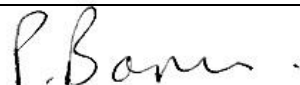
Calibrations are generally performed at the premises of the accredited laboratory, although some may be carried out in the field and some at customer premises.

Measurand	Conditions	CMC Uncertainty
5.01 Engineers' Limit Gauges		
(a) Plain plug, ring and gap gauges. Taper plug and ring gauges.		
Setting plug gauges by comparison with gauge blocks		
Mean diameter	0.5 mm to 25 mm	Q(130, 1.4L) nm, L in mm
Mean diameter	25 mm to 300 mm	Q(95, 1.8L) nm, L in mm
Setting ring gauges by comparison with gauge blocks		
Mean diameter	1 mm to 300 mm	Q(95, 1.8L) nm, L in mm
Where $Q(a,b) = \sqrt{a^2 + b^2}$		
(e) Position and receiver gauges involving both linear and angular measurements.		
Lobster tail gauges	54 mm to 60 mm	0.01 mm
(g) Other gauges involving measurements similar to those under (a) and including depth gauges, height gauges and gauges involving plane coordinated position of holes and spigots.		
Step gauge face spacing by comparison with end standards on CMM		
90 mm to 700 mm		Q(0.7, 1.2 x 10 ⁻³ L) μm, L in mm
2D CMM artefacts (ball plate centre coordinates) by comparison with end standards on CMM		
Side length between 100 mm and 600 mm		Q(0.9, 1.3 x 10 ⁻³ L) μm, L in mm

5.02 Jigs, Fixtures, Cutting Tools and Components

Measurement of components/objects on CMM

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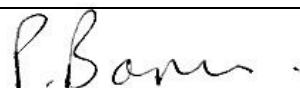
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By comparison	0.1 mm to 103 mm	Q(36, 1.4L) nm, L in mm
Measurement of variation in length		Q(30, 0.35L) nm, L in mm
(b) Length bars and accessories		
Measurement of central length and variation in length		
Long gauge blocks by comparison with gauge blocks using the Horizontal Federal		
100 mm to 300 mm		Q(91, 1.3L) nm, L in mm
Measurement of variation in length		Q(34, 0.35L) nm, L in mm
Long gauge blocks by comparison with gauge blocks using the LBC		
100 mm to 1500 mm		Q(370, 0.48L) nm, L in mm
Measurement of variation in length		100 nm
(f) Precision linear scales		
Engineer or machinist scale-line spacing		
0.1 m to 4 m		Q(10, 8.2L) μ m, L in m
(h) Precision graticules including stage micrometers and haemocytometer counting chambers		
1 μ m to 10 mm		0.5 μ m
(i) Surveying tapes and petroleum dip tapes		
4 m to 50 m		Q(10, 10.5L) μ m, L in m
Surveyor levelling rods		
0.5 m to 3 m		Q(10, 10L) μ m, L in m
(n) Geodetic Baselines (calibrations carried out on site)		
Interval distances	2 m to 1500 m	Q(0.3, 0.6 x 10 ⁻³ L) mm, L in m

5.12 Precision Measuring Instruments

(a) Length measuring machines

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Electronic distance measuring machines (EDMs)

Error of indicated displacement 1 m to 206 m $Q(0.13, 7 \times 10^{-4}L)$ mm, L in m

Error of indicated frequency 5 MHz to 100 MHz $0.16 \times 10^{-6}L$ x frequency

Error of prism constant 0.26 mm

5.14 Laser Frequency

(a) Stabilised lasers of the mise en pratique

Absolute frequency 473 612 GHz 25 kHz

(b) Other stabilised lasers

Absolute frequency 473 612 GHz 0.2 MHz

5.21 Masses

- (a) Examination of laboratory standards of mass
- (b) Examination of industrial standards of mass
- (c) Determination of the mass of solid objects

1 mg to 100 mg	0.4 µg to 0.7 µg
0.1 g to 1 g	0.7 µg to 1.6 µg
1 g to 10 g	1.6 µg to 4 µg
10 g to 100 g	4 µg to 8 µg
0.1 kg to 1 kg	8 µg to 40 µg
1 kg to 10 kg	1.1×10^{-7}
10 kg to 20 kg	1.6×10^{-7}
20 kg to 300 kg	1.5×10^{-6}
300 kg to 1000 kg	10 g to 16 g

