



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

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CALIBRATION

Valid To: November 30, 2011

Certificate Number: 1623.01

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

I. Acoustical Quantities

Parameter/Equipment	Frequency	CMC <sup>2</sup> (±)	Comments
Sound <sup>3</sup>			
94 dB re 20 uPa	1 kHz	0.25 dB	B&K 4231
114 dB re 20 uN/m <sup>2</sup>	125 Hz	0.89 dB	GenRad 1562
	250 Hz	0.89 dB	
	500 Hz	0.63 dB	
	1000 Hz	0.89 dB	
	2000 Hz	0.89 dB	

II. Chemical

Parameter/Range	Range	CMC <sup>2</sup> (±)	Comments
pH <sup>3</sup>	4.0 pH 7.0 pH 12.5 pH	0.016 pH 0.016 pH 0.059 pH	Calibrated solutions

III. Dimensional

Parameter/Equipment	Range	CMC <sup>2,7</sup> (±)	Comments
Gage Blocks	(0 to 24) in	(1.9 + 2.5L) μin	Mechanical comparison with grade 0.5 gage blocks
Cylindrical Rings	(0 to 13) in	(1.9 + 2.5L) μin	Mechanical comparison with grade 0.5 gage blocks
Threaded Rings <sup>3</sup> Inside Diameter Pitch Diameter	(0 to 13) in (4 to 96) TPI	(1.9 + 110L) μin	Mechanical comparison with grade 0.5 gage blocks
Cylindrical Plain & Threaded Plugs Outside Diameter Pitch Diameter	(0 to 13) in (4 to 96) TPI	(79 + 5L) μin	Mechanical comparison with grade 0.5 gage blocks
Tapered Plain & Threaded Plugs – Outside Diameter Pitch Diameter	(0 to 3) in (4 to 96) TPI	(83 + 5L) μin	Mechanical comparison with grade 0.5 gage blocks

Parameter/Equipment	Range	CMC <sup>2,7</sup> ( $\pm$ )	Comments
Snap Gages <sup>3</sup>	(0 to 48) in	(63 + 1.6L) $\mu$ in	Grade 1 gage blocks
Micrometer Set Standards	(0 to 5) in (5 to 12) in	(4.2 + 1.9L) $\mu$ in	Mechanical comparison with grade 0.5 gage blocks
Thread Wires	(0 to 2) in (4 to 96) TPI	21 $\mu$ in	Mechanical comparison with grade 0.5 gage blocks
Micrometers <sup>3</sup> , Height <sup>3</sup> and Depth Gages <sup>3</sup>	(0 to 48) in	(63 + 1.6L) $\mu$ in	Grade 0.5 gage blocks
Calipers <sup>3</sup>	(0 to 48) in	(620 + 1.6L) $\mu$ in	Grade 0.5 gage blocks
Indicators <sup>3</sup>	(0 to 2) in	(63 + 1.6L) $\mu$ in	Grade 0.5 gage blocks
Pins <sup>3</sup>	(0 to 0.05) in	53 $\mu$ in	Mechanical comparison with grade 0.5 gage blocks
	(0.05 to 2) in	61 $\mu$ in	Laser micrometer
Parallelism <sup>3</sup>	Surface to 24 in	9.9 $\mu$ in	Gage blocks with Tesatronic TTA 20
Rulers <sup>3</sup>	(0 to 48) in	0.009 in	Grade 1 gage blocks
Squareness <sup>3</sup>	Up to 7 in $\times$ 12 in	140 $\mu$ in	Master square
Surface Plate Flatness <sup>3</sup>	Up to 96 in $\times$ 48 in	140 $\mu$ in	48-inch Rahn Plankator
	Up to 54 in $\times$ 36 in	82 $\mu$ in	36-inch Rahn Plankator
	Up to 48 in $\times$ 24 in	66 $\mu$ in	24-inch Rahn Plankator Note: Uncertainty is to be no less than the acceptable closure error for the procedure.

Parameter/Equipment	Range	CMC <sup>2</sup> (±)	Comments
Optical Flats	(0 to 5) inch in diameter	1.4 µin	Interferometer
Optical Comparators <sup>3</sup> –			
Length	(0.02 to 12) in	200 µin	Microline 37876 mag. check scale
Magnification	(0.0625, 0.1875, 0.25, 0.625, 1.0) in	110 µin	Optical gaging 20300 ball set
Angle	0° to 30.0°	36”	China 757-AB10 angle block set

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

Parameter/Equipment	Range	CMC <sup>2</sup> (±)	Comments
DC Voltage – Generate <sup>3,4</sup>	0.001 to 1.0 V 1.0 to 10 V	0.9 µV/V + 0.14 µV 0.6 µV/V + 0.14 µV	Fluke 732B with 720A & Agilent 34420A
	10 to 20 V 20 to 200 V 200 to 1100 V	4 µV/V + 4 µV 5.5 µV/V + 40 µV 7 µV/V + 400 µV	Fluke 5720A
Fixed Points	1.018 V 10 V	0.95 µV 7.2 µV	Fluke 732B
	100 V 1000 V	64 µV 830 µV	Fluke 732B with 752A
DC Voltage – Measure <sup>3,5</sup>	Up to 100 mV (0.1 to 1) V (1 to 10) V (10 to 100) V (100 to 1000) V	6.2 µV/V + 3 µV 5.2 µV/V + 0.3 µV 5.2 µV/V + 0.05 µV 7.3 µV/V + 0.3 µV 7.3 µV/V + 0.1 µV	HP 3458A, OPT 002
	1.018 V 10 V	1.5 µV/V 7.7 µV/V	Dataproof scanner with Fluke 732B & Agilent 34420A

Parameter/Equipment	Range	CMC <sup>2,9</sup> (±)	Comments
DC Voltage – Measure <sup>3,5</sup> (cont)	(0.001 to 1.0) V	1.2 μV/V + 0.14 μV	Fluke 720A with 732B and Agilent 34420A
	(1.0 to 10) V	0.6 μV/V + 0.14 μV	
	(1 to 10) kV	0.014 %	Fluke 80E-10
	(10 to 90) kV	0.12 %	Ross VD 90
	(90 to 200) kV	0.12 %	Ross VD 200-7.6Y-H-UA-BAL
Fixed Points	100 V 1000 V	96 μV 1.2 mV	Fluke 752A with 732B and 845A
DC Current – Measure & Generate <sup>3,5</sup>	(0.1 to 100) nA	0.011 %	HP 3458A and:  Honeywell 1106 Honeywell 1105 ESI SR104 L&N 4035-B L&N 4030-B L&N 4025-B L&N 4210 L&N 4221-B L&N 4222-B
	(0.1 to 1) μA	0.0073 %	
	(1 to 10) μA	0.0051 %	
	(10 to 100) μA	0.0044 %	
	(0.1 to 1) mA	0.0043 %	
	(1 to 10) mA	0.0043 %	
	(10 to 100) mA	0.0044 %	
	(0.1 to 1) A	0.0042 %	
(1 to 10) A	0.0051 %		
	(10 to 100) A	0.0088 %	HP 3458A, L&N 4223-B
	(100 to 1000) A	0.081 %	Honeywell shunt, 3458A
DC Current – Measure <sup>3,5</sup>	(10 to 100) pA	0.011 %	HP 3458A with Guildline 9330 10M

Parameter/Equipment	Range	CMC <sup>2,9</sup> ( $\pm$ )	Comments
DC Resistance – Generate <sup>3,4</sup>	(0 to 11) $\Omega$	40 $\mu\Omega/\Omega$ + 1 m $\Omega$	Fluke 5520A
	(11 to 33) $\Omega$	30 $\mu\Omega/\Omega$ + 1.5 m $\Omega$	
	(33 to 110) $\Omega$	28 $\mu\Omega/\Omega$ + 1.4 m $\Omega$	
	(0.11 to 1.1) $\Omega$	28 $\mu\Omega/\Omega$ + 2 m $\Omega$	
	(1.1 to 11) k $\Omega$	28 $\mu\Omega/\Omega$ + 20 m $\Omega$	
	(11 to 110) k $\Omega$	28 $\mu\Omega/\Omega$ + 0.2 $\Omega$	
	(0.11 to 1.1) M $\Omega$	32 $\mu\Omega/\Omega$ + 2 $\Omega$	
	(1.1 to 3.3) M $\Omega$	60 $\mu\Omega/\Omega$ + 30 $\Omega$	
	(3.3 to 11) M $\Omega$	0.015 % of setting + 50 $\Omega$	
	(11 to 33) M $\Omega$	0.025 % of setting + 2.5 k $\Omega$	
	(33 to 110) M $\Omega$	0.05 % of setting + 3 k $\Omega$	
	(110 to 330) M $\Omega$	0.3 % of setting + 100 k $\Omega$	
	(330 to 1100) M $\Omega$	1.5 % of setting + 500 k $\Omega$	
		(10 to 100) M $\Omega$	
(0.1 to 1) G $\Omega$		0.06 % of setting	
Fixed Values	0.001 $\Omega$	0.025 $\mu\Omega$	L&N 4223-B
	0.01 $\Omega$	0.12 $\mu\Omega$	L&N 4222-B
	0.1 $\Omega$	2.5 $\mu\Omega$	L&N 4221-B
	1 $\Omega$	0.4 $\mu\Omega$	L&N 4210
	1.9 $\Omega$	190 $\mu\Omega$	Fluke 5720A
	10 $\Omega$	6 $\mu\Omega$	L&N 4025-B
	19 $\Omega$	440 $\mu\Omega$	Fluke 5720A
	100 $\Omega$	70 $\mu\Omega$	L&N 4030-B
	190 $\Omega$	1.9 m $\Omega$	Fluke 5720A
	1 k $\Omega$	0.9 m $\Omega$	L&N 4035-B
	1.9 k $\Omega$	0.17 $\Omega$	Fluke 5720A
	10 k $\Omega$	2.8 m $\Omega$	ESI SR104
	19 k $\Omega$	0.17 $\Omega$	Fluke 5720A
	100 k $\Omega$	0.14 $\Omega$	Honeywell 1105
	190 k $\Omega$	2.3 $\Omega$	Fluke 5720A
	1 M $\Omega$	1.7 $\Omega$	Honeywell 1106
	1.9 M $\Omega$	42 $\Omega$	Fluke 5720A
	10 M $\Omega$	69 $\Omega$	Guildline 9330-10M
	19 M $\Omega$	970 $\Omega$	Fluke 5720A
	100 M $\Omega$	2.8 k $\Omega$	Guildline 9330-100M
1 G $\Omega$	0.05 %	Guildline 65206-1G	
(10, 100) G $\Omega$	0.2 %	Keithley 5155	

Parameter/Equipment	Range	CMC <sup>2,9</sup> (±)	Comments
DC Power – Generate <sup>3,4</sup>	(0.1 to 330) W (0.33 to 11) kW (11 to 20.5) kW	0.2 % 0.21 % 0.23 %	Fluke 5520A
DC Resistance <sup>3,5</sup> – Measure	(0.05 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 10) MΩ (10 to 100) MΩ (0.1 to 1) GΩ  (0.1 to 1) 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 10) MΩ (10 to 100) MΩ  (0.1 to 1) GΩ (1 to 10) GΩ (10 to 100) GΩ (0.1 to 1) TΩ (1 to 10) TΩ (10 to 100) TΩ	0.0008 % 0.0006 % 0.00021 %  0.000042 % 0.000063 % 0.000076 % 0.000094 %  0.000031 % 0.00014 % 0.00019 % 0.0009 % 0.0033 %  19 μΩ/Ω + 0.05 mΩ 15 μΩ/Ω + 0.5 mΩ 13 μΩ/Ω + 0.5 mΩ 12 μΩ/Ω + 5 mΩ 13 μΩ/Ω + 0.05 Ω 24 μΩ/Ω + 2 Ω 65 μΩ/Ω + 100 Ω 0.058 % + 1 kΩ  0.06 % 0.08 % 0.14 % 0.26 % 0.42 % 0.74 %	MIL 6010B with 6011B and L&N 4210  MIL 6010B with: L&N 4210 L&N 4025-B L&N 4030-B ESI SR104  MIL 6010B with 6000B and: ESI SR104 Honeywell 1105 Honeywell 1106 Guildline 9330-10M Guildline 9330-100M  HP 3458A  Guildline 6500A
Rise Time – Generate <sup>3</sup>	< 25 ps	3.5 %	Tektronix S-52 with 7S11 and 7T11
Rise Time – Measure <sup>3,5</sup>	< 9 ps	3 %	HP 86100A with 83484A

