

**STANDARDS**  
MALAYSIA

# Certificate of Accreditation

No: SAMM 088

Accredited since: 14 September 1995

This is to certify that

SIRIM STANDARDS TECHNOLOGY SDN. BHD.  
SHAH ALAM, SELANGOR  
MALAYSIA



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[www.jsm.gov.my/cab-directories](http://www.jsm.gov.my/cab-directories)  
for the current scope of accreditation

has been granted accreditation in respect of the scope of accreditation described in the schedule, subject to the terms and conditions governing the *Skim Akreditasi Makmal Malaysia* (SAMM), the Laboratory Accreditation Scheme of Malaysia.

Laboratories accredited under SAMM meet the requirements of MS ISO/IEC 17025. This Malaysian Standard is identical with ISO/IEC 17025 published by the International Organization for Standardization (ISO).



(DATUK FADILAH BAHARIN)  
Director General  
Department of Standards Malaysia

Date of issue: 6 September 2017

**NO: SAMM 088**(Issue 2, 11 November 2020 replacement  
of SAMM 088 dated 26 August 2020)

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**LABORATORY LOCATION:**  
(PERMANENT LABORATORY)

**SIRIM STANDARDS TECHNOLOGY SDN. BHD.**  
(Company No.: 292201-P)  
LOT 12, 18 & 20, JALAN BEREMBAN 15/12  
SEKSYEN 15  
40200 SHAH ALAM, SELANGOR  
MALAYSIA

**FIELDS OF CALIBRATION:**

**ELECTRICAL, ACOUSTIC & VIBRATION  
MEASUREMENT, PRESSURE, DIMENSIONAL, MASS  
AND MASS RELATED, TEMPERATURE**

This laboratory has demonstrated its technical competence to operate in accordance with MS ISO/IEC 17025:2017 (ISO/IEC 17025:2017).

This laboratory's fulfillment of the requirements of ISO/IEC 17025 means the laboratory meets both the technical competence requirements and management system requirements that are necessary for it to consistently deliver technically valid test results and calibrations. The management system requirements in ISO/IEC 17025 are written in language relevant to laboratory operations and operate generally in accordance with the principles of ISO 9001 (see Joint ISO-ILAC-IAF Communiqué dated April 2017).

\* The expanded uncertainties are based on an estimated confidence probability of approximately 95% and have a coverage factor of  $k=2$  unless stated otherwise.

**SCOPE OF CALIBRATION: ELECTRICAL**

| Instrument Calibrated/<br>Measurement Parameter | Range                                        | Calibration and<br>Measurement<br>Capability<br>Expressed as an<br>Uncertainty ( $\pm$ ) * | Remarks     |
|-------------------------------------------------|----------------------------------------------|--------------------------------------------------------------------------------------------|-------------|
| 1. Measuring Instrument<br>DC VOLTAGE           | $\pm 220$ mV Range<br>$\pm$ (0 mV to 220 mV) | $7.5 \mu\text{V/V} + 0.4 \mu\text{V}$                                                      | Fluke 5730A |
|                                                 | $\pm 2.2$ V Range<br>$\pm$ (0 V to 2.2 V)    | $5 \mu\text{V/V} + 0.7 \mu\text{V}$                                                        |             |
|                                                 | $\pm 11$ V Range<br>$\pm$ (0 V to 11 V)      | $3.5 \mu\text{V/V} + 2.5 \mu\text{V}$                                                      |             |
|                                                 | $\pm 22$ V Range<br>$\pm$ (0 V to 22 V)      | $3.5 \mu\text{V/V} + 4 \mu\text{V}$                                                        |             |
|                                                 | $\pm 220$ V Range<br>$\pm$ (0 V to 220 V)    | $5 \mu\text{V/V} + 40 \mu\text{V}$                                                         |             |

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| Instrument Calibrated/<br>Measurement Parameter   | Range                                                                                                                    | Calibration and<br>Measurement<br>Capability Expressed<br>as an Uncertainty ( $\pm$ ) * | Remarks          |
|---------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------|------------------|
| 1. Measuring Instrument<br>Continue<br>DC VOLTAGE | $\pm 1100$ V Range<br>$\pm (100$ V to 1100 V)                                                                            | $6.5 \mu\text{V/V} + 0.4$ mV                                                            | Fluke 5730A      |
| AC VOLTAGE                                        | <u><math>2.2</math> mV to <math>220</math> V</u><br>(See Matrix A)                                                       | (See Matrix A)                                                                          | Fluke 5730A      |
|                                                   | <u><math>1100</math> V Range (<math>110</math> V to <math>1100</math> V)</u><br>$15$ Hz to $50$ Hz<br>$50$ Hz to $1$ kHz | $360 \mu\text{V/V} + 20$ mV<br>$85 \mu\text{V/V} + 4$ mV                                | Fluke 5730A      |
|                                                   | <u><math>800</math> V to <math>1050</math> V</u><br>$1$ kHz to $3$ kHz<br>$3$ kHz to $10$ kHz<br>$10$ kHz to $20$ kHz    | $0.8$ mV/V + $0.13$ V<br>$0.8$ mV/V + $0.21$ V<br>$1.2$ mV/V + $0.32$ V                 | Wavetek 9100     |
| DC CURRENT                                        | $\pm 220 \mu\text{A}$ Range<br>$\pm (0 \mu\text{A}$ to $220 \mu\text{A})$                                                | $40 \mu\text{A/A} + 6$ nA                                                               | Fluke 5730A      |
|                                                   | $\pm 2.2$ mA Range<br>$\pm (0$ mA to $2.2$ mA)                                                                           | $35 \mu\text{A/A} + 7$ nA                                                               |                  |
|                                                   | $\pm 22$ mA Range<br>$\pm (0$ mA to $22$ mA)                                                                             | $35 \mu\text{A/A} + 40$ nA                                                              |                  |
|                                                   | $\pm 220$ mA Range<br>$\pm (0$ mA to $220$ mA)                                                                           | $45 \mu\text{A/A} + 0.7 \mu\text{A}$                                                    |                  |
|                                                   | $\pm 2.2$ A Range<br>$\pm (0$ A to $2.2$ A)                                                                              | $80 \mu\text{A/A} + 12 \mu\text{A}$                                                     |                  |
|                                                   | $\pm 3.2$ A Range<br>$\pm (0.32$ A to $3.2$ A)                                                                           | $0.6$ mA/A + $0.12$ mA                                                                  | Wavetek 9100     |
|                                                   | $\pm 10.5$ A Range<br>$\pm (3.2$ A to $10.5$ A)                                                                          | $0.55$ mA/A + $0.94$ mA                                                                 |                  |
|                                                   | $\pm 20$ A Range<br>$\pm (10.5$ A to $20$ A)                                                                             | $0.55$ mA/A + $4.5$ mA                                                                  | California 3213K |
|                                                   | $\pm 100$ A Range<br>$\pm (20$ A to $100$ A)                                                                             | $0.45$ mA/A + $20$ mA                                                                   |                  |

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**SCOPE OF CALIBRATION: ELECTRICAL**

| Instrument Calibrated/<br>Measurement<br>Parameter | Range                                                                                                                                                                                            | Calibration and<br>Measurement Capability<br>Expressed as an<br>Uncertainty ( $\pm$ ) *                               | Remarks                                                 |
|----------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------|
| 1. Measuring Instrument<br>Continue<br>AC CURRENT  | <u>9 <math>\mu</math>A to 2.2 A</u><br>(See Matrix B)                                                                                                                                            | (See Matrix B)                                                                                                        | Fluke 5730A                                             |
|                                                    | <u>0.32 A to 3.2 A</u><br>10 Hz to 3 kHz<br>3 kHz to 10 kHz<br><br><u>3.2 A to 10.5 A</u><br>10 Hz to 3 kHz<br>3 kHz to 10 kHz<br><br><u>10.5 A to 20 A</u><br>10 Hz to 3 kHz<br>3 kHz to 10 kHz | 1 mA/A + 0.48 mA<br>2.5 mA/A + 2.6 mA<br><br>2 mA/A + 3 mA<br>5 mA/A + 10 mA<br><br>2 mA/A + 6.9 mA<br>5 mA/A + 23 mA | Wavetek 9100                                            |
|                                                    | <u>20 A to 100 A</u><br>10 Hz to 1 kHz<br>1 kHz to 10 kHz                                                                                                                                        | 2.5 mA/A + 0.03 A<br>5 mA/A + 0.05 A                                                                                  | California Instruments<br>CA 3213K                      |
|                                                    | <u>3 mA to 3A</u><br>At Time interval up to 5 s<br>At Time interval <190 ms                                                                                                                      | 0.14 mA/A<br>0.3 mA/A                                                                                                 | For RCD Tester<br>Calibrator<br>(using Transmille 3200) |
| CAPACITANCE                                        | (See Matrix C)                                                                                                                                                                                   | (See Matrix C)                                                                                                        | Wavetek 9100                                            |
| Fixed Value                                        | <u>20 Hz to 1 MHz</u><br>1 pF, 10 pF, 100 pF, 1000 pF,<br>0.01 $\mu$ F, 0.1 $\mu$ F and 1.0 $\mu$ F                                                                                              | 1 mF/F                                                                                                                | HP 1600A series                                         |
| INDUCTANCE<br>Fixed Value                          | <u>100 <math>\mu</math>H @ 1 kHz</u><br><u>(1, 10, 100) mH @ 1 kHz</u><br><u>1H @ 1 kHz</u>                                                                                                      | 2.5 mH/H<br>1 mH/H<br>1 mH/H                                                                                          | Ando RS-100 series                                      |

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| Instrument Calibrated/<br>Measurement Parameter                  | Range                                                                                                                                                                                                                                                                                                                   | Calibration and<br>Measurement Capability<br>Expressed as an<br>Uncertainty ( $\pm$ ) *                                                                                                                                                                                                                                                                                                                                                                                             | Remarks                                                           |
|------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------|
| 1. Measuring Instrument<br>Continue<br>RESISTANCE<br>Fixed Value | 1 m $\Omega$<br>10 m $\Omega$<br>100 m $\Omega$<br>1 $\Omega$<br>1.9 $\Omega$<br>10 $\Omega$<br>19 $\Omega$<br>100 $\Omega$<br>190 $\Omega$<br>1 k $\Omega$<br>1.9 k $\Omega$<br>10 k $\Omega$<br>19 k $\Omega$<br>100 k $\Omega$<br>190 k $\Omega$<br>1 M $\Omega$<br>1.9 M $\Omega$<br>10 M $\Omega$<br>19 M $\Omega$ | 0.2 m $\Omega/\Omega$<br>0.1 m $\Omega/\Omega$<br>0.02 m $\Omega/\Omega$<br>5 $\mu\Omega/\Omega$<br>95 $\mu\Omega/\Omega$<br>5 $\mu\Omega/\Omega$<br>23 $\mu\Omega/\Omega$<br>5 $\mu\Omega/\Omega$<br>10 $\mu\Omega/\Omega$<br>5 $\mu\Omega/\Omega$<br>6.5 $\mu\Omega/\Omega$<br>5 $\mu\Omega/\Omega$<br>6.5 $\mu\Omega/\Omega$<br>5 $\mu\Omega/\Omega$<br>8.5 $\mu\Omega/\Omega$<br>5 $\mu\Omega/\Omega$<br>18 $\mu\Omega/\Omega$<br>5 $\mu\Omega/\Omega$<br>47 $\mu\Omega/\Omega$ | Fluke 5730A & Fluke<br>742A Series Resistance<br>Standard         |
|                                                                  | 100 M $\Omega$<br>1 G $\Omega$<br>10 G $\Omega$<br>100 G $\Omega$<br>1 T $\Omega$                                                                                                                                                                                                                                       | 0.1 m $\Omega/\Omega$<br>5 $\mu\Omega/\Omega$<br>0.02 $\Omega/\Omega$<br>0.05 $\Omega/\Omega$<br>0.05 $\Omega/\Omega$                                                                                                                                                                                                                                                                                                                                                               | Fluke 5730A<br>& Takeda Riken TR45<br>Series Standard<br>Resistor |
| POWER/ ENERGY<br>(DC)                                            | 1 kW to 20 kW<br>0.1 W to 1 kW                                                                                                                                                                                                                                                                                          | 0.7 mW/W<br>0.22 mW/W                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Fluke 5520A                                                       |
| POWER / ENERGY (AC),<br>(45 Hz to 65 Hz at PF=1)                 | 10 kW to 20 kW<br>1 W to 10 kW<br>0.1 W to 1 W                                                                                                                                                                                                                                                                          | 1 mW/W<br>0.9 mW/W<br>1 mW/W                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                   |

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| Instrument Calibrated/<br>Measurement<br>Parameter                    | Range                                                                                                                          | Calibration and<br>Measurement Capability<br>Expressed as an<br>Uncertainty ( $\pm$ ) * | Remarks                                                 |
|-----------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------|---------------------------------------------------------|
| 1. Measuring Instrument<br>Continue<br>TIME                           | 1 s to 24 Hrs                                                                                                                  | 0.06 $\mu$ s/s + 0.021 s                                                                | Agilent 33250A &<br>Universal Counter HP<br>53132A      |
|                                                                       | 20 ms to 5 s                                                                                                                   | 0.7 ms                                                                                  | For RCD Tester<br>Calibrator<br>(using Transmille 3200) |
| Residual Current<br>Duration                                          | 10 ms to 5 s                                                                                                                   | 0.4 ms                                                                                  |                                                         |
| RPM Measuring<br>Instruments (Non<br>Contact)                         | 60 to 5999 rpm<br>6000 to 29999 rpm<br>30000 to 59999 rpm<br>60000 to 99999 rpm                                                | 0.07 rpm<br>7 rpm<br>36 rpm<br>70 rpm                                                   | In-House method,<br>ESF/0303                            |
| HIGH VOLTAGE<br>METER<br>DC Voltage<br><br>AC Voltage @<br>(50/60) Hz | 0.5 kV to 10 kV                                                                                                                | 5 mV/V                                                                                  | TDV 20 ADS &<br>TOS 5101                                |
|                                                                       |                                                                                                                                | 8 mV/V                                                                                  |                                                         |
| CLAMP METER<br>DC Current<br>10 – Turn Coil                           | $\pm 3.2$ A to 32 A<br>$\pm 32$ A to 105 A<br>$\pm 105$ A to 200 A                                                             | 0.06 mA/A + 1.18 mA<br>0.55 mA/A + 9.4 mA<br>0.55 mA/A + 45 mA                          | Wavetek 9100 c/w<br>Current Coil                        |
| 50 – Turn Coil                                                        | $\pm 16$ A to 160 A<br>$\pm 160$ A to 525 A<br>$\pm 525$ A to 1000 A                                                           | 0.6 mA/A + 5.9 mA<br>0.55 mA/A + 47 mA<br>0.55 mA/A + 0.23 A                            |                                                         |
| AC Current<br>10 – Turn Coil                                          | <u>3.2 A to 32 A</u><br>10 Hz to 100 Hz<br>100 Hz to 440 Hz<br><br><u>32 A to 200 A</u><br>10 Hz to 100 Hz<br>100 Hz to 440 Hz | 2 mA/A + 5.5 mA<br>7.8 mA/A + 27 mA<br><br>2.1 mA/A + 90 mA<br>6.7 mA/A + 0.25 A        |                                                         |

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| Instrument Calibrated/<br>Measurement<br>Parameter                   | Range                                                                                                                                                                                                                                                                                                                                                                                                               | Calibration and<br>Measurement Capability<br>Expressed as an<br>Uncertainty ( $\pm$ ) *                                                             | Remarks                                                                  |
|----------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------|
| 1. Measuring Instrument<br>Continue<br>CLAMP METER<br>50 – Turn Coil | <u>16 A to 160 A</u><br>10 Hz to 100 Hz<br><br><u>160 A to 1000 A</u><br>10 Hz to 100 Hz                                                                                                                                                                                                                                                                                                                            | 2 mA/A + 28 mA<br><br>2.1 mA/A + 0.45 A                                                                                                             | Wavetek 9100 c/w<br>Current Coil                                         |
| INSULATION<br>TESTER                                                 | (1 k $\Omega$ to 10 k $\Omega$ ) @ 10 V<br>(10 k $\Omega$ to 100 k $\Omega$ ) @ 50 V<br>(0.1 M $\Omega$ to 1 M $\Omega$ ) @ 150 V<br>(1 M $\Omega$ to 10 M $\Omega$ ) @ 300 V<br>(10 M $\Omega$ to 100 M $\Omega$ ) @ 500 V<br>(0.1 G $\Omega$ to 1 G $\Omega$ ) @ 1000 V<br>(1 G $\Omega$ to 10 G $\Omega$ ) @ 5000 V<br>(10 G $\Omega$ to 100 G $\Omega$ ) @ 5000 V<br>(100 G $\Omega$ to 600 G $\Omega$ ) @ 5000 | 0.5 m $\Omega/\Omega$<br><br>1 m $\Omega/\Omega$<br><br>10 m $\Omega/\Omega$<br>50 m $\Omega/\Omega$<br>0.1 $\Omega/\Omega$<br>50 m $\Omega/\Omega$ | Tinsley 4720                                                             |
| OSCILLOSCOPE<br>Vertical Deflection<br>DC Signal                     | 0 V to $\pm 6.6$ V (50 $\Omega$ Load)<br>0 V to $\pm 130$ V (1 M $\Omega$ Load)                                                                                                                                                                                                                                                                                                                                     | 2.5 mV/V + 0.04 mV<br>0.5 mV/V + 0.04 mV                                                                                                            | Fluke 5500A SC600                                                        |
| Vertical Deflection<br>Square Wave Signal                            | $\pm 1$ mVp-p to $\pm 6.6$ Vp-p<br>(50 $\Omega$ Load)<br>$\pm 1$ mVp-p to $\pm 130$ Vp-p<br>(1 M $\Omega$ Load)                                                                                                                                                                                                                                                                                                     | 2.5 mVp-p/Vp-p +<br>0.04mVp-p<br><br>1 mVp-p/Vp-p + 0.04<br>mVp-p                                                                                   |                                                                          |
| Horizontal Deflection<br>Time Markers<br>(50 $\Omega$ Load)          | 2 ns/div to 20 ms/div<br>50 ms/div to 5 s/div                                                                                                                                                                                                                                                                                                                                                                       | 2.5 $\mu$ s/s<br>(25+(Output x 1000)) $\mu$ s/s                                                                                                     |                                                                          |
| Risetime                                                             | $\leq 300$ ps                                                                                                                                                                                                                                                                                                                                                                                                       | +0 ns / -0.1 ns                                                                                                                                     |                                                                          |
| Bandwidth Frequency                                                  | 50 kHz to 600 MHz                                                                                                                                                                                                                                                                                                                                                                                                   | 2.5 $\mu$ Hz/Hz                                                                                                                                     |                                                                          |
|                                                                      | 600 MHz to 40 GHz<br>(+11 dBm to -135 dBm)                                                                                                                                                                                                                                                                                                                                                                          | 7 nHz/Hz                                                                                                                                            | Agilent E8257D<br>Reference to Pendulum<br>GPS-12R Disciplined by<br>GPS |

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| Instrument Calibrated/<br>Measurement<br>Parameter                         | Range                                                                                   | Calibration and<br>Measurement Capability<br>Expressed as an<br>Uncertainty ( $\pm$ ) * | Remarks                                                                                                     |
|----------------------------------------------------------------------------|-----------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------|
| 1. Measuring Instrument<br>Continue<br>OSCILLOSCOPE<br>Bandwidth Amplitude | 50 kHz to 600 MHz                                                                       | 0.03 Vp-p                                                                               | Fluke 5500A SC600                                                                                           |
| Frequency                                                                  | 600 MHz to 40 GHz<br>(+11 dBm to -135 dBm)                                              | 0.92 dBm                                                                                | Agilent E8257D                                                                                              |
|                                                                            | 1 $\mu$ Hz to 80 MHz<br>(10 mVpp to 10 Vpp)<br>10 kHz to 40 GHz<br>(+11 dBm to -135dBm) | 36 nHz/Hz<br><br>7 nHz/Hz                                                               | (Agilent 33250A, ifR2042<br>or<br>Agilent E8257D)<br>Reference to Pendulum<br>GPS-12R Disciplined by<br>GPS |
|                                                                            | 10 mVp-p to 10 Vp-p<br>(1 $\mu$ Hz to 80 MHz, Into 50 $\Omega$ )                        | 10 mVpp/Vpp + 1 mVpp                                                                    | Agilent 33250A                                                                                              |
| Amplitude                                                                  | +13 dBm to -144dBm<br>(10 kHz to 5.4 GHz)                                               | 0.58 dBm                                                                                | ifR2042                                                                                                     |
|                                                                            | +11 dBm to -135dBm<br>(250 kHz to 40 GHz)                                               | 0.92 dBm                                                                                | Agilent E8257D                                                                                              |
|                                                                            | Sine Wave Relative to 1 kHz<br>(Auto range On)                                          | 0.4 dBm                                                                                 | Agilent 33250A                                                                                              |
| Flatness                                                                   |                                                                                         |                                                                                         |                                                                                                             |

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**SCOPE OF CALIBRATION: ELECTRICAL**

Matrix A

AC Voltage Measurement

| Range  |                   | Frequency    |              |               |              |
|--------|-------------------|--------------|--------------|---------------|--------------|
|        |                   | Hz           |              | kHz           |              |
|        |                   | 10 to 20     | 20 to 40     | 0.04 to 20    | 20 to 50     |
| 2.2 mV | 0.22 mV to 2.2 mV | 0.24 + 0.004 | 0.09 + 0.004 | 0.08 + 0.004  | 0.2 + 0.004  |
| 22 mV  | 2.2 mV to 22 mV   | 0.24 + 0.004 | 0.09 + 0.004 | 0.08 + 0.004  | 0.2 + 0.004  |
| 220 mV | 22 mV to 220 mV   | 0.24 + 0.012 | 0.09 + 0.007 | 0.057 + 0.007 | 0.12 + 0.007 |
| 2.2 V  | 0.22 V to 2.2 V   | 0.24 + 0.04  | 0.09 + 0.015 | 0.042 + 0.008 | 0.067 + 0.01 |
| 22 V   | 2.2 V to 22 V     | 0.24 + 0.4   | 0.09 + 0.15  | 0.042 + 0.05  | 0.067 + 0.1  |
| 220 V  | 22 V to 220 V     | 0.24 + 4     | 0.09 + 1.5   | 0.052 + 0.6   | 0.08 + 1     |

| Range  |                   | Frequency    |              |             |             |
|--------|-------------------|--------------|--------------|-------------|-------------|
|        |                   | MHz          |              |             |             |
|        |                   | 0.05 to 0.1  | 0.1 to 0.3   | 0.3 to 0.5  | 0.5 to 1    |
| 2.2 mV | 0.22 mV to 2.2 mV | 0.5 + 0.005  | 1.05 + 0.01  | 1.4 + 0.02  | 2.7 + 0.02  |
| 22 mV  | 2.2 mV to 22 mV   | 0.5 + 0.005  | 1.05 + 0.01  | 1.4 + 0.02  | 2.7 + 0.02  |
| 220 mV | 22 mV to 220 mV   | 0.31 + 0.017 | 0.655 + 0.03 | 1.4 + 0.025 | 2.7 + 0.045 |
| 2.2 V  | 0.22 V to 2.2 V   | 0.085 + 0.03 | 0.336 + 0.08 | 1 + 0.2     | 1.7 + 0.3   |
| 22 V   | 2.2 V to 22 V     | 0.085 + 0.2  | 0.254 + 0.6  | 1 + 2       | 1.5 + 3.2   |
| 220 V  | 22 V to 220 V     | 0.15 + 2.5   | 0.9 + 16     | 4.4 + 40    | 8 + 80      |