5.31 Volumetric Equipment

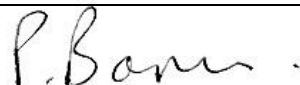
(a) Examination of laboratory volumetric glassware including examination for compliance with the Class A or Class B requirements of the relevant national or international standards

0.02 mL to 2 mL 0.0002 mL

(b) Examination of other types of volumetric apparatus

0.002 L to 50 L 0.01 %

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5.32 Density

(a) Density of solids

1400 kg/m ³ to 3000 kg/m ³	1.0 x 10 ⁻⁵
7800 kg/m ³ to 8200 kg/m ³	1.5 x 10 ⁻⁵

(b) Density of liquids

600 kg/m ³ to 2000 kg/m ³	2.0 x 10 ⁻⁵
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5.33 Hydrometers

- (a) Density hydrometers
- (b) Specific gravity hydrometers
- (c) Brix hydrometers
- (d) Proof spirit hydrometers

600 kg/m ³ to 2000 kg/m ³	2.0 x 10 ⁻⁵
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5.35 Hygrometry

(a) Humidity measuring devices

i) Dew point hygrometers

-70 °C to 0 °C	0.2 °C to 0.06 °C
0 °C to 40 °C	0.06 °C
40 °C to 70 °C	0.06 °C to 0.12 °C

ii) Relative humidity hygrometers

10 % to 95 % (Temperature between 0 °C and 70 °C)	0.006 x <i>h</i> % <i>h</i> is relative humidity expressed as a percentage, that is % rh
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iii) Dry bulb temperature

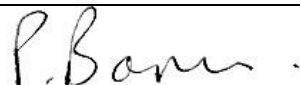
0 °C to 70 °C	0.1 °C
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5.41 Barometers

(a) Aneroid barometers (including digital barometers)

50 kPa to 90 kPa	2.0 x 10 ⁻⁵
90 kPa to 110 kPa	1.0 x 10 ⁻⁵
110 kPa to 130 kPa	2.0 x 10 ⁻⁵

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5.42 Differential Pressure Measuring Devices (including Manometers)

- (a) Diaphragm types
- (b) Liquid column types, inclined and vertical
- (c) Other types

1 Pa to 10000 Pa (6 x 10⁻³ + 4.5 x 10⁻⁵ p)
Pa, p in Pa

5.43 Pressure Gauge Testers and Pressure Balances

- i) Absolute pressure – gas medium

8 kPa to 550 kPa 2 x 10⁻⁵
 550 kPa to 7000 kPa 6 x 10⁻⁵

- ii) Gauge pressure – gas medium

-100 kPa to -10 kPa 7 x 10⁻⁵
 -10 kPa to -1 kPa 200 mPa to 100 mPa,
decreasing linearly
 1 kPa to 8 kPa 100 mPa to 160 mPa,
increasing linearly
 8 kPa to 550 kPa 2 x 10⁻⁵
 550 to 11000 kPa 6 x 10⁻⁵

- iii) Gauge pressure – liquid medium

0.1 MPa to 17 MPa (1 x 10⁻⁴ + 6.6 x 10⁻⁵ p)
MPa (p in MPa)
 17 MPa to 280 MPa (6.6 x 10⁻⁵ p + 7 x 10⁻⁷ p²)
MPa (p in MPa)

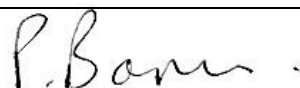
5.44 Pressure and Vacuum Measurement

- (a) Pressure gauges
- (b) Vacuum gauges
- (c) Pressure transducers
- (d) Pressure recorders

- i) Absolute pressure – gas medium

8 kPa to 90 kPa 2 x 10⁻⁵
 90 kPa to 110 kPa 1 x 10⁻⁵
 110 kPa to 550 kPa 2 x 10⁻⁵