Parameter/Range	Frequency	CMC <sup>2,9</sup> ( $\pm$ )	Comments
Distortion – Measure <sup>3</sup> 5 Hz to 600 kHz, Fundamental Frequency			HP 334A
0.3 to 100 % dist. < 30 V	10 Hz to 1 MHz (1 to 3) MHz	3.5 % 7 %	
30 to 300 V	10 Hz to 300 kHz (300 to 500) kHz (0.5 to 3) MHz	3.5 % 7 % 14 %	
0.1 % distortion < 30 V	(10 to 20) Hz (20 to 30) Hz 30 Hz to 300 kHz (300 to 500) kHz (0.5 to 1.2) MHz	14 % 7 % 3.5 % 7 % 14 %	
> 30 V	(20 to 30) Hz 30 Hz to 300 kHz (300 to 500) kHz (0.5 to 1.2) MHz	14 % 4 % 7 % 14 %	
20 Hz to 100 kHz, Fundamental Frequency			HP 8903B
0 to -99 dB 0 to -99 dB	20 Hz to 20 kHz 20 kHz to 100 kHz	1.2 dB 2.3 dB	
Phase – Generate <sup>3</sup>			
0° to 360° 50 mV to 120 V	1 Hz to 1 kHz (1 to 6.25) kHz (6.25 to 50) kHz (50 to 100) kHz	(7.1 + 0.05R) m° (13 + 0.1R) m° (19 + 0.15R) m° (52 + 0.4R) m°	Clark-Hesse 5500 bridge  In the statement of CMC, <i>R</i> is the ratio of voltages.
0°, 180°	1 Hz to 50 kHz	3.1 m°	Clark-Hesse 5002 phase verification bridge

Parameter/Range	Frequency	CMC <sup>2</sup> (±)	Comments
Phase – Measure <sup>3</sup>  0° to 360°	1 Hz to 1 kHz (1 to 6.25) kHz (6.25 to 50) kHz (50 to 100) kHz  (100 to 700) kHz	(21 + 0.05R) m° (23 + 0.1R) m° (26 + 0.15R) m° (50 + 0.4R) m°  [0.29 + (5 m°/kHz)]°	Clark-Hesse 5500 bridge With NA 2000 meter  R is the ratio of voltages.  NA 2000 meter
AC Voltage – Generate <sup>3,4</sup>  (0.2 to 22) mV  220 mV  2.2 V  22 V	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz (0.5 to 1) MHz  (10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz (0.5 to 1) MHz  (10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz (0.5 to 1) MHz  (10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz (0.5 to 1) MHz	0.024 % + 4 μV 90 μV/V + 4 μV 80 μV/V + 4 μV 0.02 % + 4 μV 0.05 % + 5 μV 0.11 % + 10 μV 0.14 % + 20 μV 0.27 % + 20 μV  0.024 % + 12 μV 90 μV/V + 7 μV 80 μV/V + 7 μV 0.02 % + 7 μV 0.046 % + 17 μV 0.09 % + 20 μV 0.14 % + 25 μV 0.27 % + 45 μV  0.024 % + 40 μV 90 μV/V + 15 μV 45 μV/V + 8 μV 75 μV/V + 10 μV 0.011 % + 30 μV 0.042 % + 80 μV 0.1 % + 200 μV 0.17 % + 300 μV  0.024 % + 0.4 mV 90 μV/V + 0.15 mV 45 μV/V + 0.05 mV 75 μV/V + 0.1 mV 0.01 % + 0.2 mV 0.028 % + 0.6 mV 0.1 % + 2 μV 0.15 % + 3.2 μV	Fluke 5720A with 5725A

Parameter/Range	Frequency	CMC <sup>2,9</sup> (±)	Comments
AC Voltage <sup>3,4</sup> – Generate (cont.)			
220 V	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz (0.5 to 1) MHz	0.024 % + 4 mV 90 μV/V + 1.5 mV 52 μV/V + 0.6 mV 80 μV/V + 1 mV 0.015 % + 2.5 mV 0.09 % + 16 mV 0.44 % + 40 mV 0.8 % + 80 mV	Fluke 5720A with 5725A
750 V	(30 to 50) kHz (50 to 100) kHz	0.06 % + 11 mV 0.23 % + 45 mV	
1100 V	(15 to 40) Hz 40 Hz to 1 kHz (1 to 20) kHz (20 to 30) kHz	0.03 % + 16 mV 90 μV/V + 4 mV 0.017 % + 6 mV 0.06 % + 11 mV	
(1 to 100) kV	60 Hz	0.58 %	High Voltage PFT-1003CM with Ross VD90 and Fluke 8060
Oscilloscopes - Bandwidth <sup>3,4</sup>	50 kHz to 100 MHz (100 to 300) MHz (300 to 600) MHz (600 to 1100) MHz	2.2 % 2.7 % 4.8 % 6.0 %	Fluke 5520A/SC1100
AC Voltage – Measure <sup>3,5</sup>			
3 μV to 2 mV	(1 to 40) Hz 40 Hz to 1 kHz (1 to 20) kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz	0.03 % + 3 μV 0.02 % + 1.1 μV 0.03 % + 1.1 μV 0.12 % + 1.1 μV 0.58 % + 1.1 μV 4.6 % + 2 μV	HP 3458A (synchronous sub-sampled mode)
(10 to 100) mV	(1 to 2) MHz	1.7 % + 10 μV	
(0.1 to 1) V	(1 to 2) MHz	1.7 % + 100 μV	
(1 to 10) V	(1 to 2) MHz	1.7 % + 1 mV	
(10 to 100) V	(0.3 to 1) MHz	1.7 % + 10 mV	

Parameter/Range	Frequency	CMC <sup>2,9</sup> (±)	Comments
AC Voltage <sup>3,4,5</sup> – Measure (cont)			
220 mV 20 mV Input	10 Hz	0.022 %	Fluke 792A with HP 3458A and Fluke 5720A/5725A
	(20, 40) Hz	0.016 %	
	(0.1, 1, 10, 20) kHz	0.015 %	
	50 kHz	0.018 %	
	100 kHz	0.029 %	
	300 kHz	0.041 %	
	500 kHz	0.061 %	
	1 MHz	0.072 %	
100 mV Input	10 Hz	0.0053 %	
	20 Hz	0.0088 %	
	40 Hz	0.0040 %	
	100 Hz	0.0059 %	
	1 kHz	0.0051 %	
	10 kHz	0.0047 %	
	20 kHz	0.0048 %	
	50 kHz	0.0058 %	
	100 kHz	0.0089 %	
	300 kHz	0.017 %	
	500 kHz	0.022 %	
	1 MHz	0.029 %	
200 mV Input	10 Hz	0.0051 %	
	20 Hz	0.0056 %	
	(40, 100) Hz	0.0037 %	
	1 kHz	0.0040 %	
	(10, 20) kHz	0.0037 %	
	50 kHz	0.0054 %	
	100 kHz	0.0091 %	
	300 kHz	0.016 %	
	500 kHz	0.013 %	
	1 MHz	0.024 %	
700 mV 200 mV Input	10 Hz	0.0052 %	
	20 Hz	0.0070 %	
	40 Hz	0.0045 %	
	100 Hz	0.0046 %	
	1 kHz	0.0044 %	
	10 kHz	0.0036 %	
	20 kHz	0.0046 %	
	50 kHz	0.0052 %	
	100 kHz	0.0085 %	
	300 kHz	0.014 %	
	500 kHz	0.018 %	
	1 MHz	0.022 %	

Parameter/Range	Frequency	CMC <sup>2,9</sup> (±)	Comments
AC Voltage <sup>3,4,5</sup> – Measure (cont)			
700 mV (cont) 600 mV Input	10 Hz	0.0036 %	Fluke 792A with HP 3458A and Fluke 5720A/5725A
	20 Hz	0.0083 %	
	40 Hz	0.0034 %	
	100 Hz	0.0029 %	
	1 kHz	0.0033 %	
	(10, 20) kHz	0.0029 %	
	50 kHz	0.0047 %	
	100 kHz	0.0058 %	
	(300, 500) kHz	0.0097 %	
	1 MHz	0.0098 %	
2.2 V 600 mV Input	10 Hz	0.0036 %	
	20 Hz	0.0057 %	
	40 Hz	0.0040 %	
	(0.1, 1, 10) kHz	0.0033 %	
	20 kHz	0.0030 %	
	50 kHz	0.0047 %	
	100 kHz	0.0058 %	
	(300, 500) kHz	0.012 %	
	1 MHz	0.012 %	
1 V Input	10 Hz	0.014 %	
	20 Hz	0.0048 %	
	40 Hz	0.0031 %	
	100 Hz	0.0028 %	
	(1, 10, 20) kHz	0.0030 %	
	50 kHz	0.0045 %	
	100 kHz	0.0050 %	
	300 kHz	0.0096 %	
	500 kHz	0.012 %	
	1 MHz	0.0096 %	

Parameter/Range	Frequency	CMC <sup>2,9</sup> (±)	Comments
AC Voltage <sup>3,4,5</sup> – Measure (cont)			
2.2 V (cont) 2 V Input	10 Hz 20 Hz 40 Hz (0.1, 1, 10, 20) kHz 50 kHz 100 kHz 300 kHz 500 kHz 1 MHz	0.01 % 0.0044 % 0.0037 % 0.0029 % 0.0045 % 0.0052 % 0.011 % 0.012 % 0.0096 %	Fluke 792A with HP 3458A and Fluke 5720A/5725A
7 V 2 V Input	10 Hz 20 Hz 40 Hz 100 Hz (1, 10, 20) kHz 50 kHz 100 kHz 300 kHz 500 kHz 1 MHz	0.0092 % 0.0051 % 0.0041 % 0.0035 % 0.0032 % 0.0051 % 0.0053 % 0.012 % 0.013 % 0.012 %	
6 V Input	10 Hz 20 Hz 40 Hz (0.1, 1, 10, 20) kHz 50 kHz 100 kHz (300, 500) kHz 1 MHz	0.0099 % 0.0044 % 0.0037 % 0.0030 % 0.0046 % 0.0051 % 0.012 % 0.0097 %	
22 V 6 V Input	10 Hz 20 Hz 40 Hz 100 Hz 1 kHz 10 kHz 20 kHz 50 kHz 100 kHz (300, 500) kHz 1 MHz	0.014 % 0.0050 % 0.0042 % 0.0030 % 0.0032 % 0.0035 % 0.0034 % 0.0050 % 0.0053 % 0.0097 % 0.015 %	

Parameter/Range	Frequency	CMC <sup>2,9</sup> (±)	Comments	
AC Voltage <sup>3,4,5</sup> – Measure (cont)	22 V 10 V Input	10 Hz	0.0037 %	Fluke 792A with HP 3458A and Fluke 5720A/5725A
		20 Hz	0.0056 %	
		40 Hz	0.0032 %	
		100 Hz	0.0031 %	
		(1, 10) kHz	0.0030 %	
		20 kHz	0.0031 %	
		50 kHz	0.0044 %	
		100 kHz	0.0053 %	
		300 kHz	0.0097 %	
		(0.5, 1) MHz	0.012 %	
	20 V Input	10 Hz	0.0038 %	
		20 Hz	0.0045 %	
		40 Hz	0.0038 %	
		(0.1, 1, 10, 20) kHz	0.0031 %	
		50 kHz	0.0044 %	
		100 kHz	0.0053 %	
		300 kHz	0.012 %	
		500 kHz	0.013 %	
	70 V 20 V Input	10 Hz	0.0093 %	
		20 Hz	0.0057 %	
		40 Hz	0.0042 %	
		100 Hz	0.0038 %	
		1 kHz	0.0037 %	
		10 kHz	0.0036 %	
		20 kHz	0.0038 %	
		50 kHz	0.0053 %	
		100 kHz	0.0068 %	
		300 kHz	0.015 %	
	60 V Input	10 Hz	0.0042 %	
		20 Hz	0.0046 %	
		40 Hz	0.0038 %	
		(0.1, 1, 10, 20) kHz	0.0033 %	
		50 kHz	0.0055 %	
		100 kHz	0.0058 %	
		300 kHz	0.0097 %	

Parameter/Range	Frequency	CMC <sup>2,9</sup> (±)	Comments
AC Voltage <sup>3,4,5</sup> – Measure (cont)			
220 V 60 V Input	10 Hz 20 Hz 40 Hz 100 Hz 1 kHz 10 kHz 20 kHz 50 kHz 100 kHz 300 kHz	0.014 % 0.0057 % 0.0040 % 0.0042 % 0.0040 % 0.0042 % 0.0048 % 0.0058 % 0.0071 % 0.014 %	Fluke 792A with HP 3458A and Fluke 5720A/5725A
100 V Input	10 Hz 20 Hz 40 Hz (0.1, 1, 10, 20) kHz 50 kHz 100 kHz	0.017 % 0.0062 % 0.0040 % 0.0038 % 0.0057 % 0.0061 %	
200 V Input	10 Hz 20 Hz (40, 100) Hz (0.1, 1, 10) kHz 20 kHz 50 kHz 100 kHz	0.0058 % 0.0051 % 0.0039 % 0.0038 % 0.0039 % 0.0059 % 0.0069 %	
1000 V 200 V Input	10 Hz 20 Hz 40 Hz 100 Hz 1 kHz 10 kHz 20 kHz 50 kHz 100 kHz	0.019 % 0.0064 % 0.0057 % 0.0044 % 0.0042 % 0.0047 % 0.0051 % 0.0058 % 0.0080 %	
1000 V Input	10 Hz 20 Hz 40 Hz 100 Hz 1 kHz 10 kHz 20 kHz 50 kHz 100 kHz	0.0075 % 0.0049 % 0.0046 % 0.0045 % 0.0046 % 0.0048 % 0.0051 % 0.0075 % 0.01 %	