The expanded uncertainties given in this table are expressed in mV/V + mV

Matrix B

AC Current Measurement

| Range                    | Frequency (kHz) |              |               |              |             |
|--------------------------|-----------------|--------------|---------------|--------------|-------------|
|                          | 0.01 to 0.02    | 0.02 to 0.04 | 0.04 to 1     | 1 to 5       | 5 to 10     |
| 9 $\mu$ A to 220 $\mu$ A | 0.25 + 0.016    | 0.16 + 0.01  | 0.103 + 0.008 | 0.28 + 0.012 | 1.1 + 0.065 |
| 0.22 mA to 2.2 mA        | 0.25 + 0.04     | 0.16 + 0.035 | 0.103 + 0.035 | 0.2 + 0.11   | 1.1 + 0.65  |
| 2.2 mA to 22 mA          | 0.25 + 0.4      | 0.16 + 0.35  | 0.103 + 0.35  | 0.2 + 0.55   | 1.1 + 5     |
| 22 mA to 220 mA          | 0.25 + 4        | 0.16 + 3.5   | 0.103 + 2.5   | 0.2 + 3.5    | 1.1 + 10    |
| 0.22 A to 2.2 A          | Frequency (kHz) |              |               |              |             |
|                          |                 |              | 0.02 to 1     | 1 to 5       | 5 to 10     |
|                          |                 |              | 0.244 + 35    | 0.45 + 80    | 7 + 160     |

The expanded uncertainties given in this table are expressed in mA/A +  $\mu$ A

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**SCOPE OF CALIBRATION: ELECTRICAL**

Matrix C

Capacitance Measurement

| Range                     | Frequency             |                        |
|---------------------------|-----------------------|------------------------|
|                           | $\leq 350$ Hz         | 350 Hz to 1.5 kHz      |
| 0.5 nF to 4 nF            | 3 mF/F + 15 pF        | 6 mF/F + 0.03 nF       |
| 4 nF to 40 nF             | 3 mF/F + 30 pF        | 6 mF/F + 0.06 nF       |
| 40 nF to 400 nF           | 3 mF/F + 0.16 nF      | 6 mF/F + 0.32 nF       |
| 400 nF to 4 $\mu$ F       | 4 mF/F + 1.6 nF       | 8 mF/F + 3.2 nF        |
|                           | 5 mF/F + 16 nF        | 10 mF/F + 32 nF        |
| 40 $\mu$ F to 400 $\mu$ F | 5 mF/F + 0.16 $\mu$ F | 10 mF/F + 0.32 $\mu$ F |
| 400 $\mu$ F to 4 mF       | 5 mF/F + 1.6 $\mu$ F  | 10 mF/F + 3.2 $\mu$ F  |
| 4 mF to 40 mF             | 10 mF/F + 0.06 mF     | 20 mF/F + 0.12 mF      |

| Instrument Calibrated/<br>Measurement<br>Parameter | Range                                                            | Calibration and<br>Measurement Capability<br>Expressed as an<br>Uncertainty ( $\pm$ )* | Remarks           |
|----------------------------------------------------|------------------------------------------------------------------|----------------------------------------------------------------------------------------|-------------------|
| 2. Generating Instrument<br>DC VOLTAGE             | $\pm 100$ mV Range<br>$\pm (100 \mu\text{V to } 120 \text{ mV})$ | $5 \mu\text{V/V} + 0.3 \mu\text{V}$                                                    | HP 3458A Opt. 002 |
|                                                    | $\pm 1$ V Range<br>$\pm (100 \text{ mV to } 1.2 \text{ V})$      | $4 \mu\text{V/V} + 0.3 \mu\text{V}$                                                    |                   |
|                                                    | $\pm 10$ V Range<br>$\pm (1 \text{ V to } 12 \text{ V})$         | $4 \mu\text{V/V} + 0.5 \mu\text{V}$                                                    |                   |
|                                                    | $\pm 100$ V Range<br>$\pm (10 \text{ V to } 120 \text{ V})$      | $6 \mu\text{V/V} + 0.03 \text{ mV}$                                                    |                   |
|                                                    | $\pm 1000$ V Range<br>$\pm (100 \text{ V to } 1050 \text{ V})$   | $6 \mu\text{V/V} + 0.1 \text{ mV}$                                                     |                   |

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| Instrument Calibrated/<br>Measurement<br>Parameter | Range                                                                    | Calibration and<br>Measurement Capability<br>Expressed as an<br>Uncertainty ( $\pm$ ) * | Remarks           |
|----------------------------------------------------|--------------------------------------------------------------------------|-----------------------------------------------------------------------------------------|-------------------|
| 2. Generating Instrument<br>Continue<br>DC VOLTAGE | 100 mV @ $\pm 100$ % Band Span<br>$\pm$ (85 mV to 115 mV)                | 4 $\mu$ V/V                                                                             | Wavetek 4950      |
|                                                    | 1 V @ $\pm 100$ % Band Span<br>$\pm$ ( 0.9 V to 1.1 V)                   | 2.2 $\mu$ V/V                                                                           |                   |
|                                                    | 10 V @ $\pm 100$ % Band Span<br>$\pm$ (9 V to 11 V)                      | 1.4 $\mu$ V/V                                                                           |                   |
|                                                    | 10 V @ $\pm 190$ % Band Span<br>$\pm$ (18 V to 19.5 V)                   | 1.8 $\mu$ V/V                                                                           |                   |
|                                                    | 100 V @ $\pm 100$ % Band Span<br>$\pm$ (90 V to 110 V)                   | 2 $\mu$ V/V                                                                             |                   |
|                                                    | 1000 V @ $\pm 100$ % Band Span<br>$\pm$ (900 V to 1100 V)                | 2 $\mu$ V/V                                                                             |                   |
| AC VOLTAGE                                         | 1 mV to 1000V<br>(See Matrix D)                                          | (See Matrix D)                                                                          | Wavetek 4950      |
|                                                    | 2.2 mV to 1000V<br>(See Matrix E)                                        | (See Matrix E)                                                                          | Fluke 5790A       |
|                                                    | 10 mV to 700V<br>(See Matrix F)                                          | (See Matrix F)                                                                          | HP 3458A Opt. 002 |
| DC CURRENT                                         | 110 $\mu$ A @ $\pm 100$ % Band Span<br>$\pm$ (90 $\mu$ A to 110 $\mu$ A) | 21 $\mu$ A/A                                                                            | Wavetek 4950      |
|                                                    | 1 mA @ $\pm 100$ % Band Span<br>$\pm$ (0.9 mA to 1.1 mA)                 | 11 $\mu$ A/A                                                                            |                   |
|                                                    | 10 mA @ $\pm 100$ % Band Span<br>$\pm$ (9 mA to 11 mA)                   | 11 $\mu$ A/A                                                                            |                   |
|                                                    | 100 mA @ $\pm 100$ % Band Span<br>$\pm$ (90 mA to 110 mA)                | 15 $\mu$ A/A                                                                            |                   |
|                                                    | 1 A @ $\pm 100$ % Band Span<br>$\pm$ (0.9 A to 1.1 A)                    | 25 $\mu$ A/A                                                                            |                   |

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| Instrument Calibrated/<br>Measurement<br>Parameter | Range                                               | Calibration and<br>Measurement Capability<br>Expressed as an<br>Uncertainty ( $\pm$ ) * | Remarks                         |
|----------------------------------------------------|-----------------------------------------------------|-----------------------------------------------------------------------------------------|---------------------------------|
| 2. Generating Instrument<br>Continue<br>DC CURRENT | $\pm$ (1 nA to 100 nA)                              | 30 $\mu$ A/A + 0.04 nA                                                                  | HP 3458A Opt. 002               |
|                                                    | $\pm$ (100 nA to 1 $\mu$ A)                         | 20 $\mu$ A/A + 0.04 nA                                                                  |                                 |
|                                                    | $\pm$ (1 $\mu$ A to 10 $\mu$ A)                     | 20 $\mu$ A/A + 0.1 nA                                                                   |                                 |
|                                                    | $\pm$ (10 $\mu$ A to 100 $\mu$ A)                   | 20 $\mu$ A/A + 0.8 nA                                                                   |                                 |
|                                                    | $\pm$ (100 $\mu$ A to 1 mA)                         | 20 $\mu$ A/A + 5 nA                                                                     |                                 |
|                                                    | $\pm$ (1 mA to 10 mA)                               | 20 $\mu$ A/A + 0.05 $\mu$ A                                                             |                                 |
|                                                    | $\pm$ (10 mA to 100 mA)                             | 35 $\mu$ A/A + 0.5 $\mu$ A                                                              |                                 |
|                                                    | $\pm$ (100 mA to 1 A)                               | 0.11 mA/A + 0.01 mA                                                                     |                                 |
|                                                    | $\pm$ (1 pA to 20 pA)                               | 0.01 A/A + 3 nA                                                                         | Keithley 6517/<br>Agilent 4339A |
|                                                    | $\pm$ (20 pA to 200 pA)                             | 0.01 A/A + 5 nA                                                                         |                                 |
|                                                    | $\pm$ (200 pA to 2 nA)                              | 2 mA/A + 0.3 $\mu$ A                                                                    | Wavetek 4950 &<br>4953          |
|                                                    | 10 A @ $\pm$ 100 % Band Span<br>$\pm$ (9 A to 11 A) | 55 $\mu$ A/A                                                                            |                                 |
|                                                    | $\pm$ (1 A to 10 A)                                 | 5.1 mA                                                                                  |                                 |
|                                                    | $\pm$ (10 A to 100 A)                               | 0.05 A                                                                                  | HP 3458A &<br>Guildline 9211A   |
| AC CURRENT                                         | 5 $\mu$ A to 1 A<br>(See Matrix G)                  | (See Matrix G)                                                                          | HP 3458A                        |
|                                                    | 90 $\mu$ A to 1 A<br>(See Matrix H)                 | (See Matrix H)                                                                          | Wavetek 4950                    |
|                                                    | 10 A @ 100 % Band Span<br>(See Matrix I)            | (See Matrix I)                                                                          | Wavetek 4950 &<br>4953          |

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**SCOPE OF CALIBRATION: ELECTRICAL**

| Instrument Calibrated/<br>Measurement<br>Parameter | Range                                                                                                                                                                                                          | Calibration and<br>Measurement Capability<br>Expressed as an<br>Uncertainty ( $\pm$ ) * | Remarks      |
|----------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------|--------------|
| 2. Generating Instrument<br>Continue<br>RESISTANCE | <u>1 k<math>\Omega</math></u><br>30 % Band Span<br>(0.2 k $\Omega$ to 0.4 k $\Omega$ ),<br>100 % Band Span<br>(0.9 k $\Omega$ to 1.1 k $\Omega$ ),<br>190 % Band Span<br>(1.8 k $\Omega$ to 1.95 k $\Omega$ )  | 3 $\mu\Omega/\Omega$                                                                    | Wavetek 4950 |
|                                                    | <u>10 k<math>\Omega</math></u><br>30 % Band Span<br>(2 k $\Omega$ to 4 k $\Omega$ ),<br>100 % Band Span<br>(9 k $\Omega$ to 11 k $\Omega$ ),<br>190 % Band Span<br>(18 k $\Omega$ to 19.5 k $\Omega$ )         | 3 $\mu\Omega/\Omega$                                                                    |              |
|                                                    | <u>100 k<math>\Omega</math></u><br>30 % Band Span<br>(20 k $\Omega$ to 40 k $\Omega$ ),<br>100 % Band Span<br>(90 k $\Omega$ to 110 k $\Omega$ ) &<br>190 % Band Span<br>(180 k $\Omega$ to 195 k $\Omega$ )   | 6 $\mu\Omega/\Omega$                                                                    |              |
|                                                    | <u>1 M<math>\Omega</math></u><br>30 % Band Span<br>(0.2 M $\Omega$ to 0.4 M $\Omega$ ),<br>100 % Band Span<br>(0.9 M $\Omega$ to 1.1 M $\Omega$ ) &<br>190 % Band Span<br>(1.8 M $\Omega$ to 1.95 M $\Omega$ ) | 11 $\mu\Omega/\Omega$                                                                   |              |
|                                                    | <u>10 M<math>\Omega</math></u><br>30 % Band Span<br>(2 M $\Omega$ to 4 M $\Omega$ ),<br>100 % Band Span<br>(9 M $\Omega$ to 11 M $\Omega$ ) &<br>190 % Band Span<br>(18 M $\Omega$ to 19.5 M $\Omega$ )        | 21 $\mu\Omega/\Omega$                                                                   |              |

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**SCOPE OF CALIBRATION: ELECTRICAL**

| Instrument Calibrated/<br>Measurement<br>Parameter | Range                                                                                                                                            | Calibration and<br>Measurement Capability<br>Expressed as an<br>Uncertainty ( $\pm$ ) * | Remarks                                                                |
|----------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------|------------------------------------------------------------------------|
| 2. Generating Instrument<br>Continue<br>RESISTANCE | <u>100 M<math>\Omega</math></u><br>30 % Band Span<br>(20 M $\Omega$ to 40 M $\Omega$ ),<br>100 % Band Span<br>(90 M $\Omega$ to 110 M $\Omega$ ) | 83 $\mu\Omega/\Omega$                                                                   | Wavetek 4950                                                           |
| CAPACITANCE                                        | 1 pF to 1 mF @<br>(10 Hz to 1 MHz)                                                                                                               | 0.5 mF/F                                                                                | HP 4284A                                                               |
| INDUCTANCE                                         | 1 $\mu$ H to 10 H @<br>(10 Hz to 1 MHz)                                                                                                          | 0.5 mH/H                                                                                |                                                                        |
| FREQUENCY                                          | 1 Hz to 5 GHz                                                                                                                                    | 0.89 pHz/Hz                                                                             | HP53132A<br>Reference to<br>Pendulum GPS-<br>12R Disciplined by<br>GPS |
| AMPLITUDE/ LEVEL                                   | -20 dBm to +30 dBm<br>(100 kHz to 2.6 GHz)                                                                                                       | 0.04 dBm                                                                                | HP 8902 with<br>11722A                                                 |
| RF FREQUENCY                                       | 5 GHz to 26.5 GHz                                                                                                                                | 0.89 Hz/Hz                                                                              | HP8563E<br>Reference to<br>Pendulum GPS-<br>12R Disciplined by<br>GPS  |
| RF AMPLITUDE/<br>LEVEL                             | -30 dB to +30 dB<br>(2.6 GHz to 18 GHz)                                                                                                          | 0.27 dBm                                                                                | Agilent E4418B<br>with HP 8481A                                        |
|                                                    | -120 dB to +30 dB<br>(30 Hz to 26.5 GHz)                                                                                                         | 1 dBm                                                                                   | HP8563E                                                                |
| TUNED RF LEVEL                                     | -127 dB to 0 dB<br>(2.5 MHz to 1.3 GHz)                                                                                                          | 0.07 dBm                                                                                | HP 8902 with<br>11722A                                                 |

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| Instrument Calibrated/<br>Measurement Parameter                                                                              | Range                                                                                 | Calibration and<br>Measurement<br>Capability Expressed<br>as an Uncertainty ( $\pm$ ) * | Remarks                |
|------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------|------------------------|
| 2. Generating Instrument<br>Continue<br>MODULATION<br>Related Signal:<br>Amplitude Modulation<br>(AM)<br>AM Depth: 5% to 99% | Carrier Frequency<br>150 kHz to 10 MHz<br>Modulation Frequency<br>50 Hz to 10 kHz     | 0.17 %                                                                                  | HP 8902 with<br>11722A |
|                                                                                                                              | Carrier Frequency<br>150 kHz to 1300 MHz<br>Modulation Frequency<br>20 Hz to 10 kHz   | 0.19 %                                                                                  |                        |
|                                                                                                                              | Carrier Frequency<br>10 MHz to 1300 MHz<br>Modulation Frequency<br>50 Hz to 100 kHz   | 0.13 %                                                                                  |                        |
| Frequency Modulation<br>(FM)<br>FM Deviation:<br>$\leq 40$ kHz peak                                                          | Carrier Frequency<br>150 kHz to 10 MHz<br>Modulation Frequency<br>20 Hz to 10 kHz     | 0.13 kHz                                                                                |                        |
| FM Deviation:<br>$\leq 400$ kHz peak                                                                                         | Carrier Frequency<br>10 MHz to 1300 MHz<br>Modulation Frequency<br>50 Hz to 100 kHz   | 0.03 kHz                                                                                |                        |
|                                                                                                                              | Carrier Frequency<br>10 MHz to 1300 MHz<br>Modulation Frequency<br>100 kHz to 200 kHz | 0.32 kHz                                                                                |                        |
| Phase Modulation<br>( $\Phi$ M)<br>$\Phi$ M Deviation:<br>$\leq 40$ Radians peak                                             | Carrier Frequency<br>150 kHz to 10 MHz<br>Modulation Frequency<br>200 Hz to 10 kHz    | 0.15 Radians                                                                            |                        |
| $\Phi$ M Deviation:<br>$\leq 400$ Radians peak                                                                               | Carrier Frequency<br>10 MHz to 1.3 GHz<br>Modulation Frequency<br>200 Hz to 20 kHz    | 0.14 Radians                                                                            |                        |

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| Instrument Calibrated/<br>Measurement<br>Parameter                                                         | Range                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Calibration and<br>Measurement Capability<br>Expressed as an<br>Uncertainty ( $\pm$ ) *                                                                                                                                                                                        | Remarks                      |
|------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------|
| 2. Generating Instrument<br>Continue<br>DISTORTION<br>Related Signal:<br>Audio Distortion<br>(-99 to 0) dB | Fundamental Frequency<br>20 Hz to 20 kHz<br><br>Fundamental Frequency<br>20 kHz to 100 kHz                                                                                                                                                                                                                                                                                                                                                                               | 1 dB<br><br>2 dB                                                                                                                                                                                                                                                               | HP 8903B                     |
| RPM<br>Non Contact<br>Measurement<br><br><br><br><br><br><br><br><br><br>Contact Measurement               | 10 to 29 rpm<br>30 to 59 rpm<br>60 to 99 rpm<br>100 to 299 rpm<br>300 to 599 rpm<br>600 to 999 rpm<br>1000 to 2999 rpm<br>3000 to 5999 rpm<br>6000 to 9999 rpm<br>10000 to 29999 rpm<br>30000 to 59999 rpm<br>60000 to 99999 rpm<br><br>20 to 29 rpm<br>30 to 59 rpm<br>60 to 99 rpm<br>100 to 299 rpm<br>300 to 599 rpm<br>600 to 999 rpm<br>1000 to 2999 rpm<br>3000 to 5999 rpm<br>6000 to 9999 rpm<br>10000 to 12999 rpm<br>13000 to 25999 rpm<br>26000 to 29999 rpm | 0.014 rpm<br>0.036 rpm<br>0.07 rpm<br>0.14 rpm<br>0.37 rpm<br>0.7 rpm<br>1.4 rpm<br>3.6 rpm<br>7 rpm<br>14 rpm<br>36 rpm<br>70 rpm<br><br>0.011 rpm<br>0.016 rpm<br>0.029 rpm<br>0.07 rpm<br>0.16 rpm<br>0.29 rpm<br>0.7 rpm<br>1.6 rpm<br>2.9 rpm<br>7 rpm<br>8 rpm<br>14 rpm | In-House method,<br>ESF/0303 |
| High Voltage Tester<br>DC VOLTAGE                                                                          | 0 kV to 9.99 kV<br>10 kV to <20 kV<br>20 kV to 35 kV<br>>35 kV to 40 kV                                                                                                                                                                                                                                                                                                                                                                                                  | 5 mV/V + 2 V<br>20 mV/V<br>10 mV/V<br>20 mV/V                                                                                                                                                                                                                                  | TDV 20 ADS<br>Fluke 80K-40   |

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| Instrument Calibrated/<br>Measurement<br>Parameter | Range                                                                                      | Calibration and<br>Measurement Capability<br>Expressed as an<br>Uncertainty ( $\pm$ ) * | Remarks                    |
|----------------------------------------------------|--------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------|----------------------------|
| 2. Generating Instrument<br>Continue<br>AC VOLTAGE | (0 kV to 9.99 kV) @ 50/60 Hz<br>(10 kV to 20 kV) @ 50/60 Hz<br>(20 kV to 28 kV) @ 50/60 Hz | 7 mV/V + 3 V<br>7 mV/V + 30 V<br>50 mV/V                                                | TDV 20 ADS<br>Fluke 80K-40 |

## Matrix D

AC Voltage Generation (Wavetek 4950)

| Range  |                 | Frequency Band |             |             |              |                 |
|--------|-----------------|----------------|-------------|-------------|--------------|-----------------|
|        |                 | 9 to 11 Hz     | 18 to 22 Hz | 27 to 33 Hz | 36 to 44 Hz  | 46.3 to 63.7 Hz |
| 1 mV   | 0.85 to 1.15 mV | 0.28 mV/V      |             |             |              |                 |
| 10 mV  | 8.5 to 11.5 mV  | 0.16 mV/V      |             |             |              |                 |
| 100 mV | 85 mV to 115 mV | 0.12 mV/V      |             |             |              |                 |
| 1 V    | 0.9 to 1.1 V    | 36 $\mu$ V/V   |             |             | 24 $\mu$ V/V |                 |
| 10 V   | 9 to 11 V       |                |             |             | 36 $\mu$ V/V |                 |
| 100 V  | 90 to 110 V     | 41 $\mu$ V/V   |             |             | 36 $\mu$ V/V |                 |
| 1000 V | 900 to 1100 V   | $\mu$          |             |             |              | 37 $\mu$ V/V    |

| Range  |                 | Frequency Band |                |              |              |              |              |
|--------|-----------------|----------------|----------------|--------------|--------------|--------------|--------------|
|        |                 | 270 to 440 Hz  | 0.9 to 1.1 kHz | 9 to 11 kHz  | 18 to 22 kHz | 27 to 33 kHz |              |
| 1 mV   | 0.85 to 1.15 mV | 0.26 mV/V      |                | 0.28 mV/V    | 0.29 mV/V    | 0.39 mV/V    |              |
| 10 mV  | 8.5 to 11.5 mV  | 0.14 mV/V      |                | 0.16 mV/V    | 0.17 mV/V    | 0.24 mV/V    |              |
| 100 mV | 85 mV to 115 mV | 89 $\mu$ V/V   |                | 0.12 mV/V    | 0.19 mV/V    |              |              |
| 1 V    | 0.9 to 1.1 V    | 24 $\mu$ V/V   |                |              |              |              |              |
| 10 V   | 9 to 11 V       |                |                |              |              |              | 26 $\mu$ V/V |
|        | 18 to 19.5 V    | $\mu$          |                | $\mu$        | $\mu$        | $\mu$        |              |
| 100 V  | 90 to 110 V     | 26 $\mu$ V/V   |                |              |              |              | 29 $\mu$ V/V |
| 1000 V | 900 to 1100 V   | 37 $\mu$ V/V   |                | 42 $\mu$ V/V | 47 $\mu$ V/V | 74 $\mu$ V/V |              |

| Range  |                 | Frequency Band (kHz) |              |            |              |               |
|--------|-----------------|----------------------|--------------|------------|--------------|---------------|
|        |                 | 45 to 55             | 90 to 110    | 180 to 220 | 270 to 330   | 450 to 550    |
| 1 mV   | 0.85 to 1.15 mV | 0.39 mV/V            | 0.62 mV/V    | $\mu$      | 0.75 mV/V    | 0.77 mV/V     |
| 10 mV  | 8.5 to 11.5 mV  | 0.24 mV/V            | 0.4 mV/V     |            | 0.58 mV/V    | 0.61 mV/V     |
| 100 mV | 85 mV to 115 mV | 0.19 mV/V            | 0.36 mV/V    |            | 96 $\mu$ V/V | 0.2 $\mu$ V/V |
| 1 V    | 0.9 to 1.1 V    | 31 $\mu$ V/V         | 37 $\mu$ V/V |            | 83 $\mu$ V/V | 0.18 mV/V     |
| 10 V   | 9 to 11 V       | 26 $\mu$ V/V         |              |            | 0.24 mV/V    | □             |
| 100 V  | 90 to 110 V     | 35 $\mu$ V/V         | 64 $\mu$ V/V |            |              |               |
| 1000 V | 600 to 800 V    | 0.11 mV/V            | 0.34 mV/V    |            |              |               |