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550 kPa to 7000 kPa	6 x 10 ⁻⁵
ii) Gauge pressure – gas medium	
-96 kPa to 8 kPa	0.0031 kPa
8 kPa to 90 kPa	2 x 10 ⁻⁵
90 kPa to 110 kPa	1 x 10 ⁻⁵
110 kPa to 550 kPa	2 x 10 ⁻⁵
550 to 11000 kPa	6 x 10 ⁻⁵
iii) Absolute pressure – liquid medium	
0.3 MPa to 17 MPa	(1 x 10 ⁻⁴ + 6.6 x 10 ⁻⁵ p) MPa (p in MPa)
17 MPa to 280 MPa	(6.6 x 10 ⁻⁵ p + 7 x 10 ⁻⁷ p ²) MPa (p in MPa)
iv) Gauge pressure – liquid medium	
0.2 MPa to 17 MPa	(1 x 10 ⁻⁴ + 6.6 x 10 ⁻⁵ p) MPa (p in MPa)
17 MPa to 280 MPa	(6.6 x 10 ⁻⁵ p + 7 x 10 ⁻⁷ p ²) MPa (p in MPa)

5.61 Temperature Measuring Equipment

(c) Platinum (and other metallic) resistance thermometers

Contact thermometers, including Standard PRTs at the following fixed points

Argon triple point (-189.3442 °C)	1 mK
Mercury triple point (-38.8344 °C)	0.4 mK
Water triple point (0.01 °C)	0.1 mK
Gallium melting point (29.7646 °C)	0.19 mK
Indium freezing point (156.5985 °C)	0.56 mK
Tin freezing point (231.928 °C)	0.85 mK
Zinc freezing point 419.527 °C)	1.9 mK
Aluminium freezing point (660.323 °C)	10 mK

(j) Radiation thermometers

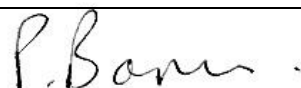
Direct reading, single spot radiation thermometers and thermal imagers

-25 °C to 1100 °C	0.6 °C
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(p) Other direct reading temperature measuring systems, including Industrial PRTs

-190 °C to 0 °C	(2.4 - 0.005 x t) mK, t in °C
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0 °C to 200 °C	(2.4 + 0.008 x t) mK, t in °C
200 °C to 550 °C	(4.0 + 0.03 x (t – 200)) mK, t in °C

5.65 Photometers and Radiometers

(a) Photometers

10 lux to 3000 lux	0.8 %
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(b) Illuminance meters

0.005 lux to 10 lux	3 %
10 lux to 3000 lux	0.8 %
3000 lux to 30000 lux	3 %

(c) Luminance meters

0.5 cd/m ² to 800 cd/m ²	1.6 %
800 cd/m ² to 27000 cd/m ²	7 %
27000 cd/m ² to 33000 cd/m ²	11 %

(d) UV meters

For Irradiance levels of 1 µW.cm⁻² to 5000 µW.cm⁻²

240 nm to 270 nm	5 %
270 nm to 310 nm	2.3 %
310 nm to 380 nm	2.5 %

(g) Laser power meters

Laser lines from 450 nm to 800 nm	0.022 %
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(h) Detector spectral responsivity measurement

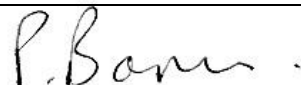
Discrete wavelengths

Laser lines from 450 nm to 800 nm	0.022 %
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The below CMCs are for spectral power levels of 0.1 µW.nm⁻¹ to 10 µW.nm⁻¹ and corresponding irradiance levels using appropriate apertures. For spectral power levels below 0.1 µW.nm⁻¹ uncertainties will increase.

240 nm to 250 nm	1.4 %
250 nm to 280 nm	1.4 % to 0.39 %, decreases linearly with wavelength
280 nm to <420 nm	0.39 %

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420 nm to 680 nm	0.06 %
680 nm to 800 nm	0.08 %
800 nm to 950 nm	0.14 % to 0.16 %, varies with wavelength

5.66 Lamps, LEDs, Lasers and Other Light Sources

Calibrations within 5.66 may be offered in the field as well as in the laboratory. An increase in uncertainty due to environmental conditions and other influence variables present in the field may need to be applied.

(a)	Lamps: luminous intensity	
	10 cd to 5000 cd	0.8 %
(e)	Illuminance	
	0.005 lux to 30000 lux	3 %
(f)	General sources: spectral irradiance	
	250 nm to 350 nm 0.0001 W/(m ² .nm) to 0.5 W/(m ² .nm)	2.6 % to 1.6 %
	350 nm to 850 nm 0.001 W/(m ² .nm) to 0.5 W/(m ² .nm)	1.6 % to 1.4 %
(h)	Photoluminescent materials	
	from 0.5 mcd/m ²	0.5 mcd/m ² or 15 %, whichever is greater

5.67 Colour of Light Sources and Colorimeters

Calibrations within 5.67 may be offered in the field as well as in the laboratory. An increase in uncertainty due to environmental conditions and other influence variables present in the field may need to be applied.