Parameter/Range	Frequency	CMC <sup>2,9</sup> (±)	Comments
AC Voltage <sup>3,4,5</sup> – Measure (cont)			
(1 to 2.2) mV	(0.5 to 1.2) MHz (1.2 to 2) MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz	0.23 % + 1 μV 0.25 % + 1 μV 0.34 % + 1 μV 0.42 % + 1 μV 0.81 % + 1 μV	Fluke 5790A Option-03
(2.2 to 7) mV	(0.5 to 1.2) MHz (1.2 to 2) MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz	0.11 % + 1 μV 0.11 % + 1 μV 0.14 % + 1 μV 0.21 % + 1 μV 0.41 % + 1 μV	
(7 to 22) mV	(0.5 to 1.2) MHz (1.2 to 2) MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz	0.095 % 0.094 % 0.12 % 0.19 % 0.39 %	
(22 to 70) mV	(0.5 to 1.2) MHz (1.2 to 2) MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz	0.06 % 0.06 % 0.11 % 0.16 % 0.36 %	
(70 to 220) mV	(0.5 to 1.2) MHz (1.2 to 2) MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz	0.056 % 0.062 % 0.11 % 0.16 % 0.36 %	
(220 to 700) mV	(0.5 to 1.2) MHz (1.2 to 2) MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz	0.073 % 0.055 % 0.11 % 0.15 % 0.35 %	
(0.7 to 2.2) V	(0.5 to 1.2) MHz (1.2 to 2) MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz	0.053 % 0.053 % 0.11 % 0.15 % 0.35 %	

Parameter/Range	Frequency	CMC <sup>2,9</sup> (±)	Comments
AC Voltage <sup>3,4,5</sup> – Measure (cont)			
(2.2 to 7) V	(0.5 to 1.2) MHz (1.2 to 2) MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz	0.053 % 0.053 % 0.11 % 0.15 % 0.35 %	Fluke 5790A Option-03
(1 to 60) kV	60 Hz	0.58 %	Ross VD90-16.5Y with Fluke 8060
(60 to 134) kV	60 Hz	0.58 %	Ross VD200-7.5Y with Fluke 8060
AC Current <sup>3,4</sup> – Generate			
(1 to 2.2) mA	(20 to 40) Hz (40 to 400) Hz (0.4 to 1) kHz (1 to 5) kHz (5 to 10) kHz	0.024 % 0.022 % 0.018 % 0.03 % 0.15 %	Fluke A40 shunts with 5720A/5725A, HP 3458A and Fluke 792A
(2.2 to 22) mA	(20 to 40) Hz (40 to 400) Hz (0.4 to 1) kHz (1 to 5) kHz (5 to 10) kHz	0.034 % 0.032 % 0.029 % 0.044 % 0.31 %	
(22 to 220) mA	(20 to 40) Hz (40 to 400) Hz (0.4 to 1) kHz (1 to 5) kHz (5 to 10) kHz	0.034 % 0.028 % 0.025 % 0.036 % 0.13 %	
(0.22 to 2.2) A	(20 to 40) Hz (40 to 400) Hz (0.4 to 1) kHz (1 to 5) kHz (5 to 10) kHz	0.046 % 0.046 % 0.044 % 0.075 % 0.58 %	
(2.2 to 11) A	(40 to 400) Hz (0.4 to 1) kHz (1 to 5) kHz (5 to 10) kHz	0.075 % 0.073 % 0.12 % 0.34 %	

Parameter/Range	Frequency	CMC <sup>2,9</sup> (±)	Comments
AC Current <sup>3,4</sup> – Generate (cont)			
(11 to 20) A	(10 to 440) Hz	0.073 %	Fluke A40 shunt with Valhalla 2555, HP 3458A and Fluke 792A
(20 to 50) A	50 Hz to 1 kHz (1 to 2) kHz	0.085 % 0.81 %	Holt shunt with Valhalla 2555, HP 3458A, and Fluke 792A
(50 to 100) A	50 Hz to 1 kHz	0.085 %	
(9 to 220) µA	(10 to 20) Hz (20 to 40) Hz 40 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz	0.025 % + 16 nA 0.016 % + 10 nA 0.012 % + 8 nA 0.028 % + 12 nA 0.11 % + 65 nA	Fluke 5720A/5725A
(0.22 to 2.2) mA	(10 to 20) Hz (20 to 40) Hz 40 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz	0.025 % + 40 nA 0.016 % + 35 nA 0.012 % + 35 nA 0.02 % + 110 nA 0.11 % + 650 nA	
(2.2 to 22) mA	(10 to 20) Hz (20 to 40) Hz 40 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz	0.025 % + 0.4 µA 0.016 % + 0.35 µA 0.012 % + 0.35 µA 0.02 % + 0.6 µA 0.11 % + 5 µA	
(22 to 220) mA	(10 to 20) Hz (20 to 40) Hz 40 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz	0.025 % + 4 µA 0.016 % + 3.5 µA 0.012 % + 2.5 µA 0.02 % + 3.5 µA 0.11 % + 10 µA	
(0.22 to 2.2) A	20 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz	0.026 % + 35 µA 0.045 % + 80 µA 0.7 % + 160 µA	
(2.2 to 11) A	40 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz	0.046 % + 170 µA 0.095 % + 380 µA 0.36 % + 750 µA	

Parameter/Range	Frequency	CMC <sup>2,9</sup> (±)	Comments
AC Current <sup>3,4</sup> – Generate (cont.)			
(0 to 110) A	(65 to 440) Hz	0.32 % output + 0.5 A	Fluke 5500A with coil
(0 to 550) A	(45 to 65) Hz	0.38 % output + 0.5 A	
AC Current <sup>4,5</sup> – Measure			
(1 to 2.2) mA	(20 to 40) Hz	0.016 %	Fluke A40 shunts with 5720A/5725A, HP 3458A, and Fluke 792A
	(40 to 400) Hz	0.016 %	
	(0.4 to 1) kHz	0.011 %	
	(1 to 5) kHz	0.011 %	
	(5 to 10) kHz	0.011 %	
(2.2 to 22) mA	(20 to 40) Hz	0.017 %	
	(40 to 400) Hz	0.017 %	
	(0.4 to 1) kHz	0.012 %	
	(1 to 5) kHz	0.012 %	
	(5 to 10) kHz	0.012 %	
(22 to 220) mA	(20 to 40) Hz	0.018 %	
	(40 to 400) Hz	0.018 %	
	(0.4 to 1) kHz	0.013 %	
	(1 to 5) kHz	0.013 %	
	(5 to 10) kHz	0.013 %	
(0.22 to 2.2) A	(20 to 40) Hz	0.024 %	
	(40 to 400) Hz	0.024 %	
	(0.4 to 1) kHz	0.02 %	
	(1 to 5) kHz	0.02 %	
	(5 to 10) kHz	0.02 %	
(2.2 to 11) A	(40 to 400) Hz	0.059 %	
	(0.4 to 1) kHz	0.058 %	
	(1 to 5) kHz	0.058 %	
	(5 to 10) kHz	0.058 %	
(11 to 20) A	(10 to 440) Hz	0.072 %	Fluke A40 shunts with HP 3458A, Fluke 792A

Parameter/Range	Frequency	CMC <sup>2,9</sup> ( $\pm$ )	Comments
AC Current <sup>3,4,5</sup> – Measure (cont)			
(1 to 20) A	DC to 5 kHz	$(0.025 + 0.012f) \%$	Fluke Y5020 ( $f$ = frequency in kHz)
(20 to 50) A	50 Hz to 1 kHz (1 to 2) kHz	0.12 % 0.81 %	Holt shunt with Valhalla 2555, HP 3458A and Fluke 792A
(50 to 100) A	50 Hz to 1 kHz	0.12 %	
AC Power <sup>3,4</sup> – Generate			
(0.01 to 0.1) W (0.1 to 890) W (0.89 to 3) kW (3 to 11) kW (11 to 20.5) kW	(45 to 65) Hz; PF = 1	0.23 % 0.14 % 0.13 % 0.15 % 0.13 %	Fluke 5520A
AC Resistance <sup>3,5</sup> – Generate			
10 $\Omega$	DC 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	0.13 % 0.14 % 0.17 % 0.19 % 0.23 % 0.66 % 1 %	HP 42030A resistor set
100 $\Omega$	DC 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	0.13 % 0.14 % 0.18 % 0.14 % 0.17 % 0.34 % 0.46 %	
1 k $\Omega$	DC to 3 MHz (3 to 5) MHz (5 to 10) MHz (10 to 13) MHz	0.09 % 0.11 % 0.28 % 0.41 %	
(10, 100) k $\Omega$	DC to 1 MHz	0.088 %	

Parameter/Range	Frequency	CMC <sup>2,9</sup> ( $\pm$ )	Comments
AC Resistance <sup>3</sup> – Generate (cont)			
24.9 $\Omega$	1 kHz	0.0005 $\Omega$	Quad Tech 7000-09 calibration kit
374 $\Omega$	1 kHz (50, 100) kHz	0.075 $\Omega$ 0.029 % of rdg	
5.97 k $\Omega$	1 kHz (25, 100) kHz	1.2 $\Omega$ 0.029 % of rdg	
95.317 k $\Omega$	1 kHz (25, 50) kHz	20 $\Omega$ 0.029 % of rdg	
AC Resistance <sup>3</sup> – Measure			
0.1 m $\Omega$ to 100 M $\Omega$	10 Hz to 500 kHz	0.05 %	Quad Tech 7600
AC Voltage Ratio <sup>3</sup> – Measure and Generate			
0 to 1.111111	50 Hz to 1 kHz	0.0002 %	ESI M1011 with NA 225 and voltage source
AC Level Flatness – Measure <sup>3,4,5</sup>			
(0.5, 1, 3) V	10 Hz (0.1, 10, 30) kHz 100 kHz (0.3, 1) MHz (3, 8, 10) MHz (20, 30) MHz 50 MHz 70 MHz 80 MHz 100 MHz	0.011 % 0.006 % 0.007 % 0.01 % 0.08 % 0.2 % 0.5 % 1 % 1 % 1 %	(0.5, 1 and 3) V thermal converters with HP 3458A and Fluke 5720A



Parameter/Range	Frequency	CMC <sup>2,9</sup> (±)	Comments
Capacitance <sup>3,5</sup> – Generate (cont)			
Fixed Values			HP 1638XX standard capacitors
10 pF	100 Hz to 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	0.062 % 0.066 % 0.075 % 0.076 % 0.083 % 0.095 % 0.15 % 0.18 %	
100 pF	100 Hz to 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	0.073 % 0.066 % 0.075 % 0.076 % 0.083 % 0.095 % 0.15 % 0.18 %	
1000 pF	100 Hz to 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	0.062 % 0.072 % 0.083 % 0.099 % 0.13 % 0.16 % 0.35 % 0.48 %	
(10, 100) nF	(100 to 120) Hz 120 Hz to 1 kHz (1 to 10) kHz (10 to 100) kHz	0.063 % 0.062 % 0.064 % 0.071 %	
1 μF	(100 to 120) Hz 120 Hz to 1 kHz (1 to 10) kHz (10 to 100) kHz	0.067 % 0.062 % 0.067 % 0.091 %	
1 pF	10 Hz & 1 kHz	0.016 %	1405-E
2 pF	10 Hz & 1 kHz	0.016 %	1405-C
10 pF	10 Hz & 1 kHz	0.016 %	1404-C
20 pF	10 Hz & 1 kHz	0.016 %	1405-A
50 pF	10 Hz & 1 kHz	0.016 %	1406-E
100 pF	10 Hz & 1 kHz	0.016 %	1404-B
200 pF	10 Hz & 1 kHz	0.016 %	1406-C
1000 pF	10 Hz & 1 kHz	0.00071 %	1404-A
10 000 pF	10 Hz & 1 kHz	0.016 %	1615-P1

Parameter/Range	Frequency	CMC <sup>2,9</sup> (±)	Comments
Capacitance – Measure <sup>3</sup>			
0.1 pF to 1 μF	50 Hz to 10 kHz	0.012 %	GenRad 1620A
1 μF to 1 mF	10 Hz to 1 MHz	0.05 %	Quad Tech 7600
1 pF to 1 mF	1 kHz	0.0005 %	Andeen Hagerling 2500A
Inductance – Generate <sup>3</sup>			
100 μH	100 Hz to 1 kHz	0.1 %	GenRad 1482
1 mH	100 Hz to 1 kHz	0.027 %	
10 mH	100 Hz to 1 kHz	0.024 %	
100 mH	100 Hz to 1 kHz	0.021 %	
1 H	100 Hz	0.023 %	
	1 kHz	0.051 %	
10 H	100 Hz	0.049 %	
	1 kHz	0.21 %	
Inductance – Measure <sup>3</sup>			
100 μH to 10 H	100 Hz to 1 MHz	0.05 %	Quad Tech 7600
100 μH	100 Hz to 1 kHz	0.1 %	Quad Tech 7600 w/ 1482X series Inductors
1 mH	100 Hz to 1 kHz	0.027 %	
10 mH	100 Hz to 1 kHz	0.024 %	
100 mH	100 Hz to 1 kHz	0.021 %	
1 H	100 Hz	0.023 %	
10 H	1 kHz	0.051 %	
	100 Hz	0.048 %	
	1 kHz	0.21 %	