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## Matrix D

AC Voltage Generation Continue (Wavetek 4950)

| Range  |                 | Frequency Band |
|--------|-----------------|----------------|
|        |                 | 0.9 to 1.1 MHz |
| 1 mV   | 0.85 to 1.15 mV | 1.1 mV/V       |
| 10 mV  | 8.5 to 11.5 mV  | 0.95 mV/V      |
| 100 mV | 85 mV to 115 mV |                |
| 1 V    | 0.9 to 1.1 V    | 0.56 mV/V      |
| 10 V   | 9 to 11 V       | 0.53 mV/V      |

## Matrix E

AC Voltage Generation (Fluke 5790A)

| Range  |                 | Frequency Band |                    |                    |                  |
|--------|-----------------|----------------|--------------------|--------------------|------------------|
|        |                 | 10 to 20 Hz    | 20 to 40 Hz        | 40 Hz to 20 kHz    | 20 to 50 kHz     |
| 2.2 mV | 0.6 to 2.2 mV   | 1.7 + 1.3      | 0.74 + 1.3         | 0.42 + 1.3         | 0.81 + 2         |
| 7 mV   | 1.9 to 7 mV     | 0.85 + 1.3     | 0.37 + 1.3         | 0.21 + 1.3         | 0.4 + 2          |
| 22 mV  | 8.5 to 11.5 mV  | 0.29 + 1.3     | 0.19 + 1.3         | 0.11 + 1.3         | 0.21 + 2         |
| 70 mV  | 19 to 70 mV     | 0.24 + 1.5     | 0.12 + 1.5         | 24 $\mu$ V/V + 1.5 | 0.13 + 2         |
| 220 mV | 60 to 220 mV    | 0.21 + 1.5     | 85 $\mu$ V/V + 1.5 | 38 $\mu$ V/V + 1.5 | 69 $\mu$ V/V + 2 |
| 700 mV | 190 to 700 mV   |                | 24 $\mu$ V/V + 1.5 | 33 $\mu$ V/V + 1.5 | 51 $\mu$ V/V + 2 |
| 2.2 V  | 0.6 to 2.2 V    | 0.2            | 66 $\mu$ V/V       | 24 $\mu$ V/V       | 46 $\mu$ V/V     |
| 7 V    | 1.9 to 7 V      |                | 67 $\mu$ V/V       |                    | 48 $\mu$ V/V     |
| 22 V   | 6 to 22 V       |                | 68 $\mu$ V/V       | 27 $\mu$ V/V       | 57 $\mu$ V/V     |
| 70 V   | 19 to 70 V      |                |                    | 32 $\mu$ V/V       |                  |
| 220 V  | 60 to 220 V     |                | 99 $\mu$ V/V       | 31 $\mu$ V/V       | 69 $\mu$ V/V     |
| 700 V  | 190 V to 700 V  |                |                    | 41 $\mu$ V/V       | 0.13             |
| 1000 V | 600 V to 1050 V |                |                    | 38 $\mu$ V/V       |                  |

| Range  |                 | Frequency Band           |                |                |                  |
|--------|-----------------|--------------------------|----------------|----------------|------------------|
|        |                 | 50 to 100 kHz            | 100 to 300 kHz | 300 to 500 kHz | 500 kHz to 1 MHz |
| 2.2 mV | 0.6 to 2.2 mV   | 1.2 + 2.5                | 2.3 + 4        | 2.4 + 8        | 3.5 + 8          |
| 7 mV   | 1.9 to 7 mV     | 0.6 + 2.5                | 1.2 + 4        | 1.3 + 8        | 2.3 + 8          |
| 22 mV  | 8.5 to 11.5 mV  | 0.31 + 2.5               | 0.81 + 4       | 0.89 + 8       | 1.7 + 8          |
| 70 mV  | 19 to 70 mV     | 0.26 + 2.5               | 0.51 + 4       | 0.67 + 8       | 1.1 + 8          |
| 220 mV | 60 to 220 mV    | 0.16 + 2.5               | 0.25 + 4       | 0.38 + 8       | 1 + 8            |
| 700 mV | 190 to 700 mV   | 79 $\mu\text{V/V}$ + 2.5 | 0.18 + 4       | 0.3 + 8        | 0.96 + 8         |
| 2.2 V  | 0.6 to 2.2 V    | 71 $\mu\text{V/V}$       | 0.16           | 0.26           | 0.9              |
| 7 V    | 1.9 to 7 V      | 81 $\mu\text{V/V}$       | 0.19           | 0.4            | 1.2              |
| 22 V   | 6 to 22 V       |                          |                |                |                  |
| 70 V   | 19 to 70 V      | 94 $\mu\text{V/V}$       | 0.2            | 0.41           |                  |
| 220 V  | 60 to 220 V     | 98 $\mu\text{V/V}$       | 0.21           | 0.5            |                  |
| 700 V  | 190 V to 700 V  | 0.5                      | $\mu$          |                |                  |
| 1000 V | 600 V to 1050 V |                          |                |                |                  |

The expanded uncertainties given in this table are expressed in mV/V +  $\mu$ V unless otherwise stated.

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## Matrix F

AC Voltage Generation (HP 3458A)

| Range |            | Frequency Band |              |            |             |             |
|-------|------------|----------------|--------------|------------|-------------|-------------|
|       |            | 1 to 40 Hz     | 0.1 to 1 MHz | 1 to 4 MHz | 4 to 8 MHz  | 8 to 10 MHz |
| 10 mV | 1 to 12 mV | 0.3 + 3        | 12 + 5       | 70 + 7     | 0.2 V/V + 8 | –           |

| Range  |              | Frequency Band        |             |             |             |                   |
|--------|--------------|-----------------------|-------------|-------------|-------------|-------------------|
|        |              | 1 to 40 Hz            | 1 to 2 MHz  | 2 to 4 MHz  | 4 to 8 MHz  | 8 to 10 MHz       |
| 100 mV | 10 to 120 mV | 70 $\mu$ V/V + 4      | 15 + 10     | 40 + 70     | 40 + 80     | 0.15 V/V + 0.1 mV |
| 1 V    | 0.1 V 1.2 V  | 70 $\mu$ V/V + 40     | 15 + 0.1 mV | 40 + 0.7 mV | 40 + 0.8 mV | 0.15 V/V + 1 mV   |
| 10 V   | 1 to 12 V    | 70 $\mu$ V/V + 0.4 mV | 15 + 1 mV   | 40 + 7 mV   | 40 + 8 mV   | 0.15 V/V + 10 mV  |

| Range  |              | Frequency Band |              |
|--------|--------------|----------------|--------------|
|        |              | 1 to 40 Hz     | 0.3 to 1 MHz |
| 100 V  | 10 to 120 V  | 0.2 + 4 mV     | 15 + 10 mV   |
| 1000 V | 100 to 700 V | 0.4 + 40 mV    |              |

The expanded uncertainties given in this table are expressed in mV/V +  $\mu$ V unless otherwise stated.

## Matrix G

AC Current Generation (HP 3458A)

| Range       |                  | Frequency Band |              |              |                 |
|-------------|------------------|----------------|--------------|--------------|-----------------|
|             |                  | 10 to 20 Hz    | 20 to 45 Hz  | 45 to 100 Hz | 100 Hz to 5 kHz |
| 100 $\mu$ A | 5 to 120 $\mu$ A | 4 + 30 nA      | 1.5 + 30 nA  | 0.6 + 3 nA   |                 |
| 1 mA        | 0.05 to 1.2 mA   | 4 + 0.2        | 1.5 + 0.2    | 0.6 + 0.2    | 0.3 + 0.2       |
| 10 mA       | 0.5 to 12 mA     | 4 + 2          | 1.5 + 2      | 0.6 + 2      | 0.3 + 2         |
| 100 mA      | 5 to 120 mA      | 4 + 20         | 1.5 + 20     | 0.6 + 20     | 0.3 + 20        |
| 1 A         | 0.05 to 1.05 A   | 4 + 0.2 mA     | 1.6 + 0.2 mA | 0.8 + 0.2 mA | 1 + 0.2 mA      |

| Range  |                | Frequency Band |              |               |
|--------|----------------|----------------|--------------|---------------|
|        |                | 5 to 20 kHz    | 20 to 50 kHz | 50 to 100 kHz |
| 1 mA   | 0.05 to 1.2 mA | 0.6 + 0.2      | 4 + 0.4      | 5.5 + 1.5     |
| 10 mA  | 0.5 to 12 mA   | 0.6 + 2        | 4 + 4        | 5.5 + 15      |
| 100 mA | 5 to 120 mA    | 0.6 + 20       | 4 + 40       | 5.5 + 0.15 mA |
| 1 A    | 0.05 to 1.05 A | 3 + 0.2 mA     | 10 + 0.4 mA  |               |

The expanded uncertainties given in this table are expressed in mA/A +  $\mu$ A unless otherwise stated.

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**SCOPE OF CALIBRATION: ELECTRICAL**

## Matrix H

AC Current Generation (Wavetek 4950)

| Range       |                   | Frequency Band |             |              |              |
|-------------|-------------------|----------------|-------------|--------------|--------------|
|             |                   | 9 to 11 Hz     | 18 to 22 Hz | 27 to 33 Hz  | 36 to 44 Hz  |
| 100 $\mu$ A | 90 to 110 $\mu$ A | 0.12           |             | 0.11         | 85 $\mu$ A/A |
| 1 mA        | 0.9 to 1.1 mA     |                |             | 0.1          | 80 $\mu$ A/A |
| 10 mA       | 9 to 11 mA        | 0.13           |             | 96 $\mu$ A/A | 75 $\mu$ A/A |
| 100 mA      | 90 to 110 mA      |                |             |              |              |
| 1 A         | 0.9 to 1.1 A      | 0.16           |             |              | 0.11         |

| Range       |                   | Frequency Band    |               |                |                |
|-------------|-------------------|-------------------|---------------|----------------|----------------|
|             |                   | 46.25 to 63.75 Hz | 270 to 440 Hz | 0.9 to 1.1 kHz | 4.5 to 5.5 kHz |
| 100 $\mu$ A | 90 to 110 $\mu$ A | 85 $\mu$ A/A      |               |                | 0.13           |
| 1 mA        | 0.9 to 1.1 mA     | 80 $\mu$ A/A      |               |                | 0.12           |
| 10 mA       | 9 to 11 mA        | 75 $\mu$ A/A      |               |                |                |
| 100 mA      | 90 to 110 mA      |                   |               |                |                |
| 1 A         | 0.9 to 1.1 A      | 0.11              |               |                | 0.21           |

| Range       |                   | Frequency Band |              |              |
|-------------|-------------------|----------------|--------------|--------------|
|             |                   | 9 to 11 kHz    | 18 to 22 kHz | 27 to 33 kHz |
| 100 $\mu$ A | 90 to 110 $\mu$ A | 0.3            | 0.33         | 0.4          |
| 1 mA        | 0.9 to 1.1 mA     | 0.26           | 0.28         | 0.35         |
| 10 mA       | 9 to 11 mA        |                |              |              |
| 100 mA      | 90 to 110 mA      |                |              |              |
| 1 A         | 0.9 to 1.1 A      |                |              |              |

The expanded uncertainties given in this table are expressed in mA/A unless otherwise stated.

## Matrix I

AC Current Generation (Wavetek 4950 &amp; 4953)

| Range |           | Frequency Band |             |             |             |                   |
|-------|-----------|----------------|-------------|-------------|-------------|-------------------|
|       |           | 9 to 11 Hz     | 18 to 22 Hz | 27 to 33 Hz | 36 to 44 Hz | 46.25 to 63.75 Hz |
| 10 A  | 9 to 11 A | 0.24           |             | 0.23        | 0.21        | 0.2               |

| Range |           | Frequency Band |                |                |             |              |
|-------|-----------|----------------|----------------|----------------|-------------|--------------|
|       |           | 270 to 440 Hz  | 0.9 to 1.1 kHz | 4.5 to 5.5 kHz | 9 to 11 kHz | 18 to 22 kHz |
| 10 A  | 9 to 11 A | 0.2            |                | 0.26           | 0.34        | 1.2          |

The expanded uncertainties given in this table are expressed in mA/A.

**Signatories:**

1. **Muhammed Fahimy Bin Ahmad Ta'adin**
2. **\*\*Mohamed Fikri Bin Mohd Nor**
3. **Syahrel Bin Shari**

\*\* Non-resident signatory

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**SCOPE OF CALIBRATION: ELECTRICAL****SITE CALIBRATION: CATEGORY I**

| Instrument Calibrated/<br>Measurement Parameter | Range                                                                           | Calibration and<br>Measurement<br>Capability Expressed<br>as an Uncertainty ( $\pm$ ) *                           | Remarks          |
|-------------------------------------------------|---------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------|------------------|
| 1. Measuring Instrument<br>DC VOLTAGE           | $\pm 220$ mV Range<br>$\pm$ (0 mV to 220 mV)                                    | $9 \mu\text{V/V} + 0.8 \mu\text{V}$                                                                               | Fluke 5700A      |
|                                                 | $\pm 2.2$ V Range<br>$\pm$ (0 V to 2.2 V)                                       | $8 \mu\text{V/V} + 1.2 \mu\text{V}$                                                                               |                  |
|                                                 | $\pm 11$ V Range<br>$\pm$ (0 V to 11 V)                                         | $8 \mu\text{V/V} + 4 \mu\text{V}$                                                                                 |                  |
|                                                 | $\pm 22$ V Range<br>$\pm$ (0 V to 22 V)                                         | $8 \mu\text{V/V} + 8 \mu\text{V}$                                                                                 |                  |
|                                                 | $\pm 220$ V Range<br>$\pm$ (0 V to 220 V)                                       | $9 \mu\text{V/V} + 0.1 \text{ mV}$                                                                                |                  |
|                                                 | $\pm 1100$ V Range<br>$\pm$ (100 V to 1100 V)                                   | $11 \mu\text{V/V} + 0.6 \text{ mV}$                                                                               |                  |
| AC VOLTAGE                                      | 2.2 mV to 220 V<br>(See Matrix A)                                               | (See Matrix A)                                                                                                    | Fluke 5700A      |
|                                                 | 1100 V Range (110 V to 1100 V)<br>50 Hz to 1 kHz                                | $90 \mu\text{V/V} + 4 \text{ mV}$                                                                                 |                  |
|                                                 | <u>800 V to 1050 V</u><br>1 kHz to 3 kHz<br>3 kHz to 10 kHz<br>10 kHz to 20 kHz | $0.8 \text{ mV/V} + 0.13 \text{ V}$<br>$0.8 \text{ mV/V} + 0.21 \text{ V}$<br>$1.2 \text{ mV/V} + 0.32 \text{ V}$ | Wavetek 9100     |
| DC CURRENT                                      | $\pm 100$ A Range<br>$\pm$ (20 A to 100 A)                                      | $0.45 \text{ mA/A} + 20 \text{ mA}$                                                                               | California 3213K |

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**SCOPE OF CALIBRATION: ELECTRICAL****SITE CALIBRATION: CATEGORY I**

| Instrument Calibrated/<br>Measurement Parameter   | Range                                                                                                                                                                                                                                                                                                                                                                                  | Calibration and<br>Measurement<br>Capability Expressed<br>as an Uncertainty ( $\pm$ ) *                                                                                                                       | Remarks                               |
|---------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------|
| 1. Measuring Instrument<br>Continue<br>DC CURRENT | $\pm 220 \mu\text{A}$ Range<br>$\pm (0 \text{ mA to } 220 \mu\text{A})$<br><br>$\pm 2.2 \text{ mA}$ Range<br>$\pm (0 \text{ mA to } 2.2 \text{ mA})$<br><br>$\pm 22 \text{ mA}$ Range<br>$\pm (0 \text{ mA to } 22 \text{ mA})$<br><br>$\pm 220 \text{ mA}$ Range<br>$\pm (0 \text{ mA to } 220 \text{ mA})$<br><br>$\pm 2.2 \text{ A}$ Range<br>$\pm (0 \text{ A to } 2.2 \text{ A})$ | $60 \mu\text{A/A} + 10 \text{ nA}$<br><br>$60 \mu\text{A/A} + 10 \text{ nA}$<br><br>$60 \mu\text{A/A} + 0.1 \mu\text{A}$<br><br>$70 \mu\text{A/A} + 1 \mu\text{A}$<br><br>$95 \mu\text{A/A} + 30 \mu\text{A}$ | Fluke 5700A                           |
|                                                   | $\pm 3.2 \text{ A}$ Range<br>$\pm (0.32 \text{ A to } 3.2 \text{ A})$<br><br>$\pm 10.5 \text{ A}$ Range<br>$\pm (3.2 \text{ A to } 10.5 \text{ A})$<br><br>$\pm 20 \text{ A}$ Range<br>$\pm (10.5 \text{ A to } 20 \text{ A})$                                                                                                                                                         | $0.6 \text{ mA/A} + 0.12 \text{ mA}$<br><br>$0.55 \text{ mA/A} + 0.94 \text{ mA}$<br><br>$0.55 \text{ mA/A} + 4.5 \text{ mA}$                                                                                 | Wavetek 9100                          |
| AC CURRENT                                        | $9 \mu\text{A}$ to $2.2 \text{ A}$<br>(See Matrix B)                                                                                                                                                                                                                                                                                                                                   | (See Matrix B)                                                                                                                                                                                                | Fluke 5700A                           |
|                                                   | $20 \text{ A}$ to $100 \text{ A}$<br>$10 \text{ Hz}$ to $1 \text{ kHz}$<br>$1 \text{ kHz}$ to $10 \text{ kHz}$                                                                                                                                                                                                                                                                         | $2.5 \text{ mA/A} + 0.03 \text{ A}$<br>$5 \text{ mA/A} + 0.05 \text{ A}$                                                                                                                                      | California<br>Instruments<br>CA 3213K |

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**SCOPE OF CALIBRATION: ELECTRICAL****SITE CALIBRATION: CATEGORY I**

| Instrument Calibrated/<br>Measurement Parameter    | Range                                                                                                                                                                                            | Calibration and<br>Measurement Capability<br>Expressed as an<br>Uncertainty ( $\pm$ ) *                               | Remarks                                                       |
|----------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------|
| 1. Measuring Instrument<br>Continue<br>AC CURRENT  | <u>0.32 A to 3.2 A</u><br>10 Hz to 3 kHz<br>3 kHz to 10 kHz<br><br><u>3.2 A to 10.5 A</u><br>10 Hz to 3 kHz<br>3 kHz to 10 kHz<br><br><u>10.5 A to 20 A</u><br>10 Hz to 3 kHz<br>3 kHz to 10 kHz | 1 mA/A + 0.48 mA<br>2.5 mA/A + 2.6 mA<br><br>2 mA/A + 3 mA<br>5 mA/A + 10 mA<br><br>2 mA/A + 6.9 mA<br>5 mA/A + 23 mA | Wavetek 9100                                                  |
| Residual Current                                   | <u>3 mA to 3A</u><br>At Time interval up to 5 s<br>At Time interval <190 ms                                                                                                                      | 0.14 mA/A<br>0.3 mA/A                                                                                                 | For RCD Tester<br>Calibrator<br>(using<br>Transmille<br>3200) |
| CAPACITANCE                                        | (See Matrix C)                                                                                                                                                                                   | (See Matrix C)                                                                                                        | Wavetek 9100                                                  |
| Fixed Value                                        | <u>20 <math>\mu</math>F to 1 MHz</u><br>1 pF, 10 pF, 100 pF, 1000 pF,<br>0.02 $\mu$ F, 0.1 $\mu$ F and 1.0 $\mu$ F                                                                               | 1 mF/F                                                                                                                | HP 1600A<br>series                                            |
| INDUCTANCE<br>Fixed Value                          | <u>100 <math>\mu</math>H @ 1 kHz</u><br><u>(1, 10, 100) mH @ 1 kHz</u><br><u>1H @ 1 kHz</u>                                                                                                      | 2.5 mH/H<br>1 mH/H<br>1 mH/H                                                                                          | Ando RS-100<br>series                                         |
| POWER/ ENERGY<br>(DC)                              | 1 kW to 20 kW<br>0.1 W to 1 kW                                                                                                                                                                   | 0.7 mW/W<br>0.22 mW/W                                                                                                 | Fluke 5520A                                                   |
| POWER/ ENERGY<br>(AC), (45 Hz to 65 Hz<br>at PF=1) | 10 kW to 20 kW<br>1 W to 10 kW<br>0.1 W to 1 W                                                                                                                                                   | 1 mW/W<br>0.9 mW/W<br>1 mW/W                                                                                          |                                                               |