(a)	General sources:	
	Colour emitted in CIE x, y colour space	0.0005 to 0.005 in x and y, varies with measurand
	Colour emitted in CIE u, v colour space	0.0007 in u and v
(d)	Lamps:	
	Correlated colour temperature 2700 K to 3000 K	20 K

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5.68 Optical Properties of Materials: Spectral

(a) Regular transmittance (T) and absorbance (OD)

Bandwidth 1 nm to 3 nm

240 nm to 380 nm	T = 0.0001 to 0.01	0.0002.T ^{0.2}
	T = 0.01 to 1.0	0.005.T
380 nm to 1000 nm	T = 0.0001 to 1.0	0.0007.T ^{0.65}
240 nm to 380 nm	OD = 2 to 4	0.000087.10 ^{0.8.OD}
	OD = 0 to 2	0.0022
380 nm to 1000 nm	OD = 0 to 4	0.00031.10 ^{0.35.OD}

(b) Wavelength calibration filters

240 nm to 800 nm	0.13 nm
800 nm to 1100 nm	0.13 nm to 0.25 nm

(c) Diffuse transmittance

240 nm to 400 nm	0.005 to 0.0002 or 5 % of value whichever is greater
400 nm to 1000 nm	0.0002 or 5 % of value whichever is greater

(d) Diffuse reflectance in 0/d and 6/d geometries

360 nm to 1000 nm	0.016 to 0.9	0.008 to 0.0036, varies with wavelength
360 nm to 1000 nm	0.9 to 1.0	0.4 % of value

(e) Specular reflectance at normal incidence

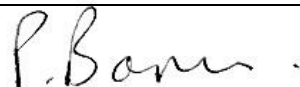
240 nm to 800 nm	0.05 to 1	1 % of value
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(f) Bidirectional reflectance distribution factor and bidirectional radiance factor

In plane geometries only, 0.001 sr ⁻¹ to 2500 sr ⁻¹	
360 nm to 400 nm	1.5 % of value
400 nm to 700 nm	0.5 % of value
700 nm to 820 nm	1.5 % of value

Representative CMCs are for 0°:45° geometry and white spectralon only. Measurement uncertainty varies with scattering geometry, radiance factor and angular dependence of scattering properties of materials.

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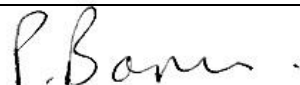
5.69 Optical Properties of Materials: Spectrally integrated

(a)	Luminous transmittance	
	Spectrally flat materials	0.3 % of value
	General materials	5 % of value
(b)	Luminous reflectance	
	General materials	5 % of value
(c)	Colour transmitted, x, y, Y or L*a*b*	
	In x and y	0.005
	Luminous transmittance Y for (0.1 < Y < 1)	5 % of value
(d)	Colour of surfaces, x, y, Y or L*a*b*	
	In x and y	0.003
	Luminance factor Y for (0.1 < Y < 1)	5 % of value
(e)	Retroreflectors: CIL value	
	Coefficient of luminous intensity	5 %

5.82 Resistors, Resistance Boxes and Potential Dividers

(a)	Precision resistors, resistance boxes and conductance boxes	
	0.1 Ω to 1 Ω (Current ≤ 100 mA)	0.2 μΩ/Ω
	1 Ω to 10 kΩ (Power dissipation ≤ 10 mW)	0.12 μΩ/Ω
	10 mΩ to 1000 mΩ (Current ≤ 1A)	25 μΩ/Ω
	0.1 mΩ to 1000 mΩ (Current = 1 A to 875 A)	63 R ^{-0.35} μΩ/Ω, R in mΩ values range from 141 μΩ/Ω to 6 μΩ/Ω
	0.01 MΩ to 1 MΩ (Applied voltages = 5 V to 100 V)	0.7 μΩ/Ω
	0.001 GΩ to 1 GΩ (Applied voltages = 5 V to 100 V)	(0.7 + 27 R - 20 R ³) μΩ/Ω, R in GΩ, values range from 0.7 μΩ/Ω to 8 μΩ/Ω