Parameter/Equipment	Range	CMC <sup>2</sup> (±)	Comments
Electrical Calibration of Thermocouple Indicators <sup>3,4</sup> –			
Type B	(600 to 800) °C (800 to 1000) °C (1000 to 1550) °C (1550 to 1820) °C	0.5 °C 0.4 °C 0.36 °C 0.39 °C	Fluke 5520A
Type C	(0 to 150) °C (150 to 650) °C (650 to 1000) °C (1000 to 1800) °C (1800 to 2316) °C	0.36 °C 0.32 °C 0.37 °C 0.56 °C 0.9 °C	
Type E	(-250 to -100) °C (-100 to -25) °C (-25 to 350) °C (350 to 650) °C (650 to 1000) °C	0.56 °C 0.22 °C 0.2 °C 0.22 °C 0.27 °C	
Type J	(-210 to -100) °C (-100 to -30) °C (-30 to 150) °C (150 to 760) °C (760 to 1200) °C	0.33 °C 0.22 °C 0.2 °C 0.23 °C 0.29 °C	
Type K	(-200 to -100) °C (-100 to -25) °C (-25 to 120) °C (120 to 1000) °C (1000 to 1372) °C	0.39 °C 0.24 °C 0.22 °C 0.32 °C 0.46 °C	
Type L	(-200 to -100) °C (-100 to 800) °C (800 to 900) °C	0.43 °C 0.32 °C 0.23 °C	
Type N	(-200 to -100) °C (-100 to -25) °C (-25 to 120) °C (120 to 410) °C (410 to 1300) °C	0.46 °C 0.28 °C 0.25 °C 0.24 °C 0.33 °C	
Type R	(0 to 250) °C (250 to 400) °C (400 to 1000) °C (1000 to 1767) °C	0.63 °C 0.41 °C 0.39 °C 0.46 °C	

Parameter/Equipment	Range	CMC <sup>2</sup> (±)	Comments
Electrical Calibration of Thermocouple Indicators <sup>3,4</sup> – (cont.)			
Type S	(0 to 250) °C (250 to 1000) °C (1000 to 1400) °C (1400 to 1767) °C	0.53 °C 0.42 °C 0.43 °C 0.52 °C	Fluke 5520A
Type T	(-250 to -150) °C (-150 to 0) °C (0 to 120) °C (120 to 400) °C	0.69 °C 0.3 °C 0.22 °C 0.2 °C	
Type U	(-200 to 0) °C (0 to 600) °C	0.62 °C 0.33 °C	
Electrical Calibration of RTDs <sup>3,4</sup> –			
Pt 385, 100 Ω	(-200 to 0) °C (0 to 100) °C (100 to 300) °C (300 to 400) °C (400 to 630) °C (630 to 800) °C	0.06 °C 0.08 °C 0.1 °C 0.11 °C 0.13 °C 0.24 °C	Fluke 5520A
Pt 3926, 100 Ω	(-200 to 0) °C (0 to 100) °C (100 to 300) °C (300 to 400) °C (400 to 630) °C	0.06 °C 0.08 °C 0.1 °C 0.11 °C 0.13 °C	
Pt 3916, 100 Ω	(-200 to -190) °C (-190 to -80) °C (-80 to 0) °C (0 to 100) °C (100 to 260) °C (260 to 300) °C (300 to 400) °C (400 to 600) °C (600 to 630) °C	0.26 °C 0.05 °C 0.06 °C 0.07 °C 0.08 °C 0.09 °C 0.1 °C 0.11 °C 0.24 °C	

Parameter/Equipment	Range	CMC <sup>2</sup> (±)	Comments
Electrical Calibration of RTDs <sup>3,4</sup> – (cont)			
Pt 385, 200 Ω	(-200 to 100) °C (100 to 260) °C (260 to 300) °C (300 to 400) °C (400 to 600) °C (600 to 630) °C	0.05 °C 0.06 °C 0.13 °C 0.14 °C 0.15 °C 0.17 °C	Fluke 5520A
Pt 385, 500 Ω	(-200 to -80) °C (-80 to 100) °C (100 to 260) °C (260 to 400) °C (400 to 600) °C (600 to 630) °C	0.05 °C 0.06 °C 0.07 °C 0.09 °C 0.1 °C 0.12 °C	
Pt 385, 1000 Ω	(-200 to 0) °C (0 to 100) °C (100 to 260) °C (260 to 300) °C (300 to 600) °C (600 to 630) °C	0.04 °C 0.05 °C 0.06 °C 0.07 °C 0.08 °C 0.24 °C	
PtNi 385, 120 Ω	(-80 to 100) °C (100 to 260) °C	0.09 °C 0.15 °C	
Cu 427, 10 Ω	(-100 to 260) °C	0.31 °C	
RPM <sup>3,5</sup> – Generate	(0 to 12 000) RPM	0.013 %	HP 3325A/B with stroboscope
RPM <sup>3,5</sup> – Measure	(0 to 100 000) RPM	0.16 %	Ametek 1726

V. Electrical – RF/Microwave

Parameter/Range	Frequency	CMC <sup>2,9</sup> (±)	Comments
RF Power – Generate <sup>3</sup>			
(+13 to -56) dBm	1 Hz to 20 MHz	0.52 dB	HP 3325B
(-10 to 8) dBm	20 MHz to 2 GHz (2 to 20) GHz	0.73 dB 0.89 dB	HP 83650B
(-10 to 3) dBm	(20 to 40) GHz	1.2 dB	
(-10 to 0) dBm	(40 to 50) GHz	2.1 dB	
(-60 to -10) dBm	20 MHz to 2 GHz (2 to 20) GHz (20 to 40) GHz (40 to 50) GHz	1.1 dB 1.2 dB 1.6 dB 2.5 dB	
(-110 to -60) dBm	20 MHz to 2 GHz (2 to 20) GHz (20 to 40) GHz (40 to 50) GHz	1.7 dB 1.8 dB 2.1 dB 3.1 dB	
(1 to 100) W	(1.5 to 400) MHz	3.5 %	IFI amplifier with signal generator and Bird 4022 with 4021 and 4421
(100 to 500) W	80 MHz to 1 GHz	3.5 %	AR 250W1000A, AR 500W1000A, signal generator and Bird 4022 with 4021 and 4421
RF Power – Measure <sup>3</sup>			
(+30 to -20) dBm	10 kHz to 26.5 GHz	2.9 %	HP 8902A w/ 11722A and 11792A
	26.5 to 50 GHz	2.9 %	Fluke 437B w/ HP 8487A
(-70 to -20) dBm	10 MHz to 18 GHz (18 to 50) GHz	2.9 % 2.9 %	HP 437B w/ HP 8481D w/ 8487D
10 µW to 25 mW	0.1 MHz to 18 GHz	0.32 %	Weinschel M1110 w/ bridge
(0.3 to 1000) W	1.8 MHz to 1 GHz	3.5 %	Bird 4022 and 4021 w/ 4421

Parameter/Range	Frequency	CMC <sup>2,9</sup> (±)	Comments
RF Attenuation – Tuned RF Power Measure <sup>3</sup>			
(-0.0 to -1.0) dB	100 kHz to 1.3 MHz	0.009 dB	HP 8902A
(-1 to -10) dB		0.024 dB	HP 11722A
(-10 to -20) dB		0.052 dB	
(-20 to -30) dB		0.074 dB	
(-30 to -40) dB		0.11 dB	
(-40 to -50) dB		0.14 dB	
(-50 to -60) dB		0.16 dB	
(-60 to -70) dB		0.20 dB	
(-70 to -80) dB		0.22 dB	
(-80 to -90) dB		0.24 dB	
(-90 to -100) dB		0.26 dB	
(-100 to -110) dB		0.32 dB	
(-110 to -120) dB		0.37 dB	
(-0.0 to -1.0) dB	1.3 MHz to 26.5 GHz	0.049 dB	HP 8902A
(-1 to -10) dB		0.053 dB	HP 11722A
(-10 to -20) dB		0.071 dB	HP 11792A
(-20 to -30) dB		0.088 dB	HP 11793A
(-30 to -40) dB		0.12 dB	
(-40 to -50) dB		0.15 dB	
(-50 to -60) dB		0.16 dB	
(-60 to -70) dB		0.20 dB	
(-70 to -80) dB		0.23 dB	
(-80 to -90) dB		0.25 dB	
(-90 to -100) dB		0.27 dB	
(-100 to -110) dB		0.32 dB	
(-110 to -120) dB		0.37 dB	
(+10 to -70) dBm	(26.5 to 50) GHz	2.9 %	HP 437B w/ 8487A, 8487D
(-70 to -120) dBm	(26.5 to 31.2) GHz	3.7 dB	HP 8565E
(31.2 to 50) GHz		3.9 dB	
RF Attenuation – Generate <sup>3</sup>			
Fixed Values			
(10, 20, 30, 40, 50) dB	30 MHz	0.008 dB	HP 11812A
Ranges (1 dB step)	DC to 18 GHz	0.35 dB	HP 8494B and 8496B
(0 to 121) dB			

Parameter/Range	Frequency	CMC <sup>2,9</sup> (±)	Comments
Phase Modulation – Measure <sup>3</sup>			
Rate: 200 Hz to 10 kHz	150 kHz to 10 MHz	4 % + 1 digit	HP 8902A
Rate: 200 Hz to 20 kHz	10 MHz to 1.3 GHz (1.3 to 26.5) GHz	3 % + 1 digit 4 % + 1 digit	HP 8902A with 11793A
Phase Modulation – Generate <sup>3</sup>			
Rate: 20 Hz to 10 kHz	Carrier:		HP 8642A
(0 to 6.25) rad	(0.1 to 4.13) MHz	5.8 % + 0.09 rad	
(0 to 0.78125) rad	(4.13 to 8.26) MHz	5.8 % + 0.09 rad	
(0 to 1.5625) rad	(8.26 to 16.52) MHz	5.8 % + 0.09 rad	
(0 to 3.125) rad	(16.52 to 33) MHz	5.8 % + 0.09 rad	
(0 to 6.25) rad	(33 to 66.09) MHz	5.8 % + 0.09 rad	
(0 to 12.5) rad	(66.09 to 132.18) MHz	5.8 % + 0.09 rad	
(0 to 25) rad	(132.18 to 264.37) MHz	5.8 % + 0.09 rad	
(0 to 50) rad	(264.37 to 528.75) MHz	5.8 % + 0.09 rad	
(0 to 100) rad	(528.75 to 1057) MHz	5.8 % + 0.09 rad	
(0 to 200) rad	(1057 to 2115) MHz	5.8 % + 0.09 rad	
Amplitude Modulation – Generate <sup>3</sup>			% = % AM
Rate: 50 Hz to 50 kHz Depths: 0 % to 99 %	11 MHz to 13.5 MHz	0.12 %	HP 11715A
Rate: 20 Hz to 50 Hz (50 to 100) kHz Depths: 0 % to 99 %	11 MHz to 13.5 MHz	0.29 %	HP 11715A
Rate: DC to 100 kHz Depths: 0 % to 30 %	10 MHz to 1.3 GHz 1.3 to 26.5 GHz	2.1 % 1.8 %	HP 83630L
Rate: 1 kHz Depths: 30 %	10 MHz to 50 GHz	5.8 %	HP 83650A/B
Rate: DC to 10 kHz Depths: 0 % to 90 %	26.5 to 50 GHz	5.8 %	HP 83650A/B

Parameter/Range	Frequency	CMC <sup>2,9</sup> (±)	Comments
<b>Frequency Modulation – Generate<sup>3</sup></b>			
Rate: DC to 100 kHz Dev.: ≤ 12.5 kHz peak	(11 to 13.5) MHz	0.12 %	HP 11715A
Rate: (100 to 200) kHz Dev.: ≤ 12.5 kHz peak	(11 to 13.5) MHz	0.29 %	HP 11715A
Rate: DC to 100 kHz Dev.: ≤ 100 kHz peak	(88 to 108) MHz	0.12 %	
Rate: (100 to 200) kHz Dev.: ≤ 100 kHz peak	(88 to 108) MHz	0.29 %	
Rate: DC to 100 kHz Dev.: ≤ 400 kHz peak	(352 to 432) MHz	0.12 %	
Rate: (100 to 200) kHz Dev.: ≤ 400 kHz peak	(352 to 432) MHz	0.29 %	
Rate: (100 to 200) kHz Dev.: ≤ 400 kHz peak	11 MHz to 26.5 GHz	5.8 %	HP 83630L
Rate: 100 kHz to 8 MHz Dev.: ≤ 10 MHz	(26.5 to 50) GHz	10 %	HP 83650A
<b>Amplitude Modulation – Measure<sup>3</sup></b>			
Rate: 50 Hz to 10 kHz Depths: 5 % to 99 %	150 kHz to 10 MHz	2 % + 1 digit	HP 8902A
Rate: 20 Hz to 10 kHz Depths: to 99 %	150 kHz to 10 MHz	3 % + 1 digit	
Rate: 50 Hz to 50 kHz Depths: 5 % to 99 %	10 MHz to 1.3 GHz	1 % + 1 digit	
Rate: 20 Hz to 100 kHz Depths: to 99 %	10 MHz to 1.3 GHz	3 % + 1 digit	
Rate: 50 Hz to 50 kHz Depths: 5 % to 99 %	(1.3 to 26.5) GHz	2.1 % + 1 digit	w/ 11793A
Rate: 20 Hz to 100 kHz Depths: to 99 %	(1.3 to 26.5) GHz	3.1 % + 1 digit	