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**SCOPE OF CALIBRATION: ELECTRICAL****SITE CALIBRATION: CATEGORY I**

| Instrument Calibrated/<br>Measurement Parameter                  | Range                                                                                                                                                                                                                                                                                                                   | Calibration and<br>Measurement<br>Capability Expressed<br>as an Uncertainty ( $\pm$ ) *                                                                                                                                                                                                                                                                                                                                                                                             | Remarks                                                    |
|------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------|
| 1. Measuring Instrument<br>Continue<br>RESISTANCE<br>Fixed Value | 1 m $\Omega$<br>10 m $\Omega$<br>100 m $\Omega$<br>1 $\Omega$<br>1.9 $\Omega$<br>10 $\Omega$<br>19 $\Omega$<br>100 $\Omega$<br>190 $\Omega$<br>1 k $\Omega$<br>1.9 k $\Omega$<br>10 k $\Omega$<br>19 k $\Omega$<br>100 k $\Omega$<br>190 k $\Omega$<br>1 M $\Omega$<br>1.9 M $\Omega$<br>10 M $\Omega$<br>19 M $\Omega$ | 0.2 m $\Omega/\Omega$<br>0.1 m $\Omega/\Omega$<br>0.02 m $\Omega/\Omega$<br>5 $\mu\Omega/\Omega$<br>0.11 m $\Omega/\Omega$<br>5 $\mu\Omega/\Omega$<br>31 $\mu\Omega/\Omega$<br>5 $\mu\Omega/\Omega$<br>0.02 m $\Omega/\Omega$<br>5 $\mu\Omega/\Omega$<br>15 $\mu\Omega/\Omega$<br>5 $\mu\Omega/\Omega$<br>14 $\mu\Omega/\Omega$<br>5 $\mu\Omega/\Omega$<br>15 $\mu\Omega/\Omega$<br>5 $\mu\Omega/\Omega$<br>24 $\mu\Omega/\Omega$<br>5 $\mu\Omega/\Omega$<br>0.05 m $\Omega/\Omega$ | Fluke 5700A &<br>Fluke 742A<br>Series                      |
|                                                                  | 100 M $\Omega$<br>1 G $\Omega$<br>10 G $\Omega$<br>100 G $\Omega$<br>1 T $\Omega$                                                                                                                                                                                                                                       | 0.13 m $\Omega/\Omega$<br>5 $\mu\Omega/\Omega$<br>0.02 $\Omega/\Omega$<br>0.05 $\Omega/\Omega$<br>0.05 $\Omega/\Omega$                                                                                                                                                                                                                                                                                                                                                              | Fluke 5700A<br>& Takeda Riken<br>TR45 Standard<br>Resistor |
| TIME                                                             | 1 s to 24 Hrs                                                                                                                                                                                                                                                                                                           | 0.06 $\mu\text{s/s}$ + 0.021 s                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Agilent 33250A &<br>Universal Counter<br>HP 53132A         |
|                                                                  | 20 ms to 5 s                                                                                                                                                                                                                                                                                                            | 0.7 ms                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | For RCD Tester<br>Calibrator<br>(using Transmille<br>3200) |
| Residual Current<br>Duration                                     | 10 ms to 5 s                                                                                                                                                                                                                                                                                                            | 0.4 ms                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                            |

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**SCOPE OF CALIBRATION: ELECTRICAL****SITE CALIBRATION: CATEGORY I**

| Instrument Calibrated/<br>Measurement Parameter                                      | Range                                                                           | Calibration and<br>Measurement<br>Capability Expressed<br>as an Uncertainty ( $\pm$ ) * | Remarks                             |
|--------------------------------------------------------------------------------------|---------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------|-------------------------------------|
| 1. Measuring Instrument<br>Continue<br>RPM Measuring<br>Instruments (Non<br>Contact) | 60 to 5999 rpm<br>6000 to 29999 rpm<br>30000 to 59999 rpm<br>60000 to 99999 rpm | 0.07 rpm<br>7 rpm<br>36 rpm<br>70 rpm                                                   | In-House method,<br>ESF/0303        |
| HIGH VOLTAGE<br>METER<br>DC Voltage<br><br>AC Voltage @<br>(50/60) Hz                | 0.5 kV to 10 kV                                                                 | 5 mV/V                                                                                  | TDV 20 ADS &<br>TOS 5101            |
|                                                                                      |                                                                                 | 8 mV/V                                                                                  |                                     |
| CLAMP METER<br>DC Current<br>10 – Turn Coil                                          | $\pm 3.2$ A to 32 A<br>$\pm 32$ A to 105 A<br>$\pm 105$ A to 200 A              | 0.06 mA/A + 1.18 mA<br>0.55 mA/A + 9.4 mA<br>0.55 mA/A + 45 mA                          | Wavetek 9100<br>c/w<br>Current Coil |
| 50 – Turn Coil                                                                       | $\pm 16$ A to 160 A<br>$\pm 160$ A to 525 A<br>$\pm 525$ A to 1000 A            | 0.6 mA/A + 5.9 mA<br>0.55 mA/A + 47 mA<br>0.55 mA/A + 0.23 A                            |                                     |
| AC Current<br><u>10 – Turn Coil</u>                                                  | <u>3.2 A to 32 A</u><br>10 Hz to 100 Hz<br>100 Hz to 440 Hz                     | 2 mA/A + 5.5 mA<br>7.8 mA/A + 27 mA                                                     |                                     |
|                                                                                      | <u>32 A to 200 A</u><br>10 Hz to 100 Hz<br>100 Hz to 440 Hz                     | 2.1 mA/A + 90 mA<br>6.7 mA/A + 0.25 A                                                   |                                     |
| CLAMP METER<br><u>50 – Turn Coil</u>                                                 | <u>16 A to 160 A</u><br>10 Hz to 100 Hz                                         | 2 mA/A + 28 mA                                                                          |                                     |
|                                                                                      | <u>160 A to 1000 A</u><br>10 Hz to 100 Hz                                       | 2.1 mA/A + 0.45 A                                                                       |                                     |

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**SCOPE OF CALIBRATION: ELECTRICAL****SITE CALIBRATION: CATEGORY I**

| Instrument Calibrated/<br>Measurement Parameter             | Range                                                                                                                                                                                                                                                                                                                                                                                                         | Calibration and<br>Measurement Capability<br>Expressed as an<br>Uncertainty ( $\pm$ ) *     | Remarks                                                                  |
|-------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------|--------------------------------------------------------------------------|
| 1. Measuring Instrument<br>Continue<br>INSULATION TESTER    | (1 k $\Omega$ to 10 k $\Omega$ ) @ 10 V<br>(10 k $\Omega$ to 100 k $\Omega$ ) @ 50 V<br>(0.1 M $\Omega$ to 1 M $\Omega$ ) @ 150 V<br>(1 M $\Omega$ to 10 M $\Omega$ ) @ 300 V<br>(10 M $\Omega$ to 100 M $\Omega$ ) @ 500 V<br>(0.1 G $\Omega$ to 1 G $\Omega$ ) @ 1 kV<br>(1 G $\Omega$ to 10 G $\Omega$ ) @ 5 kV<br>(10 G $\Omega$ to 100 G $\Omega$ ) @ 5 kV<br>(100 G $\Omega$ to 600 G $\Omega$ ) @ 5 kV | 0.5 m $\Omega/\Omega$                                                                       | Tinsley 4720                                                             |
|                                                             |                                                                                                                                                                                                                                                                                                                                                                                                               | 1 m $\Omega/\Omega$                                                                         |                                                                          |
|                                                             |                                                                                                                                                                                                                                                                                                                                                                                                               | 10 m $\Omega/\Omega$<br>50 m $\Omega/\Omega$<br>0.1 $\Omega/\Omega$<br>50 m $\Omega/\Omega$ |                                                                          |
| OSCILLOSCOPE<br>Vertical Deflection<br>DC Signal            | 0 V to $\pm 6.6$ V (50 $\Omega$ Load)<br>0 V to $\pm 130$ V (1 M $\Omega$ Load)                                                                                                                                                                                                                                                                                                                               | 2.5 mV/V + 0.04 mV<br>0.5 mV/V + 0.04 mV                                                    | Fluke 5500A SC600                                                        |
| Vertical Deflection<br><br>Square Wave Signal               | $\pm 1$ mVp-p to $\pm 6.6$ Vp-p<br>(50 $\Omega$ Load)                                                                                                                                                                                                                                                                                                                                                         | 2.5 mVp-p/Vp-p +<br>0.04mVp-p                                                               |                                                                          |
|                                                             | $\pm 1$ mVp-p to $\pm 130$ Vp-p<br>(1 M $\Omega$ Load)                                                                                                                                                                                                                                                                                                                                                        | 1 mVp-p/Vp-p +<br>0.04 mVp-p                                                                |                                                                          |
| Horizontal Deflection<br>Time Markers<br>(50 $\Omega$ Load) | 2 ns/div to 20 ms/div<br>50 ms/div to 5 s/div                                                                                                                                                                                                                                                                                                                                                                 | 2.5 $\mu$ s/s<br>(25+(Output x 1000)) $\mu$ s/s                                             |                                                                          |
| Risetime                                                    | $\leq 300$ ps                                                                                                                                                                                                                                                                                                                                                                                                 | +0 ns / -0.1 ns                                                                             |                                                                          |
| Bandwidth Frequency                                         | 50 kHz to 600 MHz                                                                                                                                                                                                                                                                                                                                                                                             | 2.5 $\mu$ Hz/Hz                                                                             |                                                                          |
| Bandwidth Amplitude                                         | 600 MHz to 40 GHz<br>(+11 dBm to -135 dBm)                                                                                                                                                                                                                                                                                                                                                                    | 7 nHz/Hz                                                                                    | Agilent E8257D<br>Reference to<br>Pendulum GPS-12R<br>Disciplined by GPS |
|                                                             | 50 kHz to 600 MHz                                                                                                                                                                                                                                                                                                                                                                                             | 0.03 Vp-p                                                                                   | Fluke 5500A SC600                                                        |

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| Instrument Calibrated/<br>Measurement Parameter                            | Range                                                                                       | Calibration and<br>Measurement Capability<br>Expressed as an<br>Uncertainty ( $\pm$ ) * | Remarks                                                                                                     |
|----------------------------------------------------------------------------|---------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------|
| 1. Measuring Instrument<br>Continue<br>OSCILLOSCOPE<br>Bandwidth Amplitude | 600 MHz to 40 GHz<br>(+11 dBm to -135 dBm)                                                  | 0.92 dBm                                                                                | Agilent E8257D                                                                                              |
| Frequency                                                                  | 1 $\mu$ Hz to 80 MHz<br>(10 mVpp to 10 Vpp)<br><br>10 kHz to 40 GHz<br>(+11 dBm to -135dBm) | 36 nHz/Hz<br><br>7 nHz/Hz                                                               | (Agilent 33250A,<br>ifR2042 or<br>Agilent E8257D)<br>Reference to Pendulum<br>GPS-12R Disciplined<br>by GPS |
| Amplitude                                                                  | 10 mVp-p to 10 Vp-p<br>(1 $\mu$ Hz to 80 MHz, Into 50 $\Omega$ )                            | 10 mVpp/Vpp + 1 mVpp                                                                    | Agilent 33250A                                                                                              |
|                                                                            | +13 dBm to -144dBm<br>(10 kHz to 5.4 GHz)                                                   | 0.58 dBm                                                                                | ifR2042                                                                                                     |
|                                                                            | +11 dBm to -135dBm<br>(250 kHz to 40 GHz)                                                   | 0.92 dBm                                                                                | Agilent E8257D                                                                                              |
| Flatness                                                                   | Sine Wave Relative to 1 kHz<br>(Auto range On)                                              | 0.4 dBm                                                                                 | Agilent 33250A                                                                                              |

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**SCOPE OF CALIBRATION: ELECTRICAL****SITE CALIBRATION: CATEGORY I****SCOPE OF ACCREDITATION:**

Matrix A

AC Voltage Measurement

| Range  |                   | Frequency   |              |               |              |
|--------|-------------------|-------------|--------------|---------------|--------------|
|        |                   | Hz          |              | kHz           |              |
|        |                   | 10 to 20    | 20 to 40     | 0.04 to 20    | 20 to 50     |
| 2.2 mV | 0.22 mV to 2.2 mV | 0.6 + 0.005 | 0.24 + 0.005 | 0.12 + 0.005  | 0.41 + 0.005 |
| 22 mV  | 2.2 mV to 22 mV   | 0.6 + 0.006 | 0.24 + 0.006 | 0.12 + 0.006  | 0.41 + 0.006 |
| 220 mV | 22 mV to 220 mV   | 0.6 + 0.016 | 0.24 + 0.01  | 0.11 + 0.01   | 0.36 + 0.01  |
| 2.2 V  | 0.22 V to 2.2 V   | 0.6 + 0.1   | 0.18 + 0.03  | 0.085 + 0.007 | 0.14 + 0.02  |
| 22 V   | 2.2 V to 22 V     | 0.6 + 1     | 0.18 + 0.3   | 0.085 + 0.07  | 0.14 + 0.2   |
| 220 V  | 22 V to 220 V     | 0.6 + 10    | 0.18 + 3     | 0.09 + 1      | 0.25 + 4     |

| Range  |                   | Frequency    |             |            |            |
|--------|-------------------|--------------|-------------|------------|------------|
|        |                   | MHz          |             |            |            |
|        |                   | 0.05 to 0.1  | 0.1 to 0.3  | 0.3 to 0.5 | 0.5 to 1   |
| 2.2 mV | 0.22 mV to 2.2 mV | 0.95 + 0.008 | 1.3 + 0.015 | 1.8 + 0.03 | 3.6 + 0.03 |
| 22 mV  | 2.2 mV to 22 mV   | 0.95 + 0.008 | 1.3 + 0.015 | 1.8 + 0.03 | 3.6 + 0.03 |
| 220 mV | 22 mV to 220 mV   | 0.9 + 0.03   | 1.1 + 0.03  | 1.8 + 0.04 | 3.6 + 0.1  |
| 2.2 V  | 0.22 V to 2.2 V   | 0.28 + 0.08  | 0.48 + 0.15 | 1.2 + 0.4  | 2.4 + 1    |
| 22 V   | 2.2 V to 22 V     | 0.28 + 0.4   | 0.6 + 1.7   | 1.4 + 5    | 3 + 9      |
| 220 V  | 22 V to 220 V     | 0.6 + 10     | 1.6 + 110   | 5.4 + 110  | 13 + 220   |

The expanded uncertainties given in this table are expressed in mV/V + mV

Matrix B

AC Current Measurement

| Range                    | Frequency (kHz) |              |             |            |            |
|--------------------------|-----------------|--------------|-------------|------------|------------|
|                          | 0.01 to 0.02    | 0.02 to 0.04 | 0.04 to 1   | 1 to 5     | 5 to 10    |
| 9 $\mu$ A to 220 $\mu$ A | 0.8 + 0.03      | 0.42 + 0.025 | 0.16 + 0.02 | 0.7 + 0.05 | 1.8 + 0.1  |
| 0.22 mA to 2.2 mA        | 0.8 + 0.05      | 0.42 + 0.04  | 0.16 + 0.04 | 0.7 + 0.5  | 1.8 + 1    |
| 2.2 mA to 22 mA          | 0.8 + 0.5       | 0.42 + 0.4   | 0.16 + 0.4  | 0.7 + 10   | 1.8 + 0.01 |
| 22 mA to 220 mA          | 0.8 + 5         | 0.42 + 4     | 0.18 + 4    | 0.7 + 50   | 1.8 + 100  |
| 0.22 A to 2.2 A          | -               | -            | 0.75 + 40   | 0.85 + 100 | 10 + 200   |

The expanded uncertainties given in this table are expressed in mA/A +  $\mu$ A

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**SCOPE OF CALIBRATION: ELECTRICAL****SITE CALIBRATION: CATEGORY I**Matrix C  
Capacitance Measurement

| Range                     | Frequency             |                        |
|---------------------------|-----------------------|------------------------|
|                           | $\leq 350$ Hz         | 350 Hz to 1.5 kHz      |
| 0.5 nF to 4 nF            | 3 mF/F + 15 pF        | 6 mF/F + 0.03 nF       |
| 4 nF to 40 nF             | 3 mF/F + 30 pF        | 6 mF/F + 0.06 nF       |
| 40 nF to 400 nF           | 3 mF/F + 0.16 nF      | 6 mF/F + 0.32 nF       |
| 400 nF to 4 $\mu$ F       | 4 mF/F + 1.6 nF       | 8 mF/F + 3.2 nF        |
| 4 $\mu$ F to 40 $\mu$ F   | 5 mF/F + 16 nF        | 10 mF/F + 32 nF        |
| 40 $\mu$ F to 400 $\mu$ F | 5 mF/F + 0.16 $\mu$ F | 10 mF/F + 0.32 $\mu$ F |
| 400 $\mu$ F to 4 mF       | 5 mF/F + 1.6 $\mu$ F  | 10 mF/F + 3.2 $\mu$ F  |
| 4 mF to 40 mF             | 10 mF/F + 0.06 mF     | 20 mF/F + 0.12 mF      |

| Instrument Calibrated/<br>Measurement<br>Parameter | Range                                                            | Calibration and<br>Measurement Capability<br>Expressed as an<br>Uncertainty ( $\pm$ ) * | Remarks           |
|----------------------------------------------------|------------------------------------------------------------------|-----------------------------------------------------------------------------------------|-------------------|
| 2. Generating Instrument<br>DC VOLTAGE             | $\pm 100$ mV Range<br>$\pm (100 \mu\text{V to } 120 \text{ mV})$ | $5 \mu\text{V/V} + 0.3 \mu\text{V}$                                                     | HP 3458A Opt. 002 |
|                                                    | $\pm 1$ V Range<br>$\pm (100 \text{ mV to } 1.2 \text{ V})$      | $4 \mu\text{V/V} + 0.3 \mu\text{V}$                                                     |                   |
|                                                    | $\pm 10$ V Range<br>$\pm (1 \text{ V to } 12 \text{ V})$         | $4 \mu\text{V/V} + 0.5 \mu\text{V}$                                                     |                   |
|                                                    | $\pm 100$ V Range<br>$\pm (10 \text{ V to } 120 \text{ V})$      | $6 \mu\text{V/V} + 0.03 \text{ mV}$                                                     |                   |
|                                                    | $\pm 1000$ V Range<br>$\pm (100 \text{ V to } 1050 \text{ V})$   | $6 \mu\text{V/V} + 0.1 \text{ mV}$                                                      |                   |
| AC VOLTAGE                                         | 10 mV to 700V<br>(See Matrix D)                                  | (See Matrix D)                                                                          | HP 3458A          |
| AC CURRENT                                         | 5 $\mu$ A to 1 A<br>(See Matrix E)                               | (See Matrix E)                                                                          |                   |

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**SCOPE OF CALIBRATION: ELECTRICAL****SITE CALIBRATION: CATEGORY I**

| Instrument Calibrated/<br>Measurement<br>Parameter | Range                                                   | Calibration and<br>Measurement Capability<br>Expressed as an<br>Uncertainty ( $\pm$ ) * | Remarks                       |
|----------------------------------------------------|---------------------------------------------------------|-----------------------------------------------------------------------------------------|-------------------------------|
| 2. Generating Instrument<br>Continue<br>AC CURRENT | 1 A to 50 A<br>50 Hz/ 60 Hz                             | 0.5 mA/A                                                                                | HP 3458A & Zenith<br>H007098  |
|                                                    | <b>50 A to 1000 A</b><br>50 Hz/ 60 Hz<br>40 Hz to 1 kHz | 15 mA/A + 2 A<br>0.03 A/A + 4 A                                                         | Kyoritsu 2003                 |
| DC CURRENT                                         | $\pm$ (1 nA to 100 nA)                                  | 30 $\mu$ A/A + 0.04 nA                                                                  | HP 3458A                      |
|                                                    | $\pm$ (100 nA to 1 $\mu$ A)                             | 20 $\mu$ A/A + 0.04 nA                                                                  |                               |
|                                                    | $\pm$ (1 $\mu$ A to 10 $\mu$ A)                         | 20 $\mu$ A/A + 0.1 nA                                                                   |                               |
|                                                    | $\pm$ (10 $\mu$ A to 100 $\mu$ A)                       | 20 $\mu$ A/A + 0.8 nA                                                                   |                               |
|                                                    | $\pm$ (100 $\mu$ A to 1 mA)                             | 20 $\mu$ A/A + 5 nA                                                                     |                               |
|                                                    | $\pm$ (1 mA to 10 mA)                                   | 20 $\mu$ A/A + 0.05 $\mu$ A                                                             | HP 3458A &<br>Guideline 9211A |
|                                                    | $\pm$ (10 mA to 100 mA)                                 | 35 $\mu$ A/A + 0.5 $\mu$ A                                                              |                               |
|                                                    | $\pm$ (100 mA to 1 A)                                   | 0.11 mA/A + 0.01 mA                                                                     |                               |
|                                                    | $\pm$ (1 A to 10 A)                                     | 5.1 mA                                                                                  |                               |
|                                                    | $\pm$ (10 A to 100 A)                                   | 0.05 A                                                                                  |                               |
|                                                    | $\pm$ (100 A to 1000 A)                                 | 15 mA/A + 2A                                                                            | Kyoritsu 2003                 |
| CAPACITANCE                                        | 1 pF to 1 mF @<br>(10 Hz to 1 MHz)                      | 0.5 mF/F                                                                                | HP 4284A                      |
| INDUCTANCE                                         | 1 $\mu$ H to 10 H @<br>(10 Hz to 1 MHz)                 | 0.5 mH/H                                                                                |                               |

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**SCOPE OF CALIBRATION:****ELECTRICAL****SITE CALIBRATION:****CATEGORY I**

| Instrument Calibrated/<br>Measurement<br>Parameter                                              | Range                                                                                                                                                                                                                                                                                                                                                                                                        | Calibration and<br>Measurement Capability<br>Expressed as an<br>Uncertainty ( $\pm$ ) *                                                                                                                                                                                                                                                                                                                                               | Remarks                                                           |
|-------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------|
| 2. Generating Instrument<br>Continue<br>RESISTANCE                                              | $0\ \Omega$ to $10\ \Omega$<br>$10\ \Omega$ to $100\ \Omega$<br>$0.1\ \text{k}\Omega$ to $1\ \text{k}\Omega$<br>$1\ \text{k}\Omega$ to $10\ \text{k}\Omega$<br>$10\ \text{k}\Omega$ to $100\ \text{k}\Omega$<br>$0.1\ \text{M}\Omega$ to $1\ \text{M}\Omega$<br>$1\ \text{M}\Omega$ to $10\ \text{M}\Omega$<br>$10\ \text{M}\Omega$ to $100\ \text{M}\Omega$<br>$100\ \text{M}\Omega$ to $1\ \text{G}\Omega$ | $15\ \mu\Omega/\Omega + 0.05\ \text{m}\Omega$<br>$12\ \mu\Omega/\Omega + 0.05\ \text{m}\Omega$<br>$10\ \mu\Omega/\Omega + 0.05\ \text{m}\Omega$<br>$10\ \mu\Omega/\Omega + 5\ \text{m}\Omega$<br>$10\ \mu\Omega/\Omega + 0.05\ \Omega$<br>$15\ \mu\Omega/\Omega + 2\ \Omega$<br>$50\ \mu\Omega/\Omega + 0.1\ \text{k}\Omega$<br>$0.5\ \text{m}\Omega/\Omega + 1\ \text{k}\Omega$<br>$5\ \text{m}\Omega/\Omega + 0.01\ \text{M}\Omega$ | HP 3458A                                                          |
| Signal Genarator<br>FREQUENCY<br><br><br><br>AMPLITUDE/ LEVEL<br><br><br><br><br>TUNED RF LEVEL | 1 Hz to 5 GHz                                                                                                                                                                                                                                                                                                                                                                                                | 0.91 pHz/Hz                                                                                                                                                                                                                                                                                                                                                                                                                           | HP53132A<br>Reference to<br>Pendulum GPS-12R<br>Manual hold-over  |
|                                                                                                 | 5 GHz to 27 GHz                                                                                                                                                                                                                                                                                                                                                                                              | 0.89 Hz/Hz                                                                                                                                                                                                                                                                                                                                                                                                                            | HP8563E Reference<br>to Pendulum GPS-<br>12R Manual hold-<br>over |
|                                                                                                 | -20 dBm to +30 dBm<br>(100 kHz to 2.6 GHz)                                                                                                                                                                                                                                                                                                                                                                   | 0.04 dBm                                                                                                                                                                                                                                                                                                                                                                                                                              | HP 8902 with<br>11722A                                            |
|                                                                                                 | -30 dB to +30 dB<br>(2.6 GHz to 18 GHz)                                                                                                                                                                                                                                                                                                                                                                      | 0.27 dBm                                                                                                                                                                                                                                                                                                                                                                                                                              | Agilent E4418B with<br>HP 8481A                                   |
|                                                                                                 | -120 dB to +30 dB<br>(30 Hz to 27 GHz)                                                                                                                                                                                                                                                                                                                                                                       | 1 dBm                                                                                                                                                                                                                                                                                                                                                                                                                                 | HP8563E                                                           |
|                                                                                                 | -127 dB to 0 dB<br>(2.5 MHz to 1.3 GHz)                                                                                                                                                                                                                                                                                                                                                                      | 0.07 dBm                                                                                                                                                                                                                                                                                                                                                                                                                              | HP 8902 with<br>11722A                                            |