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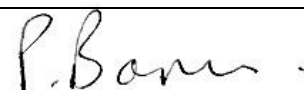
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1 MΩ to 5 TΩ (Applied voltages = 100 V to 1000 V)	$(35 + 6.9 \times 10^{-11} R^2 + 9.4 \mu\Omega/\Omega \times 10^{-4}R) \mu\Omega/\Omega$, R in MΩ, values range from 35 μΩ/Ω to 6460 μΩ/Ω
0 MΩ to 1 MΩ (frequency, $f = 40$ Hz to 2 kHz)	$(2000/f + 19 R) \mu\Omega$, f in Hz, R in Ω, values range from 1 μΩ to 19 Ω
(b) Volt ratio boxes and potential dividers	
1 V/V to 1000 V/V (Input voltage ≤ 1100 V, output voltage ≥ 1 V)	0.4×10^{-6}
0 kV to 50 kV	3 mV/V
(c) DC shunts	
0.1 mΩ to 1 Ω (Applied current 1 A to 875 A) (Applied voltage 10 mV to 1 V)	$63 R^{0.35} \mu\Omega/\Omega$, R in mΩ values range from 141 μΩ/Ω to 6 μΩ/Ω
(d) AC shunts	
0 Ω to 100 Ω (frequency, $f = 40$ Hz to 2 kHz)	$(2000/f + 19R) \mu\Omega$, f in Hz, R in Ω, values range from 1 μΩ to 1900 μΩ
0.2 A to 100 A (frequency, $f = 47$ Hz to 75 Hz)	$25 \mu\Omega/\Omega$

5.84 Capacitors

(a) Precision capacitors	
0 μF to 100 μF (frequency, $f = 40$ Hz to 2 kHz)	$(0.2/f + 22C) \text{ pF}$, f in Hz, C in μF, values range from 0.0001 pF to 2200 pF
Dissipation factor 0 to 0.2 (frequency, $f = 40$ Hz to 2 kHz) (capacitance, $C = 0.5$ pF to 100 μF)	$(0.000027 + 0.00027/C) C$ in pF, values range from 0.00057 to 0.000027
(c) Capacitance potential dividers	
1 kV rms to 35 kV rms	1 mV/V

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(frequency, $f = 50 \text{ Hz}$ to 3 kHz)

5.85 Inductors and Transformers

(a) Inductors, self and mutual

0 H to 100 H
 (frequency, $f = 40 \text{ Hz}$ to 2 kHz)

$(0.2/f + 14L) \mu\text{H}$, f in Hz
 L in H, values range from
 0.0001 μH to 1400 μH

Equivalent series resistance
 0 Ω to 1 M Ω
 (frequency, $f = 40 \text{ Hz}$ to 2 kHz)

$(2000/f + 19R) \mu\Omega$, f in Hz,
 R in Ω , values range from 1
 $\mu\Omega$ to 19 Ω

(d) Current transformers: protection and measurement

Primary currents 1 A to 4000 A, ratios 0.2 A/A to 4000 A/A

Ratio error -25 % to 25 % 0.0010 % to 0.13 %
 Phase error -36 crad to 36 crad 0.0010 crad to 0.18 crad
 (frequency, $f = 50 \text{ Hz}$; secondary currents 1 A, 5 A)

5.86 Voltage Standards and Current Standards

(b) Electronic emf reference devices

1 V 0.1 μV
 1.018 V 0.1 μV
 10 V 1.5 μV

5.87 Transfer Instruments (AC/DC)

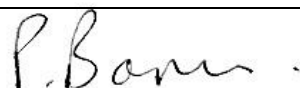
0.002 V to 0.6 V 11 $\mu\text{V/V}$ to 321 $\mu\text{V/V}$
 $> 0.6 \text{ V}$ to 6 V 6 $\mu\text{V/V}$ to 77 $\mu\text{V/V}$
 $> 6 \text{ V}$ to 1000 V 9 $\mu\text{V/V}$ to 76 $\mu\text{V/V}$
 (frequency, $f = 10 \text{ Hz}$ to 1 MHz)

1 V and 3 V 0.16 mV/V to 2.6 mV/V
 (frequency, $f = 1 \text{ MHz}$ to 100 MHz)

0.1 mA to 0.01 A 15 $\mu\text{A/A}$ to 38 $\mu\text{A/A}$
 (frequency, $f = 40 \text{ Hz}$ to 2 kHz)