Parameter/Range	Frequency	CMC <sup>2,9</sup> ( $\pm$ )	Comments
Frequency Modulation – Measure <sup>3</sup>			
Rate: 20 Hz to 10 kHz Dev.: $\leq 40$ kHz peak	250 kHz to 10 MHz	2 % + 1 digit	HP 8902A
Rate: 50 Hz to 100 kHz Dev.: $\leq 400$ kHz peak	10 MHz to 1.3 GHz	1 % + 1 digit	
Rate: 20 Hz to 200 kHz Dev.: $\leq 400$ kHz peak	10 MHz to 1.3 GHz	5 % + 1 digit	
Rate: 50 Hz to 100 kHz Dev.: $\leq 400$ kHz peak	(1.3 to 26.5) GHz	2 % + 1 digit	w/ 11793A
Rate: 20 Hz to 200 kHz Dev.: $\leq 400$ kHz peak	(1.3 to 26.5) GHz	5 % + 1 digit	
Pulse Modulation – Generate <sup>3</sup>	10 MHz to 45 GHz -0.1 to -15 dBm	0.4 dB	Agilent 83650B with Agilent 8110A
Pulse Modulation – Measure <sup>3</sup>	10 MHz to 33 GHz	0.9 % + 0.7 % <i>fs</i> *	Tektronix 2465B with HP 8470B and 8474C (* In the CMC, <i>fs</i> is the percent of full scale of time per division switch of the scope)

Parameter/Range	Frequency	CMC <sup>2</sup> (±)	Comments
VSWR – Measure <sup>3</sup> Into 50 Ω			
0.00 < P < 0.09910	(0.1 to 2) GHz	0.013 P	Wiltron 60N50 w/ 8902A w/ 11722A
0.09910 < P < 0.25094		0.018 P	
0.25094 < P < 0.500		0.038 P	
0.500 < P < 7.00		0.069 P	
0.00 < P < 0.0476	(0.01 to 8.4) GHz	0.026 P	8757E w/ 85021B
	(8.4 to 12.4) GHz	0.041 P	
	(12.4 to 18) GHz	0.036 P	
	(18 to 20) GHz	0.031 P	
	(20 to 26.5) GHz	0.055 P	
0.0476 < P < 0.1111	(0.01 to 8.4) GHz	0.031 P	P = Rho
	(8.4 to 12.4) GHz	0.051 P	
	(12.4 to 18) GHz	0.046 P	
	(18 to 20) GHz	0.04 P	
	(20 to 26.5) GHz	0.07 P	
0.1111 < P < 0.200	(0.01 to 8.4) GHz	0.045 P	
	(8.4 to 12.4) GHz	0.079 P	
	(12.4 to 18) GHz	0.072 P	
	(18 to 20) GHz	0.066 P	
	(20 to 26.5) GHz	0.11 P	
0.200 < P < 0.3333	(0.01 to 8.4) GHz	0.089 P	
	(8.4 to 12.4) GHz	0.18 P	
	(12.4 to 18) GHz	0.16 P	
	(18 to 20) GHz	0.15 P	
	(20 to 26.5) GHz	0.25 P	
0.3333 < P < 0.500	(0.01 to 8.4) GHz	0.24 P	
	(8.4 to 12.4) GHz	0.49 P	
	(12.4 to 18) GHz	0.47 P	
	(18 to 20) GHz	0.46 P	
	(20 to 26.5) GHz	0.7 P	

Parameter/Range	Frequency	CMC <sup>2</sup> (±)	Comments
Reflection Phase <sup>3</sup>			
Into 50 Ω, 0° to 360°			
0 < Γ ≤ 1.0	5 Hz to 50 MHz	3.1°	HP 3577A
0 < Γ ≤ 0.2	300 kHz to 3 GHz	6.4°	HP 8753C with 85046A and N-type connector
0.2 < Γ ≤ 0.4		4.7°	
0 < Γ ≤ 0.4	45 MHz to 2 GHz (2 to 8) GHz (8 to 18) GHz	2.9°	HP 8510C, 8517, 83650A, w/ 85054B
		5.6°	
		5.9°	
0.4 < Γ ≤ 1	45 MHz to 2 GHz (2 to 8) GHz (8 to 18) GHz	0.9°	
		1.5°	
		2.2°	
0 < Γ ≤ 0.4	45 MHz to 2 GHz (2 to 8) GHz (8 to 20) GHz (20 to 26.5) GHz	2.8°	w/ 85052B
		4.6°	
		4.8°	
		4.9°	
0.4 < Γ ≤ 1	45 MHz to 2 GHz (2 to 8) GHz (8 to 20) GHz (20 to 26.5) GHz	1.0°	
		1.9°	
		2.4°	
		2.5°	
0 < Γ ≤ 0.4	50 MHz to 20 GHz (20 to 40) GHz (40 to 50) GHz	5.8°	w/ 85056A
		9.3°	
		12°	
0.4 < Γ ≤ 1	50 MHz to 20 GHz (20 to 40) GHz (40 to 50) GHz	1.7°	
		2.8°	
		3.4°	
Into 75 Ω, 0° to 360°			
0 < Γ ≤ 0.2	300 kHz to 3 GHz	4.1°	HP 8753C with 85046B and N-type connector
0.2 < Γ ≤ 0.4		2.9°	

Parameter/Range	Frequency	CMC <sup>2</sup> (±)	Comments
Transmission Phase <sup>3</sup> – Into 50 Ω, 0° to 360° 0 < Γ < 1.0	5 Hz to 300 kHz	3.1°	HP 3577A
(+10 to 0) dB (0 to -10) dB (-10 to -20) dB (-20 to -30) dB (-30 to -40) dB (-40 to -50) dB (-50 to -60) dB (-60 to 70) dB	300 kHz to 3 GHz	5.8° 1.4° 1.4° 1.4° 1.8° 2.4° 4.9° 12°	HP 8753C with 85046A and N-type connector
(+10 to 0) dB (0 to -10) dB (-10 to -20) dB (-20 to -30) dB (-30 to -40) dB (-40 to -50) dB (-50 to -60) dB (-60 to 70) dB	45 MHz to 18 GHz	(0.3 to 1.9)° (0.3 to 1.1)° (0.3 to 1.1)° (0.3 to 1.1)° (0.5 to 1.1)° (0.75 to 1.2)° (0.8 to 3.0)° (1.3 to 8.7)°	HP 8510C, 8517A and 83650A, w/ 85054B
(+10 to 0) dB (0 to -10) dB (-10 to -20) dB (-20 to -30) dB (-30 to -40) dB (-40 to -50) dB (-50 to -60) dB (-60 to 70) dB	45 MHz to 26.5 GHz	(0.3 to 2.0)° (0.3 to 1.8)° (0.4 to 1.8)° (0.9 to 1.8)° (0.9 to 1.8)° (0.9 to 3.0)° (1.6 to 8.7)° (2.9 to 28)°	w/ 85052B
(+10 to 0) dB (0 to -10) dB (-10 to -20) dB (-20 to -30) dB (-30 to -40) dB (-40 to -50) dB (-50 to -60) dB (-60 to 70) dB	(2 to 26.5) GHz	(1.3 to 2.3)° (0.95 to 2.1)° (0.95 to 2.3)° (0.96 to 2.7)° (0.98 to 4.7)° (1.2 to 13)° (1.9 to 38)° (4.7 to 32)°	w/ 85056A
	(2 to 50) GHz		
	(2 to 40) GHz		

Parameter/Range	Frequency	CMC <sup>2</sup> (±)	Comments
Transmission Phase <sup>3</sup> – (cont)  Into 75 Ω, 0° to 360°  (+10 to 0) dB (0 to -10) dB (-10 to -20) dB (-20 to -30) dB (-30 to -40) dB (-40 to -50) dB (-50 to -60) dB (-60 to 70) dB	300 kHz to 2 GHz	5.8° 1.4° 1.4° 1.7° 2.1° 4.1° 10° 33°	HP 8753C with 85046A and N-type connector
Noise Source – Generate & Measure <sup>3</sup>  5 dB and 15 dB Excess Noise Ratio (ENR)	(10, 100) MHz (1, 2, 3, 4, 5, 6, 7) GHz 8 GHz (9, 10) GHz (11, 12) GHz 13 GHz 14 GHz (15, 16) GHz (17, 18) GHz 19 GHz 20 GHz 21 GHz 22 GHz 23 GHz 24 GHz 25 GHz 26 GHz 26.5 GHz	0.17 dB 0.15 dB 0.16 dB 0.17 dB 0.18 dB 0.17 dB 0.16 dB 0.18 dB 0.16 dB 0.18 dB 0.15 dB 0.2 dB 0.23 dB 0.19 dB 0.18 dB 0.2 dB 0.21 dB 0.19 dB	HP 346C noise source with 8970B noise figure meter

Parameter/Range	Frequency	CMC <sup>2</sup> (±)	Comments
Transmission Magnitude <sup>3</sup> –			
Into 50 Ω			
(+10 to -30) dB	5 Hz to 300 kHz	0.025 dB	HP 3577A with 35677A
(+10 to 0) dB	300 kHz to 3 GHz	0.46 dB	HP 8753C with 85046A and N-type connector
(0 to -10) dB		0.17 dB	
(-10 to -20) dB		0.17 dB	
(-20 to -30) dB		0.17 dB	
(-30 to -40) dB		0.2 dB	
(-40 to -50) dB		0.26 dB	
(-50 to -60) dB		0.58 dB	
(-60 to 70) dB		1.7 dB	
(+3 to -10) dB	45 MHz to 2 GHz	0.024 dB	HP 8510C, 8517A and 83650A, w/ 85054B
(-10 to -20) dB		0.029 dB	
(-20 to -30) dB		0.053 dB	
(+3 to -30) dB	(2 to 8) GHz	0.072 dB	
	(8 to 18) GHz	0.097 dB	
(+3 to -10) dB	45 MHz to 2 GHz	0.027 dB	w/ 85052B
(-10 to -20) dB		0.032 dB	
(-20 to -30) dB		0.057 dB	
(+3 to -30) dB	(2 to 20) GHz	0.064 dB	
	(20 to 40) GHz	0.17 dB	
	(40 to 50) GHz	0.41 dB	
(+3 to -10) dB	45 MHz to 2 GHz	0.024 dB	w/ 85056A
(-10 to -20) dB		0.03 dB	
(-20 to -30) dB		0.054 dB	
(+3 to -30) dB	(2 to 8) GHz	0.083 dB	
	(8 to 20) GHz	0.097 dB	
	(20 to 26.5) GHz	0.14 dB	
Into 75 Ω, 0° to 360°			
(+10 to 0) dB	300 kHz to 2 GHz	0.46 dB	HP 8753C with 85046A and N-type connector
(0 to -10) dB		0.15 dB	
(-10 to -20) dB		0.15 dB	
(-20 to -30) dB		0.17 dB	
(-30 to -40) dB		0.26 dB	
(-40 to -50) dB		0.52 dB	
(-50 to -60) dB		1.4 dB	
(-60 to 70) dB		3.5 dB	

Parameter/Range	Frequency	CMC <sup>2</sup> ( $\pm$ )	Comments
Reflection Magnitude <sup>3</sup> –			
Into 50 $\Omega$			
$0 < \Gamma \leq 1.0$	5 Hz to 50 MHz	0.046 $\Gamma$	HP 3577A
$0 < \Gamma \leq 0.2$	300 kHz to 3 GHz	0.021 $\Gamma$	HP 8753C with 85046A and N-type connector
$0.2 < \Gamma \leq 0.4$		0.029 $\Gamma$	
$0.4 < \Gamma \leq 0.6$		0.04 $\Gamma$	
$0.6 < \Gamma \leq 0.8$		0.052 $\Gamma$	
$0.8 < \Gamma \leq 1.0$		0.064 $\Gamma$	
$0 < \Gamma \leq 0.5$	45 MHz to 2 GHz (2 to 8) GHz (8 to 18) GHz	0.005 $\Gamma$ 0.011 $\Gamma$ 0.012 $\Gamma$	HP 8510C, 8517A and 83650A, w/ 85054B
$0.5 < \Gamma \leq 0.8$	45 MHz to 2 GHz (2 to 8) GHz (8 to 18) GHz	0.007 $\Gamma$ 0.016 $\Gamma$ 0.021 $\Gamma$	
$0.8 < \Gamma \leq 1.0$	45 MHz to 18 GHz	0.029 $\Gamma$	
$0 < \Gamma \leq 0.5$	45 MHz to 2 GHz (2 to 8) GHz (8 to 26.5) GHz	0.005 $\Gamma$ 0.008 $\Gamma$ 0.009 $\Gamma$	w/ 85052B
$0.5 < \Gamma \leq 0.8$	45 MHz to 2 GHz (2 to 8) GHz (8 to 26.5) GHz	0.009 $\Gamma$ 0.018 $\Gamma$ 0.023 $\Gamma$	
$0.8 < \Gamma \leq 1.0$	45 MHz to 18 GHz	0.035 $\Gamma$	
$0 < \Gamma \leq 0.5$	45 MHz to 20 GHz (20 to 40) GHz (40 to 50) GHz	0.011 $\Gamma$ 0.019 $\Gamma$ 0.023 $\Gamma$	w/ 85056A
$0.5 < \Gamma \leq 0.8$	45 MHz to 20 GHz (20 to 40) GHz (40 to 50) GHz	0.014 $\Gamma$ 0.025 $\Gamma$ 0.03 $\Gamma$	
$0.8 < \Gamma \leq 1.0$	45 MHz to 20 GHz (20 to 40) GHz (40 to 50) GHz	0.018 $\Gamma$ 0.032 $\Gamma$ 0.039 $\Gamma$	
Into 75 $\Omega$ , 0° to 360°			
$0 < \Gamma \leq 0.2$	300 kHz to 2 GHz	0.009 $\Gamma$	HP 8753C with 85046B and N-type connector
$0.2 < \Gamma \leq 0.4$		0.021 $\Gamma$	
$0.4 < \Gamma \leq 0.6$		0.028 $\Gamma$	
$0.6 < \Gamma \leq 0.8$		0.037 $\Gamma$	
$0.8 < \Gamma \leq 1.0$		0.048 $\Gamma$	
			$\Gamma$ refers to the magnitude of the reflection value being read.