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**SCOPE OF CALIBRATION:****ELECTRICAL****SITE CALIBRATION:****CATEGORY I**

| Instrument Calibrated/<br>Measurement<br>Parameter                | Range                                                                                                                                                                                                                            | Calibration and<br>Measurement Capability<br>Expressed as an<br>Uncertainty ( $\pm$ ) *                                              | Remarks                       |
|-------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|
| 2. Generating Instrument<br>Continue<br>RPM (Non-Contact<br>Type) | 10 to 29 rpm<br>30 to 59 rpm<br>60 to 99 rpm<br>100 to 299 rpm<br>300 to 599 rpm<br>600 to 999 rpm<br>1000 to 2999 rpm<br>3000 to 5999 rpm<br>6000 to 9999 rpm<br>10000 to 29999 rpm<br>30000 to 59999 rpm<br>60000 to 99999 rpm | 0.014 rpm<br>0.036 rpm<br>0.07 rpm<br>0.14 rpm<br>0.37 rpm<br>0.7 rpm<br>1.4 rpm<br>3.6 rpm<br>7 rpm<br>14 rpm<br>36 rpm<br>70 rpm   | In-House method,<br>ESF/0303. |
| RPM (Contact Type)                                                | 20 to 29 rpm<br>30 to 59 rpm<br>60 to 99 rpm<br>100 to 299 rpm<br>300 to 599 rpm<br>600 to 999 rpm<br>1000 to 2999 rpm<br>3000 to 5999 rpm<br>6000 to 9999 rpm<br>10000 to 12999 rpm<br>13000 to 25999 rpm<br>26000 to 29999 rpm | 0.011 rpm<br>0.016 rpm<br>0.029 rpm<br>0.07 rpm<br>0.16 rpm<br>0.29 rpm<br>0.7 rpm<br>1.6 rpm<br>2.9 rpm<br>7 rpm<br>8 rpm<br>14 rpm |                               |
| High Voltage Tester<br>DC VOLTAGE                                 | 0 kV to 9.9 kV<br>10 kV to <20 kV<br>20 kV to 35 kV<br>>35 kV to 40 kV                                                                                                                                                           | 5 mV/V + 2 V<br>20 mV/V<br>10 mV/V<br>20 mV/V                                                                                        | TDV 20 ADS<br>Fluke 80K-40    |
| AC VOLTAGE                                                        | (0 kV to 9.99 kV) @ 50/60Hz<br>(10 kV to 20 kV) @ 50/60 Hz<br>(20 kV to 28 kV) @ 50/60 Hz                                                                                                                                        | 7 mV/V + 3 V<br>7 mV/V + 30 V<br>50 mV/V                                                                                             |                               |

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**SCOPE OF CALIBRATION:****ELECTRICAL****SITE CALIBRATION:****CATEGORY I**

Matrix D

AC Voltage Generation (HP 3458A)

| Range |            | Frequency Band |              |            |             |             |
|-------|------------|----------------|--------------|------------|-------------|-------------|
|       |            | 1 to 40 Hz     | 0.1 to 1 MHz | 1 to 4 MHz | 4 to 8 MHz  | 8 to 10 MHz |
| 10 mV | 1 to 12 mV | 0.3 + 3        | 12 + 5       | 70 + 7     | 0.2 V/V + 8 | –           |

| Range  |              | Frequency Band        |             |             |             |                   |
|--------|--------------|-----------------------|-------------|-------------|-------------|-------------------|
|        |              | 1 to 40 Hz            | 1 to 2 MHz  | 2 to 4 MHz  | 4 to 8 MHz  | 8 to 10 MHz       |
| 100 mV | 10 to 120 mV | 70 $\mu$ V/V + 4      | 15 + 10     | 40 + 70     | 40 + 80     | 0.15 V/V + 0.1 mV |
| 1 V    | 0.1 V 1.2 V  | 70 $\mu$ V/V + 40     | 15 + 0.1 mV | 40 + 0.7 mV | 40 + 0.8 mV | 0.15 V/V + 1 mV   |
| 10 V   | 1 to 12 V    | 70 $\mu$ V/V + 0.4 mV | 15 + 1 mV   | 40 + 7 mV   | 40 + 8 mV   | 0.15 V/V + 10 mV  |

| Range  |              | Frequency Band |              |
|--------|--------------|----------------|--------------|
|        |              | 1 to 40 Hz     | 0.3 to 1 MHz |
| 100 V  | 10 to 120 V  | 0.2 + 4 mV     | 15 + 10 mV   |
| 1000 V | 100 to 700 V | 0.4 + 40 mV    |              |

The expanded uncertainties given in this table are expressed in mV/V +  $\mu$ V unless otherwise stated.

Matrix E

AC Current Generation (HP 3458A)

| Range       |                  | Frequency Band |              |              |                 |
|-------------|------------------|----------------|--------------|--------------|-----------------|
|             |                  | 10 to 20 Hz    | 20 to 45 Hz  | 45 to 100 Hz | 100 Hz to 5 kHz |
| 100 $\mu$ A | 5 to 120 $\mu$ A | 4 + 30 nA      | 1.5 + 30 nA  | 0.6 + 3 nA   |                 |
| 1 mA        | 0.05 to 1.2 mA   | 4 + 0.2        | 1.5 + 0.2    | 0.6 + 0.2    | 0.3 + 0.2       |
| 10 mA       | 0.5 to 12 mA     | 4 + 2          | 1.5 + 2      | 0.6 + 2      | 0.3 + 2         |
| 100 mA      | 5 to 120 mA      | 4 + 20         | 1.5 + 20     | 0.6 + 20     | 0.3 + 20        |
| 1 A         | 0.05 to 1.05 A   | 4 + 0.2 mA     | 1.6 + 0.2 mA | 0.8 + 0.2 mA | 1 + 0.2 mA      |

| Range  |                | Frequency Band |              |               |
|--------|----------------|----------------|--------------|---------------|
|        |                | 5 to 20 kHz    | 20 to 50 kHz | 50 to 100 kHz |
| 1 mA   | 0.05 to 1.2 mA | 0.6 + 0.2      | 4 + 0.4      | 5.5 + 1.5     |
| 10 mA  | 0.5 to 12 mA   | 0.6 + 2        | 4 + 4        | 5.5 + 15      |
| 100 mA | 5 to 120 mA    | 0.6 + 20       | 4 + 40       | 5.5 + 0.15 mA |
| 1 A    | 0.05 to 1.05 A | 3 + 0.2 mA     | 10 + 0.4 mA  |               |

The expanded uncertainties given in this table are expressed in mA/A +  $\mu$ A unless otherwise stated.**Signatories:**

1. **Muhammed Fahimy Bin Ahmad Ta'adin**
2. **\*\*Mohamed Fikri Bin Mohd Nor**
3. **Syahrel Bin Shari**

\*\* Non-resident signatory

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**SCOPE OF CALIBRATION: TEMPERATURE**

| Instrument Calibrated/<br>Measurement Parameter              | Range                                                                   | Calibration and<br>Measurement<br>Capability Expressed<br>as an Uncertainty ( $\pm$ ) * | Remarks                                                                                           |
|--------------------------------------------------------------|-------------------------------------------------------------------------|-----------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------|
| Liquid In-glass Thermometer<br>(Partial Immersion)           | 0 °C to 200 °C                                                          | 2 °C                                                                                    | Comparison method<br>using SPRT / PRT in<br>liquid bath.                                          |
| Liquid-in-glass thermometer<br>(Total Immersion)             | - 80 °C to 0 °C<br>0 °C to 80 °C<br>80 °C to 250 °C<br>250 °C to 500 °C | 0.05 °C<br>0.03 °C<br>0.05 °C<br>0.10 °C                                                | Comparison method<br>using SPRT / PRT in<br>liquid bath.                                          |
| Platinum Resistance<br>Thermometer                           | - 80 °C to 600 °C<br>600 °C to 950 °C                                   | 0.05 °C<br>0.5 °C                                                                       | Comparison method<br>using SPRT / PRT in<br>liquid bath/dry block                                 |
| Thermocouple                                                 | - 80 °C to 600 °C<br>600 °C to 950 °C                                   | 0.1 °C<br>0.3 °C                                                                        | Comparison method<br>using SPRT/ PRT/<br>Standard Thermocouple<br>Type R liquid bath/dry<br>block |
| Psychrometer<br>Thermohygrograph<br>Thermohygrometer @ 23 °C | 10 °C to 50 °C<br>35 % to 95 %RH                                        | 0.5 °C<br>3.0 %RH                                                                       | Comparison Method<br>Using Wet and Dry bulb<br>base on BS 1339-1<br>2002 in climatic chamber      |
| Temperature switch                                           | - 50 °C to 10 °C<br>10 °C to 100 °C<br>100 °C to 600 °C                 | 1 °C<br>2 °C<br>3 °C                                                                    | Comparison method<br>using SPRT/ PRT/<br>Thermocouple Type R in<br>liquid bath/dry block          |
| Mechanical thermometer                                       | - 80 °C to 100 °C<br>100 °C to 200 °C<br>200 °C to 600 °C               | 0.1 °C<br>0.6 °C<br>1.5 °C                                                              | Comparison method<br>using SPRT/ PRT/<br>Thermocouple Type R in<br>liquid bath/dry block          |
| Temperature Calibrator<br>(Dry block)                        | - 30 °C to 600 °C<br>600 °C to 950 °C                                   | 0.11 °C<br>0.63 °C                                                                      | EA-10 /13 (EAL<br>Guideline for calibration<br>of Dry block Calibrator)                           |

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**SCOPE OF CALIBRATION: TEMPERATURE**

| Instrument Calibrated/<br>Measurement Parameter | Range                                 | Calibration and<br>Measurement Capability<br>Expressed as an<br>Uncertainty ( $\pm$ ) * | Remarks                                                                 |
|-------------------------------------------------|---------------------------------------|-----------------------------------------------------------------------------------------|-------------------------------------------------------------------------|
| Temperature Indicating<br>Instruments           |                                       |                                                                                         |                                                                         |
| K - type                                        | - 200 °C to 0 °C<br>0 °C to 1300 °C   | 0.4 °C<br>0.4 °C                                                                        |                                                                         |
| J - type                                        | - 200 °C to 0 °C<br>0 °C to 1100 °C   | 0.3 °C<br>0.3 °C                                                                        |                                                                         |
| T - type                                        | - 200 °C to 0 °C<br>0 °C to 400 °C    | 0.5 °C<br>0.4 °C                                                                        |                                                                         |
| E - type                                        | - 200 °C to 0 °C<br>0 °C to 900 °C    | 0.4 °C<br>0.3 °C                                                                        | Calibration by Electrical<br>simulation using<br>Temperature Calibrator |
| R – type                                        | 0 °C to 1000 °C<br>1000 °C to 1700 °C | 1.3 °C<br>1.1 °C                                                                        |                                                                         |
| S - type                                        | 0 °C to 1000 °C<br>1000 °C to 1700 °C | 1.3 °C<br>1.2 °C                                                                        |                                                                         |
| Pt 100                                          | - 200 °C to 0 °C<br>0 °C to 800 °C    | 0.2 °C<br>0.5 °C                                                                        |                                                                         |

**Signatory:**1. **Zulkifli Ahmad**

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**SCOPE OF CALIBRATION: TEMPERATURE****SITE CALIBRATION: CATEGORY I**

| Instrument Calibrated/<br>Measurement Parameter | Range                                                     | Calibration and<br>Measurement<br>Capability<br>Expressed as an<br>Uncertainty ( $\pm$ ) * | Remarks                                                                 |
|-------------------------------------------------|-----------------------------------------------------------|--------------------------------------------------------------------------------------------|-------------------------------------------------------------------------|
| Humidity Chamber                                | 20 % to 95 %RH                                            | 2.0 % of RH                                                                                | AS 2853-1986<br>BS 1339-1 :2002                                         |
| Temperature Controlled<br>Enclosure             | - 60 °C to 200 °C<br>200 °C to 400 °C<br>400 °C to 950 °C | 0.8 °C<br>1.2 °C<br>2 °C                                                                   | AS 2853 -1986                                                           |
| Temperature Indicating<br>Instruments           |                                                           |                                                                                            |                                                                         |
| K - type                                        | - 200 °C to 0 °C<br>0 °C to 1300 °C                       | 0.4 °C<br>0.4 °C                                                                           | Calibration by Electrical<br>simulation using<br>Temperature Calibrator |
| J - type                                        | - 200 °C to 0 °C<br>0 °C to 1100 °C                       | 0.3 °C<br>0.3 °C                                                                           |                                                                         |
| T - type                                        | - 200 °C to 0 °C<br>0 °C to 400 °C                        | 0.5 °C<br>0.4 °C                                                                           |                                                                         |
| E - type                                        | - 200 °C to 0 °C<br>0 °C to 900 °C                        | 0.4 °C<br>0.3 °C                                                                           |                                                                         |
| R – type                                        | 0 °C to 1000 °C<br>1000 °C to 1700 °C                     | 1.3 °C<br>1.1 °C                                                                           |                                                                         |
| S - type                                        | 0 °C to 1000 °C<br>1000 °C to 1700 °C                     | 1.3 °C<br>1.2 °C                                                                           |                                                                         |
| Pt 100                                          | - 200 °C to 0 °C<br>0 °C to 800 °C                        | 0.2 °C<br>0.5 °C                                                                           |                                                                         |

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**SCOPE OF CALIBRATION: TEMPERATURE****SITE CALIBRATION: CATEGORY I**

| Instrument Calibrated/<br>Measurement Parameter | Range            | Calibration and<br>Measurement<br>Capability<br>Expressed as an<br>Uncertainty ( $\pm$ ) * | Remarks                                                    |
|-------------------------------------------------|------------------|--------------------------------------------------------------------------------------------|------------------------------------------------------------|
| Temperature Sensor with<br>Indicator<br>-PT100  | 0 °C to 300 °C   | 0.15 °C                                                                                    | Calibration by<br>comparison method<br>using:              |
|                                                 | 301 °C to 600 °C | 0.26 °C                                                                                    |                                                            |
| -Thermocouple                                   | 0 °C to 300 °C   | 0.15 °C                                                                                    | 1-Pt100 / Type R<br>Thermocouple as<br>reference standards |
|                                                 | 301 °C to 600 °C | 0.26 °C                                                                                    |                                                            |
|                                                 | 601 °C to 950 °C | 1.1 °C                                                                                     | 2-Dry Block Calibrator                                     |

**Signatory:**1. **Zulkifli Ahmad**

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**SCOPE OF CALIBRATION: DIMENSIONAL**

| Instrument Calibrated/<br>Measurement Parameter                                 | Range                                                       | Calibration and<br>Measurement Capability<br>Expressed as an<br>Uncertainty ( $\pm$ ) * | Remarks                              |
|---------------------------------------------------------------------------------|-------------------------------------------------------------|-----------------------------------------------------------------------------------------|--------------------------------------|
| Gauge Block                                                                     | 0.5 mm to 100 mm<br>100 mm to 250 mm                        | $(0.1 + 1.0 L) \mu\text{m}$<br>L in m                                                   | Reference Equipment:<br>Gauge block  |
| Gauge Block<br>(Imperial units)                                                 | 0.05 inch to 4 inch                                         | $(0.004 + 1.0 L) \mu\text{inch}$<br>L in inch                                           | Gauge block                          |
| Bevel Protractor                                                                | 0 to 360 degrees:<br>Graduation 5 min.<br>Graduation 1 deg. | 3 minute<br>0.5 degree                                                                  | Angle block                          |
| Snap Gauge / Caliper<br>Gauge                                                   | Up to 200 mm                                                | 5 $\mu\text{m}$                                                                         | Uni. Measuring M/c                   |
| Micrometer<br>25 mm travels for frame<br>Sizes 25 mm, 50 mm, 75<br>mm and 100mm | 0.001 mm to 100 mm                                          | 2 $\mu\text{m}$                                                                         | Gauge Block                          |
| Caliper                                                                         | 0.01 mm to 300 mm<br>300 mm to 600 mm<br>600 mm to 1000 mm  | 7 $\mu\text{m}$<br>9 $\mu\text{m}$<br>12 $\mu\text{m}$                                  | Gauge Block<br>Caliper Checker       |
| Height Gauge                                                                    | 0.01 mm to 600 mm                                           | 10 $\mu\text{m}$                                                                        | Caliper Checker                      |
| Caliper Checker                                                                 | 20 mm to 300 mm<br>301 mm to 600 mm                         | 3 $\mu\text{m}$<br>6 $\mu\text{m}$                                                      | Long Gauge block                     |
| Calibration Tester                                                              | 0 mm to 25 mm                                               | 2 $\mu\text{m}$                                                                         | Dig.Length Indicator<br>/Gauge Block |
| Dial / Digital Test Indicator                                                   | 0.001 mm to 100 mm                                          | 2 $\mu\text{m}$                                                                         | Dial gauge testing machine           |
| Dial / Digital Gauge                                                            | 0.001 mm to 100 mm                                          | 2 $\mu\text{m}$                                                                         | Dial gauge testing machine           |
| Dial / Digital Thickness<br>Gauge                                               | 0.01 mm to 50 mm                                            | 5 $\mu\text{m}$                                                                         | Gauge Block                          |
| Depth Micro-Checker                                                             | 0 mm to 300 mm                                              | 6 $\mu\text{m}$                                                                         | Gauge Block / Pre. Height<br>Gauge   |

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**SCOPE OF CALIBRATION: DIMENSIONAL**

| Instrument Calibrated/<br>Measurement Parameter    | Range                               | Calibration and<br>Measurement Capability<br>Expressed as an<br>Uncertainty ( $\pm$ ) *  | Remarks                                       |
|----------------------------------------------------|-------------------------------------|------------------------------------------------------------------------------------------|-----------------------------------------------|
| Feeler Gauge                                       | 0.005 mm to 2.0 mm                  | 3 $\mu$ m                                                                                | Dig.Length Indicator                          |
| Glass Scale                                        | up to 200 mm<br>200 mm to 300 mm    | 3.8 $\mu$ m<br>5.6 $\mu$ m                                                               | Uni. Measuring M/c                            |
| Grind Gauge/Fine Gauge                             | 0.001 mm to 0.15 mm                 | 2 $\mu$ m                                                                                | Dig.Length Indicator                          |
| Height master                                      | 0.001 mm to 600 mm                  | 6 $\mu$ m                                                                                | Pre. Height Gauge / Gauge Block               |
| Ruler                                              | 0.1 mm to 2000 mm                   | 0.1 mm                                                                                   | Linear scale                                  |
| Mu-checker                                         | 0.1 mm to 2000 $\mu$ m              | 2 $\mu$ m                                                                                | Gauge Block                                   |
| Precision Height Gauge                             | 0.001 mm to 600 mm                  | 4 $\mu$ m                                                                                | Gauge Block                                   |
| Straight Edge                                      | 0 mm to 600 mm                      | 1.5 $\mu$ m                                                                              | Dig.Length Indicator /<br>Straight edge       |
| Tape                                               | 0 m to 100 m                        | (0.33 + 0.019 L) mm<br><i>L is length in unit meter</i>                                  | Linear scale                                  |
| Thickness Foil                                     | 0.001 mm to 2.0 mm                  | 3 $\mu$ m                                                                                | Dig.Length Indicator                          |
| Setting/Standard Rod                               | 25 mm to 100 mm<br>100 mm to 600 mm | (0.15 + 0.0064 L)<br>(0.11 + 0.008 L)<br><i>L is length in unit mm</i>                   | Universal Length Machine<br>and Gauge Block   |
| Plain Pin or Plug Gauge<br>(Diameter Only)         | 0.2 mm to 50 mm                     | 0.5 $\mu$ m                                                                              | Universal Length Machine                      |
| Plain Ring Gauge<br>(Diameter Only)                | 1 mm to 100 mm<br>100 mm to 200 mm  | (0.007 L + 0.11) $\mu$ m<br>(0.0064 L + 0.41) $\mu$ m<br><i>L is diameter in unit mm</i> | Universal Length Machine<br>and Gauge Block   |
| Thread Plug Gauge<br>(Simple Pitch Diameter)       | 2 mm to 50 mm                       | 2 $\mu$ m                                                                                | Universal Length Machine<br>(In-house Method) |
| Length Machine<br>(For in-house equipment<br>only) | 0 mm to 1 m<br>0 mm to 10 m         | 0.1 mm<br>0.4 mm                                                                         | Standard Scale                                |

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**SCOPE OF CALIBRATION: DIMENSIONAL**

| Instrument Calibrated/<br>Measurement Parameter                                                                | Range          | Calibration and<br>Measurement Capability<br>Expressed as an<br>Uncertainty ( $\pm$ ) * | Remarks        |
|----------------------------------------------------------------------------------------------------------------|----------------|-----------------------------------------------------------------------------------------|----------------|
| Universal Measuring<br>Microscope<br>(Individual linear axis only-<br><i>For in-house equipment<br/>only</i> ) | 0 mm to 200 mm | 2.5 $\mu$ m                                                                             | Standard Scale |
| Digital Length Indicator                                                                                       | 0 to 25 mm     | 0.4 $\mu$ m                                                                             | Gauge Block    |