0.01 A to 20 A 15 $\mu\text{A/A}$ to 70 $\mu\text{A/A}$
 (frequency, $f = 40 \text{ Hz}$ to 100 kHz)

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5.88 Calibrators for Instrumentation

(a) DC voltage

0 V to 12 V

$(0.05 + 0.15U) \mu\text{V}$, U in V, values range from 0.05 μV to 1.85 μV

12 V to 1100 V

0.5 $\mu\text{V/V}$

(b) AC voltage

0.002 V to 1000 V
 (frequency, $f = 10 \text{ Hz to } 1 \text{ MHz}$)

6 $\mu\text{V/V}$ to 650 $\mu\text{V/V}$

1 V and 3 V
 (frequency, $f = 1 \text{ MHz to } 100 \text{ MHz}$)

0.3 mV/V to 8 mV/V

(c) DC current

10 pA to 10 μA

values range from 5 $\mu\text{A/A}$ to 560 $\mu\text{A/A}$

10 μA to 1 A
 1 A to 20 A

5 $\mu\text{A/A}$
 $5 I^{0.43} \mu\text{A/A}$, I in A, values range from 5 $\mu\text{A/A}$ to 18 $\mu\text{A/A}$

20 A to 1000 A

$5 I^{0.43} \mu\text{A/A}$, I in A, values range from 18 $\mu\text{A/A}$ to 97 $\mu\text{A/A}$

(d) AC current

0.1 mA to 2 A
 (frequency, $f = 40 \text{ Hz to } 2 \text{ kHz}$)

35 $\mu\text{A/A}$ to 170 $\mu\text{A/A}$

0.01 A to 100 A
 (frequency, $f = 47 \text{ Hz to } 75 \text{ Hz}$)

25 $\mu\text{A/A}$

(e) Resistance

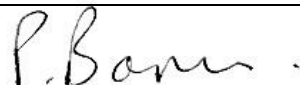
0 Ω to 10 Ω
 0.01 k Ω to 1 M Ω
 1 M Ω to 100 M Ω

40 $\mu\Omega$
 3 $\mu\Omega/\Omega$
 $(2 + R^{0.8}) \mu\Omega/\Omega$, R in M Ω , values range from 3 $\mu\Omega/\Omega$ to 42 $\mu\Omega/\Omega$

(f) AC power sources

Same as 5.89 (e) and (f)

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5.89 Indicating Instruments and Recording Instruments

(a) DC voltmeters

0 V to 0.001 V	0.05 μ V
0.001 V to 12 V	(0.05 + 0.15 U) μ V, U in V, values range from 0.05 μ V to 1.85 μ V
12 V to 1100 V	0.5 μ V/V

(b) AC voltmeters

0.002 V to 1000 V (frequency, $f = 10$ Hz to 1 MHz)	9 μ V/V to 862 μ V/V
1 V and 3 V (frequency, $f = 1$ MHz to 100 MHz)	0.3 mV/V to 8 mV/V

(c) DC ammeters

10 pA to 10 μ A	values range from 5 μ A/A to 560 μ A/A
10 μ A to 1 A	5 μ A/A
1 A to 20 A	5 $I^{0.43}$ μ A/A, I in A, values range from 5 μ A/A to 18 μ A/A
20 A to 875 A	5 $I^{0.43}$ μ A/A, I in A values range from 18 μ A/A to 92 μ A/A

(d) AC ammeters

0.1 mA to 2 A (frequency, $f = 40$ Hz to 2 kHz)	60 μ A/A to 140 μ A/A
0.2 A to 100 A (frequency, $f = 47$ Hz to 75 Hz)	25 μ A/A

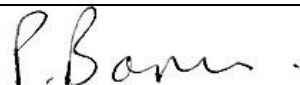
(e) Wattmeters

Conditions
 Voltage 60 V to 240 V, current 0.01 A to 120 A, frequency 45 Hz to 75 Hz, and PF 1 to 0, inductive or capacitive

Single phase 0 W to 28.8 kW	(40 μ W/VA + 6(1- PF)), values range from 40 μ W/VA to 46 μ W/VA
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Three phase 0 W to 86.4 kW	(40 μ W/VA + 6(1- PF)), values
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range from 40 $\mu\text{W}/\text{VA}$ to 46 $\mu\text{W}/\text{VA}$