Parameter/Range	Frequency	CMC <sup>2,9</sup> (±)	Comments
Power Sensor Gold Calibration <sup>3,5</sup> – Calibration Factor			
HP 8481A	10 MHz	0.88 %	Weinschel M1110, M1111, 1806, HP 3458A, 437B, 83630L, 3325B  % = % Cal Factor
	30 MHz	0.65 %	
	(50, 100, 300, 500) MHz	0.47 %	
	1 GHz	0.47 %	
	1.5 GHz	0.53 %	
	2 GHz	0.46 %	
	3 GHz	0.49 %	
	4 GHz	0.47 %	
	5 GHz	0.5 %	
	6 GHz	0.52 %	
	7 GHz	0.54 %	
	8 GHz	0.51 %	
	9 GHz	0.53 %	
	10 GHz	0.63 %	
	11 GHz	0.57 %	
	12 GHz	0.55 %	
	12.4 GHz	0.59 %	
	13 GHz	0.63 %	
	14 GHz	0.55 %	
	15 GHz	0.65 %	
	16 GHz	0.76 %	
	17 GHz	0.78 %	
	18 GHz	0.91 %	
HP 8482A	0.1 MHz	0.49 %	
	(0.3, 0.5) MHz	0.47 %	
	1 MHz	0.46 %	
	(3, 5, 10) MHz	0.58 %	
	30 MHz	0.65 %	
	(50, 100, 300, 500) MHz	0.47 %	
	1 GHz	0.47 %	
	1.5 GHz	0.53 %	
	2 GHz	0.46 %	
	2.5 GHz	0.56 %	
	3 GHz	0.49 %	
	3.5 GHz	0.55 %	
	4 GHz	0.47 %	
	4.2 GHz	0.58 %	

Parameter/Range	Frequency	CMC <sup>2,9</sup> (±)	Comments
Power Sensor Gold Calibration <sup>3,5</sup> – Calibration Factor (cont)			
HP 8478B	10 MHz	0.86 %	Weinschel M1110, 1806, HP 3458A, Agilent 34401A, 432A, 83630L  % = % Cal Factor
	30 MHz	0.62 %	
	50 MHz	0.43 %	
	(100, 300, 500) MHz	0.42 %	
	1 GHz	0.42 %	
	1.5 GHz	0.49 %	
	2 GHz	0.42 %	
	3 GHz	0.45 %	
	4 GHz	0.43 %	
	5 GHz	0.46 %	
	6 GHz	0.48 %	
	7 GHz	0.5 %	
	8 GHz	0.47 %	
	9 GHz	0.49 %	
	10 GHz	0.59 %	
	11 GHz	0.53 %	
	12 GHz	0.52 %	
	12.4 GHz	0.55 %	
	13 GHz	0.59 %	
	14 GHz	0.52 %	
15 GHz	0.62 %		
16 GHz	0.74 %		
17 GHz	0.76 %		
18 GHz	0.89 %		
HP 8481D / 8484A	10 MHz	1.2 %	
	30 MHz	1.1 %	
	(50, 100, 300, 500) MHz	0.96 %	
	1 GHz	0.96 %	
	1.5 GHz	0.99 %	
	2 GHz	0.96 %	
	3 GHz	0.97 %	
	4 GHz	0.96 %	
	5 GHz	0.98 %	
	6 GHz	0.99 %	
	7 GHz	1 %	
	8 GHz	0.98 %	
	9 GHz	0.99 %	
	10 GHz	1.1 %	
	(11, 12, 12.4) GHz	1 %	
	13 GHz	1.1 %	
	14 GHz	1 %	
	15 GHz	1.1 %	
16 GHz	1.2 %		
17 GHz	1.2 %		
18 GHz	1.3 %		

Parameter/Range	Frequency	CMC <sup>2,9</sup> (±)	Comments
Power Sensor Gold Calibration <sup>3,5</sup> – Calibration Factor (cont)			
HP 478A	10 MHz 50 MHz (100, 300, 500) MHz 1 GHz	0.86 % 0.43 % 0.42 % 0.42 %	Weinschel M1110, 1806, HP 3458A, Agilent 34401A, 432A, 83630L
HP 8485A	(50, 100, 300, 500) MHz (1, 2) GHz (3, 4, 5, 6, 7, 8) GHz (9, 10, 11, 12) GHz 12.4 GHz (13, 14, 15) GHz (16, 17, 18) GHz (19, 20) GHz (21, 22) GHz (23, 24, 25) GHz (26, 26.5) GHz	0.86 % 0.85 % 0.88 % 0.95 % 0.93 % 0.97 % 1.2 % 1.5 % 1.6 % 1.6 % 1.7 %	Weinschel M1110, 1107-7, 1806, HP 3458A, 437B, 83630L, 3325B
HP E4412A / ECP-E18A	10 MHz 30 MHz (50, 100, 300, 500) MHz (0.8, 1) GHz (1.2, 1.5) GHz 2 GHz 3 GHz 4 GHz 5 GHz 6 GHz 7 GHz 8 GHz 9 GHz 10 GHz 11 GHz 12 GHz 12.4 GHz 13 GHz 14 GHz 15 GHz 16 GHz 17 GHz 18 GHz	0.93 % 0.72 % 0.56 % 0.56 % 0.61 % 0.55 % 0.57 % 0.56 % 0.58 % 0.6 % 0.62 % 0.59 % 0.61 % 0.7 % 0.64 % 0.63 % 0.66 % 0.7 % 0.63 % 0.72 % 0.82 % 0.84 % 0.96 %	HP 8481A Gold sensor with 437A meter and DMM  % = % Cal Factor

Parameter/Range	Frequency	CMC <sup>2,9</sup> (±)	Comments
Power Sensor Gold Calibration <sup>3,5</sup> – Calibration Factor (cont)			
HP 8485A / E4413A / ECP-E26A	(50, 100, 300, 500) MHz	1.2 %	HP 8485A Gold sensor with 437A meter and DMM  % = % Cal Factor
	(1, 2) GHz	1.2 %	
	(3, 4, 5, 6, 7, 8) GHz	1.3 %	
	(9, 10, 11, 12) GHz	1.3 %	
	12.4 GHz	1.4 %	
	(13, 14, 15) GHz	1.4 %	
	(16, 17, 18) GHz	1.5 %	
	(19, 20) GHz	1.6 %	
	(21, 22) GHz	1.7 %	
	(23, 24, 25) GHz	1.8 %	
	(26, 26.5) GHz	1.9 %	
HP 9300; High Power Level	10 MHz	0.93 %	HP 8481A Gold sensor with 437A meter and DMM  % = % Cal Factor
	30 MHz	0.72 %	
	(50, 100, 300, 500) MHz	0.56 %	
	(0.8, 1) GHz	0.56 %	
	(1.2, 1.5) GHz	0.61 %	
	2 GHz	0.55 %	
	3 GHz	0.57 %	
	4 GHz	0.56 %	
	5 GHz	0.58 %	
	6 GHz	0.6 %	
	7 GHz	0.62 %	
	8 GHz	0.59 %	
	9 GHz	0.61 %	
	10 GHz	0.7 %	
	11 GHz	0.64 %	
	12 GHz	0.63 %	
	12.4 GHz	0.66 %	
	13 GHz	0.7 %	
14 GHz	0.63 %		
15 GHz	0.72 %		
16 GHz	0.82 %		
17 GHz	0.84 %		
18 GHz	0.96 %		
HP 9300; Low Power Level	10 MHz	1.3 %	HP 8485A Gold sensor with 437A meter and DMM
	30 MHz	0.1 %	
	(50, 100, 300, 500) MHz	1 %	
	(0.8, 1) GHz	1 %	
	(1.2, 1.5) GHz	1.1 %	
	(2, 3, 4, 5, 6) GHz	1 %	
	7 GHz	1.1 %	
	(8, 9) GHz	1 %	
	(10, 11, 12, 12.4, 13) GHz	1.1 %	
	(14, 15) GHz	1.1 %	
(16, 17) GHz	1.2 %		
18 GHz	1.3 %		

Parameter/Range	Frequency	CMC <sup>2,9</sup> (±)	Comments
Power Sensor Gold Calibration <sup>3,5</sup> – Calibration Factor (cont.)			
HP 9301A; High Power Level	10 MHz	0.93 %	HP 8481A Gold sensor with 437A meter and DMM  % = % Cal Factor
	30 MHz	0.72 %	
	(50, 100, 300, 500) MHz	0.56 %	
	(0.8, 1) GHz	0.56 %	
	(1.2, 1.5) GHz	0.61 %	
	2 GHz	0.55 %	
	3 GHz	0.57 %	
	4 GHz	0.56 %	
HP 9301A; Low Power Level	5 GHz	0.58 %	HP 8485A Gold sensor with 437A meter and DMM
	6 GHz	0.6 %	
	10 MHz	1.3 %	
	30 MHz	1.1 %	
	(50, 100, 300, 500) MHz	1 %	
	(0.8, 1, 1.2, 1.5) GHz	1 %	
HP 8487A	(2, 3, 4, 5, 6) GHz	1 %	HP 437A w/ 83650A w/ HP 8487A  % = % Cal Factor
	50 MHz	0.36 %	
	(100, 300, 500) MHz	2.2 %	
	1 GHz	2.2 %	
	(2, 3, 4, 5, 6, 7, 8) GHz	2.3 %	
	(9, 10, 11) GHz	2.4 %	
	(12, 13, 14) GHz	2.4 %	
	(15, 16, 17, 18) GHz	2.5 %	
	19 GHz	2.6 %	
	20 GHz	2.5 %	
	(21, 22) GHz	2.6 %	
	(23, 24, 25) GHz	2.7 %	
	(26, 27, 28, 29) GHz	2.8 %	
	(30, 31, 32) GHz	2.9 %	
	33 GHz	3 %	
	34 GHz	2.9 %	
	34.5 GHz	3 %	
	(35, 36, 37) GHz	2.9 %	
	38 GHz	3 %	
	(39, 40) GHz	3.1 %	
	41 GHz	3.2 %	
	42 GHz	3.1 %	
	43 GHz	3.2 %	
44 GHz	3.3 %		
45 GHz	3.5 %		
46 GHz	3.4 %		
47 GHz	3.5 %		
48 GHz	3.6 %		
49 GHz	3.8 %		
50 GHz	4.1 %		

Parameter/Range	Frequency	CMC <sup>2,9</sup> (±)	Comments
Power Sensor Gold Calibration <sup>3,5</sup> – Calibration Factor (cont)			
HP 8487D	50 MHz	3 %	HP 437A w/ 83650A w/ HP8487D  % = % Cal Factor
	(2, 10, 14 and 18) GHz	3 %	
	(20, 22, 24 and 26) GHz	3 %	
	(29, 30, 32 and 34) GHz	3 %	
	(36 and 38) GHz	3 %	
	40 GHz	3.1 %	
	41 GHz	3.2 %	
	42 GHz	3.1 %	
	43 GHz	3.2 %	
	44 GHz	3.3 %	
	45 GHz	3.5 %	
	46 GHz	3.4 %	
	47 GHz	3.5 %	
	48 GHz	3.6 %	
	49 GHz	3.8 %	
	50 GHz	4.1 %	
HP 8483A	0.1 MHz	0.49 %	Weinschel M1110, M111, 1806, HP 3458A, 437B, 83630L, 3325B  % = % Cal Factor
	(0.3, 0.5) MHz	0.47 %	
	1 MHz	0.46 %	
	(3, 5, 10) MHz	0.58 %	
	30 MHz	0.65 %	
	(50, 100, 300, 500) MHz	0.47 %	
	1 GHz	0.47 %	
	1.5 GHz	0.53 %	
	2 GHz	0.46 %	
Agilent E9321A / E9322A / E9323A	(50, 100, 300, 500) MHz	0.47 %	Weinschel M1110, M111, 1806, HP 3458A, E4416B, 83630L, 3325B  % = % Cal Factor
	(0.8, 1) GHz	0.47 %	
	(1.2, 1.5) GHz	0.53 %	
	2 GHz	0.46 %	
	3 GHz	0.49 %	
	4 GHz	0.47 %	
	5 GHz	0.5 %	
	6 GHz	0.52 %	