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**SCOPE OF CALIBRATION: DIMENSIONAL****SITE CALIBRATION: CATEGORY I**

| Instrument Calibrated/<br>Measurement Parameter                   | Range             | Calibration and<br>Measurement Capability<br>Expressed as an<br>Uncertainty ( $\pm$ ) * | Remarks              |
|-------------------------------------------------------------------|-------------------|-----------------------------------------------------------------------------------------|----------------------|
| Profile Projector<br>(Error of indication of<br>linear scale X-Y) | 1 mm to 200 mm    | 5 $\mu$ m                                                                               | Glass Scale          |
|                                                                   | 201 mm to 300 mm  | 7 $\mu$ m                                                                               |                      |
| Surface Table/Plate                                               | 2500 mm x 1600 mm | 4 $\mu$ m                                                                               | Levelnic / Plankator |

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**SCOPE OF CALIBRATION: MASS**

| Instrument Calibrated/<br>Measurement Parameter      | Range                                                                                                                                                                                                                                                                                                                                                    | Calibration and<br>Measurement Capability<br>Expressed as an Uncertainty<br>( $\pm$ ) *                                                                                                                                                                           | Remarks                                                                                                                                                                                                                   |
|------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Standard Weights<br>Class E2, F1, F2, M1, M2<br>& M3 | 1 mg<br>2 mg<br>5 mg<br>10 mg<br>20 mg<br>50 mg<br>100 mg<br>200 mg<br>500 mg<br>1 g<br>2 g<br>5 g<br>10 g<br>20 g<br>50 g<br>100 g<br>200 g<br>500 g<br>1 kg<br>2 kg<br>5 kg<br>10 kg<br>20 kg                                                                                                                                                          | 0.002 mg<br>0.002 mg<br>0.002 mg<br>0.003 mg<br>0.003 mg<br>0.004 mg<br>0.005 mg<br>0.006 mg<br>0.008 mg<br>0.010 mg<br>0.012 mg<br>0.016 mg<br>0.020 mg<br>0.025 mg<br>0.03 mg<br>0.05 mg<br>0.10 mg<br>0.23 mg<br>0.5 mg<br>1.0 mg<br>3.0 mg<br>16 mg<br>100 mg | With general<br>reference to<br>OIML R111. Mass<br>comparison using:<br>ABBA weighing<br>scheme for weights<br>of OIML classes E2<br>and F1; and AB, AB<br>weighing scheme for<br>weights of OIML<br>classes F2 and below |
| Weight Blocks                                        | 1 mg to 10 g<br>Above 10 g to 50 g<br>Above 50 g to 100 g<br>Above 100 g to 200 g<br>Above 200 g to 500 g<br>Above 500 g to 1 kg<br>Above 1 kg to 2 kg<br>Above 2 kg to 5 kg<br>Above 5 kg to 10 kg<br>Above 10 kg to 20 kg<br>Above 20 kg to 30 kg<br>Above 30 kg to 60 kg<br>Above 60 kg to 100 kg<br>Above 100 kg to 200 kg<br>Above 200 kg to 500 kg | 2 mg<br>3 mg<br>5 mg<br>9 mg<br>0.02 g<br>0.05 g<br>0.09 g<br>0.2 g<br>0.5 g<br>0.9 g<br>1.3 g<br>2.6 g<br>0.02 kg<br>0.02 kg<br>0.04 kg                                                                                                                          | Mass comparison<br>using AB, AB<br>weighing scheme                                                                                                                                                                        |

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**SCOPE OF CALIBRATION: MASS**

| Instrument Calibrated/<br>Measurement Parameter | Range                                                    | Calibration and<br>Measurement Capability<br>Expressed as an<br>Uncertainty ( $\pm$ ) * | Remarks                                                    |
|-------------------------------------------------|----------------------------------------------------------|-----------------------------------------------------------------------------------------|------------------------------------------------------------|
| Spring /Hanging Scale                           | up to 5 kg<br>up to 20 kg<br>up to 50 kg<br>up to 100 kg | 16 g<br>31 g<br>62 g<br>0.13 kg                                                         | Using calibrated<br>standard weights of<br>OIML classes F1 |

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**SCOPE OF CALIBRATION:****MASS****SITE CALIBRATION:****CATEGORY I**

| Instrument Calibrated/<br>Measurement Parameter                                              | Range                                                                                                                                       | Calibration and<br>Measurement Capability<br>Expressed as an Uncertainty<br>( $\pm$ ) * | Remarks                                       |
|----------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------|-----------------------------------------------|
| Analytical Balance                                                                           | up to 50 g<br>up to 100 g<br>up to 200 g                                                                                                    | 0.13 mg<br>0.15 mg<br>0.2 mg                                                            | OIML class E2<br>Reference Weights            |
| Balance / Scale<br>(Triple Beam, Single<br>Beam Spring, Top Pan,<br>Mechanical & Electronic) | up to 1000 g<br>up to 2000 g<br>up to 5000 g<br>up to 10000 g<br>up to 20 kg<br>up to 50 kg<br>up to 100 kg<br>up to 200 kg<br>up to 500 kg | 2 mg<br>0.02 g<br>0.02 g<br>0.2 g<br>0.2 g<br>2 g<br>13 g<br>0.03 kg<br>0.1 kg          | OIML classes<br>F1/F2/M2<br>Reference Weights |
| Electrical and Mechanical<br>Platform Balance                                                | up to 1000 kg<br><br>up to 2000 kg                                                                                                          | 0.27 kg<br><br>0.66 kg                                                                  | OIML class M2<br>Reference Weights            |

**Signatory:**

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**SCOPES OF CALIBRATION: FORCE & TORQUE**

| Instrument Calibrated/<br>Measurement Parameter | Range                                                                                                                                    | Calibration and<br>Measurement Capability<br>Expressed as an<br>Uncertainty ( $\pm$ )* | Remarks                                                                                                                                                      |
|-------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>FORCE MEASUREMENT</b>                        |                                                                                                                                          |                                                                                        |                                                                                                                                                              |
| Proving Rings/Load Cells                        | 0 kgf to 100 kgf<br>101 kgf to 500 kgf<br>501 kgf to 1000 kgf<br>1001 kgf to 5000 kgf<br>5001 kgf to 10000 kgf<br>10001 kgf to 30000 kgf | 0.04 kgf<br>0.2 kgf<br>0.3 kgf<br>3 kgf<br>26 kgf<br>108 kgf                           | <b>ISO 376: 2004</b><br>LC 100 kgf<br>LC 500 kgf<br>LC 1000 kgf<br>LC 5000 kgf<br>LC 10000 kgf<br>LC 45000 kgf                                               |
| Push-pull/ Force Gauge                          | 1 gf to 5 kgf<br>5 kgf to 20 kgf<br>20 kgf to 50 kgf<br>50 kgf to 100 kgf                                                                | 16 gf<br>31 gf<br>62 gf<br>124 gf                                                      | ASTM E74-95<br>Reference F1 & F2                                                                                                                             |
| Gramme/ Dial Tension<br>Gauge                   | 1 gf to 50 gf<br>50 gf to 500 gf<br>500 gf to 2000 gf                                                                                    | 1 gf<br>6 gf<br>30 gf                                                                  | ASTM E74-95<br>Reference F1 & F2                                                                                                                             |
| <b>TORQUE MEASUREMENT</b>                       |                                                                                                                                          |                                                                                        |                                                                                                                                                              |
| Torque wrench                                   | 0 N.m to 2 N.m<br>2.1 N.m to 100 N.m<br>101 N.m to 500 N.m                                                                               | 0.07 N.m<br>0.3 N.m<br>2 N.m                                                           | Comparison with torque<br>transducers with general<br>reference to BS EN ISO<br>6789 : 2003<br>Transducer 2 N.m<br>Transducer 100 N.m<br>Transducer 1000 N.m |
| Torque meter and analyser                       | 0 N.m to 2 N.m<br>3 N.m to 50 N.m<br>51 N.m to 100 N.m<br>101 N.m to 500 N.m                                                             | 0.1% of reading<br>0.1% of reading<br>0.1% of reading<br>0.1% of reading               | With general reference to<br>BS 7882: 2008                                                                                                                   |

Note: LC (Load Cell)

**Signatory:**1. **Noor Azam Ismail**

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**SCOPE OF CALIBRATION: FORCE****SITE CALIBRATION: CATEGORY I**

| Instrument Calibrated/<br>Measurement Parameter                                     | Range                                                                                                                                                               | Calibration and<br>Measurement<br>Capability Expressed<br>as an Uncertainty ( $\pm$ )* | Remarks                                                                                                                                                                                 |
|-------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Universal Testing Machine /<br>Compression mode<br>(tension mode up to 5000<br>kgf) | 0 kgf to 100 kgf<br>101 kgf to 500 kgf<br>501 kgf to 1000 kgf<br>1001 kgf to 5000 kgf<br>5001 kgf to 10000 kgf<br>10001 kgf to 60000 kgf<br>60001 kgf to 180000 kgf | 0.04 kgf<br>0.2 kgf<br>0.3 kgf<br>3 kgf<br>26 kgf<br>378 kgf<br>460 kgf                | <b>Comparison with<br/>load cell based on<br/>BS EN ISO 7500-<br/>1:2004</b><br>LC 100 kgf<br>LC 500 kgf<br>LC 1000 kgf<br>LC 5000 kgf<br>LC 10000 kgf<br>LC 90000 kgf<br>LC 200000 kgf |
| Charpy / Izod Impact Tester                                                         | 1 Joule to 300 Joules                                                                                                                                               | 1 % of reading                                                                         | BS 131-7 : 1998                                                                                                                                                                         |

Note: LC (Load Cell)

**Signatory:**

- Noor Azam Ismail**

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**SCOPE OF CALIBRATION: PRESSURE**

| Instrument Calibrated/<br>Measurement Parameter        | Range                                                          | Calibration and<br>Measurement Capability<br>Expressed as an<br>Uncertainty ( $\pm$ )* | Remarks                                                                                                             |
|--------------------------------------------------------|----------------------------------------------------------------|----------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------|
| Pressure measuring device<br>(Gas medium)              | 1 psi to 100 psi<br>101 psi to 1600 psi                        | 0.02 % of pressure<br>0.02 % of pressure                                               | Comparison with Dead<br>Weight Tester based on<br>BS EN 837-1: 1998 and<br>837-2, 837-3: 1998<br>ADWT<br>ADWT       |
| Pressure measuring device<br>(Oil and water medium)    | 10 psi to 800 psi<br>801 psi to 16000 psi                      | 0.02 % of pressure<br>0.02 % of pressure                                               | DWT<br>DWT                                                                                                          |
|                                                        | 16 0001 psi to 40000 psi                                       | 0.02 % of pressure                                                                     | Based on<br>BS EN 837-1: 1998<br>BS EN 837-3: 1998                                                                  |
| Vacuum gauge                                           | Ambient to<br>-0.9 bar (Gauge mode)<br>0.1 bar (Absolute mode) | 0.1 % of pressure                                                                      | Mercury Manometer                                                                                                   |
| Low Pressure Measuring<br>Devices<br>Mercury Manometer | 0 to 1500 mm Hg                                                | 0.02 % of pressure                                                                     | Digital Manometer<br>Reference Pressure<br>Balance                                                                  |
| Deadweight Tester                                      | 10 psi to 40 000 psi                                           | 0.02 % of pressure                                                                     | Cross float method<br>OIML R110 1994(E)<br>NCSL RISP-4 2000<br>EAL G26/EA-4/17 JULY<br>1997<br><br>Pressure Balance |

Note: ADWT (Air Dead Weight Tester)  
DWT (Dead Weight Tester)**Signatories:**

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**SCOPE OF CALIBRATION: PRESSURE****SITE CALIBRATION: CATEGORY I**

| Instrument Calibrated/<br>Measurement Parameter | Range                                                                                                                                                                     | Calibration and<br>Measurement Capability<br>Expressed as an<br>Uncertainty ( $\pm$ )*                                                                               | Remarks                                                        |
|-------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------|
| Pressure measuring device<br>(Oil medium)       | 0 psi to 500 psi<br>0 psi to 1000 psi<br>0 psi to 3000 psi<br>0 psi to 4500 psi<br>0 psi to 7500 psi<br>0 psi to 10 000 psi<br>0 psi to 12 000 psi<br>0 psi to 16 000 psi | 0.7 % of pressure<br>0.7 % of pressure<br>0.6 % of pressure<br>0.4 % of pressure<br>0.4 % of pressure<br>0.7 % of pressure<br>0.6 % of pressure<br>0.6 % of pressure | BS EN 837-1: 1998<br>BS EN 837-3: 1998<br><br>Pressure Balance |
| Vacuum Measuring<br>Devices                     | Ambient to<br>-0.9 bar (Gauge mode)<br>0.1 bar (Absolute mode)                                                                                                            | 1.0 % of pressure                                                                                                                                                    | Pressure Calibrator<br>BS EN 837-1: 1998<br>BS EN 837-3: 1998  |
| Pressure Gauge                                  | 0 bar to 20 bar                                                                                                                                                           | 0.5 % of pressure                                                                                                                                                    | Pressure Calibrator<br>BS EN 837-1: 1998<br>BS EN 837-3: 1998  |

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**SCOPE OF CALIBRATION: VOLUMETRIC**

| Instrument Calibrated/<br>Measurement Parameter | Range                                                                                                                                                                                                                                                          | Calibration and<br>Measurement<br>Capability Expressed<br>as an Uncertainty ( $\pm$ )*                                               | Remarks                                               |
|-------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------|
| Bulb Pipette                                    | 1 ml to 5 ml<br>5 ml to 100 ml                                                                                                                                                                                                                                 | 0.008 ml<br>0.03 ml                                                                                                                  | Cal. Procedure No<br>TCP 0002 REV2.0<br>Ref: ISO 4787 |
| Graduated Pipette                               | 1 ml to 5 ml<br>5 ml to 100 ml                                                                                                                                                                                                                                 | 0.008 ml<br>0.03 ml                                                                                                                  | Cal. Procedure No<br>TCP 0002 REV2.0<br>Ref: ISO 4787 |
| Measuring Cylinder                              | 5 ml to 100 ml<br>100 ml to 500 ml<br>500 ml to 1000 ml<br>1000 ml to 2000 ml                                                                                                                                                                                  | 0.05 ml<br>0.5 ml<br>2.0 ml<br>3.0 ml                                                                                                | Cal. Procedure No<br>TCP 0001 REV2.0<br>Ref: ISO 4787 |
| Burette                                         | 1 ml to 50 ml                                                                                                                                                                                                                                                  | 0.05 ml                                                                                                                              | Cal. Procedure No<br>TCP 0003 REV2.0<br>Ref: ISO 4787 |
| Beaker & Flasks                                 | 5 ml to 100 ml<br>100 ml to 1000 ml<br>1000 ml to 2000 ml                                                                                                                                                                                                      | 1.0 ml<br>3.0 ml<br>5.0 ml                                                                                                           | Cal. Procedure No<br>TCP 0004 REV2.0<br>Ref: ISO 4787 |
| Piston-operated Volumetric<br>apparatus         | 10 $\mu$ l to 20 $\mu$ l<br>20 $\mu$ l to 50 $\mu$ l<br>50 $\mu$ l to 100 $\mu$ l<br>100 $\mu$ l to 200 $\mu$ l<br>200 $\mu$ l to 500 $\mu$ l<br>500 $\mu$ l to 1000 $\mu$ l<br>1000 $\mu$ l to 5000 $\mu$ l<br>5000 $\mu$ l to 10000 $\mu$ l<br>10000 $\mu$ l | 0.03 $\mu$ l<br>0.09 $\mu$ l<br>0.15 $\mu$ l<br>0.4 $\mu$ l<br>0.8 $\mu$ l<br>1.8 $\mu$ l<br>3.5 $\mu$ l<br>20 $\mu$ l<br>40 $\mu$ l | No.TCP/0005 REV.0.0<br>Based on ISO 8655-<br>6:2002   |

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**SCOPE OF CALIBRATION: HYDROMETER**

| Instrument Calibrated/<br>Measurement Parameter | Range                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Calibration and<br>Measurement Capability<br>Expressed as an<br>Uncertainty ( $\pm$ )* | Remarks                             |
|-------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|-------------------------------------|
| Density Hydrometer                              | 0.600 g/ml to 0.650 g/ml<br>0.650 g/ml to 0.700 g/ml<br><br>0.700 g/ml to 0.750 g/ml<br>0.750 g/ml to 0.800 g/ml<br><br>0.800 g/ml to 0.850 g/ml<br>0.850 g/ml to 0.900 g/ml<br><br>0.900 g/ml to 0.950 g/ml<br>0.950 g/ml to 1.000 g/ml<br><br>1.000 g/ml to 1.050 g/ml<br>1.050 g/ml to 1.100 g/ml<br><br>1.100 g/ml to 1.150 g/ml<br>1.150 g/ml to 1.200 g/ml<br><br>1.200 g/ml to 1.250 g/ml<br>1.250 g/ml to 1.300 g/ml<br><br>1.300 g/ml to 1.350 g/ml<br>1.350 g/ml to 1.400 g/ml<br><br>1.400 g/ml to 1.450 g/ml<br>1.450 g/ml to 1.500 g/ml | 0.001 g/ml<br>(resolution 0.0005 g/ml)                                                 | Comparison<br>Method<br>BS 718:1991 |

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**SCOPE OF CALIBRATION:****HYDROMETER**

| Instrument Calibrated/<br>Measurement Parameter             | Range                                                                                                                                                                                  | Calibration and<br>Measurement Capability<br>Expressed as an<br>Uncertainty ( $\pm$ )* | Remarks                                                             |
|-------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|---------------------------------------------------------------------|
| <b>Temperature</b><br><br>1. Specific Gravity<br>Hydrometer | 0.6 to 0.65<br>0.65 to 0.7<br>0.7 to 0.75<br>0.75 to 0.8<br>0.8 to 0.85<br>0.85 to 0.9<br>0.9 to 0.95<br>0.95 to 1<br>1 to 1.1<br>1.1 to 1.2<br>1.2 to 1.3<br>1.3 to 1.4<br>1.4 to 1.5 | 0.001<br>(resolution 0.0005)                                                           | Cal. Procedure No.<br>MDL 0002 Rev.1.0<br>Reference: BS<br>718:1991 |

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**SCOPE OF CALIBRATION:****ACOUSTIC & VIBRATION**

| Instrument Calibrated/<br>Measurement Parameter           | Range                                                                                                                                                                                 | Calibration and<br>Measurement Capability<br>Expressed as an<br>Uncertainty ( $\pm$ )* | Remarks                                                                                                                                                                              |
|-----------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Measuring Instrument<br><br>Sound Level Meter             | Nominal SPL<br>94 dB, 104 dB & 114 dB<br>Reference<br>94 dB re 20 $\mu$ Pa at 1 kHz<br><br>31.5 Hz to 1600 Hz<br><br>124 dB<br>(at 250Hz)<br><br>(54 to 134) dB<br>(31.5 to 12500) Hz | <br><br><br><br>0.11 dB<br><br>0.21 dB<br><br>0.13 dB                                  | Generating using<br>Briel & Kjaer 4226<br><br><br>Generating using<br>Briel & Kjaer 4228<br><br>Electrical Signal<br>Injection from<br>signal operator<br>Agilent 33220A             |
| Sourcing/Generating<br>Instrument<br><br>Sound Calibrator | Nominal SPL<br>94dB, 104 dB & 114 dB<br>Reference<br>94 dB re 20 $\mu$ Pa at 1 kHz<br><br>31.5 Hz to 1600 Hz<br><br>124 dB<br>(at 250Hz)                                              | <br><br><br><br>0.11 dB<br><br>0.21 dB                                                 | Comparison with<br>reference<br>Calibrator Briel &<br>Kjaer 4226 and<br>Agilent 34401A<br><br>Comparison with<br>reference<br>Calibrator Briel &<br>Kjaer 4228 and<br>Agilent 34401A |

Scan this QR Code or visit [www.jsm.gov.my/cab-directories](http://www.jsm.gov.my/cab-directories) for the current scope of accreditation**Signatories:**

- \*\*Mohamed Fikri Bin Mohd Nor**
- Syahrel Bin Shari**

\*\* Non-resident signatory

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**SCOPE OF CALIBRATION: ACOUSTIC & VIBRATION****SCOPE OF ACCREDITATION: CATEGORY I**

| Instrument Calibrated/<br>Measurement Parameter           | Range                                                                                                                                                                                 | Calibration and<br>Measurement Capability<br>Expressed as an<br>Uncertainty ( $\pm$ )* | Remarks                                                                                                                                                                                              |
|-----------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Measuring Instrument<br><br>Sound Level Meter             | Nominal SPL<br>94 dB, 104 dB & 114 dB<br>Reference<br>94 dB re 20 $\mu$ Pa at 1 kHz<br><br>31.5 Hz to 1600 Hz<br><br>124 dB<br>(at 250Hz)<br><br>(54 to 134) dB<br>(31.5 to 12500) Hz | <br><br><br><br>0.11 dB<br><br>0.21 dB<br><br>0.13 dB                                  | <br><br><br>Generating using<br>Briel & Kjaer 4226<br><br><br>Generating using<br>Briel & Kjaer 4228<br><br>Electrical Signal<br>Injection from<br>signal operator<br>Agilent 33220A                 |
| Sourcing/Generating<br>Instrument<br><br>Sound Calibrator | Nominal SPL<br>94dB, 104 dB & 114 dB<br>Reference<br>94 dB re 20 $\mu$ Pa at 1 kHz<br><br>31.5 Hz to 1600 Hz<br><br>124 dB<br>(at 250Hz)                                              | <br><br><br><br>0.11 dB<br><br>0.21 dB                                                 | <br><br><br>Comparison with<br>reference<br>Calibrator Briel &<br>Kjaer 4226 and<br>Agilent 34401A<br><br><br>Comparison with<br>reference<br>Calibrator Briel &<br>Kjaer 4228 and<br>Agilent 34401A |