(The CMC range and uncertainties for star and delta are the same as for single-phase)

(f) Varmeters

Conditions

Voltage 60 V to 240 V, current 0.01 A to 120 A, frequency 45 Hz to 75 Hz, and QF 1 to 0, inductive or capacitive

0 W to 28.8 kW

(40 $\mu\text{Var}/\text{VA}$ + 90 QF), values range from 40 $\mu\text{Var}/\text{VA}$ to 130 $\mu\text{Var}/\text{VA}$

0 W to 86.4 kW

(40 $\mu\text{Var}/\text{VA}$ + 90 QF), values range from 40 $\mu\text{Var}/\text{VA}$ to 130 $\mu\text{Var}/\text{VA}$

(g) Phase angle indicators (source or meter)

Conditions

Current 0.01 A to 100 A, frequency 45 Hz to 75 Hz, Voltage 0.7 V to 7 V, 42 V to 240 V

-3.14 rad to 3.14 rad

40 μrad

(h) Power factor meters

Same conditions, CMC range and uncertainties as 5.89 (g) above

(i) Ohmmeters

0.1 m Ω to 1000 m Ω
 (applied current 875 A to 1 A)

$63R^{0.35}$ $\mu\Omega/\Omega$, R in m Ω , values range from 141 $\mu\Omega/\Omega$ to 6 $\mu\Omega/\Omega$
 0.2 $\mu\Omega/\Omega$

0.1 Ω to 1 Ω
 (applied current ≤ 100 mA)
 1 Ω to 10 k Ω
 10 k Ω to 1 G Ω

0.12 $\mu\Omega/\Omega$
 $(1 + 27R - 20R^3)$ $\mu\Omega/\Omega$, R in G Ω , values range from 1 $\mu\Omega/\Omega$ to 8 $\mu\Omega/\Omega$

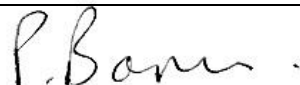
1 G Ω to 100 G Ω

$(-0.07R^2 + 22R - 15)$ $\mu\Omega/\Omega$, R in G Ω , values range from 6.9 $\mu\Omega/\Omega$ to 1485 $\mu\Omega/\Omega$

100 G Ω to 1200 G Ω

$(1300R + 2.2R)$ $\mu\Omega/\Omega$, R in G Ω , values range from 1520 $\mu\Omega/\Omega$ to 3940 $\mu\Omega/\Omega$

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(k) Galvanometers and null detectors

Same CMC range and uncertainties from 5.89 (a) DC voltmeters

(l) Energy meters

Same as 5.89 (e) and (f)

5.90 Bridges, Potentiometers and Test Sets

(a) DC bridges

Same as 5.89 (i) Ohmmeters above

(b) DC potentiometers

Same as 5.89 (a) DC Voltmeters above

(c) AC bridges (frequency, $f = 40$ Hz to 2 kHz)

0 Ω to 1 M Ω

$(2000/f + 19R)$ $\mu\Omega$, f in Hz, R in Ω , values range from 1 $\mu\Omega$ to 19 Ω

0 μF to 100 μF

$(0.2/f + 22C)$ pF, f in Hz, C in μF , values range from 0.0001 pF to 2200 pF

0 H to 1 H

$(0.2/f + 14L)$ H μH , f in Hz, L in H, values range from 0.0001 μH to 14 μH

(f) Current transformer testing sets

Ratio/Phase
 (frequencies in the range 45 Hz to 65 Hz)

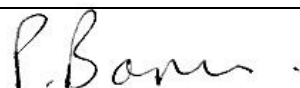
Ratio error	$\pm (0 \text{ to } 0.002)$	$5.0 \times 10^{-7} \text{ to } 1.0 \times 10^{-6}$
Ratio error	$\pm (0.002 \text{ to } 0.02)$	$2.0 \times 10^{-6} \text{ to } 8.0 \times 10^{-6}$
Ratio error	$\pm (0.02 \text{ to } 0.2)$	$2.0 \times 10^{-5} \text{ to } 8.0 \times 10^{-5}$
Phase error	$\pm 0 \text{ rad to } 0.002 \text{ rad}$	$5.0 \times 10^{-7} \text{ rad to } 1.0 \times 10^{-6} \text{ rad}$
Phase error	$\pm 0.002 \text{ rad to } 0.02 \text{ rad}$	$5.0 \times 10^{-6} \text{ rad to } 9.0 \times 10^{-6} \text{ rad}$
Phase error	$\pm 0.02 \text{ rad to } 0.2 \text{ rad}$	$5.0 \times 10^{-5} \text{ rad to } 9.0 \times 10^{-5} \text{ rad}$