Parameter/Range	Frequency	CMC <sup>2,9</sup> (±)	Comments
Power Sensor Gold Calibration <sup>3,5</sup> – Calibration Factor (cont)  Agilent E9325A / E9326A / E9327A	(50, 100, 300, 500) MHz 1 GHz 1.5 GHz 2 GHz 3 GHz 4 GHz 5 GHz 6 GHz 7 GHz 8 GHz 9 GHz 10 GHz 11 GHz 12 GHz 12.4 GHz 13 GHz 14 GHz 15 GHz 16 GHz 17 GHz 18 GHz	0.47 % 0.47 % 0.53 % 0.46 % 0.49 % 0.47 % 0.5 % 0.52 % 0.54 % 0.51 % 0.53 % 0.63 % 0.57 % 0.55 % 0.59 % 0.63 % 0.55 % 0.65 % 0.76 % 0.78 % 0.91 %	Weinschel M1110, M111, 1806, HP 3458A, E4416B, 83630L, 3325B  % = % Cal Factor



Parameter/Range	Frequency	CMC <sup>2</sup> (±)	Comments
Phase Noise <sup>3,5</sup> – Generate and Measure			
Carrier Frequency: (1 to 5) MHz	Carrier Freq. Offset: ≤ 1Hz @ ≤ -54 dBc ≤ 10 Hz @ ≤ -84 dBc ≤ 100 Hz @ ≤ -104 dBc ≤ 1 kHz @ ≤ -121 dBc ≤ 3 kHz @ ≤ -121 dBc ≤ 5 kHz @ ≤ -129 dBc ≤ 10 kHz @ ≤ -145 dBc ≤ 100 kHz @ ≤ -157 dBc	2.4 dBc Phase Noise	HP 11848A opt 201 w/ 11729C, 8665B, 8663A with HP 3561A
(5 to 1280) MHz	≤ 1Hz @ ≤ -48 dBc ≤ 10 Hz @ ≤ -78 dBc ≤ 100 Hz @ ≤ -98 dBc ≤ 1 kHz @ ≤ -115 dBc ≤ 10 kHz @ ≤ -125 dBc ≤ 100 kHz @ ≤ -126 dBc	2.4 dBc Phase Noise	
(1.28 to 3.2) GHz	≤ 1 Hz @ ≤ -43 dBc ≤ 10 Hz @ ≤ -73 dBc ≤ 100 Hz @ ≤ -93 dBc ≤ 1 kHz @ ≤ -110 dBc ≤ 10 kHz @ ≤ -124 dBc ≤ 100 kHz @ ≤ -125 dBc	2.4 dBc Phase Noise	
(3.2 to 5.76) GHz	≤ 1 Hz @ ≤ -37 dBc ≤ 10 Hz @ ≤ -67 dBc ≤ 100 Hz @ ≤ -87 dBc ≤ 1 kHz @ ≤ -104 dBc ≤ 10 kHz @ ≤ -123 dBc ≤ 100 kHz @ ≤ -126 dBc	2.4 dBc Phase Noise	
(5.76 to 8.32) GHz	≤ 1 Hz @ ≤ -33 dBc ≤ 10 Hz @ ≤ -63 dBc ≤ 100 Hz @ ≤ -83 dBc ≤ 1 kHz @ ≤ -100 dBc ≤ 10 kHz @ ≤ -121 dBc ≤ 100 kHz @ ≤ -125 dBc	2.4 dBc Phase Noise	
(8.32 to 10.88) GHz	≤ 1 Hz @ ≤ -30 dBc ≤ 10 Hz @ ≤ -60 dBc ≤ 100 Hz @ ≤ -80 dBc ≤ 1 kHz @ ≤ -97 dBc ≤ 10 kHz @ ≤ -119 dBc ≤ 100 kHz @ ≤ -125 dBc	2.4 dBc Phase Noise	

Parameter/Range	Frequency	CMC <sup>2,9</sup> (±)	Comments
Phase Noise <sup>3,5</sup> – Generate and Measure (cont)			
(10.88 to 13.44) GHz	≤ 1 Hz @ ≤ -28 dBc ≤ 10 Hz @ ≤ -58 dBc ≤ 100 Hz @ ≤ -78 dBc ≤ 1 kHz @ ≤ -95 dBc ≤ 10 kHz @ ≤ -118 dBc ≤ 100 kHz @ ≤ -125 dBc	+/- 2.4 dBc Phase Noise	HP 11848A opt 201 w/ 11729C, 8663A with HP 3561A
(13.44 to 16.0) GHz	≤ 1 Hz @ ≤ -27 dBc ≤ 10 Hz @ ≤ -57 dBc ≤ 100 Hz @ ≤ -77 dBc ≤ 1 kHz @ ≤ -94 dBc ≤ 10 kHz @ ≤ -116 dBc ≤ 100 kHz @ ≤ -124 dBc	+/- 2.4 dBc Phase Noise	
(16.0 to 18) GHz	≤ 1 Hz @ ≤ -25 dBc ≤ 10 Hz @ ≤ -55 dBc ≤ 100 Hz @ ≤ -75 dBc ≤ 1 kHz @ ≤ -92 dBc ≤ 10 kHz @ ≤ -115 dBc ≤ 100 kHz @ ≤ -123 dBc	+/- 2.4 dBc Phase Noise	
Digital Modulation – Measure <sup>3</sup>			
Carrier: 2 MHz to 26.5 GHz			Agilent 89441A
Error Vector Magnitude for Modulation Types: MSK, GMSK, BPSK, DQPSK, $\pi/4$ DQPSK, 8PSK, 16QAM and 32QAM	Mod Frequency Span: 1 Hz to 100 kHz (0.1 to 1) MHz (1 to 2650) MHz	0.36 % 0.59 % 1.2 %	
Phase Error for Modulation Types: MSK, GMSK, BPSK, DQPSK, $\pi/4$ DQPSK, 8PSK, 16QAM and 32QAM	Mod Frequency Span: 1 Hz to 100 kHz (0.1 to 1) MHz (1 to 2650) MHz	0.22° 0.45° 0.73°	

Parameter/Range	Frequency	CMC <sup>2,9</sup> (±)	Comments
Digital Modulation – Measure <sup>3</sup> (cont.)  Carrier: 2 MHz to 26.5 GHz			Agilent 89441A
Error Vector Magnitude for FSK Modulation	Mod Frequency: 3.2 kHz 1.152 kHz	0.68 % 2.1 %	
Phase Error for FSK Modulation	Mod Frequency: 3.2 kHz 1.152 kHz	17 Hz 3.4 kHz	
Error Vector Magnitude for Modulation Types: QPSK and OQPSK	Mod Frequency: 2.6 MHz	1.2 %	
Phase Error for Modulation Types: QPSK and OQPSK	Mod Frequency: 2.6 MHz	0.69°	
Digital Modulation – Generate <sup>3</sup>  Carrier: 250 kHz to 2.65 GHz			Agilent E4437B w/ 89441A
Error Vector Magnitude for Modulation Types: MSK, GMSK, BPSK, DQPSK, $\pi/4$ DQPSK, 8PSK, 16QAM and 32QAM	Mod Frequency Span: 1 Hz to 100 kHz (0.1 to 1) MHz (1 to 2650) MHz	0.36 % 0.59 % 1.2 %	
Phase Error for Modulation Types: MSK, GMSK, BPSK, DQPSK, $\pi/4$ DQPSK, 8PSK, 16QAM and 32QAM	Mod Frequency Span: 1 Hz to 100 kHz (0.1 to 1) MHz (1 to 2650) MHz	0.24° 0.49° 0.77°	
Error Vector Magnitude for FSK Modulation	Mod Frequency: 3.2 kHz 1.152 kHz	0.68 % 2.1 %	
Phase Error for FSK Modulation	Mod Frequency: 3.2 kHz 1.152 kHz	17 Hz 3.4 kHz	
Error Vector Magnitude for Modulation Types: QPSK and OQPSK	Mod Frequency: 2.6 MHz	1.2 %	
Phase Error for Modulation Types: QPSK and OQPSK	Mod Frequency: 2.6 MHz	0.72°	

Parameter/Range	Frequency	CMC <sup>2,9</sup> (±)	Comments
EFT Generator <sup>3</sup> – Voltage (±) Rise Time Impulse Duration Burst Duration Burst Period	10 V to 6 kV 5 ns ± 30 % 50 ns ± 30 % 15 ms ± 20 % 300 ms ± 20 %	3.5 % 0.71 ns 0.71 ns 0.71 ns 0.71 ns	IEC 61000-4-4 KeyTek PK1001D Agilent 54820A
Surge Generator <sup>3</sup> Front Time / Rise Time (±) Open / Short Circuit Time to Half-Value / Duration (±) Open Circuit Voltage (±) Short Circuit Current (±)	(1.2 to 50) µs (20 to 700) µs 10 V to 6 kV (0.125 to 3) kA	0.71 ns 0.71 ns 3.5 % 3.1 %	IEC 61000-4-5 Agilent 54820A KeyTek PK1001D Pearson 110
RF Isotropic Probes <sup>3</sup>	10 kHz to 1 GHz	0.63 dB	GTEM CELL with Agilent E4440A
Loop Antennas <sup>3</sup>	10 Hz to 30 MHz	2.4 dB	IEEE 291-1991, HP 3585A
Monopole/Rod Antenna <sup>3</sup>	30 Hz to 50 MHz	0.25 dB	Method (ECSM) ANSI C63.5, SAE ARP 958, HP 4195A
Dipole Antennas <sup>3</sup> – 3 Meter Distance 10 Meter Distance	(20 to 200) MHz (200 to 1000) MHz (20 to 200) MHz (200 to 1000) MHz	1.7 dB 1.8 dB 1.5 dB 1.9 dB	ANSI C63.5-1988, ANSI C63.5-1998, ANSI C63.5 HP 8562A HP 8648C

Parameter/Range	Frequency	CMC <sup>2</sup> (±)	Comments
Conical Log Spirals <sup>3</sup> – 1 Meter	(200 to 1000) MHz	2.1 dB	SAE ARP958, HP 8562A, HP 8648C
BiConical Antenna <sup>3</sup> – 1 Meter Distance – Horizontal Vertical	(20 to 300) MHz (20 to 300) MHz	1.4 dB 1.7 dB	SAE ARP958  HP 8562A HP 8648C
3 Meter Distance –  Horizontal Vertical	(20 to 300) MHz (20 to 300) MHz	1.2 dB 1.5 dB	SAE ARP958, Appendix C ANSI C63.5-1988, ANSI C63.5-1998, ANSI C63.5
10 Meter Distance –  Horizontal Vertical	(20 to 300) MHz (20 to 300) MHz	1 dB 1.2 dB	HP 8562A HP 8648C
Log-Periodic Antenna <sup>3</sup> – 1 Meter Distance – Horizontal Vertical	(200 to 3000) MHz (200 to 3000) MHz	1.2 dB 1.7 dB	SAE ARP958  HP 8562A HP 8648C
3 Meter Distance –  Horizontal Vertical	(200 to 3000) MHz (200 to 3000) MHz	1.1 dB 1.7 dB	SAE ARP958, Appendix C ANSI C63.5-1988, ANSI C63.5-1998, ANSI C63.5
10 Meter Distance –  Horizontal Vertical	(200 to 3000) MHz (200 to 3000) MHz	1.4 dB 1.8 dB	HP 8562A HP 8648C

Parameter/Range	Frequency	CMC <sup>2</sup> (±)	Comments
BiConilog Antennas – 1 Meter Distance –  Horizontal Vertical  3 Meter Distance –  Horizontal Vertical  10 Meter Distance –  Horizontal Vertical	(30 to 3000) MHz (30 to 3000) MHz   (30 to 3000) MHz (30 to 3000) MHz   (30 to 3000) MHz (30 to 3000) MHz	1.2 dB 1.7 dB   1.1 dB 1.7 dB   1.4 dB 1.8 dB	SAE ARP958  HP 8562A HP 8648C   SAE ARP958, Appendix C ANSI C63.5-1988, ANSI C63.5-1998, ANSI C63.5  HP 8562A HP 8648C
Horn Antennas  1 Meter Distance –  Horizontal Vertical    3 Meter Distance –  Horizontal Vertical	1 GHz to 40 GHz      1 GHz to 40 GHz	1.1 dB 1.1 dB     1.1 dB 1.1 dB	SAE ARP958  ETS 3117 DRG Horn antenna  AH Systems SAS-574 DRG Horn antenna  Microwave source with HP 8565E  ANSI C63.5-1988 ANSI C63.5-1998 ANSI C63.5-2004  ETS 3117 DRG Horn antenna  AH Systems SAS-574 DRG Horn antenna  Microwave source with HP 8565E

## VI. Magnetic Quantities

Parameter/Range	Frequency	CMC <sup>2,9</sup> (±)	Comments
Magnetic – Generate			
0.1 to 32 G	DC to 10 kHz	0.3 %	LA-1447, Fluke 5700A
100 G to 20 KG	DC	0.40 G	HV-10H w/ 920-MC and Keithley 2000
Magnetic – Measure			
(0.8 to 18.3) KG	DC	0.032 G	FW Bell Model 20 NMR (intrinsic)
30 mG to 300 KG	DC to 10 kHz (Axial & Transverse)	2.1 G	Bell 9103 with HTF99-0608, STF99-0404 or HAF99-2508