**Signatories:**

- \*\*Mohamed Fikri Bin Mohd Nor**
- Syahrel Bin Shari**

\*\* Non-resident signatory

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**LABORATORY LOCATION:**  
(BRANCH LABORATORY)**SIRIM STANDARDS TECHNOLOGY SDN. BHD.**  
(Company No.: 292201-P)  
**BANGUNAN SIRIM BERHAD,**  
**JALAN PINTASAN KUANTAN– KUALA TERENGGANU,**  
**KAWASAN PERINDUSTRIAN GEBENG**  
**26100 KUANTAN.**  
**PAHANG DARUL MAKMUR.**  
**MALAYSIA****FEILDS OF CALIBRATION:** ELECTRICAL & PRESSURE**SCOPE OF CALIBRATION:** ELECTRICAL

| Instrument Calibrated/<br>Measurement Parameter     | Range                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Calibration and<br>Measurement Capability<br>Expressed as an<br>Uncertainty ( $\pm$ )*                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Remarks                                            |
|-----------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------|
| 1.Measuring Instruments<br>(a) DC Voltage ( $\pm$ ) | 0 mV to 330 mV<br>0 V to 3.3 V<br>0 V to 33 V<br>30 V to 330 V<br>100 V to 1020 V                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 22 $\mu$ V/V + 1.8 $\mu$ V<br>11 $\mu$ V/V + 9.9 $\mu$ V<br>12 $\mu$ V/V + 96 $\mu$ V<br>23 $\mu$ V/V + 0.98 mV<br>23 $\mu$ V/V + 5.4 mV                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Generate using<br>calibrator model<br>Fluke 5522 A |
| (b) Resistance                                      | 0 $\Omega$ to 11 $\Omega$<br>11 $\Omega$ to 33 $\Omega$<br>33 $\Omega$ to 110 $\Omega$<br>110 $\Omega$ to 330 $\Omega$<br>330 $\Omega$ to 1.1 k $\Omega$<br>1.1 k $\Omega$ to 3.3 k $\Omega$<br>3.3 k $\Omega$ to 11 k $\Omega$<br>11 k $\Omega$ to 33 k $\Omega$<br>33 k $\Omega$ to 110 k $\Omega$<br>110 k $\Omega$ to 330 k $\Omega$<br>330 k $\Omega$ to 1.1 M $\Omega$<br>1.1 M $\Omega$ to 3.3 M $\Omega$<br>3.3 M $\Omega$ to 11 M $\Omega$<br>11 M $\Omega$ to 33 M $\Omega$<br>33 M $\Omega$ to 110 M $\Omega$<br>110 M $\Omega$ to 330 M $\Omega$<br>330 M $\Omega$ to 1100 M $\Omega$ | 47 $\mu$ $\Omega$ / $\Omega$ + 1.2 m $\Omega$<br>35 $\mu$ $\Omega$ / $\Omega$ + 1.7 m $\Omega$<br>33 $\mu$ $\Omega$ / $\Omega$ + 1.6 m $\Omega$<br>32 $\mu$ $\Omega$ / $\Omega$ + 2.3 m $\Omega$<br>13 $\mu$ $\Omega$ / $\Omega$ + 54 m $\Omega$<br>11 $\mu$ $\Omega$ / $\Omega$ + 0.55 $\Omega$<br>32 $\mu$ $\Omega$ / $\Omega$ + 28 m $\Omega$<br>29 $\mu$ $\Omega$ / $\Omega$ + 0.41 $\Omega$<br>32 $\mu$ $\Omega$ / $\Omega$ + 0.3 $\Omega$<br>37 $\mu$ $\Omega$ / $\Omega$ + 2.4 $\Omega$<br>36 $\mu$ $\Omega$ / $\Omega$ + 3.7 $\Omega$<br>69 $\mu$ $\Omega$ / $\Omega$ + 35 $\Omega$<br>0.15 m $\Omega$ / $\Omega$ + 61 $\Omega$<br>0.29 m $\Omega$ / $\Omega$ + 2.8 k $\Omega$<br>0.59 m $\Omega$ / $\Omega$ + 4.6 k $\Omega$<br>3.5 m $\Omega$ / $\Omega$ + 0.11 M $\Omega$<br>17 m $\Omega$ / $\Omega$ + 5.7 M $\Omega$ |                                                    |
| (b) Resistance                                      | 0.100 $\Omega$ to 0.110 $\Omega$<br>0.110 $\Omega$ to 0.200 $\Omega$<br>0.100 $\Omega$ to 1.100 $\Omega$<br>1.100 $\Omega$ to 10.100 $\Omega$<br>10.100 $\Omega$ to 100.100 $\Omega$<br>100.100 $\Omega$ to 1000.100 $\Omega$                                                                                                                                                                                                                                                                                                                                                                     | 0.12 m $\Omega$ / $\Omega$ + 2.3 m $\Omega$<br>0.12 m $\Omega$ / $\Omega$ + 2.3 m $\Omega$<br>0.12 m $\Omega$ / $\Omega$ + 2.3 m $\Omega$<br>0.12 m $\Omega$ / $\Omega$ + 2.3 m $\Omega$<br>0.12 m $\Omega$ / $\Omega$ + 2.3 m $\Omega$<br>0.12 m $\Omega$ / $\Omega$ + 2.3 m $\Omega$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                    |

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**SCOPE OF CALIBRATION: ELECTRICAL**

| Instrument Calibrated/<br>Measurement Parameter            | Range                                                                                                                                                                                                                                                                                                                                                                                                                  | Calibration and<br>Measurement Capability<br>Expressed as an<br>Uncertainty ( $\pm$ )*                                                                                                                                                                                                                                                                                                                            | Remarks                                            |
|------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------|
| 1. Measuring Instruments<br>(continued)<br>(c) Capacitance | 220 pF to 400 pF<br>0.4 nF to 1.1 nF<br>1.1 nF to 3.3 nF<br>3.3 nF to 11 nF<br>11 nF to 33 nF<br>33 nF to 110 nF<br>110 nF to 330 nF<br>0.33 $\mu$ F to 1.1 $\mu$ F<br>1.1 $\mu$ F to 3.3 $\mu$ F<br>3.3 $\mu$ F to 11 $\mu$ F<br>11 $\mu$ F to 33 $\mu$ F<br>33 $\mu$ F to 110 $\mu$ F<br>110 $\mu$ F to 330 $\mu$ F<br>0.33 mF to 1.1 mF<br>1.1 mF to 3.3 mF<br>3.3 mF to 11 mF<br>11 mF to 33 mF<br>33 mF to 110 mF | 5.7 $\mu$ F/F + 12 pF<br>5.5 mF/F + 13 pF<br>5.8 mF/F + 12 pF<br>2.9 mF/F + 12 pF<br>3.4 mF/F + 6.8 pF<br>2.9 mF/F + 20 pF<br>2.9 mF/F + 58 pF<br>2.9 mF/F + 1.2 nF<br>2.9 mF/F + 3.5 nF<br>2.9 mF/F + 12 nF<br>4.5 mF/F + 38 nF<br>5.2 mF/F + 0.13 $\mu$ F<br>5.1 mF/F + 0.35 $\mu$ F<br>5.2 mF/F + 1.2 $\mu$ F<br>5.2 mF/F + 3.4 $\mu$ F<br>5.7 mF/F + 17 $\mu$ F<br>8.5 mF/F + 35 $\mu$ F<br>13 mF/F + 0.12 mF | Generate using<br>calibrator model<br>Fluke 5522 A |
| (d) AC Voltage<br>(See Matrix A)                           | <u>0 mV to 1020 V</u><br>See Matrix A                                                                                                                                                                                                                                                                                                                                                                                  | See Matrix A                                                                                                                                                                                                                                                                                                                                                                                                      |                                                    |
| (e) DC Current ( $\pm$ )                                   | 0 $\mu$ A to 330 $\mu$ A<br>0 mA to 3.3 mA<br>0 mA to 33 mA<br>0 mA to 330 mA<br>0 A to 1.1 A<br>1.1 A to 3 A<br>0 A to 11 A<br>11 A to 20.5 A                                                                                                                                                                                                                                                                         | 0.18 mA/A + 23 nA<br>0.12 mA/A + 58 nA<br>0.12 mA/A + 0.32 $\mu$ A<br>0.12 mA/A + 3.0 $\mu$ A<br>0.23 mA/A + 50 $\mu$ A<br>0.43 mA/A + 57 $\mu$ A<br>0.55 mA/A + 0.91 mA<br>1.2 mA/A + 1.1 mA                                                                                                                                                                                                                     | Generate using<br>calibrator model<br>Fluke 5522 A |
| (f) AC Current<br>(See Matrix B)                           | See Matrix B                                                                                                                                                                                                                                                                                                                                                                                                           | See Matrix B                                                                                                                                                                                                                                                                                                                                                                                                      |                                                    |

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**FIELD OF CALIBRATION: ELECTRICAL**

| Instrument Calibrated/<br>Measurement Parameter     | Range                                                                     | Calibration and<br>Measurement Capability<br>Expressed as an<br>Uncertainty ( $\pm$ )* | Remarks                                                                                    |
|-----------------------------------------------------|---------------------------------------------------------------------------|----------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------|
| 1. Measuring Instruments<br>(continued)             |                                                                           |                                                                                        |                                                                                            |
| (g). Clamp Meters<br>DC Current via<br>Current Coil | 10 A to 16.5 A<br>16.5 A to 150 A<br>150 A to 1025 A                      | 2.8 mA/A + 4.2 mA<br>4.3 mA/A - 54 mA<br>2.9 mA/A + 37 mA                              | Generate using<br>Calibrator Fluke<br>5522A with<br>Fluke 5500<br>A/Coil (50-Turn<br>Coil) |
| AC Current via<br>Current Coil                      | (45 Hz to 65 Hz)<br>10 A to 16.5 A<br>16.5 A to 150 A<br>150 A to 1025 A  | 2.7 mA/A + 19 mA<br>3.1 mA/A + 43 mA<br>3.1 mA/A + 0.23 A                              |                                                                                            |
|                                                     | (65 Hz to 440 Hz)<br>10 A to 16.5 A<br>16.5 A to 150 A<br>150 A to 1025 A | 8.8 mA/A + 9.6 mA<br>9.0 mA/A + 31 mA<br>8.9 mA/A + 0.17 A                             |                                                                                            |
| (h). Power Meters<br>DC Power Energy                | 0.1 W to 1 kW<br>1 kW to 20 kW                                            | 0.25 mW/W + 0.18 mW<br>0.80 mW/W - 1.7 mW                                              | Generate using<br>Fluke 5522A                                                              |
| AC Power Energy                                     | (45 Hz to 65 Hz, PF=1)<br>0.1 W to 1 W<br>1 W to 10 kW<br>10 kW to 20 kW  | 0.2 mW/W + 23 mW<br>1.2 mW/W + 7.2 mW<br>1.2 mW/W + 31 mW                              |                                                                                            |
| (i) Time                                            | 1 s to 24 Hrs                                                             | 0.83 ps/s + 29 ms                                                                      | Agilent 33220A<br>& Fluke PM<br>6680B Timer<br>Counter<br>Analyzer                         |
| (j). Frequency                                      | 1 $\mu$ Hz to 20 MHz                                                      | 2.3 $\mu$ Hz/Hz + 2.1 $\mu$ Hz                                                         | Generate using<br>Agilent 33220A<br>Function /<br>Arbitrary<br>Waveform<br>Generator       |
|                                                     | 250 kHz – 2 GHz                                                           | 2 $\mu$ Hz/Hz + 2.9 mHz                                                                | Generate using<br>Agilent E4420B<br>ESG Series<br>Signal<br>Generator                      |

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**SCOPE OF CALIBRATION: ELECTRICAL**

| Instrument Calibrated/<br>Measurement Parameter | Range                                                             | Calibration and<br>Measurement Capability<br>Expressed as an<br>Uncertainty ( $\pm$ )* | Remarks                                                                                             |
|-------------------------------------------------|-------------------------------------------------------------------|----------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------|
| 1. Measuring Instruments<br>(continued)         |                                                                   |                                                                                        |                                                                                                     |
| (k). Time Base Input                            | 10 MHz                                                            | 1 $\mu$ Hz/Hz                                                                          | Generate using<br>Agilent E4420B<br>ESG Series<br>Signal<br>Generator<br>(Rear Time<br>Base Output) |
| (l). Amplitude                                  | 10 mVpp to 10 Vpp<br>(1 $\mu$ Hz to 20 MHz,<br>Into 50 $\Omega$ ) | 12 mVpp/Vpp + 1.1 mVpp                                                                 | Generate using<br>Agilent 33220A<br>Function/<br>Arbitrary<br>Waveform<br>Generator                 |
|                                                 | 20 mVpp to 20 Vpp<br>(1 $\mu$ Hz to 20 MHz,<br>Into open circuit) | 11 mVpp/Vpp + 9.5 mVpp                                                                 |                                                                                                     |
|                                                 | +7 to -120 dBm<br>(250 kHz to 2 GHz)                              | -0.02 dBm/dBm + 0.06 dBm                                                               | Generate using<br>Agilent E4420B<br>ESG Series<br>Signal<br>Generator                               |
| (m) Modulation                                  |                                                                   |                                                                                        |                                                                                                     |
| AM Depth Calibration factor                     | 33.33 % nominal                                                   | 0.06 %                                                                                 | Generate using<br>HP 8901A<br>(Calibration<br>Output)                                               |
| FM Deviation Calibration<br>factor              | 340 kHz peak nominal                                              | 0.08 kHz                                                                               |                                                                                                     |
| (n) RPM Measuring<br>Instruments (Non-Contact)  | 60 rpm to 999.99 rpm                                              | 17 $\mu$ rpm/rpm + 8.4 mrpm                                                            | In-House<br>method,<br>ESF/0303                                                                     |
|                                                 | 1000.0 rpm to 9999.9 rpm                                          | 17 $\mu$ rpm/rpm + 84 mrpm                                                             |                                                                                                     |
|                                                 | 10000 rpm to 99999 rpm                                            | 17 $\mu$ rpm/rpm + 0.84 rpm                                                            |                                                                                                     |

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**SCOPE OF CALIBRATION: ELECTRICAL**

| Instrument Calibrated/<br>Measurement Parameter             | Range                                                  | Calibration and<br>Measurement Capability<br>Expressed as an<br>Uncertainty ( $\pm$ )* | Remarks                                                                 |
|-------------------------------------------------------------|--------------------------------------------------------|----------------------------------------------------------------------------------------|-------------------------------------------------------------------------|
| 1. Measuring Instruments<br>(continued)                     |                                                        |                                                                                        |                                                                         |
| (o). Oscilloscope<br>Vertical Deflection<br>DC Signal       | 0 V to $\pm 6.6$ V<br>(50 $\Omega$ Load)               | 2.8 mV/V + 0.48 mV                                                                     | Generating<br>using calibrator<br>model Fluke<br>5500A SC600            |
|                                                             | 0 V to $\pm 130$ V<br>(1 M $\Omega$ Load)              | 0.56 mV/V + 0.48 mV                                                                    |                                                                         |
| Vertical Deflection<br>Square Wave Signal                   | $\pm 1$ mVp-p to<br>$\pm 6.6$ Vp-p (50 $\Omega$ Load)  | 2.8 mVp-p/Vp-p + 0.48 mVp-p                                                            |                                                                         |
|                                                             | $\pm 1$ mVp-p to $\pm 130$ Vp-p<br>(1 M $\Omega$ Load) | 1.2 mVp-p/Vp-p + 0.47 mVp-p                                                            |                                                                         |
| Horizontal Deflection Time<br>Markers<br>(50 $\Omega$ Load) | 2 ns/div to 20 ms/div<br>50 ms/div to 5 s/div          | 73 ps/s + 12 ns<br>5.5 ms/s + 0.39 ms                                                  |                                                                         |
| Risetime                                                    | 1 kHz to 10 MHz<br>10 mV to 2.5 V                      | 7.9 ns/s + 7.2 ps                                                                      | Generate using<br>Agilent E4420B<br>ESG Series<br>Signal<br>Generator   |
| Bandwidth Frequency                                         | 50 kHz to 600 MHz<br>(5 mV to 5.5 V)                   | 2 mHz/Hz + 1.4 MHz                                                                     |                                                                         |
|                                                             | 250 kHz – 2 GHz<br>(+7 to –120 dBm)                    | 2 nHz/Hz + 1.4 MHz                                                                     |                                                                         |
| Bandwidth Amplitude                                         | 5 mV to 5.5 V<br>(50 kHz to 600 MHz)                   | 0.41 mVp-p/Vp-p + 0.34 Vp-p                                                            | Generating<br>using calibrator<br>model Fluke<br>5500A SC600            |
|                                                             | +7 to –120 dBm<br>(250 kHz – 2 GHz)                    | 0.26 Vp-p                                                                              | Generating<br>using Agilent<br>E4420B ESG<br>Series Signal<br>Generator |

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**SCOPE OF CALIBRATION: ELECTRICAL**

| Instrument Calibrated/<br>Measurement Parameter | Range                                                | Calibration and<br>Measurement Capability<br>Expressed as an<br>Uncertainty ( $\pm$ )* | Remarks      |
|-------------------------------------------------|------------------------------------------------------|----------------------------------------------------------------------------------------|--------------|
| 1. Measuring Instruments<br>(continued)         |                                                      |                                                                                        |              |
| (p) Insulation Testers                          | (1.0 k $\Omega$ to 10.0 k $\Omega$ )<br>@ 10.0 V     | 1.2 m $\Omega/\Omega$ + 0.14 $\Omega$                                                  | Tinsley 4720 |
|                                                 | (10.0 k $\Omega$ to 100.0 k $\Omega$ )<br>@ 50.0 V   | 1.2 m $\Omega/\Omega$ + 1.4 $\Omega$                                                   |              |
|                                                 | (0.1 M $\Omega$ to 1.0 M $\Omega$ )<br>@ 150.0 V     | 0.94 m $\Omega/\Omega$ + 0.49 k $\Omega$                                               |              |
|                                                 | (1.0 M $\Omega$ to 10.0 M $\Omega$ )<br>@ 300.0 V    | 1.2 m $\Omega/\Omega$ + 0.14 k $\Omega$                                                |              |
|                                                 | (10.0 M $\Omega$ to 100.0 M $\Omega$ )<br>@ 500.0 V  | 1.3 m $\Omega/\Omega$ + 0.38 k $\Omega$                                                |              |
|                                                 | (0.1 G $\Omega$ to 1.0 G $\Omega$ )<br>@ 1000.0 V    | 13 m $\Omega/\Omega$ - 0.20 M $\Omega$                                                 |              |
|                                                 | (1.0 G $\Omega$ to 10.0 G $\Omega$ )<br>@ 5000.0 V   | 1.5 m $\Omega/\Omega$ - 1.9 M $\Omega$                                                 |              |
|                                                 | (10.0 G $\Omega$ to 100.0 G $\Omega$ )<br>@ 5000.0V  | 29 m $\Omega/\Omega$ - 0.43 G $\Omega$                                                 |              |
|                                                 | (100.0 G $\Omega$ to 500.0 G $\Omega$ )<br>@ 5000.0V | 40 m $\Omega/\Omega$ - 0.36 G $\Omega$                                                 |              |

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**SCOPE OF CALIBRATION: ELECTRICAL**

Matrix A

AC Voltage Measurement. Generate using calibrator model Fluke 5522 A

| Range                 | Frequency            |                      |                      |                       |                       |                       |                        |                        |                         |                          |
|-----------------------|----------------------|----------------------|----------------------|-----------------------|-----------------------|-----------------------|------------------------|------------------------|-------------------------|--------------------------|
|                       | 10 Hz<br>to<br>45 Hz | 45 Hz<br>to<br>1 kHz | 1 kHz<br>to<br>5 kHz | 5 kHz<br>to<br>10 kHz | 45 Hz<br>to<br>10 kHz | 1 kHz<br>to<br>10 kHz | 10 kHz<br>to<br>20 kHz | 20 kHz<br>to<br>50 kHz | 50 kHz<br>to<br>100 kHz | 100 kHz<br>to<br>500 kHz |
| 1 mV<br>to<br>33 mV   | 1.9 +<br>0.11        | -                    | -                    | -                     | 0.41 +<br>0.11        | -                     | 0.7 +<br>0.11          | 1.9 +<br>0.11          | 4.4 +<br>0.099          | 9.2 +<br>0.12            |
| 33 mV<br>to<br>330 mV | 1.8 +<br>0.11        | -                    | -                    | -                     | 0.43 +<br>0.11        | -                     | 0.71 +<br>0.11         | 1.8 +<br>0.11          | 2.5 +<br>0.11           | 3.2 +<br>0.13            |
| 0.33 V<br>to<br>3.3 V | 1.8 +<br>0.24        | -                    | -                    | -                     | 0.44 +<br>0.24        | -                     | 0.72 +<br>0.24         | 1.8 +<br>0.25          | 2.5 +<br>0.20           | 3.5 +<br>0.69            |
| 3.3 V<br>to<br>33 V   | 1.8 +<br>3.2         | -                    | -                    | -                     | 0.43 +<br>2.5         | -                     | 1.1 +<br>0.98          | 2.3 +<br>2.5           | 5.8 +<br>2.7            | -                        |
| 33 V<br>to<br>330 V   | -                    | 1.2 +<br>12          | -                    | -                     | -                     | 0.61 +<br>14          | 6.8 + 12               | 9.1 + 13               | 12 + 26                 | -                        |
| 330 V<br>to<br>1020 V | -                    | 1.8 +<br>36          | 0.85 +<br>37         | 0.87 +<br>37          | -                     | -                     | -                      | -                      | -                       | -                        |

The expanded uncertainties given in this table are expressed in mV/V + mV, unless otherwise stated.

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**SCOPE OF CALIBRATION: ELECTRICAL**

Matrix B:

AC Current Measurement. Generate using calibrator model Fluke 5522 A

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| Range                        | Frequency            |                          |                      |                         |                           |                         |                      |                          |                         |
|------------------------------|----------------------|--------------------------|----------------------|-------------------------|---------------------------|-------------------------|----------------------|--------------------------|-------------------------|
|                              | 10 Hz<br>to<br>20 Hz | 10 Hz<br>to<br>45 Hz     | 20 Hz<br>to<br>45 Hz | 45 Hz<br>to<br>100 Hz   | 45 Hz<br>to<br>1 kHz      | 100 Hz<br>to<br>1 kHz   | 1 kHz<br>to<br>5 kHz | 5 kHz<br>to<br>10 kHz    | 10 kHz<br>to<br>30kHz   |
| 29 $\mu$ A to<br>330 $\mu$ A | 2.6 +<br>0.56        | -                        | 1.8 +<br>0.57        | -                       | 1.2 +<br>0.57             | -                       | 6.6 + 0.59           | 15 + 0.6                 | 23 +<br>0.72            |
| 0.33 mA to<br>3.3 mA         | 2.8 +<br>1.5         | -                        | 1.5 +<br>1.5         | -                       | 0.94 +<br>1.5             | -                       | 6.1 + 1.7            | 13 + 1.7                 | 19 +<br>0.89            |
| 3.3 mA to<br>33 mA           | 2.7 +<br>6.4         | -                        | 1.2 +<br>6.1         | -                       | 0.95 +<br>6.3             | -                       | 3.6 + 6.1            | 8.5 +<br>6.5             | 13 + 2.5                |
| 33 mA<br>to<br>330 mA        | 2.7 +<br>63          | -                        | 1.2 + 59             | -                       | 0.49 +<br>59              | -                       | 1.2 + 78             | 2.6<br>mA/A +<br>0.13 mA | 8.1<br>mA/A +<br>0.2 mA |
| 0.33 A<br>to<br>1.1A         | -                    | 3.0<br>mA/A +<br>0.59 mA | -                    | -                       | 0.98<br>mA/A +<br>0.58 mA | -                       | 14 mA/A<br>+ 1.2 mA  | 37 mA/A<br>+ 5.2<br>mA   | -                       |
| 1.1 A to 3 A                 | -                    | 3.1<br>mA/A +<br>0.53 mA | -                    | -                       | 1.1<br>mA/A +<br>0.57 mA  | -                       | 14 mA/A<br>+ 1.2 mA  | 37 mA/A<br>+ 5.0<br>mA   | -                       |
| 3 A to 11 A                  | -                    | -                        | -                    | 2.4<br>mA/A +<br>4.4 mA | -                         | 1.6<br>mA/A +<br>4.2 mA | 36 mA/A<br>+ 3.3 mA  | -                        | -                       |
| 11 A to<br>20.5 A            | -                    | -                        | -                    | -                       | -                         | 2.7<br>mA/A +<br>6.1 mA | 2.7 mA/A<br>+ 7.1 mA | -                        | -                       |

The expanded uncertainties given in this table are expressed in mA/A+  $\mu$ A, unless otherwise stated.