(g) Voltage transformer testing sets

Same as 5.90 (f)

(i) AC and DC bridges for thermometry

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Resistance 0 Ω to 400 Ω (frequency, $f = DC$ to 100 Hz)	$(6 + 0.3 R) \mu\Omega$, R in Ω, values range from 6 μΩ to 126 μΩ
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Resistance ratio 0 Ω/Ω to 13 Ω/Ω (frequency, $f = DC$ to 100 Hz)	2.6×10^{-8}
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5.91 Frequency Measurement and Time Measurement

Time and frequency CMC uncertainties relate only to the reference measuring systems. These uncertainties do not contain any contribution from the instrument under calibration.

(a) Frequency meters

1 Hz to 40 GHz 0.001 Hz to 1 Hz (period)	1×10^{-10} 1 ns
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(c) Counters

1 Hz to 40 GHz 0.001 Hz to 1 Hz (period)	1×10^{-10} 1 ns
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(d) Time interval meters

10 ns to 86400 s	2 ns or 0.27 ps/s, whichever is greatest
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(e) Clocks and watches

5 ns to 1 s	50 ns
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(g) Frequency standards

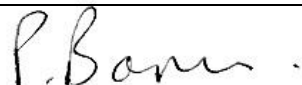
100 kHz to 10 MHz 0.001 Hz to 1 Hz (period)	2×10^{-13} 1 ns
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(h) Time measurement

Time scale difference – Local clock vs UTC (MSL) -1 s to 1 s	2 ns
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Time scale difference – Local clock vs UTC -1 s to 1 s	50 ns
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5.92 Waveform Measurement

(a) Frequency characteristics

1 Hz to 20 MHz	1 in 10^{-10}
0.001 Hz to 1 Hz (period)	1 ns

(b) Input characteristics

1 V and 3 V (frequency, $f = 1$ MHz to 100 MHz)	0.16 mV/V to 2.6 mV/V
--	-----------------------

Pulse risetime ($T > 5$ ns)
(10 mV to 10 V)

0.005 μ s to 1.00×10^6 μ s	Q(2 ns, 0.05 T), T in s
---	-------------------------

Pulse amplitude (pulse length > 200 μ s)
(10 mV, 100 mV, 1 V, 10 V)

0 V to 10 V	(30 μ V + 100 V_a + 420 V_r), applied voltage V_a in V, voltmeter range V_r in V, values range from 34.2 μ V to 5230 μ V
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(c) Timing characteristics

10 ns to 100 s (time difference)	2 ns
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5.93 Signal Sources

(a) Frequency characteristics

1 Hz to 20 MHz	1×10^{-10}
0.001 Hz to 1 Hz (period)	1 ns

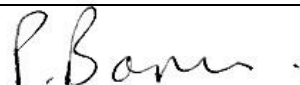
(b) Output characteristics

1 V and 3 V (frequency, $f = 1$ MHz to 100 MHz)	0.16 mV/V to 2.6 mV/V
--	-----------------------

Pulse amplitude (pulse length > 200 μ s)
(10 mV, 100 mV, 1 V, 10 V)

0 V to 10 V	(30 μ V + 100 V_a + 420 V_r) applied voltage V_a in V,
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	voltmeter range V_r in V, values range from 34.2 μ V to 5230 μ V
Pulse risetime ($T > 5$ ns) (10 mV to 10 V)	
0.005 μ s to 1.00 x 10 ⁶ μ s	Q(2 ns, 0.05T), T in s
5.97 High Voltage Testing	
(a) Direct voltage	
0 kV to 50 kV	3 mV/V
(b) Alternating voltage	
1 kV rms to 35 kV rms (frequency, $f = 50$ Hz to 3 kHz)	1 mV/V

Note 1:
 A CMC anticipates the performance of a best available device. Measurement uncertainties achieved for specific calibrations may be greater than CMC uncertainties, but a laboratory may not report measurement uncertainties lower than those in its CMCs. Please contact the laboratory to discuss your specific requirements.

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