## VII. Mechanical

Parameter/Equipment	Range	CMC <sup>2,9</sup> (±)	Comments
Vacuum Gauges and Transducers – Measuring Equipment & Measure <sup>3</sup>	0 to 23 psia (0.01 to 0.1) Torr (0.1 to 1) Torr (1 to 10) Torr (10 to 100) Torr (100 to 1000) Torr	0.009 % of full scale 0.095 % 0.061 % 0.061 % 0.061 % 0.061 %	Paroscientific 715 MKS 690A.1TRB MKS 390HA-00001SP05 MKS 690A11TRA MKS 690A12TRA MKS 390HA-01000SP05
Pressure – Measure & Measuring Equipment <sup>3</sup>	(1 to 12) inH <sub>2</sub> O	0.0047 inH <sub>2</sub> O	Dwyer hook gage
Flow <sup>3</sup>	(0 to 2) ml/m (2 to 20) ml/m (20 to 200) ml/m (200 to 2000) ml/m  (2 to 50) l/m	2.9 % + 0.003 ml/m 2.9 % + 0.04 ml/m 2.9 % + 0.35 ml/m 3.7 % + 3.5 ml/m  3.0 %	ATEQ leak/flow calibrator    Cole-Parmer 32712-40
Leak rate <sup>3</sup>	(0 to 120) cc/hr	2.9 % + 0.003 cc/hr	ATEQ leak/flow calibrator

Parameter/Equipment	Range	CMC <sup>2</sup> (±)	Comments
Mass <sup>3</sup>	1 mg	0.75 µg	Cahn C31 with Class 0 weights
	2 mg	0.78 µg	
	3 mg	0.94 µg	
	5 mg	0.81 µg	
	10 mg	1.3 µg	
	20 mg	1.5 µg	
	30 mg	1.5 µg	Mettler MT5 with Class 0 weights
	50 mg	1.6 µg	
	100 mg	1.8 µg	
	200 mg	1.5 µg	
	300 mg	1.9 µg	
	500 mg	2.1 µg	
	1 g	3 µg	Sartorius 2405 with Class 0 weights
	2 g	2.5 µg	
	3 g	3.7 µg	
	5 g	4.2 µg	
	10 g	8.7 µg	
	20 g	12 µg	
	30 g	14 µg	Sartorius R160P with Class 0 weights
	50 g	18 µg	
	100 g	36 µg	Mettler AT261 with Class 0 weights
	200 g	70 µg	
	0.3 kg	0.19 mg	Sartorius 2086 MP-6E with Class 0 weights
	0.5 kg	0.17 mg	
	1 kg	0.19 mg	
	2 kg	0.45 mg	
	3 kg	1.3 mg	Volland HCE25D with Class 0 weights
5 kg	2.5 mg		
10 kg	3.2 mg		
20 kg	11 mg		
30 kg	120 mg	Mettler PK60MC	
50 kg	130 mg		

Parameter/Equipment	Range	CMC <sup>2,9</sup> (±)	Comments
Scales & Balances <sup>3</sup>	(1 to 10) mg (10 to 500) mg (1 to 50) g (50 to 300) g (300 to 500) g (0.5 to 1) kg (1 to 3) kg (3 to 5) kg (5 to 10) kg (10 to 20) kg (20 to 30) kg  (1 to 5) lb (5 to 10) lb (10 to 25) lb (25 to 50) lb (50 to 100) lb (100 to 500) lb (500 to 1000) lb	0.011 mg 0.026 mg 0.08 mg 0.4 mg 0.6 mg 1.3 mg 4.6 mg 6.5 mg 27 mg 35 mg 45 mg  0.0006 lb 0.001 lb 0.004 lb 0.006 lb 0.02 lb 0.052 lb 0.11 lb	Class 1 weights
Pressure Gauges, Transducers and Calibrators – Measuring Equipment & Measure <sup>3,6</sup>	(0.23 to 18) psig (2 to 70) psig (2 to 700) psig (6 to 2400) psig  (30 to 12 000) psig  (12 000 to 60 000) psig	0.0012 % 0.0012 % 0.0012 % 0.0026 %  0.0041 %  0.02 %	Ruska 2465 with 2460-745 Ruska 2465 with 2460-757 Ruska 2465 with 2460-706 Ruska 2485 with 2400-736  Ruska 2485 with 2400-735  DH Brundenberg deadweight system
Cross Float for Deadweight Tester	(-14.5 to 0) psig  (200 to 20 000) psig	0.0045 %  0.0074 %	Ruska 2465 with 2460-745 in absolute mode  DH Brundenberg deadweight system

Parameter/Equipment	Range	CMC <sup>2,9</sup> (±)	Comments
Torque Wrenches <sup>3</sup>	5 in·lb to 250 ft·lb	0.33 % full scale	CDI 950-DT with TTPM-441
	(250 to 1000) ft·lb	0.33 % full scale	CDI 2001 with transducers
	(1000 to 2000) ft·lb	0.39 % full scale	
Torque Transducers and Calibrators <sup>3</sup>	(1 to 40) in·oz	0.12 %	Class F weights with: 2.5-in wheel
	40 in·oz to 55 in·lb	0.12 %	5-in wheel
	20 in·lb to 300 ft·lb	0.12 %	10-in butterfly
	(300 to 2000) ft·lb	0.12 %	40 in torq arm
Force – Compression and Tension <sup>3</sup>	(0 to 1000) lbf	0.095 lbf	Class F weights with hanger

### VIII. Optical Quantities

Parameter/Equipment	Range	CMC <sup>2,9</sup> (±)	Comments	
Fiber Optics Wavelength – Measuring Equipment <sup>3</sup>	(850, 1310, 1330) nm 1555 nm	0.0045 %	Anritsu MG09XXX series LD Sources w/ 86120C	
	(1525 to 1575) nm	0.0045 %	HP 81689A w/ 86120C	
Fiber Optics Wavelength – Measure <sup>3</sup>	(700 to 1650) nm	0.004 %	HP 86120C	
Fiber Optics Power – Measuring Equipment <sup>3</sup>			HP 8152A with	
	850 nm	-4 dBm	5.5 %	HP 81520A w/ Anritsu MG09 Source
	1330 nm (1310, 1550) nm (1525 to 1575) nm	-4 dBm -6 dBm	6.2 % 6.2 %	HP 8152A/81520 and 81521 w/ Anritsu MG09XXX Source

Parameter/Equipment	Range	CMC <sup>2,9</sup> (±)	Comments
Fiber Optics Power and Attenuation – Measure			HP 8152A with:
450 to 1020 nm	(+10 to -100) dBm	4.7 %	HP 81520A
(900 to 1700) nm	(+10 to -90) dBm	5.2 %	HP 81521B
Illuminance	(80 to 3000) fcd	2.4 %	Standard lamp
Luminance	(700 to 22 000) fL	2.3 %	Integrating sphere
Color Temperature	(2000 to 3000) K	31 K	Integrating sphere

#### IX. Time & Frequency

Parameter/Equipment	Range	CMC <sup>2</sup> (±)	Comments
Time Interval <sup>3</sup>	1 s to 24 h	0.5 s	HP 5345A
Frequency – Generate <sup>3</sup>	10 MHz	5 parts in 10 <sup>12</sup>	Datum GPS receiver
	DC to 20 MHz	5 parts in 10 <sup>12</sup>	HP 3325B
	20 MHz to 50 GHz	5 parts in 10 <sup>12</sup>	HP 83650A/B
Frequency – Measure <sup>3</sup>	10 MHz	5 parts in 10 <sup>12</sup>	HR GPS receiver
	DC to 500 MHz	5 parts in 10 <sup>12</sup> + 1 digit	HP 5345A
	(0.5 to 46) GHz	5 parts in 10 <sup>12</sup> + 10 digits	HP 5352A

X. Thermodynamics

Parameter/Equipment	Range	CMC <sup>2,9</sup> (±)	Comments
Temperature <sup>3,6</sup> – Measuring Equipment SPRT, RTDs and Thermocouples	(-30 to 232) °C	14 m°C	Hart 7012 and 6020 bath with 5699 SPRT and Hart superthermometer
	(232 to 275) °C	29 m°C	
	(275 to 400) °C	0.054 °C	Hart 9100 w meter/PRT
	(300 to 500) °C	1.2 °C	Fluke 518 drywell
	(500 to 1000) °C (1000 to 1100) °C (1100 to 1200) °C	1.1 °C 1.7 °C 3.9 °C	Hart 5650 thermocouple probe with furnace, HP 34420A, Hart ice point
Triple Point of Water	0.01 °C	4.9 m°C	Hart 5901 triple point cell
IR Temperature – Measuring Equipment <sup>3</sup>	(-20 to 100) °C	1.2 °C	Hart 9131 W/ 1521 meter/ 5618 PRT
	(100 to 250) °C	1.7 °C	
	(250 to 500) °C	1.7 °C	
Relative Humidity <sup>3</sup>	10 % to 95 % (0 to 70) °C drybulb	0.54 %	Thunder Scientific 2500
Temperature – Measure SPRT, RTDs and Thermocouples <sup>3</sup>	(-200 to -45) °C	5.3 m°C	Hart 5699 SPRT with Hart 1590 superthermometer
	(-45 to 232) °C	14 m°C	
	(232 to 420) °C	29 m°C	
	(420 to 1000) °C (1000 to 1100) °C (1100 to 1450) °C	1.2 °C 1.3 °C 3.9 °C	Hart 5650 thermocouple probe with HP 34420A, Hart ice point

Parameter/Range	Frequency	CMC <sup>2,9</sup> (±)	Comments
ESD Simulators <sup>3</sup> –  Contact Voltage Air Discharge Voltage Risetime Current RC Time Constant	(0.2 to 8) kV (0 to 30) kV (0.7 to 1) ns (0 to 100) A 600 ns 300 ns	0.06 % 0.06 % 46 ps 2.9 % 120 ps 81 ps	IEC 61000-4-2 ISO 10605  Agilent 54820A Brandenburg 149-04 Keytek CTC-3
Shielding Effectiveness <sup>3</sup>	700 MHz to 18 GHz	1.3 dB	MIL-STD 285 IEEE 299  HP 859xE HP 8495B
LISN <sup>3</sup> –  Insertion Loss  Impedance	9 kHz to 108 MHz 300 kHz to 108 MHz  9 kHz to 2 MHz 300 kHz to 108 MHz	2.9 % 0.17 dB  0.05 % 0.17 dB	ANSI C63.4, Appendix E Agilent E4418A w/ E9304A HP 8753E  QuadTech 7600 HP 8753E
Current Probes and Bulk Current Injection Probes <sup>3</sup> –  Insertion Loss  Transfer Impedance	20 Hz to 300 kHz 300 kHz to 1 GHz  20 Hz to 300 kHz 300 kHz to 1 GHz	1 dB 0.17 dB  1 dB 0.17 dB	CISPR 16-1-2 and IEC 61000-4-6  HP 4195A, HP 41952A HP 8753E  HP 3585B HP 8753E
CDN <sup>3</sup> –  Insertion Loss  Coupling Factor  Impedance	150 kHz to 230 MHz  150 kHz to 230 MHz  150 kHz to 230 MHz	0.25 dB  0.25 dB  4.1 %	IEC 61000-4-6  Agilent 4195A with 41952A

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- <sup>1</sup> This laboratory offers commercial calibration service and field calibration service.
- <sup>2</sup> Calibration and Measurement Capability (CMC) is the smallest uncertainty of measurement that a laboratory can achieve within its scope of accreditation when performing more or less routine calibrations of nearly ideal measurement standards or nearly ideal measuring equipment. Calibration and Measurement Capabilities represent expanded uncertainties expressed at approximately the 95 % level of confidence, usually using a coverage factor of  $k = 2$ . The actual measurement uncertainty of a specific calibration performed by the laboratory may be greater than the CMC due to the behavior of the customer's device and to influences from the circumstances of the specific calibration.
- <sup>3</sup> Field calibration service is available for this calibration and this laboratory meets A2LA R104 – *General Requirements: Accreditation of Field Testing and Field Calibration Laboratories* for these calibrations. Please note the actual measurement uncertainties achievable on a customer's site can normally be expected to be larger than the CMC found on the A2LA Scope. Allowance must be made for aspects such as the environment at the place of calibration and for other possible adverse effects such as those caused by transportation of the calibration equipment. The usual allowance for the actual uncertainty introduced by the item being calibrated, (e.g. resolution) must also be considered and this, on its own, could result in the actual measurement uncertainty achievable on a customer's site being larger than the CMC.
- <sup>4</sup> The measurands stated are generated with the Fluke 5000A, 792A, 5790A, 732B, 5725A, and 5720A series instruments. This capability is suitable for the calibration of the devices intended to measure the stated measurand in the ranges indicated. CMC's are expressed as either a specific value that covers the full range or as a combination of the percent or portion of the reading plus a fixed floor specification.
- <sup>5</sup> The measurands stated are measured with the HP 3458A, 86100A, 42030A, 1638XX, 8642A, 8481A, and 3325A. This capability is suitable for the calibration of the devices intended to generate the measurand in the ranges indicated. CMC's are expressed as either a specific value that covers the full range or as a combination of the percent or portion of the reading/output plus a range specification.
- <sup>6</sup> Negative gauges are limited by local barometric pressure.
- <sup>7</sup> In the statement of CMC,  $L$  is the numerical value of the nominal length of the device measured in inches.
- <sup>8</sup> 3-1 method used for the stated CMC's; higher CMC's will be given for the use of double and single substitution.
- <sup>9</sup> All CMC's listed in % are percent of reading of input unless otherwise stated.



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Presented this 30<sup>th</sup> day of October 2009.



  
\_\_\_\_\_  
Peter Meyer

President & CEO  
For the Accreditation Council  
Certificate Number 1623.01  
Valid to November 30, 2011  
Revised October 31, 2011

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