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**SCOPE OF CALIBRATION:****ELECTRICAL**

| Instrument Calibrated/<br>Measurement Parameter | Range                                                                        | Calibration and<br>Measurement Capability<br>Expressed as an<br>Uncertainty ( $\pm$ )* | Remarks                                                                |
|-------------------------------------------------|------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|------------------------------------------------------------------------|
| 1. Generating Instruments                       |                                                                              |                                                                                        |                                                                        |
| (a) DC Voltage                                  | $\pm 100$ mV Range<br>$\pm (100 \mu\text{V to } 120 \text{ mV})$             | $4.4 \mu\text{V/V} + 0.7 \mu\text{V}$                                                  | Measure using<br>8 ½ Digit<br>Multimeter<br>Keysight 3458A<br>Opt. 002 |
|                                                 | $\pm 1$ V Range<br>$\pm (0.1 \text{ V to } 1.2 \text{ V})$                   | $3.6 \mu\text{V/V} + 1.9 \mu\text{V}$                                                  |                                                                        |
|                                                 | $\pm 10$ V Range<br>$\pm (1 \text{ V to } 12 \text{ V})$                     | $4.7 \mu\text{V/V} + 2.6 \mu\text{V}$                                                  |                                                                        |
|                                                 | $\pm 100$ V Range<br>$\pm (10 \text{ V to } 120 \text{ V})$                  | $6.1 \mu\text{V/V} + 0.16 \text{ mV}$                                                  |                                                                        |
|                                                 | $\pm 1000$ V Range<br>$\pm (100 \text{ V to } 1050 \text{ V})$               | $6.1 \mu\text{V/V} + 1.5 \text{ mV}$                                                   |                                                                        |
| (b) DC Current                                  | $\pm 100$ nA Range,<br>$\pm (1 \text{ nA to } 120 \text{ nA})$               | $34 \mu\text{A/A} + 47 \text{ pA}$                                                     |                                                                        |
|                                                 | $\pm 1$ $\mu\text{A}$ Range<br>$\pm (0.1 \mu\text{A to } 1.2 \mu\text{A})$   | $24 \mu\text{A/A} + 47 \text{ pA}$                                                     |                                                                        |
|                                                 | $\pm 10$ $\mu\text{A}$ Range,<br>$\pm (1 \mu\text{A to } 12 \mu\text{A})$    | $25 \mu\text{A/A} + 0.12 \text{ nA}$                                                   |                                                                        |
|                                                 | $\pm 100$ $\mu\text{A}$ Range,<br>$\pm (10 \mu\text{A to } 120 \mu\text{A})$ | $19 \mu\text{A/A} + 2.1 \text{ nA}$                                                    |                                                                        |
|                                                 | $\pm 1$ mA Range,<br>$\pm (0.1 \text{ mA to } 1.2 \text{ mA})$               | $22 \mu\text{A/A} + 11 \text{ nA}$                                                     |                                                                        |
|                                                 | $\pm 10$ mA Range<br>$\pm (1 \text{ mA to } 12 \text{ mA})$                  | $22 \mu\text{A/A} + 0.11 \mu\text{A}$                                                  |                                                                        |
|                                                 | $\pm 100$ mA Range,<br>$\pm (10 \text{ mA to } 120 \text{ mA})$              | $41 \mu\text{A/A} + 1.2 \mu\text{A}$                                                   |                                                                        |
|                                                 | $\pm 1$ A Range,<br>$\pm (0.1 \text{ A to } 1.05 \text{ A})$                 | $0.12 \text{ mA/A} + 23 \mu\text{A}$                                                   |                                                                        |
|                                                 | $\pm 3$ A Range,<br>$\pm (1 \text{ A to } 3 \text{ A})$                      | $0.14 \text{ mA/A} + 69 \mu\text{A}$                                                   | Measure using<br>6 ½ Digit<br>Multimeter<br>HP 34401A                  |

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**SCOPE OF CALIBRATION: ELECTRICAL**

| Instrument Calibrated/<br>Measurement Parameter           | Range                                    | Calibration and<br>Measurement Capability<br>Expressed as an<br>Uncertainty ( $\pm$ )* | Remarks                                                                |
|-----------------------------------------------------------|------------------------------------------|----------------------------------------------------------------------------------------|------------------------------------------------------------------------|
| 1. Generating Instruments<br>(continued)                  |                                          |                                                                                        |                                                                        |
| (c) Resistance,<br>(Four-wire Ohms and<br>Two-wire Ohms.) | 0 $\Omega$ to 12 $\Omega$                | 3.3 $\mu\Omega/\Omega$ + 76 m $\Omega$                                                 | Measure using<br>8 ½ Digit<br>Multimeter<br>Keysight 3458A<br>Opt. 002 |
|                                                           | 10 $\Omega$ to 120 $\Omega$              | 0.32 $\mu\Omega/\Omega$ + 0.56 m $\Omega$                                              |                                                                        |
|                                                           | 0.1 k $\Omega$ to 1.2 k $\Omega$         | 0.78 $\mu\Omega/\Omega$ + 0.55 m $\Omega$                                              |                                                                        |
|                                                           | 1 k $\Omega$ to 12 k $\Omega$            | 0.79 $\mu\Omega/\Omega$ + 5.5 m $\Omega$                                               |                                                                        |
|                                                           | 10 k $\Omega$ to 120 k $\Omega$          | 8.4 $\mu\Omega/\Omega$ + 0.45 $\Omega$                                                 |                                                                        |
|                                                           | 0.1 M $\Omega$ to 1.2 M $\Omega$         | 1.2 $\mu\Omega/\Omega$ + 1.2 $\Omega$                                                  |                                                                        |
|                                                           | 1 M $\Omega$ to 12 M $\Omega$            | 5.1 $\mu\Omega/\Omega$ + 21 $\Omega$                                                   |                                                                        |
|                                                           | 10 M $\Omega$ to 120 M $\Omega$          | 0.54 m $\Omega/\Omega$ + 4.5 m $\Omega$                                                |                                                                        |
|                                                           | 0.1 G $\Omega$ to 1.2 G $\Omega$         | 57 m $\Omega/\Omega$ + 12 k $\Omega$                                                   |                                                                        |
| (d) AC Voltage                                            | 10 mV to 700V<br>(See Matrix C)          | (See Matrix C)                                                                         |                                                                        |
| (e) AC Current                                            | 5 $\mu$ A to 1 A<br>(See Matrix D)       | (See Matrix D)                                                                         |                                                                        |
| (f) Frequency or Period                                   | 0.01 Hz to 225 MHz<br>6 ns to 100 s      | 5.8 $\mu$ Hz/Hz + 0.15 mHz<br>5.8 $\mu$ s/s - 69 ps                                    | Measure using<br>Fluke PM 6680B<br>Timer Counter<br>Analyzer           |
|                                                           | 150 kHz to 650 MHz                       | 14 $\mu$ Hz/Hz + 36 $\mu$ Hz                                                           | Measure using<br>HP 8901A                                              |
|                                                           | 650 MHz to 1300 MHz                      | 14 $\mu$ Hz/Hz + 35 $\mu$ Hz                                                           |                                                                        |
| (g) Amplitude/ Level                                      | 0.1 W to 1 W<br>(150 kHz to 60 MHz)      | 0.35 nW/W + 2.2 mW                                                                     |                                                                        |
|                                                           | 0.01 W to 0.1 W<br>(150 kHz to 60 MHz)   | 35 pW/W + 2.2 mW                                                                       |                                                                        |
|                                                           | 1 mW to 10 mW<br>(150 kHz to 60 MHz)     | 3.3 pW/W + 2.2 mW                                                                      |                                                                        |
|                                                           | 0.1 W to 1 W<br>(650 MHz to 1300 MHz)    | 0.30 nW/W + 2.6 mW                                                                     |                                                                        |
|                                                           | 0.01 W to 0.1 W<br>(650 MHz to 1300 MHz) | 30 pW/W + 2.6 mW                                                                       |                                                                        |
|                                                           | 1 mW to 10 mW<br>(650 MHz to 1300 MHz)   | 2.2 pW/W + 2.6 mW                                                                      |                                                                        |

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**SCOPE OF CALIBRATION: ELECTRICAL**

| Instrument Calibrated/<br>Measurement Parameter                   | Range                                                                               | Calibration and<br>Measurement Capability<br>Expressed as an<br>Uncertainty ( $\pm$ )* | Remarks                   |
|-------------------------------------------------------------------|-------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|---------------------------|
| 1. Generating Instruments<br>(continued)                          |                                                                                     |                                                                                        | Measure using<br>HP 8901A |
| (h) MODULATION<br>Related Signal:<br>Amplitude Modulation<br>(AM) |                                                                                     |                                                                                        |                           |
| AM Depth: 1 % to 99 %                                             | Carrier Frequency<br>150 kHz to 10 MHz<br>Modulation Frequency<br>50 Hz to 10 kHz   | 0.024 %/% + 0.011 %                                                                    |                           |
| AM Depth: 1 % to 99 %                                             | Carrier Frequency<br>150 kHz to 10 MHz<br>Modulation Frequency<br>20 Hz to 10 kHz   | 0.036 %/% + 0.011 %                                                                    |                           |
| AM Depth: 1 % to 99 %                                             | Carrier Frequency<br>10 MHz to 1300 MHz<br>Modulation Frequency<br>50 Hz to 50 kHz  | 0.024 %/% + 0.011 %                                                                    |                           |
| AM Depth: 1 % to 99 %                                             | Carrier Frequency<br>10 MHz to 1300 MHz<br>Modulation Frequency<br>20 Hz to 100 kHz | 0.036 %/% + 0.011 %                                                                    |                           |
| <i>Frequency Modulation<br/>(FM)</i>                              |                                                                                     |                                                                                        |                           |
| <i>FM Deviation:<br/><math>\leq 40</math> kHz peak</i>            | Carrier Frequency<br>150 kHz to 10 MHz<br>Modulation Frequency<br>20 Hz to 10 kHz   | 0.024 kHz/kHz + 0.0049<br>kHz                                                          |                           |
| <i>FM Deviation:<br/><math>\leq 400</math> kHz peak</i>           | Carrier Frequency<br>10 MHz to 1300 MHz<br>Modulation Frequency<br>50 Hz to 100 kHz | 0.012 kHz/kHz + 0.12 kHz                                                               |                           |
| <i>FM Deviation:<br/><math>\leq 40</math> kHz peak</i>            | Carrier Frequency<br>10 MHz to 1300 MHz<br>Modulation Frequency<br>20 Hz to 200 kHz | 0.057 kHz/kHz + 0.021 kHz                                                              |                           |

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| Instrument Calibrated/<br>Measurement Parameter                                                                                                                                 | Range                                                                               | Calibration and<br>Measurement Capability<br>Expressed as an<br>Uncertainty ( $\pm$ )* | Remarks                   |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|---------------------------|
| 1. Generating Instruments<br>(continued)<br><i>Phase Modulation (<math>\Phi M</math>)</i><br><i><math>\Phi M</math> Deviation:</i><br><i><math>\leq 400</math> Radians peak</i> | Carrier Frequency<br>10 kHz to 1300 MHz<br>Modulation Frequency<br>200 Hz to 20 kHz | 0.034 Radians/Radians +<br>0.12 Radians                                                | Measure using<br>HP 8901A |
| <i><math>\Phi M</math> Deviation:</i><br><i><math>\leq 40</math> Radians peak</i>                                                                                               | Carrier Frequency<br>10 kHz to 1300 MHz<br>Modulation Frequency<br>200 Hz to 20 kHz | 0.034 Radians/Radians +<br>0.012 Radians                                               |                           |
| <i><math>\Phi M</math> Deviation:</i><br><i><math>\leq 4</math> Radians peak</i>                                                                                                | Carrier Frequency<br>10 kHz to 1300 MHz<br>Modulation Frequency<br>200 Hz to 8 kHz  | 0.034 Radians/Radians +<br>0.0013 Radians                                              |                           |

Matrix C:

AC Voltage Generation. Measure using 8 ½ Digit Multimeter Keysight 3458A Opt. 002

| Range  |                       | AC Band $\leq 2$ MHz          |                               |                              |                               |                              |                             |                         |                         |
|--------|-----------------------|-------------------------------|-------------------------------|------------------------------|-------------------------------|------------------------------|-----------------------------|-------------------------|-------------------------|
|        |                       | 1 Hz<br>to<br>40 Hz           | 40 Hz to<br>1 kHz             | 1 kHz<br>to<br>20 kHz        | 20 kHz<br>to<br>50 kHz        | 50 kHz<br>to<br>100 kHz      | 100 kHz<br>to<br>300 kHz    | 300 kHz<br>to<br>1 MHz  | 1 MHz<br>to<br>2 MHz    |
| 10 mV  | 1 mV<br>to<br>12 mV   | 0.32<br>mV/V +<br>4.4 $\mu$ V | 0.18<br>mV/V +<br>3 $\mu$ V   | 0.27<br>mV/V +<br>3 $\mu$ V  | 1.1<br>mV/V +<br>2.6 $\mu$ V  | 5.7<br>mV/V +<br>2.5 $\mu$ V | 47 mV/V<br>+ 2.7 $\mu$ V    | -                       | -                       |
| 100 mV | 12 mV<br>to<br>120 mV | 62 $\mu$ V/V +<br>9.7 $\mu$ V | 53 $\mu$ V/V<br>+ 8.7 $\mu$ V | 0.11<br>mV/V +<br>11 $\mu$ V | 0.29<br>mV/V +<br>9.5 $\mu$ V | 0.72<br>mV/V +<br>28 $\mu$ V | 3.3<br>mV/V +<br>37 $\mu$ V | 12 mV/V<br>+ 39 $\mu$ V | 18 mV/V<br>+ 31 $\mu$ V |
| 1 V    | 0.12 V<br>to<br>1.2 V | 84 $\mu$ V/V +<br>51 $\mu$ V  | 83 $\mu$ V/V<br>+ 31 $\mu$ V  | 0.17<br>mV/V +<br>29 $\mu$ V | 0.35<br>mV/V +<br>30 $\mu$ V  | 0.93<br>mV/V +<br>28 $\mu$ V | 3.5<br>mV/V +<br>0.13 mV    | 12 mV/V<br>+ 0.13 mV    | 18 mV/V<br>+ 0.18 mV    |
| 10 V   | 1.2 V<br>to<br>12 V   | 85 $\mu$ V/V +<br>0.51 mV     | 83 $\mu$ V/V<br>+ 0.31 mV     | 0.17<br>mV/V +<br>0.29 mV    | 0.35<br>mV/V +<br>0.28 mV     | 0.93<br>mV/V +<br>0.26 mV    | 3.5<br>mV/V +<br>1.3 mV     | 12 mV/V<br>+ 1.3 mV     | 18 mV/V<br>+ 1.7 mV     |

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**SCOPE OF CALIBRATION: ELECTRICAL**

Matrix C (continued)

AC Voltage Generation. Measure using 8 ½ Digit Multimeter Keysight 3458A Opt. 002

| Range  |                      | AC Band $\leq 2$ MHz     |                          |                          |                         |                         |                          |                        |                      |
|--------|----------------------|--------------------------|--------------------------|--------------------------|-------------------------|-------------------------|--------------------------|------------------------|----------------------|
|        |                      | 1 Hz<br>to<br>40 Hz      | 40 Hz to<br>1 kHz        | 1 kHz<br>to<br>20 kHz    | 20 kHz<br>to<br>50 kHz  | 50 kHz<br>to<br>100 kHz | 100 kHz<br>to<br>300 kHz | 300 kHz<br>to<br>1 MHz | 1 MHz<br>to<br>2 MHz |
| 100 V  | 12 V<br>to<br>120 V  | 0.24<br>mV/V +<br>5.1 mV | 0.23<br>mV/V +<br>2.9 mV | 0.23<br>mV/V +<br>2.9 mV | 0.4<br>mV/V +<br>3.1 mV | 1.4 mV/V<br>+ 2.6 mV    | 4.7 mV/V<br>+ 12 mV      | 18 mV/V<br>+ 12 mV     | -                    |
| 1000 V | 120 V<br>to<br>700 V | 0.45<br>mV/V +<br>67 mV  | 0.44<br>mV/V +<br>48 mV  | 0.68<br>mV/V +<br>43 mV  | 1.4<br>mV/V +<br>35 mV  | 3.5 mV/V<br>+ 28 mV     | -                        | -                      | -                    |

AC Voltage Generation. Measure using 8 ½ Digit Multimeter Keysight 3458A Opt. 002

| Range  |                 | AC Band $> 2$ MHz      |                       |                       |                        |                       |
|--------|-----------------|------------------------|-----------------------|-----------------------|------------------------|-----------------------|
|        |                 | 45 Hz to 100 kHz       | 100 kHz to 1 MHz      | 1 MHz<br>to<br>4 MHz  | 4 MHz<br>to<br>8 MHz   | 8 MHz<br>to<br>10 MHz |
| 10 mV  | 1 mV to 12 mV   | 1.1 mV/V + 7.5 $\mu$ V | 14 mV/V + 6.3 $\mu$ V | 81 mV/V + 8.3 $\mu$ V | 0.24 V/V + 9.4 $\mu$ V | -                     |
| 100 mV | 12 mV to 120 mV | 1.1 mV/V + 71 $\mu$ V  | 24 mV/V + 63 $\mu$ V  | 47 mV/V + 88 $\mu$ V  | 47 mV/V + 0.1 mV       | 0.18 V/V + 0.12 mV    |
| 1 V    | 120 mV to 1.2 V | 1.1 mV/V + 0.7 mV      | 24 mV/V + 0.58 mV     | 47 mV/V + 0.83 mV     | 47 mV/V + 0.95 mV      | 0.18 V/V + 1.2 mV     |
| 10 V   | 1.2 V to 12 V   | 1.1 mV/V + 7 mV        | 24 mV/V + 5.8 mV      | 47 mV/V + 8.7 mV      | 47 mV/V + 9.5 mV       | 0.18 V/V + 12 mV      |
| 100 V  | 12 V to 120 V   | 1.4 mV/V + 2.6 mV      | -                     | -                     | -                      | -                     |
| 1000 V | 120 V to 700 V  | 3.5 mV/V + 0.12 V      | -                     | -                     | -                      | -                     |

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**SCOPE OF CALIBRATION: ELECTRICAL**

Matrix D:

AC Current Generation. Measure using 8 ½ Digit Multimeter Keysight 3458A Opt. 002

| Range       |                          | Frequency Band               |                              |                               |                               |
|-------------|--------------------------|------------------------------|------------------------------|-------------------------------|-------------------------------|
|             |                          | 10 Hz to 20 Hz               | 20 Hz to 45 Hz               | 45 Hz to 100 Hz               | 100 Hz to 5 kHz               |
| 100 $\mu$ A | 5 $\mu$ A to 120 $\mu$ A | 4.7 nA/A + 36 nA             | 1.8 nA/A + 36 nA             | 0.7 nA/A + 36 nA              | 0.7 nA/A + 36 nA              |
| 1 mA        | 0.05 mA to 1.2 mA        | 4.7 $\mu$ A/A + 0.24 $\mu$ A | 1.8 $\mu$ A/A + 0.24 $\mu$ A | 0.71 $\mu$ A/A + 0.24 $\mu$ A | 0.36 $\mu$ A/A + 0.23 $\mu$ A |
| 10 mA       | 0.5 mA to 12 mA          | 4.7 $\mu$ A/A + 2.4 $\mu$ A  | 1.8 $\mu$ A/A + 2.4 $\mu$ A  | 0.7 $\mu$ A/A + 2.4 $\mu$ A   | 0.36 $\mu$ A/A + 2.5 $\mu$ A  |
| 100 mA      | 5 mA to 120 mA           | 4.7 $\mu$ A/A + 24 $\mu$ A   | 1.8 $\mu$ A/A + 2.4 $\mu$ A  | 0.7 $\mu$ A/A + 24 $\mu$ A    | 0.36 $\mu$ A/A + 25 $\mu$ A   |
| 1 A         | 0.05 A to 1.05 A         | 4.7 mA/A + 0.25 mA           | 1.9 mA/A + 0.25 mA           | 0.92 mA/A + 0.25 mA           | 1.3 mA/A + 0.15 mA            |

| Range  |                   | Frequency Band                |                              |                             |
|--------|-------------------|-------------------------------|------------------------------|-----------------------------|
|        |                   | 5 kHz to 20 kHz               | 20 kHz to 50 kHz             | 50 kHz to 100 kHz           |
| 1 mA   | 0.05 mA to 1.2 mA | 0.71 $\mu$ A/A + 0.24 $\mu$ A | 4.7 $\mu$ A/A + 0.47 $\mu$ A | 6.4 $\mu$ A/A + 1.8 $\mu$ A |
| 10 mA  | 0.5 mA to 12 mA   | 0.7 $\mu$ A/A + 2.4 $\mu$ A   | 4.7 $\mu$ A/A + 4.7 $\mu$ A  | 6.4 $\mu$ A/A + 18 $\mu$ A  |
| 100 mA | 5 mA to 120 mA    | 0.7 $\mu$ A/A + 24 $\mu$ A    | 4.7 $\mu$ A/A + 47 $\mu$ A   | 6.4 $\mu$ A/A + 0.18 mA     |
| 1 A    | 0.05 A to 1.05 A  | 3.5 mA/A + 0.25 mA            | 12 mA/A + 0.47 mA            | -                           |

Matrix E:

AC Current Generation. Measure using 6 ½ Digit Multimeter HP 34401A

| Range |            | Frequency Band   |                   |                   |
|-------|------------|------------------|-------------------|-------------------|
|       |            | 3 Hz to 5 Hz     | 5 Hz to 10 Hz     | 10 Hz to 5 kHz    |
| 3 A   | 1 A to 3 A | 13 mA/A + 2.1 mA | 4.0 mA/A + 2.1 mA | 1.8 mA/A + 2.1 mA |

**Signatories:**

1. Mohamed Fikri Bin Mohd Nor
2. Rushaida Abdul Aziz

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**SCOPE OF CALIBRATION:                      PRESURRE**

| Instrument Calibrated/<br>Measurement Parameter           | Range                                     | Calibration and<br>Measurement Capability<br>Expressed as an<br>Uncertainty ( $\pm$ )* | Remarks                         |
|-----------------------------------------------------------|-------------------------------------------|----------------------------------------------------------------------------------------|---------------------------------|
| Pressure measuring<br>device<br>(Hydraulic of oil medium) | 10 psi to 500 psi<br>500 psi to 10000 psi | 0.021% of pressure<br>0.025% of pressure                                               | Hydraulic Dead<br>Weight Tester |
| Pressure Vacuum Gauge                                     | -0.90 bar to 0 bar                        | 3.4 mbar                                                                               | Digital Pressure<br>Indicator   |

**Signatory:****1.              Nor Azila Mat Jusoh**